Tarantool

Выпуск 1.7.3

мар. 14, 2019

Оглавление

ГЛАВА 1

Что нового?

Здесь собрана информация о существенных изменениях, которые произошли в конкретных версиях Tarantool'a.

Более мелкие изменения и исправления дефектов указаны в отчетах о выпущенных стабильных релизах (milestone = closed) на GitHub.

1.1 Что нового в Tarantool 1.7?

The disk-based storage engine, which was called *sophia* or *phia* in earlier versions, is superseded by the *vinyl* storage engine.

Добавлены новые типы индексируемых полей.

Обновлена версия LuaJIT.

У кластера репликации появилась возможность самонастройки, что существенно упрощает настройку нового кластера.

Функция `space_object:inc()` объявлена устаревшей.

Функция `space_object:dec()` объявлена устаревшей.

ГЛАВА 2

Общие сведения

2.1 Сервер приложений + СУБД

Tarantool представляет собой сервер приложений на языке Lua, интегрированный с СУБД. В основе Tarantool лежат файберы (fibers), что позволяет нескольким Lua-приложениям работать в одном потоке (thread), при этом Tarantool-сервер может одновременно запускать другие потоки для обработки ввода-вывода данных и фоновых сервисных задач. Tarantool включает в себя LuaJIT (Just In Time) Lua-компилятор, Lua-библиотеки для решения наиболее частых задач, а также сервер баз данных Tarantool, представляющий собой NoSQL СУБД. Таким образом, Tarantool может всё то же, что node.js и Twisted, а кроме того обеспечивает сохранность данных.

Tarantool — это open-source проект. Исходный код открыт для всех и распространяется бесплатно согласно лицензии BSD license. Поддерживаемые платформы: GNU / Linux, Mac OS и FreeBSD.

Создателем Tarantool'а — а также его основным пользователем — является компания Mail.Ru, крупнейшая Интернет-компания России (30 млн пользователей, 25 млн электронных писем в день, веб-сайт в списке top 40 международного Alexa-рейтинга). Tarantool используется для обработки самых «горячих» данных Mail.Ru, таких как данные пользовательских онлайн-сессий, настройки онлайн-приложений, кеширование сервисных данных, алгоритмы распределения данных и шардинга, и т.д. Tarantool также используется во всё большем количестве проектов вне стен Mail.Ru. Это, к примеру, онлайн-игры, цифровой маркетинг, социальные сети. Несмотря на то что Mail.Ru спонсирует разработку Tarantool'а, весь процесс разработки, в т.ч. дальнейшие планы и база обнаруженных ошибок, является полностью открытым. В Tarantool включены патчи от большого числа сторонних разработчиков. Усилиями сообщества разработчиков Tarantool'а были написаны (и далее поддерживаются) библиотеки для подключения модулей на внешних языках программирования. А сообщество Lua-разработчиков предоставило сотни полезных пакетов, большинство из которых можно использовать в качестве расширений для Tarantool'а.

Пользователи Tarantool'а могут создавать, изменять и удалять **Lua-функции** прямо во время исполнения кода. Также они могут указывать **Lua-программы**, которые будут загружаться во время запуска Tarantool'а. Такие программы могут служить триггерами, выполнять фоновые задачи и взаимодействовать с другими программами по сети. В отличие от многих популярных сред разработки приложений, которые используют «реактивный» принцип, сетевое взаимодействие в Lua устроено последовательно, но очень эффективно, т.к. оно использует среду **взаимной многозадачности** самого Tarantool'а.

Один из встраиваемых Lua-пакетов — это API для функционала СУБД. Таким образом, некоторые разработчики рассматривают Tarantool как СУБД с популярным языком для написания хранимых процедур, другие рассматривают его как Lua-интерпретатор, а третьи – как вариант замены сразу нескольких компонентов в многозвенных веб-приложениях. Производительность Tarantool'а может достигать сотен тысяч транзакций в секунду на ноутбуке, и ее можно наращивать «вверх» или «вширь» за счет новых серверных ферм.

2.2 Возможности СУБД

Компонент «box» — серверная часть с функционалом СУБД — это важная часть Tarantool'а, хотя он может работать и без данного компонента.

API для функционала СУБД позволяет хранить Lua-объекты, управлять коллекциями объектов, создавать и удалять вторичные ключи, делать атомарные изменения, конфигурировать и мониторить репликацию, производить контролируемое переключение при отказе (failover), а также исполнять код на Lua, который вызывается событиями в базе. А для прозрачного доступа к удаленным (remote) экземплярам баз данных разработан API для вызова удаленных процедур.

В архитектуре серверной части СУБД Tarantool'а реализована концепция «движков» базы данных (storage engines), где в разных ситуациях используются разные наборы алгоритмов и структуры данных. В Tarantool'е есть два встроенных движка: in-memory движок, который держит все данные и индексы в оперативной памяти, и двухуровневый движок для B-деревьев, который обрабатывает данные размером в 10-1000 раз больше того, что может поместиться в оперативной памяти. Все движки в Tarantool'е поддерживают транзакции и репликацию, поскольку они используют единый механизм **упреждающей записи** (WAL = write ahead log). Это механизм обеспечивает согласованность и сохранность данных при сбоях. Таким образом, изменения не считаются завершенными, пока не проходит запись в лог WAL. Подсистема логирования также поддерживает групповые коммиты.

In-memory движок (memtx) хранит все данные в оперативной памяти, поэтому время ожидания при чтении у него очень мало. Также, когда пользователи запрашивают статические снимки (snapshots), этот движок создает персистентные копии данных в постоянной памяти, например на жестком диске. Если Tarantool-сервер прекращает работать и данные в оперативной памяти теряются, то при следующем запуске Tarantool-сервер загружает в память самую свежую копию данных с диска и применяет к ней все транзакции из лога, которые были сделаны с момента создания копии. Таким образом, данные при сбое не теряются.

В штатных ситуациях **in-memory движок работает без блокировок**. Вместо низкоуровневых механизмов параллельной обработки данных, которые предлагает операционная система (например, mutex'ов), Tarantool использует среду взаимной многозадачности, и таким образом может работать с тысячами соединений одновременно. В Tarantool'е есть фиксированное количество независимых нитей (thread), и у них нет общего состояния. Для обмена данными между нитями используются очереди сообщений, что позволяет уменьшить накладные расходы. Такой подход накладывает ограничение на количество процессорных ядер, которые Tarantool-сервер может использовать, но в то же время он позволяет избежать конкуренции за шину памяти, а также дает запас масштабируемости по скорости доступа к памяти и производительности сети. В результате даже сильно нагруженный Tarantool-сервер в среднем использует процессор не более чем на 10%. Кроме того, Tarantool поддерживает поиск как по первичным, так и по **вторичным ключам в индексах**.

Tarantool's disk-based storage engine is a fusion of ideas from modern filesystems, log-structured merge trees and classical B-trees. All data is organized into **ranges**. Each range is represented by a file on disk. Range size is a configuration option and normally is around 64MB. Each range is a collection of pages, serving different purposes. Pages in a fully merged range contain non-overlapping ranges of keys. A range can be partially merged if there were a lot of changes in its key range recently. In that case some pages represent new keys and values in the range. The disk-based storage engine is append only: new data never overwrites old data. The disk-based storage engine is named *vinyl*.

Tarantool поддерживает работу с **составными ключами в индексах**. Возможные типы ключей: HASH, TREE, BITSET и RTREE.

Tarantool также поддерживает **асинхронную репликацию** — как локальную, так и на удаленных серверах. При этом репликацию можно настроить по принципу **мастер-мастер**, когда несколько узлов могут не только обрабатывать входящую нагрузку, но и получать данные от других узлов.

ГЛАВА 3

Руководство пользователя

3.1 Предисловие

Добро пожаловать в мир Tarantool! Сейчас вы читаете «Руководство пользователя». Мы советуем начинать именно с него, а затем переходить к *«Справочникам»*, если вам понадобятся более подробные сведения.

3.1.1 Как пользоваться документацией

Знакомство с Tarantool'ом вы можете начать с того, что скачаете готовый установочный пакет (как описано в начале *главы 2 «Начало работы»*) или воспользуетесь нашим онлайн-стендом на http://try.tarantool.org. В любом случае для первого знакомства вы можете выполнить тренировочный пример «Первичный запуск Tarantool'а и создание базы данных» из второй части главы 2. После этого вы можете заглянуть в наш *«Практикум»*, где содержится еще больше практических заданий.

В *главе 3 «Функционал СУБД»* рассказано о возможностях Tarantool'а как NoSQL СУБД, а в *главе 4 «Сервер приложений»* — о возможностях Tarantool'а как сервера приложений Lua.

Глава 5 «Администрирование серверной части» предназначена в первую очередь для системных администраторов.

Глава 6 «Коннекторы» актуальна только для тех пользователей, которые хотят устанавливать соединение с Tarantool'ом с помощью программ на других языках программирования (например C, Perl или Python) — для прочих пользователей эта глава неактуальна.

Глава 7 «Вопросы и ответы» содержит ответы на некоторые часто задаваемые вопросы о Tarantool'е.

Опытным же пользователям будут полезны *«Справочники»*, *«Руководство участника проекта»* и комментарии в исходном коде.

3.1.2 Как связаться с сообществом разработчиков Tarantool'a

Оставить сообщение о найденых дефектах или сделать запрос на новый функционал можно тут: http://github.com/tarantool/tarantool/issues

Пообщаться напрямую с командой разработки Tarantool'a можно в telegram или на форумах (англоязычном или русскоязычном).

3.2 Начало работы

В этой главе рассказывается, как скачать, установить и начать работать с Tarantool'ом с нуля.

Для промышленной эксплуатации рекомендуется скачать бинарный (исполняемый) пакет. Тогда вы гарантированно получите сборку той же версии, что и у разработчиков. Это существенно упростит поиск ошибок, если вам в будущем понадобится помощь, а также позволит избежать проблем из-за того, что вы использовали инструменты или параметры отличные от тех, что использовали при сборке сами разработчики. См. раздел "*Скачивание и установка бинарного пакета*".

Для разработческих целей вы можете скачать исходные файлы и собрать бинарный пакет самостоятельно с помощью компилятора C/C++ и обычных инструментов для сборки. Хотя это и более трудный способ получить бинарный пакет, но он дает вам больший контроль над результатом. Также в состав исходных файлов входят дополнительные пакеты, например набор тестов для Tarantool'a. См. раздел «*Сборка из исходных файлов*» в «*Руководстве участника проекта*».

После установки вы можете сразу опробовать Tarantool в действии. Ниже вы найдете инструкции по созданию безопасной тестовой среды. Всего за несколько минут вы сможете запустить Tarantool-сервер и задать несколько инструкций по манипулированию данными. См. раздел «*Первичный запуск Tarantool'a и создание базы данных*".

3.2.1 Скачивание и установка бинарного пакета

Бинарные пакеты для двух версий Tarantool'a — стабильной 1.6 и самой свежей 1.7 — выложены на странице http://tarantool.org/download.html. При каждом изменении исходного кода на GitHub (репозиторий http://github.com/tarantool/tarantool, ветка «1.7») происходит сборка, автоматическое тестирование и выкладка бинарных пакетов на вышеуказанную страницу.

Чтобы скачать и установить бинарный пакет для вашей операционной системы, откройте терминал с командной строкой и введите инструкции, которые даны для вашей операционной системы на странице http://tarantool.org/download.html.

3.2.2 Первичный запуск Tarantool'a и создание базы данных

Далее рассказывается, как создать простую тестовую базу данных после установки Tarantool'a.

Создайте новую директорию. Она понадобится только для тестовых целей, и ее можно будет удалить по окончании экспериментов.

```
$ mkdir ~/tarantool_sandbox
$ cd ~/tarantool_sandbox
```

Далее рассказывается, как создать простую тестовую базу данных после установки Tarantool'a.

Запустите Tarantool-сервер. Имя программы — `tarantool`.

```
$ # Если вы скачали бинарный пакет с помощью apt-get или yum, введите:
$ /usr/bin/tarantool
$ # Если вы скачали бинарный пакет в формате TAR
$ # и разархивировали его в директорию ~/tarantool, введите:
$ ~/tarantool/bin/tarantool
$ # Если вы собрали Tarantool из исходных файлов, введите:
$ ~/tarantool/src/tarantool
```

Tarantool-сервер запускается в интерактивном режиме и выводит приглашение командной строки. Чтобы создать базу данных, задайте ее настройки с помощью вызова *box.cfg*. Вот пример минимальной конфигурации:

```
tarantool> box.cfg{listen = 3301}
```

Если все в порядке, то Tarantool-сервер начнет в прогрессе отображать процесс инициализации, например:

```
tarantool> box.cfg{listen = 3301}
2015-08-07 09:41:41.077 ... version 1.7.0-1216-g73f7154
2015-08-07 09:41:41.077 ... log level 5
2015-08-07 09:41:41.078 ... mapping 1073741824 bytes for a shared arena...
2015-08-07 09:41:41.079 ... initialized
2015-08-07 09:41:41.081 ... initializing an empty data directory
2015-08-07 09:41:41.095 ... creating './00000000000000000000.snap.inprogress'
2015-08-07 09:41:41.095 ... saving snapshot './00000000000000000000.snap.inprogress'
2015-08-07 09:41:41.127 ... done
2015-08-07 09:41:41.128 ... primary: bound to 0.0.0.0:3301
2015-08-07 09:41:41.128 ... ready to accept requests
```

Поскольку Tarantool-сервер уже запущен, вы можете запустить новый терминал и присоединиться к основному порту Tarantool-сервера, введя следующую команду:

```
$ telnet 0 3301
```

но пока что будет лучше оставить Tarantool-сервер работать в интерактивном режиме. На промышленных серверах *интерактивный режим* нужен лишь для администрирования, однако для наглядности большинство примеров в данном руководстве даны именно в интерактивном режиме. Итак, Tarantool ждет от вас ввода инструкций.

Создайте первое пространство и первый *индекс*:

```
tarantool> s = box.schema.space.create('tester')
tarantool> s:create_index('primary', {
         >   type = 'hash',
         >   parts = {1, 'unsigned'}
         > })
```

Выполните вставку трех «кортежей» (tuple) в первое «пространство» (space) из вашей базы данных:

```
tarantool> t = s:insert({1, 'Roxette'})
tarantool> t = s:insert({2, 'Scorpions', 2015})
tarantool> t = s:insert({3, 'Ace of Base', 1993})
```

Произведите выборку кортежа из первого пространства в базе по первому указанному ключу:

```
tarantool> s:select{3}
```

Вот что должно отображаться на вашем терминале к этому моменту:

```
tarantool> s = box.schema.space.create('tester')
2015-06-10 12:04:18.158 ... creating './00000000000000000000.xlog.inprogress'
---
...
tarantool>s:create_index('primary', {type = 'hash', parts = {1, 'unsigned'}})
---
...
tarantool> t = s:insert{1, 'Roxette'}
---
...
tarantool> t = s:insert{2, 'Scorpions', 2015}
---
...
tarantool> t = s:insert{3, 'Ace of Base', 1993}
---
...
tarantool> s:select{3}
---
- - [3, 'Length', 93]
...
tarantool>
```

Далее, чтобы подготовиться к тестовому примеру в следующем разделе, введите:

```
tarantool> box.schema.user.grant('guest', 'read,write,execute', 'universe')
```

3.2.3 Установка удаленного соединения

В предыдущем разделе ваш первый запрос был `box.cfg`*`listen = 3301`*. Значением `listen` может быть любой URI (универсальный код ресурса), в данном случае — просто номер локального порта (3301). Вы можете отправлять запросы на URI для прослушивания с помощью:

1. telnet,
2. коннектора (см. главу «*Коннекторы*»),
3. другого экземпляра Tarantool'а с помощью *console module*, либо
4. `tarantoolctl connect`.

Let's try (4).

Переключитесь на другой терминал. Например, в Linux-системе для этого нужно запустить новый экземпляр Bash. При этом вам не потребуется вызывать cd, чтобы переключиться на директорию `~/tarantool_sandbox`.

Start the `tarantoolctl` utility:

`$ tarantoolctl connect '3301'`

This means «use *tarantoolctl connect* to connect to the Tarantool server that's listening on `localhost:3301`».

Введите следующий запрос:

`tarantool> {{box.space.tester:select{2}}}`

Это означает «послать запрос тому Tarantool-серверу и вывести результат на экран.» Результатом в данном случае будет один из кортежей, что вы вставляли ранее. На терминале теперь должно отображаться примерно следующее:

```
$ tarantoolctl connect 3301
/usr/local/bin/tarantoolctl: connected to localhost:3301
localhost:3301> box.space.tester:select{2}
---
- - [2, 'Scorpions', 2015]
...

localhost:3301>
```

You can repeat `box.space...:insert{}` and `box.space...:select{}` indefinitely, on either Tarantool instance.

When the testing is over:

- To drop the space: `s:drop()`
- To stop `tarantoolctl`: Ctrl+C or Ctrl+D
- To stop Tarantool (an alternative): the standard Lua function os.exit()
- To stop Tarantool (from another terminal): `sudo pkill -f tarantool`
- To destroy the test: `rm -r ~/tarantool_sandbox`

If you followed all the instructions in this chapter, then so far you have: installed Tarantool from a binary repository, started up the Tarantool server, inserted and selected tuples.

3.3 Функционал СУБД

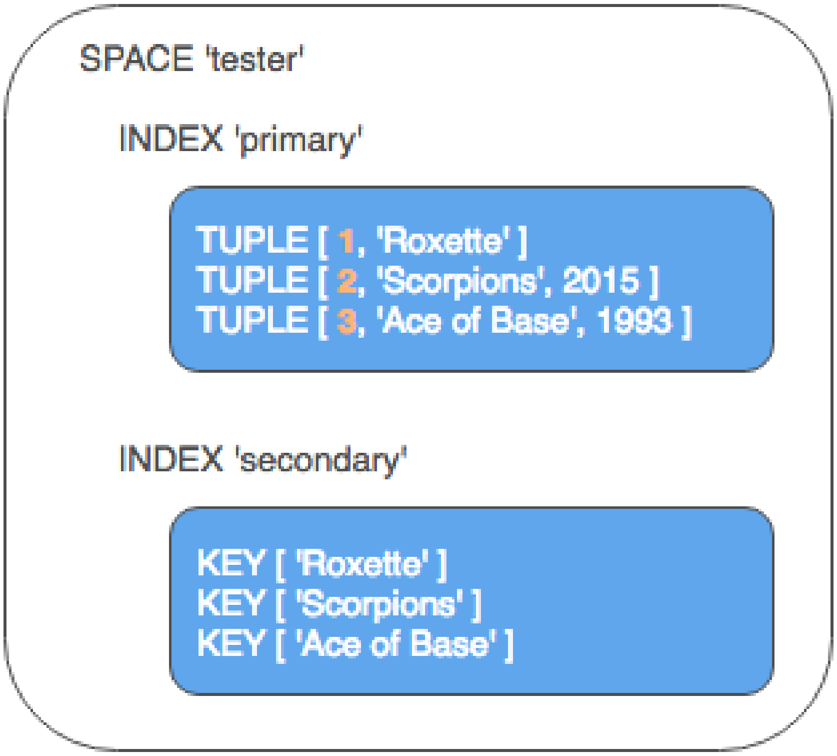
In this chapter, we introduce the basic concepts of working with Tarantool as a database manager.

This chapter contains the following sections:

3.3.1 Модель данных

В этом разделе описывается то, как в Tarantool'е организовано хранение данных и какие операции с данным он поддерживает.

If you tried out the *Starting Tarantool and making your first database* exercise from «Getting Started», then your database looks like this:



Пространство

A **space** – „tester" in our example – is a container.

When Tarantool is being used to store data, there is always at least one space. Each space has a unique **name** specified by the user. Besides, each space has a unique **numeric identifier** which can be specified by the user, but usually is assigned automatically by Tarantool. Finally, a space always has an **engine**: *memtx* (default) – in-memory engine, fast but limited in size, or *vinyl* – on-disk engine for huge data sets.

A space is a container for *tuples*. To be functional, it needs to have a *primary index*. It can also have secondary indexes.

Tuple

A **tuple** plays the same role as a "row" or a "record", and the components of a tuple (which we call "fields") play the same role as a "row column" or "record field", except that:

- fields can be composite structures, such as arrays or maps, and
- fields don't need to have names.

Any given tuple may have any number of fields, and the fields may be of different *types*. The identifier of a field is the field's number, base 1 (in Lua and other 1-based languages) or base 0 (in PHP or C/C++). For example, "1" or «0» can be used in some contexts to refer to the first field of a tuple.

Tuples in Tarantool are stored as MsgPack arrays.

When Tarantool returns a tuple value in console, it uses the YAML format, for example: `[3, 'Ace of Base', 1993]`.

Индекс

An **index** is a group of key values and pointers.

As with spaces, you should specify the index **name**, and let Tarantool come up with a unique **numeric identifier** («index id»).

An index always has a **type**. The default index type is „TREE“. TREE indexes are provided by all Tarantool engines, can index unique and non-unique values, support partial key searches, comparisons and ordered results. Additionally, memtx engine supports HASH, RTREE and BITSET indexes.

An index may be **multi-part**, that is, you can declare that an index key value is composed of two or more fields in the tuple, in any order. For example, for an ordinary TREE index, the maximum number of parts is 255.

An index may be **unique**, that is, you can declare that it would be illegal to have the same key value twice.

The first index defined on a space is called the **primary key index**, and it must be unique. All other indexes are called **secondary indexes**, and they may be non-unique.

An index definition may include identifiers of tuple fields and their expected **types** (see allowed *indexed field types* below).

In our example, we first defined the primary index (named „primary“) based on field #1 of each tuple:

```
tarantool> i = s:create_index('primary', {type = 'hash', parts = {1, 'unsigned'}})
```

The effect is that, for all tuples in space „tester“, field #1 must exist and must contain an unsigned integer. The index type is „hash“, so values in field #1 must be unique, because keys in HASH indexes are unique.

After that, we defined a secondary index (named „secondary“) based on field #2 of each tuple:

```
tarantool> i = s:create_index('secondary', {type = 'tree', parts = {2, 'string'}})
```

The effect is that, for all tuples in space „tester“, field #2 must exist and must contain a string. The index type is „tree“, so values in field #2 must not be unique, because keys in TREE indexes may be non-unique.

Примечание: Space definitions and index definitions are stored permanently in Tarantool’s system spaces *_space* and *_index* (for details, see reference on *box.space* submodule).

You can add, drop, or alter the definitions at runtime, with some restrictions. See syntax details in reference on *box* module.

Типы данных

Tarantool is both a database and an application server. Hence a developer often deals with two type sets: the programming language types (e.g. Lua) and the types of the Tarantool storage format (MsgPack).

Lua vs MsgPack

Scalar / compound	MsgPack type	Lua type	Example value
scalar	nil	«nil»	msgpack.NULL
scalar	boolean	«boolean»	true
scalar	string	«string»	„A B C“
scalar	integer	«number»	12345
scalar	double	«number»	1,2345
compound	map	«table» (with string keys)	table: 0x410f8b10
compound	array	«table» (with integer keys)	[1, 2, 3, 4, 5]
compound	array	tuple («cdata»)	[12345, „A B C“]

In Lua, a **nil** type has only one possible value, also called *nil* (displayed as **null** on Tarantool's command line, since the output is in the YAML format). Nils may be compared to values of any types with == (is-equal) or ~= (is-not-equal), but other operations will not work. Nils may not be used in Lua tables; the workaround is to use msgpack.NULL.

A **boolean** is either `true` or `false`.

A **string** is a variable-length sequence of bytes, usually represented with alphanumeric characters inside single quotes. In both Lua and MsgPack, strings are treated as binary data, with no attempts to determine a string's character set or to perform any string conversion. So, string sorting and comparison are done byte-by-byte, without any special collation rules applied. (Example: numbers are ordered by their point on the number line, so 2345 is greater than 500; meanwhile, strings are ordered by the encoding of the first byte, then the encoding of the second byte, and so on, so „2345“ is less than „500“.)

In Lua, a **number** is double-precision floating-point, but Tarantool allows both integer and floating-point values. Tarantool will try to store a Lua number as floating-point if the value contains a decimal point or is very large (greater than 100 billion = 1e14), otherwise Tarantool will store it as an integer. To ensure that even very large numbers are stored as integers, use the *tonumber64* function, or the LL (Long Long) suffix, or the ULL (Unsigned Long Long) suffix. Here are examples of numbers using regular notation, exponential notation, the ULL suffix and the `tonumber64` function: `-55`, `-2.7e+20`, `100000000000000ULL`, `tonumber64('18446744073709551615')`.

Lua **tables** with string keys are stored as MsgPack maps; Lua tables with integer keys starting with 1 – as MsgPack arrays. Nils may not be used in Lua tables; the workaround is to use msgpack.NULL.

A **tuple** is a light reference to a MsgPack array stored in the database. It is a special type (cdata) to avoid conversion to a Lua table on retrieval. A few functions may return tables with multiple tuples. For more tuple examples, see *box.tuple*.

Примечание: Tarantool uses the MsgPack format for database storage, which is variable-length. So, for example, the smallest number requires only one byte, but the largest number requires nine bytes.

Indexed field types

Indexes restrict values which Tarantool's MsgPack may contain. This is why, for example, „unsigned“ is a separate **indexed field type**, compared to 'integer' data type in MsgPack: they both store 'integer' values, but an „unsigned“ index contains only *non-negative* integer values and an 'integer' index contains *all* integer values.

Here's how Tarantool indexed field types correspond to MsgPack data types.

Indexed field type	MsgPack data type (and possible values)	Тип индекса	Примеры:
unsigned (may also be called 'uint' or 'num', but 'num' is deprecated)	**integer** (integer between 0 and 18446744073709551615, i.e. about 18 quintillion)	TREE, BITSET or HASH	123456
integer (may also be called 'int')	**integer** (integer between -9223372036854775808 and 18446744073709551615)	TREE or HASH	-2^63
number	**integer** (integer between -9223372036854775808 and 18446744073709551615) **double** (single-precision floating point number or double-precision floating point number)	TREE or HASH	1.234 -44 1.447e+44
string (may also be called 'str')	**string** (any set of octets, up to the maximum length)	TREE or HASH	'A B C' '65 66 67'
array	**array** (arrays of integers between -9223372036854775808 and 9223372036854775807)	RTREE	{10, 11} {3, 5, 9, 10}
scalar	**boolean** (true or false) **integer** (integer between -9223372036854775808 and 18446744073709551615) **double** (single-precision floating point number or double-precision floating point number) Note: When there is a mix of types, the key order is: booleans, then numbers, then strings.	TREE or HASH	true -1 1.234 '' 'py'

Persistence

In Tarantool, updates to the database are recorded in the so-called **write ahead log (WAL)** files. This ensures data persistence. When a power outage occurs or the server is killed incidentally, the in-memory database is lost. In this situation, WAL files are used to restore the data. Namely, Tarantool reads the WAL files and redoes the requests (this is called the «recovery process»). You can change the timing of the WAL writer, or turn it off, by setting *wal_mode*.

Tarantool also maintains a set of **checkpoint files**. These files contain an on-disk copy of the entire data set for a given moment. Instead of reading every WAL file since the databases were created, the recovery process can load the latest checkpoint file and then read only those WAL files that were produced after the checkpoint file was made. After checkpointing, old WAL files can be removed to free up space.

To force immediate creation of a checkpoint, you can use Tarantool's *box.snapshot()* request. To enable automatic creation of checkpoint files, you can use Tarantool's *snapshot daemon*. The snapshot daemon sets intervals for forced checkpoints. It makes sure that the states of both memtx and vinyl storage engines are synchronized and saved to disk, and automatically removes old WAL files.

Checkpoint files can be created even if there is no WAL file.

Примечание:

The memtx engine makes only forced checkpoints.
The vinyl engine runs checkpointing in background at all times.

See the *Internals* section for more details about the WAL writer and the recovery process.

Операции

Data operations

The basic data operations supported in Tarantool are:

- one data-retrieval operation (SELECT), and
- five data-manipulation operations (INSERT, UPDATE, UPSERT, DELETE, REPLACE).

All of them are implemented as functions in *box.space* submodule.

Examples

- INSERT: Add a new tuple to space „tester".

  The first field, field[1], will be 999 (MsgPack type is *integer*).

  The second field, field[2], will be „Taranto" (MsgPack type is *string*).

  ```
  tarantool> box.space.tester:insert{999, 'Taranto'}
  ```

- UPDATE: Update the tuple, changing field field[2].

  The clause «{999}», which has the value to look up in the index of the tuple's primary-key field, is mandatory, because `update()` requests must always have a clause that specifies a unique key, which in this case is field[1].

  The clause «{{„=", 2, „Tarantino"}}» specifies that assignment will happen to field[2] with the new value.

  ```
  tarantool> box.space.tester:update({999}, {{'=', 2, 'Tarantino'}})
  ```

- UPSERT: Upsert the tuple, changing field field[2] again.

  The syntax of `upsert()` is similar to the syntax of `update()`. However, the execution logic of these two requests is different. UPSERT is either UPDATE or INSERT, depending on the database's state. Also, UPSERT execution is postponed after transaction commit, so, unlike `update()`, `upsert()` doesn't return data back.

  ```
  tarantool> box.space.tester:upsert({999}, {{'=', 2, 'Tarantism'}})
  ```

- REPLACE: Replace the tuple, adding a new field.

  This is also possible with the `update()` request, but the `update()` request is usually more complicated.

  ```
  tarantool> box.space.tester:replace{999, 'Tarantella', 'Tarantula'}
  ```

- SELECT: Retrieve the tuple.

  The clause «{999}» is still mandatory, although it does not have to mention the primary key.

```
tarantool> box.space.tester:select{999}
```

- DELETE: Delete the tuple.

  In this example, we identify the primary-key field.

```
tarantool> box.space.tester:delete{999}
```

All the functions operate on tuples and accept only unique key values. So, the number of tuples in the space is always 0 or 1, since the keys are unique.

Functions `insert()`, `upsert()` and `replace()` accept only primary-key values. Functions `select()`, `delete()` and `update()` may accept either a primary-key value or a secondary-key value.

Примечание: Besides Lua, you can use *Perl, PHP, Python or other programming language connectors*. The client server protocol is open and documented. See this *annotated BNF*.

Операции с индексами

Index operations are automatic: if a data-manipulation request changes a tuple, then it also changes the index keys defined for the tuple.

The simple index-creation operation that we've illustrated before is:

```
:samp:`box.space.{имя-пространства}:create_index('{имя-индекса}')`
```

This creates a unique TREE index on the first field of all tuples (often called «Field#1»), which is assumed to be numeric.

The simple SELECT request that we've illustrated before is:

```
:extsamp:`box.space.{*{имя-пространства}*}:select({*{значение}*})`
```

This looks for a single tuple via the first index. Since the first index is always unique, the maximum number of returned tuples will be: one.

The following SELECT variations exist:

1. Помимо условия равенства, при поиске могут использоваться и другие условия сравнения.

   `box.space.`*`space-name`*`:select(value, {iterator = 'GT'})`

   The comparison operators are LT, LE, EQ, REQ, GE, GT (for «less than», «less than or equal», «equal», «reversed equal», «greater than or equal», «greater than» respectively). Comparisons make sense if and only if the index type is 'TREE".

   Этот вариант поиска может вернуть более одного кортежа. В таком случае кортежи будут отсортированы в порядке убывания по ключу (если использовался оператор LT, LE или REQ), либо в порядке возрастания (во всех остальных случаях).

2. Поиск может производиться по вторичному индексу.

   `box.space.`*`space-name`*`.index.`*`index-name`*`:select(value)`

   При поиске по первичному индексу имя индекса можно не указывать. При поиске же по вторичному индексу имя индекса указывать необходимо.

3. Поиск может производиться как по всему ключу, так и по его частям.

```
-- Suppose an index has two parts
tarantool> box.space.space-name.index.index-name.parts
---
- - type: unsigned
    fieldno: 1
  - type: string
    fieldno: 2
...
-- Suppose the space has three tuples
box.space.space-name:select()
---
- - [1, 'A']
  - [1, 'B']
  - [2, '']
...
```

4. The search may be for all fields, using a table for the value:

   `box.space.space-name:select({1, 'A'})`

   Либо же по одному полю (в этом случае используется таблица или скалярное значение):

   `box.space.space-name:select(1)`

   In the second case, the result will be two tuples: `{1, 'A'}` and `{1, 'B'}`.

   You can specify even zero fields, causing all three tuples to be returned. (Notice that partial key searches are available only in TREE indexes.)

Examples

- Пример работы с BITSET-индексом:

```
tarantool> box.schema.space.create('bitset_example')
tarantool> box.space.bitset_example:create_index('primary')
tarantool> box.space.bitset_example:create_index('bitset',{unique=false,type='BITSET
↪', parts={2,'unsigned'}})
tarantool> box.space.bitset_example:insert{1,1}
tarantool> box.space.bitset_example:insert{2,4}
tarantool> box.space.bitset_example:insert{3,7}
tarantool> box.space.bitset_example:insert{4,3}
tarantool> box.space.bitset_example.index.bitset:select(2, {iterator='BITS_ANY_SET'}
↪)
```

  Мы получим следующий результат:

```
---
- - [3, 7]
  - [4, 3]
...
```

  поскольку (7 AND 2) не равно 0 и (3 AND 2) не равно 0.

- Пример работы с RTREE-индексом:

```
tarantool> box.schema.space.create('rtree_example')
tarantool> box.space.rtree_example:create_index('primary')
tarantool> box.space.rtree_example:create_index('rtree',{unique=false,type='RTREE',␣
↪parts={2,'ARRAY'}})
tarantool> box.space.rtree_example:insert{1, {3, 5, 9, 10}}
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> box.space.rtree_example:insert{2, {10, 11}}
tarantool> box.space.rtree_example.index.rtree:select({4, 7, 5, 9}, {iterator = 'GT
↪'})
```

Мы получим следующий результат:

```
---
- - [1, [3, 5, 9, 10]]
...
```

because a rectangle whose corners are at coordinates `4,7,5,9` is entirely within a rectangle whose corners are at coordinates `3,5,9,10`.

Additionally, there exist *index iterator operations*. They can only be used with code in Lua and C/C++. Index iterators are for traversing indexes one key at a time, taking advantage of features that are specific to an index type, for example evaluating Boolean expressions when traversing BITSET indexes, or going in descending order when traversing TREE indexes.

See also other index operations like *alter()* and *drop()* in reference for *box.index* submodule.

Complexity factors

In reference for *box.space* and *box.index* submodules, there are notes about which complexity factors might affect the resource usage of each function.

Complexity factor	Effect
Размер индекса	The number of index keys is the same as the number of tuples in the data set. For a TREE index, if there are more keys, then the lookup time will be greater, although of course the effect is not linear. For a HASH index, if there are more keys, then there is more RAM used, but the number of low-level steps tends to remain constant.
Тип индекса	Typically, a HASH index is faster than a TREE index if the number of tuples in the space is greater than one.
Количество обращений к индексам	Ordinarily, only one index is accessed to retrieve one tuple. But to update the tuple, there must be N accesses if the space has N different indexes. Note re storage engine: Vinyl optimizes away such accesses if secondary index fields are unchanged by the update. So, this complexity factor applies only to memtx, since it always makes a full-tuple copy on every update.
Количество обращений к кортежам	A few requests, for example SELECT, can retrieve multiple tuples. This factor is usually less important than the others.
Настройки WAL	Важным параметром для записи в WAL является *wal_mode*. Если запись в WAL отключена или задана запись с задержкой, но этот фактор не так важен. Если же запись в WAL производится при каждом запросе на изменение данных, то при каждом таком запросе приходится ждать, пока отработает обращение к более медленному диску, и данный фактор становится важнее всех остальных.

3.3.2 Контроль транзакций

Transactions in Tarantool occur in **fibers** on a single **thread**. That is why Tarantool has a guarantee of execution atomicity. That requires emphasis.

Threads, fibers and yields

How does Tarantool process a basic operation? As an example, let's take this query:

```
tarantool> box.space.tester:update({3}, {{'=', 2, 'size'}, {'=', 3, 0}})
```

This is equivalent to an SQL statement like:

```
UPDATE tester SET "field[2]" = 'size', "field[3]" = 0 WHERE "field[[1]" = 3
```

This query will be processed with three operating system **threads**:

1. If we issue the query on a remote client, then the **network thread** on the server side receives the query, parses the statement and changes it to a server executable message which has already been checked, and which the server can understand without parsing everything again.

2. The network thread ships this message to the server's **«transaction processor» thread** using a lock-free message bus. Lua programs execute directly in the transaction processor thread, and do not require parsing and preparation.

   The server's transaction processor thread uses the primary-key index on field[1] to find the location of the tuple. It determines that the tuple can be updated (not much can go wrong when you're merely changing an unindexed field value to something shorter).

3. The transaction processor thread sends a message to the **write-ahead logging (WAL) thread** to commit the transaction. When done, the WAL thread replies with a COMMIT or ROLLBACK result, which is returned to the client.

Notice that there is only one transaction processor thread in Tarantool. Some people are used to the idea that there can be multiple threads operating on the database, with (say) thread #1 reading row #x, while thread #2 writes row #y. With Tarantool, no such thing ever happens. Only the transaction processor thread can access the database, and there is only one transaction processor thread for each instance of the server.

Like any other Tarantool thread, the transaction processor thread can handle many **fibers**. A fiber is a set of computer instructions that may contain «**yield**» signals. The transaction processor thread will execute all computer instructions until a yield, then switch to execute the instructions of a different fiber. Thus (say) the thread reads row #x for the sake of fiber #1, then writes row #y for the sake of fiber #2.

Yields must happen, otherwise the transaction processor thread would stick permanently on the same fiber. There are two types of yields:

- *implicit yields*: every data-change operation or network-access causes an implicit yield, and every statement that goes through the Tarantool client causes an implicit yield.

- explicit yields: in a Lua function, you can (and should) add "yield" statements to prevent hogging. This is called **cooperative multitasking**.

Среда взаимной многозадачности

Cooperative multitasking means: unless a running fiber deliberately yields control, it is not preempted by some other fiber. But a running fiber will deliberately yield when it encounters a "yield point": a transaction commit, an operating system call, or an explicit `yield()` request. Any system call which can block will be performed asynchronously, and any running fiber which must wait for a system call will be preempted, so that another ready-to-run fiber takes its place and becomes the new running fiber.

This model makes all programmatic locks unnecessary: cooperative multitasking ensures that there will be no concurrency around a resource, no race conditions, and no memory consistency issues.

When requests are small, for example simple UPDATE or INSERT or DELETE or SELECT, fiber scheduling is fair: it takes only a little time to process the request, schedule a disk write, and yield to a fiber serving the next client.

However, a function might perform complex computations or might be written in such a way that yields do not occur for a long time. This can lead to unfair scheduling, when a single client throttles the rest of the system, or to apparent stalls in request processing. Avoiding this situation is the responsibility of the function's author.

Transactions

In the absence of transactions, any function that contains yield points may see changes in the database state caused by fibers that preempt. Multi-statement transactions exist to provide isolation: each transaction sees a consistent database state and commits all its changes atomically. At commit time, a yield happens and all transaction changes are written to the write ahead log in a single batch.

To implement isolation, Tarantool uses a simple optimistic scheduler: the first transaction to commit wins. If a concurrent active transaction has read a value modified by a committed transaction, it is aborted.

The cooperative scheduler ensures that, in absence of yields, a multi-statement transaction is not preempted and hence is never aborted. Therefore, understanding yields is essential to writing abort-free code.

Примечание: You can't mix storage engines in a transaction today.

Implicit yields

The only explicit yield requests in Tarantool are *fiber.sleep()* and *fiber.yield()*, but many other requests «imply» yields because Tarantool is designed to avoid blocking.

Database operations usually do not yield, but it depends on the engine:

- In memtx, reads or writes do not require I/O and do not yield.
- In vinyl, not all data is in memory, and SELECT often incurs a disc I/O, and therefore yields, while a write may stall waiting for memory to free up, thus also causing a yield.

In the «autocommit» mode, all data change operations are followed by an automatic commit, which yields. So does an explicit commit of a multi-statement transaction, *box.commit()*.

Many functions in modules *fio*, *net_box*, *console* and *socket* (the «os» and «network» requests) yield.

Example #1

- *Engine = memtx* `select() insert()` has one yield, at the end of insertion, caused by implicit commit; `select()` has nothing to write to WAL and so does not yield.
- *Engine = vinyl* `select() insert()` has between one and three yields, since `select()` may yield if the data is not in cache, `insert()` may yield waiting for available memory, and there is an implicit yield at commit.
- The sequence `begin() insert() insert() commit()` yields only at commit if the engine is memtx, and can yield up to 3 times if the engine is vinyl.

Example #2

Assume that in space 'tester' there are tuples in which the third field represents a positive dollar amount. Let's start a transaction, withdraw from tuple#1, deposit in tuple#2, and end the transaction, making its effects permanent.

```
tarantool> function txn_example(from, to, amount_of_money)
         >   box.begin()
         >   box.space.tester:update(from, {{'-', 3, amount_of_money}})
         >   box.space.tester:update(to,   {{'+', 3, amount_of_money}})
         >   box.commit()
         >   return "ok"
         > end
---
...
tarantool> txn_example({999}, {1000}, 1.00)
---
- "ok"
...
```

If *wal_mode* = 'none', then implicit yielding at commit time does not take place, because there are no writes to the WAL.

If a task is interactive – sending requests to the server and receiving responses – then it involves network IO, and therefore there is an implicit yield, even if the request that is sent to the server is not itself an implicit yield request. Therefore, the sequence:

```
select
select
select
```

causes blocking (in memtx), if it is inside a function or Lua program being executed on the server, but causes yielding (in both memtx and vinyl) if it is done as a series of transmissions from a client, including a client which operates via telnet, via one of the connectors, or via the MySQL and PostgreSQL rocks, or via the interactive mode when *using Tarantool as a client*.

After a fiber has yielded and then has regained control, it immediately issues *testcancel*.

3.3.3 Ограничение доступа

Understanding security details is primarily an issue for administrators. Meanwhile, ordinary users should at least skim this section to get an idea of how Tarantool makes it possible for administrators to prevent unauthorized access to the database and to certain functions.

In a nutshell:

- There is a method to guarantee with password checks that users really are who they say they are ("authentication").
- There is a *_user* system space, where usernames and password-hashes are stored.
- There are functions for saying that certain users are allowed to do certain things ("privileges").
- There is a *_priv* system space, where privileges are stored. Whenever a user tries to do an operation, there is a check whether the user has the privilege to do the operation ("access control").

Further on, we explain all of this in more detail.

Users

There is a notion of the **current user** in any program working with Tarantool, local or remote. If a remote connection is using the *binary protocol*, the current user, by default, is „**guest**“. If the connection is using the *text protocol*, its current user is „**admin**“. When executing a *Lua initialization script*, Tarantool's current user is also 'admin'.

The current user can be changed:

- For a binary protocol connection – with AUTH protocol command, supported by most clients;
- For a text protocol connection and in a Lua initialization script – with *box.session.su*;
- For a stored function invoked with CALL command over the binary protocol – with *SETUID* property enabled for the function, which makes Tarantool temporarily replace the current user with the function's creator, with all creator's privileges, during function execution.

Passwords

Each user may have a **password**. The password is any alphanumeric string.

Tarantool passwords are stored in the *_user* system space with a cryptographic hash function so that, if the password is 'x', the stored hash-password is a long string like 'lL3OvhkIPOKh+Vn9Avlkx69M/Ck=‘. When a client connects to a Tarantool server, the server sends a random salt value which the client must mix with the hashed-password before sending to the server. Thus the original value 'x' is never stored anywhere except in the user's head, and the hashed value is never passed down a network wire except when mixed with a random salt.

Примечание: For more details of the password hashing algorithm (e.g. for the purpose of writing a new client application), read the scramble.h header file.

This system prevents malicious onlookers from finding passwords by snooping in the log files or snooping on the wire. It is the same system that MySQL introduced several years ago, which has proved adequate for medium-security installations. Nevertheless, administrators should warn users that no system is foolproof against determined long-term attacks, so passwords should be guarded and changed occasionally. Administrators should also advise users to choose long unobvious passwords, but it is ultimately up to the users to choose or change their own passwords.

There are two functions for managing passwords in Tarantool: *box.schema.user.password()* for changing a user's password and *box.schema.user.passwd()* for getting a hash-password.

Owners and privileges

In Tarantool, all objects are organized into a hierarchy of ownership. The **owner** of every object is its creator. The creator of the initial database state (we call it 'universe') – including the database itself, the system spaces, the users – is 'admin'.

An object's owner can share some rights on the object by **granting privileges** to other users. The following privileges are implemented:

- Read an object,
- Write, i.e. modify contents of an object,
- Execute, i.e. use an object (if the privilege makes sense for the object; for example, spaces can not be «executed», but functions can).

Примечание: Currently, «drop» and «grant» privileges can not be granted to other users. This possibility will be added in future versions of Tarantool.

This is how the privilege system works under the hood. To be able to create objects, a user needs to have write access to Tarantool's system spaces. The „admin" user, who is at the top of the hierarchy and who is the ultimate source of privileges, shares write access to a system space (e.g. *_space*) with some users. Now the users can insert data into the system space (e.g. creating new spaces) and themselves become creators/definers of new objects. For the objects they created, the users can in turn share privileges with other users.

This is why only an object's owner can drop the object, but not other ordinary users. Meanwhile, „admin" can drop any object or delete any other user, because „admin" is the creator and ultimate owner of them all.

The syntax of all *grant()/revoke()* commands in Tarantool follows this basic idea.

- Their first argument is «who gets» or «who is revoked» a grant.
- Their second argument is the type of privilege granted, or a list of privileges.
- Their third argument is the object type on which the privilege is granted.
- Their fourth and optional argument is the object name ('universe" has no name, because there is only one 'universe', but you need to specify names for functions/users/spaces/etc).

Example #1

Here we disable all privileges and run Tarantool in the 'no-privilege' mode.

```
box.schema.user.grant('guest', 'read,write,execute', 'universe')
```

Example #2

Here we create a Lua function that will be executed under the user id of its creator, even if called by another user.

First, we create two spaces („u" and „i") and grant a no-password user („internal") full access to them. Then we define a function („read_and_modify") and the no-password user becomes this function's creator. Finally, we grant another user („public_user") access to execute Lua functions created by the no-password user.

```
box.schema.space.create('u')
box.schema.space.create('i')
box.schema.space.u:create_index('pk')
box.schema.space.i:create_index('pk')

box.schema.user.create(‘internal’)

box.schema.user.grant('internal', 'read,write', 'space', 'u')
box.schema.user.grant('internal', 'read,write', 'space', 'i')

function read_and_modify(key)
  local u = box.space.u
  local i = box.space.i
  local fiber = require('fiber')
  local t = u:get{key}
  if t ~= nil
        u:put{key, box.session.uid()}
        i:put{key, fiber.time()}
  end
end
```

(continues on next page)

(продолжение с предыдущей страницы)

```
box.session.su('internal')
box.schema.func.create('read_and_modify', {setuid= true})
box.session.su('admin')
box.schema.user.create('public_user', {password = 'secret'})
box.schema.user.grant('public_user', 'execute', 'function', 'read_and_modify')
```

Roles

A **role** is a container for privileges which can be granted to regular users. Instead of granting or revoking individual privileges, you can put all the privileges in a role and then grant or revoke the role.

Role information is stored in the *_user* space, but the third field in the tuple – the type field – is 'role' rather than 'user'.

An important feature in role management is that roles can be **nested**. For example, role R1 can be granted a privilege «role R2», so users with the role R1 will subsequently get all privileges from both roles R1 and R2. In other words, a user gets all the privileges that are granted to a user's roles, directly or indirectly.

Example

```
-- This example will work for a user with many privileges, such as 'admin'
-- Create space T with a primary index
box.schema.space.create('T')
box.space.T:create_index('primary', {})
-- Create user U1 so that later we can change the current user to U1
box.schema.user.create('U1')
-- Create two roles, R1 and R2
box.schema.role.create('R1')
box.schema.role.create('R2')
-- Grant role R2 to role R1 and role R1 to user U1 (order doesn't matter)
box.schema.role.grant('R1', 'execute', 'role', 'R2')
box.schema.user.grant('U1', 'execute', 'role', 'R1')
-- Grant read/write privileges for space T to role R2
-- (but not to role R1 and not to user U1)
box.schema.role.grant('R2', 'read,write', 'space', 'T')
-- Change the current user to user U1
box.session.su('U1')
-- An insertion to space T will now succeed because, due to nested roles,
-- user U1 has write privilege on space T
box.space.T:insert{1}
```

For details about Tarantool functions related to role management, see reference on *box.schema* submodule.

Sessions and security

A **session** is the state of a connection to Tarantool. It contains:

- an integer id identifying the connection,
- the *current user* associated with the connection,
- text description of the connected peer, and
- session local state, such as Lua variables and functions.

In Tarantool, a single session can execute multiple concurrent transactions. Each transaction is identified by a unique integer id, which can be queried at start of the transaction using *box.session.sync()*.

Примечание: To track all connects and disconnects, you can use *connection and authentication triggers*.

3.3.4 Триггеры

Triggers, also known as **callbacks**, are functions which the server executes when certain events happen.

There are three types of triggers in Tarantool:

- *connection triggers*, which are executed when a session begins or ends,
- *authentication triggers*, which are executed during authentication, and
- *replace triggers*, which are for database events.

All of them are implemented as functions in Tarantool built-in libraries.

All triggers have the following characteristics:

- Triggers associate a function with an event. The request to «define a trigger» implies passing the name of the trigger's function to one of the «on_event-name()» functions from the *box.session* submodule: *on_connect()*, *on_auth()*, *on_disconnect()*, or *on_replace()*.
- Triggers are defined only by the „admin" user.
- Triggers are stored in the server's memory, not in the database. So, triggers disappear when the server is shut down. To make them permanent, put function definitions and trigger settings into Tarantool's *initialization script*.
- Triggers have low overhead. If a trigger is not defined, then the overhead is minimal: merely a pointer dereference and check. If a trigger is defined, then its overhead is equivalent to the overhead of calling a stored procedure.
- There can be multiple triggers for one event. In this case, triggers are executed in the reverse order that they were defined in.
- Triggers must work within the event context. However, effects are undefined if a function contains requests which normally could not occur immediately after the event, but only before the return from the event. For example, putting os.exit() or *box.rollback()* in a trigger function would be bringing in requests outside the event context.
- Triggers are replaceable. The request to «redefine a trigger» implies passing the names of a new trigger function and an old trigger function to one of the «on_event-name()» functions.

To get a list of triggers, you can use:

- on_connect() – with no arguments – to return a table of all connect-trigger functions;
- on_auth() to return all authentication-trigger functions;
- on_disconnect() to return all disconnect-trigger functions;
- on_replace() to return all replace-trigger functions.

Example

Here we log connect and disconnect events into Tarantool server log.

```
log = require('log')

function on_connect_impl()
  log.info("connected "..box.session.peer()..", sid "..box.session.id())
end

function on_disconnect_impl()
  log.info("disconnected, sid "..box.session.id())
end

function on_auth_impl(user)
  log.info("authenticated sid "..box.session.id().." as "..user)
end

function on_connect() pcall(on_connect_impl) end
function on_disconnect() pcall(on_disconnect_impl) end
function on_auth(user) pcall(on_auth_impl, user) end

box.session.on_connect(on_connect)
box.session.on_disconnect(on_disconnect)
box.session.on_auth(on_auth)
```

3.3.5 Ограничения

Number of parts in an index

For TREE or HASH indexes, the maximum is 255 (`box.schema.INDEX_PART_MAX`). For RTREE indexes, the maximum is 1 but the field is an ARRAY of up to 20 dimensions. For BITSET indexes, the maximum is 1.

Number of indexes in a space

128 (`box.schema.INDEX_MAX`).

Number of fields in a tuple

The theoretical maximum is 2,147,483,647 (`box.schema.FIELD_MAX`). The practical maximum is whatever is specified by the space's *field_count* member, or the maximal tuple length.

Number of bytes in a tuple

The maximal number of bytes in a tuple is roughly equal to *slab_alloc_maximal* (with a metadata overhead of about 20 bytes per tuple, which is added on top of useful bytes). By default, the value of `slab_alloc_maximal` is 1,048,576. To increase it, specify a larger value when starting the server. For example, `box.cfg{slab_alloc_maximal=2*1048576}`.

Slab size

The maximal size of an allocatable memory unit (slab) is equal to one quarter of *slab_alloc_maximal* (by default, approximately 262,000 bytes). To see memory usage statistics broken down by slab size, use *box.slab.stats()*.

Number of bytes in an index key

If a field in a tuple can contain a million bytes, then the index key can contain a million bytes, so the maximum is determined by factors such as *Number of bytes in a tuple*, not by the index support.

Number of spaces

The theoretical maximum is 65,000 (`box.schema.SPACE_MAX`).

Number of connections

The practical limit is the number of file descriptors that one can set with the operating system.

Space size

The total maximum size for all spaces is in effect set by *slab_alloc_arena*, which in turn is limited by the total available memory.

Update operations count

The maximum number of operations that can be in a single update is 4000 (`BOX_UPDATE_OP_CNT_MAX`).

Number of users and roles

32 (BOX_USER_MAX).

Length of an index name or space name or user name

32 (`box.schema.NAME_MAX`).

Number of replicas in a cluster

32 (`box.schema.REPLICA_MAX`).

3.4 Сервер приложений

3.4.1 Про модули/rocks

Alongside with using Tarantool as a database manager, you can also use it as an application server. This means that you can write your own logic, install it as a module in Tarantool — and see Tarantool perform your logic. So, a module is an optional library which enhances Tarantool functionality.

Tarantool's native language for writing modules is Lua. Modules in Lua are also called «rocks». If you are new to Lua, we recommend following this Lua modules tutorial before reading this section.

3.4.2 Установка существующего модуля

Модули, созданные командой Tarantool'а и членами сообщества разработчиков, выложены на rocks.tarantool.org. Про некоторые из этих модулей — *expirationd*, *mysql*, *postgresql*, *shard* – подробнее говорится в других разделах текущей документации.

Шаг 1: Установите LuaRocks. Общее описание того, как установить LuaRocks в Unix-системе, приводится в кратком руководстве по LuaRocks. Например, установить LuaRocks в Ubuntu можно следующей командой:

```
$ sudo apt-get install luarocks
```

Шаг 2: Добавьте репозиторий Tarantool'а в список rocks-серверов. Для этого добавьте rocks.tarantool.org в файл `.luarocks/config.lua`:

```
$ mkdir ~/.luarocks
$ echo "rocks_servers = {[[http://rocks.tarantool.org/]]}" >> ~/.luarocks/config.lua
```

Теперь можно:

- искать существующие модули в общем репозитории

  `$ luarocks search module-name`

- добавлять новые модули в свой локальный репозиторий

  `$ luarocks install module-name --local`

- загружать любой модуль для Tarantool'а с помощью `require`

  `tarantool> local-name = require('module-name')`

(вот почему многие примеры в этой документации начинаются с вызова `require`.)

Далее на странице репозитория «tarantool/rocks» на GitHub вы можете посмотреть примеры модулей и инструкции по добавлению собственных модулей в общий репозиторий.

For developers, we provide *instructions on creating their own Tarantool modules in Lua, C/C++ and Lua+C*.

3.4.3 Создание нового модуля на языке Lua

Для примера создадим новый Lua-файл с именем `mymodule.lua`, в котором опишем экспортируемую функцию с некоторым именем, а затем с помощью Tarantool'а загрузим и просмотрим наш новый модуль и вызовем описанную в нем функцию.

Lua-файл в нашем примере будет таким:

```
-- mymodule - простейший Lua-модуль для Tarantool'а
local exports = {}
exports.myfun = function(input_string)
    print('Hello', input_string)
end
return exports
```

Для загрузки и просмотра модуля, а также вызова описанной в нем функции, выполним следующие команды:

```
tarantool> mymodule = require('mymodule')
---
...

tarantool> mymodule
---
- myfun: 'function: 0x405edf20'
...

tarantool> mymodule.myfun(os.getenv('USER'))
Hello world
---
...
```

3.4.4 Создание нового модуля на языке C/C++

Для примера создадим новый C-файл с именем `mymodule.c`, в котором опишем экспортируемую функцию с некоторым именем, а затем с помощью Tarantool'а загрузим и просмотрим наш новый модуль и вызовем описанную в нем функцию.

Обратите внимание, что для корректной работы требуется заранее установить модуль `tarantool-dev`.

С-файл в нашем примере будет таким:

```
/* mycmodule - a simple Tarantool module */
#include <lua.h>
#include <lauxlib.h>
#include <lualib.h>
#include <tarantool/module.h>
static int
myfun(lua_State *L)
{
    if (lua_gettop(L) < 1)
        return luaL_error(L, "Usage: myfun(name)");

    /* Get first argument */
    const char *name = lua_tostring(L, 1);

    /* Push one result to Lua stack */
    lua_pushfstring(L, "Hello, %s", name);
    return 1; /* the function returns one result */
}

LUA_API int
luaopen_mycmodule(lua_State *L)
{
    static const struct luaL_reg reg[] = {
        { "myfun", myfun },
        { NULL, NULL }
    };
    luaL_register(L, "mycmodule", reg);
    return 1;
}
```

С помощью gcc скомпилируем наш код в виде shared-библиотеки (без префикса «lib»), а затем просмотрим ее содержимое с помощью ls:

```
$ gcc mycmodule.c -shared -fPIC -I/usr/include/tarantool -o mycmodule.so
$ ls mycmodule.so -l
-rwxr-xr-x 1 roman roman 7272 Jun  3 16:51 mycmodule.so
```

Для автоматизации сборки рекомендуется использовать CMake-скрипты для Tarantool'a.

Для загрузки и просмотра модуля, а также вызова описанной в нем функции, выполним следующие команды:

```
tarantool> mycmodule = require('mycmodule')
---
...
tarantool> mycmodule
---
- myfun: 'function: 0x4100ec98'
...
tarantool> mycmodule.myfun(os.getenv('USER'))
---
- Hello, world
...
```

Вы можете аналогичным образом создавать модули на C++ при условии, что в их коде не будут выбрасываться исключения.

3.4.5 Создание нового модуля на смеси языков Lua/C

(1) Создайте новый Lua-модуль и назовите его, например, `myfunmodule`.

(2) Создайте (вложенный) модуль на C и назовите его, например, `myfunmodule.internal`.

(3) Загрузите новый C-модуль из Lua-кода с помощью `require('myfunmodule.internal')`, а затем сделайте для него обертку или вызывайте его функции напрямую.

Примеры модулей на смеси языков Lua/C можно посмотреть в репозитории «tarantool/http» на GitHub.

3.4.6 Примечания для особых случаев

- В среде Lua все загруженные модули кешируются в таблице `package.loaded`. Чтобы перегрузить какой-либо модуль с диска, укажите для его ключа значение *nil*:

  ```
  tarantool> package.loaded['modulename'] = nil
  ```

- Для поиска `.lua`-модулей используйте команду `package.path`, а для поиска бинарных модулей на C используйте команду `package.cpath`.

  ```
  tarantool> package.path
  ---
  - ./?.lua;./?/init.lua;/home/roman/.luarocks/share/lua/5.1/?.lua;/home/roma
  n/.luarocks/share/lua/5.1/?/init.lua;/home/roman/.luarocks/share/lua/?.lua;
  /home/roman/.luarocks/share/lua/?/init.lua;/usr/share/tarantool/?.lua;/usr/
  share/tarantool/?/init.lua;./?.lua;/usr/local/share/luajit-2.0.3/?.lua;/usr
  /local/share/lua/5.1/?.lua;/usr/local/share/lua/5.1/?/init.lua
  ...
  tarantool> package.cpath
  ---
  - ./?.so;/home/roman/.luarocks/lib/lua/5.1/?.so;/home/roman/.luarocks/lib/l
  ua/?.so;/usr/lib/tarantool/?.so;./?.so;/usr/local/lib/lua/5.1/?.so;/usr/loc
  al/lib/lua/5.1/loadall.so
  ...
  ```

  Знаки вопроса стоят вместо имени модуля, которое было указано ранее при вызове `require('имя_модуля')`.

- Для просмотра внутреннего состояния прямо изнутри Lua-модуля используйте `state` и соответствующую локальную переменную в рамках модуля:

  ```
  -- mymodule
  local exports = {}
  local state = {}
  exports.myfun = function()
      state.x = 42 -- используем state
  end
  return exports
  ```

- Обратите внимание, что в текущей документации в примерах Lua-кода используются *локальные* переменные. Будьте аккуратны, если в своих модулях вы будете использовать *глобальные* переменные, поскольку пользователи ваших модулей могут не знать об этих переменных.

3.4.7 Tips on Lua syntax

The Lua syntax for *data-manipulation functions* can vary. Here are examples of the variations with `select()` requests. The same rules exist for the other data-manipulation functions.

Every one of the examples does the same thing: select a tuple set from a space named „tester" where the primary-key field value equals 1. For these examples, we assume that the numeric id of „tester" is 512, which happens to be the case in our sandbox example only.

First, there are three **object reference variations**:

```
-- #1 module . submodule . name
tarantool> box.space.tester:select{1}
-- #2 replace name with a literal in square brackets
tarantool> box.space['tester']:select{1}
-- #3 use a variable for the entire object reference
tarantool> s = box.space.tester
tarantool> s:select{1}
```

Examples in this manual usually have the «`box.space.`*`tester`*`:`» form (#1). However, this is a matter of user preference and all the variations exist in the wild.

Also, descriptions in this manual use the syntax «`space_object:`» for references to objects which are spaces, and «`index_object:`» for references to objects which are indexes (for example `box.space.`*`tester`*`.index.`*`primary`*`:`).

Then, there are seven **parameter variations**:

```
-- #1
tarantool> box.space.tester:select{1}
-- #2
tarantool> box.space.tester:select({1})
-- #3
tarantool> box.space.tester:select(1)
-- #4
tarantool> box.space.tester.select(box.space.tester,1)
-- #5
tarantool> box.space.tester:select({1},{iterator='EQ'})
-- #6
tarantool> variable = 1
tarantool> box.space.tester:select{variable}
-- #7
tarantool> variable = {1}
tarantool> box.space.tester:select(variable)
```

Lua allows to omit parentheses `()` when invoking a function if its only argument is a Lua table, and we use it sometimes in our examples. This is why `select{1}` is equivalent to `select({1})`. Literal values such as 1 (a scalar value) or `{1}` (a Lua table value) may be replaced by variable names, as in examples #6 and #7. Although there are special cases where braces can be omitted, they are preferable because they signal «Lua table». Examples and descriptions in this manual have the `{1}` form. However, this too is a matter of user preference and all the variations exist in the wild.

3.4.8 Книга рецептов

Here are contributions of Lua programs for some frequent or tricky situations.

Any of the programs can be executed by copying the code into a .lua file, and then entering `chmod +x ./`*`program-name`*`.lua` and `./`*`program-name`*`.lua` on the terminal. As is usual for Tarantool/Lua programs, the first line is a «hashbang» #!/usr/bin/env tarantool This runs the Tarantool Lua application server, which should be on the execution path.

Use freely.

hello_world.lua

The standard example of a simple program.

```
#!/usr/bin/env tarantool

print('Hello, World!')
```

console_start.lua

Use *box.once()* to initialize a database (creating spaces) if this is the first time the server has been run. Then use *console.start()* to start interactive mode.

```
#!/usr/bin/env tarantool

-- Configure database
box.cfg {
    listen = 3313
}

box.once("bootstrap", function()
    box.schema.space.create('tweedledum')
    box.space.tweedledum:create_index('primary',
        { type = 'TREE', parts = {1, 'unsigned'}})
end)

require('console').start()
```

fio_read.lua

Use the *fio module* to open, read, and close a file.

```
#!/usr/bin/env tarantool

local fio = require('fio')
local errno = require('errno')
local f = fio.open('/tmp/xxxx.txt', {'O_RDONLY' })
if not f then
    error("Failed to open file: "..errno.strerror())
end
local data = f:read(4096)
f:close()
print(data)
```

fio_write.lua

Use the *fio module* to open, write, and close a file.

```
#!/usr/bin/env tarantool

local fio = require('fio')
local errno = require('errno')
local f = fio.open('/tmp/xxxx.txt', {'O_CREAT', 'O_WRONLY', 'O_APPEND'},
    tonumber('0666', 8))
if not f then
    error("Failed to open file: "..errno.strerror())
end
f:write("Hello\n");
f:close()
```

ffi_printf.lua

Use the LuaJIT ffi library to call a C built-in function: printf(). (For help understanding ffi, see the FFI tutorial.)

```
#!/usr/bin/env tarantool

local ffi = require('ffi')
ffi.cdef[[
    int printf(const char *format, ...);
]]

ffi.C.printf("Hello, %s\n", os.getenv("USER"));
```

ffi_gettimeofday.lua

Use the LuaJIT ffi library to call a C function: gettimeofday(). This delivers time with millisecond precision, unlike the time function in Tarantool's *clock module*.

```
#!/usr/bin/env tarantool

local ffi = require('ffi')
ffi.cdef[[
    typedef long time_t;
    typedef struct timeval {
    time_t tv_sec;
    time_t tv_usec;
} timeval;
    int gettimeofday(struct timeval *t, void *tzp);
]]

local timeval_buf = ffi.new("timeval")
local now = function()
    ffi.C.gettimeofday(timeval_buf, nil)
    return tonumber(timeval_buf.tv_sec * 1000 + (timeval_buf.tv_usec / 1000))
end
```

ffi_zlib.lua

Use the LuaJIT ffi library to call a C library function. (For help understanding ffi, see the FFI tutorial.)

```
#!/usr/bin/env tarantool

local ffi = require("ffi")
ffi.cdef[[
    unsigned long compressBound(unsigned long sourceLen);
    int compress2(uint8_t *dest, unsigned long *destLen,
    const uint8_t *source, unsigned long sourceLen, int level);
    int uncompress(uint8_t *dest, unsigned long *destLen,
    const uint8_t *source, unsigned long sourceLen);
]]
local zlib = ffi.load(ffi.os == "Windows" and "zlib1" or "z")

-- Lua wrapper for compress2()
local function compress(txt)
    local n = zlib.compressBound(#txt)
    local buf = ffi.new("uint8_t[?]", n)
    local buflen = ffi.new("unsigned long[1]", n)
    local res = zlib.compress2(buf, buflen, txt, #txt, 9)
    assert(res == 0)
    return ffi.string(buf, buflen[0])
end

-- Lua wrapper for uncompress
local function uncompress(comp, n)
    local buf = ffi.new("uint8_t[?]", n)
    local buflen = ffi.new("unsigned long[1]", n)
    local res = zlib.uncompress(buf, buflen, comp, #comp)
    assert(res == 0)
    return ffi.string(buf, buflen[0])
end

-- Simple test code.
local txt = string.rep("abcd", 1000)
print("Uncompressed size: ", #txt)
local c = compress(txt)
print("Compressed size: ", #c)
local txt2 = uncompress(c, #txt)
assert(txt2 == txt)
```

ffi_meta.lua

Use the LuaJIT ffi library to access a C object via a metamethod (a method which is defined with a metatable).

```
#!/usr/bin/env tarantool

local ffi = require("ffi")
ffi.cdef[[
typedef struct { double x, y; } point_t;
]]

local point
local mt = {
  __add = function(a, b) return point(a.x+b.x, a.y+b.y) end,
  __len = function(a) return math.sqrt(a.x*a.x + a.y*a.y) end,
  __index = {
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    area = function(a) return a.x*a.x + a.y*a.y end,
  },
}
point = ffi.metatype("point_t", mt)

local a = point(3, 4)
print(a.x, a.y)  --> 3  4
print(#a)        --> 5
print(a:area())  --> 25
local b = a + point(0.5, 8)
print(#b)        --> 12.5
```

print_arrays.lua

Create Lua tables, and print them. Notice that for the „array" table the iterator function is ipairs(), while for the „map" table the iterator function is pairs(). (*ipairs()* is faster than *pairs()*, but pairs() is recommended for map-like tables or mixed tables.) The display will look like: «1 Apple | 2 Orange | 3 Grapefruit | 4 Banana | k3 v3 | k1 v1 | k2 v2».

```
#!/usr/bin/env tarantool

array = { 'Apple', 'Orange', 'Grapefruit', 'Banana'}
for k, v in ipairs(array) do print(k, v) end

map = { k1 = 'v1', k2 = 'v2', k3 = 'v3' }
for k, v in pairs(map) do print(k, v) end
```

count_array.lua

Use the „#" operator to get the number of items in an array-like Lua table. This operation has O(log(N)) complexity.

```
#!/usr/bin/env tarantool

array = { 1, 2, 3}
print(#array)
```

count_array_with_nils.lua

Missing elements in arrays, which Lua treats a «nil»s, cause the simple «#» operator to deliver improper results. The «print(#t)» instruction will print «4»; the «print(counter)» instruction will print «3»; the «print(max)» instruction will print «10». Other table functions, such as table.sort(), will also misbehave when «nils» are present.

```
#!/usr/bin/env tarantool

local t = {}
t[1] = 1
t[4] = 4
t[10] = 10
print(#t)
```

(continues on next page)

(продолжение с предыдущей страницы)

```
local counter = 0
for k,v in pairs(t) do counter = counter + 1 end
print(counter)
local max = 0
for k,v in pairs(t) do if k > max then max = k end end
print(max)
```

count_array_with_nulls.lua

Use explicit NULL values to avoid the problems caused by Lua's nil == missing value behavior. Although `json.NULL == nil` is `true`, all the print instructions in this program will print the correct value: 10.

```
#!/usr/bin/env tarantool

local json = require('json')
local t = {}
t[1] = 1; t[2] = json.NULL; t[3]= json.NULL;
t[4] = 4; t[5] = json.NULL; t[6]= json.NULL;
t[6] = 4; t[7] = json.NULL; t[8]= json.NULL;
t[9] = json.NULL
t[10] = 10
print(#t)
local counter = 0
for k,v in pairs(t) do counter = counter + 1 end
print(counter)
local max = 0
for k,v in pairs(t) do if k > max then max = k end end
print(max)
```

count_map.lua

Get the number of elements in a map-like table.

```
#!/usr/bin/env tarantool

local map = { a = 10, b = 15, c = 20 }
local size = 0
for _ in pairs(map) do size = size + 1; end
print(size)
```

swap.lua

Use a Lua peculiarity to swap two variables without needing a third variable.

```
#!/usr/bin/env tarantool

local x = 1
local y = 2
x, y = y, x
print(x, y)
```

uri.lua

Use built-in function `uri_parse` to see what is in a *URI <configuration-uri>*:

```
#!/usr/bin/env tarantool

local uri = require('uri')
local r= uri.parse("scheme://login:password@host:service:/path1/path2/path3?q1=v1&q2=v2#fragment")
print('r.password=',r.password)
print('r.path=',r.path)
print('r.scheme',r.scheme)
print('r.login=',r.login)
print('r.query=',r.query)
print('r.service=',r.service)
print('r.fragment=',r.fragment)
print('r.host=',r.host)
```

class.lua

Create a class, create a metatable for the class, create an instance of the class. Another illustration is at http://lua-users.org/wiki/LuaClassesWithMetatable.

```
#!/usr/bin/env tarantool

-- define class objects
local myclass_somemethod = function(self)
    print('test 1', self.data)
end

local myclass_someothermethod = function(self)
    print('test 2', self.data)
end

local myclass_tostring = function(self)
    return 'MyClass <'..self.data..'>'
end

local myclass_mt = {
    __tostring = myclass_tostring;
    __index = {
        somemethod = myclass_somemethod;
        someothermethod = myclass_someothermethod;
    }
}

-- create a new object of myclass
local object = setmetatable({ data = 'data'}, myclass_mt)
print(object:somemethod())
print(object.data)
```

garbage.lua

Force Lua garbage collection with the collectgarbage function.

```
#!/usr/bin/env tarantool

collectgarbage('collect')
```

fiber_producer_and_consumer.lua

Start one fiber for producer and one fiber for consumer. Use *fiber.channel()* to exchange data and synchronize. One can tweak the channel size (`ch_size` in the program code) to control the number of simultaneous tasks waiting for processing.

```
#!/usr/bin/env tarantool

local fiber = require('fiber')
local function consumer_loop(ch, i)
    -- initialize consumer synchronously or raise an error()
    fiber.sleep(0) -- allow fiber.create() to continue
    while true do
        local data = ch:get()
        if data == nil then
            break
        end
        print('consumed', i, data)
        fiber.sleep(math.random()) -- simulate some work
    end
end

local function producer_loop(ch, i)
    -- initialize consumer synchronously or raise an error()
    fiber.sleep(0) -- allow fiber.create() to continue
    while true do
        local data = math.random()
        ch:put(data)
        print('produced', i, data)
    end
end

local function start()
    local consumer_n = 5
    local producer_n = 3

    -- Create a channel
    local ch_size = math.max(consumer_n, producer_n)
    local ch = fiber.channel(ch_size)

    -- Start consumers
    for i=1, consumer_n,1 do
        fiber.create(consumer_loop, ch, i)
    end

    -- Start producers
    for i=1, producer_n,1 do
        fiber.create(producer_loop, ch, i)
    end
end
```

(continues on next page)

(продолжение с предыдущей страницы)

```
start()
print('started')
```

socket_tcpconnect.lua

Use *socket.tcp_connect()* to connect to a remote host via TCP. Display the connection details and the result of a GET request.

```
#!/usr/bin/env tarantool

local s = require('socket').tcp_connect('google.com', 80)
print(s:peer().host)
print(s:peer().family)
print(s:peer().type)
print(s:peer().protocol)
print(s:peer().port)
print(s:write("GET / HTTP/1.0\r\n\r\n"))
print(s:read('\r\n'))
print(s:read('\r\n'))
```

socket_tcp_echo.lua

Use *socket.tcp_connect()* to set up a simple TCP server, by creating a function that handles requests and echos them, and passing the function to *socket.tcp_server()*. This program has been used to test with 100,000 clients, with each client getting a separate fiber.

```
#!/usr/bin/env tarantool

local function handler(s, peer)
    s:write("Welcome to test server, " .. peer.host .."\n")
    while true do
        local line = s:read('\n')
        if line == nil then
            break -- error or eof
        end
        if not s:write("pong: "..line) then
            break -- error or eof
        end
    end
end

local server, addr = require('socket').tcp_server('localhost', 3311, handler)
```

getaddrinfo.lua

Use *socket.getaddrinfo()* to perform non-blocking DNS resolution, getting both the AF_INET6 and AF_INET information for „google.com“. This technique is not always necessary for tcp connections because *socket.tcp_connect()* performs *socket.getaddrinfo* under the hood, before trying to connect to the first available address.

```
#!/usr/bin/env tarantool

local s = require('socket').getaddrinfo('google.com', 'http', { type = 'SOCK_STREAM' })
print('host=',s[1].host)
print('family=',s[1].family)
print('type=',s[1].type)
print('protocol=',s[1].protocol)
print('port=',s[1].port)
print('host=',s[2].host)
print('family=',s[2].family)
print('type=',s[2].type)
print('protocol=',s[2].protocol)
print('port=',s[2].port)
```

socket_udp_echo.lua

Tarantool does not currently have a *udp_server* function, therefore socket_udp_echo.lua is more complicated than socket_tcp_echo.lua. It can be implemented with sockets and fibers.

```
#!/usr/bin/env tarantool

local socket = require('socket')
local errno = require('errno')
local fiber = require('fiber')

local function udp_server_loop(s, handler)
    fiber.name("udp_server")
    while true do
        -- try to read a datagram first
        local msg, peer = s:recvfrom()
        if msg == "" then
            -- socket was closed via s:close()
            break
        elseif msg ~= nil then
            -- got a new datagram
            handler(s, peer, msg)
        else
            if s:errno() == errno.EAGAIN or s:errno() == errno.EINTR then
                -- socket is not ready
                s:readable() -- yield, epoll will wake us when new data arrives
            else
                -- socket error
                local msg = s:error()
                s:close() -- save resources and don't wait GC
                error("Socket error: " .. msg)
            end
        end
    end
end

local function udp_server(host, port, handler)
    local s = socket('AF_INET', 'SOCK_DGRAM', 0)
    if not s then
        return nil -- check errno:strerror()
    end
    if not s:bind(host, port) then
```

(continues on next page)

(продолжение с предыдущей страницы)

```
        local e = s:errno() -- save errno
        s:close()
        errno(e) -- restore errno
        return nil -- check errno:strerror()
    end

    fiber.create(udp_server_loop, s, handler) -- start a new background fiber
    return s
end
```

A function for a client that connects to this server could look something like this ...

```
local function handler(s, peer, msg)
    -- You don't have to wait until socket is ready to send UDP
    -- s:writable()
    s:sendto(peer.host, peer.port, "Pong: " .. msg)
end

local server = udp_server('127.0.0.1', 3548, handler)
if not server then
    error('Failed to bind: ' .. errno.strerror())
end

print('Started')

require('console').start()
```

http_get.lua

Use the http rock (which must first be installed) to get data via HTTP.

```
#!/usr/bin/env tarantool

local http_client = require('http.client')
local json = require('json')
local r = http_client.get('http://api.openweathermap.org/data/2.5/weather?q=Oakland,us')
if r.status ~= 200 then
    print('Failed to get weather forecast ', r.reason)
    return
end
local data = json.decode(r.body)
print('Oakland wind speed: ', data.wind.speed)
```

http_send.lua

Use the http rock (which must first be installed) to send data via HTTP.

```
#!/usr/bin/env tarantool

local http_client = require('http.client')
local json = require('json')
local data = json.encode({ Key = 'Value'})
local headers = { Token = 'xxxx', ['X-Secret-Value'] = 42 }
```

(continues on next page)

(продолжение с предыдущей страницы)

```
local r = http_client.post('http://localhost:8081', data, { headers = headers})
if r.status == 200 then
    print 'Success'
end
```

http_server.lua

Use the http rock (which must first be installed) to turn Tarantool into a web server.

```
#!/usr/bin/env tarantool

local function handler(self)
    return self:render{ json = { ['Your-IP-Is'] = self.peer.host } }
end

local server = require('http.server').new(nil, 8080) -- listen *:8080
server:route({ path = '/' }, handler)
server:start()
-- connect to localhost:8080 and see json
```

http_generate_html.lua

Use the http *rock* (which must first be installed) to generate HTML pages from templates. The http rock has a fairly simple template engine which allows execution of regular Lua code inside text blocks (like PHP). Therefore there is no need to learn new languages in order to write templates.

```
#!/usr/bin/env tarantool

local function handler(self)
local fruits = { 'Apple', 'Orange', 'Grapefruit', 'Banana'}
    return self:render{ fruits = fruits }
end

local server = require('http.server').new(nil, 8080) -- nil means '*'
server:route({ path = '/', file = 'index.html.lua' }, handler)
server:start()
```

An «HTML» file for this server, including Lua, could look like this (it would produce «1 Apple | 2 Orange | 3 Grapefruit | 4 Banana»).

```
<html>
<body>
    <table border="1">
        % for i,v in pairs(fruits) do
        <tr>
            <td><%= i %></td>
            <td><%= v %></td>
        </tr>
        % end
    </table>
</body>
</html>
```

3.5 Администрирование серверной части

Типичные задачи администрирования серверной части включают в себя запуск и остановку сервера, перезагрузку настроек, создание снимков, ротацию логов.

3.5.1 Using Tarantool as a client

Если `tarantool` запущен без *файла инициализации*, или же в файле инициализации указана функция *console.start()*, то `tarantool` стартует в интерактивном режиме: он выводит приглашение командной строки («`tarantool>`»), и запросы можно вводить прямо в консоли. В таком режиме `tarantool` можно использовать в качестве клиента для удаленного сервера.

В этом разделе описаны синтаксические правила для ввода запросов в консоли Tarantool'а, с примечаниями и примерами. Другие клиентские программы могут иметь схожие параметры и синтаксис запросов. Некоторые сведения из этого раздела дублируются в главе *Справочник по конфигурированию*.

Условные обозначения, используемые в этом разделе

Токены — это последовательности символов, которые рассматриваются как синтаксические единицы в рамках запроса. Квадратные скобки [и] используются для обозначения необязательных токенов. Три точки в строке ... означают, что предыдущие токены могут повторяться. Вертикальная черта | означает, что предыдущие и последующие токены являются взаимоисключающими альтернативами.

Параметры запуска клиента из командной строки

Общий вид:

```
$ tarantool
ИЛИ
$ tarantool опции
ИЛИ
$ tarantool файл-инициализации-на-lua [ аргументы ]
```

файл-инициализации-на-lua — это любой скрипт, содержащий логику инициализации. Код из этого файла выполняется при запуске Tarantool'а. Например: `init.lua`. Примечания: При использовании скрипта, Tarantool не выводит приглашение командной строки. Скрипт должен содержать конфигурационные настройки, в т.ч. `box.cfg...listen=...` или `box.listen(...)`, чтобы внешние программы могли установить соединение с Tarantool-сервером на одном из указанных портов.

Опция — это одно из следующих значений (указаны в алфавитном порядке, по полному имени опции):

`-?, -h, --help`
: Tarantool-клиент выводит краткую справку, включая список всех параметров. Например: `tarantool --help`. Вывод останавливается после показа справки.

`-V, --version`
: Tarantool-клиент выводит свой номер версии. Например: `tarantool --version`. Вывод останавливается после показа номера версии.

Токены, запросы и специальные комбинации клавиш

Идентификатором процедуры может быть любая последовательность букв, цифр и/или подчеркиваний, которая отвечает правилам именования идентификаторов в Lua. Термин «идентификаторы процедур» также применяют к именам функций. Примечание: в случае с именами функций регистр имеет значение, поэтому `insert` и `Insert` — это не одно и то же.

Строковым литералом может быть любая последовательность из нуля и более символов, которая заключена в *одинарные кавычки*. *Двойные кавычки* также допустимы, но предпочтительным вариантом являются одинарные кавычки. А *двойные квадратные скобки* нужны для многострочных литералов (см. документацию по языку Lua). Например: „Hello, world", „A", [[A\B!]].

Числовым литералом может быть любая последовательность символов, состоящая из одной и более цифр с необязательным знаком + или - в начале. В состав больших числовых литералов, а также числовых литералов с плавающей точкой может входить десятичный разделитель (запятая или точка), символы для экспоненциального представления и суффиксы. Например: 500, -500, 5e2, 500.1, 5LL, 5ULL.

Однобайтовым символом может быть запятая, открывающая или закрывающая круглая скобка, а также арифметический оператор. Например: * , ( ).

Токены должны разделяться одним или бОльшим количеством пробелов. Исключением являются однобайтовые токены и строковые литералы — вокруг них пробелы не нужны.

Запросы

Запросы вводятся после приглашения командной строки, когда Tarantool работает в интерактивном режиме. (Приглашение — это слово tarantool и знак «больше», вот так: `tarantool>`). Маркером конца запроса по умолчанию является перевод строки.

Для ввода многострочных запросов можно задать другой маркер конца запроса. Для этого введите команду следующего вида: `console = require('console'); console.delimiter(`*`новый-маркер`*`)`. В качестве нового маркера укажите строковый литерал в одинарных кавычках. После этого вам нужно будет вводить указанный маркер в конце каждого запроса, потому что Tarantool перестанет интерпретировать перевод строки как конец запроса. Чтобы вернуться к обычному режиму, введите: `console.delimiter('')`*`string-literal`*. Как правило, задавать свой маркер нет необходимости, поскольку Tarantool сам распознает, что запрос введен не полностью (скажем, когда Tarantool не встречает слова `end` в объявлении функции). Например:

```
console = require('console'); console.delimiter('!')
function f ()
  statement_1 = 'a'
  statement_2 = 'b'
end!
console.delimiter('')!
```

См. также *описание формата клиентских запросов* в виде аннотированных BNF-диаграмм (Backus-Naur Form).

Работая в *интерактивном* режиме, Tarantool-сервер принимает введенные запросы и выводит результаты. Запросы, как правило, вводит пользователь. Вот пример интерактивной пользовательской сессии:

```
$ tarantool
[ здесь tarantool выводит приветствие и номер версии ]
tarantool> box.cfg{listen = 3301}
[ здесь tarantool выводит свои текущие настройки ]
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> s = box.schema.space.create('tester')
[ здесь tarantool может вывести сообщение о том,
  что идет обработка запроса ]
---
...
tarantool> s:create_index('primary', {type = 'hash', parts = {1, 'unsigned'}})
---
...
tarantool> box.space.tester:insert{1,'My first tuple'}
---
- [1, 'My first tuple']
...
tarantool> box.space.tester:select(1)
---
- - [1, 'My first tuple']
...
tarantool> box.space.tester:drop()
---
...
tarantool> os.exit()
2014-04-30 10:28:00.886 [20436] main/101/spawner I> Exiting: master shutdown
$
```

Пояснения к приведенному выше примеру:

- На многие запросы Tarantool возвращает типизированные объекты. В ответ на запрос `box.cfg`*listen=3301* Tarantool выведет результат на экран. Если в запросе задано, что его результат должен быть записан в некоторую переменную, например `c = box.cfg`*listen=3301*, то в таком случае вывода результата на экран не происходит.
- Вывод объекта в Tarantool'е всегда начинается со строки «`---`» и заканчивается строкой «`...`».
- По запросу на вставку данных возвращается объект типа кортеж (tuple), и в этом случае перед выводом будет стоять одиночное тире („-„). А по запросу на выборку данных возвращается объект типа таблица кортежей (table of tuples), и в этом случае перед выводом будут стоять два тире („- -„).

3.5.2 Утилита tarantoolctl

With `tarantoolctl`, you can say: «start an instance of the Tarantool server which runs a single user-written Lua program, allocating disk resources specifically for that program, via a standardized deployment method.»

If Tarantool was installed with Debian or Red Hat installation packages, the script is in `/usr/bin/tarantoolctl` or `/usr/local/bin/tarantoolctl`. The script handles such things as: starting, stopping, rotating logs, logging in to the application's console, and checking status.

Also, you can use `tarantoolctl` *as a client* to connect to another instance of Tarantool server and pass requests.

Конфигурирование tarantoolctl

Скрипт `tarantoolctl` сначала проверяет наличие файла конфигурации в текущей директории (`$PWD/.tarantoolctl`). Если не находит, то проверяет домашнюю директорию текущего пользователя (`$HOME/.config/tarantool/tarantool`). Если опять не находит, то проверяет директорию, указанную в переменной SYSCONFDIR (обычно это `/etc/sysconfig/tarantool`, но на разных платформах этот путь может различаться). Большинство параметров tarantoolctl аналогичны тем, что задаются в запросе box.cfg...; однако tarantoolctl меняет значение некоторых параметров, дописывая к ним имя приложения. Далее приводится копия файла usr/local/etc/default/tarantool, где для всех параметров указаны их значения по умолчанию:

```
default_cfg = {
    pid_file   = "/var/run/tarantool",
    wal_dir    = "/var/lib/tarantool",
    snap_dir   = "/var/lib/tarantool",
    vinyl_dir = "/var/lib/tarantool",
    logger     = "/var/log/tarantool",
    username   = "tarantool",
}
instance_dir = "/etc/tarantool/instances.enabled"
```

Комментарии к параметрам в приведенном выше скрипте:

pid_file Директория, где хранятся pid-файл и socket-файл. Скрипт tarantoolctl добавляет «/*instance-name*» к имени директории.

wal_dir Директория, где хранятся *.xlog-файлы. Скрипт tarantoolctl добавляет «/*instance-name*» к имени директории.

snap_dir Директория, где хранятся *.snap-файлы. Скрипт tarantoolctl добавляет «/*instance-name*» к имени директории.

vinyl_dir Директория, где хранятся файлы движка vinyl. Скрипт tarantoolctl добавляет «/*instance-name*» к имени директории.

logger Директория, где хранятся файлы журнала с сообщениями от Tarantool-приложений. Скрипт tarantoolctl добавляет «/*instance-name*» к имени директории.

username Имя пользователя, из-под которого запущен Tarantool-сервер. Это имя пользователя в операционной системе, а не в Tarantool-клиенте.

instance_dir Имя директории, где хранятся исходные файлы всех Tarantool-приложений для данного хоста. Пользователю, который пишет приложение для tarantoolctl, нужно положить исходный код своего приложения в эту директорию или настроить симлинк. Далее для примеров в этом разделе мы используем Tarantool-приложение с именем my_app, и его исходный код должен лежать в файле *instance_dir*/my_app.lua.

Команды для tarantoolctl

Команды для tarantoolctl имеют вид tarantoolctl *операция имя_приложения*. В качестве *операции* можно указать одно из следующих значений: start, stop, enter, logrotate, status, eval.

start <application>
: Запустить приложение с именем *<application>*

stop <application>
: Остановить приложение

enter <application>
: Вывести консоль для управления приложением

logrotate <application>
: Произвести ротацию журналов указанного приложения (создать новые, удалить старые)

status <application>
: Проверить статус приложения

`eval <application> <scriptname>`
: Выполнить код из файла *<scriptname>* от имени запущенного экземпляра приложения *<application>*

`connect <URI>`
: Connect to a Tarantool server running at the specified *URI*

Примеры кода для tarantoolctl

Проверить, запущено ли приложение `my_app`:

```
if tarantoolctl status my_app; then
...
fi
```

Выполнить инструкции из файла `init.d` во время запуска приложения:

```
for (каждый файл в директории instance_dir):
    tarantoolctl start `basename $ file .lua`
```

Указать файл конфигурации для ротации журнала, например:

```
/path/to/tarantool/*.log {
    daily
    size 512k
    missingok
    rotate 10
    compress
    delaycompress
    create 0640 tarantool adm
    postrotate
        /path/to/tarantoolctl logrotate basename $ 1 .log
    endscript
}
```

Подробный пример для tarantoolctl

The example's objective is to make a temporary directory where `tarantoolctl` can start a long-running application and monitor it.

Итак, наши исходные условия: нам известен пароль root-пользователя; компьютер используется только для тестирования; Tarantool-сервер настроен и готов к запуску, но пока еще не запущен ;программа `tarantoolctl` установлена в пользовательском окружении; пока не существует директории с именем `tarantool_test`.

Создадим директорию с именем `/tarantool_test`:

```
$ sudo mkdir /tarantool_test
```

Отредактируем файл `/usr/local/etc/default/tarantool`. Для этого нам сначала может понадобиться выполнить команду `sudo mkdir /usr/local/etc/default`. Указанный файл будет содержать следующие настройки:

```
default_cfg = {
    pid_file = "/tarantool_test/my_app.pid",
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    wal_dir = "/tarantool_test",
    snap_dir = "/tarantool_test",
    vinyl_dir = "/tarantool_test",
    logger = "/tarantool_test/log",
    username = "tarantool",
}
instance_dir = "/tarantool_test"
```

Создадим файл /tarantool_test/my_app.lua для приложения my_app:

```
box.cfg{listen = 3301}
box.schema.user.passwd('Gx5!')
box.schema.user.grant('guest','read,write,execute','universe')
fiber = require('fiber')
box.schema.space.create('tester')
box.space.tester:create_index('primary',{})
i = 0
while 0 == 0 do
    fiber.sleep(5)
    i = i + 1
    print('insert ' .. i)
    box.space.tester:insert{i, 'my_app tuple'}
end
```

С помощью tarantoolctl запустим наше приложение…

```
$ cd /tarantool_test
$ sudo tarantoolctl start my_app
```

… и получим сообщения о том, что экземпляр нашего приложения запущен. Затем скажем:

```
$ ls -l /tarantool_test/my_app
```

… и увидим .snap-файл и .xlog-файл. Затем скажем:

```
$ sudo less /tarantool_test/log/my_app.log
```

… и увидим содержимое файла журнала для приложения my_app, в т.ч. сообщения об ошибках, если они были. Затем скажем:

```
$ cd /tarantool_test
$ # допустим, что 'tarantool' запускает Tarantool-сервер
$ sudo tarantool
tarantool> box.cfg{}
tarantool> console = require('console')
tarantool> console.connect('localhost:3301')
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
```

… и увидим те несколько кортежей, которые создало приложение my_app.

Всё. Теперь остановим приложение my_app. Единственный корректный способ — это использовать tarantoolctl:

```
$ sudo tarantoolctl stop my_app
```

Почистим систему после тестирования. Приведем содержимое файла /usr/local/etc/default/tarantool к исходному виду и удалим нашу тестовую директорию:

```
$ cd /
$ sudo rm -R tarantool_test
```

An example for tarantoolctl connect

```
$ tarantoolctl connect username:password@127.0.0.1:3306
```

Примечание: There are alternatives to `tarantoolctl connect` – you can use the *console module* or the *net.box module* from a Tarantool server. Also, you can write your client programs with any of the Connectors. However, most of the examples in this manual illustrate usage with either `tarantoolctl connect` or with *using the Tarantool server as a client*.

3.5.3 Служебные порты

Термины «порт для администрирования», «консоль для администрирования», «текстовый протокол» относятся к установке соединения с помощью *console.listen(...)* для ввода запросов от администраторов.

Термины «бинарный порт», «бинарный протокол», «первичный порт» относятся к другому виду соединения — тому, что устанавливается с помощью параметра *box.cfg{listen=...}* и предназначено для ввода запросов от любых пользователей.

Для обычных соединений с Tarantool-сервером должен использоваться бинарный протокол. А порты для администрирования нужны для особых случаев, когда повышены требования к безопасности.

При установке соединение через порт для администрирования:

- Пароль не требуется
- Пользователь автоматически получает привилегии администратора.

Поэтому порты для администрирования следует настраивать очень осторожно. Если это TCP-порт, то он должен быть открыть только для определенного IP-адреса. В идеале мы рекомендуем вовсе не использовать TCP-порты. Вместо них лучше настроить доменный Unix-сокет, который требует настройки прав доступа к серверной машине. Тогда типичная настройка порта для администрирования будет выглядеть следующим образом:

```
console.listen('/var/lib/tarantool/socket_name.sock')
```

а типичный *URI* для соединения будет таким:

```
admin:any_string@/var/lib/tarantool/socket_name.sock
```

Это в том случае, если у сервера (listener'а) есть привилегии на запись в файл `/var/lib/tarantool`, а на стороне клиента (connector'а) есть привилегии на чтение из того же файла. Аналогично можно установить соединение и задать настройки с помощью *tarantoolctl*.

Если не задан пароль администратора, который можно сообщить пользователям, а порты для администрирования настроены с ограничением доступа по IP либо через сокеты, то запросы, требующие привилегий администратора, можно делать только локально, где вопросы безопасности и мониторинга регулируются с помощью средств Unix-системы.

В целях дополнительной безопасности некоторые запросы на портах для администрирования запрещены. Например, *conn:eval* вернет сообщение об ошибке - `error: console does not support this request type`, поскольку запрос `conn:eval` должен осуществляться в рамках бинарного протокола.

Если вопросы безопасности на портах для администрирования неактуальны, то стать пользователем с правами администратора можно, *используя Tarantool-сервер в качестве клиента* или указав администраторский пароль при установке соединения по бинарному протоколу.

Выяснить, является ли некий TCP-порт портом для администрирования, можно с помощью `telnet`. Например:

```
$ telnet 0 3303
Trying 0.0.0.0...
Connected to 0.
Escape character is '^]'.
Tarantool 1.7.2-70-gbc479ad (Lua console)
type 'help' for interactive help
```

В этом примере в ответе от сервера нет слова «binary» и есть слова «Lua console». Это значит, что мы установили соединение на порту для администрирования и можем вводить администраторские запросы на этом терминале.

3.5.4 Служебные запросы

To learn which functions are considered to be administrative, type `help()`. A reference description also follows below:

`box.snapshot()`

Take a snapshot of all data and store it in *snap_dir*/`<latest-lsn>.snap`. To take a snapshot, Tarantool first enters the delayed garbage collection mode for all data. In this mode, tuples which were allocated before the snapshot has started are not freed until the snapshot has finished. To preserve consistency of the primary key, used to iterate over tuples, a copy-on-write technique is employed. If the master process changes part of a primary key, the corresponding process page is split, and the snapshot process obtains an old copy of the page. In effect, the snapshot process uses multi-version concurrency control in order to avoid copying changes which are superseded while it is running.

Since a snapshot is written sequentially, one can expect a very high write performance (averaging to 80MB/second on modern disks), which means an average database instance gets saved in a matter of minutes. Note: as long as there are any changes to the parent index memory through concurrent updates, there are going to be page splits, and therefore one needs to have some extra free memory to run this command. 10% of *slab_alloc_arena* is, on average, sufficient. This statement waits until a snapshot is taken and returns operation result.

Change Notice: prior to Tarantool version 1.6.6, the snapshot process caused a fork, which could cause occasional latency spikes. Starting with Tarantool version 1.6.6, the snapshot process creates a consistent read view and writes this view to the snapshot file from a separate thread.

Although box.snapshot() does not cause a fork, there is a separate fiber which may produce snapshots at regular intervals – see the discussion of the *snapshot daemon*.

Example:

```
tarantool> box.info.version
---
- 1.7.0-1216-g73f7154
...
tarantool> box.snapshot()
```

(continues on next page)

(продолжение с предыдущей страницы)

```
---
- ok
...
tarantool> box.snapshot()
---
- error: can't save snapshot, errno 17 (File exists)
...
```

Taking a snapshot does not cause the server to start a new write-ahead log. Once a snapshot is taken, old WALs can be deleted as long as all replicas are up to date. But the WAL which was current at the time `box.snapshot()` started must be kept for recovery, since it still contains log records written after the start of `box.snapshot()`.

An alternative way to save a snapshot is to send the server SIGUSR1 UNIX signal. While this approach could be handy, it is not recommended for use in automation: a signal provides no way to find out whether the snapshot was taken successfully or not.

`coredump()`

Fork and dump a core. Since Tarantool stores all tuples in memory, it can take some time. Mainly useful for debugging.

3.5.5 Просмотр состояния сервера

For server introspection, use the reports provided by functions in the following submodules:

- *box.cfg* submodule (check and specify all configuration parameters for the Tarantool server)
- *box.slab* submodule (monitor the total use and fragmentation of memory allocated for storing data in Tarantool)
- *box.info* submodule (introspect Tarantool's server variables)
- *box.stat* submodule (introspect Tarantool's request and network statistics)

3.5.6 Репликация

Механизм репликации позволяет сразу многим Tarantool-серверам работать с копиями одних и тех же баз данных. При этом все базы остаются в синхронизированном состоянии благодаря тому, что каждый сервер может сообщать другим серверам о совершенных им изменениях. Сервера, которые работают над одними и теми же базами, представляют собой «кластер». У каждого сервера в кластере есть числовой идентификатор (server id), уникальный в рамках кластера.

Чтобы настроить репликацию, необходимо настроить главные сервера (master), которые первыми обрабатывают запросы на изменение данных, затем настроить сервера-реплики (replica), которые копируют к себе запросы на изменение данных с главных серверов, и прописать процедуры для восстановления после сбоя.

Архитектура механизма репликации

Чтобы знать о всех изменениях на стороне главного сервера, каждая реплика непрерывно опрашивает главный сервер на предмет обновлений в его WAL-файле (write ahead log) и применяет эти обновления на своей стороне. Каждая запись в WAL-файле представляет собой один запрос на изменение данных (например, INSERT, UPDATE или DELETE) и присвоенный данной записи номер (LSN = log sequence number). Номера присваиваются в порядке возрастания. По сути, репликация в Tarantool'е является построчной: все команды на изменение данных полностью детерминированы, и каждая такая команда относится только к одному кортежу.

Вызовы хранимых Lua-процедур фиксируются не в WAL-файле, а в журнале событий (event log). Таким образом гарантируется, что не детерминированное поведение логики на Lua не приведет к рассинхронизации реплицированных данных.

Setting up a master

Чтобы настроить возможность установки соединения для реплик, на стороне главного сервера требуется лишь указать значение для параметра «*listen*» в init-запросе `box.cfg`. Например, `box.cfg{listen=3301}`. Когда URI для прослушивания задан, главный сервер готов принимать запросы на соединение от любого количества реплик. Каждая реплика при этом находится в некотором *статусе репликации*.

Настройка сервера-реплики

Каждому Tarantool-серверу необходим корректный файл со статическим снимком данных (.snap-файл). Файл-снимок создается на сервере при первом запросе `box.cfg`. Если при первом таком запросе на сервере не определен источник репликации (replication source), то сервер стартует в режиме главного сервера и создает для себя новый кластер с новым уникальными UUID. Если же источник репликации при первом `box.cfg`-запросе определен, то сервер стартует в режиме реплики, а файл-снимок и информация о кластере берутся из WAL-файлов на главном сервере. Поэтому при настройке репликации нужно указать параметр *replication_source* в запросе `box.cfg`. При первом соединении с главным сервером сервер-реплика включается в состав кластера. В дальнейшем такая реплика общается только с главным сервером из данного кластера.

После установки соединения с главным сервером реплика запрашивает у него все изменения, чьи LSN-номера в WAL-файле больше номера последнего локального изменения на реплике. Поэтому WAL-файлы на главном сервере нужно хранить до тех пор, пока все реплики не применят изменения из этих WAL-файлов на своей стороне. Состояние реплики можно «обнулить», удалив все файлы репликации (.snap-файл со снимком и .xlog-файлы с записями WAL) и запустив сервер снова. Реплика при этом возьмет все кортежи с главного сервера и придет в синхронизированное состояние. Обратите внимание, что такая процедура «обнуления» сработает, только если на главном сервере будут доступны все нужные WAL-файлы.

Примечание: Параметры репликации можно менять на лету, что позволяет назначать реплику на роль главного сервера и наоборот. Для этого используется запрос *box.cfg*.

Примечание: Реплика не берет настройки конфигурации с главного сервера, например настройки запуска *фоновой программы для работы со снимками* на главном сервере. Чтобы получить те же настройки на реплике, нужно задать их явным образом.

Примечание: Replication requires privileges. Privileges for accessing spaces could be granted directly to the user who will start the replica. However, it is more usual to grant privileges for accessing spaces to a *role*, and then grant the role to the user who will start the replica.

Восстановление после сбоя

«Сбой» — это ситуация, когда главный сервер становится недоступен вследствие проблем с оборудованием, сетевых неполадок или программной ошибки. У реплики нет способа автоматически обнаружить, что связь с главным сервером утеряна насовсем, поскольку причины сбоя и окружение, в котором развернута репликация, могут быть очень разными. Поэтому обнаруживать сбой должен человек.

However, once a master failure is detected, the recovery is simple: declare that the replica is now the new master, by saying `box.cfg{... listen=URI ...}` Then, if there are updates on the old master that were not propagated before the old master went down, they would have to be re-applied manually.

Quick startup of a new simple two-server cluster

Шаг 1. Запустите первый сервер со следующими настройками:

```
box.cfg{listen = *uri#1*}
-- в этом запросе можно задать больше ограничений
box.schema.user.grant('guest', 'read,write,execute', 'universe')
box.snapshot()
```

... Итак, создался новый кластер.

Шаг 2. На втором сервере проверьте пути, по которым будут храниться файлы репликации. Эти пути задаются в параметрах *snap_dir* (для .snap-файлов) и *wal_dir* (для .xlog-файлов). В указанных директориях должно быть пусто, чтобы не случилось конфликта с теми начальными данными, что придут с первого сервера, когда второй сервер присоединится к кластеру.

Step 3. Запустите второй сервер со следующими настройками:

```
box.cfg{
  listen = uri#2,
  replication_source = uri#1
}
```

... где `uri#1` = *URI*, на котором включено прослушивание у первого сервера.

Вот и всё.

В описанной выше конфигурации первый сервер выполняет роль «главного», а второй служит «репликой». Далее все изменения, происходящие на стороне главного сервера, будут доступны с реплики. Простой кластер из двух серверов, где главный сервер запущен на одном компьютере, а сервер-реплика — на другом, встречается очень часто и обладает двумя важными преимуществами: FAILOVER (т.е. отказоустойчивость, поскольку в случае отключения главного сервера его место может занять сервер-реплика) и LOAD BALANCING (т.е. балансировка нагрузки, поскольку клиенты могут обращаться с SELECT-запросами как к главному серверу, так и к реплике). При необходимости в настройках реплики можно задать параметр *read_only = true*.

Мониторинг действий реплики

In *box.info* there is a `box.info.replication.status` field: «off», «stopped», «connecting», «auth», «follow», or «disconnected». If a replica's status is «follow», then there will be more fields – the list is in the section *Submodule box.info*.

В *журнале* ведется запись о действиях, связанных с репликацией. Если главный сервер запущен со следующими настройками:

```
box.cfg{
  <...>,
  logger = *имя_файла_для_ведения_журнала*,
  <...>
}
```

то на каждую установку/потерю соединения реплики с главным сервером в журнале будут появляться строчки со словом «relay».

Предотвращение дублирующихся действий

Предположим, что реплика пытается сделать нечто, что уже было сделано на главном сервере. Например: `box.schema.space.create('X')` Это приведет к ошибке «Space X exists» («Пространство X уже существует»). В данном частном случае можно скорректировать инструкцию следующим образом: `box.schema.space.create('X', {if_not_exists=true})` Но существует и более общее решение: использовать метод `box.once(`***key***`, `***function***`)`. Если `box.once()` был вызван ранее с тем же значением параметра ***key***, то функция ***function*** игнорируется; в противном случае функция ***function*** будет выполнена. Поэтому действия, которые должны совершаться только один раз за время текущей сессии репликации, нужно помещать в функцию и вызывать ее с помощью метода `box.once()`. Например:

```
function f()
  box.schema.space.create('X')
end
box.once('space_creator', f)
```

Репликация по схеме master-master

В случае настройки репликации по схеме master-replica изменения на главном сервере доступны для просмотра с реплики, но не наоборот, потому как главный сервер в такой схеме указан в качестве единственного источника репликации. В случае схемы master-master (иногда ее также называет multi-master) просмотр изменений возможен в любом направлении. В простом случае (master-master с двумя серверами) на первом сервере нужно задать следующие настройки:

`box.cfg{ replication_source = `*`uri#2`*` }`

Этот запрос можно выполнить в любой момент, т.к. параметр *replication_source* можно задавать на ходу.

В данном примере оба сервера являются одновременно и «главными», и «репликами». Поэтому каждое изменение, которое случается на одном сервере, становится доступно для просмотра с другого сервера. Отказоустойчивость в такой конфигурации сохраняется, а возможности по балансировке нагрузки становятся еще шире (теперь клиенты могут обращаться к обоим серверам со всеми типами запросов — как на чтение данных, так и на изменение).

Если две операции над одним и тем же кортежем производятся «параллельно» (а это может потребовать много времени, поскольку репликация — это асинхронный процесс), причем одна из операций — это `delete`, а вторая — `replace`, то существует вероятность, что данные на серверах станут различаться.

Ответы на вопросы «Что если?»

Q What if there are more than two servers with master-master?

A On each server, specify the *replication_source* for all the others. For example, server #3 would have a request:

```
box.cfg{ replication_source = {uri1}, {uri2} }
```

Q What if a server should be taken out of the cluster?

A For a replica, run `box.cfg{}` again specifying a blank replication source: `box.cfg{replication_source=''}`

Q What if a server leaves the cluster?

A The other servers carry on. If the wayward server rejoins, it will receive all the updates that the other servers made while it was away.

Q What if two servers both change the same tuple?

A The last changer wins. For example, suppose that server#1 changes the tuple, then server#2 changes the tuple. In that case server#2's change overrides whatever server#1 did. In order to keep track of who came last, Tarantool implements a vector clock.

Q What if two servers both insert the same tuple?

A If a master tries to insert a tuple which a replica has inserted already, this is an example of a severe error. Replication stops. It will have to be restarted manually.

Q What if a master disappears and the replica must take over?

A A message will appear on the replica stating that the connection is lost. The replica must now become independent, which can be done by saying `box.cfg{replication_source=''}`.

Q What if it's necessary to know what cluster a server is in?

A The identification of the cluster is a UUID which is generated when the first master starts for the first time. This UUID is stored in a tuple of the *box.space._schema* system space. So to see it, say: `box.space._schema:select{'cluster'}`

Q What if it's necessary to know what other servers belong in the cluster?

A The universal identification of a server is a UUID in `box.info.server.uuid`. The ordinal identification of a server within a cluster is a number in `box.info.server.id`. To see all the servers in the cluster, say: `box.space._cluster:select{}`. This will return a table with all {server.id, server.uuid} tuples for every server that has ever joined the cluster.

Q What if one of the server's files is corrupted or deleted?

A Stop the server, destroy all the database files (the ones with extension «snap» or «xlog» or «.inprogress»), restart the server, and catch up with the master by contacting it again (just say `box.cfg{...replication_source=...}`).

Q What if replication causes security concerns?

A Prevent unauthorized replication sources by associating a password with every user that has access privileges for the relevant spaces, and every user that has a replication *role*. That way, the *URI* for the *replication_source* parameter will always have to have the long form `replication_source='username:password@host:port'`

Q What if advanced users want to understand better how it all works?

A See the description of server startup with replication in the *Internals* section.

Практическое руководство по репликации

Ниже приводятся пошаговые инструкции, которые помогут вам получить практический опыт администрирования кластера, а именно опыт создания кластера и добавления реплики.

Запустите два терминала, каждый в своем окне, и расположите их рядом на экране. (Далее в примерах оба терминала показаны в виде закладок. Щелкните на заголовок закладки — «Terminal #1» или «Terminal #2», — чтобы увидеть вывод на соответствующем терминале.)

```
$
```

```
$
```

В первом терминале (Terminal #1) выполните следующие команды:

```
$ # Terminal 1
$ mkdir -p ~/tarantool_test_node_1
$ cd ~/tarantool_test_node_1
$ rm -R ~/tarantool_test_node_1/*
$ ~/tarantool/src/tarantool
tarantool> box.cfg{listen = 3301}
tarantool> box.schema.user.create('replicator', {password = 'password'})
tarantool> box.schema.user.grant('replicator','execute','role','replication')
tarantool> box.space._cluster:select({0}, {iterator = 'GE'})
```

В результате были заданы настройки нового кластера, а на экране был выведен UUID текущего сервера. Теперь вывод на экране выглядит следующим образом (за тем исключением, что UUID у вас будут другие):

```
$ # Terminal 1
$ mkdir -p ~/tarantool_test_node_1
$ cd ~/tarantool_test_node_1
$ rm -R ./*
$ ~/tarantool/src/tarantool
$ ~/tarantool/src/tarantool: version 1.7.0-1724-g033ed69
type 'help' for interactive help
tarantool> box.cfg{listen = 3301}
<... ...>
tarantool> box.schema.user.create('replicator', {password = 'password'})
<...> I> creating ./00000000000000000000.xlog.inprogress'
---
...
tarantool> box.schema.user.grant('replicator','execute','role','replication')
---
...
tarantool> box.space._cluster:select({0}, {iterator = 'GE'})
---
- - [1, '6190d919-1133-4452-b123-beca0b178b32']
...
```

```
$
```

Во втором терминале (Terminal #2) выполните следующие команды:

```
$ # Terminal 2
$ mkdir -p ~/tarantool_test_node_2
$ cd ~/tarantool_test_node_2
```

(continues on next page)

(продолжение с предыдущей страницы)

```
$ rm -R ~/tarantool_test_node_2/*
$ ~/tarantool/src/tarantool
tarantool> box.cfg{
         >   listen = 3302,
         >   replication_source = 'replicator:password@localhost:3301'
         > }
tarantool> box.space._cluster:select({0}, {iterator = 'GE'})
```

В результате были заданы настройки сервера-реплики. На экране первого терминала (Terminal #1) появились сообщения с подтверждениями, что реплика установила соединение с главным сервером и что содержимое WAL-файла было отправлено на реплику. На экране второго терминала (Terminal #2) появились сообщения о том, что репликация начинается, а также там были выведены UUID из системного пространства _cluster (один из них совпадает с UUID в первом терминале, поскольку оба сервера входят в общий кластер).

```
$ # Terminal 1
$ mkdir -p ~/tarantool_test_node_1
<... ...>
tarantool> box.space._cluster:select({0}, {iterator = 'GE'})
---
- - [1, '6190d919-1133-4452-b123-beca0b178b32']
...
tarantool>
<...> [11031] relay/127.0.0.1:58734/101/main I> recovery start
<...> [11031] relay/127.0.0.1:58734/101/main I> recovering from `./00000000000000000000.snap'
<...> [11031] relay/127.0.0.1:58734/101/main I> snapshot sent
<...> [11031] relay/127.0.0.1:58734/101/main I> recover from `./00000000000000000000.xlog'
<...> [11031] relay/127.0.0.1:58734/101/main recovery.cc:211 W> file
      `./00000000000000000000.xlog` wasn't correctly closed
<...> [11031] relay/127.0.0.1:58734/102/main I> recover from `./00000000000000000000.xlog'
```

```
$ # Terminal 2
$ mkdir -p ~/tarantool_test_node_2
$ cd ~/tarantool_test_node_2
$ rm -R ./*
$ ~/tarantool/src/tarantool
/home/username/tarantool/src/tarantool: version 1.7.0-1724-g033ed69
type 'help' for interactive help
tarantool> box.cfg{
         >   listen = 3302,
         >   replication_source = 'replicator:password@localhost:3301'
         > }
<...>
<...> [11243] main/101/interactive I> mapping 1073741824 bytes for tuple arena...
<...> [11243] main/101/interactive C> starting replication from localhost:3301
<...> [11243] main/102/applier/localhost:3301 I> connected to 1.7.0 at 127.0.0.1:3301
<...> [11243] main/102/applier/localhost:3301 I> authenticated
<...> [11243] main/102/applier/localhost:3301 I> downloading a snapshot from 127.0.0.1:3301
<...> [11243] main/102/applier/localhost:3301 I> done
<...> [11243] snapshot/101/main I> creating `./00000000000000000000.snap.inprogress'
<...> [11243] snapshot/101/main I> saving snapshot `./00000000000000000000.snap.inprogress'
<...> [11243] snapshot/101/main I> done
<...> [11243] iproto I> binary: started
<...> [11243] iproto I> binary: bound to 0.0.0.0:3302
<...> [11243] wal/101/main I> creating `./00000000000000000000.xlog.inprogress'
<...> [11243] main/101/interactive I> ready to accept requests
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> box.space._cluster:select({0}, {iterator = 'GE'})
- - [1, '6190d919-1133-4452-b123-beca0b178b32']
  - [2, '236230b8-af3e-406b-b709-15a60b44c20c']
...
```

В первом терминале (Terminal #1) выполните следующие запросы:

```
tarantool> s = box.schema.space.create('tester')
tarantool> i = s:create_index('primary', {})
tarantool> s:insert{1, 'Tuple inserted on Terminal #1'}
```

Теперь вывод на экране выглядит следующим образом:

```
<... ...>
tarantool>
tarantool>
<...> [11031] relay/127.0.0.1:58734/101/main I> recovery start
<...> [11031] relay/127.0.0.1:58734/101/main I> recovering from `./00000000000000000000.snap'
<...> [11031] relay/127.0.0.1:58734/101/main I> snapshot sent
<...> [11031] relay/127.0.0.1:58734/101/main I> recover from `./00000000000000000000.xlog'
<...> [11031] relay/127.0.0.1:58734/101/main recovery.cc:211 W> file
      `./00000000000000000000.xlog` wasn't correctly closed
<...> [11031] relay/127.0.0.1:58734/102/main I> recover from `./00000000000000000000.xlog'
tarantool> s = box.schema.space.create('tester')
---
...
tarantool> i = s:create_index('primary', {})
---
...
tarantool> s:insert{1, 'Tuple inserted on Terminal #1'}
---
- [1, 'Tuple inserted on Terminal #1']
...
```

```
$ # Terminal 2
$ mkdir -p ~/tarantool_test_node_2
$ cd ~/tarantool_test_node_2
$ rm -R ./*
$ ~/tarantool/src/tarantool
/home/username/tarantool/src/tarantool: version 1.7.0-1724-g033ed69
type 'help' for interactive help
tarantool> box.cfg{
         >   listen = 3302,
         >   replication_source = 'replicator:password@localhost:3301'
         > }
<...>
<...> [11243] main/101/interactive I> mapping 1073741824 bytes for tuple arena...
<...> [11243] main/101/interactive C> starting replication from localhost:3301
<...> [11243] main/102/applier/localhost:3301 I> connected to 1.7.0 at 127.0.0.1:3301
<...> [11243] main/102/applier/localhost:3301 I> authenticated
<...> [11243] main/102/applier/localhost:3301 I> downloading a snapshot from 127.0.0.1:3301
<...> [11243] main/102/applier/localhost:3301 I> done
<...> [11243] snapshot/101/main I> creating `./00000000000000000000.snap.inprogress'
<...> [11243] snapshot/101/main I> saving snapshot `./00000000000000000000.snap.inprogress'
<...> [11243] snapshot/101/main I> done
<...> [11243] iproto I> binary: started
```

(continues on next page)

(продолжение с предыдущей страницы)

```
<...> [11243] iproto I> binary: bound to 0.0.0.0:3302
<...> [11243] wal/101/main I> creating `./00000000000000000000.xlog.inprogress'
<...> [11243] main/101/interactive I> ready to accept requests
tarantool> box.space._cluster:select({0}, {iterator = 'GE'})
- - [1, '6190d919-1133-4452-b123-beca0b178b32']
  - [2, '236230b8-af3e-406b-b709-15a60b44c20c']
...
```

В первом терминале успешно отработали операции CREATE и INSERT. Но во втором терминале ничего не произошло.

Во втором терминале (Terminal #2) выполните следующие запросы:

```
tarantool> s = box.space.tester
tarantool> s:select({1}, {iterator = 'GE'})
tarantool> s:insert{2, 'Tuple inserted on Terminal #2'}
```

Теперь вывод на экране выглядит следующим образом:

```
<... ...>
tarantool>
tarantool>
<...> [11031] relay/127.0.0.1:58734/101/main I> recovery start
<...> [11031] relay/127.0.0.1:58734/101/main I> recovering from `./00000000000000000000.snap'
<...> [11031] relay/127.0.0.1:58734/101/main I> snapshot sent
<...> [11031] relay/127.0.0.1:58734/101/main I> recover from `./00000000000000000000.xlog'
<...> [11031] relay/127.0.0.1:58734/101/main recovery.cc:211 W> file
      `./00000000000000000000.xlog` wasn't correctly closed
<...> [11031] relay/127.0.0.1:58734/102/main I> recover from `./00000000000000000000.xlog'
tarantool> s = box.schema.space.create('tester')
---
...
tarantool> i = s:create_index('primary', {})
---
...
tarantool> s:insert{1, 'Tuple inserted on Terminal #1'}
---
- [1, 'Tuple inserted on Terminal #1']
...
```

```
<... ...>
tarantool> box.space._cluster:select({0}, {iterator = 'GE'})
- - [1, '6190d919-1133-4452-b123-beca0b178b32']
  - [2, '236230b8-af3e-406b-b709-15a60b44c20c']
...
tarantool> s = box.space.tester
---
...
tarantool> s:select({1}, {iterator = 'GE'})
---
- - [1, 'Tuple inserted on Terminal #1']
...
tarantool> s:insert{2, 'Tuple inserted on Terminal #2'}
---
- [2, 'Tuple inserted on Terminal #2']
...
```

Во втором терминале успешно отработали операции SELECT и INSERT. Но в первом терминале ничего не произошло.

В первом терминале (Terminal #1) выполните следующие запросы и команды:

```
$ os.exit()
$ ls -l ~/tarantool_test_node_1
$ ls -l ~/tarantool_test_node_2
```

Теперь Tarantool-сервер в первом терминале остановлен. В окне второго терминала появились сообщения об этом событии. С помощью команд `ls -l` мы убедились, что на обоих серверах создались файлы-снимки с одинаковыми размерами, поскольку там содержатся одни и те же кортежи.

```
<... ...>
tarantool> s:insert{1, 'Tuple inserted on Terminal #1'}
---
- [1, 'Tuple inserted on Terminal #1']
...
$ ls -l ~/tarantool_test_node_1
tarantool> os.exit()
total 8
-rw-rw-r-- 1  4925 May  5 11:12 00000000000000000000.snap
-rw-rw-r-- 1   634 May  5 11:45 00000000000000000000.xlog
$ ls -l ~/tarantool_test_node_2/
total 8
-rw-rw-r-- 1  4925 May  5 11:20 00000000000000000000.snap
-rw-rw-r-- 1   704 May  5 11:38 00000000000000000000.xlog
$
```

```
<... ...>
tarantool> s:select({1}, {iterator = 'GE'})
---
- - [1, 'Tuple inserted on Terminal #1']
...
tarantool> s:insert{2, 'Tuple inserted on Terminal #2'}
---
- [2, 'Tuple inserted on Terminal #2']
...
tarantool>
<...> [25579] main/103/replica/localhost:3301 I> can't read row
<...> [25579] main/103/replica/localhost:3301 !> SystemError
  unexpected EOF when reading from socket,
  called on fd 10, aka 127.0.0.1:50884, peer of 127.0.0.1:3301: Broken pipe
<...> [25579] main/103/replica/localhost:3301 I> will retry every 1 second
```

Во втором терминале (Terminal #2) проигнорируйте сообщения об ошибках и выполните следующие запросы:

```
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
tarantool> box.space.tester:insert{3, 'Another'}
```

Теперь вывод на экране выглядит следующим образом (сообщения об ошибках мы не приводим):

```
<... ...>
tarantool> s:insert{1, 'Tuple inserted on Terminal #1'}
---
- [1, 'Tuple inserted on Terminal #1']
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
$ ls -l ~/tarantool_test_node_1
tarantool> os.exit()
total 8
-rw-rw-r-- 1  4925 May  5 11:12 00000000000000000000.snap
-rw-rw-r-- 1   634 May  5 11:45 00000000000000000000.xlog
$ ls -l ~/tarantool_test_node_2/
total 8
-rw-rw-r-- 1  4925 May  5 11:20 00000000000000000000.snap
-rw-rw-r-- 1   704 May  5 11:38 00000000000000000000.xlog
$
```

```
<... ...>
tarantool> s:insert{2, 'Tuple inserted on Terminal #2'}
---
- [2, 'Tuple inserted on Terminal #2']
...
tarantool>
<...> [11243] main/105/applier/localhost:3301 I> can't read row
<...> [11243] main/105/applier/localhost:3301 coio.cc:352 !> SystemError
  unexpected EOF when reading from socket,
  called on fd 6, aka 127.0.0.1:58734, peer of 127.0.0.1:3301: Broken pipe
<...> [11243] main/105/applier/localhost:3301 I> will retry every 1 second
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
---
- - [1, 'Tuple inserted on Terminal #1']
  - [2, 'Tuple inserted on Terminal #2']
...
tarantool> box.space.tester:insert{3, 'Another'}
---
- [3, 'Another']
...
```

Запросы SELECT и INSERT во втором терминале отработали несмотря на то, что сервер в первом терминале остановлен.

В первом терминале (Terminal #1) выполните следующие запросы:

```
$ ~/tarantool/src/tarantool
tarantool> box.cfg{listen = 3301}
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
```

Теперь вывод на экране выглядит следующим образом:

```
<... ...>
tarantool> s:insert{1, 'Tuple inserted on Terminal #1'}
---
- [1, 'Tuple inserted on Terminal #1']
...
$ ls -l ~/tarantool_test_node_1
tarantool> os.exit()
total 8
-rw-rw-r-- 1  4925 May  5 11:12 00000000000000000000.snap
-rw-rw-r-- 1   634 May  5 11:45 00000000000000000000.xlog
$ ls -l ~/tarantool_test_node_2/
total 8
```

(continues on next page)

(продолжение с предыдущей страницы)

```
-rw-rw-r-- 1  4925 May  5 11:20 00000000000000000000.snap
-rw-rw-r-- 1   704 May  5 11:38 00000000000000000000.xlog
$ ~/tarantool/src/tarantool
<...>
tarantool> box.cfg{listen = 3301}
<...> [22612] main/101/interactive I> ready to accept requests
<... ...>
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
- - [1, 'Tuple inserted on Terminal #1']
...
```

```
<... ...>
tarantool> s:insert{2, 'Tuple inserted on Terminal #2'}
---
- [2, 'Tuple inserted on Terminal #2']
...
tarantool>
<...> [25579] main/103/replica/localhost:3301 I> can't read row
<...> [25579] main/103/replica/localhost:3301 !> SystemError
  unexpected EOF when reading from socket,
  called on fd 10, aka 127.0.0.1:50884, peer of 127.0.0.1:3301: Broken pipe
<...> [25579] main/103/replica/localhost:3301 I> will retry every 1 second
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
---
- - [1, 'Tuple inserted on Terminal #1']
  - [2, 'Tuple inserted on Terminal #2']
...
tarantool> box.space.tester:insert{3, 'Another'}
---
- [3, 'Another']
...
<...> [11243] main/105/applier/localhost:3301 I> connected to 1.7.0 at 127.0.0.1:3301
<...> [11243] main/105/applier/localhost:3301 I> authenticated
```

Главный сервер снова установил соединение с кластером и НЕ обнаружил изменения, сделанные репликой за время его недоступности. Это и не удивительно: мы же не просили реплику выступать в качестве источника репликации.

В первом терминале (Terminal #1) введите:

```
tarantool> box.cfg{
         >   replication_source = 'replicator:password@localhost:3302'
         > }
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
```

Теперь вывод на экране выглядит следующим образом:

```
<... ...>
$ ~/tarantool/src/tarantool
<...>
tarantool> box.cfg{listen = 3301}
<...> [22612] main/101/interactive I> ready to accept requests
<... ...>
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
---
- - [1, 'Tuple inserted on Terminal #1']
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
tarantool> box.cfg{
         >   replication_source='replicator:password@localhost:3302'
         > }
[28987] main/101/interactive C> starting replication from localhost:3302
---
...
[22612] main/101/interactive C> starting replication from localhost:3302
[22612] main/101/interactive I> set 'replication_source' configuration
        option to "replicator:password@localhost:3302"
[22612] main/104/applier/localhost:3302 I> connected to 1.7.0 at 127.0.0.1:3302
[22612] main/104/applier/localhost:3302 I> authenticated
[22612] wal/101/main I> creating `./00000000000000000008.xlog.inprogress'
[22612] relay/127.0.0.1:33510/102/main I> done `./00000000000000000000.xlog'
[22612] relay/127.0.0.1:33510/102/main I> recover from `./00000000000000000008.xlog'
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
---
- - [1, 'Tuple inserted on Terminal #1']
  - [2, 'Tuple inserted on Terminal #2']
  - [3, 'Another']
...
```

```
<... ...>
tarantool> s:insert{2, 'Tuple inserted on Terminal #2'}
---
- [2, 'Tuple inserted on Terminal #2']
...
tarantool>
<...> [25579] main/103/replica/localhost:3301 I> can't read row
<...> [25579] main/103/replica/localhost:3301 !> SystemError
  unexpected EOF when reading from socket,
  called on fd 10, aka 127.0.0.1:50884, peer of 127.0.0.1:3301: Broken pipe
<...> [25579] main/103/replica/localhost:3301 I> will retry every 1 second
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
---
- - [1, 'Tuple inserted on Terminal #1']
  - [2, 'Tuple inserted on Terminal #2']
...
tarantool> box.space.tester:insert{3, 'Another'}
---
- [3, 'Another']
...
<...> [11243] main/105/applier/localhost:3301 I> connected to 1.7.0 at 127.0.0.1:3301
<...> [11243] main/105/applier/localhost:3301 I> authenticated
tarantool>
<...> [11243] relay/127.0.0.1:36150/101/main I> recover from `./00000000000000000000.xlog'
<...> [11243] relay/127.0.0.1:36150/101/main recovery.cc:211 W> file
     `./00000000000000000000.xlog` wasn't correctly closed
<...> [11243] relay/127.0.0.1:36150/102/main I> recover from `./00000000000000000000.xlog'
```

Тут мы видим, что оба сервера снова синхронизовались и что каждый из них видит те записи, которые сделал другой.

Чтобы удалить все тестовые данные, выполните «`os.exit()`» на обоих терминалах, а затем на каждом из них выполните следующие команды:

```
$ cd ~
$ rm -R ~/tarantool_test_node_1
$ rm -R ~/tarantool_test_node_2
```

3.5.7 Резервное копирование

При выборе конкретной процедуры для резервного копирования базы данных нужно учитывать следующие требования: насколько актуальной должна быть копия, можно ли временно отключать других пользователей, а также нужна ли оптимизация размера копии (чтобы копия занимала меньше места на диске) или скорости самой процедуры (чтобы процедура занимала меньше времени). Выбирать можно из нескольких вариантов в диапазоне от «простого и холодного» до «трудного и горячего».

Cold backup

Суть процедуры: последний созданный Tarantool'ом файл-снимок является резервной копией всей базы; а WAL-файлы, созданные следом, являются инкрементными копиями. Поэтому вся процедура резервирования сводится к копированию последнего файла-снимка и последующих WAL-файлов.

(1) Временно запретите всем пользователям делать записи в базе. Для этого можно остановить Tarantool-сервер, либо ввести запрос `box.cfg{read_only=true}` и убедиться, что все обращения на запись завершились (для этого можно использовать `fsync`).

(2) Если вы хотите создать резервную копию для всей базы целиком, введите запрос `box.snapshot()`.

(3) С помощью `tar` создайте сжатую (насколько это можно) копию последнего `.snap`-файла и последующих `.xlog`-файлов из директорий *snap_dir* и *wal_dir*.

(4) Если того требуют правила безопасности, зашифруйте получившийся `tar`-файл.

(5) Скопируйте `tar`-файл в надежное место.

… В дальнейшем вы сможете восстановить базу данных, просто взяв этот `tar`-файл и разархивировав его содержимое в директории `snap_dir` и `wal_dir`.

Continuous remote backup

Суть процедуры: для резервирования (а также для балансирования нагрузки) можно использовать *репликацию*. Процедура резервирования в рамках репликационного кластера сводится к тому, чтобы держать все реплики в актуальном состоянии и периодически делать с них «холодные» копии. Поскольку во время снятия копии с какой-либо одной реплики все остальные реплики продолжают синхронизироваться с главным сервером, то эта процедура несколько отличается от описанной выше процедуры «холодного» резервирования. Регулярное резервирование в кластере можно настроить с помощью планировщика `cron` или Tarantool-файбера.

Hot backup

Суть процедуры: по ходу работы системы нужно сохранять записи об изменениях, сделанных со времени последнего «холодного» резервирования.

Для этого вам понадобится специальная утилита для копирования частей файлов (например, rsync), которая позволит удаленно и на постоянной основе копировать только изменившиеся части файлов-снимков и WAL-файлов, а не все эти файлы целиком.

Вы можете взять и обычную утилиту (для копирования файлов целиком), но тогда вам придется создавать файлы-снимки и WAL-файлы на каждое изменение, чтобы нужно было копировать только новые файлы.

Примечание про движок: при организации резервирования для баз данных на движке vinyl понадобятся дополнительные действия.

3.5.8 Обновление сервера и базы данных

Обновление Tarantool'а в условиях эксплуатации

Во-первых, вынесите всю бизнес-логику своего приложения в отдельный Tarantool-модуль на языке Lua так, чтобы все нужные функции были доступны для вызова извне (CALL).

Вот пример такого модуля, файл `/usr/share/tarantool/myapp.lua`:

```
local function start()
  -- Initial version
  box.once("myapp:.1.0", function()
  box.schema.space.create("somedata")
  box.space.somedata:create_index("primary")
  ...

  -- migration code from 1.0 to 1.1
  box.once("myapp:.v1.1", function()
  box.space.somedata.index.primary:alter(...)
  ...

  -- migration code from 1.1 to 1.2
  box.once("myapp:.v1.2", function()
  box.space.somedata.space:alter(...)
  box.space.somedata:insert(...)
  ...
end

-- start some background fibers if you need

local function stop()
  -- stop all background fibers and cleanup resources
end

local function api_for_call(xxx)
  -- do some business
end

return {
  start = start;
  stop = stop;
  api_for_call = api_for_call;
}
```

Поддержка этого файла лежит на стороне разработчиков приложения. А команда разработки Tarantool'а со своей стороны предлагает шаблоны, для того чтобы вы могли создать у себя deb/rpm-сборку, а также утилиты для быстрого создания сборок под разные платформы. Если понадобится, вы можете разбить приложения на отдельные файлы и/или модули.

Во вторых, положите скрипт инициализации в директорию `/etc/tarantool/instances.available`.

Вот пример такого скрипта, файл /etc/tarantool/instances.available/myappcfg.lua:

```
#!/usr/bin/env tarantool

box.cfg {
  listen = 3301;
}

if myapp ~= nil then
  -- hot code reload using tarantoolctl or dofile()

  -- unload old application
  myapp.stop()
  -- clear cache for loaded modules and dependencies
  package.loaded['myapp'] = nil
  package.loaded['somedep'] = nil; -- dependency of 'myapp'
end

-- load a new version of app and all dependencies
myapp = require('myapp').start({some app options controlled by sysadmins})
```

Более детальный пример (со всеми настройками) содержится в файле example.lua, который входит в состав дистрибутива Tarantool'а.

Этот скрипт инициализации по сути является конфигурационным файлом. Его поддержкой должны заниматься системные администраторы, в то время как разработчики только предоставляют им шаблон.

Теперь обновите файл с вашим приложением в директории /usr/share/tarantool. Замените старую версию файла (например, /usr/share/tarantool/myapp.lua) и вручную загрузите скрипт инициализации myappcfg.lua с помощью утилиты tarantoolctl:

```
$ tarantoolctl eval /etc/tarantool/instance.enabled/myappcfg.lua
```

После этого вам нужно вручную очистить кеш модулей package.loaded.

Чтобы создать deb/rpm-сборку, вы можете добавить инструкцию tarantoolctl eval прямо в спецификацию Tarantool'а в файле RPM.spec и в директории /debian.

В итоге клиенты делают вызов (CALL) функции myapp.api_for_call и других функций из API.

Если вы используете tarantool-http, то запускать бинарный протокол не нужно.

Upgrading a Tarantool database

Эта информация полезна в том случае, если у вас есть база данных, работающая на какой-либо старой версии Tarantool'а, а теперь вы установили Tarantool новой версии. В этом случае выполните запрос box.schema.upgrade().

Например, вот что происходит, если выполнить запрос box.schema.upgrade() для базы, созданной в начале 2015 года (для примера показана лишь малая часть выводимых сообщений):

```
tarantool> box.schema.upgrade()
alter index primary on _space set options to {"unique":true}, parts to [[0,"unsigned"]]
alter space _schema set options to {}
create view _vindex...
grant read access to 'public' role for _vindex view
set schema version to 1.7.0
```

(continues on next page)

(продолжение с предыдущей страницы)

```
---
...
```

3.5.9 Обработка сигналов от сервера

Во время основного цикла Tarantool-сервер обрабатывает следующие сигналы:

SIGHUP может привести к ротации лога, см. *пример в разделе «Запись в журнал»*.

SIGUSR1 может привести к сохранению снимка, см. описание функции *box.snapshot*.

SIGTERM может привести к корректному завершению работы (с предварительным сохранением всех данных).

SIGINT (или «прерывание с клавиатуры») может привести к корректному завершению работы (с предварительным сохранением всех данных).

SIGKILL приводит к аварийному завершению работы (с возможной потерей данных).

Действие других сигналов определяется операционной системой. Все сигналы, кроме SIGKILL, могут быть проигнорированы, особенно если Tarantool-сервер выполняет длительную процедуру, которая позволяет вернуться к главному циклу.

3.5.10 Название процесса

Операционные системы Linux и FreeBSD позволяют запущенному процессу менять его название (title), в котором изначально содержится имя программы (name). Tarantool использует эту возможность, чтобы упростить работу системного администратора, например посмотреть, какие службы запущены на хосте, их статус и т.д.

Название процесса Tarantool-сервера состоит из следующих частей:

`имя_программы [имя_файла_инициализации] <имя_роли> [название_процесса]`

- **имя_программы** — это, как правило, «tarantool».
- **имя_файла_инициализации** — это имя *файла инициализации на Lua*, если этот файл был указан при запуске.
- **имя_роли** — это может быть один из следующих вариантов:
  - «running» (узел находится в режиме «готов к принятию запросов»),
  - «loading» (узел, который загружает данные из ранее сохраненного снимка и WAL-файла),
  - «orphan» (узел не входит в состав кластера),
  - «hot_standby», or
  - «dumper» + process-id (идет сохранение снимка).
- **название_процесса** — это необязательное название Tarantool-процесса в системе, которое берется из конфигурационного параметра *custom_proc_title*, если он указан.

Например:

```
$ ps -AF | grep tarantool
1000     17337 16716  1 91362  6916   0 11:07 pts/5    00:00:13 tarantool script.lua <running>
```

3.5.11 Заметки по администрированию для разных платформ

This section will contain information about issues or features which exist on some platforms but not others - for example, on certain versions of a particular Linux distribution.

Debian GNU/Linux and Ubuntu

Настройка конкретного экземпляра Tarantool-сервера:

```
$ ln -s /etc/tarantool/instances.available/*instance-name.cfg* /etc/tarantool/instances.enabled/
```

Запуск всех экземпляров:

```
$ service tarantool start
```

Остановка всех экземпляров:

```
$ service tarantool stop
```

Запуск/остановка конкретного экземпляра:

```
$ service tarantool-instance-name start/stop
```

Fedora, RHEL, CentOS

Известных воспроизводящихся дефектов для данных платформ нет. Если вы столкнулись с плавающим дефектом, посмотрите описания проблем на странице http://github.com/tarantool/tarantool/issues, введя в строке поиска слово «RHEL», «CentOS», «Fedora» или «Red Hat».

FreeBSD

Известных воспроизводящихся дефектов для данной платформы нет. Если вы столкнулись с плавающим дефектом, посмотрите описания проблем на странице http://github.com/tarantool/tarantool/issues, введя в строке поиска слово «FreeBSD».

Mac OS X

Известных воспроизводящихся дефектов для данных платформ нет. Если вы столкнулись с плавающим дефектом, посмотрите описания проблем на странице http://github.com/tarantool/tarantool/issues, введя в строке поиска слово «OS X».

3.5.12 Заметки для пользователей systemd

Tarantool полностью поддерживает работу с `systemd` как со средством для управления экземплярами и контроля за фоновыми программами базы данных.

Управление экземплярами

В архитектуре Tarantool'а заложена возможность запуска сразу многих экземпляров Tarantool-сервера на одной машине. С помощью `systemctl` *start/stop/restart/status* `tarantool@$`*MYAPP* можно управлять базами данных и Lua-приложениями.

Создание экземпляров

Задайте все настройки в виде Lua-скрипта и поместите их в файл /etc/tarantool/instances.available/$*MYAPP*.lua:

```
box.cfg{listen = 3313}
require('myappcode').start()
```

(это пример минимально достаточной конфигурации).

Также вы можете посмотреть пример Lua-скрипт в файле example.lua, который входит в состав дистрибутива Tarantool'а и содержит значения всех опций.

Запуск экземпляров

Для запуска экземпляра ${MYAPP} выполните команду systemctl start tarantool@$*MYAPP*:

```
$ systemctl start tarantool@example
$ ps axuf|grep exampl[e]
taranto+  5350  1.3  0.3 1448872 7736 ?        Ssl  20:05   0:28 tarantool example.lua <running>
```

(здесь и далее мы приводим примеры консольного вывода для Fedora).

Для автоматической загрузки экземпляра ${MYAPP} во время запуска всей системы используйте команду systemctl enable tarantool@$*MYAPP*.

Мониторинг экземпляров

Для проверки информации об экземпляре ${MYAPP} выполните команду systemctl status tarantool@$*MYAPP*:

```
$ systemctl status tarantool@example
tarantool@example.service - Tarantool Database Server
Loaded: loaded (/etc/systemd/system/tarantool@.service; disabled; vendor preset: disabled)
Active: active (running)
Docs: man:tarantool(1)
Process: 5346 ExecStart=/usr/bin/tarantoolctl start %I (code=exited, status=0/SUCCESS)
Main PID: 5350 (tarantool)
Tasks: 11 (limit: 512)
CGroup: /system.slice/system-tarantool.slice/tarantool@example.service
+ 5350 tarantool example.lua <running>
```

Для проверки журнала загрузки выполните команду journalctl -u tarantool@$*MYAPP*:

```
$ journalctl -u tarantool@example -n 5
-- Logs begin at Fri 2016-01-08 12:21:53 MSK, end at Thu 2016-01-21 21:17:47 MSK. --
Jan 21 21:17:47 localhost.localdomain systemd[1]: Stopped Tarantool Database Server.
Jan 21 21:17:47 localhost.localdomain systemd[1]: Starting Tarantool Database Server...
Jan 21 21:17:47 localhost.localdomain tarantoolctl[5969]: /usr/bin/tarantoolctl: Found example.lua␣
↪in /etc/tarantool/instances.available
Jan 21 21:17:47 localhost.localdomain tarantoolctl[5969]: /usr/bin/tarantoolctl: Starting instance.
↪..
Jan 21 21:17:47 localhost.localdomain systemd[1]: Started Tarantool Database Server
```

Подсоединение к экземплярам

Вы можете подсоединиться к запущенному экземпляру Tarantool-сервера и выполнить некий Lua-скрипт с помощью утилиты `tarantoolctl`:

```
$ tarantoolctl enter example
/bin/tarantoolctl: Found example.lua in /etc/tarantool/instances.available
/bin/tarantoolctl: Connecting to /var/run/tarantool/example.control
/bin/tarantoolctl: connected to unix/:/var/run/tarantool/example.control
unix/:/var/run/tarantool/example.control> 1 + 1
---
- 2
...
unix/:/var/run/tarantool/example.control>
```

Проверка журнала

Tarantool ведет записи о важных событиях в файле `/var/log/tarantool/$MYAPP.log`.

Давайте запишем что-нибудь в файл журнала:

```
$ tarantoolctl enter example
/bin/tarantoolctl: Found example.lua in /etc/tarantool/instances.available
/bin/tarantoolctl: Connecting to /var/run/tarantool/example.control
/bin/tarantoolctl: connected to unix/:/var/run/tarantool/example.control
unix/:/var/run/tarantool/example.control> require('log').info("Hello for README.systemd readers")
---
...
```

Затем проверим содержимое журнала:

```
$ tail /var/log/tarantool/example.log
2016-01-21 21:09:45.982 [5914] iproto I> binary: started
2016-01-21 21:09:45.982 [5914] iproto I> binary: bound to 0.0.0.0:3301
2016-01-21 21:09:45.983 [5914] main/101/tarantoolctl I> ready to accept requests
2016-01-21 21:09:45.983 [5914] main/101/example I> Run console at /var/run/tarantool/example.
↪control
2016-01-21 21:09:45.984 [5914] main/101/example I> tcp_server: remove dead UNIX socket: /var/run/
↪tarantool/example.control
2016-01-21 21:09:45.984 [5914] main/104/console/unix/:/var/run/tarant I> started
2016-01-21 21:09:45.985 [5914] main C> entering the event loop
2016-01-21 21:14:43.320 [5914] main/105/console/unix/: I> client unix/: connected
2016-01-21 21:15:07.115 [5914] main/105/console/unix/: I> Hello for README.systemd readers
2016-01-21 21:15:09.250 [5914] main/105/console/unix/: I> client unix/: disconnected
```

Для ротации журнала нужно установить программу `logrotate`. Настройки для ротации можно задать в файле `/etc/logrotate.d/tarantool`.

Остановка экземпляров

Для просмотра информации о запущенном экземпляре `${MYAPP}` выполните команду `systemctl stop tarantool@$MYAPP`.

```
$ systemctl stop tarantool@example
```

Контроль за фоновыми программами

Если какой-либо экземпляр Tarantool-сервера выходит из строя, `systemd` автоматически перезапускает его.

Давайте попробуем вывести из строя один экземпляр:

```
$ systemctl status tarantool@example|grep PID
Main PID: 5885 (tarantool)
$ tarantoolctl enter example
/bin/tarantoolctl: Found example.lua in /etc/tarantool/instances.available
/bin/tarantoolctl: Connecting to /var/run/tarantool/example.control
/bin/tarantoolctl: connected to unix/:/var/run/tarantool/example.control
unix/:/var/run/tarantool/example.control> os.exit(-1)
/bin/tarantoolctl: unix/:/var/run/tarantool/example.control: Remote host closed connection
```

А теперь убедимся, что `systemd` перезапустила его:

```
$ systemctl status tarantool@example|grep PID
Main PID: 5914 (tarantool)
```

И под конец проверим содержимое журнала загрузки:

```
$ journalctl -u tarantool@example -n 8
-- Logs begin at Fri 2016-01-08 12:21:53 MSK, end at Thu 2016-01-21 21:09:45 MSK. --
Jan 21 21:09:45 localhost.localdomain systemd[1]: tarantool@example.service: Unit entered failed␣
↪state.
Jan 21 21:09:45 localhost.localdomain systemd[1]: tarantool@example.service: Failed with result
↪'exit-code'.
Jan 21 21:09:45 localhost.localdomain systemd[1]: tarantool@example.service: Service hold-off time␣
↪over, scheduling restart.
Jan 21 21:09:45 localhost.localdomain systemd[1]: Stopped Tarantool Database Server.
Jan 21 21:09:45 localhost.localdomain systemd[1]: Starting Tarantool Database Server...
Jan 21 21:09:45 localhost.localdomain tarantoolctl[5910]: /usr/bin/tarantoolctl: Found example.lua␣
↪in /etc/tarantool/instances.available
Jan 21 21:09:45 localhost.localdomain tarantoolctl[5910]: /usr/bin/tarantoolctl: Starting instance.
↪..
Jan 21 21:09:45 localhost.localdomain systemd[1]: Started Tarantool Database Server.
```

Правка настроек сервисного файла

Пожалуйста, не редактируйте файл `tarantool@.service` по месту, поскольку все ваши изменения будут перезаписаны при последующих обновлениях Tarantool'а. Мы рекомендуем скопировать этот файл в `/etc/systemd/system` и править настройки уже в копии. Либо вы можете создать поддиректорию с именем `unit.d/` в директории `/etc/systemd/system` и положить туда drop-in файл с именем `name.conf`, в котором будут указаны только те настройки, которые нужно поменять. См. подробности в `systemd.unit(5)`.

Отладка

При аварийном завершении Tarantool-сервера, `coredumpctl` автоматически сохраняет дампы памяти (core dumps) и трассировку стека (stack traces). Вот как работает этот механизм:

```
$ # !!! ВНИМАНИЕ: никогда не делайте этого
  # в условиях промышленной эксплуатации !!!
$ tarantoolctl enter example
/bin/tarantoolctl: Found example.lua in /etc/tarantool/instances.available
/bin/tarantoolctl: Connecting to /var/run/tarantool/example.control
/bin/tarantoolctl: connected to unix/:/var/run/tarantool/example.control
unix/:/var/run/tarantool/example.control> require('ffi').cast('char *', 0)[0] = 48
/bin/tarantoolctl: unix/:/var/run/tarantool/example.control: Remote host closed connection
```

Введем `coredumpctl list /usr/bin/tarantool`, чтобы получить отчет о последних аварийных завершениях Tarantool-демона:

```
$ coredumpctl list /usr/bin/tarantool
MTIME                           PID   UID   GID SIG PRESENT EXE
Sat 2016-01-23 15:21:24 MSK   20681  1000  1000   6   /usr/bin/tarantool
Sat 2016-01-23 15:51:56 MSK   21035   995   992   6   /usr/bin/tarantool
```

Чтобы получить трассировку стека и прочую полезную информацию, введем `coredumpctl info <pid>`:

```
$ coredumpctl info 21035
          PID: 21035 (tarantool)
          UID: 995 (tarantool)
          GID: 992 (tarantool)
       Signal: 6 (ABRT)
    Timestamp: Sat 2016-01-23 15:51:42 MSK (4h 36min ago)
 Command Line: tarantool example.lua <running>
   Executable: /usr/bin/tarantool
Control Group: /system.slice/system-tarantool.slice/tarantool@example.service
         Unit: tarantool@example.service
        Slice: system-tarantool.slice
      Boot ID: 7c686e2ef4dc4e3ea59122757e3067e2
   Machine ID: a4a878729c654c7093dc6693f6a8e5ee
     Hostname: localhost.localdomain
      Message: Process 21035 (tarantool) of user 995 dumped core.

               Stack trace of thread 21035:
               #0  0x00007f84993aa618 raise (libc.so.6)
               #1  0x00007f84993ac21a abort (libc.so.6)
               #2  0x0000560d0a9e9233 _ZL12sig_fatal_cbi (tarantool)
               #3  0x00007f849a211220 __restore_rt (libpthread.so.0)
               #4  0x0000560d0aaa5d9d lj_cconv_ct_ct (tarantool)
               #5  0x0000560d0aaa687f lj_cconv_ct_tv (tarantool)
               #6  0x0000560d0aaabe33 lj_cf_ffi_meta___newindex (tarantool)
               #7  0x0000560d0aaae2f7 lj_BC_FUNCC (tarantool)
               #8  0x0000560d0aa9aabd lua_pcall (tarantool)
               #9  0x0000560d0aa71400 lbox_call (tarantool)
               #10 0x0000560d0aa6ce36 lua_fiber_run_f (tarantool)
               #11 0x0000560d0a9e8d0c _ZL16fiber_cxx_invokePFiP13__va_list_tagES0_ (tarantool)
               #12 0x0000560d0aa7b255 fiber_loop (tarantool)
               #13 0x0000560d0ab38ed1 coro_init (tarantool)
               ...
```

Теперь введем `coredumpctl -o filename.core info <pid>`, чтобы сохранить дамп памяти в отдельный файл.

Далее с помощью команды `coredumpctl gdb <pid>` запустим отладчик `gdb` и подадим сохраненный дамп памяти ему на вход.

Мы очень рекомендуем установить пакет `tarantool-debuginfo`, чтобы сделать отладку средствами gdb более эффективной. Например:

```
$ dnf debuginfo-install tarantool
```

С помощью gdb вы можете узнать, какие еще debuginfo-пакеты нужно установить:

```
$ # gdb -p <pid>
...
Missing separate debuginfos, use: dnf debuginfo-install
glibc-2.22.90-26.fc24.x86_64 krb5-libs-1.14-12.fc24.x86_64
libgcc-5.3.1-3.fc24.x86_64 libgomp-5.3.1-3.fc24.x86_64
libselinux-2.4-6.fc24.x86_64 libstdc++-5.3.1-3.fc24.x86_64
libyaml-0.1.6-7.fc23.x86_64 ncurses-libs-6.0-1.20150810.fc24.x86_64
openssl-libs-1.0.2e-3.fc24.x86_64
```

В трассировке стека используются символические имена, даже если у вас не установлен пакет tarantool-debuginfo.

Дополнительно см. документацию по вашей Linux-системе.

Особые указания

- Пожалуйста, не используйте `tarantoolctl {start,stop,restart}` для управления экземплярами, которые были запущены с помощью `systemd`. Но вы можете использовать `tarantoolctl` для запуска/остановки экземпляров в ваших локальных директориях (например, `$HOME`), что не требует пользовательских прав уровня `ROOT`.
- Утилита `tarantoolctl` уже настроена так, чтобы корректно работать с `systemd`. Пожалуйста, не меняйте общесистемные настройки для `tarantoolctl`, такие как пути, настройки прав для директорий и имена пользователей, т.к. это может привести к неожиданным проблемам.
- Поддержкой скриптов для `systemd` занимается команда разработки Tarantool'а (http://tarantool.org). Если у вас возникли проблемы при работе Tarantool'а с `systemd`, то мы просим сообщать об этом нашей команде (https://github.com/tarantool/tarantool/issues/), а не разработчикам вашего Linux-дистрибутива.

Ограничения

These limitations exist due to decisions by packagers to support systemd alongside sysvinit.

`/etc/init.d/tarantool start` under systemd, or `systemctl start tarantool` (without an @instance argument), will start only those instances which were enabled before reboot or before the last time that systemd was reloaded with `systemctl daemon-reload`.

(`systemctl start tarantool`, without an @instance argument, is provided only for interoperability with sysvinit scripts. Please use `systemctl start tarantool@instance` instead.)

`/etc/init.d/tarantool stop` under systemd, or `systemctl tarantool stop` (without an @instance argument), will do nothing.

Starting with Tarantool version 1.7.1.42, a new version of tarantool-common is required. (tarantool-common is a downloadable package which provides scripts to work with tarantool configuration and log files.) An attempt to upgrade tarantool-common will cause restart of all instances.

sysvinit -> systemd conversion

These instructions apply only for Debian/Ubuntu distros where both sysvinit and systemd exist.

Install new systemd-enabled packages.

#For each instancename in /etc/tarantool/instances.enabled/: #To enable the instance to be automatically loaded by systemd: `systemctl enable tarantool@instancename`

#The following command does nothing but is recommended for consistency: `/etc/init.d/tarantool stop`

#Disable sysvinit-compatible wrappers: `systemctl disable tarantool; update-rc.d tarantool remove`

3.6 Коннекторы

В этой главе описаны API для различных языков программирования.

3.6.1 Протокол

Бинарный протокол для передачи данных в Tarantool'е был разработан с учетом потребностей асинхронного ввода-вывода. Основная его задача — облегчить интеграцию Tarantool'а с клиентскими приложениями. Клиентский запрос в Tarantool-протоколе начинается с бинарного заголовка переменной длины. В заголовке указывается идентификатор и тип запроса, идентификатор сервера, номер записи в журнале и т.д.

Также в заголовке обязательно указывается длина запроса, что облегчает обработку данных. Ответ на запрос посылается по мере готовности. В заголовке ответа указывается тот же идентификатор и тип запроса, что и в изначальном запросе. По идентификатору можно легко соотнести запрос с ответом, даже если ответ был получен не в порядке отсылки запросов.

Вдаваться в тонкости реализации Tarantool-протокола нужно только при разработке нового коннектора для Tarantool'а — см. *полное описание бинарного протокола в Tarantool'е* в виде аннотированных BNF-диаграмм (Backus-Naur Form). В остальных случаях достаточно взять уже существующий коннектор для нужного вам языка программирования. Такие коннекторы позволяют легко хранить структуры данных из разных языков в формате Tarantool'а.

3.6.2 Пример пакета данных

The Tarantool API exists so that a client program can send a request packet to the server, and receive a response. Here is an example of a what the client would send for `box.space[513]:insert{'A', 'BB'}`. The BNF description of the components is on the page about *Tarantool's binary protocol*.

Компонент	Байт #0	Байт #1	Байт #2	Байт #3
код для вставки	02			
остаток заголовка	...	...	...	...
число из 2 цифр: ID пространства	cd	02	01	
код для кортежа	21			
число из 1 цифры: количество полей = 2	92			
строка из 1 символа: поле[1]	a1	41		
строка из 2 символов: поле[2]	a2	42	42	

Now, you could send that packet to the Tarantool server, and interpret the response (the page about *Tarantool's binary protocol* has a description of the packet format for responses as well as requests). But it would be easier, and less error-prone, if you could invoke a routine that formats the packet according to typed parameters. Something like `response = tarantool_routine("insert", 513, "A", "B");`. And that is why APIs exist for drivers for Perl, Python, PHP, and so on.

3.6.3 Настройка окружения для примеров работы с коннекторами

This chapter has examples that show how to connect to the Tarantool server via the Perl, PHP, Python, node.js, and C connectors. The examples contain hard code that will work if and only if the following conditions are met:

- the server (tarantool) is running on localhost (127.0.0.1) and is listening on port 3301 (`box.cfg.listen = '3301'`),
- space `examples` has id = 999 (`box.space.examples.id = 999`) and has a primary-key index for a numeric field (`box.space[999].index[0].parts[1].type = "unsigned"`),
- для пользователя „guest“ настроены привилегии на чтение и запись.

Такое тестовое окружение легко настроить, запустив Tarantool-сервер локально и выполнив следующие запросы:

```
box.cfg{listen=3301}
box.schema.space.create('examples',{id=999})
box.space.examples:create_index('primary', {type = 'hash', parts = {1, 'unsigned'}})
box.schema.user.grant('guest','read,write','space','examples')
box.schema.user.grant('guest','read','space','_space')
```

3.6.4 Java

См. http://github.com/tarantool/tarantool-java/.

3.6.5 Go

См. https://github.com/mialinx/go-tarantool.

3.6.6 R

См. https://github.com/thekvs/tarantoolr.

3.6.7 Erlang

See Erlang tarantool driver.

3.6.8 Perl

Наиболее популярным Tarantool-коннектором для языка Perl является DR::Tarantool. Он устанавливается отдельно от Tarantool'а, например с помощью `cpan` (см. CPAN, the Comprehensive Perl Archive Network), и требует предварительной установки еще несколько зависимых модулей. Вот пример установки этого коннектора под Ubuntu:

```
$ sudo cpan install AnyEvent
$ sudo cpan install Devel::GlobalDestruction
$ sudo cpan install Coro
$ sudo cpan install Test::Pod
$ sudo cpan install Test::Spelling
$ sudo cpan install PAR::Dist
$ sudo cpan install List::MoreUtils
$ sudo cpan install DR::Tarantool
```

Далее приводится пример полноценной программы на языке Perl, которая осуществляет вставку кортежа `[99999,'BB']` в пространство `space[999]` с помощью Tarantool API для языка Perl. Перед запуском данной программы проверьте, что ваше тестовое окружение настроено так, как *описано выше* (у Tarantool-сервера задан порт для прослушивания и в базе создано пространство `examples`). Чтобы запустить тестовую программу, сохраните ее исходный код в файл с именем `example.pl` и выполните команду `perl example.pl`. Программа установит соединение, используя указанное в ней описание пространства, откроет сокет для соединения с Tarantool-сервером по адресу `localhost:3301`, пошлет INSERT-запрос, а затем — если всё хорошо — закончит работу без каких-либо сообщений. Если окажется, что Tarantool-сервер не запущен на прослушивание по указанному адресу, то программа выдаст сообщение об ошибке "Connection refused".

```
#!/usr/bin/perl
use DR::Tarantool ':constant', 'tarantool';
use DR::Tarantool ':all';
use DR::Tarantool::MsgPack::SyncClient;

my $tnt = DR::Tarantool::MsgPack::SyncClient->connect(
  host    => '127.0.0.1',                      # поиск Tarantool-сервера по адресу localhost
  port    => 3301,                             # на порту 3301
  user    => 'guest',                          # имя пользователя; здесь же можно добавить
↪'password=>...'

  spaces  => {
    999 => {                                   # определение пространства space[999] ...
      name => 'examples',                      # имя пространства space[999] = 'examples'
      default_type => 'STR',                   # если тип поля в space[999] не задан, то = 'STR'
      fields => [ {                            # определение полей в пространстве space[999] ...
          name => 'field1', type => 'NUM' } ], # имя поля space[999].field[1]='field1', тип ='NUM'
      indexes => {                             # определение индексов пространства space[999] ...
        0 => {
          name => 'primary', fields => [ 'field1' ] } } } } );

$tnt->insert('examples' => [ 99999, 'BB' ]);
```

Из-за существующих ограничений в языке Perl, вместо полей типа „string“ и „unsigned“ в тестовой программе указаны поля типа „STR“ и „NUM“.

В этой программе мы привели пример использования лишь одного запроса. Для полноценной работы с Tarantool'ом с помощью Perl API, пожалуйста, обратитесь к документации из CPAN-репозитория DR::Tarantool.

3.6.9 PHP

The most commonly used PHP driver is tarantool-php. It is not supplied as part of the Tarantool repository; it must be installed separately, for example with `git`. See installation instructions. in the driver's `README` file.

Here is a complete PHP program that inserts [99999,'BB'] into a space named examples via the PHP API. Before trying to run, check that the server is listening at localhost:3301 and that the space examples exists, as *described earlier*. To run, paste the code into a file named example.php and say php -d extension=~/tarantool-php/modules/tarantool.so example.php. The program will open a socket connection with the Tarantool server at localhost:3301, then send an INSERT request, then — if all is well — print «Insert succeeded». If the tuple already exists, the program will print "Duplicate key exists in unique index „primary" in space „examples"".

```
<?php
$tarantool = new Tarantool('localhost', 3301);

try {
    $tarantool->insert('examples', array(99999, 'BB'));
    echo "Insert succeeded\n";
} catch (Exception $e) {
    echo "Exception: ", $e->getMessage(), "\n";
}
```

The example program only shows one request and does not show all that's necessary for good practice. For that, please see tarantool/tarantool-php project at GitHub.

Besides, you can use an alternative PHP driver from another GitHub project: it includes a *client* (see tarantool-php/client) and a *mapper* for that client (see tarantool-php/mapper).

3.6.10 Python

Далее приводится пример полноценной программы на языке Python, которая осуществляет вставку кортежа [99999,'Value','Value'] в пространство examples с помощью высокоуровневого Tarantool API для языка Python.

```
#!/usr/bin/python
from tarantool import Connection

c = Connection("127.0.0.1", 3301)
result = c.insert("examples",(99999,'Value', 'Value'))
print result
```

Перед запуском данной программы проверьте, что ваше тестовое окружение настроено так, как *описано выше* (у Tarantool-сервера задан порт для прослушивания и в базе создано пространство examples), и установите коннектор tarantool-python. Для установки коннектора воспользуйтесь либо командой pip install tarantool>0.4 (для установки в директорию /usr; вам потребуются права уровня **root**), либо командой pip install tarantool>0.4 --user (для установки в директорию ~, т.е. в используемую по умолчанию директорию текущего пользователя). Чтобы запустить тестовую программу, сохраните ее исходный код в файл с именем example.py и выполните команду python example.py. Программа установит соединение с Tarantool-сервером, пошлет запрос и не сгенерирует никакого исключения, если всё прошло хорошо. Если окажется, что такой кортеж уже существует, то программа сгенерирует исключение tarantool.error.DatabaseError: (3, "Duplicate key exists in unique index 'primary' in space 'examples'").

The example program only shows one request and does not show all that's necessary for good practice. For that, please see tarantool-python project at GitHub. For an example of using Python API with queue managers for Tarantool, see queue-python project at GitHub.

3.6.11 Node.js

The most commonly used node.js driver is the Node Tarantool driver. It is not supplied as part of the Tarantool repository; it must be installed separately. The most common way to install it is with npm. For example, on Ubuntu, the installation could look like this after npm has been installed:

```
npm install tarantool-driver --global
```

Here is a complete node.js program that inserts `[99999,'BB']` into `space[999]` via the node.js API. Before trying to run, check that the server is listening at `localhost:3301` and that the space `examples` exists, as *described earlier*. To run, paste the code into a file named `example.rs` and say `node example.rs`. The program will connect using an application-specific definition of the space. The program will open a socket connection with the Tarantool server at `localhost:3301`, then send an INSERT request, then — if all is well — end after saying «Insert succeeded». If Tarantool is not running on `localhost` with listen port = 3301, the program will print "Connect failed". If user `guest` does not have authorization to connect, the program will print «Auth failed». If the insert request fails for any reason, for example because the tuple already exists, the program will print «Insert failed».

```
var TarantoolConnection = require('tarantool-driver');
var conn = new TarantoolConnection({port: 3301});
var insertTuple = [99999, "BB"];
conn.connect().then(function() {
    conn.auth("guest", "").then(function() {
        conn.insert(999, insertTuple).then(function() {
            console.log("Insert succeeded");
            process.exit(0);
    }, function(e) { console.log("Insert failed");  process.exit(1); });
    }, function(e) { console.log("Auth failed");    process.exit(1); });
    }, function(e) { console.log("Connect failed"); process.exit(1); });
```

The example program only shows one request and does not show all that's necessary for good practice. For that, please see The node.js driver repository.

3.6.12 C#

The most commonly used csharp driver is the ProGaudi tarantool-csharp driver. It is not supplied as part of the Tarantool repository; it must be installed separately. The makers recommend installation on Windows and not on other platforms. However, to be consistent with the other instructions in this chapter, here is an unofficial way to install the driver on Ubuntu 16.04.

Install dotnet preview from Microsoft – mono will not work, and dotnet from xbuild will not work. Read the Microsoft End User License Agreement first, because it is not an ordinary open-source agreement and there will be a message during installation saying «This software may collect information about you and your use of the software, and send that to Microsoft.» The dotnet instructions are at https://www.microsoft.com/net/core#ubuntu.

```
# Install tarantool-csharp from the github repository source -- nuget will
# not work, so building from source is necessary, thus:
cd ~
mkdir dotnet
cd dotnet
git clone https://github.com/progaudi/tarantool-csharp tarantool-csharp
cd tarantool-csharp
dotnet restore
cd src/tarantool.client
```

(continues on next page)

(продолжение с предыдущей страницы)

```
dotnet build
# Find the .dll file that was produced by the "dotnet build" step. The next
instruction assumes it was produced in 'bin/Debug/netcoreapp1.0'.
cd bin/Debug/netcoreapp1.0
# Find the project.json file used for samples. The next instruction assumes
# the docker-compose/dotnet directory has a suitable one, which is true at
# time of writing.
cp ~/dotnet/tarantool-csharp/samples/docker-compose/dotnet/project.json project.json
dotnet restore
```

Do not change directories now, the example program should be in the same directory as the .dll file.

Here is a complete C# program that inserts `[99999,'BB']` into space `examples` via the tarantool-csharp API. Before trying to run, check that the server is listening at `localhost:3301` and that the space `examples` exists, as *described earlier*. To run, paste the code into a file named `example.cs` and say `dotnet run example.cs`. The program will connect using an application-specific definition of the space. The program will open a socket connection with the Tarantool server at `localhost:3301`, then send an INSERT request, then — if all is well — end without saying anything. If Tarantool is not running on `localhost` with listen port = 3301, or if user `guest` does not have authorization to connect, or if the insert request fails for any reason, the program will print an error message, among other things.

```
using System;
using System.Linq;
using System.Threading.Tasks;
using ProGaudi.Tarantool.Client;
using ProGaudi.Tarantool.Client.Model;
public class HelloWorld
{
  static public void Main ()
  {
    Test().Wait();
  }
  static async Task Test()
  {
    var tarantoolClient = await Box.Connect("127.0.0.1:3301");
    var schema = tarantoolClient.getSchema();
    var space = await schema.getSpace("examples");
    await space.Insert(TarantoolTuple.Create(99999, "BB"));
  }
}
```

The same program should work on Windows with far less difficulty – just install with nuget and run.

The example program only shows one request and does not show all that's necessary for good practice. For that, please see The tarantool-csharp driver repository.

3.6.13 C

В этом разделе даны два примера использования высокоуровневого API для Tarantool'a и языка C.

Пример 1

Далее приводится пример полноценной программы на языке C, которая осуществляет вставку кортежа `[99999,'B']` в пространство `examples` с помощью высокоуровневого Tarantool API для языка C.

```
#include <stdio.h>
#include <stdlib.h>

#include <tarantool/tarantool.h>
#include <tarantool/tnt_net.h>
#include <tarantool/tnt_opt.h>

void main() {
   struct tnt_stream *tnt = tnt_net(NULL);          /* См. ниже = НАСТРОЙКА */
   tnt_set(tnt, TNT_OPT_URI, "localhost:3301");
   if (tnt_connect(tnt) < 0) {                      /* См. ниже = СОЕДИНЕНИЕ */
       printf("Connection refused\n");
       exit(-1);
   }
   struct tnt_stream *tuple = tnt_object(NULL);     /* См. ниже = СОЗДАНИЕ ЗАПРОСА */
   tnt_object_format(tuple, "[%d%s]", 99999, "B");
   tnt_insert(tnt, 999, tuple);                     /* См. ниже = ОТПРАВКА ЗАПРОСА */
   tnt_flush(tnt);
   struct tnt_reply reply;  tnt_reply_init(&reply); /* См. ниже = ПОЛУЧЕНИЕ ОТВЕТА */
   tnt->read_reply(tnt, &reply);
   if (reply.code != 0) {
       printf("Insert failed %lu.\n", reply.code);
   }
   tnt_close(tnt);                                  /* См. ниже = ЗАВЕРШЕНИЕ */
   tnt_stream_free(tuple);
   tnt_stream_free(tnt);
}
```

Скопируйте исходный код программы в файл с именем `example.c` и установите коннектор `tarantool-c`. Вот один из способов установки `tarantool-c` (под Ubuntu):

```
$ git clone git://github.com/tarantool/tarantool-c.git ~/tarantool-c
$ cd ~/tarantool-c
$ git submodule init
$ git submodule update
$ cmake .
$ make
$ make install
```

Чтобы скомпилировать и слинковать тестовую программу, выполните следующую команду:

```
$ # иногда это необходимо:
$ export LD_LIBRARY_PATH=/usr/local/lib
$ gcc -o example example.c -ltarantool
```

Перед запуском программы проверьте, что ваше тестовое окружение настроено так, как *описано выше* (у Tarantool-сервера задан порт для прослушивания и в базе создано пространство `examples`). Чтобы запустить тестовую программу, выполните команду `./example`. Программа установит соединение с Tarantool-сервером и пошлет запрос. Если окажется, что Tarantool-сервер не запущен на прослушивание по указанному адресу, то программа выдаст сообщение об ошибке "Connection refused". А если не пройдет INSERT-запрос, то программа выдаст сообщение «Insert failed» и код ошибки (все коды ошибок в Tarantool'е см. в исходном файле /src/box/errcode.h).

Далее следуют примечания, на которые мы ссылались в комментариях к исходному коду тестовой программы.

НАСТРОЙКА: Настройка начинается с создания потока (`tnt_stream`).

```
struct tnt_stream *tnt = tnt_net(NULL);
tnt_set(tnt, TNT_OPT_URI, "localhost:3301");
```

В нашей тестовой программе поток назван `tnt`. Перед установкой соединения нужно задать ряд настроечных опций. Самая важная из них — TNT_OPT_URI. Для этой опции указана URI-строка `localhost:3301`, т.е. адрес, по которому должно быть настроено прослушивание на стороне Tarantool-сервера.

Описание функции:

`struct tnt_stream *tnt_net(struct tnt_stream *s)`
`int tnt_set(struct tnt_stream *s, int option, variant option-value)`

СОЕДИНЕНИЕ: Теперь когда мы создали поток с именем `tnt` и связали его с конкретным URI, наша программа может устанавливать соединение с Tarantool-сервером.

```
if (tnt_connect(tnt) < 0)
   { printf("Connection refused\n"); exit(-1); }
```

Описание функции:

`int tnt_connect(struct tnt_stream *s)`

Попытка соединения может и не удаться, например если Tarantool-сервер не запущен или в URI-строке указан неверный пароль. В случае неудачи функция `tnt_connect()` вернет -1.

СОЗДАНИЕ ЗАПРОСА: В большинстве запросов требуется передавать структурированные данные, например содержимое кортежа.

```
struct tnt_stream *tuple = tnt_object(NULL);
tnt_object_format(tuple, "[%d%s]", 99999, "B");
```

В данной программе мы используем запрос INSERT, а кортеж содержит целое число и строку. Это простой набор значений без каких-либо вложенных структур или массивов. И передаваемые значения мы можем указать самым простым образом — аналогично тому, как это сделано в стандартной C-функции `printf()`: `%d` для обозначения целого числа, `%s` для обозначения строки, затем числовое значение, затем указатель на строковое значение.

Описание функции:

`ssize_t tnt_object_format(struct tnt_stream *s, const char *fmt, ...)`

ОТПРАВКА ЗАПРОСА: Отправка запросов на изменение данных в базе делается аналогично тому, как это делается в Tarantool-библиотеке `box`.

```
tnt_insert(tnt, 999, tuple);
tnt_flush(tnt);
```

В данной программе мы делаем INSERT-запрос. В этом запросе мы передаем поток `tnt`, который ранее использовали для установки соединения, и поток `tuple`, который также ранее настроили с помощью функции `tnt_object_format()`.

Описание функции:

```
ssize_t tnt_insert(struct tnt_stream *s, uint32_t space, struct tnt_stream *tuple)
ssize_t tnt_replace(struct tnt_stream *s, uint32_t space, struct tnt_stream *tuple)
ssize_t tnt_select(struct tnt_stream *s, uint32_t space, uint32_t index,
                   uint32_t limit, uint32_t offset, uint8_t iterator,
                   struct tnt_stream *key)
ssize_t tnt_update(struct tnt_stream *s, uint32_t space, uint32_t index,
```

```
                    struct tnt_stream *key, struct tnt_stream *ops)
```

ПОЛУЧЕНИЕ ОТВЕТА: На большинство запросов клиент получает ответ, который содержит информацию о том, был ли данный запрос успешно выполнен, а также содержит набор кортежей.

```
struct tnt_reply reply;  tnt_reply_init(&reply);
tnt->read_reply(tnt, &reply);
if (reply.code != 0)
   { printf("Insert failed %lu.\n", reply.code); }
```

Данная программа проверяет, был ли запрос выполнен успешно, но никак не интерпретирует оставшуюся часть ответа.

Описание функции:

```
struct tnt_reply *tnt_reply_init(struct tnt_reply *r)
tnt->read_reply(struct tnt_stream *s, struct tnt_reply *r)
void tnt_reply_free(struct tnt_reply *r)
```

ЗАВЕРШЕНИЕ: По окончании сессии нам нужно закрыть соединение, созданное с помощью функции `tnt_connect()`, и удалить объекты, созданные на этапе настройки.

```
tnt_close(tnt);
tnt_stream_free(tuple);
tnt_stream_free(tnt);
```

Описание функции:

```
void tnt_close(struct tnt_stream *s)
void tnt_stream_free(struct tnt_stream *s)
```

Пример 2

Далее приводится еще один пример полноценной программы на языке C, которая осуществляет выборку по индекс-ключу `[99999]` из пространства `examples` с помощью высокоуровневого Tarantool API для языка C. Для вывода результатов в этой программе используются функции из библиотеки MsgPuck. Эти функции нужны для декодирования массивов значений в формате MessagePack.

```
#include <stdio.h>
#include <stdlib.h>
#include <tarantool/tarantool.h>
#include <tarantool/tnt_net.h>
#include <tarantool/tnt_opt.h>

#define MP_SOURCE 1
#include <msgpuck.h>

void main() {
    struct tnt_stream *tnt = tnt_net(NULL);
    tnt_set(tnt, TNT_OPT_URI, "localhost:3301");
    if (tnt_connect(tnt) < 0) {
        printf("Connection refused\n");
        exit(1);
    }
    struct tnt_stream *tuple = tnt_object(NULL);
    tnt_object_format(tuple, "[%d]", 99999); /* кортеж tuple = ключ для поиска */
    tnt_select(tnt, 999, 0, (2^32) - 1, 0, 0, tuple);
    tnt_flush(tnt);
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    struct tnt_reply reply; tnt_reply_init(&reply);
    tnt->read_reply(tnt, &reply);
    if (reply.code != 0) {
        printf("Select failed.\n");
        exit(1);
    }
    char field_type;
    field_type = mp_typeof(*reply.data);
    if (field_type != MP_ARRAY) {
        printf("no tuple array\n");
        exit(1);
    }
    long unsigned int row_count;
    uint32_t tuple_count = mp_decode_array(&reply.data);
    printf("tuple count=%u\n", tuple_count);
    unsigned int i, j;
    for (i = 0; i < tuple_count; ++i) {
        field_type = mp_typeof(*reply.data);
        if (field_type != MP_ARRAY) {
            printf("no field array\n");
            exit(1);
        }
        uint32_t field_count = mp_decode_array(&reply.data);
        printf("  field count=%u\n", field_count);
        for (j = 0; j < field_count; ++j) {
            field_type = mp_typeof(*reply.data);
            if (field_type == MP_UINT) {
                uint64_t num_value = mp_decode_uint(&reply.data);
                printf("    value=%lu.\n", num_value);
            } else if (field_type == MP_STR) {
                const char *str_value;
                uint32_t str_value_length;
                str_value = mp_decode_str(&reply.data, &str_value_length);
                printf("    value=%.*s.\n", str_value_length, str_value);
            } else {
                printf("wrong field type\n");
                exit(1);
            }
        }
    }
    tnt_close(tnt);
    tnt_stream_free(tuple);
    tnt_stream_free(tnt);
}
```

Аналогично первому примеру, сохраните исходный код программы в файле с именем `example2.c`.

Чтобы скомпилировать и слинковать тестовую программу, выполните следующую команду:

```
$ gcc -o example2 example2.c -ltarantool
```

Для запуска программы выполните команду `./example2`.

В этих двух программах мы привели пример использования лишь двух запросов. Для полноценной работы с Tarantool'ом с помощью C API, пожалуйста, обратитесь к документации из проекта tarantool-c на GitHub.

3.6.14 Интерпретация возвращаемых значений

При работе с любым Tarantool-коннектором функции, вызванные с помощью Tarantool'а, возвращают значения в формате MsgPack. Если функция была вызвана через API коннектора, то формат возвращаемых значений будет следующим: скалярные значения возвращаются в виде кортежей (сначала идет идентификатор типа из формата MsgPack, а затем идет значение); все прочие (не скалярные) значения возвращаются в виде групп кортежей (сначала идет идентификатор массива в формате MsgPack, а затем идут скалярные значения). Но если функция была вызвана в рамках бинарного протокола (с помощью команды `eval`), а не через API коннектора, то подобных изменений формата возвращаемых значений не происходит.

Далее приводится пример создания Lua-функции. Поскольку эту функцию будет вызывать внешний пользователь „guest", то нужно настроить привилегии на исполнение с помощью `grant`. Эта функция возвращает пустой массив, строку-скаляр, два логических значения и короткое целое число. Значение будут теми же, что описаны в разделе про MsgPack в таблице *Стандартные типы в MsgPack-кодировке*.

```
tarantool> box.cfg{listen=3301}
2016-03-03 18:45:52.802 [27381] main/101/interactive I> ready to accept requests
---
...
tarantool> function f() return {},'a',false,true,127; end
---
...
tarantool> box.schema.func.create('f')
---
...
tarantool> box.schema.user.grant('guest','execute','function','f')
---
...
```

Далее идет пример программы на C, из который мы вызываем эту Lua-функцию. Хотя в примере использован код на C, результат будет одинаковым, на каком бы языке ни была написана вызываемая программа: Perl, PHP, Python, Go или Java.

```
#include <stdio.h>
#include <stdlib.h>
#include <tarantool/tarantool.h>
#include <tarantool/tnt_net.h>
#include <tarantool/tnt_opt.h>
void main() {
  struct tnt_stream *tnt = tnt_net(NULL);            /* НАСТРОЙКА */
  tnt_set(tnt, TNT_OPT_URI, "localhost:3301");
   if (tnt_connect(tnt) < 0) {                        /* СОЕДИНЕНИЕ */
       printf("Connection refused\n");
       exit(-1);
   }
   struct tnt_stream *tuple = tnt_object(NULL);       /* СОЗДАНИЕ ЗАПРОСА */
   struct tnt_stream *arg; arg = tnt_object(NULL);
   tnt_object_add_array(arg, 0);
   struct tnt_request *req1 = tnt_request_call(NULL); /* ВЫЗОВ function f() */
   tnt_request_set_funcz(req1, "f");
   tnt_request_set_tuple(req1, arg);
   uint64_t sync1 = tnt_request_compile(tnt, req1);
   tnt_flush(tnt);                                    /* ОТПРАВКА ЗАПРОСА */
   struct tnt_reply reply;  tnt_reply_init(&reply);   /* ПОЛУЧЕНИЕ ОТВЕТА */
   tnt->read_reply(tnt, &reply);
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    if (reply.code != 0) {
      printf("Call failed %lu.\n", reply.code);
      exit(-1);
    }
    const unsigned char *p= (unsigned char*)reply.data;/* ВЫВОД ОТВЕТА */
    while (p < (unsigned char *) reply.data_end)
    {
      printf("%x ", *p);
      ++p;
    }
    printf("\n");
    tnt_close(tnt);                                    /* ЗАВЕРШЕНИЕ */
    tnt_stream_free(tuple);
    tnt_stream_free(tnt);
}
```

По завершении программа выведет на экран следующие значения:

```
dd 0 0 0 5 90 91 a1 61 91 c2 91 c3 91 7f
```

Первые пять байт — `dd 0 0 0 5` — это фрагмент данных в формате MsgPack, означающий «32-битный заголовок массива со значением 5» (см. спецификацию на формат MsgPack). Остальные значения описаны в таблице *Стандартные типы в MsgPack-кодировке*.

3.7 Вопросы и ответы

Q Why Tarantool?

A Tarantool is the latest generation of a family of in-memory data servers developed for web applications. It is the result of practical experience and trials within Mail.Ru since development began in 2008.

Q Why Lua?

A Lua is a lightweight, fast, extensible multi-paradigm language. Lua also happens to be very easy to embed. Lua coroutines relate very closely to Tarantool fibers, and Lua architecture works well with Tarantool internals. Lua acts well as a stored program language for Tarantool, although connecting with other languages is also easy.

Q What's the key advantage of Tarantool?

A

Tarantool provides a rich database feature set (HASH, TREE, RTREE, BITSET indexes, secondary indexes, composite indexes, transactions, triggers, asynchronous replication) in a flexible environment of a Lua interpreter.

These two properties make it possible to be a fast, atomic and reliable in-memory data server which handles non-trivial application-specific logic. The advantage over traditional SQL servers is in performance: low-overhead, lock-free architecture means Tarantool can serve an order of magnitude more requests per second, on comparable hardware. The advantage over NoSQL alternatives is in flexibility: Lua allows flexible processing of data stored in a compact, denormalized format.

Q What are your development plans?

A We continuously improve server performance. On the feature front, automatic sharding and synchronous replication, and a subset of SQL are the major goals for 2016-2018. We have an open roadmap to which we encourage anyone to add feature requests.

Q Who is developing Tarantool?

A There is an engineering team employed by Mail.Ru – check out our commit logs on github.com/tarantool. The development is fully open. Most of the connectors" authors, and the maintainers for different distributions, come from the wider community.

Q How serious is Mail.Ru about Tarantool?

A Tarantool is an open source project, distributed under a BSD license, so it does not depend on any one sponsor. However, it is an integral part of the Mail.Ru backbone, so it gets a lot of support from Mail.Ru.

Q Are there problems associated with being an in-memory server?

A The principal storage engine is designed for RAM plus persistent storage. It is immune to data loss because there is a write-ahead log. Its memory-allocation and compression techniques ensure there is no waste. And if Tarantool runs out of memory, then it will stop accepting updates until more memory is available, but will continue to handle read and delete requests without difficulty. However, for databases which are much larger than the available RAM space, Tarantool has a second storage engine which is only limited by the available disk space.

ГЛАВА 4

Справочники

4.1 Справочник по встроенной библиотеке

This reference covers Tarantool's built-in Lua modules.

Примечание: Some functions in these modules are analogs to functions from standard Lua libraries. For better results, we recommend using functions from Tarantool's built-in modules.

4.1.1 Модуль *box*

As well as executing Lua chunks or defining their own functions, you can exploit Tarantool's storage functionality with the `box` module and its submodules.

The contents of the `box` library can be inspected at runtime with `box`, with no arguments. The submodules inside the box library are:

Вложенный модуль *box.schema*

The `box.schema` submodule has data-definition functions for spaces, users, roles, and function tuples.

`box.schema.space.create(`*space-name*[, *{options}*]`)`
Create a space.

Параметры

- `space-name` (*string*) – name of space, which should not be a number and should not contain special characters
- `options` (*table*) – see «Options for box.schema.space.create» chart, below

Return space object

Rtype userdata

Options for box.schema.space.create

Name	Effect	Type	Default
temporary	space is temporary	boolean	false
id	unique identifier	number	last space's id, +1
field_count	fixed field count	number	0 i.e. not fixed
if_not_exists	no error if duplicate name	boolean	false
engine	storage engine = „memtx" or „vinyl"	string	„memtx"
user	user name	string	current user's name
format	field names+types	table	(blank)

There are three *syntax variations* for object references targeting space objects, for example `box.schema.space.drop(`*`space-id`*`)` will drop a space. However, the common approach is to use functions attached to the space objects, for example *space_object:drop()*.

Примечание:

Note re storage engine:
vinyl does not support temporary spaces.

Example

```
tarantool> s = box.schema.space.create('space55')
---
...
tarantool> s = box.schema.space.create('space55', {
         >   id = 555,
         >   temporary = false
         > })
---
- error: Space 'space55' already exists
...
tarantool> s = box.schema.space.create('space55', {
         >   if_not_exists = true
         > })
---
...
```

For an illustration with the `format` clause, see *box.space._space* example.

After a space is created, usually the next step is to *create an index* for it, and then it is available for insert, select, and all the other *box.space* functions.

`box.schema.user.create(`*user-name*[, *{options}*]`)`

Create a user. For explanation of how Tarantool maintains user data, see section *Users* and reference on *_user* space.

The possible options are:

- `if_not_exists` = `true|false` (default = `true`) - bool, where `false` is for throwing no error if the user already exists,
- `password` (default = „") - string; the `password` = *password* specification is good because in a *URI* (Uniform Resource Identifier) it is usually illegal to include a user-name without a password.

Примечание: The maximum number of users is 32.

Параметры

- user-name (*string*) – name of user, which should not be a number and should not contain special characters
- options (*table*) – if_not_exists, password

Return nil

Примеры:

```
box.schema.user.create('Lena')
box.schema.user.create('Lena', {password = 'X'})
box.schema.user.create('Lena', {if_not_exists = false})
```

box.schema.user.drop(*user-name*[, *{options}*])

Drop a user. For explanation of how Tarantool maintains user data, see section *Users* and reference on *_user* space.

Параметры

- user-name (*string*) – the name of the user
- options (*table*) – if_exists

Примеры:

```
box.schema.user.drop('Lena')
box.schema.user.drop('Lena',{if_exists=false})
```

box.schema.user.exists(*user-name*)

Return `true` if a user exists; return `false` if a user does not exist. For explanation of how Tarantool maintains user data, see section *Users* and reference on *_user* space.

Параметры

- user-name (*string*) – the name of the user

Rtype bool

Example:

```
box.schema.user.exists('Lena')
```

box.schema.user.grant(*user-name*, *priveleges*, *object-type*, *object-name*[, *{options}*])

box.schema.user.grant(*user-name*, *priveleges*, *'universe'*[, *nil*, *{options}*])

box.schema.user.grant(*user-name*, *role-name*[, *nil*, *nil*, *{options}*])

Grant *privileges* to a user or to another role.

Параметры

- user-name (*string*) – the name of the user
- priveleges (*string*) – „read“ or „write“ or „execute“ or a combination,
- object-type (*string*) – „space“ or „function“.
- object-name (*string*) – name of object to grant permissions to

- role-name (*string*) – name of role to grant to user.
- options (*table*) – grantor, if_not_exists

If 'function','*object-name*' is specified, then a _func tuple with that object-name must exist.

Variation: instead of object-type, object-name say „universe" which means „all object-types and all objects". In this case, object name is omitted.

Variation: instead of privilege, object-type, object-name say role-name (see section *Roles*).

The possible options are:

- grantor = *grantor_name_or_id* – string or number, for custom grantor,
- if_not_exists = true|false (default = true) - bool, where false is for throwing no error if user already has the privilege.

Example:

```
box.schema.user.grant('Lena', 'read', 'space', 'tester')
box.schema.user.grant('Lena', 'execute', 'function', 'f')
box.schema.user.grant('Lena', 'read,write', 'universe')
box.schema.user.grant('Lena', 'Accountant')
box.schema.user.grant('Lena', 'read,write,execute', 'universe')
box.schema.user.grant('X', 'read', 'universe', nil, {if_not_exists=true}))
```

box.schema.user.revoke(*user-name*, *privilege*, *object-type*, *object-name*)
box.schema.user.revoke(*user-name*, *privilege*, *'role'*, *role-name*)

Revoke *privileges* from a user or from another role.

Параметры

- user-name (*string*) – the name of the user
- privilege (*string*) – „read" or „write" or „execute" or a combination
- object-type (*string*) – „space" or „function"
- object-name (*string*) – the name of a function or space

The user must exist, and the object must exist, but it is not an error if the user does not have the privilege.

Variation: instead of object-type, object-name say „universe" which means „all object-types and all objects".

Variation: instead of privilege, object-type, object-name say role-name (see section *Roles*).

Example:

```
box.schema.user.revoke('Lena', 'read', 'space', 'tester')
box.schema.user.revoke('Lena', 'execute', 'function', 'f')
box.schema.user.revoke('Lena', 'read,write', 'universe')
box.schema.user.revoke('Lena', 'Accountant')
```

box.schema.user.password(*password*)

Return a hash of a user's password. For explanation of how Tarantool maintains passwords, see section *Passwords* and reference on *_user* space.

Примечание:

- If a non-„guest" user has no password, it's **impossible** to connect to Tarantool using this user. The user is regarded as "internal" only, not usable from a remote connection. Such users can be useful if they have defined some procedures with the *SETUID* option, on which privileges are granted to externally-connectable users. This way, external users cannot create/drop objects, they can only invoke procedures.
- For the „guest" user, it's impossible to set a password: that would be misleading, since „guest" is the default user on a newly-established connection over the *binary protocol*, and Tarantool does not require a password to establish a binary connection. It is, however, possible to change the current user to 'guest' by providing the AUTH packet with no password at all or an empty password. This feature is useful for connection pools, which want to reuse a connection for a different user without re-establishing it.

Параметры

- `password` (*string*) – password

Rtype string

Example:

```
box.schema.user.password('ЛЕНА')
```

`box.schema.user.passwd(`[*user-name*], *password*`)`

Associate a password with the user who is currently logged in. or with another user. Users who wish to change their own passwords should use `box.schema.user.passwd(password)`. Administrators who wish to change passwords of other users should use `box.schema.user.passwd(user-name, password)`.

Параметры

- `user-name` (*string*) – user-name
- `password` (*string*) – password

Example:

```
box.schema.user.passwd('ЛЕНА')
box.schema.user.passwd('Lena', 'ЛЕНА')
```

`box.schema.user.info(`[*user-name*]`)`

Return a description of a user's privileges. For explanation of how Tarantool maintains user data, see section *Users* and reference on *_user* space.

Параметры

- `user-name` (*string*) – the name of the user. This is optional; if it is not supplied, then the information will be for the user who is currently logged in.

Example:

```
box.schema.user.info()
box.schema.user.info('Lena')
```

`box.schema.role.create(`*role-name*[, *{options}*]`)`

Create a role. For explanation of how Tarantool maintains role data, see section *Roles*.

Параметры

- role-name (*string*) – name of role, which should not be a number and should not contain special characters
- options (*table*) – if_not_exists

Return nil

Example:

```
box.schema.role.create('Accountant')
box.schema.role.create('Accountant', {if_not_exists = false})
```

box.schema.role.drop(*role-name*)

Drop a role. For explanation of how Tarantool maintains role data, see section *Roles*.

Параметры

- role-name (*string*) – the name of the role

Example:

```
box.schema.role.drop('Accountant')
```

box.schema.role.exists(*role-name*)

Return true if a role exists; return false if a role does not exist.

Параметры

- role-name (*string*) – the name of the role

Rtype bool

Example:

```
box.schema.role.exists('Accountant')
```

box.schema.role.grant(*user-name*, *privilege*, *object-type*, *object-name*[, *option*])

box.schema.role.grant(*user-name*, *privilege*, *'universe'*[, *nil*, *option*])

box.schema.role.grant(*role-name*, *role-name*[, *nil*, *nil*, *option*])

Grant *privileges* to a role.

Параметры

- user-name (*string*) – the name of the role
- privilege (*string*) – „read“ or „write“ or „execute“ or a combination
- object-type (*string*) – „space“ or „function“
- object-name (*string*) – the name of a function or space
- option (*bool*) – {if_not_exists=true} or {if_not_exists=false}

The role must exist, and the object must exist.

Variation: instead of object-type, object-name say „universe“ which means „all object-types and all objects“.

Variation: instead of privilege, object-type, object-name say role-name – to grant a role to a role.

Example:

```
box.schema.role.grant('Accountant', 'read', 'space', 'tester')
box.schema.role.grant('Accountant', 'execute', 'function', 'f')
box.schema.role.grant('Accountant', 'read,write', 'universe')
box.schema.role.grant('public', 'Accountant')
box.schema.role.grant('role1', 'role2', nil, nil, {if_not_exists=false})
```

`box.schema.role.revoke(`*user-name*, *privilege*, *object-type*, *object-name*`)`

Revoke *privileges* from a role.

Параметры

- `user-name` (*string*) – the name of the role
- `privilege` (*string*) – „read" or „write" or „execute" or a combination
- `object-type` (*string*) – „space" or „function"
- `object-name` (*string*) – the name of a function or space

The role must exist, and the object must exist, but it is not an error if the role does not have the privilege.

Variation: instead of `object-type, object-name` say „universe" which means „all object-types and all objects".

Variation: instead of `privilege, object-type, object-name` say `role-name`.

Example:

```
box.schema.role.revoke('Accountant', 'read', 'space', 'tester')
box.schema.role.revoke('Accountant', 'execute', 'function', 'f')
box.schema.role.revoke('Accountant', 'read,write', 'universe')
box.schema.role.revoke('public', 'Accountant')
```

`box.schema.role.info(`[*role-name*]`)`

Return a description of a role's privileges.

Параметры

- `role-name` (*string*) – the name of the role.

Example:

```
box.schema.role.info('Accountant')
```

`box.schema.func.create(`*func-name*[, *{options}*]`)`

Create a function tuple. This does not create the function itself – that is done with Lua – but if it is necessary to grant privileges for a function, box.schema.func.create must be done first. For explanation of how Tarantool maintains function data, see reference on *_func* space.

The possible options are:

- `if_not_exists` = `true|false` (default = `false`) - with `false` to cause error: `Function '...' already exists` if the `_func` tuple already exists.
- `setuid` = `true|false` (default = false) - with `true` to make Tarantool treat the function's caller as the function's creator, with full privileges. Remember that SETUID works only over the *binary protocol*. SETUID doesn't work if you invoke a function via text console or inside a Lua script.
- `language` = „LUA"|"C" (default = 'LUA').

Параметры

- func-name (*string*) – name of function, which should not be a number and should not contain special characters
- options (*table*) – if_not_exists, setuid, language.

Return nil

Example:

```
box.schema.func.create('calculate')
box.schema.func.create('calculate', {if_not_exists = false})
box.schema.func.create('calculate', {setuid = false})
box.schema.func.create('calculate', {language = 'LUA'})
```

box.schema.func.drop(*func-name*)

Drop a function tuple. For explanation of how Tarantool maintains function data, see reference on *_func space*.

Параметры

- func-name (*string*) – the name of the function

Example:

```
box.schema.func.drop('calculate')
```

box.schema.func.exists(*func-name*)

Return true if a function tuple exists; return false if a function tuple does not exist.

Параметры

- func-name (*string*) – the name of the function

Rtype bool

Example:

```
box.schema.func.exists('calculate')
```

Вложенный модуль *box.space*

The box.space submodule has the data-manipulation functions select, insert, replace, update, upsert, delete, get, put. It also has members, such as id, and whether or not a space is enabled. Submodule source code is available in file src/box/lua/schema.lua.

A list of all box.space functions follows, then comes a list of all box.space members.

The functions and members of box.space

Name	Use
space_object:create_index()	Create an index
space_object:insert()	Insert a tuple
space_object:select()	Select one or more tuples
space_object:get()	Select a tuple
space_object:drop()	Destroy a space
space_object:rename()	Rename a space
space_object:replace()	Insert or replace a tuple
space_object:put()	Insert or replace a tuple
space_object:update()	Update a tuple
space_object:upsert()	Update a tuple
space_object:delete()	Delete a tuple
space_object:count()	Get count of tuples
space_object:len()	Get count of tuples
space_object:truncate()	Delete all tuples
space_object:auto_increment()	Generate key + Insert a tuple
space_object:pairs()	Prepare for iterating
space_object:on_replace()	Create a replace trigger
space_object:run_triggers()	Enable/disable a replace trigger
space_object.id	Numeric identifier of space
space_object.enabled	Flag, true if space is enabled
space_object.field_count	Required number of fields
space_object.index	Container of space's indexes
box.space._schema	(Metadata) List of schemas
box.space._space	(Metadata) List of spaces
box.space._index	(Metadata) List of indexes
box.space._user	(Metadata) List of users
box.space._priv	(Metadata) List of privileges
box.space._cluster	(Metadata) List of clusters
box.space._func	(Metadata) List of function tuples

`object space_object`

`space_object:create_index(`*index-name*[, *options*]`)`

Create an index. It is mandatory to create an index for a space before trying to insert tuples into it, or select tuples from it. The first created index, which will be used as the primary-key index, must be unique.

Параметры

- `space_object` (*space_object*) – an *object reference*
- `index_name` (*string*) – name of index, which should not be a number and should not contain special characters
- `options` (*table*) –

Return index object

Rtype index_object

Options for `space_object:create_index`:

Name	Effect	Type	Default
type	type of index	string („HASH" or „TREE" or „BITSET" or „RTREE")	„TREE"
id	unique identifier	number	last index's id, +1
unique	index is unique	boolean	`true`
if_not_exists	no error if duplicate name	boolean	`false`
parts	field-numbers + types	{field_no, „unsigned" or „string" or „integer" or „number" or „array" or „scalar"}	`{1, 'unsigned'}`

Possible errors: too many parts. Index „. . ." already exists. Primary key must be unique.

Примечание:

Note re storage engine:

vinyl supports only the TREE index type, and vinyl secondary indexes must be created before tuples are inserted.

```
tarantool> s = box.space.space55
---
...
tarantool> s:create_index('primary', {unique = true, parts = {1, 'unsigned', 2, 'string'}
↪})
---
...
```

Details about index field types:

The six index field types (unsigned | string | integer | number | array | scalar) differ depending on what values are allowed, and what index types are allowed.

- **unsigned**: unsigned integers between 0 and 18446744073709551615, about 18 quintillion. May also be called „uint" or „num", but „num" is deprecated. Legal in memtx TREE or HASH indexes, and in vinyl TREE indexes.
- **string**: any set of octets, up to the *maximum length*. May also be called „str". Legal in memtx TREE or HASH or BITSET indexes, and in vinyl TREE indexes.
- **integer**: integers between -9223372036854775808 and 18446744073709551615. May also be called „int". Legal in memtx TREE or HASH indexes, and in vinyl TREE indexes.
- **number**: integers between -9223372036854775808 and 18446744073709551615, single-precision floating point numbers, or double-precision floating point numbers. Legal in memtx TREE or HASH indexes, and in vinyl TREE indexes.
- **array**: array of integers between -9223372036854775808 and 9223372036854775807. Legal in memtx RTREE indexes.
- **scalar**: booleans (true or false), or integers between -9223372036854775808 and 18446744073709551615, or single-precision floating point numbers, or double-precison floating-point numbers, or strings. When there is a mix of types, the key order is: booleans, then numbers, then strings. Legal in memtx TREE or HASH indexes, and in vinyl TREE indexes.

Index field types to use in create_index

Тип поля для индексирования	What can be in it	Where is it legal	Примеры:
unsigned	integers between 0 and 18446744073709551615	memtx TREE or HASH indexes, vinyl TREE indexes	123456
string	strings – any set of octets	memtx TREE or HASH indexes vinyl TREE indexes	„A B C“ „\65 \66 \67“
integer	integers between -9223372036854775808 and 18446744073709551615	memtx TREE or HASH indexes, vinyl TREE indexes	-2^63
number	integers between -9223372036854775808 and 18446744073709551615, single-precision floating point numbers, double-precision floating point numbers	memtx TREE or HASH indexes, vinyl TREE indexes	1.234 -44 1.447e+44
array	array of integers between -9223372036854775808 and 9223372036854775807	memtx RTREE indexes	{10, 11} {3, 5, 9, 10}
scalar	booleans (true or false), integers between -9223372036854775808 and 18446744073709551615, single-precision floating point numbers, double-precision floating point numbers, strings	memtx TREE or HASH indexes, vinyl TREE indexes	true -1 1.234 „“ „py“

space_object:insert(*tuple*)

Insert a tuple into a space.

Параметры

- space_object (*space_object*) – an *object reference*
- tuple (*tuple/table*) – tuple to be inserted.

Return the inserted tuple

Rtype tuple

Possible errors: If a tuple with the same unique-key value already exists, returns ER_TUPLE_FOUND.

Example:

```
tarantool> box.space.tester:insert{5000,'tuple number five thousand'}
---
- [5000, 'tuple number five thousand']
...
```

space_object:select([*key*])

Search for a tuple or a set of tuples in the given space.

Параметры

- space_object (*space_object*) – an *object reference*
- key (*scalar/table*) – value to be matched against the index key, which may be multi-part.

Return the tuples whose primary-key fields are equal to the fields of the passed key. If the number of passed fields is less than the number of fields in the primary key, then only the passed fields are compared, so select{1,2} will match a tuple whose primary key is {1,2,3}.

Rtype array of tuples

Possible errors: No such space; wrong type.

Complexity factors: Index size, Index type.

Example:

```
tarantool> s = box.schema.space.create('tmp', {temporary=true})
---
...
tarantool> s:create_index('primary',{parts = {1,'unsigned', 2, 'string'}})
---
...
tarantool> s:insert{1,'A'}
---
- [1, 'A']
...
tarantool> s:insert{1,'B'}
---
- [1, 'B']
...
tarantool> s:insert{1,'C'}
---
- [1, 'C']
...
tarantool> s:insert{2,'D'}
---
- [2, 'D']
...
tarantool> -- must equal both primary-key fields
tarantool> s:select{1,'B'}
---
- - [1, 'B']
...
tarantool> -- must equal only one primary-key field
tarantool> s:select{1}
---
- - [1, 'A']
  - [1, 'B']
  - [1, 'C']
...
tarantool> -- must equal 0 fields, so returns all tuples
tarantool> s:select{}
---
- - [1, 'A']
  - [1, 'B']
  - [1, 'C']
  - [2, 'D']
...
```

For examples of complex `select` requests, where one can specify which index to search and what condition to use (for example «greater than» instead of «equal to») and how many tuples to return, see the later section *index_object:select*.

`space_object:get(key)`

Search for a tuple in the given space.

Параметры

- `space_object` (*space_object*) – an *object reference*
- `key` (*scalar/table*) – value to be matched against the index key, which may be multi-part.

Return the tuple whose index key matches `key`, or `nil`.

Rtype tuple

Possible errors: If space_object does not exist.

Complexity factors: Index size, Index type, Number of indexes accessed, WAL settings.

The `box.space...select` function returns a set of tuples as a Lua table; the `box.space...get` function returns at most a single tuple. And it is possible to get the first tuple in a space by appending `[1]`. Therefore `box.space.tester:get{1}` has the same effect as `box.space.tester:select{1}[1]`, if exactly one tuple is found.

Example:

```
box.space.tester:get{1}
```

`space_object:drop()`

Drop a space.

Параметры

- `space_object` (*space_object*) – an *object reference*

Return nil

Possible errors: If `space_object` does not exist.

Complexity factors: Index size, Index type, Number of indexes accessed, WAL settings.

Example:

```
box.space.space_that_does_not_exist:drop()
```

`space_object:rename(space-name)`

Rename a space.

Параметры

- `space_object` (*space_object*) – an *object reference*
- `space-name` (*string*) – new name for space

Return nil

Possible errors: `space_object` does not exist.

Example:

```
tarantool> box.space.space55:rename('space56')
---
...
tarantool> box.space.space56:rename('space55')
---
...
```

space_object:replace(*tuple*)
space_object:put(*tuple*)

Insert a tuple into a space. If a tuple with the same primary key already exists, `box.space...:replace()` replaces the existing tuple with a new one. The syntax variants `box.space...:replace()` and `box.space...:put()` have the same effect; the latter is sometimes used to show that the effect is the converse of `box.space...:get()`.

Параметры

- `space_object` (*space_object*) – an *object reference*
- `tuple` (*table/tuple*) – tuple to be inserted

Return the inserted tuple.

Rtype tuple

Possible errors: If a different tuple with the same unique-key value already exists, returns `ER_TUPLE_FOUND`. (This will only happen if there is a unique secondary index.)

Complexity factors: Index size, Index type, Number of indexes accessed, WAL settings.

Example:

```
box.space.tester:replace{5000, 'tuple number five thousand'}
```

space_object:update(*key*, *{{operator*, *field_no*, *value}*, *...}*)

Update a tuple.

The `update` function supports operations on fields — assignment, arithmetic (if the field is numeric), cutting and pasting fragments of a field, deleting or inserting a field. Multiple operations can be combined in a single update request, and in this case they are performed atomically and sequentially. Each operation requires specification of a field number. When multiple operations are present, the field number for each operation is assumed to be relative to the most recent state of the tuple, that is, as if all previous operations in a multi-operation update have already been applied. In other words, it is always safe to merge multiple `update` invocations into a single invocation, with no change in semantics.

Possible operators are:

- `+` for addition (values must be numeric)
- `-` for subtraction (values must be numeric)
- `&` for bitwise AND (values must be unsigned numeric)
- `|` for bitwise OR (values must be unsigned numeric)
- `^` for bitwise XOR (exclusive OR) (values must be unsigned numeric)
- `:` for string splice
- `!` for insertion
- `#` for deletion
- `=` for assignment

For ! and = operations the field number can be -1, meaning the last field in the tuple.

Параметры

- space_object (*space_object*) – an *object reference*
- key (*scalar/table*) – primary-key field values, must be passed as a Lua table if key is multi-part
- operator (*string*) – operation type represented in string
- field_no (*number*) – what field the operation will apply to. The field number can be negative, meaning the position from the end of tuple. (#tuple + negative field number + 1)
- value (*lua_value*) – what value will be applied

Return the updated tuple.

Rtype tuple

Possible errors: it is illegal to modify a primary-key field.

Complexity factors: Index size, Index type, number of indexes accessed, WAL settings.

Thus, in the instruction:

```
s:update(44, {{'+', 1, 55 }, {'=', 3, 'x'}})
```

the primary-key value is 44, the operators are '+' and '=' meaning *add a value to a field and then assign a value to a field*, the first affected field is field 1 and the value which will be added to it is 55, the second affected field is field 3 and the value which will be assigned to it is 'x'.

Example:

Assume that initially there is a space named tester with a primary-key index whose type is unsigned. There is one tuple, with field[1] = 999 and field[2] = 'A'.

In the update: box.space.tester:update(999, {{'=', 2, 'B'}}) The first argument is tester, that is, the affected space is tester. The second argument is 999, that is, the affected tuple is identified by primary key value = 999. The third argument is =, that is, there is one operation — *assignment to a field*. The fourth argument is 2, that is, the affected field is field[2]. The fifth argument is 'B', that is, field[2] contents change to 'B'. Therefore, after this update, field[1] = 999 and field[2] = 'B'.

In the update: box.space.tester:update({999}, {{'=', 2, 'B'}}) the arguments are the same, except that the key is passed as a Lua table (inside braces). This is unnecessary when the primary key has only one field, but would be necessary if the primary key had more than one field. Therefore, after this update, field[1] = 999 and field[2] = 'B' (no change).

In the update: box.space.tester:update({999}, {{'=', 3, 1}}) the arguments are the same, except that the fourth argument is 3, that is, the affected field is field[3]. It is okay that, until now, field[3] has not existed. It gets added. Therefore, after this update, field[1] = 999, field[2] = 'B', field[3] = 1.

In the update: box.space.tester:update({999}, {{'+', 3, 1}}) the arguments are the same, except that the third argument is '+', that is, the operation is addition rather than assignment. Since field[3] previously contained 1, this means we're adding 1 to 1. Therefore, after this update, field[1] = 999, field[2] = 'B', field[3] = 2.

In the update: box.space.tester:update({999}, {{'|', 3, 1}, {'=', 2, 'C'}}) the idea is to modify two fields at once. The formats are '|' and =, that is, there are two operations, OR and assignment. The fourth and fifth arguments mean that field[3] gets OR'ed with 1.

The seventh and eighth arguments mean that `field[2]` gets assigned `'C'`. Therefore, after this update, `field[1]` = `999`, `field[2]` = `'C'`, `field[3]` = `3`.

In the update: `box.space.tester:update({999}, {{'#', 2, 1}, {'-', 2, 3}})` The idea is to delete `field[2]`, then subtract `3` from `field[3]`. But after the delete, there is a renumbering, so `field[3]` becomes `field[2]`` before we subtract `3` from it, and that's why the seventh argument is `2`, not `3`. Therefore, after this update, `field[1]` = `999`, `field[2]` = `0`.

In the update: `box.space.tester:update({999}, {{'=', 2, 'XYZ'}})` we're making a long string so that splice will work in the next example. Therefore, after this update, `field[1]` = `999`, `field[2]` = `'XYZ'`.

In the update: `box.space.tester:update({999}, {{':', 2, 2, 1, '!!'}})` The third argument is `':'`, that is, this is the example of splice. The fourth argument is `2` because the change will occur in `field[2]`. The fifth argument is 2 because deletion will begin with the second byte. The sixth argument is 1 because the number of bytes to delete is 1. The seventh argument is `'!!'`, because `'!!'` is to be added at this position. Therefore, after this update, `field[1]` = `999`, `field[2]` = `'X!!Z'`.

`space_object:upsert`(*tuple_value*, *{{operator*, *field_no*, *value}*, *...}*)

Update or insert a tuple.

If there is an existing tuple which matches the key fields of `tuple_value`, then the request has the same effect as *space_object:update()* and the `{{operator, field_no, value}, ...}` parameter is used. If there is no existing tuple which matches the key fields of `tuple_value`, then the request has the same effect as *space_object:insert()* and the `{tuple_value}` parameter is used. However, unlike `insert` or `update`, `upsert` will not read a tuple and perform error checks before returning – this is a design feature which enhances throughput but requires more caution on the part of the user.

Параметры

- `space_object` (*space_object*) – an *object reference*
- `tuple` (*table/tuple*) – default tuple to be inserted, if analogue isn't found
- `operator` (*string*) – operation type represented in string
- `field_no` (*number*) – what field the operation will apply to. The field number can be negative, meaning the position from the end of tuple. (#tuple + negative field number + 1)
- `value` (*lua_value*) – what value will be applied

Return null

Possible errors: it is illegal to modify a primary-key field. It is illegal to use upsert with a space that has a unique secondary index.

Complexity factors: Index size, Index type, number of indexes accessed, WAL settings.

Example:

```
box.space.tester:upsert({12,'c'}, {{'=', 3, 'a'}, {'=', 4, 'b'}})
```

`space_object:delete`(*key*)

Delete a tuple identified by a primary key.

Параметры

- `space_object` (*space_object*) – an *object reference*

- key (*scalar/table*) – primary-key field values, must be passed as a Lua table if key is multi-part

Return the deleted tuple

Rtype tuple

Complexity factors: Index size, Index type

Примечание:

Note re storage engine:
vinyl will return `nil`, rather than the deleted tuple.

Example:

```
tarantool> box.space.tester:delete(1)
---
- [1, 'My first tuple']
...
tarantool> box.space.tester:delete(1)
---
...
tarantool> box.space.tester:delete('a')
---
- error: 'Supplied key type of part 0 does not match index part type:
  expected unsigned'
...
```

`space_object.id`

Ordinal space number. Spaces can be referenced by either name or number. Thus, if space `tester` has `id = 800`, then `box.space.tester:insert{0}` and `box.space[800]:insert{0}` are equivalent requests.

Example:

```
tarantool> box.space.tester.id
---
- 512
...
```

`space_object.enabled`

Whether or not this space is enabled. The value is `false` if the space has no index.

`space_object.field_count`

The required field count for all tuples in this space. The field_count can be set initially with:

```
box.schema.space.create(..., {
    ... ,
    field_count = field_count_value ,
    ...
})
```

The default value is `0`, which means there is no required field count.

Example:

```
tarantool> box.space.tester.field_count
---
```

(continues on next page)

(продолжение с предыдущей страницы)

```
- 0
...
```

space_object.index
A container for all defined indexes. There is a Lua object of type *box.index* with methods to search tuples and iterate over them in predefined order.

Rtype table

Example:

```
tarantool> #box.space.tester.index
---
- 1
...
tarantool> box.space.tester.index.primary.type
---
- TREE
...
```

space_object:count([*key*][, *iterator*])

Параметры

- space_object (*space_object*) – an *object reference*
- key (*scalar/table*) – primary-key field values, must be passed as a Lua table if key is multi-part
- iterator – comparison method

Return Number of tuples.

Example:

```
tarantool> box.space.tester:count(2, {iterator='GE'})
---
- 1
...
```

space_object:len()

Параметры

- space_object (*space_object*) – an *object reference*

Return Number of tuples in the space.

Example:

```
tarantool> box.space.tester:len()
---
- 2
...
```

Примечание:

Note re storage engine:
vinyl does not support `len()`. One possible workaround is to say `#select(...)`.

space_object:truncate()

Deletes all tuples.

Параметры

- space_object (*space_object*) – an *object reference*

Complexity factors: Index size, Index type, Number of tuples accessed.

Return nil

Примечание: Note that truncate must be called only by the user who created the space OR under a *setuid* function created by that user. Read more about *setuid* functions in reference on *box.schema.func.create()*.

Example:

```
tarantool> box.space.tester:truncate()
---
...
tarantool> box.space.tester:len()
---
- 0
...
```

space_object:auto_increment(*tuple*)

Insert a new tuple using an auto-increment primary key. The space specified by space_object must have an unsigned or integer or numeric primary key index of type TREE. The primary-key field will be incremented before the insert.

Параметры

- space_object (*space_object*) – an *object reference*
- tuple (*table/tuple*) – tuple's fields, other than the primary-key field

Return the inserted tuple.

Rtype tuple

Complexity factors: Index size, Index type, Number of indexes accessed, WAL settings.

Possible errors: index has wrong type or primary-key indexed field is not a number.

Example:

```
tarantool> box.space.tester:auto_increment{'Fld#1', 'Fld#2'}
---
- [1, 'Fld#1', 'Fld#2']
...
tarantool> box.space.tester:auto_increment{'Fld#3'}
---
- [2, 'Fld#3']
...
```

space_object:pairs([*key*[, *iterator*]])

Search for a tuple or a set of tuples in the given space, and allow iterating over one tuple at a time.

Параметры

- space_object (*space_object*) – an *object reference*

- key (*scalar/table*) – value to be matched against the index key, which may be multi-part
- iterator – see *index_object:pairs*

Return iterator which can be used in a for/end loop or with totable()

Possible errors: No such space; wrong type.

Complexity factors: Index size, Index type.

For examples of complex pairs requests, where one can specify which index to search and what condition to use (for example «greater than» instead of «equal to»), see the later section *index_object:pairs*.

Example:

```
tarantool> s = box.schema.space.create('space33')
---
...
tarantool> -- index 'X' has default parts {1, 'unsigned'}
tarantool> s:create_index('X', {})
---
...
tarantool> s:insert{0, 'Hello my '}, s:insert{1, 'Lua world'}
---
- [0, 'Hello my ']
- [1, 'Lua world']
...
tarantool> tmp = ''
---
...
tarantool> for k, v in s:pairs() do
         >   tmp = tmp .. v[2]
         > end
---
...
tarantool> tmp
---
- Hello my Lua world
...
```

space_object:on_replace(*trigger-function*[, *old-trigger-function*])

Create a «replace trigger». The trigger-function will be executed whenever a replace() or insert() or update() or upsert() or delete() happens to a tuple in <space-name>.

Параметры

- trigger-function (*function*) – function which will become the trigger function
- old-trigger-function (*function*) – existing trigger function which will be replaced by trigger-function

Return nil or function list

If the parameters are (nil, old-trigger-function-name), then the old trigger is deleted.

Example #1:

```
tarantool> function f ()
         >   x = x + 1
```

(continues on next page)

(продолжение с предыдущей страницы)

```
        > end
tarantool> box.space.X:on_replace(f)
```

The `trigger-function` can have two parameters: old tuple, new tuple. For example, the following code causes nil to be printed when the insert request is processed, and causes [1, „Hi“] to be printed when the delete request is processed:

```
box.schema.space.create('space_1')
box.space.space_1:create_index('space_1_index',{})
function on_replace_function (old, new) print(old) end
box.space.space_1:on_replace(on_replace_function)
box.space.space_1:insert{1,'Hi'}
box.space.space_1:delete{1}
```

Example #2:

The following series of requests will create a space, create an index, create a function which increments a counter, create a trigger, do two inserts, drop the space, and display the counter value - which is 2, because the function is executed once after each insert.

```
tarantool> s = box.schema.space.create('space53')
tarantool> s:create_index('primary', {parts = {1, 'unsigned'}})
tarantool> function replace_trigger()
         >   replace_counter = replace_counter + 1
         > end
tarantool> s:on_replace(replace_trigger)
tarantool> replace_counter = 0
tarantool> t = s:insert{1, 'First replace'}
tarantool> t = s:insert{2, 'Second replace'}
tarantool> s:drop()
tarantool> replace_counter
```

`space_object:run_triggers(`*true|false*`)`

At the time that a trigger is defined, it is automatically enabled - that is, it will be executed. Replace triggers can be disabled with `box.space.`*`space-name`*`:run_triggers(false)` and re-enabled with `box.space.`*`space-name`*`:run_triggers(true)`.

Return nil

Example #1:

The following series of requests will associate an existing function named F with an existing space named T, associate the function a second time with the same space (so it will be called twice), disable all triggers of T, and delete each trigger by replacing with `nil`.

```
tarantool> box.space.T:on_replace(F)
tarantool> box.space.T:on_replace(F)
tarantool> box.space.T:run_triggers(false)
tarantool> box.space.T:on_replace(nil, F)
tarantool> box.space.T:on_replace(nil, F)
```

Example #2:

The following series of requests will create a space, create an index, create a function which increments a counter, create a trigger, do two inserts, drop the space, and display the counter value – which is 2, because the function is executed once after each insert.

```
tarantool> s = box.schema.space.create('space53')
tarantool> s:create_index('primary', {parts = {1, 'unsigned'}})
tarantool> function replace_trigger()
         >  replace_counter = replace_counter + 1
         > end
tarantool> s:on_replace(replace_trigger)
tarantool> replace_counter = 0
tarantool> t = s:insert{1, 'First replace'}
tarantool> t = s:insert{2, 'Second replace'}
tarantool> s:drop()
tarantool> replace_counter
```

`box.space._schema`

`_schema` is a system space.

The single tuple in this space contains the following fields: * `version`, * `major-version-number`, * `minor-version-number`.

Example:

The following function will display all fields in all tuples of `_schema`:

```
function example()
  local ta = {}
  local i, line
  for k, v in box.space._schema:pairs() do
    i = 1
    line = ''
    while i <= #v do
      line = line .. v[i] .. ' '
      i = i + 1
    end
    table.insert(ta, line)
  end
  return ta
end
```

Here is what `example()` returns in a typical installation:

```
tarantool> example()
---
- - 'cluster 1ec4e1f8-8f1b-4304-bb22-6c47ce0cf9c6 '
  - 'max_id 520 '
  - 'version 1 7 0 '
...
```

`box.space._space`

`_space` is a system space.

Tuples in this space contain the following fields:

- `id`,
- `owner` (= id of user who owns the space),
- `name`, `engine`, `field_count`,
- `flags` (e.g. temporary), `format`.

These fields are established by *space.create()*.

Example #1:

The following function will display all simple fields in all tuples of _space.

```
function example()
  local ta = {}
  local i, line
  for k, v in box.space._space:pairs() do
    i = 1
    line = ''
    while i <= #v do
      if type(v[i]) ~= 'table' then
        line = line .. v[i] .. ' '
      end
      i = i + 1
    end
    table.insert(ta, line)
  end
  return ta
end
```

Here is what example() returns in a typical installation:

```
tarantool> example()
---
- - '272 1 _schema memtx 0  '
  - '280 1 _space memtx 0  '
  - '281 1 _vspace sysview 0  '
  - '288 1 _index memtx 0  '
  - '296 1 _func memtx 0  '
  - '304 1 _user memtx 0  '
  - '305 1 _vuser sysview 0  '
  - '312 1 _priv memtx 0  '
  - '313 1 _vpriv sysview 0  '
  - '320 1 _cluster memtx 0  '
  - '512 1 tester memtx 0  '
  - '513 1 origin vinyl 0  '
  - '514 1 archive memtx 0  '
...
```

Example #2:

The following requests will create a space using box.schema.space.create() with a format clause. Then it retrieves the _space tuple for the new space. This illustrates the typical use of the format clause, it shows the recommended names and data types for the fields.

```
tarantool> box.schema.space.create('TM', {
         >   id = 12345,
         >   format = {
         >     [1] = {["name"] = "field_1"},
         >     [2] = {["type"] = "unsigned"}
         >   }
         > })
---
- index: []
  on_replace: 'function: 0x41c67338'
  temporary: false
  id: 12345
```

(continues on next page)

(продолжение с предыдущей страницы)

```
  engine: memtx
  enabled: false
  name: TM
  field_count: 0
- created
...
tarantool> box.space._space:select(12345)
---
- - [12345, 1, 'TM', 'memtx', 0, {}, [{'name': 'field_1'}, {'type': 'unsigned'}]]
...
```

box.space._index

_index is a system space.

Tuples in this space contain the following fields: * id (= id of space), * iid (= index number within space), * name, * type, * opts (e.g. unique option), [tuple-field-no, tuple-field-type …].

The following function will display all fields in all tuples of _index: (notice that the fifth field gets special treatment as a map value and the sixth or later fields get special treatment as arrays):

```
function example()
  local ta = {}
  local i, line, value
  for k, v in box.space._index:pairs() do
    i = 1
    line = ''
     while v[i] ~= nil do
      if i < 5 then
        value = v[i]
        end
      if i == 5 then
        if v[i].unique == true then
          value = 'true'
          end
        end
      if i > 5 then
        value = v[i][1][1] .. ' ' .. v[i][1][2]
        end
      line = line .. value .. ' '
      i = i + 1
    end
    table.insert(ta, line)
    end
  return ta
end
```

Here is what example() returns in a typical installation:

```
tarantool> example()
---
- - '272 0 primary tree true 0 str '
  - '280 0 primary tree true 0 num '
  - '280 1 owner tree tree 1 num '
  - '280 2 name tree true 2 str '
  - '281 0 primary tree true 0 num '
  - '281 1 owner tree tree 1 num '
  - '281 2 name tree true 2 str '
```

(continues on next page)

(продолжение с предыдущей страницы)

```
  - '288 0 primary tree true 0 num '
  - '288 2 name tree true 0 num '
  - '289 0 primary tree true 0 num '
  - '289 2 name tree true 0 num '
  - '296 0 primary tree true 0 num '
  - '296 1 owner tree tree 1 num '
  - '296 2 name tree true 2 str '
  - '297 0 primary tree true 0 num '
  - '297 1 owner tree tree 1 num '
  - '297 2 name tree true 2 str '
  - '304 0 primary tree true 0 num '
  - '304 1 owner tree tree 1 num '
  - '304 2 name tree true 2 str '
  - '305 0 primary tree true 0 num '
  - '305 1 owner tree tree 1 num '
  - '305 2 name tree true 2 str '
  - '312 0 primary tree true 1 num '
  - '312 1 owner tree tree 0 num '
  - '312 2 object tree tree 2 str '
  - '313 0 primary tree true 1 num '
  - '313 1 owner tree tree 0 num '
  - '313 2 object tree tree 2 str '
  - '320 0 primary tree true 0 num '
  - '320 1 uuid tree true 1 str '
  - '512 0 primary tree true 0 num '
  - '513 0 primary tree true 0 num '
  - '516 0 primary tree true 0 STR '
...
```

`box.space._user`

`_user` is a system space where usernames and password hashes are stored.

Tuples in this space contain the following fields:

- the numeric id of the tuple («id»),
- the numeric id of the tuple's creator,
- the name,
- the type: „user" or „role",
- optional password.

There are four special tuples in the `_user` space: „guest", „admin", „public" and „replication".

Name	ID	Type	Description
guest	0	user	Default user when connecting remotely. Usually an untrusted user with few privileges.
admin	1	user	Default user when using Tarantool as a console. Usually an administrative user with all privileges.
public	2	role	Pre-defined *role*, automatically assigned to new users when they are created with `box.schema.user.create(user-name)`. Therefore, a convenient way to grant „read" on space „t" to every user that will ever exist is with `box.schema.role.grant('public','read','space','t')`.
replication	3	role	Pre-defined *role*, assigned by the „admin" user to users who need to use *replication* features.

To select a row from the _user space, use box.space._user:select(). For example, here is what happens with a select for user id = 0, which is the „guest" user, which by default has no password:

```
tarantool> box.space._user:select{0}
---
- - [0, 1, 'guest', 'user']
...
```

Предупреждение: To change tuples in the _user space, do not use ordinary box.space functions for insert or update or delete. The _user space is special, so there are special functions which have appropriate error checking.

To create a new user, use *box.schema.user.create()*:

```
box.schema.user.create(user-name)
box.schema.user.create(user-name, {if_not_exists = true})
box.schema.user.create(user-name, {password = password})
```

To change the user's password, use *box.schema.user.password()*:

```
-- To change the current user's password
box.schema.user.passwd(password)

-- To change a different user's password
-- (usually only 'admin' can do it)
box.schema.user.passwd(user-name, password)
```

To drop a user, use *box.schema.user.drop()*:

```
box.schema.user.drop(user-name)
```

To check whether a user exists, use *box.schema.user.exists()*, which returns true or false:

```
box.schema.user.exists(user-name)
```

To find what privileges a user has, use *box.schema.user.info()*:

```
box.schema.user.info(user-name)
```

Примечание: The maximum number of users is 32.

Example:

Here is a session which creates a new user with a strong password, selects a tuple in the _user space, and then drops the user.

```
tarantool> box.schema.user.create('JeanMartin', {password = 'Iwtso_6_os$$'})
---
...
tarantool> box.space._user.index.name:select{'JeanMartin'}
---
- - [17, 1, 'JeanMartin', 'user', {'chap-sha1': 't3xjUpQdrt857O+YRvGbMY5py8Q='}]
...
tarantool> box.schema.user.drop('JeanMartin')
---
...
```

box.space._priv

_priv is a system space where *privileges* are stored.

Tuples in this space contain the following fields:

- the numeric id of the user who gave the privilege («grantor_id»),

- the numeric id of the user who received the privilege («grantee_id»),
- the type of object: „space“, „function“ or „universe“,
- the numeric id of the object,
- the type of operation: «read» = 1, «write» = 2, «execute» = 4, or a combination such as «read,write,execute».

You can:

- Grant a privilege with *box.schema.user.grant()*.
- Revoke a privilege with *box.schema.user.revoke()*.

Примечание:

- Generally, privileges are granted or revoked by the owner of the object (the user who created it), or by the „admin“ user.
- Before dropping any objects or users, make sure that all their associated privileges have been revoked.
- Only the „admin“ user can grant privileges for the „universe“.
- Except the „admin“ user, only the creator of a space can drop, alter, or truncate the space.
- Except the „admin“ user, only the creator of a user can change a different user's password.

`box.space._cluster`

`_cluster` is a system space for support of the *replication feature*.

`box.space._func`

`_func` is a system space with function tuples made by *box.schema.func.create()*.

Tuples in this space contain the following fields:

- the numeric function id, a number,
- the function name,
- flag,
- a language name (optional): „LUA“ (default) or „C“.

The `_func` space does not include the function's body. You continue to create Lua functions in the usual way, by saying `function function_name () ... end`, without adding anything in the `_func` space. The `_func` space only exists for storing function tuples so that their names can be used within grant/revoke functions.

You can:

- Create a `_func` tuple with *box.schema.func.create()*,
- Drop a `_func` tuple with *box.schema.func.drop()*,
- Check whether a `_func` tuple exists with *box.schema.func.exists()*.

Example:

In the following example, we create a function named 'f7', put it into Tarantool's `_func` space and grant „execute“ privilege for this function to „guest“ user.

```
tarantool> function f7()
         >  box.session.uid()
         > end
---
...
tarantool> box.schema.func.create('f7')
---
...
tarantool> box.schema.user.grant('guest', 'execute', 'function', 'f7')
---
...
tarantool> box.schema.user.revoke('guest', 'execute', 'function', 'f7')
---
...
```

Example: use box.space functions to read _space tuples

This function will illustrate how to look at all the spaces, and for each display: approximately how many tuples it contains, and the first field of its first tuple. The function uses Tarantool `box.space` functions `len()` and `pairs()`. The iteration through the spaces is coded as a scan of the `_space` system space, which contains metadata. The third field in `_space` contains the space name, so the key instruction `space_name = v[3]` means `space_name` is the `space_name` field in the tuple of `_space` that we've just fetched with `pairs()`. The function returns a table:

```
function example()
  local tuple_count, space_name, line
  local ta = {}
  for k, v in box.space._space:pairs() do
    space_name = v[3]
    if box.space[space_name].index[0] ~= nil then
      tuple_count = '1 or more'
    else
      tuple_count = '0'
    end
    line = space_name .. ' tuple_count =' .. tuple_count
    if tuple_count == '1 or more' then
      for k1, v1 in box.space[space_name]:pairs() do
        line = line .. '. first field in first tuple = ' .. v1[1]
        break
      end
    end
    table.insert(ta, line)
  end
  return ta
end
```

And here is what happens when one invokes the function:

```
tarantool> example()
---
- - _schema tuple_count =1 or more. first field in first tuple = cluster
  - _space tuple_count =1 or more. first field in first tuple = 272
  - _vspace tuple_count =1 or more. first field in first tuple = 272
  - _index tuple_count =1 or more. first field in first tuple = 272
  - _vindex tuple_count =1 or more. first field in first tuple = 272
```

(continues on next page)

(продолжение с предыдущей страницы)

```
  - _func tuple_count =1 or more. first field in first tuple = 1
  - _vfunc tuple_count =1 or more. first field in first tuple = 1
  - _user tuple_count =1 or more. first field in first tuple = 0
  - _vuser tuple_count =1 or more. first field in first tuple = 0
  - _priv tuple_count =1 or more. first field in first tuple = 1
  - _vpriv tuple_count =1 or more. first field in first tuple = 1
  - _cluster tuple_count =1 or more. first field in first tuple = 1
...
```

Example: use box.space functions to organize a _space tuple

The objective is to display field names and field types of a system space – using metadata to find metadata.

To begin: how can one select the _space tuple that describes _space?

A simple way is to look at the constants in box.schema, which tell us that there is an item named SPACE_ID == 288, so these statements will retrieve the correct tuple:

`box.space._space:select{ 288 }`
or
`box.space._space:select{ box.schema.SPACE_ID }`

Another way is to look at the tuples in box.space._index, which tell us that there is a secondary index named „name" for space number 288, so this statement also will retrieve the correct tuple:

`box.space._space.index.name:select{ '_space' }`

However, the retrieved tuple is not easy to read:

```
tarantool> box.space._space.index.name:select{'_space'}
---
- - [280, 1, '_space', 'memtx', 0, {}, [{'name': 'id', 'type': 'num'}, {'name': 'owner',
        'type': 'num'}, {'name': 'name', 'type': 'str'}, {'name': 'engine', 'type': 'str'},
      {'name': 'field_count', 'type': 'num'}, {'name': 'flags', 'type': 'str'}, {
        'name': 'format', 'type': '*'}]]
...
```

It looks disorganized because field number 7 has been formatted with recommended names and data types. How can one get those specific sub-fields? Since it's visible that field number 7 is an array of maps, this *for* loop will do the organizing:

```
tarantool> do
         >   local tuple_of_space = box.space._space.index.name:get{'_space'}
         >   for _, field in ipairs(tuple_of_space[7]) do
         >     print(field.name .. ', ' .. field.type)
         >   end
         > end
id, num
owner, num
name, str
engine, str
field_count, num
flags, str
```

(continues on next page)

(продолжение с предыдущей страницы)

```
format, *
---
...
```

Вложенный модуль *box.index*

The `box.index` submodule provides read-only access for index definitions and index keys. Indexes are contained in `box.space.`*`space-name`*`.index` array within each space object. They provide an API for ordered iteration over tuples. This API is a direct binding to corresponding methods of index objects of type `box.index` in the storage engine.

`object index_object`

`index_object.unique`
True if the index is unique, false if the index is not unique.

Rtype boolean

`index_object.type`
Index type, „TREE" or „HASH" or „BITSET" or „RTREE".

`index_object.parts`
An array describing index key fields.

Rtype table

Example:

```
tarantool> box.space.tester.index.primary
---
- unique: true
  parts:
  - type: unsigned
    fieldno: 1
  id: 0
  space_id: 513
  name: primary
  type: TREE
...
```

`index_object:pairs(`[*key*[, *iterator-type*]]`)`
Search for a tuple or a set of tuples via the given index, and allow iterating over one tuple at a time.

The *`key`* parameter specifies what must match within the index. The *`iterator`* parameter specifies the rule for matching and ordering. Different index types support different iterators. For example, a TREE index maintains a strict order of keys and can return all tuples in ascending or descending order, starting from the specified key. Other index types, however, do not support ordering.

To understand consistency of tuples returned by an iterator, it's essential to know the principles of the Tarantool transaction processing subsystem. An iterator in Tarantool does not own a consistent read view. Instead, each procedure is granted exclusive access to all tuples and spaces until there is a «context switch»: which may happen due to *the implicit yield rules*, or by an explicit call to *fiber.yield*. When the execution flow returns to the yielded procedure, the data set could have changed significantly. Iteration, resumed after a yield point, does not preserve the read view, but continues with the new content of the database. The tutorial *Indexed pattern search* shows one way that iterators and yields can be used together.

Параметры

- `index_object` (*index_object*) – an *object reference*.
- `key` (*scalar/table*) – value to be matched against the index key, which may be multi-part
- `iterator` – as defined in tables below. The default iterator type is „EQ“

Return iterator which can be used in a for/end loop or with totable()

Possible errors: No such space; wrong type; Selected iteration type is not supported for the index type; or key is not supported for the iteration type.

Complexity factors: Index size, Index type; Number of tuples accessed.

A search-key-value can be a number (for example `1234`), a string (for example `'abcd'`), or a table of numbers and strings (for example `{1234, 'abcd'}`). Each part of a key will be compared to each part of an index key.

Iterator types for TREE indexes

Примечание: Formally the logic for TREE index searches is: comparison-operator is = or >= or > or <= or < depending on iterator-type

```
for i = 1 to number-of-parts-of-search-value
    if (search-value-part[i] is nil and <comparison-operator> is "=") or
        (search-value-part[i] <comparison-operator> index-key-part[i] is true)␣
↪then
            comparison-result[i] is true
    endif
```

if all comparison-results are true, then search-value «matches» index key.

Notice how, according to this logic, regardless what the index-key-part contains, the comparison-result for equality is always true when a search-value-part is `nil` or is missing. This behavior of searches with nil is subject to change.

Type	Arguments	Description
box.index.EQ or „EQ“	search value	The comparison operator is „==“ (equal to). If an index key is equal to a search value, it matches. Tuples are returned in ascending order by index key. This is the default.
box.index.REQ or „REQ“	search value	Matching is the same as for `box.index.EQ`. Tuples are returned in descending order by index key.
box.index.GT or „GT“	search value	The comparison operator is „>“ (greater than). If an index key is greater than a search value, it matches. Tuples are returned in ascending order by index key.
box.index.GE or „GE“	search value	The comparison operator is „>=“ (greater than or equal to). If an index key is greater than or equal to a search value, it matches. Tuples are returned in ascending order by index key.
box.index.ALL or „ALL“	search value	Same as box.index.GE.
box.index.LT or „LT“	search value	The comparison operator is „<“ (less than). If an index key is less than a search value, it matches. Tuples are returned in descending order by index key.
box.index.LE or „LE“	search value	The comparison operator is „<=“ (less than or equal to). If an index key is less than or equal to a search value, it matches. Tuples are returned in descending order by index key.

Iterator types for HASH indexes

Type	Arguments	Description
box.index.ALL	none	All index keys match. Tuples are returned in ascending order by hash of index key, which will appear to be random.
box.index.EQ or „EQ“	search value	The comparison operator is „==“ (equal to). If an index key is equal to a search value, it matches. The number of returned tuples will be 0 or 1. This is the default.
box.index.GT or „GT“	search value	The comparison operator is „>“ (greater than). If a hash of an index key is greater than a hash of a search value, it matches. Tuples are returned in ascending order by hash of index key, which will appear to be random. Provided that the space is not being updated, one can retrieve all the tuples in a space, N tuples at a time, by using {iterator=“GT“, limit=N} in each search, and using the last returned value from the previous result as the start search value for the next search.

Iterator types for BITSET indexes

Type	Arguments	Description
box.index.ALL or „ALL“	none	All index keys match. Tuples are returned in their order within the space.
box.index.EQ or „EQ“	bitset value	If an index key is equal to a bitset value, it matches. Tuples are returned in their order within the space. This is the default.
box.index.BITS_ALL_SET	bitset value	If all of the bits which are 1 in the bitset value are 1 in the index key, it matches. Tuples are returned in their order within the space.
box.index.BITS_ANY_SET	bitset value	If any of the bits which are 1 in the bitset value are 1 in the index key, it matches. Tuples are returned in their order within the space.
box.index.BITS_ALL_NOT_SET	bitset value	If all of the bits which are 1 in the bitset value are 0 in the index key, it matches. Tuples are returned in their order within the space.

Iterator types for RTREE indexes

Type	Arguments	Description
box.index.ALL or „ALL“	none	All keys match. Tuples are returned in their order within the space.
box.index.EQ or „EQ“	search value	If all points of the rectangle-or-box defined by the search value are the same as the rectangle-or-box defined by the index key, it matches. Tuples are returned in their order within the space. «Rectangle-or-box» means «rectangle-or-box as explained in section about *RTREE*». This is the default.
box.index.GT or „GT“	search value	If all points of the rectangle-or-box defined by the search value are within the rectangle-or-box defined by the index key, it matches. Tuples are returned in their order within the space.
box.index.GE or „GE“	search value	If all points of the rectangle-or-box defined by the search value are within, or at the side of, the rectangle-or-box defined by the index key, it matches. Tuples are returned in their order within the space.
box.index.LT or „LT“	search value	If all points of the rectangle-or-box defined by the index key are within the rectangle-or-box defined by the search key, it matches. Tuples are returned in their order within the space.
box.index.LE or „LE“	search value	If all points of the rectangle-or-box defined by the index key are within, or at the side of, the rectangle-or-box defined by the search key, it matches. Tuples are returned in their order within the space.
box.index.OVERLAPS or „OVERLAPS“	search values	If some points of the rectangle-or-box defined by the search value are within the rectangle-or-box defined by the index key, it matches. Tuples are returned in their order within the space.
box.index.NEIGHBOR or „NEIGHBOR“	search value	If some points of the rectangle-or-box defined by the defined by the key are within, or at the side of, defined by the index key, it matches. Tuples are returned in order: nearest neighbor first.

First Example of index pairs():

Default „TREE“ Index and `pairs()` function:

```
tarantool> s = box.schema.space.create('space17')
---
...
tarantool> s:create_index('primary', {
         >   parts = {1, 'string', 2, 'string'}
         > })
---
...
tarantool> s:insert{'C', 'C'}
---
- ['C', 'C']
...
tarantool> s:insert{'B', 'A'}
---
- ['B', 'A']
...
tarantool> s:insert{'C', '!'}
---
- ['C', '!']
...
tarantool> s:insert{'A', 'C'}
---
- ['A', 'C']
...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> function example()
         >   for _, tuple in
         >     s.index.primary:pairs(nil, {
         >         iterator = box.index.ALL}) do
         >       print(tuple)
         >   end
         > end
---
...
tarantool> example()
['A', 'C']
['B', 'A']
['C', '!']
['C', 'C']
---
...
tarantool> s:drop()
---
...
```

Second Example of index pairs():

This Lua code finds all the tuples whose primary key values begin with „XY". The assumptions include that there is a one-part primary-key TREE index on the first field, which must be a string. The iterator loop ensures that the search will return tuples where the first value is greater than or equal to „XY". The conditional statement within the loop ensures that the looping will stop when the first two letters are not „XY".

```
for tuple in
box.space.t.index.primary:pairs("XY",{iterator = "GE"}) do
  if (string.sub(tuple[1], 1, 2) ~= "XY") then break end
  print(tuple)
end
```

Third Example of index pairs():

This Lua code finds all the tuples whose primary key values are greater than or equal to 1000, and less than or equal to 1999 (this type of request is sometimes called a «range search» or a «between search»). The assumptions include that there is a one-part primary-key TREE index on the first field, which must be a number. The iterator loop ensures that the search will return tuples where the first value is greater than or equal to 1000. The conditional statement within the loop ensures that the looping will stop when the first value is greater than 1999.

```
for tuple in
box.space.t2.index.primary:pairs(1000,{iterator = "GE"}) do
  if (tuple[1] > 1999) then break end
  print(tuple)
end
```

`index_object:select(`*search-key*, *options*`)`

This is an alternative to *box.space...select()* which goes via a particular index and can make use of additional parameters that specify the iterator type, and the limit (that is, the maximum number of tuples to return) and the offset (that is, which tuple to start with in the list).

Параметры

- `index_object` (*index_object*) – an *object reference*.

- key (*scalar/table*) – values to be matched against the index key
- options (*table/nil*) – none, any or all of next parameters
- options.iterator – type of iterator
- options.limit (*number*) – maximum number of tuples
- options.offset (*number*) – start tuple number

Return the tuple or tuples that match the field values.

Rtype array of tuples

Example:

```
-- Create a space named tester.
tarantool> sp = box.schema.space.create('tester')
-- Create a unique index 'primary'
-- which won't be needed for this example.
tarantool> sp:create_index('primary', {parts = {1, 'unsigned' }})
-- Create a non-unique index 'secondary'
-- with an index on the second field.
tarantool> sp:create_index('secondary', {
         >   type = 'tree',
         >   unique = false,
         >   parts = {2, 'string'}
         > })
-- Insert three tuples, values in field[2]
-- equal to 'X', 'Y', and 'Z'.
tarantool> sp:insert{1, 'X', 'Row with field[2]=X'}
tarantool> sp:insert{2, 'Y', 'Row with field[2]=Y'}
tarantool> sp:insert{3, 'Z', 'Row with field[2]=Z'}
-- Select all tuples where the secondary index
-- keys are greater than 'X'.`
tarantool> sp.index.secondary:select({'X'}, {
         >   iterator = 'GT',
         >   limit = 1000
         > })
```

The result will be a table of tuple and will look like this:

```
---
- - [2, 'Y', 'Row with field[2]=Y']
  - [3, 'Z', 'Row with field[2]=Z']
...
```

Примечание: index.*index-name* is optional. If it is omitted, then the assumed index is the first (primary-key) index. Therefore, for the example above, box.space.tester:select({1}, {iterator = 'GT'}) would have returned the same two rows, via the „primary" index.

Примечание: iterator = *iterator-type* is optional. If it is omitted, then iterator = 'EQ' is assumed.

Примечание: *field-value* [, *field-value* ...] is optional. If it is omitted, then every key in the index is considered to be a match, regardless of iterator type. Therefore, for the example above, `box.space.tester:select{}` will select every tuple in the tester space via the first (primary-key) index.

Примечание: `box.space.`*space-name*`.index.`*index-name*`:select(...)[1]``. can be replaced by `box.space.`*space-name*`.index.`*index-name*`:get(...)`. That is, `get` can be used as a convenient shorthand to get the first tuple in the tuple set that would be returned by `select`. However, if there is more than one tuple in the tuple set, then `get` returns an error.

Example with BITSET index:

The following script shows creation and search with a BITSET index. Notice: BITSET cannot be unique, so first a primary-key index is created. Notice: bit values are entered as hexadecimal literals for easier reading.

```
tarantool> s = box.schema.space.create('space_with_bitset')
tarantool> s:create_index('primary_index', {
         >   parts = {1, 'string'},
         >   unique = true,
         >   type = 'TREE'
         > })
tarantool> s:create_index('bitset_index', {
         >   parts = {2, 'unsigned'},
         >   unique = false,
         >   type = 'BITSET'
         > })
tarantool> s:insert{'Tuple with bit value = 01', 0x01}
tarantool> s:insert{'Tuple with bit value = 10', 0x02}
tarantool> s:insert{'Tuple with bit value = 11', 0x03}
tarantool> s.index.bitset_index:select(0x02, {
         >   iterator = box.index.EQ
         > })
---
- - ['Tuple with bit value = 10', 2]
...
tarantool> s.index.bitset_index:select(0x02, {
         >   iterator = box.index.BITS_ANY_SET
         > })
---
- - ['Tuple with bit value = 10', 2]
  - ['Tuple with bit value = 11', 3]
...
tarantool> s.index.bitset_index:select(0x02, {
         >   iterator = box.index.BITS_ALL_SET
         > })
---
- - ['Tuple with bit value = 10', 2]
  - ['Tuple with bit value = 11', 3]
...
tarantool> s.index.bitset_index:select(0x02, {
         >   iterator = box.index.BITS_ALL_NOT_SET
         > })
---
- - ['Tuple with bit value = 01', 1]
...
```

`index_object:get(`*key*`)`

Search for a tuple via the given index, as described *earlier*.

Параметры

- index_object (*index_object*) – an *object reference*.
- key (*scalar/table*) – values to be matched against the index key

Return the tuple whose index-key fields are equal to the passed key values.

Rtype tuple

Possible errors: No such index; wrong type; more than one tuple matches.

Complexity factors: Index size, Index type. See also *space_object:get()*.

Example:

```
tarantool> box.space.tester.index.primary:get(2)
---
- [2, 'Music']
...
```

index_object:min([*key*])

Find the minimum value in the specified index.

Параметры

- index_object (*index_object*) – an *object reference*.
- key (*scalar/table*) – values to be matched against the index key

Return the tuple for the first key in the index. If optional `key-value` is supplied, returns the first key which is greater than or equal to `key-value`.

Rtype tuple

Possible errors: index is not of type „TREE“.

Complexity factors: Index size, Index type.

Example:

```
tarantool> box.space.tester.index.primary:min()
---
- ['Alpha!', 55, 'This is the first tuple!']
...
```

index_object:max([*key*])

Find the maximum value in the specified index.

Параметры

- index_object (*index_object*) – an *object reference*.
- key (*scalar/table*) – values to be matched against the index key

Return the tuple for the last key in the index. If optional `key-value` is supplied, returns the last key which is less than or equal to `key-value`.

Rtype tuple

Possible errors: index is not of type „TREE“.

Complexity factors: Index size, Index type.

Example:

```
tarantool> box.space.tester.index.primary:max()
---
- ['Gamma!', 55, 'This is the third tuple!']
...
```

index_object:random(*seed*)

Find a random value in the specified index. This method is useful when it's important to get insight into data distribution in an index without having to iterate over the entire data set.

Параметры

- index_object (*index_object*) – an *object reference*.
- seed (*number*) – an arbitrary non-negative integer

Return the tuple for the random key in the index.

Rtype tuple

Complexity factors: Index size, Index type.

Примечание:

Note re storage engine:
vinyl does not support `random()`.

Example:

```
tarantool> box.space.tester.index.secondary:random(1)
---
- ['Beta!', 66, 'This is the second tuple!']
...
```

index_object:count([*key*][, *iterator*])

Iterate over an index, counting the number of tuples which match the key-value.

Параметры

- index_object (*index_object*) – an *object reference*.
- key (*scalar/table*) – values to be matched against the index key
- iterator – comparison method

Return the number of matching index keys.

Rtype number

Example:

```
tarantool> box.space.tester.index.primary:count(999)
---
- 0
...
tarantool> box.space.tester.index.primary:count('Alpha!', { iterator = 'LE' })
---
- 1
...
```

index_object:update(*key, {{operator, field_no, value}, ...}*)

Update a tuple.

Same as *box.space...update()*, but key is searched in this index instead of primary key. This index ought to be unique.

Параметры

- `index_object` (*index_object*) – an *object reference*.
- `key` (*scalar/table*) – values to be matched against the index key
- `operator` (*string*) – operation type represented in string
- `field_no` (*number*) – what field the operation will apply to. The field number can be negative, meaning the position from the end of tuple. (#tuple + negative field number + 1)
- `value` (*lua_value*) – what value will be applied

Return the updated tuple.

Rtype tuple

`index_object:delete(`*key*`)`

Delete a tuple identified by a key.

Same as *box.space...delete()*, but key is searched in this index instead of in the primary-key index. This index ought to be unique.

Параметры

- `index_object` (*index_object*) – an *object reference*.
- `key` (*scalar/table*) – values to be matched against the index key

Return the deleted tuple.

Rtype tuple

Примечание:

Note re storage engine:
vinyl will return *nil*, rather than the deleted tuple.

`index_object:alter(`*{options}*`)`

Alter an index.

Параметры

- `index_object` (*index_object*) – an *object reference*.
- `options` (*table*) – options list, same as the options list for *create_index*

Return nil

Possible errors: Index does not exist, or the first index cannot be changed to {unique = false}, or the alter function is only applicable for the memtx storage engine.

Примечание:

Note re storage engine:
vinyl does not support `alter()`.

Example:

```
tarantool> box.space.space55.index.primary:alter({type = 'HASH'})
---
...
```

index_object:drop()

Drop an index. Dropping a primary-key index has a side effect: all tuples are deleted.

Параметры

- index_object (*index_object*) – an *object reference*.

Return nil.

Possible errors: Index does not exist, or a primary-key index cannot be dropped while a secondary-key index exists.

Example:

```
tarantool> box.space.space55.index.primary:drop()
---
...
```

index_object:rename(*index-name*)

Rename an index.

Параметры

- index_object (*index_object*) – an *object reference*.
- index-name (*string*) – new name for index

Return nil

Possible errors: index_object does not exist.

Example:

```
tarantool> box.space.space55.index.primary:rename('secondary')
---
...
```

Complexity factors: Index size, Index type, Number of tuples accessed.

index_object:bsize()

Return the total number of bytes taken by the index.

Параметры

- index_object (*index_object*) – an *object reference*.

Return number of bytes

Rtype number

Example showing use of the box functions

This example will work with the sandbox configuration described in the preface. That is, there is a space named tester with a numeric primary key. The example function will:

- select a tuple whose key value is 1000;
- return an error if the tuple already exists and already has 3 fields;

- **Insert or replace the tuple with:**
  - field[1] = 1000
  - field[2] = a uuid
  - field[3] = number of seconds since 1970-01-01;
- Get field[3] from what was replaced;
- Format the value from field[3] as yyyy-mm-dd hh:mm:ss.ffff;
- Return the formatted value.

The function uses Tarantool box functions *box.space...select*, *box.space...replace*, *fiber.time*, *uuid.str*. The function uses Lua functions os.date() and string.sub().

```
function example()
  local a, b, c, table_of_selected_tuples, d
  local replaced_tuple, time_field
  local formatted_time_field
  local fiber = require('fiber')
  table_of_selected_tuples = box.space.tester:select{1000}
  if table_of_selected_tuples ~= nil then
    if table_of_selected_tuples[1] ~= nil then
      if #table_of_selected_tuples[1] == 3 then
        box.error({code=1, reason='This tuple already has 3 fields'})
      end
    end
  end
  replaced_tuple = box.space.tester:replace
    {1000,  require('uuid').str(), tostring(fiber.time())}
  time_field = tonumber(replaced_tuple[3])
  formatted_time_field = os.date("%Y-%m-%d %H:%M:%S", time_field)
  c = time_field % 1
  d = string.sub(c, 3, 6)
  formatted_time_field = formatted_time_field .. '.' .. d
  return formatted_time_field
end
```

... And here is what happens when one invokes the function:

```
tarantool> box.space.tester:delete(1000)
---
- [1000, '264ee2da03634f24972be76c43808254', '1391037015.6809']
...
tarantool> example(1000)
---
- 2014-01-29 16:11:51.1582
...
tarantool> example(1000)
---
- error: 'This tuple already has 3 fields'
...
```

Example showing a user-defined iterator

Here is an example that shows how to build one's own iterator. The `paged_iter` function is an «iterator function», which will only be understood by programmers who have read the Lua manual section Iterators and Closures. It does paginated retrievals, that is, it returns 10 tuples at a time from a table named «t», whose primary key was defined with `create_index('primary',{parts={1,'string'}})`.

```
function paged_iter(search_key, tuples_per_page)
  local iterator_string = "GE"
  return function ()
  local page = box.space.t.index[0]:select(search_key,
    {iterator = iterator_string, limit=tuples_per_page})
  if #page == 0 then return nil end
  search_key = page[#page][1]
  iterator_string = "GT"
  return page
  end
end
```

Programmers who use `paged_iter` do not need to know why it works, they only need to know that, if they call it within a loop, they will get 10 tuples at a time until there are no more tuples. In this example the tuples are merely printed, a page at a time. But it should be simple to change the functionality, for example by yielding after each retrieval, or by breaking when the tuples fail to match some additional criteria.

```
for page in paged_iter("X", 10) do
  print("New Page. Number Of Tuples = " .. #page)
  for i = 1, #page, 1 do
    print(page[i])
  end
end
```

Submodule *box.index* with index type = RTREE for spatial searches

The *box.index* submodule may be used for spatial searches if the index type is RTREE. There are operations for searching *rectangles* (geometric objects with 4 corners and 4 sides) and *boxes* (geometric objects with more than 4 corners and more than 4 sides, sometimes called hyperrectangles). This manual uses the term *rectangle-or-box* for the whole class of objects that includes both rectangles and boxes. Only rectangles will be illustrated.

Rectangles are described according to their X-axis (horizontal axis) and Y-axis (vertical axis) coordinates in a grid of arbitrary size. Here is a picture of four rectangles on a grid with 11 horizontal points and 11 vertical points:

```
           X AXIS
           1   2   3   4   5   6   7   8   9   10  11
        1
        2  #-------+                                      <-Rectangle#1
Y AXIS  3  |       |
        4  +-------#
        5          #-----------------------+              <-Rectangle#2
        6          |                       |
        7          |   #---+               |              <-Rectangle#3
        8          |   |   |               |
        9          |   +---#               |
        10         +-----------------------#
        11                                     #          <-Rectangle#4
```

The rectangles are defined according to this scheme: {X-axis coordinate of top left, Y-axis coordinate of top left, X-axis coordinate of bottom right, Y-axis coordinate of bottom right} – or more succinctly: {x1,y1,x2,y2}. So in the picture … Rectangle#1 starts at position 1 on the X axis and position 2 on the Y axis, and ends at position 3 on the X axis and position 4 on the Y axis, so its coordinates are {1,2,3,4}. Rectangle#2's coordinates are {3,5,9,10}. Rectangle#3's coordinates are {4,7,5,9}. And finally Rectangle#4's coordinates are {10,11,10,11}. Rectangle#4 is actually a «point» since it has zero width and zero height, so it could have been described with only two digits: {10,11}.

Some relationships between the rectangles are: «Rectangle#1's nearest neighbor is Rectangle#2», and «Rectangle#3 is entirely inside Rectangle#2».

Now let us create a space and add an RTREE index.

```
tarantool> s = box.schema.space.create('rectangles')
tarantool> i = s:create_index('primary', {
         >   type = 'HASH',
         >   parts = {1, 'unsigned'}
         > })
tarantool> r = s:create_index('rtree', {
         >   type = 'RTREE',
         >   unique = false,
         >   parts = {2, 'ARRAY'}
         > })
```

Field#1 doesn't matter, we just make it because we need a primary-key index. (RTREE indexes cannot be unique and therefore cannot be primary-key indexes.) The second field must be an «array», which means its values must represent {x,y} points or {x1,y1,x2,y2} rectangles. Now let us populate the table by inserting two tuples, containing the coordinates of Rectangle#2 and Rectangle#4.

```
tarantool> s:insert{1, {3, 5, 9, 10}}
tarantool> s:insert{2, {10, 11}}
```

And now, following the description of *RTREE iterator types*, we can search the rectangles with these requests:

```
tarantool> r:select({10, 11, 10, 11}, {iterator = 'EQ'})
---
- - [2, [10, 11]]
...
tarantool> r:select({4, 7, 5, 9}, {iterator = 'GT'})
---
- - [1, [3, 5, 9, 10]]
...
tarantool> r:select({1, 2, 3, 4}, {iterator = 'NEIGHBOR'})
---
- - [1, [3, 5, 9, 10]]
  - [2, [10, 11]]
...
```

Request#1 returns 1 tuple because the point {10,11} is the same as the rectangle {10,11,10,11} («Rectangle#4» in the picture). Request#2 returns 1 tuple because the rectangle {4,7,5,9}, which was «Rectangle#3» in the picture, is entirely within{3,5,9,10} which was Rectangle#2. Request#3 returns 2 tuples, because the NEIGHBOR iterator always returns all tuples, and the first returned tuple will be {3,5,9,10} («Rectangle#2» in the picture) because it is the closest neighbor of {1,2,3,4} («Rectangle#1» in the picture).

Now let us create a space and index for cuboids, which are rectangle-or-boxes that have 6 corners and 6 sides.

```
tarantool> s = box.schema.space.create('R')
tarantool> i = s:create_index('primary', {parts = {1, 'unsigned'}})
tarantool> r = s:create_index('S', {
```

(continues on next page)

(продолжение с предыдущей страницы)

```
        >   type = 'RTREE',
        >   unique = false,
        >   dimension = 3,
        >   parts = {2, 'ARRAY'}
        > })
```

The additional field here is `dimension=3`. The default dimension is 2, which is why it didn't need to be specified for the examples of rectangle. The maximum dimension is 20. Now for insertions and selections there will usually be 6 coordinates. For example:

```
tarantool> s:insert{1, {0, 3, 0, 3, 0, 3}}
tarantool> r:select({1, 2, 1, 2, 1, 2}, {iterator = box.index.GT})
```

Now let us create a space and index for Manhattan-style spatial objects, which are rectangle-or-boxes that have a different way to calculate neighbors.

```
tarantool> s = box.schema.space.create('R')
tarantool> i = s:create_index('primary', {parts = {1, 'unsigned'}})
tarantool> r = s:create_index('S', {
        >   type = 'RTREE',
        >   unique = false,
        >   distance = 'manhattan',
        >   parts = {2, 'ARRAY'}
        > })
```

The additional field here is `distance='manhattan'`. The default distance calculator is „euclid", which is the straightforward as-the-crow-flies method. The optional distance calculator is „manhattan", which can be a more appropriate method if one is following the lines of a grid rather than traveling in a straight line.

```
tarantool> s:insert{1, {0, 3, 0, 3}}
tarantool> r:select({1, 2, 1, 2}, {iterator = box.index.NEIGHBOR})
```

More examples of spatial searching are online in the file R tree index quick start and usage.

Вложенный модуль *box.session*

The `box.session` submodule allows querying the session state, writing to a session-specific temporary Lua table, or setting up triggers which will fire when a session starts or ends. A *session* is an object associated with each client connection.

`box.session.id()`

Return the unique identifier (ID) for the current session. The result can be 0 meaning there is no session.

Rtype number

`box.session.exists(`*id*`)`

Return 1 if the session exists, 0 if the session does not exist.

Rtype number

`box.session.peer(`*id*`)`

This function works only if there is a peer, that is, if a connection has been made to a separate server.

Return The host address and port of the session peer, for example «127.0.0.1:55457». If the session exists but there is no connection to a separate server, the return is null. The command is executed on the server, so the «local name» is the server's host and port, and the «peer name» is the client's host and port.

Rtype string

Possible errors: „session.peer(): session does not exist“

`box.session.sync()`

Return the value of the `sync` integer constant used in the binary protocol.

Rtype number

`box.session.su(`*user-name*`)`

Change Tarantool's *current user*.

Параметры

- `user-name` (*string*) – name of a target user

`box.session.storage`

A Lua table that can hold arbitrary unordered session-specific names and values, which will last until the session ends. For example, this table could be useful to store current tasks when working with a Tarantool queue manager.

Example

```
tarantool> box.session.peer(box.session.id())
---
- 127.0.0.1:45129
...
tarantool> box.session.storage.random_memorandum = "Don't forget the eggs"
---
...
tarantool> box.session.storage.radius_of_mars = 3396
---
...
tarantool> m = ''
---
...
tarantool> for k, v in pairs(box.session.storage) do
         >   m = m .. k .. '='.. v .. ' '
         > end
---
...
tarantool> m
---
- 'radius_of_mars=3396 random_memorandum=Don''t forget the eggs. '
...
```

`box.session.on_connect(`*trigger-function*[, *old-trigger-function-name*]`)`

Define a trigger for execution when a new session is created due to an event such as *console.connect*. The trigger function will be the first thing executed after a new session is created. If the trigger fails by raising an error, the error is sent to the client and the connection is closed.

Параметры

- `trigger-function` (*function*) – function which will become the trigger function
- `old-trigger-function-name` (*function*) – existing trigger function which will be replaced by trigger-function

Return nil or function list

If the parameters are (nil, old-trigger-function-name), then the old trigger is deleted.

Example

```
tarantool> function f ()
         >   x = x + 1
         > end
tarantool> box.session.on_connect(f)
```

Предупреждение: If a trigger always results in an error, it may become impossible to connect to the server to reset it.

`box.session.on_disconnect(`*trigger-function*[, *old-trigger-function-name*]`)`

Define a trigger for execution after a client has disconnected. If the trigger function causes an error, the error is logged but otherwise is ignored. The trigger is invoked while the session associated with the client still exists and can access session properties, such as box.session.id.

Параметры

- `trigger-function` (*function*) – function which will become the trigger function
- `old-trigger-function-name` (*function*) – existing trigger function which will be replaced by trigger-function

Return nil or function list

If the parameters are (nil, old-trigger-function-name), then the old trigger is deleted.

Example #1

```
tarantool> function f ()
         >   x = x + 1
         > end
tarantool> box.session.on_disconnect(f)
```

Example #2

After the following series of requests, the server will write a message using the *log* module whenever any user connects or disconnects.

```
function log_connect ()
  local log = require('log')
  local m = 'Connection. user=' .. box.session.user() .. ' id=' .. box.session.id()
  log.info(m)
end

function log_disconnect ()
  local log = require('log')
  local m = 'Disconnection. user=' .. box.session.user() .. ' id=' .. box.session.id()
  log.info(m)
end

box.session.on_connect(log_connect)
box.session.on_disconnect(log_disconnect)
```

Here is what might appear in the log file in a typical installation:

```
2014-12-15 13:21:34.444 [11360] main/103/iproto I>
    Connection. user=guest id=3
2014-12-15 13:22:19.289 [11360] main/103/iproto I>
    Disconnection. user=guest id=3
```

`box.session.on_auth(`*trigger-function*[, *old-trigger-function-name*]`)`

Define a trigger for execution during authentication.

The `on_auth` trigger function is invoked in these circumstances:

(1) The *console.connect* function includes an authentication check for all users except „guest". For this case, the `on_auth` trigger function is invoked after the `on_connect` trigger function, if and only if the connection has succeeded so far.

(2) The *binary protocol* has a separate *authentication packet*. For this case, connection and authentication are considered to be separate steps.

Unlike other trigger types, `on_auth` trigger functions are invoked **before** the event. Therefore a trigger function like `function auth_function () v = box.session.user(); end` will set `v` to «guest», the user name before the authentication is done. To get the user name **after** the authentication is done, use the special syntax: `function auth_function (user_name) v = user_name; end`

If the trigger fails by raising an error, the error is sent to the client and the connection is closed.

Параметры

- `trigger-function` (*function*) – function which will become the trigger function
- `old-trigger-function-name` (*function*) – existing trigger function which will be replaced by trigger-function

Return nil

If the parameters are (nil, old-trigger-function-name), then the old trigger is deleted.

Example

```
tarantool> function f ()
         >   x = x + 1
         > end
tarantool> box.session.on_auth(f)
```

Вложенный модуль *box.tuple*

The `box.tuple` submodule provides read-only access for the `tuple` userdata type. It allows, for a single tuple: selective retrieval of the field contents, retrieval of information about size, iteration over all the fields, and conversion to a Lua table.

`box.tuple.new(`*value*`)`

Construct a new tuple from either a scalar or a Lua table. Alternatively, one can get new tuples from tarantool's *select* or *insert* or *replace* or *update* requests, which can be regarded as statements that do `new()` implicitly.

Параметры

- `value` (*lua-value*) – the value that will become the tuple contents.

Return a new tuple

Rtype tuple

In the following example, x will be a new table object containing one tuple and t will be a new tuple object. Saying t returns the entire tuple t.

Example:

```
tarantool> x = box.space.tester:insert{
         >   33,
         >   tonumber('1'),
         >   tonumber64('2')
         > }:totable()
---
...
tarantool> t = box.tuple.new{'abc', 'def', 'ghi', 'abc'}
---
...
tarantool> t
---
- ['abc', 'def', 'ghi', 'abc']
...
```

object tuple_object

#<tuple_object>

The # operator in Lua means «return count of components». So, if t is a tuple instance, #t will return the number of fields.

Rtype number

In the following example, a tuple named t is created and then the number of fields in t is returned.

```
tarantool> t = box.tuple.new{'Fld#1', 'Fld#2', 'Fld#3', 'Fld#4'}
---
...
tarantool> #t
---
- 4
...
```

tuple_object:bsize()

If t is a tuple instance, t:bsize() will return the number of bytes in the tuple. It is useful to check this number when making changes to data, because there is a fixed maximum: one megabyte. Every field has one or more «length» bytes preceding the actual contents, so bsize() returns a value which is slightly greater than the sum of the lengths of the contents.

Return number of bytes

Rtype number

In the following example, a tuple named t is created which has three fields, and for each field it takes one byte to store the length and three bytes to store the contents, and a bit for overhead, so bsize() returns 3*(1+3)+1.

```
tarantool> t = box.tuple.new{'aaa', 'bbb', 'ccc'}
---
...
tarantool> t:bsize()
---
- 13
...
```

<tuple_object>(*field-number*)

If `t` is a tuple instance, `t[field-number]` will return the field numbered field-number in the tuple. The first field is `t[1]`.

Return field value.

Rtype lua-value

In the following example, a tuple named `t` is created and then the second field in `t` is returned.

```
tarantool> t = box.tuple.new{'Fld#1', 'Fld#2', 'Fld#3', 'Fld#4'}
---
...
tarantool> t[2]
---
- Fld#2
...
```

`tuple_object:find(`[*field-number*], *search-value*)

`tuple_object:findall(`[*field-number*], *search-value*)

If `t` is a tuple instance, `t:find(search-value)` will return the number of the first field in `t` that matches the search value, and `t:findall(search-value [, search-value ...])` will return numbers of all fields in `t` that match the search value. Optionally one can put a numeric argument `field-number` before the search-value to indicate "start searching at field number `field-number`."

Return the number of the field in the tuple.

Rtype number

In the following example, a tuple named `t` is created and then: the number of the first field in `t` which matches „a" is returned, then the numbers of all the fields in `t` which match „a" are returned, then the numbers of all the fields in t which match „a" and are at or after the second field are returned.

```
tarantool> t = box.tuple.new{'a', 'b', 'c', 'a'}
---
...
tarantool> t:find('a')
---
- 1
...
tarantool> t:findall('a')
---
- 1
- 4
...
tarantool> t:findall(2, 'a')
---
- 4
...
```

`tuple_object:transform(`*start-field-number*, *fields-to-remove*[, *field-value*, ...])

If `t` is a tuple instance, `t:transform(`*`start-field-number`*`,`*`fields-to-remove`*`)` will return a tuple where, starting from field `start-field-number`, a number of fields (`fields-to-remove`) are removed. Optionally one can add more arguments after `fields-to-remove` to indicate new values that will replace what was removed.

Параметры

- `start-field-number` (*integer*) – base 1, may be negative

- fields-to-remove (*integer*) –
- field-value(s) (*lua-value*) –

Return tuple

Rtype tuple

In the following example, a tuple named t is created and then, starting from the second field, two fields are removed but one new one is added, then the result is returned.

```
tarantool> t = box.tuple.new{'Fld#1', 'Fld#2', 'Fld#3', 'Fld#4', 'Fld#5'}
---
...
tarantool> t:transform(2, 2, 'x')
---
- ['Fld#1', 'x', 'Fld#4', 'Fld#5']
...
```

tuple_object:unpack([*start-field-number*[, *end-field-number*]])

If t is a tuple instance, t:unpack() will return all fields, t:unpack(1) will return all fields starting with field number 1, t:unpack(1,5) will return all fields between field number 1 and field number 5.

Return field(s) from the tuple.

Rtype lua-value(s)

In the following example, a tuple named t is created and then all its fields are selected, then the result is returned.

```
tarantool> t = box.tuple.new{'Fld#1', 'Fld#2', 'Fld#3', 'Fld#4', 'Fld#5'}
---
...
tarantool> t:unpack()
---
- Fld#1
- Fld#2
- Fld#3
- Fld#4
- Fld#5
...
```

tuple_object:pairs()

In Lua, lua-table-value:pairs() is a method which returns: function, lua-table-value, nil. Tarantool has extended this so that tuple-value:pairs() returns: function, tuple-value, nil. It is useful for Lua iterators, because Lua iterators traverse a value's components until an end marker is reached.

Return function, tuple-value, nil

Rtype function, lua-value, nil

In the following example, a tuple named t is created and then all its fields are selected using a Lua for-end loop.

```
tarantool> t = box.tuple.new{'Fld#1', 'Fld#2', 'Fld#3', 'Fld#4', 'Fld#5'}
---
...
tarantool> tmp = ''
---
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
tarantool> for k, v in t:pairs() do
         >   tmp = tmp .. v
         > end
---
...
tarantool> tmp
---
- Fld#1Fld#2Fld#3Fld#4Fld#5
...
```

`tuple_object:update({{operator, field_no, value}, ...})`

Update a tuple.

This function updates a tuple which is not in a space. Compare the function `box.space.space-name:update(key, {{format, field_no, value}, ...})` which updates a tuple in a space.

For details: see the description for `operator`, `field_no`, and `value` in the section *box.space.space-name:update{key, format, {field_number, value}...)*.

Параметры

- `operator` (*string*) – operation type represented in string (e.g. „=" for „assign new value")
- `field_no` (*number*) – what field the operation will apply to. The field number can be negative, meaning the position from the end of tuple. (#tuple + negative field number + 1)
- `value` (*lua_value*) – what value will be applied

Return new tuple

Rtype tuple

In the following example, a tuple named `t` is created and then its second field is updated to equal „B".

```
tarantool> t = box.tuple.new{'Fld#1', 'Fld#2', 'Fld#3', 'Fld#4', 'Fld#5'}
---
...
tarantool> t:update({{'=', 2, 'B'}})
---
- ['Fld#1', 'B', 'Fld#3', 'Fld#4', 'Fld#5']
...
```

Пример

This function will illustrate how to convert tuples to/from Lua tables and lists of scalars:

```
tuple = box.tuple.new({scalar1, scalar2, ... scalar_n}) -- scalars to tuple
lua_table = {tuple:unpack()}                            -- tuple to Lua table
scalar1, scalar2, ... scalar_n = tuple:unpack()         -- tuple to scalars
tuple = box.tuple.new(lua_table)                        -- Lua table to tuple
```

Then it will find the field that contains „b“, remove that field from the tuple, and display how many bytes remain in the tuple. The function uses Tarantool `box.tuple` functions `new()`, `unpack()`, `find()`, `transform()`, `bsize()`.

```
function example()
  local tuple1, tuple2, lua_table_1, scalar1, scalar2, scalar3, field_number
  local luatable1 = {}
  tuple1 = box.tuple.new({'a', 'b', 'c'})
  luatable1 = {tuple1:unpack()}
  scalar1, scalar2, scalar3 = tuple1:unpack()
  tuple2 = box.tuple.new(luatable1)
  field_number = tuple2:find('b')
  tuple2 = tuple2:transform(field_number, 1)
  return 'tuple2 = ' , tuple2 , ' # of bytes = ' , tuple2:bsize()
end
```

. . . And here is what happens when one invokes the function:

```
tarantool> example()
---
- tuple2 =
- ['a', 'c']
- ' # of bytes = '
- 5
...
```

Submodule *box.cfg*

The `box.cfg` submodule is for administrators to specify all the server configuration parameters (see «Configuration reference» for *a complete description of all configuration parameters*). Use `box.cfg` without braces to get read-only access to those parameters.

Example:

```
tarantool> box.cfg
---
- snapshot_count: 6
  too_long_threshold: 0.5
  slab_alloc_factor: 1.1
  slab_alloc_maximal: 1048576
  background: false
  <...>
...
```

Submodule *box.slab*

The `box.slab` submodule provides access to slab allocator statistics. The slab allocator is the main allocator used to store tuples. This can be used to monitor the total memory usage and memory fragmentation.

`box.runtime.info()`

Show a memory usage report (in bytes) for the Lua runtime.

Return

- `lua` is the heap size of the Lua garbage collector;
- `maxalloc` is the maximal memory quota that can be allocated for Lua;

- used is the current memory size used by Lua.

Rtype table

Example:

```
tarantool> box.runtime.info()
---
- lua: 913710
  maxalloc: 4398046510080
  used: 12582912
...
tarantool> box.runtime.info().used
---
- used: 12582912
...
```

box.slab.info()

Show an aggregated memory usage report (in bytes) for the slab allocator.

This report is useful for assessing out-of-memory risks: the risks are high if both arena_used_ratio and quota_used_ratio are high (90-95%).

If quota_used_ratio is low, then high arena_used_ratio and/or items_used_ratio indicate that the memory fragmentation is low (i.e. the memory is used efficiently).

If quota_used_ratio is high (approaching 100%), then low arena_used_ratio (50-60%) indicates that the memory is heavily fragmentized. Most probably, there is no immediate out-of-memory risk in this case, but generally this is an issue to consider. For example, probable risks are that the entire memory quota is used for tuples, and there is are no slabs left for a piece of an index. Or that all slabs are allocated for storing tuples, but in fact all the slabs are half-empty.

Return

- items_size is the *total* amount of memory (including allocated, but currently free slabs) used only for tuples, no indexes;
- items_used_ratio = items_used / slab_count * slab_size (these are slabs used only for tuples, no indexes);
- quota_size is the maximum amount of memory that the slab allocator can use for both tuples and indexes (as configured in *slab_alloc_arena* parameter, e.g. the default is 1 gigabyte = 2^30 bytes = 1,073,741,824 bytes);
- quota_used_ratio = quota_used / quota_size;
- arena_used_ratio = arena_used / arena_size;
- items_used is the *efficient* amount of memory (omitting allocated, but currently free slabs) used only for tuples, no indexes;
- quota_used is the percentage of *slab_alloc_arena* that is already distributed to the slab allocator;
- arena_size is the *total* memory used for tuples and indexes together (including allocated, but currently free slabs);
- arena_used is the *efficient* memory used for storing tuples and indexes together (omitting allocated, but currently free slabs).

Rtype table

Example:

```
tarantool> box.slab.info()
---
- items_size: 228128
  items_used_ratio: 1.8%
  quota_size: 1073741824
  quota_used_ratio: 0.8%
  arena_used_ratio: 43.2%
  items_used: 4208
  quota_used: 8388608
  arena_size: 2325176
  arena_used: 1003632
...

tarantool> box.slab.info().arena_used
---
- 1003632
...
```

box.slab.stats()

Show a detailed memory usage report (in bytes) for the slab allocator. The report is broken down into groups by *data item size* as well as by *slab size* (64-byte, 136-byte, etc). The report includes the memory allocated for storing both tuples and indexes.

return

- mem_free is the allocated, but currently unused memory;
- mem_used is the memory used for storing data items (tuples and indexes);
- item_count is the number of stored items;
- item_size is the size of each data item;
- slab_count is the number of slabs allocated;
- slab_size is the size of each allocated slab.

rtype table

Example:

Here is a sample report for the first group:

```
tarantool> box.slab.stats()[1]
---
- mem_free: 16232
  mem_used: 48
  item_count: 2
  item_size: 24
  slab_count: 1
  slab_size: 16384
...
```

This report is saying that there are 2 data items (item_count = 2) stored in one (slab_count = 1) 24-byte slab (item_size = 24), so mem_used = 2 * 24 = 48 bytes. Also, slab_size is 16384 bytes, of which 16384 - 48 = 16232 bytes are free (mem_free).

A complete report would show memory usage statistics for all groups:

```
tarantool> box.slab.stats()
---
- - mem_free: 16232
    mem_used: 48
    item_count: 2
    item_size: 24
    slab_count: 1
    slab_size: 16384
  - mem_free: 15720
    mem_used: 560
    item_count: 14
    item_size: 40
    slab_count: 1
    slab_size: 16384
  <...>
  - mem_free: 32472
    mem_used: 192
    item_count: 1
    item_size: 192
    slab_count: 1
    slab_size: 32768
  - mem_free: 1097624
    mem_used: 999424
    item_count: 61
    item_size: 16384
    slab_count: 1
    slab_size: 2097152
  ...
```

The total `mem_used` for all groups in this report equals `arena_used` in *box.slab.info()* report.

Submodule *box.info*

The `box.info` submodule provides access to information about server variables.

- **server.lsn** Log Sequence Number for the latest entry in the WAL.
- **server.ro** True if the server is in «read_only» mode (same as *read_only* in box.cfg).
- **server.uuid** The unique identifier of this server, as stored in the database. This value is also in the *box.space._cluster* system space.
- **server.id** The number of this server within a cluster.
- **version** Tarantool version. This value is also shown by *tarantool –version*.
- **status** Usually this is „running“, but it can be „loading“, „orphan“, or „hot_standby“.
- **vclock** Same as replication.vclock.
- **pid** Process ID. This value is also shown by the *tarantool* module. This value is also shown by the Linux «ps -A» command.
- **cluster.uuid** UUID of the cluster. Every server in a cluster will have the same cluster.uuid value. This value is also in the *box.space._schema* system space.
- **vinyl()** Returns runtime statistics for the vinyl storage engine.
- **replication.lag** Number of seconds that the replica is behind the master.

- **replication.status** Usually this is „follow“, but it can be „off“, „stopped“, „connecting“, „auth“, or „disconnected“.
- **replication.idle** Number of seconds that the server has been idle.
- **replication.vclock** See the *discussion of «vector clock»* in the Internals section.
- **replication.uuid** The unique identifier of a master to which this server is connected.
- **replication.uptime** Number of seconds since the server started. This value can also be retrieved with *tarantool.uptime()*.

The replication fields are blank unless the server is a *replica*. The replication fields are in an array if the server is a replica for more than one master.

`box.info()`

Since `box.info` contents are dynamic, it's not possible to iterate over keys with the Lua `pairs()` function. For this purpose, `box.info()` builds and returns a Lua table with all keys and values provided in the submodule.

Return keys and values in the submodule.

Rtype table

Example:

```
tarantool> box.info()
---
- server:
    lsn: 0
    ro: false
    uuid: 25684d65-636e-44cd-ab5d-4bb38d9b4411
    id: 1
  version: 1.7.3-28-g75ec202
  status: running
  vclock: {}
  pid: 8228
  cluster:
    uuid: e17aac30-e85a-40be-ad4a-9bf4c1f9ed43
    signature: 0
  vinyl: []
  replication: {}
  uptime: 15
...
tarantool> box.info.pid
---
- 12932
...
tarantool> box.info.status
---
- running
...
tarantool> box.info.uptime
---
- 1065
...
tarantool> box.info.version
---
- 1.7.3-28-g75ec202
...
```

Submodule *box.stat*

The `box.stat` submodule provides access to request and network statistics. Show the average number of requests per second, and the total number of requests since startup, broken down by request type and network events statistics.

```
tarantool> type(box.stat), type(box.stat.net) -- virtual tables
---
- table
- table
...
tarantool> box.stat, box.stat.net
---
- net: []
- []
...
tarantool> box.stat()
---
- DELETE:
    total: 1873949
    rps: 123
  SELECT:
    total: 1237723
    rps: 4099
  INSERT:
    total: 0
    rps: 0
  EVAL:
    total: 0
    rps: 0
  CALL:
    total: 0
    rps: 0
  REPLACE:
    total: 1239123
    rps: 7849
  UPSERT:
    total: 0
    rps: 0
  AUTH:
    total: 0
    rps: 0
  ERROR:
    total: 0
    rps: 0
  UPDATE:
    total: 0
    rps: 0
...
tarantool> box.stat().DELETE -- a selected item of the table
---
- total: 0
  rps: 0
...
tarantool> box.stat.net()
---
- SENT:
    total: 0
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    rps: 0
  EVENTS:
    total: 2
    rps: 0
  LOCKS:
    total: 6
    rps: 0
  RECEIVED:
    total: 0
    rps: 0
...
```

Functions for transaction management

For general information and examples, see section *Transaction control*.

Observe the following rules when working with transactions:

Rule #1

The requests in a transaction must be sent to the server as a single block. It is not enough to enclose them between begin and commit or rollback. To ensure they are sent as a single block: put them in a function, or put them all on one line, or use a delimiter so that multi-line requests are handled together.

Rule #2

All database operations in a transaction should use the same storage engine. It is not safe to access tuple sets that are defined with `{engine='vinyl'}` and also access tuple sets that are defined with `{engine='memtx'}`, in the same transaction.

`box.begin()`
: Begin the transaction. Disable implicit yields until the transaction ends. Signal that writes to the write-ahead log will be deferred until the transaction ends. In effect the fiber which executes `box.begin()` is starting an «active multi-request transaction», blocking all other fibers.

`box.commit()`
: End the transaction, and make all its data-change operations permanent.

`box.rollback()`
: End the transaction, but cancel all its data-change operations. An explicit call to functions outside `box.space` that always yield, such as *fiber.sleep()* or *fiber.yield()*, will have the same effect.

Every submodule contains one or more Lua functions. A few submodules contain members as well as functions. The functions allow data definition (create alter drop), data manipulation (insert delete update upsert select replace), and introspection (inspecting contents of spaces, accessing server configuration).

4.1.2 Модуль *clock*

The `clock` module returns time values derived from the Posix / C CLOCK_GETTIME function or equivalent. Most functions in the module return a number of seconds; functions whose names end in «64» return a 64-bit number of nanoseconds.

`clock.time()`
`clock.time64()`
`clock.realtime()`
`clock.realtime64()`

The wall clock time. Derived from C function clock_gettime(CLOCK_REALTIME). This is the best function for knowing what the official time is, as determined by the system administrator.

Return seconds or nanoseconds since epoch (1970-01-01 00:00:00), adjusted.

Rtype number or number64

Example:

```
-- This will print an approximate number of years since 1970.
clock = require('clock')
print(clock.time() / (365*24*60*60))
```

See also *fiber.time64* and the standard Lua function os.clock.

`clock.monotonic()`
`clock.monotonic64()`

The monotonic time. Derived from C function clock_gettime(CLOCK_MONOTONIC). Monotonic time is similar to wall clock time but is not affected by changes to or from daylight saving time, or by changes done by a user. This is the best function to use with benchmarks that need to calculate elapsed time.

Return seconds or nanoseconds since the last time that the computer was booted.

Rtype number or number64

Example:

```
-- This will print nanoseconds since the start.
clock = require('clock')
print(clock.monotonic64())
```

`clock.proc()`
`clock.proc64()`

The processor time. Derived from C function `clock_gettime(CLOCK_PROCESS_CPUTIME_ID)`. This is the best function to use with benchmarks that need to calculate how much time has been spent within a CPU.

Return seconds or nanoseconds since processor start.

Rtype number or number64

Example:

```
-- This will print nanoseconds in the CPU since the start.
clock = require('clock')
print(clock.proc64())
```

`clock.thread()`
`clock.thread64()`

The thread time. Derived from C function `clock_gettime(CLOCK_THREAD_CPUTIME_ID)`. This is the best function to use with benchmarks that need to calculate how much time has been spent within a thread within a CPU.

Return seconds or nanoseconds since thread start.

Rtype number or number64

Example:

```
-- This will print seconds in the thread since the start.
clock = require('clock')
print(clock.thread64())
```

`clock.bench(`*function*[, *...*]`)`

The time that a function takes within a processor. This function uses `clock.proc()`, therefore it calculates elapsed CPU time. Therefore it is not useful for showing actual elapsed time.

Параметры

- `function` (*function*) – function or function reference
- `...` – whatever values are required by the function.

Return table. first element - seconds of CPU time, second element - whatever the function returns.

Example:

```
-- Benchmark a function which sleeps 10 seconds.
-- NB: bench() will not calculate sleep time.
-- So the returned value will be {a number less than 10, 88}.
clock = require('clock')
fiber = require('fiber')
function f(param)
  fiber.sleep(param)
  return 88
end
clock.bench(f, 10)
```

4.1.3 Модуль *console*

The console module allows one Tarantool server to access another Tarantool server, and allows one Tarantool server to start listening on an *admin port*.

`console.connect(`*uri*`)`

Connect to the server at *URI*, change the prompt from „`tarantool>`" to „*uri*`>`", and act henceforth as a client until the user ends the session or types `control-D`.

The console.connect function allows one Tarantool server, in interactive mode, to access another Tarantool server. Subsequent requests will appear to be handled locally, but in reality the requests are being sent to the remote server and the local server is acting as a client. Once connection is successful, the prompt will change and subsequent requests are sent to, and executed on, the remote server. Results are displayed on the local server. To return to local mode, enter `control-D`.

If the Tarantool server at `uri` requires authentication, the connection might look something like: `console.connect('admin:secretpassword@distanthost.com:3301')`.

There are no restrictions on the types of requests that can be entered, except those which are due to privilege restrictions – by default the login to the remote server is done with user name = „guest". The remote server could allow for this by granting at least one privilege: `box.schema.user.grant('guest', 'execute','universe')`.

Параметры

- `uri` (*string*) – the URI of the remote server

Return nil

Possible errors: the connection will fail if the target Tarantool server was not initiated with `box.cfg{listen=...}`.

Example:

```
tarantool> console = require('console')
---
...
tarantool> console.connect('198.18.44.44:3301')
---
...
198.18.44.44:3301> -- prompt is telling us that server is remote
```

`console.listen(`*uri*`)`

Listen on *URI*. The primary way of listening for incoming requests is via the connection-information string, or URI, specified in `box.cfg{listen=...}`. The alternative way of listening is via the URI specified in `console.listen(...)`. This alternative way is called «administrative» or simply *«admin port»*. The listening is usually over a local host with a Unix domain socket.

Параметры

- `uri` (*string*) – the URI of the local server

The «admin» address is the URI to listen on. It has no default value, so it must be specified if connections will occur via an admin port. The parameter is expressed with URI = Universal Resource Identifier format, for example «/tmpdir/unix_domain_socket.sock», or a numeric TCP port. Connections are often made with telnet. A typical port value is 3313.

Example:

```
tarantool> console = require('console')
---
...
tarantool> console.listen('unix/:/tmp/X.sock')
... main/103/console/unix/:/tmp/X I> started
---
- fd: 6
  name:
    host: unix/
    family: AF_UNIX
    type: SOCK_STREAM
    protocol: 0
    port: /tmp/X.sock
...
```

`console.start()`

Start the console on the current interactive terminal.

Example:

A special use of `console.start()` is with *initialization files*. Normally, if one starts the tarantool server with `tarantool` ***`initialization file`*** there is no console. This can be remedied by adding these lines at the end of the initialization file:

```
local console = require('console')
console.start()
```

`console.ac(`[*true|false*]`)`

Set the auto-completion flag. If auto-completion is *true*, and the user is using tarantool as a client or the user is using tarantool via `console.connect()`, then hitting the TAB key may cause tarantool to complete a word automatically. The default auto-completion value is *true*.

4.1.4 Модуль *crypto*

«Crypto» is short for «Cryptography», which generally refers to the production of a digest value from a function (usually a Cryptographic hash function), applied against a string. Tarantool's crypto module supports ten types of cryptographic hash functions (AES, DES, DSS, MD4, MD5, MDC2, RIPEMD, SHA-0, SHA-1, SHA-2). Some of the crypto functionality is also present in the *Модуль digest* module. The functions in crypto are:

`crypto.cipher.{aes128|aes192|aes256|des}.{cbc|cfb|ecb|ofb}.encrypt(`*string*, *key*, *initialization_vector*`)`
`crypto.cipher.{aes128|aes192|aes256|des}.{cbc|cfb|ecb|ofb}.decrypt(`*string*, *key*, *initialization_vector*`)`

Pass or return a cipher derived from the string, key, and (optionally, sometimes) initialization vector. The four choices of algorithms:

- aes128 - aes-128 (with 192-bit binary strings using AES)
- aes192 - aes-192 (with 192-bit binary strings using AES)
- aes256 - aes-256 (with 256-bit binary strings using AES)
- des - des (with 56-bit binary strings using DES, though DES is not recommended)

Four choices of block cipher modes are also available:

- cbc - Cipher Block Chaining
- cfb - Cipher Feedback
- ecb - Electronic Codebook
- ofb - Output Feedback

For more information on, read article about Encryption Modes

Example:

```
crypto.cipher.aes192.cbc.encrypt('string', 'key', 'initialization')
crypto.cipher.aes256.ecb.decrypt('string', 'key', 'initialization')
```

`crypto.digest.{dss|dss1|md4|md5|mdc2|ripemd160}(`*string*`)`
`crypto.digest.{sha|sha1|sha224|sha256|sha384|sha512}(`*string*`)`

Pass or return a digest derived from the string. The twelve choices of algorithms:

- dss - dss (using DSS)
- dss1 - dss (using DSS-1)
- md4 - md4 (with 128-bit binary strings using MD4)
- md5 - md5 (with 128-bit binary strings using MD5)
- mdc2 - mdc2 (using MDC2)
- ripemd160 -
- sha - sha (with 160-bit binary strings using SHA-0)
- sha1 - sha-1 (with 160-bit binary strings using SHA-1)
- sha224 - sha-224 (with 224-bit binary strings using SHA-2)

- sha256 - sha-256 (with 256-bit binary strings using SHA-2)
- sha384 - sha-384 (with 384-bit binary strings using SHA-2)
- sha512 - sha-512(with 512-bit binary strings using SHA-2).

Example:

```
crypto.digest.md4('string')
crypto.digest.sha512('string')
```

Incremental methods in the crypto module

Suppose that a digest is done for a string „A“, then a new part „B“ is appended to the string, then a new digest is required. The new digest could be recomputed for the whole string „AB“, but it is faster to take what was computed before for „A“ and apply changes based on the new part „B“. This is called multi-step or «incremental» digesting, which Tarantool supports for all crypto functions..

```
crypto = require('crypto')

-- print aes-192 digest of 'AB', with one step, then incrementally
print(crypto.cipher.aes192.cbc.encrypt('AB', 'key'))
c = crypto.cipher.aes192.cbc.encrypt.new()
c:init()
c:update('A', 'key')
c:update('B', 'key')
print(c:result())
c:free()

-- print sha-256 digest of 'AB', with one step, then incrementally
print(crypto.digest.sha256('AB'))
c = crypto.digest.sha256.new()
c:init()
c:update('A')
c:update('B')
print(c:result())
c:free()
```

Getting the same results from digest and crypto modules

The following functions are equivalent. For example, the `digest` function and the `crypto` function will both produce the same result.

```
crypto.cipher.aes256.cbc.encrypt('string', 'key') == digest.aes256cbc.encrypt('string', 'key')
crypto.digest.md4('string') == digest.md4('string')
crypto.digest.md5('string') == digest.md5('string')
crypto.digest.sha('string') == digest.sha('string')
crypto.digest.sha1('string') == digest.sha1('string')
crypto.digest.sha224('string') == digest.sha224('string')
crypto.digest.sha256('string') == digest.sha256('string')
crypto.digest.sha384('string') == digest.sha384('string')
crypto.digest.sha512('string') == digest.sha512('string')
```

4.1.5 Module *csv*

The csv module handles records formatted according to Comma-Separated-Values (CSV) rules.

The default formatting rules are:

- Lua escape sequences such as \n or \10 are legal within strings but not within files,
- Commas designate end-of-field,
- Line feeds, or line feeds plus carriage returns, designate end-of-record,
- Leading or trailing spaces are ignored,
- Quote marks may enclose fields or parts of fields,
- When enclosed by quote marks, commas and line feeds and spaces are treated as ordinary characters, and a pair of quote marks «» is treated as a single quote mark.

The possible options which can be passed to csv functions are:

- `delimiter = string` (default: comma) – single-byte character to designate end-of-field
- `quote_char = string` (default: quote mark) – single-byte character to designate encloser of string
- `chunk_size = number` (default: 4096) – number of characters to read at once (usually for file-IO efficiency)
- `skip_head_lines = number` (default: 0) – number of lines to skip at the start (usually for a header)

`csv.load(readable[, {options}])`

Get CSV-formatted input from `readable` and return a table as output. Usually `readable` is either a string or a file opened for reading. Usually *options* is not specified.

Параметры

- `readable` (*object*) – a string, or any object which has a read() method, formatted according to the CSV rules
- `options` (*table*) – see *above*

Return loaded_value

Rtype table

Example:

Readable string has 3 fields, field#2 has comma and space so use quote marks:

```
tarantool> csv = require('csv')
---
...
tarantool> csv.load('a,"b,c ",d')
---
- - - a
    - 'b,c '
    - d
...
```

Readable string contains 2-byte character = Cyrillic Letter Palochka: (This displays a palochka if and only if character set = UTF-8.)

```
tarantool> csv.load('a\\211\\128b')
---
- - - a\211\128b
...
```

Semicolon instead of comma for the delimiter:

```
tarantool> csv.load('a,b;c,d', {delimiter = ';'})
---
- - - a,b
    - c,d
...
```

Readable file `./file.csv` contains two CSV records. Explanation of `fio` is in section *fio*. Source CSV file and example respectively:

```
tarantool> -- input in file.csv is:
tarantool> -- a,"b,c ",d
tarantool> -- a\\211\\128b
tarantool> fio = require('fio')
---
...
tarantool> f = fio.open('./file.csv', {'O_RDONLY'})
---
...
tarantool> csv.load(f, {chunk_size = 4096})
---
- - - a
    - 'b,c '
    - d
  - - a\\211\\128b
...
tarantool> f:close(nn)
---
- true
...
```

`csv.dump(`*csv-table*[, *options*, *writable*])

Get table input from `csv-table` and return a CSV-formatted string as output. Or, get table input from `csv-table` and put the output in `writable`. Usually ***options*** is not specified. Usually `writable`, if specified, is a file opened for writing. *csv.dump()* is the reverse of *csv.load()*.

Параметры

- `csv-table` (***table***) – a table which can be formatted according to the CSV rules.
- `options` (***table***) – optional. see *above*
- `writable` (***object***) – any object which has a `write()` method

Return dumped_value

Rtype string, which is written to `writable` if specified

Example:

CSV-table has 3 fields, field#2 has «,» so result has quote marks

```
tarantool> csv = require('csv')
---
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
tarantool> csv.dump({'a','b,c ','d'})
---
- 'a,"b,c ",d

'
...
```

Round Trip: from string to table and back to string

```
tarantool> csv_table = csv.load('a,b,c')
---
...
tarantool> csv.dump(csv_table)
---
- 'a,b,c

'
...
```

`csv.iterate(`*input*, *{options}*`)`

Form a Lua iterator function for going through CSV records one field at a time. Use of an iterator is strongly recommended if the amount of data is large (ten or more megabytes).

Параметры

- `csv-table` (*table*) – a table which can be formatted according to the CSV rules.
- `options` (*table*) – see *above*

Return Lua iterator function

Rtype iterator function

Example:

csv.iterate() is the low level of *csv.load()* and *csv.dump()*. To illustrate that, here is a function which is the same as the *csv.load()* function, as seen in the Tarantool source code.

```
tarantool> load = function(readable, opts)
         >   opts = opts or {}
         >   local result = {}
         >   for i, tup in csv.iterate(readable, opts) do
         >     result[i] = tup
         >   end
         >   return result
         > end
---
...
tarantool> load('a,b,c')
---
- - - a
    - b
    - c
...
```

4.1.6 Модуль *digest*

A «digest» is a value which is returned by a function (usually a Cryptographic hash function), applied against a string. Tarantool's digest module supports several types of cryptographic hash functions (AES, MD4, MD5, SHA-0, SHA-1, SHA-2) as well as a checksum function (CRC32), two functions for base64, and two non-cryptographic hash functions (guava, murmur). Some of the digest functionality is also present in the *crypto* module.

The functions in digest are:

`digest.aes256cbc.encrypt(`*string*, *key*, *iv*`)`
`digest.aes256cbc.decrypt(`*string*, *key*, *iv*`)`
Returns 256-bit binary string = digest made with AES.

`digest.md4(`*string*`)`
Returns 128-bit binary string = digest made with MD4.

`digest.md4_hex(`*string*`)`
Returns 32-byte string = hexadecimal of a digest calculated with md4.

`digest.md5(`*string*`)`
Returns 128-bit binary string = digest made with MD5.

`digest.md5_hex(`*string*`)`
Returns 32-byte string = hexadecimal of a digest calculated with md5.

`digest.sha(`*string*`)`
Returns 160-bit binary string = digest made with SHA-0.|br| Not recommended.

`digest.sha_hex(`*string*`)`
Returns 40-byte string = hexadecimal of a digest calculated with sha.

`digest.sha1(`*string*`)`
Returns 160-bit binary string = digest made with SHA-1.

`digest.sha1_hex(`*string*`)`
Returns 40-byte string = hexadecimal of a digest calculated with sha1.

`digest.sha224(`*string*`)`
Returns 224-bit binary string = digest made with SHA-2.

`digest.sha224_hex(`*string*`)`
Returns 56-byte string = hexadecimal of a digest calculated with sha224.

`digest.sha256(`*string*`)`
Returns 256-bit binary string = digest made with SHA-2.

`digest.sha256_hex(`*string*`)`
Returns 64-byte string = hexadecimal of a digest calculated with sha256.

`digest.sha384(`*string*`)`
Returns 384-bit binary string = digest made with SHA-2.

`digest.sha384_hex(`*string*`)`
Returns 96-byte string = hexadecimal of a digest calculated with sha384.

`digest.sha512(`*string*`)`
Returns 512-bit binary tring = digest made with SHA-2.

`digest.sha512_hex(`*string*`)`
Returns 128-byte string = hexadecimal of a digest calculated with sha512.

`digest.base64_encode(string)`
Returns base64 encoding from a regular string.

`digest.base64_decode(string)`
Returns a regular string from a base64 encoding.

`digest.urandom(integer)`
Returns array of random bytes with length = integer.

`digest.crc32(string)`
Returns 32-bit checksum made with CRC32.

The crc32 and crc32_update functions use the CRC-32C (Castagnoli) polynomial value: `0x1EDC6F41` / `4812730177`. If it is necessary to be compatible with other checksum functions in other programming languages, ensure that the other functions use the same polynomial value.

For example, in Python, install the `crcmod` package and say:

```
>>> import crcmod
>>> fun = crcmod.mkCrcFun('4812730177')
>>> fun('string')
3304160206L
```

In Perl, install the `Digest::CRC` module and run the following code:

```
use Digest::CRC;
$d = Digest::CRC->new(width => 32, poly => 0x1EDC6F41, init => 0xFFFFFFFF, refin => 1, refout␣
↪=> 1);
$d->add('string');
print $d->digest;
```

(the expected output is 3304160206).

`digest.crc32.new()`
Initiates incremental crc32. See *incremental methods* notes.

`digest.guava(state, bucket)`
Returns a number made with consistent hash.

The guava function uses the Consistent Hashing algorithm of the Google guava library. The first parameter should be a hash code; the second parameter should be the number of buckets; the returned value will be an integer between 0 and the number of buckets. For example,

```
tarantool> digest.guava(10863919174838991, 11)
---
- 8
...
```

`digest.murmur(string)`
Returns 32-bit binary string = digest made with MurmurHash.

`digest.murmur.new([seed])`
Initiates incremental MurmurHash. See *incremental methods* notes.

Incremental methods in the digest module

Suppose that a digest is done for a string „A“, then a new part „B“ is appended to the string, then a new digest is required. The new digest could be recomputed for the whole string „AB“, but it is faster to take what was computed before for „A" and apply changes based on the new part „B". This is called multi-step or «incremental» digesting, which Tarantool supports with crc32 and with murmur…

```
digest = require('digest')

-- print crc32 of 'AB', with one step, then incrementally
print(digest.crc32('AB'))
c = digest.crc32.new()
c:update('A')
c:update('B')
print(c:result())

-- print murmur hash of 'AB', with one step, then incrementally
print(digest.murmur('AB'))
m = digest.murmur.new()
m:update('A')
m:update('B')
print(m:result())
```

Пример

In the following example, the user creates two functions, `password_insert()` which inserts a SHA-1 digest of the word «**^S^e^c^ret Wordpass**» into a tuple set, and `password_check()` which requires input of a password.

```
tarantool> digest = require('digest')
---
...
tarantool> function password_insert()
         >   box.space.tester:insert{1234, digest.sha1('^S^e^c^ret Wordpass')}
         >   return 'OK'
         > end
---
...
tarantool> function password_check(password)
         >   local t = box.space.tester:select{12345}
         >   if digest.sha1(password) == t[2] then
         >     return 'Password is valid'
         >   else
         >     return 'Password is not valid'
         >   end
         > end
---
...
tarantool> password_insert()
---
- 'OK'
...
```

If a later user calls the `password_check()` function and enters the wrong password, the result is an error.

```
tarantool> password_check('Secret Password')
---
- 'Password is not valid'
...
```

4.1.7 Module *errno*

The errno module has a function strerror() which will return the text of an operating-system error, given its error number. Typically this module is used within a function or within a Lua program, in association with a module whose functions can return operating-system errors, such as *fio*.

errno.strerror([*code*])

Return a string, given an error number. The string will contain the conventional error message for the current operating system. If code is not supplied, the error message will be for the last operating-system-related function, or 0.

Параметры

- code (*integer*) – number of an operating-system error

Return type: string

Example:

This function displays the result of a call to *fio.open()* which causes error 2 (errno.ENOENT).

```
tarantool> function f()
         >   local fio = require('fio')
         >   local errno = require('errno')
         >   fio.open('no_such_file')
         >   return errno.strerror()
         > end
---
...

tarantool> f()
---
- "No such file or directory"
...
```

4.1.8 Вложенный модуль *box.error*

The box.error function is for raising an error. The difference between this function and Lua's built-in error() function is that when the error reaches the client, its error code is preserved. In contrast, a Lua error would always be presented to the client as ER_PROC_LUA.

box.error(*reason=string*[, *code=number*])

When called with a Lua-table argument, the code and reason have any user-desired values. The result will be those values.

Параметры

- code (*integer*) –
- reason (*string*) –

box.error()

When called without arguments, box.error() re-throws whatever the last error was.

box.error(*code*, *errtext*[, *errtext ...*])

Emulate a request error, with text based on one of the pre-defined Tarantool errors defined in the file errcode.h in the source tree. Lua constants which correspond to those Tarantool errors are defined as members of box.error, for example box.error.NO_SUCH_USER == 45.

Параметры

- code (*number*) – number of a pre-defined error
- errtext(s) (*string*) – part of the message which will accompany the error

Например:

the NO_SUCH_USER message is «User '%s' is not found» – it includes one «%s» component which will be replaced with errtext. Thus a call to box.error(box.error.NO_SUCH_USER, 'joe') or box.error(45, 'joe') will result in an error with the accompanying message «User 'joe' is not found».

Except whatever is specified in errcode-number.

Example:

```
tarantool> box.error{code = 555, reason = 'Arbitrary message'}
---
- error: Arbitrary message
...
tarantool> box.error()
---
- error: Arbitrary message
...
tarantool> box.error(box.error.FUNCTION_ACCESS_DENIED, 'A', 'B', 'C')
---
- error: A access denied for user 'B' to function 'C'
...
```

box.error.last()

Returns a description of the last error, as a Lua table with five members: «line» (number) Tarantool source file line number, «code» (number) error's number, «type», (string) error's C++ class, «message» (string) error's message, «file» (string) Tarantool source file. Additionally, if the error is a system error (for example due to a failure in socket or file io), there may be a sixth member: «errno» (number) C standard error number.

rtype: table

box.error.clear()

Clears the record of errors, so functions like *box.error()* or *box.error.last()* will have no effect.

Example:

```
tarantool> box.error{code = 555, reason = 'Arbitrary message'}
---
- error: Arbitrary message
...
tarantool> box.schema.space.create('#')
---
- error: Invalid identifier '#' (expected letters, digits or an underscore)
...
tarantool> box.error.last()
---
- line: 278
  code: 70
  type: ClientError
  message: Invalid identifier '#' (expected letters, digits or an underscore)
  file: /tmp/buildd/tarantool-1.7.0.252.g1654e31~precise/src/box/key_def.cc
...
tarantool> box.error.clear()
---
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
tarantool> box.error.last()
---
- null
...
```

4.1.9 Модуль *fiber*

The `fiber` module allows for creating, running and managing *fibers*.

A fiber is a set of instructions which are executed with cooperative multitasking. Fibers managed by the fiber module are associated with a user-supplied function called the *fiber function*. A fiber has three possible states: **running**, **suspended** or **dead**. When a fiber is created with *fiber.create()*, it is running. When a fiber yields control with *fiber.sleep()*, it is suspended. When a fiber ends (because the fiber function ends), it is dead.

All fibers are part of the fiber registry. This registry can be searched with *fiber.find()* - via fiber id (fid), which is a numeric identifier.

A runaway fiber can be stopped with *fiber_object.cancel*. However, *fiber_object.cancel* is advisory — it works only if the runaway fiber calls *fiber.testcancel()* occasionally. Most `box.*` functions, such as *box.space...delete()* or *box.space...update()*, do call *fiber.testcancel()* but *box.space...select{}* does not. In practice, a runaway fiber can only become unresponsive if it does many computations and does not check whether it has been cancelled.

The other potential problem comes from fibers which never get scheduled, because they are not subscribed to any events, or because no relevant events occur. Such morphing fibers can be killed with *fiber.kill()* at any time, since *fiber.kill()* sends an asynchronous wakeup event to the fiber, and *fiber.testcancel()* is checked whenever such a wakeup event occurs.

Like all Lua objects, dead fibers are garbage collected. The garbage collector frees pool allocator memory owned by the fiber, resets all fiber data, and returns the fiber (now called a fiber carcass) to the fiber pool. The carcass can be reused when another fiber is created.

A fiber has all the features of a Lua coroutine and all the programming concepts that apply for Lua coroutines will apply for fibers as well. However, Tarantool has made some enhancements for fibers and has used fibers internally. So, although use of coroutines is possible and supported, use of fibers is recommended.

`fiber.create(`*function*[, *function-arguments*]`)`

Create and start a fiber. The fiber is created and begins to run immediately.

Параметры

- `function` – the function to be associated with the fiber
- `function-arguments` – what will be passed to function

Return created fiber object

Rtype userdata

Example:

```
tarantool> fiber = require('fiber')
---
...
tarantool> function function_name()
         >   fiber.sleep(1000)
```

(continues on next page)

(продолжение с предыдущей страницы)

```
         > end
---
...
tarantool> fiber_object = fiber.create(function_name)
---
...
```

`fiber.self()`

Return fiber object for the currently scheduled fiber.

Rtype userdata

Example:

```
tarantool> fiber.self()
---
- status: running
  name: interactive
  id: 101
...
```

`fiber.find(`*id*`)`

Параметры

- `id` – numeric identifier of the fiber.

Return fiber object for the specified fiber.

Rtype userdata

Example:

```
tarantool> fiber.find(101)
---
- status: running
  name: interactive
  id: 101
...
```

`fiber.sleep(`*time*`)`

Yield control to the transaction processor thread and sleep for the specified number of seconds. Only the current fiber can be made to sleep.

Параметры

- `time` – number of seconds to sleep.

Example:

```
tarantool> fiber.sleep(1.5)
---
...
```

`fiber.yield()`

Yield control to the scheduler. Equivalent to *fiber.sleep(0)*.

Example:

```
tarantool> fiber.yield()
---
...
```

`fiber.status()`

Return the status of the current fiber.

Return the status of `fiber`. One of: "dead", "suspended", or "running".

Rtype string

Example:

```
tarantool> fiber.status()
---
- running
...
```

`fiber.info()`

Return information about all fibers.

Return number of context switches, backtrace, id, total memory, used memory, name for each fiber.

Rtype table

Example:

```
tarantool> fiber.info()
---
- 101:
    csw: 7
    backtrace: []
    fid: 101
    memory:
      total: 65776
      used: 0
    name: interactive
...
```

`fiber.kill(`*id*`)`

Locate a fiber by its numeric id and cancel it. In other words, *fiber.kill()* combines *fiber.find()* and *fiber_object:cancel()*.

Параметры

- `id` – the id of the fiber to be cancelled.

Exception the specified fiber does not exist or cancel is not permitted.

Example:

```
tarantool> fiber.kill(fiber.id())
---
- error: fiber is cancelled
...
```

`fiber.testcancel()`

Check if the current fiber has been cancelled and throw an exception if this is the case.

Example:

```
tarantool> fiber.testcancel()
---
- error: fiber is cancelled
...
```

object fiber_object

fiber_object:id()

Параметры

- self – fiber object, for example the fiber object returned by *fiber.create*

Return id of the fiber.

Rtype number

Example:

```
tarantool> fiber_object = fiber.self()
---
...
tarantool> fiber_object:id()
---
- 101
...
```

fiber_object:name()

Параметры

- self – fiber object, for example the fiber object returned by *fiber.create*

Return name of the fiber.

Rtype string

Example:

```
tarantool> fiber.self():name()
---
- interactive
...
```

fiber_object:name(*name*)

Change the fiber name. By default the Tarantool server's interactive-mode fiber is named „interactive" and new fibers created due to *fiber.create* are named „lua". Giving fibers distinct names makes it easier to distinguish them when using *fiber.info*.

Параметры

- self – fiber object, for example the fiber object returned by *fiber.create*
- name (*string*) – the new name of the fiber.

Return nil

Example:

```
tarantool> fiber.self():name('non-interactive')
---
...
```

`fiber_object:status()`

Return the status of the specified fiber.

Параметры

- `self` – fiber object, for example the fiber object returned by *fiber.create*

Return the status of fiber. One of: "dead", "suspended", or "running".

Rtype string

Example:

```
tarantool> fiber.self():status()
---
- running
...
```

`fiber_object:cancel()`

Cancel a fiber. Running and suspended fibers can be cancelled. After a fiber has been cancelled, attempts to operate on it will cause errors, for example *fiber_object:id()* will cause `error: the fiber is dead`.

Параметры

- `self` – fiber object, for example the fiber object returned by *fiber.create*

Return nil

Possible errors: cancel is not permitted for the specified fiber object.

Example:

```
tarantool> fiber.self():cancel()
---
- error: fiber is cancelled
...
```

`fiber_object.storage`

Local storage within the fiber. The storage can contain any number of named values, subject to memory limitations. Naming may be done with `fiber_object.storage.name` or `fiber_object.storage['name'].` or with a number `fiber_object.storage[number]`. Values may be either numbers or strings. The storage is garbage-collected when `fiber_object:cancel()` happens.

Example:

```
tarantool> fiber = require('fiber')
---
...
tarantool> function f () fiber.sleep(1000); end
---
...
tarantool> fiber_function = fiber:create(f)
---
- error: '[string "fiber_function = fiber:create(f)"]:1: fiber.create(function, ...):
    bad arguments'
...
tarantool> fiber_function = fiber.create(f)
---
...
tarantool> fiber_function.storage.str1 = 'string'
```

(continues on next page)

(продолжение с предыдущей страницы)

```
---
...
tarantool> fiber_function.storage['str1']
---
- string
...
tarantool> fiber_function:cancel()
---
...
tarantool> fiber_function.storage['str1']
---
- error: '[string "return fiber_function.storage[''str1'']"]:1: the fiber is dead'
...
```

See also *box.session.storage*.

`fiber.time()`

Return current system time (in seconds since the epoch) as a Lua number. The time is taken from the event loop clock, which makes this call very cheap, but still useful for constructing artificial tuple keys.

Rtype num

Example:

```
tarantool> fiber.time(), fiber.time()
---
- 1448466279.2415
- 1448466279.2415
...
```

`fiber.time64()`

Return current system time (in microseconds since the epoch) as a 64-bit integer. The time is taken from the event loop clock.

Rtype num

Example:

```
tarantool> fiber.time(), fiber.time64()
---
- 1448466351.2708
- 1448466351270762
...
```

Example Of Fiber Use

Make the function which will be associated with the fiber. This function contains an infinite loop (`while 0 == 0` is always true). Each iteration of the loop adds 1 to a global variable named gvar, then goes to sleep for 2 seconds. The sleep causes an implicit *fiber.yield()*.

```
tarantool> fiber = require('fiber')
tarantool> function function_x()
         >   gvar = 0
         >   while 0 == 0 do
```

(continues on next page)

(продолжение с предыдущей страницы)

```
         >     gvar = gvar + 1
         >     fiber.sleep(2)
         >   end
         > end
---
...
```

Make a fiber, associate function_x with the fiber, and start function_x. It will immediately «detach» so it will be running independently of the caller.

```
tarantool> gvar = 0

tarantool> fiber_of_x = fiber.create(function_x)
---
...
```

Get the id of the fiber (fid), to be used in later displays.

```
tarantool> fid = fiber_of_x:id()
---
...
```

Pause for a while, while the detached function runs. Then … Display the fiber id, the fiber status, and gvar (gvar will have gone up a bit depending how long the pause lasted). The status is suspended because the fiber spends almost all its time sleeping or yielding.

```
tarantool> print('#', fid, '. ', fiber_of_x:status(), '. gvar=', gvar)
# 102 .  suspended . gvar= 399
---
...
```

Pause for a while, while the detached function runs. Then … Cancel the fiber. Then, once again … Display the fiber id, the fiber status, and gvar (gvar will have gone up a bit more depending how long the pause lasted). This time the status is dead because the cancel worked.

```
tarantool> fiber_of_x:cancel()
---
...
tarantool> print('#', fid, '. ', fiber_of_x:status(), '. gvar=', gvar)
# 102 .  dead . gvar= 421
---
...
```

4.1.10 Модуль *fiber-ipc*

The `fiber-ipc` submodule allows sending and receiving messages between different processes and has synchronization mechanism for fibers, similar to «Condition Variables» and similar to operating-system functions such as `pthread_cond_wait()` plus `pthread_cond_signal()`. The words «different processes» in this context mean different connections, different sessions, or different fibers.

Call `fiber.channel()` to allocate space and get a channel object, which will be called channel for examples in this section. Call the other `fiber-ipc` routines, via channel, to send messages, receive messages, or check ipc status. Message exchange is synchronous. The channel is garbage collected when no one is using it, as with any other Lua object. Use object-oriented syntax, for example `channel:put(message)` rather than `fiber.channel.put(message)`.

Call `fiber.cond()` to create a named condition variable, which will be called cond for examples in this section. Call `cond:wait()` to make a fiber wait for a signal via a condition variable. Call `cond:signal()` to send a signal to wake up a single fiber that has executed `cond:wait()`. Call `cond:broadcast()` to send a signal to all fibers that have executed `cond:wait()`.

Channel

`fiber.channel([capacity])`
Create a new communication channel.

Параметры

- `capacity` (*int*) – positive integer as great as the maximum number of slots (spaces for `get` or `put` messages) that might be pending at any given time.

Return new channel.

Rtype userdata, possibly including the string «channel …».

`object channel_object`

`channel_object:put(message[, timeout])`
Send a message using a channel. If the channel is full, `channel:put()` blocks until there is a free slot in the channel.

Параметры

- `message` (*lua_object*) – string
- `timeout` – number

Return If timeout is provided, and there is no free slot in the channel for the duration of the timeout, `channel:put()` returns false. Otherwise it returns true.

Rtype boolean

`channel_object:close()`
Close the channel. All waiters in the channel will be woken up. All following `channel:put()` or `channel:get()` operations will return an error (`nil`).

`channel_object:get([timeout])`
Fetch a message from a channel. If the channel is empty, `channel:get()` blocks until there is a message.

Параметры

- `timeout` – number

Return the message placed on the channel by `channel:put()`. If timeout is provided, and there is no message in the channel for the duration of the timeout, `channel:get()` returns nil.

Rtype string

`channel_object:is_empty()`
Check whether the specified channel is empty (has no messages).

Return true if the specified channel is empty

Rtype boolean

`channel_object:count()`
Find out how many messages are on the channel. The answer is 0 if the channel is empty.

Return the number of messages.

Rtype number

`channel_object:is_full()`
Check whether the specified channel is full.

Return true if the specified channel is full (has no room for a new message).

Rtype boolean

`channel_object:has_readers()`
Check whether the specified channel is empty and has readers waiting for a message (because they have issued `channel:get()` and then blocked).

Return true if blocked users are waiting. Otherwise false.

Rtype boolean

`channel_object:has_writers()`
Check whether the specified channel is full and has writers waiting (because they have issued `channel:put()` and then blocked due to lack of room).

Return true if blocked users are waiting. Otherwise false.

Rtype boolean

`channel_object:is_closed()`

Return true if the specified channel is already closed. Otherwise false.

Rtype boolean

Пример

This example should give a rough idea of what some functions for fibers should look like. It's assumed that the functions would be referenced in *fiber.create()*.

```
fiber = require('fiber')
channel = fiber.channel(10)
function consumer_fiber()
    while true do
        local task = channel:get()
        ...
    end
end

function consumer2_fiber()
    while true do
        -- 10 seconds
        local task = channel:get(10)
        if task ~= nil then
            ...
        else
            -- timeout
        end
    end
end
```

(continues on next page)

(продолжение с предыдущей страницы)

```
function producer_fiber()
    while true do
        task = box.space...:select{...}
        ...
        if channel:is_empty() then
            -- channel is empty
        end

        if channel:is_full() then
            -- channel is full
        end

        ...
        if channel:has_readers() then
            -- there are some fibers
            -- that are waiting for data
        end
        ...

        if channel:has_writers() then
            -- there are some fibers
            -- that are waiting for readers
        end
        channel:put(task)
    end
end

function producer2_fiber()
    while true do
        task = box.space...select{...}
        -- 10 seconds
        if channel:put(task, 10) then
            ...
        else
            -- timeout
        end
    end
end
```

Condition variables

`fiber.cond()`

Create a new condition variable.

Return new condition variable.

Rtype Lua object

`object cond_object`

`cond_object:wait([timeout])`

Make the current fiber go to sleep, waiting until until another fiber invokes the `signal()` or `broadcast()` method on the cond object. The sleep causes an implicit *fiber.yield()*.

Параметры

- `timeout` – number of seconds to wait, default = forever.

Return If timeout is provided, and a signal doesn't happen for the duration of the timeout, `wait()` returns false. If a signal or broadcast happens, `wait()` returns true.

Rtype boolean

`cond_object:signal()`
Wake up a single fiber that has executed `wait()` for the same variable.

Rtype nil

`cond_object:broadcast()`
Wake up all fibers that have executed `wait()` for the same variable.

Rtype nil

Пример

Assume that a tarantool server is running and listening for connections on localhost port 3301. Assume that guest users have privileges to connect. We will use the tarantoolctl utility to start two clients.

On terminal #1, say

```
$ tarantoolctl connect '3301'
tarantool> fiber = require('fiber')
tarantool> cond = fiber.cond()
tarantool> cond:wait()
```

The job will hang because `cond:wait()` – without an optional timeout argument – will go to sleep until the condition variable changes.

On terminal #2, say

```
$ tarantoolctl connect '3301'
tarantool> cond:signal()
```

Now look again at terminal #1. It will show that the waiting stopped, and the `cond:wait()` function returned `true`.

This example depended on the use of a global conditional variable with the arbitrary name `cond`. In real life, programmers would make sure to use different conditional variable names for different applications.

4.1.11 Module *fio*

Tarantool supports file input/output with an API that is similar to POSIX syscalls. All operations are performed asynchronously. Multiple fibers can access the same file simultaneously.

Common pathname manipulations

`fio.pathjoin(`*partial-string*[, *partial-string ...*]`)`
Concatenate partial string, separated by „/“ to form a path name.

Параметры

- `partial-string` (*string*) – one or more strings to be concatenated.

Return path name

Rtype string

Example:

```
tarantool> fio.pathjoin('/etc', 'default', 'myfile')
---
- /etc/default/myfile
...
```

`fio.basename(`*path-name*[, *suffix*]`)`

Given a full path name, remove all but the final part (the file name). Also remove the suffix, if it is passed.

Параметры

- `path-name` (*string*) – path name
- `suffix` (*string*) – suffix

Return file name

Rtype string

Example:

```
tarantool> fio.basename('/path/to/my.lua', '.lua')
---
- my
...
```

`fio.dirname(`*path-name*`)`

Given a full path name, remove the final part (the file name).

Параметры

- `path-name` (*string*) – path name

Return directory name, that is, path name except for file name.

Rtype string

Example:

```
tarantool> fio.dirname('path/to/my.lua')
---
- 'path/to/'
...
```

Common file manipulations

`fio.umask(`*mask-bits*`)`

Set the mask bits used when creating files or directories. For a detailed description type «man 2 umask».

Параметры

- `mask-bits` (*number*) – mask bits.

Return previous mask bits.

Rtype number

Example:

```
tarantool> fio.umask(tonumber('755', 8))
---
- 493
...
```

fio.lstat(*path-name*)
fio.stat(*path-name*)
Returns information about a file object. For details type «man 2 lstat» or «man 2 stat».

Параметры

- path-name (*string*) – path name of file.

Return fields which describe the file's block size, creation time, size, and other attributes.

Rtype table

Example:

```
tarantool> fio.lstat('/etc')
---
- inode: 1048577
  rdev: 0
  size: 12288
  atime: 1421340698
  mode: 16877
  mtime: 1424615337
  nlink: 160
  uid: 0
  blksize: 4096
  gid: 0
  ctime: 1424615337
  dev: 2049
  blocks: 24
...
```

fio.mkdir(*path-name*[, *mode*])
fio.rmdir(*path-name*)
Create or delete a directory. For details type «man 2 mkdir» or «man 2 rmdir».

Параметры

- path-name (*string*) – path of directory.
- mode (*number*) – Mode bits can be passed as a number or as string constants, for example „“*S_IWUSR*». Mode bits can be combined by enclosing them in braces.

Return true if success, false if failure.

Rtype boolean

Example:

```
tarantool> fio.mkdir('/etc')
---
- false
...
```

fio.glob(*path-name*)
Return a list of files that match an input string. The list is constructed with a single flag that controls the behavior of the function: GLOB_NOESCAPE. For details type «man 3 glob».

Параметры

- path-name (*string*) – path-name, which may contain wildcard characters.

Return list of files whose names match the input string

Rtype table

Possible errors: nil.

Example:

```
tarantool> fio.glob('/etc/x*')
---
- - /etc/xdg
  - /etc/xml
  - /etc/xul-ext
...
```

fio.tempdir()

Return the name of a directory that can be used to store temporary files.

Example:

```
tarantool> fio.tempdir()
---
- /tmp/lG31e7
...
```

fio.cwd()

Return the name of the current working directory.

Example:

```
tarantool> fio.cwd()
---
- /home/username/tarantool_sandbox
...
```

fio.link(*src*, *dst*)
fio.symlink(*src*, *dst*)
fio.readlink(*src*)
fio.unlink(*src*)

Functions to create and delete links. For details type «man readlink», «man 2 link», «man 2 symlink», «man 2 unlink»..

Параметры

- src (*string*) – existing file name.
- dst (*string*) – linked name.

Return fio.link and fio.symlink and fio.unlink return true if success, false if failure. fio.readlink returns the link value if success, nil if failure.

Example:

```
tarantool> fio.link('/home/username/tmp.txt', '/home/username/tmp.txt2')
---
- true
...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> fio.unlink('/home/username/tmp.txt2')
---
- true
...
```

fio.rename(*path-name*, *new-path-name*)

Rename a file or directory. For details type «man 2 rename».

Параметры

- path-name (*string*) – original name.
- new-path-name (*string*) – new name.

Return true if success, false if failure.

Rtype boolean

Example:

```
tarantool> fio.rename('/home/username/tmp.txt', '/home/username/tmp.txt2')
---
- true
...
```

fio.chown(*path-name*, *owner-user*, *owner-group*)
fio.chmod(*path-name*, *new-rights*)

Manage the rights to file objects, or ownership of file objects. For details type «man 2 chown» or «man 2 chmod».

Параметры

- owner-user (*string*) – new user uid.
- owner-group (*string*) – new group uid.
- new-rights (*number*) – new permissions

Example:

```
tarantool> fio.chmod('/home/username/tmp.txt', tonumber('0755', 8))
---
- true
...
tarantool> fio.chown('/home/username/tmp.txt', 'username', 'username')
---
- true
...
```

fio.truncate(*path-name*, *new-size*)

Reduce file size to a specified value. For details type «man 2 truncate».

Параметры

- path-name (*string*) –
- new-size (*number*) –

Return true if success, false if failure.

Rtype boolean

Example:

```
tarantool> fio.truncate('/home/username/tmp.txt', 99999)
---
- true
...
```

fio.sync()

Ensure that changes are written to disk. For details type «man 2 sync».

Return true if success, false if failure.

Rtype boolean

Example:

```
tarantool> fio.sync()
---
- true
...
```

fio.open(*path-name*[, *flags*[, *mode*]])

Open a file in preparation for reading or writing or seeking.

Параметры

- path-name (*string*) –
- flags (*number*) – Flags can be passed as a number or as string constants, for example „O_RDONLY", „O_WRONLY", „O_RDWR". Flags can be combined by enclosing them in braces.
- mode (*number*) – Mode bits can be passed as a number or as string constants, for example „"*S_IWUSR*». Mode bits are significant if flags include *O_CREATE* or *O_TMPFILE*. Mode bits can be combined by enclosing them in braces.

Return file handle (later - fh)

Rtype userdata

Possible errors: nil.

Example:

```
tarantool> fh = fio.open('/home/username/tmp.txt', {'O_RDWR', 'O_APPEND'})
---
...
tarantool> fh -- display file handle returned by fio.open
---
- fh: 11
...
```

object file-handle

file-handle:close()

Close a file that was opened with fio.open. For details type «man 2 close».

Параметры

- fh (*userdata*) – file-handle as returned by fio.open().

Return true if success, false on failure.

Rtype boolean

Example:

```
tarantool> fh:close() -- where fh = file-handle
---
- true
...
```

file-handle:pread(*count*, *offset*)
file-handle:pwrite(*new-string*, *offset*)

Perform read/write random-access operation on a file, without affecting the current seek position of the file. For details type «man 2 pread» or «man 2 pwrite».

Параметры

- fh (*userdata*) – file-handle as returned by `fio.open()`.
- count (*number*) – number of bytes to read
- new-string (*string*) – value to write
- offset (*number*) – offset within file where reading or writing begins

Return `fh:pwrite` returns true if success, false if failure. `fh:pread` returns the data that was read, or nil if failure.

Example:

```
tarantool> fh:pread(25, 25)
---
- |
  elete from t8//
  insert in
...
```

file-handle:read(*count*)
file-handle:write(*new-string*)

Perform non-random-access read or write on a file. For details type «man 2 read» or «man 2 write».

Примечание: `fh:read` and `fh:write` affect the seek position within the file, and this must be taken into account when working on the same file from multiple fibers. It is possible to limit or prevent file access from other fibers with `fiber.ipc`.

Параметры

- fh (*userdata*) – file-handle as returned by `fio.open()`.
- count (*number*) – number of bytes to read
- new-string (*string*) – value to write

Return `fh:write` returns true if success, false if failure. `fh:read` returns the data that was read, or nil if failure.

Example:

```
tarantool> fh:write('new data')
---
```

(continues on next page)

(продолжение с предыдущей страницы)

```
- true
...
```

`file-handle:truncate(new-size)`

Change the size of an open file. Differs from `fio.truncate`, which changes the size of a closed file.

Параметры

- `fh` (*userdata*) – file-handle as returned by `fio.open()`.

Return true if success, false if failure.

Rtype boolean

Example:

```
tarantool> fh:truncate(0)
---
- true
...
```

`file-handle:seek(position[, offset-from])`

Shift position in the file to the specified position. For details type «man 2 seek».

Параметры

- `fh` (*userdata*) – file-handle as returned by `fio.open()`.
- `position` (*number*) – position to seek to
- `offset-from` (*string*) – „SEEK_END" = end of file, „SEEK_CUR" = current position, „SEEK_SET" = start of file.

Return the new position if success

Rtype number

Possible errors: nil.

Example:

```
tarantool> fh:seek(20, 'SEEK_SET')
---
- 20
...
```

`file-handle:stat()`

Return statistics about an open file. This differs from `fio.stat` which return statistics about a closed file. For details type «man 2 stat».

Параметры

- `fh` (*userdata*) – file-handle as returned by `fio.open()`.

Return details about the file.

Rtype table

Example:

```
tarantool> fh:stat()
---
- inode: 729866
  rdev: 0
  size: 100
  atime: 140942855
  mode: 33261
  mtime: 1409430660
  nlink: 1
  uid: 1000
  blksize: 4096
  gid: 1000
  ctime: 1409430660
  dev: 2049
  blocks: 8
...
```

`file-handle:fsync()`
`file-handle:fdatasync()`

Ensure that file changes are written to disk, for an open file. Compare `fio.sync`, which is for all files. For details type «man 2 fsync» or «man 2 fdatasync».

Параметры

- `fh` (*userdata*) – file-handle as returned by `fio.open()`.

Return true if success, false if failure.

Example:

```
tarantool> fh:fsync()
---
- true
...
```

4.1.12 Module *fun*

Luafun, also known as the Lua Functional Library, takes advantage of the features of LuaJIT to help users create complex functions. Inside the module are «sequence processors» such as `map`, `filter`, `reduce`, `zip` – they take a user-written function as an argument and run it against every element in a sequence, which can be faster or more convenient than a user-written loop. Inside the module are «generators» such as `range`, `tabulate`, and `rands` – they return a bounded or boundless series of values. Within the module are «reducers», «filters», «composers» … or, in short, all the important features found in languages like Standard ML, Haskell, or Erlang.

The full documentation is On the luafun section of github. However, the first chapter can be skipped because installation is already done, it's inside Tarantool. All that is needed is the usual `require` request. After that, all the operations described in the Lua fun manual will work, provided they are preceded by the name returned by the `require` request. For example:

```
tarantool> fun = require('fun')
---
...
tarantool> for _k, a in fun.range(3) do
         >   print(a)
         > end
```

(continues on next page)

(продолжение с предыдущей страницы)

```
1
2
3
---
...
```

4.1.13 Module *json*

The json module provides JSON manipulation routines. It is based on the Lua-CJSON module by Mark Pulford. For a complete manual on Lua-CJSON please read the official documentation.

`json.encode(`*lua-value*`)`

Convert a Lua object to a JSON string.

Параметры

- `lua_value` – either a scalar value or a Lua table value.

Return the original value reformatted as a JSON string.

Rtype string

Example:

```
tarantool> json=require('json')
---
...
tarantool> json.encode(123)
---
- '123'
...
tarantool> json.encode({123})
---
- '[123]'
...
tarantool> json.encode({123, 234, 345})
---
- '[123,234,345]'
...
tarantool> json.encode({abc = 234, cde = 345})
---
- '{"cde":345,"abc":234}'
...
tarantool> json.encode({hello = {'world'}})
---
- '{"hello":["world"]}'
...
```

`json.decode(`*string*`)`

Convert a JSON string to a Lua object.

Параметры

- `string` (*string*) – a string formatted as JSON.

Return the original contents formatted as a Lua table.

Rtype table

Example:

```
tarantool> json = require('json')
---
...
tarantool> json.decode('123')
---
- 123
...
tarantool> json.decode('[123, "hello"]')
---
- [123, 'hello']
...
tarantool> json.decode('{"hello": "world"}').hello
---
- world
...
```

`json.NULL`
A value comparable to Lua «nil» which may be useful as a placeholder in a tuple.

Example:

```
-- When nil is assigned to a Lua-table field, the field is null
tarantool> {nil, 'a', 'b'}
---
- - null
  - a
  - b
...
-- When json.NULL is assigned to a Lua-table field, the field is json.NULL
tarantool> {json.NULL, 'a', 'b'}
---
- - null
  - a
  - b
...
-- When json.NULL is assigned to a JSON field, the field is null
tarantool> json.encode({field2 = json.NULL, field1 = 'a', field3 = 'c'}
---
- '{"field2":null,"field1":"a","field3":"c"}'
...
```

The JSON output structure can be specified with `__serialize`:

- `__serialize="seq"` for an array
- `__serialize="map"` for a map

Serializing „A“ and „B“ with different `__serialize` values causes different results:

```
tarantool> json.encode(setmetatable({'A', 'B'}, { __serialize="seq"}))
---
- '["A","B"]'
...
tarantool> json.encode(setmetatable({'A', 'B'}, { __serialize="map"}))
---
- '{"1":"A","2":"B"}'
...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> json.encode({setmetatable({f1 = 'A', f2 = 'B'}, { __serialize="map"})})
---
- '[{"f2":"B","f1":"A"}]'
...
tarantool> json.encode({setmetatable({f1 = 'A', f2 = 'B'}, { __serialize="seq"})})
---
- '[[]]'
...
```

Configuration settings

There are configuration settings which affect the way that Tarantool encodes invalid numbers or types. They are all boolean `true`/`false` values

- `cfg.encode_invalid_numbers` (default is true) – allow nan and inf
- `cfg.encode_use_tostring` (default is false) – use tostring for unrecognizable types
- `cfg.encode_invalid_as_nil` (default is false) – use null for all unrecognizable types
- `cfg.encode_load_metatables` (default is false) – load metatables

For example, the following code will interpret 0/0 (which is «not a number») and 1/0 (which is «infinity») as special values rather than nulls or errors:

```
json = require('json')
json.cfg{encode_invalid_numbers = true}
x = 0/0
y = 1/0
json.encode({1, x, y, 2})
```

The result of the json.encode request will look like this:

```
tarantool> json.encode({1, x, y, 2})
---
- '[1,nan,inf,2]
...
```

The same configuration settings exist for json, for *MsgPack*, and for *YAML*.

4.1.14 Module *log*

The Tarantool server puts all diagnostic messages in a log file specified by the *logger* configuration parameter. Diagnostic messages may be either system-generated by the server's internal code, or user-generated with the `log.`*`log_level`* function.

`log.error(`*message*`)`
`log.warn(`*message*`)`
`log.info(`*message*`)`
`log.debug(`*message*`)`

Output a user-generated message to the *log file*, given log_level_function_name = `error` or `warn` or `info` or `debug`.

Параметры

- `message` (*string*) – The actual output will be a line containing the current timestamp, a module name, „E“ or „W“ or „I“ or „D“ or „R“ depending on `log_level_function_name`, and `message`. Output will not occur if `log_level_function_name` is for a type greater than *log_level*. Messages may contain C-style format specifiers %d or %s, so `log.error('...%d...%s', x, y)` will work if x is a number and y is a string.

Return nil

`log.logger_pid()`

`log.rotate()`

Пример

```
$ ~/tarantool/src/tarantool
$ less tarantool.txt
tarantool> box.cfg{log_level=3, logger='tarantool.txt'}
tarantool> log = require('log')
tarantool> log.error('Error')
tarantool> log.info('Info %s', box.info.version)
tarantool> os.exit()
```

```
2...0 [5257] main/101/interactive C> version 1.7.0-355-ga4f762d
2...1 [5257] main/101/interactive C> log level 3
2...1 [5261] main/101/spawner C> initialized
2...0 [5257] main/101/interactive [C]:-1 E> Error
```

The „Error“ line is visible in tarantool.txt preceded by the letter E.

The „Info“ line is not present because the log_level is 3.

4.1.15 Модуль *msgpack*

The `msgpack` module takes strings in MsgPack format and decodes them, or takes a series of non-MsgPack values and encodes them.

`msgpack.encode(`*lua_value*`)`
Convert a Lua object to a MsgPack string.

Параметры

- `lua_value` – either a scalar value or a Lua table value.

Return the original value reformatted as a MsgPack string.

Rtype string

`msgpack.decode(`*string*`)`
Convert a MsgPack string to a Lua object.

Параметры

- `string` – a string formatted as MsgPack.

- the original contents formatted as a Lua table;
- the number of bytes that were decoded.

Rtype lua object

msgpack.NULL
A value comparable to Lua «nil» which may be useful as a placeholder in a tuple.

Пример

```
tarantool> msgpack = require('msgpack')
---
...
tarantool> y = msgpack.encode({'a',1,'b',2})
---
...
tarantool> z = msgpack.decode(y)
---
...
tarantool> z[1], z[2], z[3], z[4]
---
- a
- 1
- b
- 2
...
tarantool> box.space.tester:insert{20, msgpack.NULL, 20}
---
- [20, null, 20]
...
```

The MsgPack output structure can be specified with `__serialize`:

- `__serialize = "seq"` or `"sequence"` for an array
- `__serialize = "map"` or `"mapping"` for a map

Serializing „A“ and „B“ with different `__serialize` values causes different results. To show this, here is a routine which encodes *{„A“,“B“}* both as an array and as a map, then displays each result in hexadecimal.

```
function hexdump(bytes)
    local result = ''
    for i = 1, #bytes do
        result = result .. string.format("%x", string.byte(bytes, i)) .. ' '
    end
    return result
end

msgpack = require('msgpack')
m1 = msgpack.encode(setmetatable({'A', 'B'}, {
                             __serialize = "seq"
                          }))
m2 = msgpack.encode(setmetatable({'A', 'B'}, {
                             __serialize = "map"
                          }))
print('array encoding: ', hexdump(m1))
print('map encoding: ', hexdump(m2))
```

Result:

```
array encoding: 92 a1 41 a1 42
```

```
map encoding:   82 01 a1 41 02 a1 42
```

The MsgPack Specification page explains that the first encoding means:

```
fixarray(2), fixstr(1), "A", fixstr(1), "B"
```

and the second encoding means:

```
fixmap(2), key(1), fixstr(1), "A", key(2), fixstr(2), "B".
```

Here are examples for all the common types, with the Lua-table representation on the left, with the MsgPack format name and encoding on the right.

Common Types and MsgPack Encodings

{}	„fixmap" if metatable is „map" = 80 otherwise „fixarray" = 90
„a"	„fixstr" = a1 61
false	„false" = c2
true	„true" = c3
127	„positive fixint" = 7f
65535	„uint 16" = cd ff ff
4294967295	„uint 32" = ce ff ff ff ff
nil	„nil" = c0
msgpack.NULL	same as nil
[0] = 5	„fixmap(1)" + „positive fixint" (for the key) + „positive fixint" (for the value) = 81 00 05
[0] = nil	„fixmap(0)" = 80 – nil is not stored when it is a missing map value
1.5	„float 64" = cb 3f f8 00 00 00 00 00 00

Also, some MsgPack configuration settings for encoding can be changed, in the same way that they can be changed for *JSON*.

4.1.16 Модуль *net.box*

The `net.box` module contains connectors to remote database systems. One variant, to be discussed later, is connecting to MySQL or MariaDB or PostgreSQL (see *SQL DBMS modules* reference). The other variant, which is discussed in this section, is connecting to Tarantool servers via a network using the built-in `net.box` module.

You can call the following methods:

- `require('net.box')` to get a `net.box` object (named `net_box` for examples in this section),
- `net_box.connect()` to connect and get a connection object (named `conn` for examples in this section),
- other `net.box()` routines, passing `conn:`, to execute requests on a remote box,
- `conn:close` to disconnect.

All `net.box` methods are fiber-safe, that is, it is safe to share and use the same connection object across multiple concurrent fibers. In fact, it's perhaps the best programming practice with Tarantool. When multiple fibers use the same connection, all requests are pipelined through the same network socket, but each fiber gets back a correct response. Reducing the number of active sockets lowers the overhead of system calls and increases the overall server performance. There are, however, cases when a single connection is not enough — for example, when it's necessary to prioritize requests or to use different authentication IDs.

The diagram below shows possible connection states and transitions:

On this diagram:

- The state machine starts in the „initial" state.
- `net_box.connect()` method changes the state to „connecting" and spawns a worker fiber.
- If authentication and schema upload are required, it's possible later on to re-enter the „fetch_schema" state from „active" if a request fails due to a schema version mismatch error, so schema reload is triggered.
- `conn.close()` method sets the state to „closed" and kills the worker. If the transport is already in the „error" state, `close()` does nothing.

`net_box.connect(`*URI*[, *{option[s]}*]`)`

`net_box.new(`*URI*[, *{option[s]}*]`)`

Примечание: The names `connect()` and `new()` are synonymous with the only difference that `connect()` is the preferred name, while `new()` is retained for backward compatibility.

Create a new connection. The connection is established on demand, at the time of the first request. It can be re-established automatically after a disconnect (see `reconnect_after` option below). The returned `conn` object supports methods for making remote requests, such as select, update or delete.

For a local Tarantool server, there is a pre-created always-established connection object named `net_box.self`. Its purpose is to make polymorphic use of the `net_box` API easier. Therefore `conn = net_box.connect('localhost:3301')` can be replaced by `conn = net_box.self`. However, there is an important difference between the embedded connection and a remote one. With the embedded connection, requests which do not modify data do not yield. When using a remote connection, due to *the implicit rules* any request can yield, and database state may have changed by the time it regains control.

Possible options:

- *wait_connected*: by default, connection creation is blocked until the connection is established, but passing `wait_connected=false` makes it return immediately. Also, passing a timeout makes it wait before returning (e.g. `wait_connected=1.5` makes it wait at most 1.5 secs).

  Примечание: In the presence of `reconnect_after`, `wait_connected` ignores transient failures. The wait completes once the connection is established or is closed explicitly.

- *reconnect_after*: a `net.box` instance automatically reconnects any time the connection is broken or if a connection attempt fails. This makes transient network failures become transparent to the application. Reconnect happens automatically in the background, so queries/requests that suffered due to connectivity loss are transparently retried. The number of retries is unlimited, connection attempts are done over the specified timeout (e.g. `reconnect_after=5` for 5 secs). Once a connection is explicitly closed (or garbage-collected), reconnects stop.
- *call_16*: [since 1.7.2] by default, `net.box` connections comply with a new binary protocol command for CALL, which is not backward compatible with previous versions. The new CALL no longer restricts a function to returning an array of tuples and allows returning an arbitrary MsgPack/JSON result, including scalars, nil and void (nothing). The old CALL is left intact for backward compatibility. It will be removed in the next major release. All programming language drivers will be gradually changed to use the new CALL. To connect to a Tarantool instance that uses the old CALL, specify `call_16=true`.

- *console*: depending on the option's value, the connection supports different methods (as if instances of different classes were returned). With `console = true`, you can use `conn` methods `close()`, `is_connected()`, `wait_state()`, `eval()` (in this case, both binary and Lua console network protocols are supported). With `console = false` (default), you can also use `conn` database methods (in this case, only the binary protocol is supported).

  Параметры

  - `URI` (*string*) – the *URI* of the target for the connection
  - `options` – possible options are *wait_connected*, *reconnect_after*, *call_16* and *console*

  Return conn object

  Rtype userdata

Example:

```
conn = net_box.connect('localhost:3301')
conn = net_box.connect('127.0.0.1:3302', {wait_connected = false})
conn = net_box.connect('127.0.0.1:3303', {reconnect_after = 5, call_16 = true})
```

`object conn`

`conn:ping()`

Execute a PING command.

Return true on success, false on error

Rtype boolean

Example:

```
net_box.self:ping()
```

`conn:wait_connected([timeout])`

Wait for connection to be active or closed.

Параметры

- `timeout` (*number*) – in seconds

Return true when connected, false on failure.

Rtype boolean

Example:

```
net_box.self:wait_connected()
```

`conn:is_connected()`

Show whether connection is active or closed.

Return true if connected, false on failure.

Rtype boolean

Example:

```
net_box.self:is_connected()
```

conn:wait_state(*state[s]*[, *timeout*])
[since 1.7.2] Wait for a target state.

Параметры

- states (*string*) – target states
- timeout (*number*) – in seconds

Return true when a target state is reached, false on timeout or connection closure

Rtype boolean

Example:

```
-- wait infinitely for 'active' state:
conn:wait_state('active')

-- wait for 1.5 secs at most:
conn:wait_state('active', 1.5)

-- wait infinitely for either `active` or `fetch_schema` state:
conn:wait_state({active=true, fetch_schema=true})
```

conn:close()
Close a connection.

Connection objects are garbage collected just like any other objects in Lua, so an explicit destruction is not mandatory. However, since close() is a system call, it is good programming practice to close a connection explicitly when it is no longer needed, to avoid lengthy stalls of the garbage collector.

Example:

```
conn:close()
```

conn.space.<space-name>:select{field-value, ...}
conn.space.*space-name*:select{...} is the remote-call equivalent of the local call box.space.*space-name*:select{...}.

Примечание: Due to *the implicit yield rules* a local box.space.*space-name*:select{...} does not yield, but a remote conn.space.*space-name*:select{...} call does yield, so global variables or database tuples data may change when a remote conn.space.*space-name*:select{...} occurs.

conn.space.<space-name>:get{field-value, ...}
conn.space.*space-name*:get(...) is the remote-call equivalent of the local call box.space.*space-name*:get(...).

conn.space.<space-name>:insert{field-value, ...}
conn.space.*space-name*:insert(...) is the remote-call equivalent of the local call box.space.*space-name*:insert(...).

conn.space.<space-name>:replace{field-value, ...}
conn.space.*space-name*:replace(...) is the remote-call equivalent of the local call box.space.*space-name*:replace(...).

conn.space.<space-name>:update{field-value, ...}
conn.space.*space-name*:update(...) is the remote-call equivalent of the local call box.space.*space-name*:update(...).

conn.space.<space-name>:upsert{field-value, ...}
: conn.space.*space-name*:upsert(...) is the remote-call equivalent of the local call box.space.*space-name*:upsert(...).

conn.space.<space-name>:delete{field-value, ...}
: conn.space.*space-name*:delete(...) is the remote-call equivalent of the local call box.space.*space-name*:delete(...).

conn:call(*function-name*[, *arguments*])
: conn:call('func', '1', '2', '3') is the remote-call equivalent of func('1', '2', '3'). That is, conn:call is a remote stored-procedure call.

Example:

```
conn:call('function5')
```

conn:eval(*Lua-string*)
: conn:eval(*Lua-string*) evaluates and executes the expression in Lua-string, which may be any statement or series of statements. An *execute privilege* is required; if the user does not have it, an administrator may grant it with box.schema.user.grant(*username*, 'execute', 'universe').

Example:

```
conn:eval('return 5+5')
```

conn:timeout(*timeout*)
: timeout(...) is a wrapper which sets a timeout for the request that follows it.

Example:

```
conn:timeout(0.5).space.tester:update({1}, {{'=', 2, 15}})
```

All remote calls support execution timeouts. Using a wrapper object makes the remote connection API compatible with the local one, removing the need for a separate timeout argument, which the local version would ignore. Once a request is sent, it cannot be revoked from the remote server even if a timeout expires: the timeout expiration only aborts the wait for the remote server response, not the request itself.

Пример

This example shows the use of most of the net.box methods.

The sandbox configuration for this example assumes that:

- the Tarantool server is running on localhost 127.0.0.1:3301,
- there is a space named tester with a numeric primary key and with a tuple that contains a key value = 800,
- the current user has read, write and execute privileges.

Here are commands for a quick sandbox setup:

```
box.cfg{listen = 3301}
s = box.schema.space.create('tester')
s:create_index('primary', {type = 'hash', parts = {1, 'unsigned'}})
t = s:insert({800, 'TEST'})
box.schema.user.grant('guest', 'read,write,execute', 'universe')
```

And here starts the example:

```
tarantool> net_box = require('net.box')
---
...
tarantool> function example()
         >   local conn, wtuple
         >   if net_box.self:ping() then
         >     table.insert(ta, 'self:ping() succeeded')
         >     table.insert(ta, '  (no surprise -- self connection is pre-established)')
         >   end
         >   if box.cfg.listen == '3301' then
         >     table.insert(ta,'The local server listen address = 3301')
         >   else
         >     table.insert(ta, 'The local server listen address is not 3301')
         >     table.insert(ta, '(  (maybe box.cfg{...listen="3301"...} was not stated)')
         >     table.insert(ta, '(  (so connect will fail)')
         >   end
         >   conn = net_box.connect('127.0.0.1:3301')
         >   conn.space.tester:delete{800}
         >   table.insert(ta, 'conn delete done on tester.')
         >   conn.space.tester:insert{800, 'data'}
         >   table.insert(ta, 'conn insert done on tester, index 0')
         >   table.insert(ta, '  primary key value = 800.')
         >   wtuple = conn.space.tester:select{800}
         >   table.insert(ta, 'conn select done on tester, index 0')
         >   table.insert(ta, '  number of fields = ' .. #wtuple)
         >   conn.space.tester:delete{800}
         >   table.insert(ta, 'conn delete done on tester')
         >   conn.space.tester:replace{800, 'New data', 'Extra data'}
         >   table.insert(ta, 'conn:replace done on tester')
         >   conn:timeout(0.5).space.tester:update({800}, {{'=', 2, 'Fld#1'}})
         >   table.insert(ta, 'conn update done on tester')
         >   conn:close()
         >   table.insert(ta, 'conn close done')
         > end
---
...
tarantool> ta = {}
---
...
tarantool> example()
---
...
tarantool> ta
---
- - self:ping() succeeded
  - '  (no surprise -- self connection is pre-established)'
  - The local server listen address = 3301
  - conn delete done on tester.
  - conn insert done on tester, index 0
  - '  primary key value = 800.'
  - conn select done on tester, index 0
  - '  number of fields = 1'
  - conn delete done on tester
  - conn:replace done on tester
  - conn update done on tester
  - conn close done
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
```

4.1.17 Функция *box.once*

box.once(*key*, *function*[, *...*])

Execute a function, provided it has not been executed before. A passed value is checked to see whether the function has already been executed. If it has been executed before, nothing happens. If it has not been executed before, the function is invoked. For an explanation why `box.once` is useful, see the section *Preventing Duplicate Actions*.

Параметры

- `key` (*string*) – a value that will be checked
- `function` (*function*) – a function
- `...` – arguments, that must be passed to function

4.1.18 Модуль *pickle*

pickle.pack(*format*, *argument*[, *argument ...*])

To use Tarantool binary protocol primitives from Lua, it's necessary to convert Lua variables to binary format. The `pickle.pack()` helper function is prototyped after Perl „pack".

Format specifiers

b, B	converts Lua variable to a 1-byte integer, and stores the integer in the resulting string
s, S	converts Lua variable to a 2-byte integer, and stores the integer in the resulting string, low byte first
i, I	converts Lua variable to a 4-byte integer, and stores the integer in the resulting string, low byte first
l, L	converts Lua variable to an 8-byte integer, and stores the integer in the resulting string, low byte first
n	converts Lua variable to a 2-byte integer, and stores the integer in the resulting string, big endian,
N	converts Lua variable to a 4-byte integer, and stores the integer in the resulting string, big
q, Q	converts Lua variable to an 8-byte integer, and stores the integer in the resulting string, big endian,
f	converts Lua variable to a 4-byte float, and stores the float in the resulting string
d	converts Lua variable to a 8-byte double, and stores the double in the resulting string
a, A	converts Lua variable to a sequence of bytes, and stores the sequence in the resulting string

Параметры

- `format` (*string*) – string containing format specifiers
- `argument(s)` (*scalar-value*) – scalar values to be formatted

Return a binary string containing all arguments, packed according to the format specifiers.

Rtype string

Possible errors: unknown format specifier.

Example:

```
tarantool> pickle = require('pickle')
---
...
tarantool> box.space.tester:insert{0, 'hello world'}
---
- [0, 'hello world']
...
tarantool> box.space.tester:update({0}, {{'=', 2, 'bye world'}})
---
- [0, 'bye world']
...
tarantool> box.space.tester:update({0}, {
         >   {'=', 2, pickle.pack('iiA', 0, 3, 'hello')}
         > })
---
- [0, "\0\0\0\0\x03\0\0\0hello"]
...
tarantool> box.space.tester:update({0}, {{'=', 2, 4}})
---
- [0, 4]
...
tarantool> box.space.tester:update({0}, {{'+', 2, 4}})
---
- [0, 8]
...
tarantool> box.space.tester:update({0}, {{'^', 2, 4}})
---
- [0, 12]
...
```

`pickle.unpack(`*format*, *binary-string*`)`

Counterpart to `pickle.pack()`. Warning: if format specifier „A" is used, it must be the last item.

Параметры

- `format` (*string*) –
- `binary-string` (*string*) –

Return A list of strings or numbers.

Rtype table

Example:

```
tarantool> pickle = require('pickle')
---
...
tarantool> tuple = box.space.tester:replace{0}
---
...
tarantool> string.len(tuple[1])
---
- 1
...
tarantool> pickle.unpack('b', tuple[1])
```

(continues on next page)

(продолжение с предыдущей страницы)

```
---
- 48
...
tarantool> pickle.unpack('bsi', pickle.pack('bsi', 255, 65535, 4294967295))
---
- 255
- 65535
- 4294967295
...
tarantool> pickle.unpack('ls', pickle.pack('ls', tonumber64('18446744073709551615'), 65535))
---
...
tarantool> num, num64, str = pickle.unpack('slA', pickle.pack('slA', 666,
         > tonumber64('666666666666666'), 'string'))
---
...
```

4.1.19 Модуль *socket*

The `socket` module allows exchanging data via BSD sockets with a local or remote host in connection-oriented (TCP) or datagram-oriented (UDP) mode. Semantics of the calls in the `socket` API closely follow semantics of the corresponding POSIX calls. Function names and signatures are mostly compatible with luasocket.

The functions for setting up and connecting are `socket`, `sysconnect`, `tcp_connect`. The functions for sending data are `send`, `sendto`, `write`, `syswrite`. The functions for receiving data are `recv`, `recvfrom`, `read`. The functions for waiting before sending/receiving data are `wait`, `readable`, `writable`. The functions for setting flags are `nonblock`, `setsockopt`. The functions for stopping and disconnecting are `shutdown`, `close`. The functions for error checking are `errno`, `error`.

Socket functions

Purposes	Names
setup	*socket()*
«»	*socket.tcp_connect()*
«»	*socket.tcp_server()*
«»	*socket_object:sysconnect()*
«»	*socket_object:send()*
sending	*socket_object:sendto()*
«»	*socket_object:write()*
«»	*socket_object:syswrite()*
receiving	*socket_object:recv()*
«»	*socket_object:recvfrom()*
«»	*socket_object:read()*
flag setting	*socket_object:nonblock()*
«»	*socket_object:setsockopt()*
«»	*socket_object:linger()*
client/server	*socket_object:listen()*
«»	*socket_object:accept()*
teardown	*socket_object:shutdown()*
«»	*socket_object:close()*
error checking	*socket_object:error()*
«»	*socket_object:errno()*
information	*socket.getaddrinfo()*
«»	*socket_object:getsockopt()*
«»	*socket_object:peer()*
«»	*socket_object:name()*
state checking	*socket_object:readable()*
«»	*socket_object:writable()*
«»	*socket_object:wait()*
«»	*socket.iowait()*

Typically a socket session will begin with the setup functions, will set one or more flags, will have a loop with sending and receiving functions, will end with the teardown functions – as an example at the end of this section will show. Throughout, there may be error-checking and waiting functions for synchronization. To prevent a fiber containing socket functions from «blocking» other fibers, the *implicit yield rules* will cause a yield so that other processes may take over, as is the norm for cooperative multitasking.

For all examples in this section the socket name will be sock and the function invocations will look like `sock:function_name(...)`.

`socket.__call`(*domain*, *type*, *protocol*)

Create a new TCP or UDP socket. The argument values are the same as in the Linux socket(2) man page.

Return an unconnected socket, or nil.

Rtype userdata

Example:

```
socket('AF_INET', 'SOCK_STREAM', 'tcp')
```

`socket.tcp_connect`(*host*[, *port*[, *timeout*]])

Connect a socket to a remote host.

Параметры

- host (*string*) – URL or IP address
- port (*number*) – port number
- timeout (*number*) – timeout

Return a connected socket, if no error.

Rtype userdata

Example:

```
socket.tcp_connect('127.0.0.1', 3301)
```

socket.getaddrinfo(*host*, *type*[, *{option-list}*])

The socket.getaddrinfo() function is useful for finding information about a remote site so that the correct arguments for sock:sysconnect() can be passed.

Return A table containing these fields: «host», «family», «type», «protocol», «port».

Rtype table

Example:

socket.getaddrinfo('tarantool.org', 'http') will return variable information such as

```
---
- - host: 188.93.56.70
    family: AF_INET
    type: SOCK_STREAM
    protocol: tcp
    port: 80
  - host: 188.93.56.70
    family: AF_INET
    type: SOCK_DGRAM
    protocol: udp
    port: 80
...
```

socket.tcp_server(*host*, *port*, *handler-function*[, *timeout*])

The socket.tcp_server() function makes Tarantool act as a server that can accept connections. Usually the same objective is accomplished with *box.cfg{listen=. . . }*.

Параметры

- host (*string*) – host name or IP
- port (*number*) – host port, may be 0
- handler (*function/table*) – what to execute when a connection occurs
- timeout (*number*) – number of seconds to wait before timing out

The handler-function parameter may be a function name (for example function_55), a function declaration (for example function () print('!') end), or a table including handler = function (for example {handler=function_55, name='A'}).

Example:

```
socket.tcp_server('localhost', 3302, function () end)
```

object socket_object

`socket_object:sysconnect(`*host*, *port*`)`

Connect an existing socket to a remote host. The argument values are the same as in tcp_connect(). The host must be an IP address.

Parameters:

- **Either:**
  - host - a string representation of an IPv4 address or an IPv6 address;
  - port - a number.
- **Or:**
  - host - a string containing «unix/»;
  - port - a string containing a path to a unix socket.
- **Or:**
  - host - a number, 0 (zero), meaning «all local interfaces»;
  - port - a number. If a port number is 0 (zero), the socket will be bound to a random local port.

Return the socket object value may change if sysconnect() succeeds.

Rtype boolean

Example:

```
socket = require('socket')
sock = socket('AF_INET', 'SOCK_STREAM', 'tcp')
sock:sysconnect(0, 3301)
```

`socket_object:send(`*data*`)`
`socket_object:write(`*data*`)`

Send data over a connected socket.

Параметры

- `data` (*string*) –

Return the number of bytes sent.

Rtype number

Possible errors: nil on error.

`socket_object:syswrite(`*size*`)`

Write as much as possible data to the socket buffer if non-blocking. Rarely used. For details see this description.

`socket_object:recv(`*size*`)`

Read `size` bytes from a connected socket. An internal read-ahead buffer is used to reduce the cost of this call.

Параметры

- `size` (*integer*) –

Return a string of the requested length on success.

Rtype string

Possible errors: On error, returns an empty string, followed by status, errno, errstr. In case the writing side has closed its end, returns the remainder read from the socket (possibly an empty string), followed by «eof» status.

socket_object:read(*limit*[, *timeout*])

socket_object:read(*delimiter*[, *timeout*])

socket_object:read(*{limit=limit}*[, *timeout*])

socket_object:read(*{delimiter=delimiter}*[, *timeout*])

socket_object:read(*{limit=limit, delimiter=delimiter}*[, *timeout*])

Read from a connected socket until some condition is true, and return the bytes that were read. Reading goes on until `limit` bytes have been read, or a delimiter has been read, or a timeout has expired.

Параметры

- `limit` (*integer*) – maximum number of bytes to read, for example 50 means «stop after 50 bytes»
- `delimiter` (*string*) – separator for example „?" means «stop after a question mark»
- `timeout` (*number*) – maximum number of seconds to wait for example 50 means «stop after 50 seconds».

Return an empty string if there is nothing more to read, or a nil value if error, or a string up to `limit` bytes long, which may include the bytes that matched the `delimiter` expression.

Rtype string

socket_object:sysread(*size*)

Return data from the socket buffer if non-blocking. In case the socket is blocking, `sysread()` can block the calling process. Rarely used. For details, see also this description.

Параметры

- `size` (*integer*) – maximum number of bytes to read, for example 50 means «stop after 50 bytes»

Return an empty string if there is nothing more to read, or a nil value if error, or a string up to `size` bytes long.

Rtype string

socket_object:bind(*host*[, *port*])

Bind a socket to the given host/port. A UDP socket after binding can be used to receive data (see *socket_object.recvfrom*). A TCP socket can be used to accept new connections, after it has been put in listen mode.

Параметры

- `host` –
- `port` –

Return a socket object on success

Rtype userdata

Possible errors: Returns nil, status, errno, errstr on error.

`socket_object:listen(backlog)`
Start listening for incoming connections.

Параметры

- `backlog` – On Linux the listen `backlog` backlog may be from /proc/sys/net/core/somaxconn, on BSD the backlog may be `SOMAXCONN`.

Return true for success, false for error.

Rtype boolean.

`socket_object:accept()`
Accept a new client connection and create a new connected socket. It is good practice to set the socket's blocking mode explicitly after accepting.

Return new socket if success.

Rtype userdata

Possible errors: nil.

`socket_object:sendto(host, port, data)`
Send a message on a UDP socket to a specified host.

Параметры

- `host` (*string*) –
- `port` (*number*) –
- `data` (*string*) –

Return the number of bytes sent.

Rtype number

Possible errors: on error, returns status, errno, errstr.

`socket_object:recvfrom(limit)`
Receive a message on a UDP socket.

Параметры

- `limit` (*integer*) –

Return message, a table containing «host», «family» and «port» fields.

Rtype string, table

Possible errors: on error, returns status, errno, errstr.

Example:

After `message_content, message_sender = recvfrom(1)` the value of `message_content` might be a string containing „X" and the value of `message_sender` might be a table containing

```
message_sender.host = '18.44.0.1'
message_sender.family = 'AF_INET'
message_sender.port = 43065
```

`socket_object:shutdown(how)`
Shutdown a reading end, a writing end, or both ends of a socket.

Параметры

- `how` – socket.SHUT_RD, socket.SHUT_WR, or socket.SHUT_RDWR.

Return true or false.

Rtype boolean

`socket_object:close()`

Close (destroy) a socket. A closed socket should not be used any more. A socket is closed automatically when its userdata is garbage collected by Lua.

Return true on success, false on error. For example, if sock is already closed, sock:close() returns false.

Rtype boolean

`socket_object:error()`
`socket_object:errno()`

Retrieve information about the last error that occurred on a socket, if any. Errors do not cause throwing of exceptions so these functions are usually necessary.

Return result for `sock:errno()`, result for `sock:error()`. If there is no error, then `sock:errno()` will return 0 and `sock:error()`.

Rtype number, string

`socket_object:setsockopt(`*level*, *name*, *value*`)`

Set socket flags. The argument values are the same as in the Linux getsockopt(2) man page. The ones that Tarantool accepts are:

- SO_ACCEPTCONN
- SO_BINDTODEVICE
- SO_BROADCAST
- SO_DEBUG
- SO_DOMAIN
- SO_ERROR
- SO_DONTROUTE
- SO_KEEPALIVE
- SO_MARK
- SO_OOBINLINE
- SO_PASSCRED
- SO_PEERCRED
- SO_PRIORITY
- SO_PROTOCOL
- SO_RCVBUF
- SO_RCVBUFFORCE
- SO_RCVLOWAT
- SO_SNDLOWAT
- SO_RCVTIMEO
- SO_SNDTIMEO
- SO_REUSEADDR

- SO_SNDBUF
- SO_SNDBUFFORCE
- SO_TIMESTAMP
- SO_TYPE

Setting SO_LINGER is done with `sock:linger(active)`.

`socket_object:getsockopt(`*level*, *name*`)`

Get socket flags. For a list of possible flags see `sock:setsockopt()`.

`socket_object:linger(`[*active*]`)`

Set or clear the SO_LINGER flag. For a description of the flag, see the Linux man page.

Параметры

- `active` (*boolean*) –

Return new active and timeout values.

`socket_object:nonblock(`[*flag*]`)`

- `sock:nonblock()` returns the current flag value.
- `sock:nonblock(false)` sets the flag to false and returns false.
- `sock:nonblock(true)` sets the flag to true and returns true.

This function may be useful before invoking a function which might otherwise block indefinitely.

`socket_object:readable(`[*timeout*]`)`

Wait until something is readable, or until a timeout value expires.

Return true if the socket is now readable, false if timeout expired;

`socket_object:writable(`[*timeout*]`)`

Wait until something is writable, or until a timeout value expires.

Return true if the socket is now writable, false if timeout expired;

`socket_object:wait(`[*timeout*]`)`

Wait until something is either readable or writable, or until a timeout value expires.

Return „R" if the socket is now readable, „W" if the socket is now writable, „RW" if the socket is now both readable and writable, „" (empty string) if timeout expired;

`socket_object:name()`

The `sock:name()` function is used to get information about the near side of the connection. If a socket was bound to `xyz.com:45`, then `sock:name` will return information about `[host:xyz.com, port:45]`. The equivalent POSIX function is `getsockname()`.

Return A table containing these fields: «host», «family», «type», «protocol», «port».

Rtype table

`socket_object:peer()`

The `sock:peer()` function is used to get information about the far side of a connection. If a TCP connection has been made to a distant host `tarantool.org:80`, `sock:peer()` will return information about `[host:tarantool.org, port:80]`. The equivalent POSIX function is `getpeername()`.

Return A table containing these fields: «host», «family», «type», «protocol», «port».

Rtype table

socket.iowait(*fd*, *read-or-write-flags*[, *timeout*])

The socket.iowait() function is used to wait until read-or-write activity occurs for a file descriptor.

Параметры

- fd – file descriptor
- read-or-write-flags – „R" or 1 = read, „W" or 2 = write, „RW" or 3 = read|write.
- timeout – number of seconds to wait

If the fd parameter is nil, then there will be a sleep until the timeout. If the timeout parameter is nil or unspecified, then timeout is infinite.

Ordinarily the return value is the activity that occurred („R" or „W" or „RW" or 1 or 2 or 3). If the timeout period goes by without any reading or writing, the return is an error = ETIMEDOUT.

Example: socket.iowait(sock:fd(), 'r', 1.11)

Примеры:

Use of a TCP socket over the Internet

In this example a connection is made over the internet between the Tarantool server and tarantool.org, then an HTTP «head» message is sent, and a response is received: «HTTP/1.1 200 OK» or something else if the site has moved. This is not a useful way to communicate with this particular site, but shows that the system works.

```
tarantool> socket = require('socket')
---
...
tarantool> sock = socket.tcp_connect('tarantool.org', 80)
---
...
tarantool> type(sock)
---
- table
...
tarantool> sock:error()
---
- null
...
tarantool> sock:send("HEAD / HTTP/1.0\r\nHost: tarantool.org\r\n\r\n")
---
- 40
...
tarantool> sock:read(17)
---
- HTTP/1.1 302 Move
...
tarantool> sock:close()
---
- true
...
```

Use of a UDP socket on localhost

Here is an example with datagrams. Set up two connections on 127.0.0.1 (localhost): `sock_1` and `sock_2`. Using `sock_2`, send a message to `sock_1`. Using `sock_1`, receive a message. Display the received message. Close both connections. This is not a useful way for a computer to communicate with itself, but shows that the system works.

```
tarantool> socket = require('socket')
---
...
tarantool> sock_1 = socket('AF_INET', 'SOCK_DGRAM', 'udp')
---
...
tarantool> sock_1:bind('127.0.0.1')
---
- true
...
tarantool> sock_2 = socket('AF_INET', 'SOCK_DGRAM', 'udp')
---
...
tarantool> sock_2:sendto('127.0.0.1', sock_1:name().port,'X')
---
- true
...
tarantool> message = sock_1:recvfrom()
---
...
tarantool> message
---
- X
...
tarantool> sock_1:close()
---
- true
...
tarantool> sock_2:close()
---
- true
...
```

Use tcp_server to accept file contents sent with socat

Here is an example of the tcp_server function, reading strings from the client and printing them. On the client side, the Linux socat utility will be used to ship a whole file for the tcp_server function to read.

Start two shells. The first shell will be the server. The second shell will be the client.

On the first shell, start Tarantool and say:

```
box.cfg{}
socket = require('socket')
socket.tcp_server('0.0.0.0', 3302, function(s)
    while true do
      local request
      request = s:read("\n");
      if request == "" or request == nil then
```

(continues on next page)

(продолжение с предыдущей страницы)

```
        break
      end
      print(request)
    end
  end)
```

The above code means: use *tcp_server()* to wait for a connection from any host on port 3302. When it happens, enter a loop that reads on the socket and prints what it reads. The «delimiter» for the read function is «\n» so each *read()* will read a string as far as the next line feed, including the line feed.

On the second shell, create a file that contains a few lines. The contents don't matter. Suppose the first line contains A, the second line contains B, the third line contains C. Call this file «tmp.txt».

On the second shell, use the socat utility to ship the tmp.txt file to the server's host and port:

```
$ socat TCP:localhost:3302 ./tmp.txt
```

Now watch what happens on the first shell. The strings «A», «B», «C» are printed.

4.1.20 Модуль *strict*

The `strict` module has functions for turning «strict mode» on or off. When strict mode is on, an attempt to use an undeclared global variable will cause an error. A global variable is considered «undeclared» if it has never had a value assigned to it. Often this is an indication of a programming error.

By default strict mode is off, unless tarantool was built with the `-DCMAKE_BUILD_TYPE=Debug` option – see the description of build options in section *building-from-source*.

Example:

```
tarantool> strict = require('strict')
---
...
tarantool> strict.on()
---
...
tarantool> a = b -- strict mode is on so this will cause an error
---
- error: ... variable ''b'' is not declared'
...
tarantool> strict.off()
---
...
tarantool> a = b -- strict mode is off so this will not cause an error
---
...
```

4.1.21 Module *tap*

The tap module streamlines the testing of other modules. It allows writing of tests in the TAP protocol. The results from the tests can be parsed by standard TAP-analyzers so they can be passed to utilities such as prove. Thus one can run tests and then use the results for statistics, decision-making, and so on.

`tap.test(`*test-name*`)`
Initialize.

The result of `tap.test` is an object, which will be called taptest in the rest of this discussion, which is necessary for `taptest:plan()` and all the other methods.

Параметры

- `test-name` (*string*) – an arbitrary name to give for the test outputs.

Return taptest

Rtype userdata

```
tap = require('tap')
taptest = tap.test('test-name')
```

`object taptest`

`taptest:plan(`*count*`)`

Indicate how many tests will be performed.

Параметры

- `count` (*number*) –

Return nil

`taptest:check()`

Checks the number of tests performed. This check should only be done after all planned tests are complete, so ordinarily `taptest:check()` will only appear at the end of a script.

Will display `# bad plan: ...` if the number of completed tests is not equal to the number of tests specified by `taptest:plan(...)`.

Return nil

`taptest:diag(`*message*`)`

Display a diagnostic message.

Параметры

- `message` (*string*) – the message to be displayed.

Return nil

`taptest:ok(`*condition*, *test-name*`)`

This is a basic function which is used by other functions. Depending on the value of `condition`, print „ok" or „not ok" along with debugging information. Displays the message.

Параметры

- `condition` (*boolean*) – an expression which is true or false
- `test-name` (*string*) – name of test

Return true or false.

Rtype boolean

Example:

```
tarantool> taptest:ok(true, 'x')
ok - x
---
- true
...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> tap = require('tap')
---
...
tarantool> taptest = tap.test('test-name')
TAP version 13
---
...
tarantool> taptest:ok(1 + 1 == 2, 'X')
ok - X
---
- true
...
```

`taptest:fail(`*test-name*`)`

`taptest:fail('x')` is equivalent to `taptest:ok(false, 'x')`. Displays the message.

Параметры

- `test-name` (*string*) – name of test

Return true or false.

Rtype boolean

`taptest:skip(`*message*`)`

`taptest:skip('x')` is equivalent to `taptest:ok(true, 'x' .. '# skip')`. Displays the message.

Параметры

- `test-name` (*string*) – name of test

Return nil

Example:

```
tarantool> taptest:skip('message')
ok - message # skip
---
- true
...
```

`taptest:is(`*got*, *expected*, *test-name*`)`

Check whether the first argument equals the second argument. Displays extensive message if the result is false.

Параметры

- `got` (*number*) – actual result
- `expected` (*number*) – expected result
- `test-name` (*string*) – name of test

Return true or false.

Rtype boolean

`taptest:isnt(`*got*, *expected*, *test-name*`)`

This is the negation of `taptest:is(...)`.

Параметры

- got (*number*) – actual result
- expected (*number*) – expected result
- test-name (*string*) – name of test

Return true or false.

Rtype boolean

taptest:isnil(*value*, *test-name*)
taptest:isstring(*value*, *test-name*)
taptest:isnumber(*value*, *test-name*)
taptest:istable(*value*, *test-name*)
taptest:isboolean(*value*, *test-name*)
taptest:isudata(*value*, *test-name*)
taptest:iscdata(*value*, *test-name*)

Test whether a value has a particular type. Displays a long message if the value is not of the specified type.

Параметры

- value (*lua-value*) –
- test-name (*string*) – name of test

Return true or false.

Rtype boolean

taptest:is_deeply(*got*, *expected*, *test-name*)

Recursive version of `taptest:is(...)`, which can be be used to compare tables as well as scalar values.

Return true or false.

Rtype boolean

Параметры

- got (*lua-value*) – actual result
- expected (*lua-value*) – expected result
- test-name (*string*) – name of test

Пример

To run this example: put the script in a file named ./tap.lua, then make tap.lua executable by saying `chmod a+x ./tap.lua`, then execute using Tarantool as a script processor by saying ./tap.lua.

```
#!/usr/bin/tarantool
local tap = require('tap')
test = tap.test("my test name")
test:plan(2)
test:ok(2 * 2 == 4, "2 * 2 is 4")
test:test("some subtests for test2", function(test)
    test:plan(2)
    test:is(2 + 2, 4, "2 + 2 is 4")
    test:isnt(2 + 3, 4, "2 + 3 is not 4")
end)
test:check()
```

The output from the above script will look approximately like this:

```
TAP version 13
1..2
ok - 2 * 2 is 4
    # Some subtests for test2
    1..2
    ok - 2 + 2 is 4,
    ok - 2 + 3 is not 4
    # Some subtests for test2: end
ok - some subtests for test2
```

4.1.22 Модуль *tarantool*

By saying `require('tarantool')`, one can answer some questions about how the tarantool server was built, such as «what flags were used», or «what was the version of the compiler».

Additionally one can see the uptime and the server version and the process id. Those information items can also be accessed with *box.info()* but use of the tarantool module is recommended.

Example:

```
tarantool> tarantool = require('tarantool')
---
...
tarantool> tarantool
---
- build:
    target: Linux-x86_64-RelWithDebInfo
    options: cmake . -DCMAKE_INSTALL_PREFIX=/usr -DENABLE_BACKTRACE=ON
    mod_format: so
    flags: ' -fno-common -fno-omit-frame-pointer -fno-stack-protector -fexceptions
      -funwind-tables -fopenmp -msse2 -std=c11 -Wall -Wextra -Wno-sign-compare -Wno-strict-aliasing
      -fno-gnu89-inline'
    compiler: /usr/bin/x86_64-linux-gnu-gcc /usr/bin/x86_64-linux-gnu-g++
  uptime: 'function: 0x408668e0'
  version: 1.7.0-66-g9093daa
  pid: 'function: 0x40866900'
...
tarantool> tarantool.pid()
---
- 30155
...
tarantool> tarantool.uptime()
---
- 108.64641499519
...
```

4.1.23 Module *uuid*

A «UUID» is a Universally unique identifier. If an application requires that a value be unique only within a single computer or on a single database, then a simple counter is better than a UUID, because getting a UUID is time-consuming (it requires a syscall). For clusters of computers, or widely distributed applications, UUIDs are better.

The functions that can return a UUID are:

- *uuid()*
- *uuid.bin()*
- *uuid.str()*

The functions that can convert between different types of UUID are:

- *uuid_object:bin()*
- *uuid_object:str()*
- *uuid.fromstr()*
- *uuid.frombin()*

The function that can determine whether a UUID is an all-zero value is:

- *uuid_object:isnil()*

`uuid.nil`
A nil object

`uuid.__call()`

Return a UUID

Rtype cdata

`uuid.bin()`

Return a UUID

Rtype 16-byte string

`uuid.str()`

Return a UUID

Rtype 36-byte binary string

`uuid.fromstr(`*uuid_str*`)`

Параметры

- `uuid_str` – UUID in 36-byte hexadecimal string

Return converted UUID

Rtype cdata

`uuid.frombin(`*uuid_bin*`)`

Параметры

- `uuid_str` – UUID in 16-byte binary string

Return converted UUID

Rtype cdata

`object uuid_object`

`uuid_object:bin(`[*byte-order*]`)`
`byte-order` can be one of next flags:

- „l" - little-endian,
- „b" - big-endian,

- „h“ - endianness depends on host (default),
- „n“ - endianness depends on network

Параметры

- `byte-order` (*string*) – one of `'l'`, `'b'`, `'h'` or `'n'`.

Return UUID converted from cdata input value.

Rtype 16-byte binary string

`uuid_object:str()`

Return UUID converted from cdata input value.

Rtype 36-byte hexadecimal string

`uuid_object:isnil()`

The all-zero UUID value can be expressed as uuid.NULL, or as `uuid.fromstr('00000000-0000-0000-0000-000000000000')`. The comparison with an all-zero value can also be expressed as `uuid_with_type_cdata == uuid.NULL`.

Return true if the value is all zero, otherwise false.

Rtype bool

Пример

```
tarantool> uuid = require('uuid')
---
...
tarantool> uuid(), uuid.bin(), uuid.str()
---
- 16ffedc8-cbae-4f93-a05e-349f3ab70baa
- !!binary FvG+Vy1MfUC6kIyeM81DYw==
- 67c999d2-5dce-4e58-be16-ac1bcb93160f
...
tarantool> uu = uuid()
---
...
tarantool> #uui:bin(), #uu:str(), type(uu), uu:isnil()
---
- 16
- 36
- cdata
- false
...
```

4.1.24 Module *xlog*

The xlog module contains one function: `pairs()`. It can be used to read Tarantool's snapshot files or write-ahead-log (WAL) files. A description of the file format is in section *Data persistence and the WAL file format*.

`xlog.pairs([file-name])`

Open a file, and allow iterating over one file entry at a time.

Returns iterator which can be used in a for/end loop.

Rtype iterator

Possible errors: File does not contain properly formatted snapshot or write-ahead-log information.

Example:

This will read the first write-ahead-log (WAL) file that was created in the *wal_dir* directory by the introductory sandbox exercise «*Starting Tarantool and making your first database*“.

Each result from `pairs()` is formatted with MsgPack so its structure can be specified with *__serialize*.

```
xlog = require('xlog')
t = {}
for k, v in xlog.pairs('00000000000000000000.xlog') do
  table.insert(t, setmetatable(v, { __serialize = "map"}))
end
return t
```

The first lines of the result will look like:

```
(...)
---
- - {'BODY':   {'space_id': 272, 'index_base': 1, 'key': ['max_id'],
                'tuple': [['+', 2, 1]]},
     'HEADER': {'type': 'UPDATE', 'timestamp': 1477846870.8541,
                'lsn': 1, 'server_id': 1}}
  - {'BODY':   {'space_id': 280,
                 'tuple': [512, 1, 'tester', 'memtx', 0, {}, []]},
     'HEADER': {'type': 'INSERT', 'timestamp': 1477846870.8597,
                'lsn': 2, 'server_id': 1}}
```

4.1.25 Module *yaml*

The `yaml` module takes strings in YAML format and decodes them, or takes a series of non-YAML values and encodes them.

`yaml.encode(`*lua_value*`)`

Convert a Lua object to a YAML string.

Параметры

- `lua_value` – either a scalar value or a Lua table value.

Return the original value reformatted as a YAML string.

Rtype string

`yaml.decode(`*string*`)`

Convert a YAML string to a Lua object.

Параметры

- `string` – a string formatted as YAML.

Return the original contents formatted as a Lua table.

Rtype table

`yaml.NULL`

A value comparable to Lua «nil» which may be useful as a placeholder in a tuple.

Пример

```
tarantool> yaml = require('yaml')
---
...
tarantool> y = yaml.encode({'a', 1, 'b', 2})
---
...
tarantool> z = yaml.decode(y)
---
...
tarantool> z[1], z[2], z[3], z[4]
---
- a
- 1
- b
- 2
...
tarantool> if yaml.NULL == nil then print('hi') end
hi
---
...
```

The YAML collection style can be specified with `__serialize`:

- `__serialize="sequence"` for a Block Sequence array,
- `__serialize="seq"` for a Flow Sequence array,
- `__serialize="mapping"` for a Block Mapping map,
- `__serialize="map"` for a Flow Mapping map.

Serializing „A“ and „B“ with different `__serialize` values causes different results:

```
tarantool> yaml = require('yaml')
---
...
tarantool> yaml.encode(setmetatable({'A', 'B'}, { __serialize="sequence"}))
---
- |
  ---
  - A
  - B
  ...
...
tarantool> yaml.encode(setmetatable({'A', 'B'}, { __serialize="seq"}))
---
- |
  ---
  ['A', 'B']
  ...
...
tarantool> yaml.encode({setmetatable({f1 = 'A', f2 = 'B'}, { __serialize="map"})})
---
- |
  ---
  - {'f2': 'B', 'f1': 'A'}
  ...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
tarantool> yaml.encode({setmetatable({f1 = 'A', f2 = 'B'}, { __serialize="mapping"})})
---
- |
  ---
  - f2: B
    f1: A
  ...
...
```

Also, some YAML configuration settings for encoding can be changed, in the same way that they can be changed for *JSON*.

4.1.26 Разное

`tonumber64(value)`

Convert a string or a Lua number to a 64-bit integer. The result can be used in arithmetic, and the arithmetic will be 64-bit integer arithmetic rather than floating-point arithmetic. (Operations on an unconverted Lua number use floating-point arithmetic.) The `tonumber64()` function is added by Tarantool; the name is global.

Example:

```
tarantool> type(123456789012345), type(tonumber64(123456789012345))
---
- number
- number
...
tarantool> i = tonumber64('1000000000')
---
...
tarantool> type(i), i / 2, i - 2, i * 2, i + 2, i % 2, i ^ 2
---
- number
- 500000000
- 999999998
- 2000000000
- 1000000002
- 0
- 1000000000000000000
...
```

`dostring(lua-chunk-string[, lua-chunk-string-argument ...])`

Parse and execute an arbitrary chunk of Lua code. This function is mainly useful to define and run Lua code without having to introduce changes to the global Lua environment.

Параметры

- `lua-chunk-string` (*string*) – Lua code
- `lua-chunk-string-argument` (*lua-value*) – zero or more scalar values which will be appended to, or substitute for, items in the Lua chunk.

Return whatever is returned by the Lua code chunk.

Possible errors: If there is a compilation error, it is raised as a Lua error.

Example:

```
tarantool> dostring('abc')
---
error: '[string "abc"]:1: ''='' expected near ''<eof>'''
...
tarantool> dostring('return 1')
---
- 1
...
tarantool> dostring('return ...', 'hello', 'world')
---
- hello
- world
...
tarantool> dostring([[
         >   local f = function(key)
         >     local t = box.space.tester:select{key}
         >     if t ~= nil then
         >       return t[1]
         >     else
         >       return nil
         >     end
         >   end
         >   return f(...)]], 1)
---
- null
...
```

4.1.27 Коды ошибок от базы данных

In the current version of the binary protocol, error messages, which are normally more descriptive than error codes, are not present in server responses. The actual message may contain a file name, a detailed reason or operating system error code. All such messages, however, are logged in the error log. Below are general descriptions of some popular codes. A complete list of errors can be found in file errcode.h in the source tree.

List of error codes

ER_NONMASTER	Can't modify data on a replication slave.
ER_ILLEGAL_PARAMS	Illegal parameters. Malformed protocol message.
ER_MEMORY_ISSUE	Out of memory: *slab_alloc_arena* limit has been reached.
ER_WAL_IO	Failed to write to disk. May mean: failed to record a change in the write-ahead log. Some sort of disk error.
ER_KEY_PART_COUNT	Key part count is not the same as index part count
ER_NO_SUCH_SPACE	The specified space does not exist.
ER_NO_SUCH_INDEX	The specified index in the specified space does not exist.
ER_PROC_LUA	An error occurred inside a Lua procedure.
ER_FIBER_STACK	The recursion limit was reached when creating a new fiber. This usually indicates that a stored procedure is recursively invoking itself too often.
ER_UPDATE_FIELD	An error occurred during update of a field.
ER_TUPLE_FOUND	A duplicate key exists in a unique index.

4.1.28 Handling errors

Here are some procedures that can make Lua functions more robust when there are errors, particularly database errors.

1. Invoke with pcall.

   Take advantage of Lua's mechanisms for «Error handling and exceptions», particularly `pcall`. That is, instead of simply invoking with

   `box.space.`*space-name*`:`*function-name*`()`

   say

   `if pcall(box.space.`*space-name*`.`*function-name*`, box.space.`*space-name*`) ...`

   For some Tarantool box functions, pcall also returns error details including a file-name and line-number within Tarantool's source code. This can be seen by unpacking. For example:

   ```
   x, y = pcall(function() box.schema.space.create('') end)
   y:unpack()
   ```

   See the tutorial *Sum a JSON field for all tuples* to see how pcall can fit in an application.

2. Examine and raise with box.error.

   To make a new error and pass it on, the box.error module provides *box.error(code, errtext [, errtext ...])*.

   To find the last error, the box.error module provides *box.error.last()*. (There is also a way to find the text of the last operating-system error for certain functions – *errno.strerror([code])*.)

3. Log.

   Put messages in a log using the *log module*.

   And filter messages that are automatically generated, with the *logger* configuration parameter.

4.2 Справочник по сторонним библиотекам

This reference covers third-party Lua modules for Tarantool.

4.2.1 SQL DBMS Modules

The discussion here in the reference is about incorporating and using two modules that have already been created: the «SQL DBMS rocks» for MySQL and PostgreSQL.

To call another DBMS from Tarantool, the essential requirements are: another DBMS, and Tarantool. The module which connects Tarantool to another DBMS may be called a «connector». Within the module there is a shared library which may be called a «driver».

Tarantool supplies DBMS connector modules with the module manager for Lua, LuaRocks. So the connector modules may be called «rocks».

The Tarantool rocks allow for connecting to an SQL server and executing SQL statements the same way that a MySQL or PostgreSQL client does. The SQL statements are visible as Lua methods. Thus Tarantool can serve as a «MySQL Lua Connector» or «PostgreSQL Lua Connector», which would be useful even if that was all Tarantool could do. But of course Tarantool is also a DBMS, so the module also is useful for any operations, such as database copying and accelerating, which work best when the application can work on both SQL and Tarantool inside the same Lua routine. The methods for connect/select/insert/etc. are similar to the ones in the *net.box* module.

From a user's point of view the MySQL and PostgreSQL rocks are very similar, so the following sections – «MySQL Example» and «PostgreSQL Example» – contain some redundancy.

MySQL Example

This example assumes that MySQL 5.5 or MySQL 5.6 or MySQL 5.7 has been installed. Recent MariaDB versions will also work, the MariaDB C connector is used. The package that matters most is the MySQL client developer package, typically named something like libmysqlclient-dev. The file that matters most from this package is libmysqlclient.so or a similar name. One can use `find` or `whereis` to see what directories these files are installed in.

It will be necessary to install Tarantool's MySQL driver shared library, load it, and use it to connect to a MySQL server. After that, one can pass any MySQL statement to the server and receive results, including multiple result sets.

Installation

Check the instructions for *Downloading and installing a binary package* that apply for the environment where tarantool was installed. In addition to installing `tarantool`, install `tarantool-dev`. For example, on Ubuntu, add the line

```
sudo apt-get install tarantool-dev
```

Now, for the MySQL driver shared library, there are two ways to install:

With LuaRocks

Begin by installing luarocks and making sure that tarantool is among the upstream servers, as in the instructions on rocks.tarantool.org, the Tarantool luarocks page. Now execute this:

```
luarocks install mysql [MYSQL_LIBDIR = path]
                       [MYSQL_INCDIR = path]
                       [--local]
```

Например:

```
luarocks install mysql MYSQL_LIBDIR=/usr/local/mysql/lib
```

See also *Modules*.

With GitHub

Go the site github.com/tarantool/mysql. Follow the instructions there, saying:

```
git clone https://github.com/tarantool/mysql.git
cd mysql && cmake . -DCMAKE_BUILD_TYPE=RelWithDebInfo
make
make install
```

At this point it is a good idea to check that the installation produced a file named `driver.so`, and to check that this file is on a directory that is searched by the `require` request.

Connecting

Begin by making a `require` request for the mysql driver. We will assume that the name is `mysql` in further examples.

```
mysql = require('mysql')
```

Now, say:

`connection_name` `= mysql.connect(`*`connection options`*`)`

The connection-options parameter is a table. Possible options are:

- `host =` *`host-name`* - string, default value = „localhost“
- `port =` *`port-number`* - number, default value = 3306
- `user =` *`user-name`* - string, default value is operating-system user name
- `password =` *`password`* - string, default value is blank
- `db =` *`database-name`* - string, default value is blank
- `raise =` *`true/false`* - boolean, default value is false

The option names, except for *raise*, are similar to the names that MySQL's mysql client uses, for details see the MySQL manual at dev.mysql.com/doc/refman/5.6/en/connecting.html. The *raise* option should be set to true if errors should be raised when encountered. To connect with a Unix socket rather than with TCP, specify `host = 'unix/'` and `port =` *`socket-name`*.

Example, using a table literal enclosed in {braces}:

```
conn = mysql.connect({
    host = '127.0.0.1',
    port = 3306,
    user = 'p',
    password = 'p',
    db = 'test',
    raise = true
})
-- OR
conn = mysql.connect({
    host = 'unix/',
    port = '/var/run/mysqld/mysqld.sock'
})
```

Example, creating a function which sets each option in a separate line:

```
tarantool> -- Connection function. Usage: conn = mysql_connect()
tarantool> function mysql_connection()
         >   local p = {}
         >   p.host = 'widgets.com'
         >   p.db = 'test'
         >   conn = mysql.connect(p)
         >   return conn
         > end
---
```

(continues on next page)

(продолжение с предыдущей страницы)

```
...
tarantool> conn = mysql_connect()
---
...
```

We will assume that the name is „conn“ in further examples.

How to ping

To ensure that a connection is working, the request is:

connection-name:ping()

Example:

```
tarantool> conn:ping()
---
- true
...
```

Executing a statement

For all MySQL statements, the request is:

connection-name:execute(*sql-statement* [, *parameters*])

where `sql-statement` is a string, and the optional `parameters` are extra values that can be plugged in to replace any question marks («?»s) in the SQL statement.

Example:

```
tarantool> conn:execute('select table_name from information_schema.tables')
---
- - table_name: ALL_PLUGINS
  - table_name: APPLICABLE_ROLES
  - table_name: CHARACTER_SETS
  <...>
- 78
...
```

Closing connection

To end a session that began with `mysql.connect`, the request is:

connection-name:close()

Example:

```
tarantool> conn:close()
---
...
```

For further information, including examples of rarely-used requests, see the README.md file at github.com/tarantool/mysql.

Пример

The example was run on an Ubuntu 12.04 («precise») machine where tarantool had been installed in a /usr subdirectory, and a copy of MySQL had been installed on ~/mysql-5.5. The mysqld server is already running on the local host 127.0.0.1.

```
$ export TMDIR=~/mysql-5.5
$ # Check that the include subdirectory exists by looking
$ # for .../include/mysql.h. (If this fails, there's a chance
$ # that it's in .../include/mysql/mysql.h instead.)
$ [ -f $TMDIR/include/mysql.h ] && echo "OK" || echo "Error"
OK

$ # Check that the library subdirectory exists and has the
$ # necessary .so file.
$ [ -f $TMDIR/lib/libmysqlclient.so ] && echo "OK" || echo "Error"
OK

$ # Check that the mysql client can connect using some factory
$ # defaults: port = 3306, user = 'root', user password = '',
$ # database = 'test'. These can be changed, provided one uses
$ # the changed values in all places.
$ $TMDIR/bin/mysql --port=3306 -h 127.0.0.1 --user=root \
    --password= --database=test
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 25
Server version: 5.5.35 MySQL Community Server (GPL)
...
Type 'help;' or '\h' for help. Type '\c' to clear ...

$ # Insert a row in database test, and quit.
mysql> CREATE TABLE IF NOT EXISTS test (s1 INT, s2 VARCHAR(50));
Query OK, 0 rows affected (0.13 sec)
mysql> INSERT INTO test.test VALUES (1,'MySQL row');
Query OK, 1 row affected (0.02 sec)
mysql> QUIT
Bye

$ # Install luarocks
$ sudo apt-get -y install luarocks | grep -E "Setting up|already"
Setting up luarocks (2.0.8-2) ...

$ # Set up the Tarantool rock list in ~/.luarocks,
$ # following instructions at rocks.tarantool.org
$ mkdir ~/.luarocks
$ echo "rocks_servers = {[[http://rocks.tarantool.org/]]}" >> \
    ~/.luarocks/config.lua

$ # Ensure that the next "install" will get files from Tarantool
$ # master repository. The resultant display is normal for Ubuntu
$ # 12.04 precise
$ cat /etc/apt/sources.list.d/tarantool.list
deb http://tarantool.org/dist/1.7/ubuntu/ precise main
deb-src http://tarantool.org/dist/1.7/ubuntu/ precise main

$ # Install tarantool-dev. The displayed line should show version = 1.6
$ sudo apt-get -y install tarantool-dev | grep -E "Setting up|already"
```

(continues on next page)

(продолжение с предыдущей страницы)

```
Setting up tarantool-dev (1.6.6.222.g48b98bb~precise-1) ...
$

$ # Use luarocks to install locally, that is, relative to $HOME
$ luarocks install mysql MYSQL_LIBDIR=/usr/local/mysql/lib --local
Installing http://rocks.tarantool.org/mysql-scm-1.rockspec...
... (more info about building the Tarantool/MySQL driver appears here)
mysql scm-1 is now built and installed in ~/.luarocks/

$ # Ensure driver.so now has been created in a place
$ # tarantool will look at
$ find ~/.luarocks -name "driver.so"
~/.luarocks/lib/lua/5.1/mysql/driver.so

$ # Change directory to a directory which can be used for
$ # temporary tests. For this example we assume that the name
$ # of this directory is /home/pgulutzan/tarantool_sandbox.
$ # (Change "/home/pgulutzan" to whatever is the user's actual
$ # home directory for the machine that's used for this test.)
$ cd /home/pgulutzan/tarantool_sandbox

$ # Start the Tarantool server. Do not use a Lua initialization file.

$ tarantool
tarantool: version 1.7.0-222-g48b98bb
type 'help' for interactive help
tarantool>
```

Configure tarantool and load mysql module. Make sure that tarantool doesn't reply «error» for the call to «require()».

```
tarantool> box.cfg{}
...
tarantool> mysql = require('mysql')
---
...
```

Create a Lua function that will connect to the MySQL server, (using some factory default values for the port and user and password), retrieve one row, and display the row. For explanations of the statement types used here, read the Lua tutorial earlier in the Tarantool user manual.

```
tarantool> function mysql_select ()
         >   local conn = mysql.connect({
         >     host = '127.0.0.1',
         >     port = 3306,
         >     user = 'root',
         >     db = 'test'
         >   })
         >   local test = conn:execute('SELECT * FROM test WHERE s1 = 1')
         >   local row = ''
         >   for i, card in pairs(test) do
         >       row = row .. card.s2 .. ' '
         >       end
         >   conn:close()
         >   return row
         > end
```

(continues on next page)

(продолжение с предыдущей страницы)

```
---
...
tarantool> mysql_select()
---
- 'MySQL row '
...
```

Observe the result. It contains «MySQL row». So this is the row that was inserted into the MySQL database. And now it's been selected with the Tarantool client.

PostgreSQL Example

This example assumes that PostgreSQL 8 or PostgreSQL 9 has been installed. More recent versions should also work. The package that matters most is the PostgreSQL developer package, typically named something like libpq-dev. On Ubuntu this can be installed with:

```
sudo apt-get install libpq-dev
```

However, because not all platforms are alike, for this example the assumption is that the user must check that the appropriate PostgreSQL files are present and must explicitly state where they are when building the Tarantool/PostgreSQL driver. One can use `find` or `whereis` to see what directories PostgreSQL files are installed in.

It will be necessary to install Tarantool's PostgreSQL driver shared library, load it, and use it to connect to a PostgreSQL server. After that, one can pass any PostgreSQL statement to the server and receive results.

Installation

Check the instructions for *Downloading and installing a binary package* that apply for the environment where tarantool was installed. In addition to installing `tarantool`, install `tarantool-dev`. For example, on Ubuntu, add the line:

```
sudo apt-get install tarantool-dev
```

Now, for the PostgreSQL driver shared library, there are two ways to install:

With LuaRocks

Begin by installing luarocks and making sure that tarantool is among the upstream servers, as in the instructions on rocks.tarantool.org, the Tarantool luarocks page. Now execute this:

```
luarocks install pg [POSTGRESQL_LIBDIR = path]
                    [POSTGRESQL_INCDIR = path]
                    [--local]
```

Например:

```
luarocks install pg POSTGRESQL_LIBDIR=/usr/local/postgresql/lib
```

See also *Modules*.

With GitHub

Go the site github.com/tarantool/pg. Follow the instructions there, saying:

```
git clone https://github.com/tarantool/pg.git
cd pg && cmake . -DCMAKE_BUILD_TYPE=RelWithDebInfo
make
make install
```

At this point it is a good idea to check that the installation produced a file named `driver.so`, and to check that this file is on a directory that is searched by the `require` request.

Connecting

Begin by making a `require` request for the pg driver. We will assume that the name is `pg` in further examples.

```
pg = require('pg')
```

Now, say:

`connection_name = pg.connect(connection options)`

The connection-options parameter is a table. Possible options are:

- `host = host-name` - string, default value = „localhost"
- `port = port-number` - number, default value = 3306
- `user = user-name` - string, default value is operating-system user name
- `pass = password` or `password = password` - string, default value is blank
- `db = database-name` - string, default value is blank

The names are similar to the names that PostgreSQL itself uses.

Example, using a table literal enclosed in {braces}:

```
conn = pg.connect({
    host = '127.0.0.1',
    port = 5432,
    user = 'p',
    password = 'p',
    db = 'test'
})
```

Example, creating a function which sets each option in a separate line:

```
tarantool> function pg_connect()
         >   local p = {}
         >   p.host = 'widgets.com'
         >   p.db = 'test'
         >   p.user = 'postgres'
         >   p.password = 'postgres'
         >   local conn = pg.connect(p)
         >   return conn
         > end
---
...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> conn = pg_connect()
---
...
```

We will assume that the name is „conn“ in further examples.

How to ping

To ensure that a connection is working, the request is:

connection-name :ping()

Example:

```
tarantool> conn:ping()
---
- true
...
```

Executing a statement

For all PostgreSQL statements, the request is:

connection-name :execute(*sql-statement* [, *parameters*])

where `sql-statement` is a string, and the optional `parameters` are extra values that can be plugged in to replace any question marks («?»s) in the SQL statement.

Example:

```
tarantool> conn:execute('select tablename from pg_tables')
---
- - tablename: pg_statistic
  - tablename: pg_type
  - tablename: pg_authid
  <...>
...
```

Closing connection

To end a session that began with `pg.connect`, the request is:

connection-name :close()

Example:

```
tarantool> conn:close()
---
...
```

For further information, including examples of rarely-used requests, see the README.md file at github.com/tarantool/pg.

Пример

The example was run on an Ubuntu 12.04 («precise») machine where tarantool had been installed in a /usr subdirectory, and a copy of PostgreSQL had been installed on /usr. The PostgreSQL server is already running on the local host 127.0.0.1.

```
$ # Check that the include subdirectory exists
$ # by looking for /usr/include/postgresql/libpq-fe-h.
$ [ -f /usr/include/postgresql/libpq-fe.h ] && echo "OK" || echo "Error"
OK

$ # Check that the library subdirectory exists and has the necessary .so file.
$ [ -f /usr/lib/x86_64-linux-gnu/libpq.so ] && echo "OK" || echo "Error"
OK

$ # Check that the psql client can connect using some factory defaults:
$ # port = 5432, user = 'postgres', user password = 'postgres',
$ # database = 'postgres'. These can be changed, provided one changes
$ # them in all places. Insert a row in database postgres, and quit.
$ psql -h 127.0.0.1 -p 5432 -U postgres -d postgres
Password for user postgres:
psql (9.3.10)
SSL connection (cipher: DHE-RSA-AES256-SHA, bits: 256)
Type "help" for help.

postgres=# CREATE TABLE test (s1 INT, s2 VARCHAR(50));
CREATE TABLE
postgres=# INSERT INTO test VALUES (1,'PostgreSQL row');
INSERT 0 1
postgres=# \q
$

$ # Install luarocks
$ sudo apt-get -y install luarocks | grep -E "Setting up|already"
Setting up luarocks (2.0.8-2) ...

$ # Set up the Tarantool rock list in ~/.luarocks,
$ # following instructions at rocks.tarantool.org
$ mkdir ~/.luarocks
$ echo "rocks_servers = {[[http://rocks.tarantool.org/]]}" >> \
        ~/.luarocks/config.lua

$ # Ensure that the next "install" will get files from Tarantool master
$ # repository. The resultant display is normal for Ubuntu 12.04 precise
$ cat /etc/apt/sources.list.d/tarantool.list
deb http://tarantool.org/dist/1.7/ubuntu/ precise main
deb-src http://tarantool.org/dist/1.7/ubuntu/ precise main

$ # Install tarantool-dev. The displayed line should show version = 1.7
$ sudo apt-get -y install tarantool-dev | grep -E "Setting up|already"
Setting up tarantool-dev (1.7.0.222.g48b98bb~precise-1) ...
$

$ # Use luarocks to install locally, that is, relative to $HOME
$ luarocks install pg POSTGRESQL_LIBDIR=/usr/lib/x86_64-linux-gnu --local
Installing http://rocks.tarantool.org/pg-scm-1.rockspec...
... (more info about building the Tarantool/PostgreSQL driver appears here)
```

(continues on next page)

(продолжение с предыдущей страницы)

```
pg scm-1 is now built and installed in ~/.luarocks/

$ # Ensure driver.so now has been created in a place
$ # tarantool will look at
$ find ~/.luarocks -name "driver.so"
~/.luarocks/lib/lua/5.1/pg/driver.so

$ # Change directory to a directory which can be used for
$ # temporary tests. For this example we assume that the
$ # name of this directory is $HOME/tarantool_sandbox.
$ # (Change "$HOME" to whatever is the user's actual
$ # home directory for the machine that's used for this test.)
cd $HOME/tarantool_sandbox

$ # Start the Tarantool server. Do not use a Lua initialization file.

$ tarantool
tarantool: version 1.7.0-412-g803b15c
type 'help' for interactive help
tarantool>
```

Configure tarantool and load pg module. Make sure that tarantool doesn't reply «error» for the call to «require()».

```
tarantool> box.cfg{}
...
tarantool> pg = require('pg')
---
...
```

Create a Lua function that will connect to the PostgreSQL server, (using some factory default values for the port and user and password), retrieve one row, and display the row. For explanations of the statement types used here, read the Lua tutorial earlier in the Tarantool user manual.

```
tarantool> function pg_select ()
         >   local conn = pg.connect({
         >     host = '127.0.0.1',
         >     port = 5432,
         >     user = 'postgres',
         >     password = 'postgres',
         >     db = 'postgres'
         >   })
         >   local test = conn:execute('SELECT * FROM test WHERE s1 = 1')
         >   local row = ''
         >   for i, card in pairs(test) do
         >       row = row .. card.s2 .. ' '
         >       end
         >   conn:close()
         >   return row
         > end
---
...
tarantool> pg_select()
---
- 'PostgreSQL row '
...
```

Observe the result. It contains «PostgreSQL row». So this is the row that was inserted into the PostgreSQL database. And now it's been selected with the Tarantool client.

4.2.2 Модуль *expirationd*

For a commercial-grade example of a Lua rock that works with Tarantool, let us look at expirationd, which Tarantool supplies on GitHub with an Artistic license. The expirationd.lua program is lengthy (about 500 lines), so here we will only highlight the matters that will be enhanced by studying the full source later.

```
task.worker_fiber = fiber.create(worker_loop, task)
log.info("expiration: task %q restarted", task.name)
...
fiber.sleep(expirationd.constants.check_interval)
...
```

Whenever one hears «daemon» in Tarantool, one should suspect it's being done with a *fiber*. The program is making a fiber and turning control over to it so it runs occasionally, goes to sleep, then comes back for more.

```
for _, tuple in scan_space.index[0]:pairs(nil, {iterator = box.index.ALL}) do
...
        if task.is_tuple_expired(task.args, tuple) then
        task.expired_tuples_count = task.expired_tuples_count + 1
        task.process_expired_tuple(task.space_id, task.args, tuple)
...
```

The «for» instruction can be translated as «iterate through the index of the space that is being scanned», and within it, if the tuple is «expired» (for example, if the tuple has a timestamp field which is less than the current time), process the tuple as an expired tuple.

```
-- default process_expired_tuple function
local function default_tuple_drop(space_id, args, tuple)
    local key = fun.map(
        function(x) return tuple[x.fieldno] end,
        box.space[space_id].index[0].parts
    ):totable()
    box.space[space_id]:delete(key)
end
```

Ultimately the tuple-expiry process leads to `default_tuple_drop()` which does a «delete» of a tuple from its original space. First the fun *fun* module is used, specifically fun.map. Remembering that index[0] is always the space's primary key, and index[0].parts[N].fieldno is always the field number for key part N, fun.map() is creating a table from the primary-key values of the tuple. The result of fun.map() is passed to *space_object:delete()*.

```
local function expirationd_run_task(name, space_id, is_tuple_expired, options)
...
```

At this point, if the above explanation is worthwhile, it's clear that `expirationd.lua` starts a background routine (fiber) which iterates through all the tuples in a space, sleeps cooperatively so that other fibers can operate at the same time, and - whenever it finds a tuple that has expired - deletes it from this space. Now the «`expirationd_run_task()`» function can be used in a test which creates sample data, lets the daemon run for a while, and prints results.

For those who like to see things run, here are the exact steps to get expirationd through the test.

1. Get `expirationd.lua`. There are standard ways - it is after all part of a standard rock - but for this purpose just copy the contents of expirationd.lua to a default directory.
2. Start the Tarantool server as described before.
3. Execute these requests:

```
fiber = require('fiber')
expd = require('expirationd')
box.cfg{}
e = box.schema.space.create('expirationd_test')
e:create_index('primary', {type = 'hash', parts = {1, 'unsigned'}})
e:replace{1, fiber.time() + 3}
e:replace{2, fiber.time() + 30}
function is_tuple_expired(args, tuple)
  if (tuple[2] < fiber.time()) then return true end
  return false
  end
expd.run_task('expirationd_test', e.id, is_tuple_expired)
retval = {}
fiber.sleep(2)
expd.task_stats()
fiber.sleep(2)
expd.task_stats()
expd.kill_task('expirationd_test')
e:drop()
os.exit()
```

The database-specific requests (`cfg`, *space.create*, *create_index*) should already be familiar.

The function which will be supplied to expirationd is is_tuple_expired, which is saying «if the second field of the tuple is less than the *current time* , then return true, otherwise return false».

The key for getting the rock rolling is `expd = require('expirationd')`. The «`require`» function is what reads in the program; it will appear in many later examples in this manual, when it's necessary to get a module that's not part of the Tarantool kernel. After the Lua variable expd has been assigned the value of the expirationd module, it's possible to invoke the module's `run_task()` function.

After *sleeping* for two seconds, when the task has had time to do its iterations through the spaces, `expd.task_stats()` will print out a report showing how many tuples have expired – «expired_count: 0». After sleeping for two more seconds, `expd.task_stats()` will print out a report showing how many tuples have expired – «expired_count: 1». This shows that the is_tuple_expired() function eventually returned «true» for one of the tuples, because its timestamp field was more than three seconds old.

Of course, expirationd can be customized to do different things by passing different parameters, which will be evident after looking in more detail at the source code.

4.2.3 Модуль *shard*

With sharding, the tuples of a tuple set are distributed to multiple nodes, with a Tarantool database server on each node. With this arrangement, each server is handling only a subset of the total data, so larger loads can be handled by simply adding more computers to a network.

The Tarantool shard module has facilities for creating shards, as well as analogues for the data-manipulation functions of the box library (select, insert, replace, update, delete).

First some terminology:

Consistent Hash The shard module distributes according to a hash algorithm, that is, it applies a hash function to a tuple's primary-key value in order to decide which shard the tuple belongs to. The hash function is consistent so that changing the number of servers will not affect results for many keys. The specific hash function that the shard module uses is *digest.guava* in the digest module.

Queue A temporary list of recent update requests. Sometimes called «batching». Since updates to a sharded database can be slow, it may speed up throughput to send requests to a queue rather than wait for the update to finish on ever node. The shard module has functions for adding requests to the queue, which it will process without further intervention. Queuing is optional.

Redundancy The number of replicas in each shard.

Replica A complete copy of the data. The shard module handles both sharding and replication. One shard can contain one or more replicas. When a write occurs, the write is attempted on every replica in turn. The shard module does not use the built-in replication feature.

Shard A subset of the tuples in the database partitioned according to the value returned by the consistent hash function. Usually each shard is on a separate node, or a separate set of nodes (for example if redundancy = 3 then the shard will be on three nodes).

Zone A physical location where the nodes are closely connected, with the same security and backup and access points. The simplest example of a zone is a single computer with a single tarantool-server instance. A shard's replicas should be in different zones.

The shard package is distributed separately from the main tarantool package. To acquire it, do a separate install. For example on Ubuntu say:

```
sudo apt-get install tarantool-shard tarantool-pool
```

Or, download from github tarantool/shard and compile as described in the README. Then, before using the module, say `shard = require('shard')`

The most important function is:

`shard.init(`*`shard-configuration`*`)`

This must be called for every shard. The shard-configuration is a table with these fields:

- servers (a list of URIs of nodes and the zones the nodes are in)
- login (the user name which applies for accessing via the shard module)
- password (the password for the login)
- redundancy (a number, minimum 1)
- binary (a port number that this host is listening on, on the current host) (distinguishable from the „listen" port specified by box.cfg)

Possible Errors: Redundancy should not be greater than the number of servers; the servers must be alive; two replicas of the same shard should not be in the same zone.

Example: shard.init syntax for one shard

The number of replicas per shard (redundancy) is 3. The number of servers is 3. The shard module will conclude that there is only one shard.

```
tarantool> cfg = {
         >   servers = {
         >     { uri = 'localhost:33131', zone = '1' },
         >     { uri = 'localhost:33132', zone = '2' },
```

(continues on next page)

(продолжение с предыдущей страницы)

```
        >     { uri = 'localhost:33133', zone = '3' }
        >   },
        >   login = 'tester',
        >   password = 'pass',
        >   redundancy = '3',
        >   binary = 33131,
        > }
---
...
tarantool> shard.init(cfg)
---
...
```

Example: shard.init syntax for three shards

This describes three shards. Each shard has two replicas. Since the number of servers is 7, and the number of replicas per shard is 2, and dividing 7 / 2 leaves a remainder of 1, one of the servers will not be used. This is not necessarily an error, because perhaps one of the servers in the list is not alive.

```
tarantool> cfg = {
        >   servers = {
        >     { uri = 'host1:33131', zone = '1' },
        >     { uri = 'host2:33131', zone = '2' },
        >     { uri = 'host3:33131', zone = '3' },
        >     { uri = 'host4:33131', zone = '4' },
        >     { uri = 'host5:33131', zone = '5' },
        >     { uri = 'host6:33131', zone = '6' },
        >     { uri = 'host7:33131', zone = '7' }
        >   },
        >   login = 'tester',
        >   password = 'pass',
        >   redundancy = '2',
        >   binary = 33131,
        > }
---
...
tarantool> shard.init(cfg)
---
...
```

shard[*space-name*].insert{...}
shard[*space-name*].replace{...}
shard[*space-name*].delete{...}
shard[*space-name*].select{...}
shard[*space-name*].update{...}
shard[*space-name*].auto_increment{...}

Every data-access function in the box module has an analogue in the shard module, so (for example) to insert in table T in a sharded database one simply says `shard.T:insert{...}` instead of `box.space.T:insert{...}`. A `shard.T:select{}` request without a primary key will search all shards.

shard[*space-name*].q_insert{...}
shard[*space-name*].q_replace{...}
shard[*space-name*].q_delete{...}
shard[*space-name*].q_select{...}

shard[*space-name*].q_update{...}
shard[*space-name*].q_auto_increment{...}

Every queued data-access function has an analogue in the shard module. The user must add an operation_id. The details of queued data-access functions, and of maintenance-related functions, are on the shard section of github.

Example: Shard, Minimal Configuration

There is only one shard, and that shard contains only one replica. So this isn't illustrating the features of either replication or sharding, it's only illustrating what the syntax is, and what the messages look like, that anyone could duplicate in a minute or two with the magic of cut-and-paste.

```
$ mkdir ~/tarantool_sandbox_1
$ cd ~/tarantool_sandbox_1
$ rm -r *.snap
$ rm -r *.xlog
$ ~/tarantool-1.7/src/tarantool

tarantool> box.cfg{listen = 3301}
tarantool> box.schema.space.create('tester')
tarantool> box.space.tester:create_index('primary', {})
tarantool> box.schema.user.passwd('admin', 'password')
tarantool> cfg = {
         >   servers = {
         >       { uri = 'localhost:3301', zone = '1' },
         >   },
         >   login = 'admin';
         >   password = 'password';
         >   redundancy = 1;
         >   binary = 3301;
         > }
tarantool> shard = require('shard')
tarantool> shard.init(cfg)
tarantool> -- Now put something in ...
tarantool> shard.tester:insert{1,'Tuple #1'}
```

If one cuts and pastes the above, then the result, showing only the requests and responses for shard.init and shard.tester, should look approximately like this:

```
tarantool> shard.init(cfg)
2015-08-09 ... I> Sharding initialization started...
2015-08-09 ... I> establishing connection to cluster servers...
2015-08-09 ... I>  - localhost:3301 - connecting...
2015-08-09 ... I>  - localhost:3301 - connected
2015-08-09 ... I> connected to all servers
2015-08-09 ... I> started
2015-08-09 ... I> redundancy = 1
2015-08-09 ... I> Zone len=1 THERE
2015-08-09 ... I> Adding localhost:3301 to shard 1
2015-08-09 ... I> Zone len=1 THERE
2015-08-09 ... I> shards = 1
2015-08-09 ... I> Done
---
- true
...
tarantool> -- Now put something in ...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
---
...
tarantool> shard.tester:insert{1,'Tuple #1'}
---
- - [1, 'Tuple #1']
...
```

Example: Shard, Scaling Out

There are two shards, and each shard contains one replica. This requires two nodes. In real life the two nodes would be two computers, but for this illustration the requirement is merely: start two shells, which we'll call Terminal#1 and Terminal #2.

В первом терминале (Terminal #1) введите:

```
$ mkdir ~/tarantool_sandbox_1
$ cd ~/tarantool_sandbox_1
$ rm -r *.snap
$ rm -r *.xlog
$ ~/tarantool-1.7/src/tarantool

tarantool> box.cfg{listen = 3301}
tarantool> box.schema.space.create('tester')
tarantool> box.space.tester:create_index('primary', {})
tarantool> box.schema.user.passwd('admin', 'password')
tarantool> console = require('console')
tarantool> cfg = {
         >   servers = {
         >     { uri = 'localhost:3301', zone = '1' },
         >     { uri = 'localhost:3302', zone = '2' },
         >   },
         >   login = 'admin',
         >   password = 'password',
         >   redundancy = 1,
         >   binary = 3301,
         > }
tarantool> shard = require('shard')
tarantool> shard.init(cfg)
tarantool> -- Now put something in ...
tarantool> shard.tester:insert{1,'Tuple #1'}
```

On Terminal #2, say:

```
$ mkdir ~/tarantool_sandbox_2
$ cd ~/tarantool_sandbox_2
$ rm -r *.snap
$ rm -r *.xlog
$ ~/tarantool-1.7/src/tarantool

tarantool> box.cfg{listen = 3302}
tarantool> box.schema.space.create('tester')
tarantool> box.space.tester:create_index('primary', {})
tarantool> box.schema.user.passwd('admin', 'password')
tarantool> console = require('console')
tarantool> cfg = {
```

(continues on next page)

(продолжение с предыдущей страницы)

```
         >   servers = {
         >     { uri = 'localhost:3301', zone = '1' };
         >     { uri = 'localhost:3302', zone = '2' };
         >   };
         >   login = 'admin';
         >   password = 'password';
         >   redundancy = 1;
         >   binary = 3302;
         > }
tarantool> shard = require('shard')
tarantool> shard.init(cfg)
tarantool> -- Now get something out ...
tarantool> shard.tester:select{1}
```

What will appear on Terminal #1 is: a loop of error messages saying «Connection refused» and «server check failure». This is normal. It will go on until Terminal #2 process starts.

What will appear on Terminal #2, at the end, should look like this:

```
tarantool> shard.tester:select{1}
---
- - - [1, 'Tuple #1']
...
```

This shows that what was inserted by Terminal #1 can be selected by Terminal #2, via the shard module.

Details are on the shard section of github.

4.2.4 Module *tdb*

The Tarantool Debugger (abbreviation = tdb) can be used with any Lua program. The operational features include: setting breakpoints, examining variables, going forward one line at a time, backtracing, and showing information about fibers. The display features include: using different colors for different situations, including line numbers, and adding hints.

It is not supplied as part of the Tarantool repository; it must be installed separately. Here is the usual way:

```
git clone --recursive https://github.com/Sulverus/tdb
cd tdb
make
sudo make install prefix=/usr/share/tarantool/
```

To initiate tdb within a Lua program and set a breakpoint, edit the program to include these lines:

```
tdb = require('tdb')
tdb.start()
```

To start the debugging session, execute the Lua program. Execution will stop at the breakpoint, and it will be possible to enter debugging commands.

Debugger Commands

bt Backtrace – show the stack (in red), with program/function names and line numbers of whatever has been invoked to reach the current line.

c Continue till next breakpoint or till program ends.

e Enter evaluation mode. When the program is in evaluation mode, one can execute certain Lua statements that would be valid in the context. This is particularly useful for displaying the values of the program's variables. Other debugger commands will not work until one exits evaluation mode by typing -e.

-e Exit evaluation mode.

f Display the fiber id, the program name, and the percentage of memory used, as a table.

n Go to the next line, skipping over any function calls.

globals Display names of variables or functions which are defined as global.

h Display a list of debugger commands.

locals Display names and values of variables, for example the control variables of a Lua «for» statement.

q Quit immediately.

Example Session

Put the following program in a default directory and call it «example.lua»:

```
tdb = require('tdb')
tdb.start()
i = 1
j = 'a' .. i
print('end of program')
```

Now start Tarantool, using example.lua as the initialization file

```
$ tarantool example.lua
```

The screen should now look like this:

```
$ tarantool example.lua
(TDB)  Tarantool debugger v.0.0.3. Type h for help
example.lua
(TDB)  [example.lua]
(TDB)  3: i = 1
(TDB)>
```

Debugger prompts are blue, debugger hints and information are green, and the current line – line 3 of example.lua – is the default color. Now enter six debugger commands:

```
n  -- go to next line
n  -- go to next line
e  -- enter evaluation mode
j  -- display j
-e -- exit evaluation mode
q  -- quit
```

The screen should now look like this:

```
$ tarantool example.lua
(TDB)  Tarantool debugger v.0.0.3. Type h for help
example.lua
(TDB)  [example.lua]
(TDB)  3: i = 1
(TDB)> n
(TDB)  4: j = 'a' .. i
(TDB)> n
```

```
(TDB)  5: print('end of program')
(TDB)> e
(TDB)  Eval mode ON
(TDB)> j
j       a1
(TDB)> -e
(TDB)  Eval mode OFF
(TDB)> q
```

Another debugger example can be found here.

4.3 Справочник по настройке

This reference covers all options and parameters which can be set for Tarantool on the command line or in an initialization file.

Tarantool is started by entering the following command:

```
$ tarantool
# OR
$ tarantool options
# OR
$ tarantool lua-initialization-file [ arguments ]
```

4.3.1 Опции комнандной строки

`-h, --help`
Print an annotated list of all available options and exit.

`-V, --version`
Print product name and version, for example:

```
$ ./tarantool --version
Tarantool 1.7.0-1216-g73f7154
Target: Linux-x86_64-Debug
...
```

In this example:

"Tarantool" is the name of the reusable asynchronous networking programming framework.

The 3-number version follows the standard `<major>-<minor>-<patch>` scheme, in which `<major>` number is changed only rarely, `<minor>` is incremented for each new milestone and indicates possible incompatible changes, and `<patch>` stands for the number of bug fix releases made after the start of the milestone. For non-released versions only, there may be a commit number and commit SHA1 to indicate how much this particular build has diverged from the last release.

"Target" is the platform tarantool was built on. Some platform-specific details may follow this line.

Примечание: Tarantool uses git describe to produce its version id, and this id can be used at any time to check out the corresponding source from our git repository.

4.3.2 Универсальный код ресурса (URI)

Some configuration parameters and some functions depend on a URI, or «Universal Resource Identifier». The URI string format is similar to the generic syntax for a URI schema. So it may contain (in order) a user name for login, a password, a host name or host IP address, and a port number. Only the port number is always mandatory. The password is mandatory if the user name is specified, unless the user name is „guest". So, formally, the URI syntax is `[host:]port` or `[username:password@]host:port`. If host is omitted, then „0.0.0.0" or „[::]" is assumed, meaning respectively any IPv4 address or any IPv6 address, on the local machine. If username:password is omitted, then „guest" is assumed. Some examples:

URI fragment	Пример
port	3301
host:port	127.0.0.1:3301
username:password@host:port	notguest:sesame@mail.ru:3301

In certain circumstances a Unix domain socket may be used where a URI is expected, for example «unix/:/tmp/unix_domain_socket.sock» or simply «/tmp/unix_domain_socket.sock».

A method for parsing URIs is illustrated in *Cookbook recipes*.

4.3.3 Файл инициализации

If the command to start Tarantool includes lua-initialization-file, then Tarantool begins by invoking the Lua program in the file, which by convention may have the name «`script.lua`». The Lua program may get further arguments from the command line or may use operating-system functions, such as `getenv()`. The Lua program almost always begins by invoking `box.cfg()`, if the database server will be used or if ports need to be opened. For example, suppose `script.lua` contains the lines

```
#!/usr/bin/env tarantool
box.cfg{
    listen              = os.getenv("LISTEN_URI"),
    slab_alloc_arena    = 0.1,
    pid_file            = "tarantool.pid",
    rows_per_wal        = 50
}
print('Starting ', arg[1])
```

and suppose the environment variable LISTEN_URI contains 3301, and suppose the command line is `~/tarantool/src/tarantool script.lua ARG`. Then the screen might look like this:

```
$ export LISTEN_URI=3301
$ ~/tarantool/src/tarantool script.lua ARG
... main/101/script.lua C> version 1.7.0-1216-g73f7154
... main/101/script.lua C> log level 5
... main/101/script.lua I> mapping 107374184 bytes for a shared arena...
... main/101/script.lua I> recovery start
... main/101/script.lua I> recovering from './00000000000000000000.snap'
... main/101/script.lua I> primary: bound to 0.0.0.0:3301
... main/102/leave_local_hot_standby I> ready to accept requests
Starting  ARG
... main C> entering the event loop
```

If one wishes to start an interactive session on the same terminal after initialization is complete, one can use *console.start()*.

4.3.4 Параметры конфигурации

Configuration parameters have the form: `box.cfg{[key = value [, key = value ...]]}`

Since `box.cfg` may contain many configuration parameters and since some of the parameters (such as directory addresses) are semi-permanent, it's best to keep `box.cfg` in a Lua file. Typically this Lua file is the initialization file which is specified on the tarantool command line.

Most configuration parameters are for allocating resources, opening ports, and specifying database behavior. All parameters are optional. A few parameters are dynamic, that is, they can be changed at runtime by calling `box.cfg{}` a second time.

To see all the non-null parameters, say `box.cfg` (no parentheses). To see a particular parameter, for example the listen address, say `box.cfg.listen`.

The following sections describe all parameters for basic operation, for storage, for binary logging and snapshots, for replication, for networking, and for logging.

Basic parameters

- *background*
- *coredump*
- *custom_proc_title*
- *listen*
- *pid_file*
- *read_only*
- *snap_dir*
- *vinyl_dir*
- *username*
- *wal_dir*
- *work_dir*

`background`

Run the server as a background task. The *logger* and *pid_file* parameters must be non-null for this to work.

Type: boolean
Default: false
Dynamic: no

`coredump`

Deprecated. Do not use.

Type: boolean
Default: false
Dynamic: no

`custom_proc_title`

Add the given string to the server's *Process title* (what's shown in the COMMAND column for `ps -ef` and `top -c` commands).

For example, ordinarily `ps -ef` shows the Tarantool server process thus:

```
$ ps -ef | grep tarantool
1000     14939 14188  1 10:53 pts/2    00:00:13 tarantool <running>
```

But if the configuration parameters include `custom_proc_title='sessions'` then the output looks like:

```
$ ps -ef | grep tarantool
1000     14939 14188  1 10:53 pts/2    00:00:16 tarantool <running>: sessions
```

Type: string
Default: null
Dynamic: yes

`listen`

The read/write data port number or *URI* (Universal Resource Identifier) string. Has no default value, so **must be specified** if connections will occur from remote clients that do not use the *"admin port"*. Connections made with `listen = URI` are sometimes called «binary protocol» or «primary port» connections.

A typical value is 3301. The listen parameter may also be set for local hot standby.

Примечание: A replica also binds to this port, and accepts connections, but these connections can only serve reads until the replica becomes a master.

Type: integer or string
Default: null
Dynamic: yes

`pid_file`

Store the process id in this file. Can be relative to *work_dir*. A typical value is "`tarantool.pid`".

Type: string
Default: null
Dynamic: no

`read_only`

Put the server in read-only mode. After this, any requests that try to change data will fail with error `ER_READONLY`.

Type: boolean

Default: false

Dynamic: yes

`snap_dir`

A directory where snapshot (.snap) files will be stored. Can be relative to *work_dir*. If not specified, defaults to `work_dir`. See also *wal_dir*.

Type: string

Default: «.»

Dynamic: no

`vinyl_dir`

A directory where vinyl files or subdirectories will be stored. Can be relative to *work_dir*. If not specified, defaults to `work_dir`.

Type: string

Default: «.»

Dynamic: no

`username`

UNIX user name to switch to after start.

Type: string

Default: null

Dynamic: no

`wal_dir`

A directory where write-ahead log (.xlog) files are stored. Can be relative to *work_dir*. Sometimes `wal_dir` and *snap_dir* are specified with different values, so that write-ahead log files and snapshot files can be stored on different disks. If not specified, defaults to `work_dir`.

Type: string

Default: «.»

Dynamic: no

`work_dir`

A directory where database working files will be stored. The server switches to work_dir with *chdir(2)* after start. Can be relative to the current directory. If not specified, defaults to the current directory. Other directory parameters may be relative to `work_dir`, for example:

```
box.cfg{ work_dir = '/home/user/A', wal_dir = 'B', snap_dir = 'C' }
```

will put xlog files in /home/user/A/B, snapshot files in /home/user/A/C, and all other files or subdirectories in /home/user/A.

Type: string
Default: null
Dynamic: no

Configuring the storage

- *slab_alloc_arena*
- *slab_alloc_factor*
- *slab_alloc_maximal*
- *slab_alloc_minimal*
- *vinyl.memory_limit*
- *vinyl.compact_wm*
- *vinyl.threads*

`slab_alloc_arena`

How much memory Tarantool allocates to actually store tuples, in gigabytes. When the limit is reached, INSERT or UPDATE requests begin failing with error `ER_MEMORY_ISSUE`. While the server does not go beyond the defined limit to allocate tuples, there is additional memory used to store indexes and connection information. Depending on actual configuration and workload, Tarantool can consume up to 20% more than the limit set here.

Type: float
Default: 1.0
Dynamic: no

`slab_alloc_factor`

Use slab_alloc_factor as the multiplier for computing the sizes of memory chunks that tuples are stored in. A lower value may result in less wasted memory depending on the total amount of memory available and the distribution of item sizes.

Type: float
Default: 1.1
Dynamic: no

`slab_alloc_maximal`

Size of the largest allocation unit. It can be increased if it is necessary to store large tuples.

Type: integer
Default: 1048576
Dynamic: no

`slab_alloc_minimal`
Size of the smallest allocation unit. It can be decreased if most of the tuples are very small. The value must be between 8 and 1048280 inclusive.

Type: integer
Default: 16
Dynamic: no

`vinyl`
The default vinyl configuration can be changed with

```
vinyl = {
    memory_limit = number,
    compact_wm = number,
    threads = number,
}
```

`memory_limit`
The maximum number of in-memory bytes that vinyl uses.

Type: integer.
Default = 1.
Dynamic: no

`compact_wm`
The «compaction watermark». If the number of runs becomes greater than compact_wm, then compaction occurs.

Type: integer.
Default: 2.
Dynamic: no

`threads`
The maximum number of threads that vinyl can use for some concurrent operations, such as I/O and compression.

Type: integer.
Default = 1.
Dynamic: no

This method may change in the future.

Snapshot daemon

- *snapshot_period*

- *snapshot_count*

The snapshot daemon is a fiber which is constantly running. At intervals, it may make new snapshot (.snap) files and then may remove old snapshot files. If the snapshot daemon removes an old snapshot file, it will also remove any write-ahead log (.xlog) files that are older than the snapshot file and contain information that is present in the snapshot file.

The *snapshot_period* and *snapshot_count* configuration settings determine how long the intervals are, and how many snapshots should exist before removals occur.

`snapshot_period`

The interval between actions by the snapshot daemon, in seconds. If `snapshot_period` is set to a value greater than zero, and there is activity which causes change to a database, then the snapshot daemon will call *box.snapshot* every `snapshot_period` seconds, creating a new snapshot file each time.

For example: `box.cfg{snapshot_period=3600}` will cause the snapshot daemon to create a new database snapshot once per hour.

Type: integer
Default: 0
Dynamic: yes

`snapshot_count`

The maximum number of snapshots that may exist on the snap_dir directory before the snapshot daemon will remove old snapshots. If `snapshot_count` equals zero, then the snapshot daemon does not remove old snapshots. For example:

```
box.cfg{
    snapshot_period = 3600,
    snapshot_count  = 10
}
```

will cause the snapshot daemon to create a new snapshot each hour until it has created ten snapshots. After that, it will remove the oldest snapshot (and any associated write-ahead-log files) after creating a new one.

Type: integer
Default: 6
Dynamic: yes

Binary logging and snapshots

- *panic_on_snap_error*,
- *panic_on_wal_error*,
- *rows_per_wal*,
- *snap_io_rate_limit*,
- *wal_mode*,
- *wal_dir_rescan_delay*

`panic_on_snap_error`

If there is an error while reading the snapshot file (at server start), abort.

Type: boolean
Default: true
Dynamic: no

`panic_on_wal_error`

If there is an error while reading a write-ahead log file (at server start or to relay to a replica), abort.

Type: boolean
Default: true
Dynamic: yes

`rows_per_wal`

How many log records to store in a single write-ahead log file. When this limit is reached, Tarantool creates another WAL file named `<first-lsn-in-wal>.xlog`. This can be useful for simple rsync-based backups.

Type: integer
Default: 500000
Dynamic: no

`snap_io_rate_limit`

Reduce the throttling effect of *box.snapshot* on INSERT/UPDATE/DELETE performance by setting a limit on how many megabytes per second it can write to disk. The same can be achieved by splitting *wal_dir* and *snap_dir* locations and moving snapshots to a separate disk.

Type: float
Default: null
Dynamic: **yes**

`wal_mode`

Specify fiber-WAL-disk synchronization mode as:

- `none`: write-ahead log is not maintained;
- `write`: fibers wait for their data to be written to the write-ahead log (no *fsync(2)*);
- `fsync`: fibers wait for their data, *fsync(2)* follows each *write(2)*;

Type: string
Default: «write»
Dynamic: **yes**

`wal_dir_rescan_delay`
Number of seconds between periodic scans of the write-ahead-log file directory, when checking for changes to write-ahead-log files for the sake of replication or local hot standby.

Type: float
Default: 2
Dynamic: no

Репликация

- *replication_source*

`replication_source`
If replication_source is not an empty string, the server is considered to be a Tarantool *replica*. The replica server will try to connect to the master which replication_source specifies with a *URI* (Universal Resource Identifier), for example *konstantin:secret_password@tarantool.org:3301*.

If there is more than one replication source in a cluster, specify an array of URIs, for example
`box.cfg{ replication_source = { „uri1“, „uri2“ } }`

If one of the URIs is «self» – that is, if one of the URIs is for the same server that `box.cfg{}` is being executed on – then it is ignored. Thus it is possible to use the same `replication_source` specification on multiple servers.

The default user name is 'guest'. A replica server does not accept data-change requests on the *listen* port. The replication_source parameter is dynamic, that is, to enter master mode, simply set `replication_source` to an empty string and issue `box.cfg{ replication_source = new-value }`.

Type: string
Default: null
Dynamic: **yes**

Networking

- *io_collect_interval*,
- *readahead*

`io_collect_interval`
The server will sleep for io_collect_interval seconds between iterations of the event loop. Can be used to reduce CPU load in deployments in which the number of client connections is large, but requests are not so frequent (for example, each connection issues just a handful of requests per second).

Type: float
Default: null
Dynamic: **yes**

`readahead`
The size of the read-ahead buffer associated with a client connection. The larger the buffer, the more memory an active connection consumes and the more requests can be read from the operating system buffer in a single system call. The rule of thumb is to make sure the buffer can contain at least a few dozen requests. Therefore, if a typical tuple in a request is large, e.g. a few kilobytes or even megabytes, the read-ahead buffer size should be increased. If batched request processing is not used, it's prudent to leave this setting at its default.

Type: integer
Default: 16320
Dynamic: **yes**

Logging

- *log_level*
- *logger*
- *logger_nonblock*
- *too_long_threshold*

`log_level`
How verbose the logging is. There are six log verbosity classes:

- 1 – `SYSERROR`
- 2 – `ERROR`
- 3 – `CRITICAL`
- 4 – `WARNING`
- 5 – `INFO`
- 6 – `DEBUG`

By setting log_level, one can enable logging of all classes below or equal to the given level. Tarantool prints its logs to the standard error stream by default, but this can be changed with the *logger* configuration parameter.

Type: integer
Default: 5
Dynamic: **yes**

`logger`
By default, the log is sent to the standard error stream (`stderr`). If `logger` is specified, the log is sent to a file, or to a pipe, or to the system logger.

Example setting:

```
box.cfg{logger = 'tarantool.log'}
-- or
box.cfg{logger = 'file: tarantool.log'}
```

This will open the file `tarantool.log` for output on the server's default directory. If the `logger` string has no prefix or has the prefix «file:», then the string is interpreted as a file path.

Example setting:

```
box.cfg{logger = '| cronolog tarantool.log'}
-- or
box.cfg{logger = 'pipe: cronolog tarantool.log'}'
```

This will start the program `cronolog` when the server starts, and will send all log messages to the standard input (`stdin`) of cronolog. If the `logger` string begins with „|" or has the prefix «pipe:», then the string is interpreted as a Unix pipeline.

Example setting:

```
box.cfg{logger = 'syslog:identity=tarantool'}
-- or
box.cfg{logger = 'syslog:facility=user'}
-- or
box.cfg{logger = 'syslog:identity=tarantool,facility=user'}
```

If the `logger` string has the prefix «syslog:», then the string is interpreted as a message for the syslogd program which normally is running in the background of any Unix-like platform. One can optionally specify an `identity`, a `facility`, or both. The `identity` is an arbitrary string, default value = `tarantool`, which will be placed at the beginning of all messages. The facility is an abbreviation for the name of one of the syslog facilities, default value = `user`, which tell syslogd where the message should go.

Possible values for `facility` are: auth, authpriv, cron, daemon, ftp, kern, lpr, mail, news, security, syslog, user, uucp, local0, local1, local2, local3, local4, local5, local6, local7.

The `facility` setting is currently ignored but will be used in the future.

When logging to a file, tarantool reopens the log on SIGHUP. When log is a program, its pid is saved in the *log.logger_pid* variable. You need to send it a signal to rotate logs.

Type: string
Default: null
Dynamic: no

`logger_nonblock`

If `logger_nonblock` equals true, Tarantool does not block on the log file descriptor when it's not ready for write, and drops the message instead. If *log_level* is high, and a lot of messages go to the log file, setting `logger_nonblock` to true may improve logging performance at the cost of some log messages getting lost.

Type: boolean
Default: true
Dynamic: no

`too_long_threshold`

If processing a request takes longer than the given value (in seconds), warn about it in the log. Has effect only if *log_level* is more than or equal to 4 (WARNING).

Type: float

Default: 0.5

Dynamic: **yes**

Logging example:

This will illustrate how «rotation» works, that is, what happens when the server is writing to a log and signals are used when archiving it.

Start with two terminal shells, Terminal #1 and Terminal #2.

On Terminal #1: start an interactive Tarantool session, then say the logging will go to *Log_file*, then put a message «Log Line #1» in the log file:

```
box.cfg{logger='Log_file'}
log = require('log')
log.info('Log Line #1')
```

On Terminal #2: use `mv` so the log file is now named *Log_file.bak*. The result of this is: the next log message will go to *Log_file.bak*.

```
mv Log_file Log_file.bak
```

On Terminal #1: put a message «Log Line #2» in the log file.

```
log.info('Log Line #2')
```

On Terminal #2: use `ps` to find the process ID of the Tarantool server.

```
ps -A | grep tarantool
```

On Terminal #2: use `kill -HUP` to send a SIGHUP signal to the Tarantool server. The result of this is: Tarantool will open *Log_file* again, and the next log message will go to *Log_file*. (The same effect could be accomplished by executing log.rotate() on the server.)

`kill -HUP` *`process_id`*

On Terminal #1: put a message «Log Line #3» in the log file.

```
log.info('Log Line #3')
```

On Terminal #2: use `less` to examine files. *Log_file.bak* will have these lines, except that the date and time will depend on when the example is done:

```
2015-11-30 15:13:06.373 [27469] main/101/interactive I> Log Line #1`
2015-11-30 15:14:25.973 [27469] main/101/interactive I> Log Line #2`
```

and *Log_file* will have

```
log file has been reopened
2015-11-30 15:15:32.629 [27469] main/101/interactive I> Log Line #3
```

ГЛАВА 5

Практикум

5.1 Практические задания на Lua

Here are three tutorials on using Lua stored procedures with Tarantool:

- *Insert one million tuples with a Lua stored procedure*,
- *Sum a JSON field for all tuples*,
- *Indexed pattern search*.

5.1.1 Вставка 1 млн кортежей с помощью хранимой процедуры на языке Lua

This is an exercise assignment: "Insert one million tuples. Each tuple should have a constantly-increasing numeric primary-key field and a random alphabetic 10-character string field."

The purpose of the exercise is to show what Lua functions look like inside Tarantool. It will be necessary to employ the Lua math library, the Lua string library, the Tarantool box library, the Tarantool box.tuple library, loops, and concatenations. It should be easy to follow even for a person who has not used either Lua or Tarantool before. The only requirement is a knowledge of how other programming languages work and a memory of the first two chapters of this manual. But for better understanding, follow the comments and the links, which point to the Lua manual or to elsewhere in this Tarantool manual. To further enhance learning, type the statements in with the tarantool client while reading along.

Configure

We are going to use the «tarantool_sandbox» that was created in section *first database*. So there is a single space, and a numeric primary key, and a running tarantool server which also serves as a client.

Delimiter

In earlier versions of Tarantool, multi-line functions had to be enclosed within «delimiters». They are no longer necessary, and so they will not be used in this tutorial. However, they are still supported. Users who wish to use delimiters, or users of older versions of Tarantool, should check the syntax description for *declaring a delimiter* before proceeding.

Create a function that returns a string

We will start by making a function that returns a fixed string, "Hello world".

```
function string_function()
  return "hello world"
end
```

The word «`function`» is a Lua keyword – we're about to go into Lua. The function name is string_function. The function has one executable statement, `return "hello world"`. The string «hello world» is enclosed in double quotes here, although Lua doesn't care – one could use single quotes instead. The word «`end`» means "this is the end of the Lua function declaration." To confirm that the function works, we can say

```
string_function()
```

Sending `function-name()` means "invoke the Lua function." The effect is that the string which the function returns will end up on the screen.

For more about Lua strings see Lua manual chapter 2.4 «Strings» . For more about functions see Lua manual chapter 5 «Functions».

Теперь вывод на экране выглядит следующим образом:

```
tarantool> function string_funciton()
         >   return "hello world"
         > end
---
...
tarantool> string_function()
---
- hello world
...
tarantool>
```

Create a function that calls another function and sets a variable

Now that `string_function` exists, we can invoke it from another function.

```
function main_function()
  local string_value
  string_value = string_function()
  return string_value
end
```

We begin by declaring a variable «`string_value`». The word «`local`» means that string_value appears only in `main_function`. If we didn't use «`local`» then `string_value` would be visible everywhere - even by other users using other clients connected to this server! Sometimes that's a very desirable feature for inter-client communication, but not this time.

Then we assign a value to `string_value`, namely, the result of `string_function()`. Soon we will invoke `main_function()` to check that it got the value.

For more about Lua variables see Lua manual chapter 4.2 «Local Variables and Blocks» .

Теперь вывод на экране выглядит следующим образом:

```
tarantool> function main_function()
         >   local string_value
         >   string_value = string_function()
         >   return string_value
         > end
---
...
tarantool> main_function()
---
- hello world
...
tarantool>
```

Modify the function so it returns a one-letter random string

Now that it's a bit clearer how to make a variable, we can change `string_function()` so that, instead of returning a fixed literal «Hello world», it returns a random letter between „A“ and „Z“.

```
function string_function()
  local random_number
  local random_string
  random_number = math.random(65, 90)
  random_string = string.char(random_number)
  return random_string
end
```

It is not necessary to destroy the old `string_function()` contents, they're simply overwritten. The first assignment invokes a random-number function in Lua's math library; the parameters mean "the number must be an integer between 65 and 90." The second assignment invokes an integer-to-character function in Lua's string library; the parameter is the code point of the character. Luckily the ASCII value of „A“ is 65 and the ASCII value of „Z“ is 90 so the result will always be a letter between A and Z.

For more about Lua math-library functions see Lua users «Math Library Tutorial». For more about Lua string-library functions see Lua users «String Library Tutorial» .

Once again the `string_function()` can be invoked from main_function() which can be invoked with `main_function()`.

Теперь вывод на экране выглядит следующим образом:

```
tarantool> function string_function()
         >   local random_number
         >   local random_string
         >   random_number = math.random(65, 90)
         >   random_string = string.char(random_number)
         >   return random_string
         > end
---
...
tarantool> main_function()
```

(continues on next page)

(продолжение с предыдущей страницы)

```
---
- C
...
tarantool>
```

… Well, actually it won't always look like this because `math.random()` produces random numbers. But for the illustration purposes it won't matter what the random string values are.

Modify the function so it returns a ten-letter random string

Now that it's clear how to produce one-letter random strings, we can reach our goal of producing a ten-letter string by concatenating ten one-letter strings, in a loop.

```
function string_function()
  local random_number
  local random_string
  random_string = ""
  for x = 1,10,1 do
    random_number = math.random(65, 90)
    random_string = random_string .. string.char(random_number)
  end
  return random_string
end
```

The words «for x = 1,10,1» mean "start with x equals 1, loop until x equals 10, increment x by 1 for each iteration." The symbol «..» means «concatenate», that is, add the string on the right of the «..» sign to the string on the left of the «..» sign. Since we start by saying that random_string is «» (a blank string), the end result is that random_string has 10 random letters. Once again the `string_function()` can be invoked from `main_function()` which can be invoked with `main_function()`.

For more about Lua loops see Lua manual chapter 4.3.4 «Numeric for».

Теперь вывод на экране выглядит следующим образом:

```
tarantool> function string_function()
         >   local random_number
         >   local random_string
         >   random_string = ""
         >   for x = 1,10,1 do
         >     random_number = math.random(65, 90)
         >     random_string = random_string .. string.char(random_number)
         >   end
         >   return random_string
         > end
---
...
tarantool> main_function()
---
- 'ZUDJBHKEFM'
...
tarantool>
```

Make a tuple out of a number and a string

Now that it's clear how to make a 10-letter random string, it's possible to make a tuple that contains a number and a 10-letter random string, by invoking a function in Tarantool's library of Lua functions.

```
function main_function()
  local string_value, t
  string_value = string_function()
  t = box.tuple.new({1, string_value})
  return t
end
```

Once this is done, t will be the value of a new tuple which has two fields. The first field is numeric: 1. The second field is a random string. Once again the `string_function()` can be invoked from `main_function()` which can be invoked with `main_function()`.

For more about Tarantool tuples see Tarantool manual section *Submodule box.tuple*.

Теперь вывод на экране выглядит следующим образом:

```
tarantool> function main_function()
         > local string_value, t
         > string_value = string_function()
         > t = box.tuple.new({1, string_value})
         > return t
         > end
---
...
tarantool> main_function()
---
- [1, 'PNPZPCOOKA']
...
tarantool>
```

Modify main_function to insert a tuple into the database

Now that it's clear how to make a tuple that contains a number and a 10-letter random string, the only trick remaining is putting that tuple into tester. Remember that tester is the first space that was defined in the sandbox, so it's like a database table.

```
function main_function()
  local string_value, t
  string_value = string_function()
  t = box.tuple.new({1,string_value})
  box.space.tester:replace(t)
end
```

The new line here is `box.space.tester:replace(t)`. The name contains „tester" because the insertion is going to be to tester. The second parameter is the tuple value. To be perfectly correct we could have said `box.space.tester:insert(t)` here, rather than `box.space.tester:replace(t)`, but «replace» means "insert even if there is already a tuple whose primary-key value is a duplicate", and that makes it easier to re-run the exercise even if the sandbox database isn't empty. Once this is done, tester will contain a tuple with two fields. The first field will be 1. The second field will be a random 10-letter string. Once again the `string_function()` can be invoked from `main_function()` which can be invoked with `main_function()`. But `main_function()` won't tell the whole story, because it does not return t, it only puts t into the database. To confirm that something got inserted, we'll use a SELECT request.

```
main_function()
box.space.tester:select{1}
```

For more about Tarantool insert and replace calls, see Tarantool manual section *Submodule box.space*.

Теперь вывод на экране выглядит следующим образом:

```
tarantool> function main_function()
         >   local string_value, t
         >   string_value = string_function()
         >   t = box.tuple.new({1,string_value})
         >   box.space.tester:replace(t)
         > end
---
...
tarantool> main_function()
---
...
tarantool> box.space.tester:select{1}
---
- - [1, 'EUJYVEECIL']
...
tarantool>
```

Modify main_function to insert a million tuples into the database

Now that it's clear how to insert one tuple into the database, it's no big deal to figure out how to scale up: instead of inserting with a literal value = 1 for the primary key, insert with a variable value = between 1 and 1 million, in a loop. Since we already saw how to loop, that's a simple thing. The only extra wrinkle that we add here is a timing function.

```
function main_function()
  local string_value, t
  for i = 1,1000000,1 do
    string_value = string_function()
    t = box.tuple.new({i,string_value})
    box.space.tester:replace(t)
  end
end
start_time = os.clock()
main_function()
end_time = os.clock()
'insert done in ' .. end_time - start_time .. ' seconds'
```

The standard Lua function os.clock() will return the number of CPU seconds since the start. Therefore, by getting start_time = number of seconds just before the inserting, and then getting end_time = number of seconds just after the inserting, we can calculate (end_time - start_time) = elapsed time in seconds. We will display that value by putting it in a request without any assignments, which causes Tarantool to send the value to the client, which prints it. (Lua's answer to the C `printf()` function, which is `print()`, will also work.)

For more on Lua `os.clock()` see Lua manual chapter 22.1 «Date and Time». For more on Lua print() see Lua manual chapter 5 «Functions».

Since this is the grand finale, we will redo the final versions of all the necessary requests: the request that created `string_function()`, the request that created `main_function()`, and the request that invokes `main_function()`.

```
function string_function()
  local random_number
  local random_string
  random_string = ""
  for x = 1,10,1 do
    random_number = math.random(65, 90)
    random_string = random_string .. string.char(random_number)
  end
  return random_string
end

function main_function()
  local string_value, t
  for i = 1,1000000,1 do
    string_value = string_function()
    t = box.tuple.new({i,string_value})
    box.space.tester:replace(t)
  end
end
start_time = os.clock()
main_function()
end_time = os.clock()
'insert done in ' .. end_time - start_time .. ' seconds'
```

Теперь вывод на экране выглядит следующим образом:

```
tarantool> function string_function()
         >   local random_number
         >   local random_string
         >   random_string = ""
         >   for x = 1,10,1 do
         >     random_number = math.random(65, 90)
         >     random_string = random_string .. string.char(random_number)
         >   end
         >   return random_string
         > end
---
...
tarantool> function main_function()
         >   local string_value, t
         >   for i = 1,1000000,1 do
         >     string_value = string_function()
         >     t = box.tuple.new({i,string_value})
         >     box.space.tester:replace(t)
         >   end
         > end
---
...
tarantool> start_time = os.clock()
---
...
tarantool> main_function()
---
...
tarantool> end_time = os.clock()
---
...
```

(continues on next page)

(продолжение с предыдущей страницы)

```
tarantool> 'insert done in ' .. end_time - start_time .. ' seconds'
---
- insert done in 37.62 seconds
...
tarantool>
```

What has been shown is that Lua functions are quite expressive (in fact one can do more with Tarantool's Lua stored procedures than one can do with stored procedures in some SQL DBMSs), and that it's straightforward to combine Lua-library functions and Tarantool-library functions.

What has also been shown is that inserting a million tuples took 37 seconds. The host computer was a Linux laptop. By changing *wal_mode* to „none" before running the test, one can reduce the elapsed time to 4 seconds.

5.1.2 Подсчет суммы по JSON-полям во всех кортежах

This is an exercise assignment: "Assume that inside every tuple there is a string formatted as JSON. Inside that string there is a JSON numeric field. For each tuple, find the numeric field's value and add it to a „sum" variable. At end, return the „sum" variable." The purpose of the exercise is to get experience in one way to read and process tuples.

```
1  json = require('json')
2  function sum_json_field(field_name)
3    local v, t, sum, field_value, is_valid_json, lua_table
4    sum = 0
5    for v, t in box.space.tester:pairs() do
6      is_valid_json, lua_table = pcall(json.decode, t[2])
7      if is_valid_json then
8        field_value = lua_table[field_name]
9        if type(field_value) == "number" then sum = sum + field_value end
10     end
11   end
12   return sum
13 end
```

LINE 3: WHY «LOCAL». This line declares all the variables that will be used in the function. Actually it's not necessary to declare all variables at the start, and in a long function it would be better to declare variables just before using them. In fact it's not even necessary to declare variables at all, but an undeclared variable is «global». That's not desirable for any of the variables that are declared in line 1, because all of them are for use only within the function.

LINE 5: WHY «PAIRS()». Our job is to go through all the rows and there are two ways to do it: with *box.space.space_object:pairs()* or with `variable = select(...)` followed by `for i, n, 1 do` *`some-function`*`(variable[i]) end`. We preferred `pairs()` for this example.

LINE 5: START THE MAIN LOOP. Everything inside this «`for`» loop will be repeated as long as there is another index key. A tuple is fetched and can be referenced with variable `t`.

LINE 6: WHY «PCALL». If we simply said `lua_table = json.decode(t[2]))`, then the function would abort with an error if it encountered something wrong with the JSON string - a missing colon, for example. By putting the function inside «`pcall`» (protected call), we're saying: we want to intercept that sort of error, so if there's a problem just set `is_valid_json = false` and we will know what to do about it later.

LINE 6: MEANING. The function is *json.decode* which means decode a JSON string, and the parameter is t[2] which is a reference to a JSON string. There's a bit of hard coding here, we're assuming that the second field in the tuple is where the JSON string was inserted. For example, we're assuming a tuple looks like

```
field[1]: 444
field[2]: '{"Hello": "world", "Quantity": 15}'
```

meaning that the tuple's first field, the primary key field, is a number while the tuple's second field, the JSON string, is a string. Thus the entire statement means «decode `t[2]` (the tuple's second field) as a JSON string; if there's an error set `is_valid_json = false`; if there's no error set `is_valid_json = true` and set `lua_table =` a Lua table which has the decoded string».

LINE 8. At last we are ready to get the JSON field value from the Lua table that came from the JSON string. The value in field_name, which is the parameter for the whole function, must be a name of a JSON field. For example, inside the JSON string `'{"Hello": "world", "Quantity": 15}'`, there are two JSON fields: «Hello» and «Quantity». If the whole function is invoked with `sum_json_field("Quantity")`, then `field_value = lua_table[field_name]` is effectively the same as `field_value = lua_table["Quantity"]` or even `field_value = lua_table.Quantity`. Those are just three different ways of saying: for the Quantity field in the Lua table, get the value and put it in variable `field_value`.

LINE 9: WHY «IF». Suppose that the JSON string is well formed but the JSON field is not a number, or is missing. In that case, the function would be aborted when there was an attempt to add it to the sum. By first checking `type(field_value) == "number"`, we avoid that abortion. Anyone who knows that the database is in perfect shape can skip this kind of thing.

And the function is complete. Time to test it. Starting with an empty database, defined the same way as the sandbox database that was introduced in *first database*,

```
-- if tester is left over from some previous test, destroy it
box.space.tester:drop()
box.schema.space.create('tester')
box.space.tester:create_index('primary', {parts = {1, 'unsigned'}})
```

then add some tuples where the first field is a number and the second field is a string.

```
box.space.tester:insert{444, '{"Item": "widget", "Quantity": 15}'}
box.space.tester:insert{445, '{"Item": "widget", "Quantity": 7}'}
box.space.tester:insert{446, '{"Item": "golf club", "Quantity": "sunshine"}'}
box.space.tester:insert{447, '{"Item": "waffle iron", "Quantit": 3}'}
```

Since this is a test, there are deliberate errors. The «golf club» and the «waffle iron» do not have numeric Quantity fields, so must be ignored. Therefore the real sum of the Quantity field in the JSON strings should be: $15 + 7 = 22$.

Invoke the function with `sum_json_field("Quantity")`.

```
tarantool> sum_json_field("Quantity")
---
- 22
...
```

It works. We'll just leave, as exercises for future improvement, the possibility that the «hard coding» assumptions could be removed, that there might have to be an overflow check if some field values are huge, and that the function should contain a «yield» instruction if the count of tuples is huge.

5.1.3 Индексированный поиск по шаблонам

Here is a generic function which takes a field identifier and a search pattern, and returns all tuples that match. * The field must be the first field of a TREE index. * The function will use Lua pattern matching, which allows «magic characters» in regular expressions. * The initial characters in the pattern, as far as the first magic character, will be used as an index search key. For each tuple that is found via the index, there will be a match of the whole pattern. * To be *cooperative*, the function should yield after every 10 tuples, unless there is a reason to delay yielding. With this function, we can take advantage of Tarantool's indexes for speed, and take advantage of Lua's pattern matching for flexibility. It does everything that an SQL «LIKE» search can do, and far more.

Read the following Lua code to see how it works. The comments that begin with «SEE NOTE ...» refer to long explanations that follow the code.

```
function indexed_pattern_search(space_name, field_no, pattern)
  -- SEE NOTE #1 "FIND AN APPROPRIATE INDEX"
  if (box.space[space_name] == nil) then
    print("Error: Failed to find the specified space")
    return nil
  end
  local index_no = -1
  for i=0,box.schema.INDEX_MAX,1 do
    if (box.space[space_name].index[i] == nil) then break end
    if (box.space[space_name].index[i].type == "TREE"
        and box.space[space_name].index[i].parts[1].fieldno == field_no
        and (box.space[space_name].index[i].parts[1].type == "scalar"
        or box.space[space_name].index[i].parts[1].type == "string")) then
      index_no = i
      break
    end
  end
  if (index_no == -1) then
    print("Error: Failed to find an appropriate index")
    return nil
  end
  -- SEE NOTE #2 "DERIVE INDEX SEARCH KEY FROM PATTERN"
  local index_search_key = ""
  local index_search_key_length = 0
  local last_character = ""
  local c = ""
  local c2 = ""
  for i=1,string.len(pattern),1 do
    c = string.sub(pattern, i, i)
    if (last_character ~= "%") then
      if (c == '^' or c == "$" or c == "(" or c == ")" or c == "."
                   or c == "[" or c == "]" or c == "*" or c == "+"
                   or c == "-" or c == "?") then
        break
      end
      if (c == "%") then
        c2 = string.sub(pattern, i + 1, i + 1)
        if (string.match(c2, "%p") == nil) then break end
        index_search_key = index_search_key .. c2
      else
        index_search_key = index_search_key .. c
      end
    end
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    last_character = c
  end
  index_search_key_length = string.len(index_search_key)
  if (index_search_key_length < 3) then
    print("Error: index search key " .. index_search_key .. " is too short")
    return nil
  end
  -- SEE NOTE #3 "OUTER LOOP: INITIATE"
  local result_set = {}
  local number_of_tuples_in_result_set = 0
  local previous_tuple_field = ""
  while true do
    local number_of_tuples_since_last_yield = 0
    local is_time_for_a_yield = false
    -- SEE NOTE #4 "INNER LOOP: ITERATOR"
    for _,tuple in box.space[space_name].index[index_no]:
    pairs(index_search_key,{iterator = box.index.GE}) do
      -- SEE NOTE #5 "INNER LOOP: BREAK IF INDEX KEY IS TOO GREAT"
      if (string.sub(tuple[field_no], 1, index_search_key_length)
      > index_search_key) then
        break
      end
      -- SEE NOTE #6 "INNER LOOP: BREAK AFTER EVERY 10 TUPLES -- MAYBE"
      number_of_tuples_since_last_yield = number_of_tuples_since_last_yield + 1
      if (number_of_tuples_since_last_yield >= 10
          and tuple[field_no] ~= previous_tuple_field) then
        index_search_key = tuple[field_no]
        is_time_for_a_yield = true
        break
        end
      previous_tuple_field = tuple[field_no]
      -- SEE NOTE #7 "INNER LOOP: ADD TO RESULT SET IF PATTERN MATCHES"
      if (string.match(tuple[field_no], pattern) ~= nil) then
        number_of_tuples_in_result_set = number_of_tuples_in_result_set + 1
        result_set[number_of_tuples_in_result_set] = tuple
      end
    end
    -- SEE NOTE #8 "OUTER LOOP: BREAK, OR YIELD AND CONTINUE"
    if (is_time_for_a_yield ~= true) then
      break
    end
    require('fiber').yield()
  end
  return result_set
end
```

NOTE #1 «FIND AN APPROPRIATE INDEX» The caller has passed space_name (a string) and field_no (a number). The requirements are: (a) index type must be «TREE» because for other index types (HASH, BITSET, RTREE) a search with iterator=GE will not return strings in order by string value; (b) field_no must be the first index part; (c) the field must contain strings, because for other data types (such as «unsigned») pattern searches are not possible; If these requirements are not met by any index, then print an error message and return nil.

NOTE #2 «DERIVE INDEX SEARCH KEY FROM PATTERN» The caller has passed pattern (a string). The index search key will be the characters in the pattern as far as the first magic character. Lua's magic characters are % ^ $ ( ) . [ ] * + - ?. For example, if the pattern is «ABC.E», the period is a magic character and therefore the index search key will be «ABC». But there is a complication … If we see «%» followed by a punctuation character, that punctuation character is «escaped» so remove the «%» when making the index search key. For example, if the pattern is «AB%$E», the dollar sign is escaped and therefore the index search key will be «AB$E». Finally there is a check that the index search key length must be at least three – this is an arbitrary number, and in fact zero would be okay, but short index search keys will cause long search times.

NOTE #3 – «OUTER LOOP: INITIATE» The function's job is to return a result set, just as box.space.select would. We will fill it within an outer loop that contains an inner loop. The outer loop's job is to execute the inner loop, and possibly yield, until the search ends. The inner loop's job is to find tuples via the index, and put them in the result set if they match the pattern.

NOTE #4 «INNER LOOP: ITERATOR» The for loop here is using pairs(), see the *explanation of what index iterators are*. Within the inner loop, there will be a local variable named «tuple» which contains the latest tuple found via the index search key.

NOTE #5 «INNER LOOP: BREAK IF INDEX KEY IS TOO GREAT» The iterator is GE (Greater or Equal), and we must be more specific: if the search index key has N characters, then the leftmost N characters of the result's index field must not be greater than the search index key. For example, if the search index key is „ABC", then „ABCDE" is a potential match, but „ABD" is a signal that no more matches are possible.

NOTE #6 «INNER LOOP: BREAK AFTER EVERY 10 TUPLES – MAYBE» This chunk of code is for cooperative multitasking. The number 10 is arbitrary, and usually a larger number would be okay. The simple rule would be «after checking 10 tuples, yield, and then resume the search (that is, do the inner loop again) starting after the last value that was found». However, if the index is non-unique or if there is more than one field in the index, then we might have duplicates – for example {«ABC»,1}, {«ABC», 2}, {«ABC», 3}» – and it would be difficult to decide which «ABC» tuple to resume with. Therefore, if the result's index field is the same as the previous result's index field, there is no break.

NOTE #7 «INNER LOOP: ADD TO RESULT SET IF PATTERN MATCHES» Compare the result's index field to the entire pattern. For example, suppose that the caller passed pattern «ABC.E» and there is an indexed field containing «ABCDE». Therefore the initial index search key is «ABC». Therefore a tuple containing an indexed field with «ABCDE» will be found by the iterator, because «ABCDE» > «ABC». In that case string.match will return a value which is not nil. Therefore this tuple can be added to the result set.

NOTE #8 «OUTER LOOP: BREAK, OR YIELD AND CONTINUE» There are three conditions which will cause a break from the inner loop: (1) the for loop ends naturally because there are no more index keys which are greater than or equal to the index search key, (2) the index key is too great as described in NOTE #5, (3) it is time for a yield as described in NOTE #6. If condition (1) or condition (2) is true, then there is nothing more to do, the outer loop ends too. If and only if condition (3) is true, the outer loop must yield and then continue. If it does continue, then the inner loop – the iterator search – will happen again with a new value for the index search key.

EXAMPLE:

Start Tarantool, cut and paste the code for function `indexed_pattern_search`, and try the following:

```
box.space.t:drop()
box.schema.space.create('t')
box.space.t:create_index('primary',{})
box.space.t:create_index('secondary',{unique=false,parts={2,'string',3,'string'}})
box.space.t:insert{1,'A','a'}
box.space.t:insert{2,'AB',''}
box.space.t:insert{3,'ABC','a'}
box.space.t:insert{4,'ABCD',''}
box.space.t:insert{5,'ABCDE','a'}
box.space.t:insert{6,'ABCDE',''}
box.space.t:insert{7,'ABCDEF','a'}
```

(continues on next page)

(продолжение с предыдущей страницы)

```
box.space.t:insert{8,'ABCDF',''}
indexed_pattern_search("t", 2, "ABC.E.")
```

Мы получим следующий результат:

```
tarantool> indexed_pattern_search("t", 2, "ABC.E.")
---
- - [7, 'ABCDEF', 'a']
...
```

5.2 Практическое задание на C

Here is one C tutorial: *C stored procedures*.

5.2.1 Хранимые процедуры на языке C

Tarantool can call C code with *modules*, or with *ffi*, or with C stored procedures. This tutorial only is about the third option, C stored procedures. In fact the routines are always «C functions» but the phrase «stored procedure» is commonly used for historical reasons.

In this tutorial, which can be followed by anyone with a Tarantool development package and a C compiler, there are three tasks. The first – `easy.c` – prints «hello world». The second – `harder.c` – decodes a passed parameter value. The third – `hardest.c` – uses the C API to do DBMS work.

After following the instructions, and seeing that the results are what is described here, users should feel confident about writing their own stored procedures.

Preparation

Check that these items exist on the computer: * Tarantool 1.7 * A gcc compiler, any modern version should work * «module.h» * «msgpuck.h»

The «module.h» file will exist if Tarantool 1.7 was installed from source. Otherwise Tarantool's «developer» package must be installed. For example on Ubuntu say `sudo apt-get install tarantool-dev` or on Fedora say `dnf -y install tarantool-devel`

The «msgpuck.h» file will exist if Tarantool 1.7 was installed from source. Otherwise the «msgpuck» package must be installed from https://github.com/rtsisyk/msgpuck.

Both module.h and msgpuck.h must be on the include path for the C compiler to see them. For example, if module.h address is /usr/local/include/tarantool/module.h, and msgpuck.h address is /usr/local/include/msgpuck/msgpuck.h, and they are not currently on the include path, say `export CPATH=/usr/local/include/tarantool:/usr/local/include/msgpuck`

Requests will be done using tarantool as a *client*. Start tarantool, and enter these requests.

```
box.cfg{listen=3306}
box.schema.space.create('capi_test')
box.space.capi_test:create_index('primary')
net_box = require('net.box')
capi_connection = net_box:new(3306)
```

In plainer language: create a space named capi_test, and make a connection to self named capi_connection.

Leave the client running. It will be necessary to enter more requests later.

easy.c

Start another shell. Change directory (cd) so that it is the same as the directory that the client is running on.

Create a file. Name it easy.c. Put these six lines in it.

```
#include "module.h"
int easy(box_function_ctx_t *ctx, const char *args, const char *args_end)
{
  printf("hello world\n");
  return 0;
}
```

Compile the program, producing a library file named easy.so: `gcc -shared -o easy.so -fPIC easy.c`

Now go back to the client and execute these requests:

```
box.schema.func.create('easy', {language = 'C'})
box.schema.user.grant('guest', 'execute', 'function', 'easy')
capi_connection:call('easy')
```

If these requests appear unfamiliar, re-read the descriptions of *box.schema.func.create* and *box.schema.user.grant* and *conn:call*.

The function that matters is capi_connection:call(„easy“).

Its first job is to find the „easy“ function, which should be easy because by default Tarantool looks on the current directory for a file named easy.so.

Its second job is to call the „easy“ function. Since the easy() function in easy.c begins with `printf("hello world\n")`, the words «hello world» will appear on the screen.

Its third job is to check that the call was successful. Since the easy() function in easy.c ends with `return 0`, there is no error message to display and the request is over.

The result should look like this:

```
tarantool> capi_connection:call('easy')
hello world
---
- []
...
```

Conclusion: calling a C function is easy.

harder.c

Go back to the shell where the easy.c program was created.

Create a file. Name it harder.c. Put these 17 lines in it:

```
#include "module.h"
#include "msgpuck.h"
int harder(box_function_ctx_t *ctx, const char *args, const char *args_end)
{
  uint32_t arg_count = mp_decode_array(&args);
  printf("arg_count = %d\n", arg_count);
  uint32_t field_count = mp_decode_array(&args);
  printf("field_count = %d\n", field_count);
  uint32_t val;
```

(continues on next page)

(продолжение с предыдущей страницы)

```
  int i;
  for (i = 0; i < field_count; ++i)
  {
    val = mp_decode_uint(&args);
    printf("val=%d.\n", val);
  }
  return 0;
}
```

Compile the program, producing a library file named harder.so: `gcc -shared -o harder.so -fPIC harder.c`

Now go back to the client and execute these requests:

```
box.schema.func.create('harder', {language = 'C'})
box.schema.user.grant('guest', 'execute', 'function', 'harder')
passable_table = {}
table.insert(passable_table, 1)
table.insert(passable_table, 2)
table.insert(passable_table, 3)
capi_connection:call('harder', passable_table)
```

This time the call is passing a Lua table (passable_table) to the harder() function. The harder() function will see it, it's in the `char *args` parameter.

At this point the harder() function will start using functions defined in msgpuck.h, which are documented in http://rtsisyk.github.io/msgpuck. The routines that begin with «mp» are msgpuck functions that handle data formatted according to the MsgPack specification. Passes and returns are always done with this format so one must become acquainted with msgpuck to become proficient with the C API.

For now, though, it's enough to know that mp_decode_array() returns the number of elements in an array, and mp_decode_uint returns an unsigned integer, from `args`. And there's a side effect: when the decoding finishes, `args` has changed and is now pointing to the next element.

Therefore the first displayed line will be «arg_count = 1» because there was only one item passed: passable_table. The second displayed line will be «field_count = 3» because there are three items in the table. The next three lines will be «1» and «2» and «3» because those are the values in the items in the table.

And now the screen looks like this:

```
tarantool> capi_connection:call('harder', passable_table)
arg_count = 1
field_count = 3
val=1.
val=2.
val=3.
---
- []
...
```

Conclusion: decoding parameter values passed to a C function is not easy at first, but there are routines to do the job, and they're documented, and there aren't very many of them.

hardest.c

Go back to the shell where the easy.c and the harder.c programs were created.

Create a file. Name it hardest.c. Put these 13 lines in it:

```
#include "module.h"
#include "msgpuck.h"
int hardest(box_function_ctx_t *ctx, const char *args, const char *args_end)
{
  uint32_t space_id = box_space_id_by_name("capi_test", strlen("capi_test"));
  char tuple[1024];
  char *tuple_pointer = tuple;
  tuple_pointer = mp_encode_array(tuple_pointer, 2);
  tuple_pointer = mp_encode_uint(tuple_pointer, 10000);
  tuple_pointer = mp_encode_str(tuple_pointer, "String 2", 8);
  int n = box_insert(space_id, tuple, tuple_pointer, NULL);
  return n;
}
```

Compile the program, producing a library file named hardest.so: `gcc -shared -o hardest.so -fPIC hardest.c`

Now go back to the client and execute these requests:

```
box.schema.func.create('hardest', {language = "C"})
box.schema.user.grant('guest', 'execute', 'function', 'hardest')
box.schema.user.grant('guest', 'read,write', 'space', 'capi_test')
capi_connection:call('hardest')
```

This time the C function is doing three things: (1) finding the numeric identifier of the «capi_test» space by calling box_space_id_by_name(); (2) formatting a tuple using more msgpuck.h functions; (3) inserting a row using box_insert.

Now, still on the client, execute this request: `box.space.capi_test:select()`

The result should look like this:

```
tarantool> box.space.capi_test:select()
---
- - [10000, 'String 2']
...
```

This proves that the hardest() function succeeded, but where did box_space_id_by_name() and box_insert() come from? Answer: the C API. The whole C API is documented *here*. The function box_space_id_by_name() is documented *here*. The function box_insert() is documented *here*.

Conclusion: the long description of the C API is there for a good reason. All of the functions in it can be called from C functions which are called from Lua. So C «stored procedures» have full access to the database.

Cleaning up

Get rid of each of the function tuples with *box.schema.func.drop*, and get rid of the capi_test space with *box.schema.capi_test:drop()*, and remove the .c and .so files that were created for this tutorial.

An example in the test suite

Download the source code of Tarantool. Look in a subdirectory `test/box`. Notice that there is a file named `tuple_bench.test.lua` and another file named `tuple_bench.c`. Examine the Lua file and observe that it is calling a function in the C file, using the same techniques that this tutorial has shown.

Conclusion: parts of the standard test suite use C stored procedures, and they must work, because releases don't happen if Tarantool doesn't pass the tests.

ГЛАВА 6

Contributor's Guide

6.1 Справочник по C API

6.1.1 Модуль *box*

`box_function_ctx_t`
: Opaque structure passed to the stored C procedure

int `box_return_tuple`(*box_function_ctx_t *ctx*, *box_tuple_t *tuple*)
: Return a tuple from stored C procedure.

  Returned tuple is automatically reference counted by Tarantool.

  Параметры

  - `ctx` (*box_funtion_ctx_t**) – an opaque structure passed to the stored C procedure by Tarantool
  - `tuple` (`box_tuple_t*`) – a tuple to return

  Результат -1 on error (perhaps, out of memory; check *box_error_last()*)

  Результат 0 otherwise

uint32_t `box_space_id_by_name`(const char **name*, uint32_t *len*)
: Find space id by name.

  This function performs SELECT request to _vspace system space.

  Параметры

  - `char* name` (*const*) – space name
  - `len` (*uint32_t*) – length of `name`

  Результат `BOX_ID_NIL` on error or if not found (check *box_error_last()*)

  Результат space_id otherwise

See also: *box_index_id_by_name*

uint32_t `box_index_id_by_name`(uint32_t *space_id*, const char **name*, uint32_t *len*)

Find index id by name.

Параметры

- `space_id` (*uint32_t*) – space identifier
- `char* name` (*const*) – index name
- `len` (*uint32_t*) – length of `name`

Результат `BOX_ID_NIL` on error or if not found (check *box_error_last()*)

Результат space_id otherwise

This function performs SELECT request to _vindex system space.

See also: *box_space_id_by_name*

int `box_insert`(uint32_t *space_id*, const char **tuple*, const char **tuple_end*, *box_tuple_t* ***result*)

Execute an INSERT/REPLACE request.

Параметры

- `space_id` (*uint32_t*) – space identifier
- `char* tuple` (*const*) – encoded tuple in MsgPack Array format ([field1, field2, …])
- `char* tuple_end` (*const*) – end of a `tuple`
- `result` (`box_tuple_t**`) – output argument. Resulted tuple. Can be set to NULL to discard result

Результат -1 on error (check *box_error_last()*)

Результат 0 otherwise

See also *space_object.insert()*

int `box_replace`(uint32_t *space_id*, const char **tuple*, const char **tuple_end*, *box_tuple_t* ***result*)

Execute an REPLACE request.

Параметры

- `space_id` (*uint32_t*) – space identifier
- `char* tuple` (*const*) – encoded tuple in MsgPack Array format ([field1, field2, …])
- `char* tuple_end` (*const*) – end of a `tuple`
- `result` (`box_tuple_t**`) – output argument. Resulted tuple. Can be set to NULL to discard result

Результат -1 on error (check *box_error_last()*)

Результат 0 otherwise

See also *space_object.replace()*

int `box_delete`(uint32_t *space_id*, uint32_t *index_id*, const char **key*, const char **key_end*, *box_tuple_t* ***result*)

Execute an DELETE request.

Параметры

- space_id (*uint32_t*) – space identifier
- index_id (*uint32_t*) – index identifier
- char* key (*const*) – encoded key in MsgPack Array format ([field1, field2, ...])
- char* key_end (*const*) – end of a key
- result (box_tuple_t**) – output argument. Result an old tuple. Can be set to NULL to discard result

Результат -1 on error (check *box_error_last()*)

Результат 0 otherwise

See also *space_object.delete()*

int box_update(uint32_t *space_id*, uint32_t *index_id*, const char **key*, const char **key_end*, const char **ops*, const char **ops_end*, int *index_base*, *box_tuple_t* ***result*)

Execute an UPDATE request.

Параметры

- space_id (*uint32_t*) – space identifier
- index_id (*uint32_t*) – index identifier
- char* key (*const*) – encoded key in MsgPack Array format ([field1, field2, ...])
- char* key_end (*const*) – end of a key
- char* ops (*const*) – encoded operations in MsgPack Arrat format, e.g. `[[ '=', field_id, value ], ['!', 2, 'xxx']]`
- char* ops_end (*const*) – end of a ops
- index_base (*int*) – 0 if field_ids in update operation are zero-based indexed (like C) or 1 if for one-based indexed field ids (like Lua).
- result (box_tuple_t**) – output argument. Result an old tuple. Can be set to NULL to discard result

Результат -1 on error (check *box_error_last()*)

Результат 0 otherwise

See also *space_object.update()*

int box_upsert(uint32_t *space_id*, uint32_t *index_id*, const char **tuple*, const char **tuple_end*, const char **ops*, const char **ops_end*, int *index_base*, *box_tuple_t* ***result*)

Execute an UPSERT request.

Параметры

- space_id (*uint32_t*) – space identifier
- index_id (*uint32_t*) – index identifier
- char* tuple (*const*) – encoded tuple in MsgPack Array format ([field1, field2, ...])
- char* tuple_end (*const*) – end of a tuple
- char* ops (*const*) – encoded operations in MsgPack Arrat format, e.g. `[[ '=', field_id, value ], ['!', 2, 'xxx']]`
- char* ops_end (*const*) – end of a ops

- index_base (*int*) – 0 if field_ids in update operation are zero-based indexed (like C) or 1 if for one-based indexed field ids (like Lua).
- result (box_tuple_t**) – output argument. Result an old tuple. Can be set to NULL to discard result

Результат -1 on error (check :*box_error_last()*)

Результат 0 otherwise

See also *space_object.upsert()*

6.1.2 Модуль *clock*

double clock_realtime(void)
double clock_monotonic(void)
double clock_process(void)
double clock_thread(void)

uint64_t clock_realtime64(void)
uint64_t clock_monotonic64(void)
uint64_t clock_process64(void)
uint64_t clock_thread64(void)

6.1.3 Модуль *coio*

enum COIO_EVENT

enumerator COIO_READ
READ event

enumerator COIO_WRITE
WRITE event

int coio_wait(int *fd*, int *event*, double *timeout*)
Wait until READ or WRITE event on socket (fd). Yields.

Параметры

- fd (*int*) – non-blocking socket file description
- event (*int*) – requested events to wait. Combination of COIO_READ | COIO_WRITE bit flags.
- timeout (*double*) – timeout in seconds.

Результат 0 - timeout

Результат >0 - returned events. Combination of TNT_IO_READ | TNT_IO_WRITE bit flags.

ssize_t coio_call(ssize_t (**func*)(va_list), ...)
Create new eio task with specified function and arguments. Yield and wait until the task is complete or a timeout occurs.

This function doesn't throw exceptions to avoid double error checking: in most cases it's also necessary to check the return value of the called function and perform necessary actions. If func sets errno, the errno is preserved across the call.

Результат -1 and errno = ENOMEM if failed to create a task

Результат the function return (errno is preserved).

Example:

```
static ssize_t openfile_cb(va_list ap)
{
        const char* filename = va_arg(ap);
        int flags = va_arg(ap);
        return open(filename, flags);
}

if (coio_call(openfile_cb, 0.10, "/tmp/file", 0) == -1)
    // handle errors.
...
```

int coio_getaddrinfo(const char *host, const char *port, const struct addrinfo *hints, struct addrinfo **res, double timeout)

Fiber-friendly version of *getaddrinfo(3)*.

6.1.4 Модуль *error*

enum box_error_code

enumerator ER_UNKNOWN

enumerator ER_ILLEGAL_PARAMS

enumerator ER_MEMORY_ISSUE

enumerator ER_TUPLE_FOUND

enumerator ER_TUPLE_NOT_FOUND

enumerator ER_UNSUPPORTED

enumerator ER_NONMASTER

enumerator ER_READONLY

enumerator ER_INJECTION

enumerator ER_CREATE_SPACE

enumerator ER_SPACE_EXISTS

enumerator ER_DROP_SPACE

enumerator ER_ALTER_SPACE

enumerator ER_INDEX_TYPE

enumerator ER_MODIFY_INDEX

enumerator ER_LAST_DROP

enumerator ER_TUPLE_FORMAT_LIMIT

enumerator ER_DROP_PRIMARY_KEY

enumerator ER_KEY_PART_TYPE

enumerator ER_EXACT_MATCH

enumerator ER_INVALID_MSGPACK

enumerator ER_PROC_RET

enumerator ER_TUPLE_NOT_ARRAY

enumerator ER_FIELD_TYPE

enumerator ER_FIELD_TYPE_MISMATCH

enumerator ER_SPLICE

enumerator ER_ARG_TYPE

enumerator ER_TUPLE_IS_TOO_LONG

enumerator ER_UNKNOWN_UPDATE_OP

enumerator ER_UPDATE_FIELD

enumerator ER_FIBER_STACK

enumerator ER_KEY_PART_COUNT

enumerator ER_PROC_LUA

enumerator ER_NO_SUCH_PROC

enumerator ER_NO_SUCH_TRIGGER

enumerator ER_NO_SUCH_INDEX

enumerator ER_NO_SUCH_SPACE

enumerator ER_NO_SUCH_FIELD

enumerator ER_SPACE_FIELD_COUNT

enumerator ER_INDEX_FIELD_COUNT

enumerator ER_WAL_IO

enumerator ER_MORE_THAN_ONE_TUPLE

enumerator ER_ACCESS_DENIED

enumerator ER_CREATE_USER

enumerator ER_DROP_USER

enumerator ER_NO_SUCH_USER

enumerator ER_USER_EXISTS

enumerator ER_PASSWORD_MISMATCH

enumerator ER_UNKNOWN_REQUEST_TYPE

enumerator ER_UNKNOWN_SCHEMA_OBJECT

enumerator ER_CREATE_FUNCTION

enumerator ER_NO_SUCH_FUNCTION

enumerator ER_FUNCTION_EXISTS

enumerator ER_FUNCTION_ACCESS_DENIED

enumerator ER_FUNCTION_MAX

enumerator ER_SPACE_ACCESS_DENIED

enumerator ER_USER_MAX

enumerator ER_NO_SUCH_ENGINE

enumerator ER_RELOAD_CFG

enumerator ER_CFG

enumerator ER_SOPHIA

enumerator ER_LOCAL_SERVER_IS_NOT_ACTIVE

enumerator ER_UNKNOWN_SERVER

enumerator ER_CLUSTER_ID_MISMATCH

enumerator ER_INVALID_UUID

enumerator ER_CLUSTER_ID_IS_RO

enumerator ER_RESERVED66

enumerator ER_SERVER_ID_IS_RESERVED

enumerator ER_INVALID_ORDER

enumerator ER_MISSING_REQUEST_FIELD

enumerator ER_IDENTIFIER

enumerator ER_DROP_FUNCTION

enumerator ER_ITERATOR_TYPE

enumerator ER_REPLICA_MAX

enumerator ER_INVALID_XLOG

enumerator ER_INVALID_XLOG_NAME

enumerator ER_INVALID_XLOG_ORDER

enumerator ER_NO_CONNECTION

enumerator ER_TIMEOUT

enumerator ER_ACTIVE_TRANSACTION

enumerator ER_NO_ACTIVE_TRANSACTION

enumerator ER_CROSS_ENGINE_TRANSACTION

enumerator ER_NO_SUCH_ROLE

enumerator ER_ROLE_EXISTS

enumerator ER_CREATE_ROLE

enumerator ER_INDEX_EXISTS

enumerator ER_TUPLE_REF_OVERFLOW

enumerator ER_ROLE_LOOP

enumerator ER_GRANT

enumerator ER_PRIV_GRANTED

enumerator ER_ROLE_GRANTED

enumerator ER_PRIV_NOT_GRANTED

enumerator ER_ROLE_NOT_GRANTED

enumerator ER_MISSING_SNAPSHOT

enumerator ER_CANT_UPDATE_PRIMARY_KEY

enumerator ER_UPDATE_INTEGER_OVERFLOW

enumerator ER_GUEST_USER_PASSWORD

enumerator ER_TRANSACTION_CONFLICT

enumerator ER_UNSUPPORTED_ROLE_PRIV

enumerator ER_LOAD_FUNCTION

enumerator ER_FUNCTION_LANGUAGE

enumerator ER_RTREE_RECT

enumerator ER_PROC_C

enumerator ER_UNKNOWN_RTREE_INDEX_DISTANCE_TYPE

enumerator ER_PROTOCOL

enumerator ER_UPSERT_UNIQUE_SECONDARY_KEY

enumerator ER_WRONG_INDEX_RECORD

enumerator ER_WRONG_INDEX_PARTS

enumerator ER_WRONG_INDEX_OPTIONS

enumerator ER_WRONG_SCHEMA_VERSION

enumerator ER_SLAB_ALLOC_MAX

enumerator ER_WRONG_SPACE_OPTIONS

enumerator ER_UNSUPPORTED_INDEX_FEATURE

enumerator ER_VIEW_IS_RO

enumerator box_error_code_MAX

box_error_t
Error - contains information about error.

const char * box_error_type(const *box_error_t* **error*)
Return the error type, e.g. «ClientError», «SocketError», etc.

Параметры

- error (box_error_t*) – error

Результат not-null string

uint32_t box_error_code(const *box_error_t* **error*)
Return IPROTO error code

Параметры

- error (box_error_t*) – error

Результат enum *box_error_code*

const char * box_error_message(const *box_error_t* **error*)
Return the error message

Параметры

- error (box_error_t*) – error

Результат not-null string

box_error_t * box_error_last(void)

Get the information about the last API call error.

The Tarantool error handling works most like libc's errno. All API calls return -1 or NULL in the event of error. An internal pointer to box_error_t type is set by API functions to indicate what went wrong. This value is only significant if API call failed (returned -1 or NULL).

Successful function can also touch the last error in some cases. You don't have to clear the last error before calling API functions. The returned object is valid only until next call to **any** API function.

You must set the last error using box_error_set() in your stored C procedures if you want to return a custom error message. You can re-throw the last API error to IPROTO client by keeping the current value and returning -1 to Tarantool from your stored procedure.

Результат last error

void box_error_clear(void)

Clear the last error.

int box_error_set(const char **file*, unsigned *line*, uint32_t *code*, const char **format*, ...)

Set the last error.

Параметры

- char* file (*const*) –
- line (*unsigned*) –
- code (*uint32_t*) – IPROTO *error code*
- char* format (*const*) –
- ... – format arguments

See also: IPROTO *error code*

box_error_raise(code, format, ...)

A backward-compatible API define.

6.1.5 Модуль *fiber*

struct fiber

Fiber - contains information about fiber

struct *fiber* *fiber_new(const char **name*, fiber_func *f*)

typedef int (*fuber_func)(va_list)

Create a new fiber.

Takes a fiber from fiber cache, if it's not empty. Can fail only if there is not enough memory for the fiber structure or fiber stack.

The created fiber automatically returns itself to the fiber cache when its «main» function completes.

Параметры

- char* name (*const*) – string with fiber name
- f (*fiber_func*) – func for run inside fiber

See also: *fiber_start()*

void `fiber_yield`(void)

Return control to another fiber and wait until it'll be woken.

See also: *fiber_wakeup()*

void `fiber_start`(struct *fiber* **callee*, ...)

Start execution of created fiber.

Параметры

- `fiber* callee` (*struct*) – fiber to start
- `...` – arguments to start the fiber with

void `fiber_wakeup`(struct *fiber* **f*)

Interrupt a synchronous wait of a fiber

Параметры

- `fiber* f` (*struct*) – fiber to be woken up

void `fiber_cancel`(struct *fiber* **f*)

Cancel the subject fiber (set `FIBER_IS_CANCELLED` flag)

If target fiber's flag `FIBER_IS_CANCELLABLE` set, then it would be woken up (maybe prematurely). Then current fiber yields until the target fiber is dead (or is woken up by *fiber_wakeup()*).

Параметры

- `fiber* f` (*struct*) – fiber to be cancelled

bool `fiber_set_cancellable`(bool *yesno*)

Make it possible or not possible to wakeup the current fiber immediately when it's cancelled.

Параметры

- `fiber* f` (*struct*) – fiber
- `yesno` (*bool*) – status to set

Результат previous state

void `fiber_set_joinable`(struct *fiber* **fiber*, bool *yesno*)

Set fiber to be joinable (`false` by default).

Параметры

- `fiber* f` (*struct*) – fiber
- `yesno` (*bool*) – status to set

void `fiber_join`(struct *fiber* **f*)

Wait until the fiber is dead and then move its execution status to the caller. The fiber must not be detached.

Параметры

- `fiber* f` (*struct*) – fiber to be woken up

Before: `FIBER_IS_JOINABLE` flag is set.

See also: *fiber_set_joinable()*

void `fiber_sleep`(double *s*)

Put the current fiber to sleep for at least „s" seconds.

Параметры

- s (*double*) – time to sleep

Note: this is a cancellation point.

See also: *fiber_is_cancelled()*

bool `fiber_is_cancelled()`
Check current fiber for cancellation (it must be checked manually).

double `fiber_time`(void)
Report loop begin time as double (cheap).

uint64_t `fiber_time64`(void)
Report loop begin time as 64-bit int.

void `fiber_reschedule`(void)
Reschedule fiber to end of event loop cycle.

struct `slab_cache`

struct *slab_cache* `*cord_slab_cache`(void)
Return slab_cache suitable to use with `tarantool/small` library

6.1.6 Модуль *index*

`box_iterator_t`
A space iterator

`enum iterator_type`
Controls how to iterate over tuples in an index. Different index types support different iterator types. For example, one can start iteration from a particular value (request key) and then retrieve all tuples where keys are greater or equal (= GE) to this key.

If iterator type is not supported by the selected index type, iterator constructor must fail with ER_UNSUPPORTED. To be selectable for primary key, an index must support at least ITER_EQ and ITER_GE types.

NULL value of request key corresponds to the first or last key in the index, depending on iteration direction. (first key for GE and GT types, and last key for LE and LT). Therefore, to iterate over all tuples in an index, one can use ITER_GE or ITER_LE iteration types with start key equal to NULL. For ITER_EQ, the key must not be NULL.

`enumerator ITER_EQ`
key == x ASC order

`enumerator ITER_REQ`
key == x DESC order

`enumerator ITER_ALL`
all tuples

`enumerator ITER_LT`
key < x

`enumerator ITER_LE`
key <= x

`enumerator ITER_GE`
key >= x

`enumerator ITER_GT`
key > x

`enumerator ITER_BITS_ALL_SET`
all bits from x are set in key

`enumerator ITER_BITS_ANY_SET`
at least one x's bit is set

`enumerator ITER_BITS_ALL_NOT_SET`
all bits are not set

`enumerator ITER_OVERLAPS`
key overlaps x

`enumerator ITER_NEIGHBOR`
tuples in distance ascending order from specified point

box_iterator_t *`box_index_iterator`(uint32_t *space_id*, uint32_t *index_id*, int *type*, const char **key*, const char **key_end*)
Allocate and initialize iterator for space_id, index_id.

The returned iterator must be destroyed by *box_iterator_free*.

Параметры

- `space_id` (*uint32_t*) – space identifier
- `index_id` (*uint32_t*) – index identifier
- `type` (*int*) – *iterator_type*
- `char* key` (*const*) – encode key in MsgPack Array format ([part1, part2, …])
- `char* key_end` (*const*) – the end of encoded `key`

Результат NULL on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Результат iterator otherwise

See also *box_iterator_next*, *box_iterator_free*

int `box_iterator_next`(*box_iterator_t* **iterator*, *box_tuple_t* ***result*)
Retrieve the next item from the `iterator`.

Параметры

- `iterator` (`box_iterator_t*`) – an iterator returned by :ref:box_index_iterator‘c_api-box_index-box_index_iterator>‘
- `result` (`box_tuple_t**`) – output argument. result a tuple or NULL if there is no more data.

Результат -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Результат 0 on success. The end of data is not an error.

void `box_iterator_free`(*box_iterator_t* **iterator*)
Destroy and deallocate iterator.

Параметры

- `iterator` (`box_iterator_t*`) – an iterator returned by :ref:box_index_iterator‘c_api-box_index-box_index_iterator>‘

ssize_t `box_index_len`(uint32_t *space_id*, uint32_t *index_id*)
Return the number of element in the index.

Параметры

- `space_id` (*uint32_t*) – space identifier

- `index_id` (*uint32_t*) – index identifier

Результат -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Результат >= 0 otherwise

ssize_t `box_index_bsize`(uint32_t *space_id*, uint32_t *index_id*)
Return the number of bytes used in memory by the index.

Параметры

- `space_id` (*uint32_t*) – space identifier
- `index_id` (*uint32_t*) – index identifier

Результат -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Результат >= 0 otherwise

int `box_index_random`(uint32_t *space_id*, uint32_t *index_id*, uint32_t *rnd*, *box_tuple_t* ***result*)
Return a random tuple from the index (useful for statistical analysis).

Параметры

- `space_id` (*uint32_t*) – space identifier
- `index_id` (*uint32_t*) – index identifier
- `rnd` (*uint32_t*) – random seed
- `result` (`box_tuple_t**`) – output argument. result a tuple or NULL if there is no tuples in space

See also: *index_object.random*

int `box_index_get`(uint32_t *space_id*, uint32_t *index_id*, const char **key*, const char **key_end*, *box_tuple_t* ***result*)
Get a tuple from index by the key.

Please note that this function works much more faster than *index_object.select* or *box_index_iterator* + *box_iterator_next*.

Параметры

- `space_id` (*uint32_t*) – space identifier
- `index_id` (*uint32_t*) – index identifier
- `char* key` (*const*) – encode key in MsgPack Array format ([part1, part2, . . .])
- `char* key_end` (*const*) – the end of encoded `key`
- `result` (`box_tuple_t**`) – output argument. result a tuple or NULL if there is no tuples in space

Результат -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Результат 0 on success

See also: `index_object.get()`

int `box_index_min`(uint32_t *space_id*, uint32_t *index_id*, const char **key*, const char **key_end*, *box_tuple_t* ***result*)
Return a first (minimal) tuple matched the provided key.

Параметры

- `space_id` (*uint32_t*) – space identifier

- index_id (*uint32_t*) – index identifier
- char* key (*const*) – encode key in MsgPack Array format ([part1, part2, ...])
- char* key_end (*const*) – the end of encoded key
- result (box_tuple_t**) – output argument. result a tuple or NULL if there is no tuples in space

Результат -1 on error (check :ref:box_error_last()‘c_api-error-box_error_last>‘)

Результат 0 on success

See also: *index_object.min()*

int box_index_max(uint32_t *space_id*, uint32_t *index_id*, const char **key*, const char **key_end*, *box_tuple_t* ***result*)

Return a last (maximal) tuple matched the provided key.

Параметры

- space_id (*uint32_t*) – space identifier
- index_id (*uint32_t*) – index identifier
- char* key (*const*) – encode key in MsgPack Array format ([part1, part2, ...])
- char* key_end (*const*) – the end of encoded key
- result (box_tuple_t**) – output argument. result a tuple or NULL if there is no tuples in space

Результат -1 on error (check :ref:box_error_last()‘c_api-error-box_error_last>‘)

Результат 0 on success

See also: *index_object.max()*

ssize_t box_index_count(uint32_t *space_id*, uint32_t *index_id*, int *type*, const char **key*, const char **key_end*)

Count the number of tuple matched the provided key.

Параметры

- space_id (*uint32_t*) – space identifier
- index_id (*uint32_t*) – index identifier
- type (*int*) – *iterator_type*
- char* key (*const*) – encode key in MsgPack Array format ([part1, part2, ...])
- char* key_end (*const*) – the end of encoded key

Результат -1 on error (check :ref:box_error_last()‘c_api-error-box_error_last>‘)

Результат 0 on success

See also: *index_object.count()*

6.1.7 Модуль *latch*

box_latch_t

A lock for cooperative multitasking environment

box_latch_t *box_latch_new(void)

Allocate and initialize the new latch.

Результат allocated latch object

Тип результата box_latch_t *

void `box_latch_delete`(*box_latch_t *latch*)

Destroy and free the latch.

Параметры

- `latch` (`box_latch_t*`) – latch to destroy

void `box_latch_lock`(*box_latch_t *latch*)

Lock a latch. Waits indefinitely until the current fiber can gain access to the latch.

param box_latch_t* latch latch to lock

int `box_latch_trylock`(*box_latch_t *latch*)

Try to lock a latch. Return immediately if the latch is locked.

Параметры

- `latch` (`box_latch_t*`) – latch to lock

Результат status of operation. 0 - success, 1 - latch is locked

Тип результата int

void `box_latch_unlock`(*box_latch_t *latch*)

Unlock a latch. The fiber calling this function must own the latch.

Параметры

- `latch` (`box_latch_t*`) – latch to unlock

6.1.8 Модуль *lua/utils*

void *`luaL_pushcdata`(struct lua_State **L*, uint32_t *ctypeid*)

Push cdata of given `ctypeid` onto the stack.

CTypeID must be used from FFI at least once. Allocated memory returned uninitialized. Only numbers and pointers are supported.

Параметры

- `L` (*lua_State**) – Lua State
- `ctypeid` (*uint32_t*) – FFI's CTypeID of this cdata

Результат memory associated with this cdata

See also: *luaL_checkcdata()*

void *`luaL_checkcdata`(struct lua_State **L*, int *idx*, uint32_t **ctypeid*)

Checks whether the function argument `idx` is a cdata

Параметры

- `L` (*lua_State**) – Lua State
- `idx` (*int*) – stack index
- `ctypeid` (*uint32_t**) – output argument. FFI's CTypeID of returned cdata

Результат memory associated with this cdata

See also: *luaL_pushcdata()*

void `luaL_setcdatagc`(struct lua_State *L*, int *idx*)

Sets finalizer function on a cdata object.

Equivalent to call *ffi.gc(obj, function)*. Finalizer function must be on the top of the stack.

Параметры

- `L` (*lua_State**) – Lua State
- `idx` (*int*) – stack index

uint32_t `luaL_ctypeid`(struct lua_State *L*, const char **ctypename*)

Return CTypeID (FFI) of given CDATA type

Параметры

- `L` (*lua_State**) – Lua State
- `char* ctypename` (*const*) – C type name as string (e.g. «struct request» or «uint32_t»)

Результат CTypeID

See also: *luaL_pushcdata()*, *luaL_checkcdata()*

int `luaL_cdef`(struct lua_State *L*, const char **ctypename*)

Declare symbols for FFI

Параметры

- `L` (*lua_State**) – Lua State
- `char* ctypename` (*const*) – C definitions (e.g. «struct stat»)

Результат 0 on success

Результат `LUA_ERRRUN`, `LUA_ERRMEM` or ``LUA_ERRERR` otherwise.

See also: `ffi.cdef(def)`

void `luaL_pushuint64`(struct lua_State *L*, uint64_t *val*)

Push uint64_t onto the stack

Параметры

- `L` (*lua_State**) – Lua State
- `val` (*uint64_t*) – value to push

void `luaL_pushint64`(struct lua_State *L*, int64_t *val*)

Push int64_t onto the stack

Параметры

- `L` (*lua_State**) – Lua State
- `val` (*int64_t*) – value to push

uint64_t `luaL_checkuint64`(struct lua_State *L*, int *idx*)

Checks whether the argument idx is a uint64 or a convertable string and returns this number.

Throws error if the argument can't be converted

uint64_t `luaL_checkint64`(struct lua_State *L*, int *idx*)

Checks whether the argument idx is a int64 or a convertable string and returns this number.

Throws error if the argument can't be converted uint64_t **luaL_touint64**(struct lua_State **L*, int *idx*)

Checks whether the argument idx is a uint64 or a convertable string and returns this number.

Результат the converted number or 0 of argument can't be converted

int64_t **luaL_toint64**(struct lua_State **L*, int *idx*)

Checks whether the argument idx is a int64 or a convertable string and returns this number.

Результат the converted number or 0 of argument can't be converted

6.1.9 Модуль *say* (логирование)

`enum say_level`

`enumerator S_FATAL`

do not use this value directly

`enumerator S_SYSERROR`

`enumerator S_ERROR`

`enumerator S_CRIT`

`enumerator S_WARN`

`enumerator S_INFO`

`enumerator S_DEBUG`

`say`(level, format, ...)

Format and print a message to Tarantool log file.

Параметры

- `level` (*int*) – *log level*
- `char* format` (*const*) – `printf()`-like format string
- `...` – format arguments

See also *printf(3)*, *say_level*

`say_error`(format, ...)
`say_crit`(format, ...)
`say_warn`(format, ...)
`say_info`(format, ...)
`say_debug`(format, ...)
`say_syserror`(format, ...)

Format and print a message to Tarantool log file.

Параметры

- `char* format` (*const*) – `printf()`-like format string
- `...` – format arguments

See also *printf(3)*, *say_level*

Example:

```
say_info("Some useful information: %s", status);
```

6.1.10 Модуль *schema*

`enum SCHEMA`

`enumerator BOX_SYSTEM_ID_MIN`
Start of the reserved range of system spaces.

`enumerator BOX_SCHEMA_ID`
Space id of _schema.

`enumerator BOX_SPACE_ID`
Space id of _space.

`enumerator BOX_VSPACE_ID`
Space id of _vspace view.

`enumerator BOX_INDEX_ID`
Space id of _index.

`enumerator BOX_VINDEX_ID`
Space id of _vindex view.

`enumerator BOX_FUNC_ID`
Space id of _func.

`enumerator BOX_VFUNC_ID`
Space id of _vfunc view.

`enumerator BOX_USER_ID`
Space id of _user.

`enumerator BOX_VUSER_ID`
Space id of _vuser view.

`enumerator BOX_PRIV_ID`
Space id of _priv.

`enumerator BOX_VPRIV_ID`
Space id of _vpriv view.

`enumerator BOX_CLUSTER_ID`
Space id of _cluster.

`enumerator BOX_SYSTEM_ID_MAX`
End of reserved range of system spaces.

`enumerator BOX_ID_NIL`
NULL value, returned on error.

6.1.11 Модуль *trivia/config*

`API_EXPORT`
Extern modifier for all public functions.

`PACKAGE_VERSION_MAJOR`
Package major version - 1 for 1.7.0.

`PACKAGE_VERSION_MINOR`
Package minor version - 7 for 1.7.0.

`PACKAGE_VERSION_PATCH`
Package patch version - 0 for 1.7.0.

`PACKAGE_VERSION`
A string with major-minor-patch-commit-id identifier of the release, e.g. 1.7.0-1216-g73f7154.

`SYSCONF_DIR`
System configuration dir (e.g `/etc`)

`INSTALL_PREFIX`
Install prefix (e.g. `/usr`)

`BUILD_TYPE`
Build type, e.g. Debug or Release

`BUILD_INFO`
CMake build type signature, e.g. `Linux-x86_64-Debug`

`BUILD_OPTIONS`
Command line used to run CMake.

`COMPILER_INFO`
Pathes to C and CXX compilers.

`TARANTOOL_C_FLAGS`
C compile flags used to build Tarantool.

`TARANTOOL_CXX_FLAGS`
CXX compile flags used to build Tarantool.

`MODULE_LIBDIR`
A path to install `*.lua` module files.

`MODULE_LUADIR`
A path to install `*.so`/`*.dylib` module files.

`MODULE_INCLUDEDIR`
A path to Lua includes (the same directory where this file is contained)

`MODULE_LUAPATH`
A constant added to `package.path` in Lua to find `*.lua` module files.

`MODULE_LIBPATH`
A constant added to `package.cpath` in Lua to find `*.so` module files.

6.1.12 Модуль *tuple*

`box_tuple_format_t`

box_tuple_format_t `*box_tuple_format_default`(void)
Tuple format.

Each Tuple has associated format (class). Default format is used to create tuples which are not attach to any particular space.

`box_tuple_t`
Tuple

box_tuple_t `*box_tuple_new`(*box_tuple_format_t* **format*, const char **tuple*, const char **tuple_end*)
Allocate and initialize a new tuple from a raw MsgPack Array data.

Параметры

- format (box_tuple_format_t*) – tuple format. Use *box_tuple_format_default()* to create space-independent tuple.
- char* tuple (*const*) – tuple data in MsgPack Array format ([field1, field2, ...])
- char* tuple_end (*const*) – the end of data

Результат NULL on out of memory

Результат tuple otherwise

See also: *box.tuple.new()*

int box_tuple_ref(*box_tuple_t* **tuple*)

Increase the reference counter of tuple.

Tuples are reference counted. All functions that return tuples guarantee that the last returned tuple is refcounted internally until the next call to API function that yields or returns another tuple.

You should increase the reference counter before taking tuples for long processing in your code. Such tuples will not be garbage collected even if another fiber remove they from space. After processing please decrement the reference counter using *box_tuple_unref()*, otherwise the tuple will leak.

Параметры

- tuple (box_tuple_t*) – a tuple

Результат -1 on error

Результат 0 otherwise

See also: *box_tuple_unref()*

void box_tuple_unref(*box_tuple_t* **tuple*)

Decrease the reference counter of tuple.

Параметры

- tuple (box_tuple_t*) – a tuple

Результат -1 on error

Результат 0 otherwise

See also: *box_tuple_ref()*

uint32_t box_tuple_field_count(const *box_tuple_t* **tuple*)

Return the number of fields in tuple (the size of MsgPack Array).

Параметры

- tuple (box_tuple_t*) – a tuple

size_t box_tuple_bsize(const *box_tuple_t* **tuple*)

Return the number of bytes used to store internal tuple data (MsgPack Array).

Параметры

- tuple (box_tuple_t*) – a tuple

ssize_t box_tuple_to_buf(const *box_tuple_t* **tuple*, char **buf*, size_t *size*)

Dump raw MsgPack data to the memory buffer buf of size size.

Store tuple fields in the memory buffer.

Upon successful return, the function returns the number of bytes written. If buffer size is not enough then the return value is the number of bytes which would have been written if enough space had been available.

Результат -1 on error

Результат number of bytes written on success.

box_tuple_format_t *box_tuple_format(const *box_tuple_t* **tuple*)

Return the associated format.

Параметры

- tuple (box_tuple_t*) – a tuple

Результат tuple format

const char *box_tuple_field(const *box_tuple_t* **tuple*, uint32_t *field_id*)

Return the raw tuple field in MsgPack format.

The buffer is valid until next call to box_tuple_* functions.

Параметры

- tuple (box_tuple_t*) – a tuple
- field_id (*uint32_t*) – zero-based index in MsgPack array.

Результат NULL if i >= *box_tuple_field_count()*

Результат msgpack otherwise

box_tuple_iterator_t

Tuple iterator

box_tuple_iterator_t *box_tuple_iterator(*box_tuple_t* **tuple*)

Allocate and initialize a new tuple iterator. The tuple iterator allow to iterate over fields at root level of MsgPack array.

Example:

```
box_tuple_iterator_t* it = box_tuple_iterator(tuple);
if (it == NULL) {
    // error handling using box_error_last()
}
const char* field;
while (field = box_tuple_next(it)) {
    // process raw MsgPack data
}

// rewind iterator to first position
box_tuple_rewind(it)
assert(box_tuple_position(it) == 0);

// rewind three fields
field = box_tuple_seek(it, 3);
assert(box_tuple_position(it) == 4);

box_iterator_free(it);
```

void box_tuple_iterator_free(*box_tuple_iterator_t* **it*)

Destroy and free tuple iterator

uint32_t box_tuple_position(*box_tuple_iterator_t* **it*)

Return zero-based next position in iterator. That is, this function return the field id of field that will be returned by the next call to *box_tuple_next()*. Returned value is zero after initialization or rewind and *box_tuple_field_count()* after the end of iteration.

Параметры

- `it` (box_tuple_iterator_t*) – a tuple iterator

Результат position

void `box_tuple_rewind`(*box_tuple_iterator_t *it*)
Rewind iterator to the initial position.

Параметры

- `it` (box_tuple_iterator_t*) – a tuple iterator

After: `box_tuple_position(it) == 0`

const char *`box_tuple_seek`(*box_tuple_iterator_t *it*, uint32_t *field_no*)
Seek the tuple iterator.

The returned buffer is valid until next call to box_tuple_* API. Requested field_no returned by next call to box_tuple_next(it).

Параметры

- `it` (box_tuple_iterator_t*) – a tuple iterator
- `field_no` (*uint32_t*) – field number - zero-based position in MsgPack array

After:

- `box_tuple_position(it) == field_not` if returned value is not NULL.
- `box_tuple_position(it) == box_tuple_field_count(tuple)` if returned value is NULL.

const char *`box_tuple_next`(*box_tuple_iterator_t *it*)
Return the next tuple field from tuple iterator.

The returned buffer is valid until next call to box_tuple_* API.

Параметры

- `it` (box_tuple_iterator_t*) –

Результат NULL if there are no more fields

Результат MsgPack otherwise

Before: *box_tuple_position()* is zero-based ID of returned field.

After: `box_tuple_position(it) == box_tuple_field_count(tuple)` if returned value is NULL.

box_tuple_t *`box_tuple_update`(const *box_tuple_t *tuple*, const char **expr*, const char **expr_end*)

box_tuple_t *`box_tuple_upsert`(const *box_tuple_t *tuple*, const char **expr*, const char **expr_end*)

6.1.13 Модуль *txn*

bool `box_txn`(void)
Return true if there is an active transaction.

int `box_txn_begin`(void)
Begin a transaction in the current fiber.

A transaction is attached to caller fiber, therefore one fiber can have only one active transaction.

Результат 0 on success

Результат -1 on error. Perhaps a transaction has already been started

int **box_txn_commit**(void)
Commit the current transaction.

Результат 0 on success

Результат -1 on error. Perhaps a disk write failure

void **box_txn_rollback**(void)
Rollback the current transaction.

void ***box_txn_alloc**(size_t *size*)
Allocate memory on txn memory pool.

The memory is automatically deallocated when the transaction is committed or rolled back.

Результат NULL on out of memory

6.2 Internals

6.2.1 Tarantool's binary protocol

Tarantool's binary protocol is a binary request/response protocol.

Notation in diagrams

```
0    X
+----+
|    | - X bytes
+----+
 TYPE - type of MsgPack value (if it is a MsgPack object)

+====+
|    | - Variable size MsgPack object
+====+
 TYPE - type of MsgPack value

+~~~~+
|    | - Variable size MsgPack Array/Map
+~~~~+
 TYPE - type of MsgPack value
```

MsgPack data types:

- **MP_INT** - Integer
- **MP_MAP** - Map
- **MP_ARR** - Array
- **MP_STRING** - String
- **MP_FIXSTR** - Fixed size string
- **MP_OBJECT** - Any MsgPack object
- **MP_BIN** - MsgPack binary format

Greeting packet

```
TARANTOOL'S GREETING:

0                                     63
+--------------------------------------+
|                                      |
| Tarantool Greeting (server version)  |
|               64 bytes               |
+---------------------+----------------+
|                     |                |
| BASE64 encoded SALT |      NULL      |
|      44 bytes       |                |
+---------------------+----------------+
64                  107              127
```

The server begins the dialogue by sending a fixed-size (128-byte) text greeting to the client. The greeting always contains two 64-byte lines of ASCII text, each line ending with a newline character („\n"). The first line contains the server version and protocol type. The second line contains up to 44 bytes of base64-encoded random string, to use in the authentication packet, and ends with up to 23 spaces.

Unified packet structure

Once a greeting is read, the protocol becomes pure request/response and features a complete access to Tarantool functionality, including:

- request multiplexing, e.g. ability to asynchronously issue multiple requests via the same connection
- response format that supports zero-copy writes

For data structuring and encoding, the protocol uses msgpack data format, see http://msgpack.org

The Tarantool protocol mandates use of a few integer constants serving as keys in maps used in the protocol. These constants are defined in src/box/iproto_constants.h

We list them here too:

```
-- user keys
<code>          ::= 0x00
<sync>          ::= 0x01
<schema_id>     ::= 0x05
<space_id>      ::= 0x10
<index_id>      ::= 0x11
<limit>         ::= 0x12
<offset>        ::= 0x13
<iterator>      ::= 0x14
<key>           ::= 0x20
<tuple>         ::= 0x21
<function_name> ::= 0x22
<username>      ::= 0x23
<expression>    ::= 0x27
<ops>           ::= 0x28
<data>          ::= 0x30
<error>         ::= 0x31
```

```
-- -- Value for <code> key in request can be:
-- User command codes
```

(continues on next page)

(продолжение с предыдущей страницы)

```
<select>  ::= 0x01
<insert>  ::= 0x02
<replace> ::= 0x03
<update>  ::= 0x04
<delete>  ::= 0x05
<call_16> ::= 0x06
<auth>    ::= 0x07
<eval>    ::= 0x08
<upsert>  ::= 0x09
<call>    ::= 0x0a
-- Admin command codes
<ping>    ::= 0x40

-- -- Value for <code> key in response can be:
<OK>      ::= 0x00
<ERROR>   ::= 0x8XXX
```

Both <header> and <body> are msgpack maps:

```
Request/Response:

0        5
+--------+ +============+ +===================================+
| BODY + | |            | |                                   |
| HEADER | |   HEADER   | |               BODY                |
|  SIZE  | |            | |                                   |
+--------+ +============+ +===================================+
  MP_INT       MP_MAP                     MP_MAP
```

```
UNIFIED HEADER:

+================+================+=====================+
|                |                |                     |
|   0x00: CODE   |   0x01: SYNC   |    0x05: SCHEMA_ID  |
| MP_INT: MP_INT | MP_INT: MP_INT |  MP_INT: MP_INT     |
|                |                |                     |
+================+================+=====================+
                          MP_MAP
```

They only differ in the allowed set of keys and values. The key defines the type of value that follows. If a body has no keys, the entire msgpack map for the body may be missing. Such is the case, for example, for a <ping> request. schema_id may be absent in the request's header, meaning that there will be no version checking, but it must be present in the response. If schema_id is sent in the header, then it will be checked.

Authentication

When a client connects to the server, the server responds with a 128-byte text greeting message. Part of the greeting is base-64 encoded session salt - a random string which can be used for authentication. The length of decoded salt (44 bytes) exceeds the amount necessary to sign the authentication message (first 20 bytes). An excess is reserved for future authentication schemas.

```
PREPARE SCRAMBLE:

    LEN(ENCODED_SALT) = 44;
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    LEN(SCRAMBLE)     = 20;

prepare 'chap-sha1' scramble:

    salt = base64_decode(encoded_salt);
    step_1 = sha1(password);
    step_2 = sha1(step_1);
    step_3 = sha1(salt, step_2);
    scramble = xor(step_1, step_3);
    return scramble;

AUTHORIZATION BODY: CODE = 0x07

+==================+====================================+
|                  |        +-------------+-----------+ |
|  (KEY)           | (TUPLE)|  len == 9   | len == 20 | |
|   0x23:USERNAME  |   0x21:| "chap-sha1" |  SCRAMBLE | |
| MP_INT:MP_STRING | MP_INT:|  MP_STRING  |  MP_BIN   | |
|                  |        +-------------+-----------+ |
|                  |                   MP_ARRAY         |
+==================+====================================+
                        MP_MAP
```

`<key>` holds the user name. `<tuple>` must be an array of 2 fields: authentication mechanism («chap-sha1» is the only supported mechanism right now) and password, encrypted according to the specified mechanism. Authentication in Tarantool is optional, if no authentication is performed, session user is „guest“. The server responds to authentication packet with a standard response with 0 tuples.

Запросы

- SELECT: CODE - 0x01 Find tuples matching the search pattern

```
SELECT BODY:

+==================+==================+==================+
|                  |                  |                  |
|   0x10: SPACE_ID |   0x11: INDEX_ID |   0x12: LIMIT    |
| MP_INT: MP_INT   | MP_INT: MP_INT   | MP_INT: MP_INT   |
|                  |                  |                  |
+==================+==================+==================+
|                  |                  |                  |
|   0x13: OFFSET   |   0x14: ITERATOR |   0x20: KEY      |
| MP_INT: MP_INT   | MP_INT: MP_INT   | MP_INT: MP_ARRAY |
|                  |                  |                  |
+==================+==================+==================+
                          MP_MAP
```

- INSERT: CODE - 0x02 Inserts tuple into the space, if no tuple with same unique keys exists. Otherwise throw *duplicate key* error.
- REPLACE: CODE - 0x03 Insert a tuple into the space or replace an existing one.

```
INSERT/REPLACE BODY:

+==================+==================+
```

(continues on next page)

(продолжение с предыдущей страницы)

```
|                  |                  |
|   0x10: SPACE_ID |   0x21: TUPLE    |
| MP_INT: MP_INT   | MP_INT: MP_ARRAY |
|                  |                  |
+==================+==================+
                 MP_MAP
```

- UPDATE: CODE - 0x04 Update a tuple

```
UPDATE BODY:

+==================+=======================+
|                  |                       |
|   0x10: SPACE_ID |   0x11: INDEX_ID      |
| MP_INT: MP_INT   | MP_INT: MP_INT        |
|                  |                       |
+==================+=======================+
|                  |          +~~~~~~~~~~+ |
|                  |          |          | |
|                  | (TUPLE)  |    OP    | |
|   0x20: KEY      |    0x21: |          | |
| MP_INT: MP_ARRAY |  MP_INT: +~~~~~~~~~~+ |
|                  |            MP_ARRAY   |
+==================+=======================+
                 MP_MAP
```

```
OP:
    Works only for integer fields:
    * Addition    OP = '+' . space[key][field_no] += argument
    * Subtraction OP = '-' . space[key][field_no] -= argument
    * Bitwise AND OP = '&' . space[key][field_no] &= argument
    * Bitwise XOR OP = '^' . space[key][field_no] ^= argument
    * Bitwise OR  OP = '|' . space[key][field_no] |= argument
    Works on any fields:
    * Delete      OP = '#'
      delete <argument> fields starting
      from <field_no> in the space[<key>]

0           2
+-----------+==========+==========+
|           |          |          |
|    OP     | FIELD_NO | ARGUMENT |
| MP_FIXSTR |  MP_INT  |  MP_INT  |
|           |          |          |
+-----------+==========+==========+
              MP_ARRAY
```

```
    * Insert      OP = '!'
      insert <argument> before <field_no>
    * Assign      OP = '='
      assign <argument> to field <field_no>.
      will extend the tuple if <field_no> == <max_field_no> + 1

0           2
+-----------+==========+===========+
|           |          |           |
```

(continues on next page)

(продолжение с предыдущей страницы)

```
|    OP     | FIELD_NO | ARGUMENT  |
| MP_FIXSTR |  MP_INT  | MP_OBJECT |
|           |          |           |
+-----------+==========+===========+
              MP_ARRAY

    Works on string fields:
    * Splice      OP = ':'
      take the string from space[key][field_no] and
      substitute <offset> bytes from <position> with <argument>
```

```
0           2
+-----------+==========+==========+========+==========+
|           |          |          |        |          |
|    ':'    | FIELD_NO | POSITION | OFFSET | ARGUMENT |
| MP_FIXSTR |  MP_INT  |  MP_INT  | MP_INT |  MP_STR  |
|           |          |          |        |          |
+-----------+==========+==========+========+==========+
                         MP_ARRAY
```

It is an error to specify an argument of a type that differs from the expected type.

- DELETE: CODE - 0x05 Delete a tuple

```
DELETE BODY:

+==================+==================+==================+
|                  |                  |                  |
|   0x10: SPACE_ID |   0x11: INDEX_ID |   0x20: KEY      |
| MP_INT: MP_INT   | MP_INT: MP_INT   | MP_INT: MP_ARRAY |
|                  |                  |                  |
+==================+==================+==================+
                          MP_MAP
```

- CALL_16: CODE - 0x06 Call a stored function, returning an array of tuples. This is deprecated; CALL (0x0a) is recommended instead.

```
CALL_16 BODY:

+=======================+==================+
|                       |                  |
|   0x22: FUNCTION_NAME |   0x21: TUPLE    |
| MP_INT: MP_STRING     | MP_INT: MP_ARRAY |
|                       |                  |
+=======================+==================+
                    MP_MAP
```

- EVAL: CODE - 0x08 Evaulate Lua expression

```
EVAL BODY:

+=======================+==================+
|                       |                  |
|   0x27: EXPRESSION    |   0x21: TUPLE    |
| MP_INT: MP_STRING     | MP_INT: MP_ARRAY |
|                       |                  |
```

(continues on next page)

(продолжение с предыдущей страницы)

```
+=======================+==================+
                   MP_MAP
```

- UPSERT: CODE - 0x09 Update tuple if it would be found elsewhere try to insert tuple. Always use primary index for key.

```
UPSERT BODY:

+==================+==================+==========================+
|                  |                  |             +~~~~~~~~~~+ |
|                  |                  |             |          | |
|   0x10: SPACE_ID |   0x21: TUPLE    |       (OPS) |    OP    | |
| MP_INT: MP_INT   | MP_INT: MP_ARRAY |       0x28: |          | |
|                  |                  |     MP_INT: +~~~~~~~~~~+ |
|                  |                  |               MP_ARRAY   |
+==================+==================+==========================+
                               MP_MAP

Operations structure same as for UPDATE operation.
   0           2
+-----------+==========+==========+
|           |          |          |
|    OP     | FIELD_NO | ARGUMENT |
| MP_FIXSTR |  MP_INT  |  MP_INT  |
|           |          |          |
+-----------+==========+==========+
              MP_ARRAY

Supported operations:

'+' - add a value to a numeric field. If the filed is not numeric, it's
      changed to 0 first. If the field does not exist, the operation is
      skipped. There is no error in case of overflow either, the value
      simply wraps around in C style. The range of the integer is MsgPack:
      from -2^63 to 2^64-1
'-' - same as the previous, but subtract a value
'=' - assign a field to a value. The field must exist, if it does not exist,
      the operation is skipped.
'!' - insert a field. It's only possible to insert a field if this create no
      nil "gaps" between fields. E.g. it's possible to add a field between
      existing fields or as the last field of the tuple.
'#' - delete a field. If the field does not exist, the operation is skipped.
      It's not possible to change with update operations a part of the primary
      key (this is validated before performing upsert).
```

- CALL: CODE - 0x0a Similar to CALL_16, but – like EVAL, CALL returns a list of values, unconverted

```
CALL BODY:

+=======================+==================+
|                       |                  |
|   0x22: FUNCTION_NAME |   0x21: TUPLE    |
| MP_INT: MP_STRING     | MP_INT: MP_ARRAY |
|                       |                  |
+=======================+==================+
                   MP_MAP
```

Response packet structure

We will show whole packets here:

```
OK:    LEN + HEADER + BODY

0      5                                          OPTIONAL
+------++================+================++===================+
|      ||                |                ||                   |
| BODY ||   0x00: 0x00   |   0x01: SYNC   ||   0x30: DATA      |
|HEADER|| MP_INT: MP_INT | MP_INT: MP_INT || MP_INT: MP_OBJECT |
| SIZE ||                |                ||                   |
+------++================+================++===================+
 MP_INT                MP_MAP                     MP_MAP
```

Set of tuples in the response `<data>` expects a msgpack array of tuples as value EVAL command returns arbitrary *MP_ARRAY* with arbitrary MsgPack values.

```
ERROR: LEN + HEADER + BODY

0      5
+------++================+================++===================+
|      ||                |                ||                   |
| BODY ||   0x00: 0x8XXX |   0x01: SYNC   ||   0x31: ERROR     |
|HEADER|| MP_INT: MP_INT | MP_INT: MP_INT || MP_INT: MP_STRING |
| SIZE ||                |                ||                   |
+------++================+================++===================+
 MP_INT                MP_MAP                     MP_MAP

Where 0xXXX is ERRCODE.
```

An error message is present in the response only if there is an error; `<error>` expects as value a msgpack string.

Convenience macros which define hexadecimal constants for return codes can be found in src/box/errcode.h

Replication packet structure

```
-- replication keys
<server_id>     ::= 0x02
<lsn>           ::= 0x03
<timestamp>     ::= 0x04
<server_uuid>   ::= 0x24
<cluster_uuid>  ::= 0x25
<vclock>        ::= 0x26
```

```
-- replication codes
<join>      ::= 0x41
<subscribe> ::= 0x42
```

```
JOIN:

In the beginning you must send JOIN
                         HEADER                          BODY
+================+================+===================++-------+
```

(continues on next page)

(продолжение с предыдущей страницы)

```
|               |               |    SERVER_UUID    ||       |
|   0x00: 0x41  |   0x01: SYNC  |   0x24: UUID      || EMPTY |
| MP_INT: MP_INT | MP_INT: MP_INT | MP_INT: MP_STRING ||       |
|               |               |                   ||       |
+===============+===============+===================++-------+
              MP_MAP                                  MP_MAP

Then server, which we connect to, will send last SNAP file by, simply,
creating a number of INSERTs (with additional LSN and ServerID)
(don't reply). Then it'll send a vclock's MP_MAP and close a socket.

+===============+===============++============================+
|               |               ||        +~~~~~~~~~~~~~~~~~+ |
|               |               ||        |                 | |
|   0x00: 0x00  |   0x01: SYNC  ||   0x26:| SRV_ID: SRV_LSN | |
| MP_INT: MP_INT | MP_INT: MP_INT || MP_INT:| MP_INT: MP_INT  | |
|               |               ||        +~~~~~~~~~~~~~~~~~+ |
|               |               ||              MP_MAP       |
+===============+===============++============================+
              MP_MAP                        MP_MAP

SUBSCRIBE:

Then you must send SUBSCRIBE:

                              HEADER
+===================+===================+
|                   |                   |
|     0x00: 0x41    |     0x01: SYNC    |
|   MP_INT: MP_INT  |   MP_INT: MP_INT  |
|                   |                   |
+===================+===================+
|    SERVER_UUID    |    CLUSTER_UUID   |
|   0x24: UUID      |   0x25: UUID      |
| MP_INT: MP_STRING | MP_INT: MP_STRING |
|                   |                   |
+===================+===================+
                MP_MAP

      BODY
+================+
|                |
|   0x26: VCLOCK |
| MP_INT: MP_INT |
|                |
+================+
      MP_MAP

Then you must process every query that'll came through other masters.
Every request between masters will have Additional LSN and SERVER_ID.
```

XLOG / SNAP

XLOG and SNAP files have nearly the same format. The header looks like:

```
<type>\n                  SNAP\n or XLOG\n
<version>\n               currently 0.13\n
Server: <server_uuid>\n   where UUID is a 36-byte string
VClock: <vclock_map>\n    e.g. {1: 0}\n
\n
```

After the file header come the data tuples. Tuples begin with a row marker `0xd5ba0bab` and the last tuple may be followed by an EOF marker `0xd510aded`. Thus, between the file header and the EOF marker, there may be data tuples that have this form:

```
0            3 4                                     17
+-------------+========+============+===========+=========+
|             |        |            |           |         |
| 0xd5ba0bab  | LENGTH | CRC32 PREV | CRC32 CUR | PADDING |
|             |        |            |           |         |
+-------------+========+============+===========+=========+
  MP_FIXEXT2    MP_INT     MP_INT       MP_INT      ---

+============+ +===================================+
|            | |                                   |
|   HEADER   | |                BODY               |
|            | |                                   |
+============+ +===================================+
    MP_MAP                     MP_MAP
```

See the example in the following section.

6.2.2 Data persistence and the WAL file format

To maintain data persistence, Tarantool writes each data change request (insert, update, delete, replace, upsert) into a write-ahead log (WAL) file in the *wal_dir* directory. A new WAL file is created for every *rows_per_wal* records. Each data change request gets assigned a continuously growing 64-bit log sequence number. The name of the WAL file is based on the log sequence number of the first record in the file, plus an extension `.xlog`.

Apart from a log sequence number and the data change request (formatted as in *Tarantool's binary protocol*), each WAL record contains a header, some metadata, and then the data formatted according to msgpack rules. For example this is what the WAL file looks like after the first INSERT request («s:insert({1})») for the introductory sandbox exercise «*Starting Tarantool and making your first database*". On the left are the hexadecimal bytes that one would see with: `$ hexdump 00000000000000000000.xlog` and on the right are comments.

```
Hex dump of WAL file       Comment
--------------------       -------
58 4c 4f 47 0a             "XLOG\n"
30 2e 31 33 0a             "0.13\n" = version
53 65 72 76 65 72 3a 20    "Server: "
38 62 66 32 32 33 65 30 2d [Server UUID]\n
36 39 31 34 2d 34 62 35 35
2d 39 34 64 32 2d 64 32 62
36 64 30 39 62 30 31 39 36
0a
56 43 6c 6f 63 6b 3a 20    "Vclock: "
7b 7d                      "{}" = vclock value, initially blank
...                        (not shown = tuples for system spaces)
```

(continues on next page)

(продолжение с предыдущей страницы)

```
d5 ba 0b ab                 Magic row marker always = 0xab0bbad5
19                          Length, not including length of header, = 25 bytes
00                            Record header: previous crc32
ce 8c 3e d6 70                Record header: current crc32
a7 cc 73 7f 00 00 66 39       Record header: padding
84                          msgpack code meaning "Map of 4 elements" follows
00 02                          element#1: tag=request type, value=0x02=IPROTO_INSERT
02 01                          element#2: tag=server id, value=0x01
03 04                          element#3: tag=lsn, value=0x04
04 cb 41 d4 e2 2f 62 fd d5 d4 element#4: tag=timestamp, value=an 8-byte "Float64"
82                          msgpack code meaning "map of 2 elements" follows
10 cd 02 00                    element#1: tag=space id, value=512, big byte first
21 91 01                       element#2: tag=tuple, value=1-element fixed array={1}
```

Tarantool processes requests atomically: a change is either accepted and recorded in the WAL, or discarded completely. Let's clarify how this happens, using the REPLACE request as an example:

1. The server attempts to locate the original tuple by primary key. If found, a reference to the tuple is retained for later use.
2. The new tuple is validated. If for example it does not contain an indexed field, or it has an indexed field whose type does not match the type according to the index definition, the change is aborted.
3. The new tuple replaces the old tuple in all existing indexes.
4. A message is sent to WAL writer running in a separate thread, requesting that the change be recorded in the WAL. The server switches to work on the next request until the write is acknowledged.
5. On success, a confirmation is sent to the client. On failure, a rollback procedure is begun. During the rollback procedure, the transaction processor rolls back all changes to the database which occurred after the first failed change, from latest to oldest, up to the first failed change. All rolled back requests are aborted with `ER_WAL_IO` error. No new change is applied while rollback is in progress. When the rollback procedure is finished, the server restarts the processing pipeline.

One advantage of the described algorithm is that complete request pipelining is achieved, even for requests on the same value of the primary key. As a result, database performance doesn't degrade even if all requests refer to the same key in the same space.

The transaction processor thread communicates with the WAL writer thread using asynchronous (yet reliable) messaging; the transaction processor thread, not being blocked on WAL tasks, continues to handle requests quickly even at high volumes of disk I/O. A response to a request is sent as soon as it is ready, even if there were earlier incomplete requests on the same connection. In particular, SELECT performance, even for SELECTs running on a connection packed with UPDATEs and DELETEs, remains unaffected by disk load.

The WAL writer employs a number of durability modes, as defined in configuration variable *wal_mode*. It is possible to turn the write-ahead log completely off, by setting *wal_mode* to *none*. Even without the write-ahead log it's still possible to take a persistent copy of the entire data set with the *box.snapshot()* request.

An .xlog file always contains changes based on the primary key. Even if the client requested an update or delete using a secondary key, the record in the .xlog file will contain the primary key.

6.2.3 The snapshot file format

The format of a snapshot .snap file is nearly the same as the format of a WAL .xlog file. However, the snapshot header differs: it contains the server's global unique identifier and the snapshot file's position in history, relative to earlier snapshot files. Also, the content differs: an .xlog file may contain records for any data-change requests (inserts, updates, upserts, and deletes), a .snap file may only contain records of inserts to memtx spaces.

Primarily, the .snap file's records are ordered by space id. Therefore the records of system spaces, such as _schema and _space and _index and _func and _priv and _cluster, will be at the start of the .snap file, before the records of any spaces that were created by users.

Secondarily, the .snap file's records are ordered by primary key within space id.

6.2.4 The recovery process

The recovery process begins when box.cfg{} happens for the first time after the Tarantool server starts.

The recovery process must recover the databases as of the moment when the server was last shut down. For this it may use the latest snapshot file and any WAL files that were written after the snapshot. One complicating factor is that Tarantool has two engines – the memtx data must be reconstructed entirely from the snapshot and the WAL files, while the vinyl data will be on disk but might require updating around the time of a checkpoint. (When a snapshot happens, Tarantool tells the vinyl engine to make a checkpoint, and the snapshot operation is rolled back if anything goes wrong, so vinyl's checkpoint is at least as fresh as the snapshot file.)

Step 1 Read the configuration parameters in the `box.cfg{}` request. Parameters which affect recovery may include *work_dir*, *wal_dir*, *snap_dir*, *vinyl_dir*, *panic_on_snap_error*, and *panic_on_wal_error*.

Step 2 Find the latest snapshot file. Use its data to reconstruct the in-memory databases. Instruct the vinyl engine to recover to the latest checkpoint.

There are actually two variations of the reconstruction procedure for the memtx databases, depending whether the recovery process is «default».

If it is default (`panic_on_snap_error` is `true` and `panic_on_wal_error` is `true`), memtx can read data in the snapshot with all indexes disabled. First, all tuples are read into memory. Then, primary keys are built in bulk, taking advantage of the fact that the data is already sorted by primary key within each space.

If it is not default (`panic_on_snap_error` is `false` or `panic_on_wal_error` is `false`), Tarantool performs additional checking. Indexes are enabled at the start, and tuples are added one by one. This means that any unique-key constraint violations will be caught, and any duplicates will be skipped. Normally there will be no constraint violations or duplicates, so these checks are only made if an error has occurred.

Step 2 Find the WAL file that was made at the time of, or after, the snapshot file. Read its log entries until the log-entry LSN is greater than the LSN of the snapshot, or greater than the LSN of the vinyl checkpoint. This is the recovery process's «start position»; it matches the current state of the engines.

Step 3 Redo the log entries, from the start position to the end of the WAL. The engine skips a redo instruction if it is older than the engine's checkpoint.

Step 4 For the memtx engine, re-create all secondary indexes.

6.2.5 Server startup with replication

In addition to the recovery process described above, the server must take additional steps and precautions if *replication* is enabled.

Once again the startup procedure is initiated by the `box.cfg{}` request. One of the box.cfg parameters may be *replication_source*. We will refer to this server, which is starting up due to box.cfg, as the «local» server to distinguish it from the other servers in a cluster, which we will refer to as «distant» servers.

If there is no snapshot .snap file and replication_source is empty: then the local server assumes it is an unreplicated «standalone» server, or is the first server of a new replication cluster. It will generate new UUIDs for itself and for the cluster. The server UUID is stored in the _cluster space; the cluster UUID is stored in the _schema space. Since a snapshot contains all the data in all the spaces, that means the local server's snapshot will contain the server UUID and the cluster UUID. Therefore, when the local server restarts on later occasions, it will be able to recover these UUIDs when it reads the .snap file.

If there is no snapshot .snap file and replication_source is not empty and the _cluster space contains no other server UUIDs: then the local server assumes it is not a standalone server, but is not yet part of a cluster. It must now join the cluster. It will send its server UUID to the first distant server which is listed in replication_source, which will act as a master. This is called the «join request». When a distant server receives a join request, it will send back:

(1) the distant server's cluster UUID,

(2) the contents of the distant server's .snap file. When the local server receives this information, it puts the cluster UUID in its _schema space, puts the distant server's UUID and connection information in its _cluster space, and makes a snapshot containing all the data sent by the distant server. Then, if the local server has data in its WAL .xlog files, it sends that data to the distant server. The distant server will receive this and update its own copy of the data, and add the local server's UUID to its _cluster space.

If there is no snapshot .snap file and replication_source is not empty and the _cluster space contains other server UUIDs: then the local server assumes it is not a standalone server, and is already part of a cluster. It will send its server UUID and cluster UUID to all the distant servers which are listed in replication_source. This is called the «on-connect handshake». When a distant server receives an on-connect handshake:

(1) the distant server compares its own copy of the cluster UUID to the one in the on-connect handshake. If there is no match, then the handshake fails and the local server will display an error.

(2) the distant server looks for a record of the connecting instance in its _cluster space. If there is none, then the handshake fails. Otherwise the handshake is successful. The distant server will read any new information from its own .snap and .xlog files, and send the new requests to the local server.

In the end ... the local server knows what cluster it belongs to, the distant server knows that the local server is a member of the cluster, and both servers have the same database contents.

If there is a snapshot file and replication source is not empty: first the local server goes through the recovery process described in the previous section, using its own .snap and .xlog files. Then it sends a «subscribe» request to all the other servers of the cluster. The subscribe request contains the server vector clock. The vector clock has a collection of pairs „server id, lsn" for every server in the _cluster system space. Each distant server, upon receiving a subscribe request, will read its .xlog files" requests and send them to the local server if (lsn of .xlog file request) is greater than (lsn of the vector clock in the subscribe request). After all the other servers of the cluster have responded to the local server's subscribe request, the server startup is complete.

The following temporary limitations apply for version 1.7:

- The URIs in replication_source should all be in the same order on all servers. This is not mandatory but is an aid to consistency.
- The servers of a cluster should be started up at slightly different times. This is not mandatory but prevents a situation where each server is waiting for the other server to be ready.
- The maximum number of entries in the _cluster space is 32. Tuples for out-of-date replicas are not automatically re-used, so if this 32-replica limit is reached, users may have to reorganize the _cluster space manually.

6.3 Build and contribute

6.3.1 Building from source

For downloading Tarantool source and building it, the platforms can differ and the preferences can differ. But the steps are always the same. Here in the manual we'll explain what the steps are, and after that you can look at some example scripts on the Internet.

1. Get tools and libraries that will be necessary for building and testing.

   The absolutely necessary ones are:

   - A program for downloading source repositories. For all platforms, this is `git`. It allows to download the latest complete set of source files from the Tarantool repository at GitHub.
   - A C/C++ compiler. Ordinarily, this is `gcc` and `g++` version 4.6 or later. On Mac OS X, this is `Clang` version 3.2 or later.
   - A program for managing the build process. For all platforms, this is `CMake`. The CMake version should be 2.8 or later.
   - Command-line interpreter for Python-based code (namely, for Tarantool test suite). For all platforms, this is `python`. The Python version should be greater than 2.6 – preferably 2.7 – and less than 3.0.

   Here are names of tools and libraries which may have to be installed in advance, using `sudo apt-get` (for Ubuntu), `sudo yum install` (for CentOS), or the equivalent on other platforms. Different platforms may use slightly different names. Ignore the ones marked *optional, only in Mac OS scripts* unless the platform is Mac OS.

   - **gcc** and **g++**, or **clang** # see above
   - **git** # see above
   - **cmake** # see above
   - **python** # see above; for test suite
   - **libreadline-dev** or **libreadline6-dev** or **readline-devel** # for interactive mode
   - **libssl-dev** # for *digest* module
   - **autoconf** # optional, only in Mac OS scripts
   - **zlib1g** or **zlib** # optional, only in Mac OS scripts

2. Set up Python modules for running the test suite.

   This step is optional. Python modules are not necessary for building Tarantool itself, unless you intend to use the «Run the test suite» option in step 7.

   You need the following Python modules:

   - pip, any version
   - dev, any version
   - pyYAML version 3.10
   - argparse version 1.1
   - msgpack-python version 0.4.6
   - gevent version 1.1b5

- six version 1.8.0

On Ubuntu, you can get the modules from the repository:

```
sudo apt-get install python-pip python-dev python-yaml <...>
```

On CentOS 6, you can likewise get the modules from the repository:

```
sudo yum install python26 python26-PyYAML <...>
```

If some modules are not available on a repository, it is best to set up the modules by getting a tarball and doing the setup with `python setup.py`, thus:

```
# On some machines, this initial command may be necessary:
# wget https://bootstrap.pypa.io/ez_setup.py -O - | sudo python

# Python module for parsing YAML (pyYAML), for test suite:
# (If wget fails, check at http://pyyaml.org/wiki/PyYAML
# what the current version is.)
cd ~
wget http://pyyaml.org/download/pyyaml/PyYAML-3.10.tar.gz
tar -xzf PyYAML-3.10.tar.gz
cd PyYAML-3.10
sudo python setup.py install
```

Finally, use Python `pip` to bring in Python packages that may not be up-to-date in the distro repositories. (On CentOS 7, it will be necessary to install `pip` first, with `sudo yum install epel-release` followed by `sudo yum install python-pip`.)

```
pip install tarantool\>0.4 --user
```

3. Use `git` to download the latest Tarantool source code from the GitHub repository `tarantool/tarantool`, branch 1.7. For example, to a local directory named *~/tarantool*:

```
git clone https://github.com/tarantool/tarantool.git ~/tarantool
```

4. Use `git` again so that third-party contributions will be seen as well.

The build depends on the following external libraries:

- Readline development files (`libreadline-dev/readline-devel` package).
- OpenSSL development files (`libssl-dev/openssl-devel` package).
- `libyaml` (`libyaml-dev/libyaml-devel` package).
- `liblz4` (`liblz4-dev/lz4-devel` package).
- GNU `bfd` which is the part of GNU `binutils` (`binutils-dev/binutils-devel` package).

This step is only necessary once, the first time you do a download.

```
cd ~/tarantool
git submodule init
git submodule update --recursive
cd ../
```

On rare occasions, the submodules will need to be updated again with the command:

```
git submodule update --init --recursive
```

Note: There is an alternative – to say `git clone --recursive` earlier in step 3, – but we prefer the method above because it works with older versions of `git`.

5. Use CMake to initiate the build.

```
cd ~/tarantool
make clean         # unnecessary, added for good luck
rm CMakeCache.txt  # unnecessary, added for good luck
cmake .            # start initiating with build type=Debug
```

On some platforms, it may be necessary to specify the C and C++ versions, for example:

```
CC=gcc-4.8 CXX=g++-4.8 cmake .
```

The CMake option for specifying build type is `-DCMAKE_BUILD_TYPE=type`, where `type` can be:

- `Debug` – used by project maintainers
- `Release` – used only if the highest performance is required
- `RelWithDebInfo` – used for production, also provides debugging capabilities

The CMake option for hinting that the result will be distributed is `-DENABLE_DIST=ON`. If this option is on, then later `make install` will install tarantoolctl files in addition to tarantool files.

6. Use `make` to complete the build.

```
make
```

This creates the „tarantool" executable in the directory *src/*

Next, it's highly recommended to say `make install` to install Tarantool to the */usr/local* directory and keep your system clean. However, it is possible to run the Tarantool executable without installation.

7. Run the test suite.

This step is optional. Tarantool's developers always run the test suite before they publish new versions. You should run the test suite too, if you make any changes in the code. Assuming you downloaded to `~/tarantool`, the principal steps are:

```
# make a subdirectory named `bin`
mkdir ~/tarantool/bin
# link python to bin (this may require superuser privilege)
ln /usr/bin/python ~/tarantool/bin/python
# get on the test subdirectory
cd ~/tarantool/test
# run tests using python
PATH=~/tarantool/bin:$PATH ./test-run.py
```

The output should contain reassuring reports, for example:

```
======================================================================
TEST                                                RESULT
------------------------------------------------------------
box/bad_trigger.test.py                             [ pass ]
box/call.test.py                                    [ pass ]
box/iproto.test.py                                  [ pass ]
box/xlog.test.py                                    [ pass ]
box/admin.test.lua                                  [ pass ]
box/auth_access.test.lua                            [ pass ]
... etc.
```

To prevent later confusion, clean up what's in the *bin* subdirectory:

```
rm ~/tarantool/bin/python
rmdir ~/tarantool/bin
```

8. Make an rpm package.

   This step is optional. It's only for people who want to redistribute Tarantool. Package maintainers who want to build with `rpmbuild` should consult the `rpm-build` instructions for the appropriate platform.

9. Verify your Tarantool installation.

```
tarantool $ ./src/tarantool
```

   This will start Tarantool in the interactive mode.

For your added convenience, we provide OS-specific README files with example scripts at GitHub:

- README.FreeBSD for FreeBSD 10.1
- README.MacOSX for Mac OS X *El Capitan*
- README.md for generic GNU/Linux

These example scripts assume that the intent is to download from the 1.7 branch, build the server and run tests after build.

6.3.2 Building documentation

This documentation is built using a simplified markup system named `Sphinx` (see http://sphinx-doc.org). You can build a local version of this documentation and contribute to it.

You need to install:

- `git` (a program for downloading source repositories)
- `CMake` version 2.8 or later (a program for managing the build process)
- `Python` version greater than 2.6 – preferably 2.7 – and less than 3.0 (Sphinx is a Python-based tool)

Also, make sure to install the following Python modules:

- pip, any version
- dev, any version
- pyYAML version 3.10
- Sphinx version 1.4.4
- sphinx-intl version 0.9.9
- pelican, any version
- BeautifulSoup, any version
- gevent version 1.1b5

See installation details in the *build-from-source* section of this documentation. The procedure below implies that all the prerequisites are met.

1. Use `git` to download the latest source code of this documentation from the GitHub repository `tarantool/doc`, branch 1.7. For example, to a local directory named *~/tarantool-doc*:

```
git clone https://github.com/tarantool/doc.git ~/tarantool-doc
```

2. Use CMake to initiate the build.

```
cd ~/tarantool-doc
make clean         # unnecessary, added for good luck
rm CMakeCache.txt  # unnecessary, added for good luck
cmake .            # start initiating
```

3. Build a local version of the existing documentation package.

   Run the make command with an appropriate option to specify which documentation version to build.

```
cd ~/tarantool-doc
make all                # all versions
make sphinx-html        # multi-page English version
make sphinx-singlehtml  # one-page English version
make sphinx-html-ru     # multi-page Russian version
make sphinx-singlehtml  # one-page Russian version
```

   Documentation is created and stored at */www/output*:

   - */www/output/doc* (English versions)
   - */www/output/doc/ru* (Russian versions)

   The entry point for each version is *index.html* file in the appropriate directory.

4. Set up a web-server.

   Run the following command to set up a web-server (the example below is for Ubuntu, but the procedure is similar for other supported OS's). Make sure to run it from the documentation output folder, as specified below:

```
cd ~/tarantool-doc/www/output
python -m SimpleHTTPServer 8000
```

5. Open your browser and enter 127.0.0.1:8000/doc into the address box. If your local documentation build is valid, the default version (English multi-page) will be displayed in the browser.

6. To contribute to documentation, use the .rst format for drafting and submit your updates as «Pull Requests» via GitHub.

   To comply with the writing and formatting style, use the *guidelines* provided in the documentation, common sense and existing documents.

   Notes:

   - If you suggest creating a new documentation section (i.e., a whole new page), it has to be saved to the relevant section at GitHub.
   - If you want to contribute to localizing this documentation (e.g. into Russian), add your translation strings to .po files stored in the corresponding locale directory (e.g. /sphinx/locale/ru/LC_MESSAGES/ for Russian). See more about localizing with Sphinx at http://www.sphinx-doc.org/en/stable/intl.html

6.3.3 Release management

How to make a minor release

```
$ git tag -a 1.4.4 -m "Next minor in 1.4 series"
$ vim CMakeLists.txt # edit CPACK_PACKAGE_VERSION_PATCH
$ git push --tags
```

Update the Web site in doc/www

Update all issues, upload the ChangeLog based on `git log` output. The ChangeLog must only include items which are mentioned as issues on github. If anything significant is there, which is not mentioned, something went wrong in release planning and the release should be held up until this is cleared.

Click „Release milestone". Create a milestone for the next minor release. Alert the driver to target bugs and blueprints to the new milestone.

6.4 Guidelines

6.4.1 Developer guidelines

How to work on a bug

Any defect, even minor, if it changes the user-visible server behavior, needs a bug report. Report a bug at http://github.com/tarantool/tarantool/issues.

When reporting a bug, try to come up with a test case right away. Set the current maintenance milestone for the bug fix, and specify the series. Assign the bug to yourself. Put the status to „In progress" Once the patch is ready, put the bug the bug to „In review" and solicit a review for the fix.

Once there is a positive code review, push the patch and set the status to „Closed"

Patches for bugs should contain a reference to the respective Launchpad bug page or at least bug id. Each patch should have a test, unless coming up with one is difficult in the current framework, in which case QA should be alerted.

There are two things you need to do when your patch makes it into the master:

- put the bug to „fix committed",
- delete the remote branch.

6.4.2 Documentation guidelines

These guidelines are updated on the on-demand basis, covering only those issues that cause pains to the existing writers. At this point, we do not aim to come up with an exhaustive Documentation Style Guide for the Tarantool project.

Markup issues

Wrapping text

The limit is 80 characters per line for plain text, and no limit for any other constructions when wrapping affects ReST readability and/or HTML output. Also, it makes no sense to wrap text into lines shorter than

80 characters unless you have a good reason to do so.

The 80-character limit comes from the ISO/ANSI 80x24 screen resolution, and it's unlikely that readers/writers will use 80-character consoles. Yet it's still a standard for many coding guidelines (including Tarantool). As for writers, the benefit is that an 80-character page guide allows keeping the text window rather narrow most of the time, leaving more space for other applications in a wide-screen environment.

Formatting code snippets

For code snippets, we mainly use the `code-block` directive with an appropriate highlighting language. The most commonly used highlighting languages are:

- `.. code-block:: tarantoolsession`
- `.. code-block:: console`
- `.. code-block:: lua`

For example (a code snippet in Lua):

```lua
for page in paged_iter("X", 10) do
  print("New Page. Number Of Tuples = " .. #page)
  for i=1,#page,1 do print(page[i]) end
end
```

In rare cases, when we need custom highlight for specific parts of a code snippet and the `code-block` directive is not enough, we use the per-line `codenormal` directive together and explicit output formatting (defined in `doc/sphinx/_static/sphinx_design.css`).

Examples:

- Function syntax (the placeholder *space-name* is displayed in italics):

  box.space.space-name:create_index(„index-name“)

- A tdb session (user input is in bold, command prompt is in blue, computer output is in green):

```
$ tarantool example.lua
(TDB)  Tarantool debugger v.0.0.3. Type h for help
example.lua
(TDB)  [example.lua]
(TDB)  3: i = 1
```

Warning: Every entry of explicit output formatting (`codenormal`, `codebold`, etc) tends to cause troubles when this documentation is translated to other languages. Please avoid using explicit output formatting unless it is REALLY needed.

Using separated links

Avoid separating the link and the target definition (ref), like this:

```
This is a paragraph that contains `a link`_.

.. _a link: http://example.com/
```

Use non-separated links instead:

```
This is a paragraph that contains `a link <http://example.com/>`_.
```

Warning: Every separated link tends to cause troubles when this documentation is translated to other languages. Please avoid using separated links unless it is REALLY needed (e.g. in tables).

Creating labels for local links

We avoid using links that sphinx generates automatically for most objects. Instead, we add our own labels for linking to any place in this documentation.

Our naming convention is as follows:

- Character set: a through z, 0 through 9, dash, underscore.
- Format: `path dash filename dash tag`

  Example: `_c_api-box_index-iterator_type` where: `c_api` is the directory name, `box_index` is the file name (without «.rst»), and `iterator_type` is the tag.

The file name is useful for knowing, when you see «ref», where it is pointing to. And if the file name is meaningful, you see that better.

The file name alone, without a path, is enough when the file name is unique within `doc/sphinx`. So, for `fiber.rst` it should be just «fiber», not «reference-fiber». While for «index.rst» (we have a handful of «index.rst» in different directories) please specify the path before the file name, e.g. «reference-index».

Use a dash «-» to delimit the path and the file name. In the documentation source, we use only underscores «_» in paths and file names, reserving dash «-» as the delimiter for local links.

The tag can be anything meaningful. The only guideline is for Tarantool syntax items (such as members), where the preferred tag syntax is `module_or_object_name dash member_name`. For example, `box_space-drop`.

Making comments

Sometimes we may need to leave comments in a ReST file. To make sphinx ignore some text during processing, use the following per-line notation with «.. //» as the comment marker:

```
.. // your comment here
```

The starting symbols «.. //» do not interfere with the other ReST markup, and they are easy to find both visually and using grep. There are no symbols to escape in grep search, just go ahead with something like this:

```
grep ".. //" doc/sphinx/dev_guide/*.rst
```

These comments don't work properly in nested documentation, though (e.g. if you leave a comment in module -> object -> method, sphinx ignores the comment and all nested content that follows in the method description).

Language and style issues

US vs British spelling

We use English US spelling.

Examples and templates

Module and function

Here is an example of documenting a module (`my_fiber`) and a function (`my_fiber.create`).

`my_fiber.create(`*function*[, *function-arguments*]`)`

Create and start a `my_fiber` object. The object is created and begins to run immediately.

Параметры

- `function` – the function to be associated with the `my_fiber` object
- `function-arguments` – what will be passed to function

Return created `my_fiber` object

Rtype userdata

Example:

```
tarantool> my_fiber = require('my_fiber')
---
...
tarantool> function function_name()
         >   my_fiber.sleep(1000)
         > end
---
...
tarantool> my_fiber_object = my_fiber.create(function_name)
---
...
```

Module, class and method

Here is an example of documenting a module (`my_box.index`), a class (`my_index_object`) and a function (`my_index_object.rename`).

`object my_index_object`

`my_index_object:rename(`*index-name*`)`

Rename an index.

Параметры

- `index_object` – an object reference
- `index_name` – a new name for the index (type = string)

Return nil

Possible errors: index_object does not exist.

Example:

```
tarantool> box.space.space55.index.primary:rename('secondary')
---
...
```

Complexity Factors: Index size, Index type, Number of tuples accessed.

6.4.3 C Style Guide

The project's coding style is based on a version of the Linux kernel coding style.

The latest version of the Linux style can be found at: http://www.kernel.org/doc/Documentation/CodingStyle

Since it is open for changes, the version of style that we follow, one from 2007-July-13, will be also copied later in this document.

There are a few additional guidelines, either unique to Tarantool or deviating from the Kernel guidelines.

A. Chapters 10 «Kconfig configuration files», 11 «Data structures», 13 «Printing kernel messages», 14 «Allocating memory» and 17 «Don't re-invent the kernel macros» do not apply, since they are specific to Linux kernel programming environment.

B. The rest of Linux Kernel Coding Style is amended as follows:

General guidelines

We use Git for revision control. The latest development is happening in the „master" branch. Our git repository is hosted on github, and can be checked out with git clone git://github.com/tarantool/tarantool.git # anonymous read-only access

If you have any questions about Tarantool internals, please post them on the developer discussion list, https://groups.google.com/forum/#!forum/tarantool. However, please be warned: Launchpad silently deletes posts from non-subscribed members, thus please be sure to have subscribed to the list prior to posting. Additionally, some engineers are always present on #tarantool channel on irc.freenode.net.

Commenting style

Use Doxygen comment format, Javadoc flavor, i.e. *@tag* rather than *tag*. The main tags in use are @param, @retval, @return, @see, @note and @todo.

Every function, except perhaps a very short and obvious one, should have a comment. A sample function comment may look like below:

```
/** Write all data to a descriptor.
 *
 * This function is equivalent to 'write', except it would ensure
 * that all data is written to the file unless a non-ignorable
 * error occurs.
 *
 * @retval 0  Success
 *
 * @reval  1  An error occurred (not EINTR)
 * /
static int
write_all(int fd, void \*data, size_t len);
```

Public structures and important structure members should be commented as well.

Header files

Use header guards. Put the header guard in the first line in the header, before the copyright or declarations. Use all-uppercase name for the header guard. Derive the header guard name from the file name, and append

_INCLUDED to get a macro name. For example, core/log_io.h -> CORE_LOG_IO_H_INCLUDED. In `.c` (implementation) file, include the respective declaration header before all other headers, to ensure that the header is self- sufficient. Header «header.h» is self-sufficient if the following compiles without errors:

```
#include "header.h"
```

Allocating memory

Prefer the supplied slab (salloc) and pool (palloc) allocators to malloc()/free() for any performance-intensive or large memory allocations. Repetitive use of malloc()/free() can lead to memory fragmentation and should therefore be avoided.

Always free all allocated memory, even allocated at start-up. We aim at being valgrind leak-check clean, and in most cases it's just as easy to free() the allocated memory as it is to write a valgrind suppression. Freeing all allocated memory is also dynamic-load friendly: assuming a plug-in can be dynamically loaded and unloaded multiple times, reload should not lead to a memory leak.

Other

Select GNU C99 extensions are acceptable. It's OK to mix declarations and statements, use true and false.

The not-so-current list of all GCC C extensions can be found at: http://gcc.gnu.org/onlinedocs/gcc-4.3.5/gcc/C-Extensions.html

Linux kernel coding style

This is a short document describing the preferred coding style for the linux kernel. Coding style is very personal, and I won't _force_ my views on anybody, but this is what goes for anything that I have to be able to maintain, and I'd prefer it for most other things too. Please at least consider the points made here.

First off, I'd suggest printing out a copy of the GNU coding standards, and NOT read it. Burn them, it's a great symbolic gesture.

Anyway, here goes:

Chapter 1: Indentation

Tabs are 8 characters, and thus indentations are also 8 characters. There are heretic movements that try to make indentations 4 (or even 2!) characters deep, and that is akin to trying to define the value of PI to be 3.

Rationale: The whole idea behind indentation is to clearly define where a block of control starts and ends. Especially when you've been looking at your screen for 20 straight hours, you'll find it a lot easier to see how the indentation works if you have large indentations.

Now, some people will claim that having 8-character indentations makes the code move too far to the right, and makes it hard to read on a 80-character terminal screen. The answer to that is that if you need more than 3 levels of indentation, you're screwed anyway, and should fix your program.

In short, 8-char indents make things easier to read, and have the added benefit of warning you when you're nesting your functions too deep. Heed that warning.

The preferred way to ease multiple indentation levels in a switch statement is to align the «switch» and its subordinate «case» labels in the same column instead of «double-indenting» the «case» labels. e.g.:

```
switch (suffix) {
case 'G':
case 'g':
    mem <<= 30;
    break;
case 'M':
case 'm':
    mem <<= 20;
    break;
case 'K':
case 'k':
    mem <<= 10;
    /* fall through */
default:
    break;
}
```

Don't put multiple statements on a single line unless you have something to hide:

```
if (condition) do_this;
  do_something_everytime;
```

Don't put multiple assignments on a single line either. Kernel coding style is super simple. Avoid tricky expressions.

Outside of comments, documentation and except in Kconfig, spaces are never used for indentation, and the above example is deliberately broken.

Get a decent editor and don't leave whitespace at the end of lines.

Chapter 2: Breaking long lines and strings

Coding style is all about readability and maintainability using commonly available tools.

The limit on the length of lines is 80 columns and this is a strongly preferred limit.

Statements longer than 80 columns will be broken into sensible chunks. Descendants are always substantially shorter than the parent and are placed substantially to the right. The same applies to function headers with a long argument list. Long strings are as well broken into shorter strings. The only exception to this is where exceeding 80 columns significantly increases readability and does not hide information.

```
void fun(int a, int b, int c)
{
    if (condition)
        printk(KERN_WARNING "Warning this is a long printk with "
                            "3 parameters a: %u b: %u "
                            "c: %u \n", a, b, c);
    else
        next_statement;
}
```

Chapter 3: Placing Braces and Spaces

The other issue that always comes up in C styling is the placement of braces. Unlike the indent size, there are few technical reasons to choose one placement strategy over the other, but the preferred way, as shown to us by the prophets Kernighan and Ritchie, is to put the opening brace last on the line, and put the closing brace first, thusly:

```
if (x is true) {
    we do y
}
```

This applies to all non-function statement blocks (if, switch, for, while, do). e.g.:

```
switch (action) {
case KOBJ_ADD:
    return "add";
case KOBJ_REMOVE:
    return "remove";
case KOBJ_CHANGE:
    return "change";
default:
    return NULL;
}
```

However, there is one special case, namely functions: they have the opening brace at the beginning of the next line, thus:

```
int function(int x)
{
    body of function;
}
```

Heretic people all over the world have claimed that this inconsistency is ... well ... inconsistent, but all right-thinking people know that (a) K&R are _right_ and (b) K&R are right. Besides, functions are special anyway (you can't nest them in C).

Note that the closing brace is empty on a line of its own, _except_ in the cases where it is followed by a continuation of the same statement, ie a «while» in a do-statement or an «else» in an if-statement, like this:

```
do {
    body of do-loop;
} while (condition);
```

and

```
if (x == y) {
    ..
} else if (x > y) {
    ...
} else {
    ....
}
```

Rationale: K&R.

Also, note that this brace-placement also minimizes the number of empty (or almost empty) lines, without any loss of readability. Thus, as the supply of new-lines on your screen is not a renewable resource (think 25-line terminal screens here), you have more empty lines to put comments on.

Do not unnecessarily use braces where a single statement will do.

```
if (condition)
    action();
```

This does not apply if one branch of a conditional statement is a single statement. Use braces in both branches.

```
if (condition) {
    do_this();
    do_that();
} else {
    otherwise();
}
```

Chapter 3.1: Spaces

Linux kernel style for use of spaces depends (mostly) on function-versus-keyword usage. Use a space after (most) keywords. The notable exceptions are sizeof, typeof, alignof, and __attribute__, which look somewhat like functions (and are usually used with parentheses in Linux, although they are not required in the language, as in: «sizeof info» after «struct fileinfo info;» is declared).

So use a space after these keywords: if, switch, case, for, do, while but not with sizeof, typeof, alignof, or __attribute__. E.g.,

```
s = sizeof(struct file);
```

Do not add spaces around (inside) parenthesized expressions. This example is **bad**:

```
s = sizeof( struct file );
```

When declaring pointer data or a function that returns a pointer type, the preferred use of „*“ is adjacent to the data name or function name and not adjacent to the type name. Examples:

```
char *linux_banner;
unsigned long long memparse(char *ptr, char **retptr);
char *match_strdup(substring_t *s);
```

Use one space around (on each side of) most binary and ternary operators, such as any of these:

> = + - < > * / % | & ^ <= >= == != ? :

but no space after unary operators:

> & * + - ~ ! sizeof typeof alignof __attribute__ defined

no space before the postfix increment & decrement unary operators:

> ++ –

no space after the prefix increment & decrement unary operators:

> ++ –

and no space around the „.“ and «->» structure member operators.

Do not leave trailing whitespace at the ends of lines. Some editors with «smart» indentation will insert whitespace at the beginning of new lines as appropriate, so you can start typing the next line of code right away. However, some such editors do not remove the whitespace if you end up not putting a line of code there, such as if you leave a blank line. As a result, you end up with lines containing trailing whitespace.

Git will warn you about patches that introduce trailing whitespace, and can optionally strip the trailing whitespace for you; however, if applying a series of patches, this may make later patches in the series fail by changing their context lines.

Chapter 4: Naming

C is a Spartan language, and so should your naming be. Unlike Modula-2 and Pascal programmers, C programmers do not use cute names like ThisVariableIsATemporaryCounter. A C programmer would call that variable «tmp», which is much easier to write, and not the least more difficult to understand.

HOWEVER, while mixed-case names are frowned upon, descriptive names for global variables are a must. To call a global function «foo» is a shooting offense.

GLOBAL variables (to be used only if you _really_ need them) need to have descriptive names, as do global functions. If you have a function that counts the number of active users, you should call that «count_active_users()» or similar, you should _not_ call it «cntusr()».

Encoding the type of a function into the name (so-called Hungarian notation) is brain damaged - the compiler knows the types anyway and can check those, and it only confuses the programmer. No wonder MicroSoft makes buggy programs.

LOCAL variable names should be short, and to the point. If you have some random integer loop counter, it should probably be called «i». Calling it «loop_counter» is non-productive, if there is no chance of it being mis-understood. Similarly, «tmp» can be just about any type of variable that is used to hold a temporary value.

If you are afraid to mix up your local variable names, you have another problem, which is called the function-growth-hormone-imbalance syndrome. See chapter 6 (Functions).

Chapter 5: Typedefs

Please don't use things like «vps_t».

It's a _mistake_ to use typedef for structures and pointers. When you see a

```
vps_t a;
```

in the source, what does it mean?

In contrast, if it says

```
struct virtual_container *a;
```

you can actually tell what «a» is.

Lots of people think that typedefs «help readability». Not so. They are useful only for:

(a) totally opaque objects (where the typedef is actively used to _hide_ what the object is).

  Example: «pte_t» etc. opaque objects that you can only access using the proper accessor functions.

  NOTE! Opaqueness and «accessor functions» are not good in themselves. The reason we have them for things like pte_t etc. is that there really is absolutely _zero_ portably accessible information there.

(b) Clear integer types, where the abstraction _helps_ avoid confusion whether it is «int» or «long».

  u8/u16/u32 are perfectly fine typedefs, although they fit into category (d) better than here.

  NOTE! Again - there needs to be a _reason_ for this. If something is «unsigned long», then there's no reason to do

  ```
  typedef unsigned long myflags_t;
  ```

  but if there is a clear reason for why it under certain circumstances might be an «unsigned int» and under other configurations might be «unsigned long», then by all means go ahead and use a typedef.

(c) when you use sparse to literally create a _new_ type for type-checking.

(d) New types which are identical to standard C99 types, in certain exceptional circumstances.

Although it would only take a short amount of time for the eyes and brain to become accustomed to the standard types like „uint32_t", some people object to their use anyway.

Therefore, the Linux-specific „u8/u16/u32/u64" types and their signed equivalents which are identical to standard types are permitted – although they are not mandatory in new code of your own.

When editing existing code which already uses one or the other set of types, you should conform to the existing choices in that code.

(e) Types safe for use in userspace.

In certain structures which are visible to userspace, we cannot require C99 types and cannot use the „u32" form above. Thus, we use __u32 and similar types in all structures which are shared with userspace.

Maybe there are other cases too, but the rule should basically be to NEVER EVER use a typedef unless you can clearly match one of those rules.

In general, a pointer, or a struct that has elements that can reasonably be directly accessed should **never** be a typedef.

Chapter 6: Functions

Functions should be short and sweet, and do just one thing. They should fit on one or two screenfuls of text (the ISO/ANSI screen size is 80x24, as we all know), and do one thing and do that well.

The maximum length of a function is inversely proportional to the complexity and indentation level of that function. So, if you have a conceptually simple function that is just one long (but simple) case-statement, where you have to do lots of small things for a lot of different cases, it's OK to have a longer function.

However, if you have a complex function, and you suspect that a less-than-gifted first-year high-school student might not even understand what the function is all about, you should adhere to the maximum limits all the more closely. Use helper functions with descriptive names (you can ask the compiler to in-line them if you think it's performance-critical, and it will probably do a better job of it than you would have done).

Another measure of the function is the number of local variables. They shouldn't exceed 5-10, or you're doing something wrong. Re-think the function, and split it into smaller pieces. A human brain can generally easily keep track of about 7 different things, anything more and it gets confu/sed. You know you're brilliant, but maybe you'd like to understand what you did 2 weeks from now.

In source files, separate functions with one blank line. If the function is exported, the EXPORT* macro for it should follow immediately after the closing function brace line. E.g.:

```
int system_is_up(void)
{
    return system_state == SYSTEM_RUNNING;
}
EXPORT_SYMBOL(system_is_up);
```

In function prototypes, include parameter names with their data types. Although this is not required by the C language, it is preferred in Linux because it is a simple way to add valuable information for the reader.

Chapter 7: Centralized exiting of functions

Albeit deprecated by some people, the equivalent of the goto statement is used frequently by compilers in form of the unconditional jump instruction.

The goto statement comes in handy when a function exits from multiple locations and some common work such as cleanup has to be done.

The rationale is:

- unconditional statements are easier to understand and follow
- nesting is reduced
- errors by not updating individual exit points when making modifications are prevented
- saves the compiler work to optimize redundant code away ;)

```
int fun(int a)
{
    int result = 0;
    char *buffer = kmalloc(SIZE);

    if (buffer == NULL)
        return -ENOMEM;

    if (condition1) {
        while (loop1) {
            ...
        }
        result = 1;
        goto out;
    }
    ...
out:
    kfree(buffer);
    return result;
}
```

Chapter 8: Commenting

Comments are good, but there is also a danger of over-commenting. NEVER try to explain HOW your code works in a comment: it's much better to write the code so that the _working_ is obvious, and it's a waste of time to explain badly written code. c Generally, you want your comments to tell WHAT your code does, not HOW. Also, try to avoid putting comments inside a function body: if the function is so complex that you need to separately comment parts of it, you should probably go back to chapter 6 for a while. You can make small comments to note or warn about something particularly clever (or ugly), but try to avoid excess. Instead, put the comments at the head of the function, telling people what it does, and possibly WHY it does it.

When commenting the kernel API functions, please use the kernel-doc format. See the files Documentation/kernel-doc-nano-HOWTO.txt and scripts/kernel-doc for details.

Linux style for comments is the C89 `"/\* ... \*/"` style. Don't use C99-style `"// ..."` comments.

The preferred style for long (multi-line) comments is:

```
/*
 * This is the preferred style for multi-line
 * comments in the Linux kernel source code.
 * Please use it consistently.
 *
 * Description:  A column of asterisks on the left side,
 * with beginning and ending almost-blank lines.
 */
```

It's also important to comment data, whether they are basic types or derived types. To this end, use just one data declaration per line (no commas for multiple data declarations). This leaves you room for a small comment on each item, explaining its use.

Chapter 9: You've made a mess of it

That's OK, we all do. You've probably been told by your long-time Unix user helper that «GNU emacs» automatically formats the C sources for you, and you've noticed that yes, it does do that, but the defaults it uses are less than desirable (in fact, they are worse than random typing - an infinite number of monkeys typing into GNU emacs would never make a good program).

So, you can either get rid of GNU emacs, or change it to use saner values. To do the latter, you can stick the following in your .emacs file:

```
(defun c-lineup-arglist-tabs-only (ignored)
"Line up argument lists by tabs, not spaces"
(let* ((anchor (c-langelem-pos c-syntactic-element))
    (column (c-langelem-2nd-pos c-syntactic-element))
    (offset (- (1+ column) anchor))
    (steps (floor offset c-basic-offset)))
    (* (max steps 1)
    c-basic-offset)))

(add-hook 'c-mode-common-hook
        (lambda ()
            ;; Add kernel style
            (c-add-style
            "linux-tabs-only"
            '("linux" (c-offsets-alist
                        (arglist-cont-nonempty
                        c-lineup-gcc-asm-reg
                        c-lineup-arglist-tabs-only))))))

(add-hook 'c-mode-hook
        (lambda ()
            (let ((filename (buffer-file-name)))
            ;; Enable kernel mode for the appropriate files
            (when (and filename
                        (string-match (expand-file-name "~/src/linux-trees")
                                    filename))
                (setq indent-tabs-mode t)
                (c-set-style "linux-tabs-only")))))
```

This will make emacs go better with the kernel coding style for C files below ~/src/linux-trees.

But even if you fail in getting emacs to do sane formatting, not everything is lost: use «indent».

Now, again, GNU indent has the same brain-dead settings that GNU emacs has, which is why you need to give it a few command line options. However, that's not too bad, because even the makers of GNU indent recognize the authority of K&R (the GNU people aren't evil, they are just severely misguided in this matter), so you just give indent the options «-kr -i8» (stands for «K&R, 8 character indents»), or use «scripts/Lindent», which indents in the latest style.

«indent» has a lot of options, and especially when it comes to comment re-formatting you may want to take a look at the man page. But remember: «indent» is not a fix for bad programming.

Chapter 10: Kconfig configuration files

For all of the Kconfig* configuration files throughout the source tree, the indentation is somewhat different. Lines under a «config» definition are indented with one tab, while help text is indented an additional two spaces. Example:

```
config AUDIT
    bool "Auditing support"
    depends on NET
    help
    Enable auditing infrastructure that can be used with another
    kernel subsystem, such as SELinux (which requires this for
    logging of avc messages output).  Does not do system-call
    auditing without CONFIG_AUDITSYSCALL.
```

Features that might still be considered unstable should be defined as dependent on «EXPERIMENTAL»:

```
config SLUB
    depends on EXPERIMENTAL && !ARCH_USES_SLAB_PAGE_STRUCT
    bool "SLUB (Unqueued Allocator)"
    ...
```

while seriously dangerous features (such as write support for certain filesystems) should advertise this prominently in their prompt string:

```
config ADFS_FS_RW
    bool "ADFS write support (DANGEROUS)"
    depends on ADFS_FS
    ...
```

For full documentation on the configuration files, see the file Documentation/kbuild/kconfig-language.txt.

Chapter 11: Data structures

Data structures that have visibility outside the single-threaded environment they are created and destroyed in should always have reference counts. In the kernel, garbage collection doesn't exist (and outside the kernel garbage collection is slow and inefficient), which means that you absolutely _have_ to reference count all your uses.

Reference counting means that you can avoid locking, and allows multiple users to have access to the data structure in parallel - and not having to worry about the structure suddenly going away from under them just because they slept or did something else for a while.

Note that locking is _not_ a replacement for reference counting. Locking is used to keep data structures coherent, while reference counting is a memory management technique. Usually both are needed, and they are not to be confused with each other.

Many data structures can indeed have two levels of reference counting, when there are users of different «classes». The subclass count counts the number of subclass users, and decrements the global count just once when the subclass count goes to zero.

Examples of this kind of «multi-level-reference-counting» can be found in memory management («struct mm_struct»: mm_users and mm_count), and in filesystem code («struct super_block»: s_count and s_active).

Remember: if another thread can find your data structure, and you don't have a reference count on it, you almost certainly have a bug.

Chapter 12: Macros, Enums and RTL

Names of macros defining constants and labels in enums are capitalized.

```
#define CONSTANT 0x12345
```

Enums are preferred when defining several related constants.

CAPITALIZED macro names are appreciated but macros resembling functions may be named in lower case.

Generally, inline functions are preferable to macros resembling functions.

Macros with multiple statements should be enclosed in a do - while block:

```
#define macrofun(a, b, c)   \
    do {                    \
        if (a == 5)         \
            do_this(b, c);  \
    } while (0)
```

Things to avoid when using macros:

1. macros that affect control flow:

   ```
   #define FOO(x)                  \
       do {                        \
           if (blah(x) < 0)        \
               return -EBUGGERED;  \
       } while(0)
   ```

   is a _very_ bad idea. It looks like a function call but exits the «calling» function; don't break the internal parsers of those who will read the code.

2. macros that depend on having a local variable with a magic name:

   ```
   #define FOO(val) bar(index, val)
   ```

   might look like a good thing, but it's confusing as hell when one reads the code and it's prone to breakage from seemingly innocent changes.

3. macros with arguments that are used as l-values: FOO(x) = y; will bite you if somebody e.g. turns FOO into an inline function.

4. forgetting about precedence: macros defining constants using expressions must enclose the expression in parentheses. Beware of similar issues with macros using parameters.

   ```
   #define CONSTANT 0x4000
   #define CONSTEXP (CONSTANT | 3)
   ```

The cpp manual deals with macros exhaustively. The gcc internals manual also covers RTL which is used frequently with assembly language in the kernel.

Chapter 13: Printing kernel messages

Kernel developers like to be seen as literate. Do mind the spelling of kernel messages to make a good impression. Do not use crippled words like «dont»; use «do not» or «don't» instead. Make the messages concise, clear, and unambiguous.

Kernel messages do not have to be terminated with a period.

Printing numbers in parentheses (%d) adds no value and should be avoided.

There are a number of driver model diagnostic macros in <linux/device.h> which you should use to make sure messages are matched to the right device and driver, and are tagged with the right level: dev_err(), dev_warn(), dev_info(), and so forth. For messages that aren't associated with a particular device, <linux/kernel.h> defines pr_debug() and pr_info().

Coming up with good debugging messages can be quite a challenge; and once you have them, they can be a huge help for remote troubleshooting. Such messages should be compiled out when the DEBUG symbol is not defined (that is, by default they are not included). When you use dev_dbg() or pr_debug(), that's automatic. Many subsystems have Kconfig options to turn on -DDEBUG. A related convention uses VERBOSE_DEBUG to add dev_vdbg() messages to the ones already enabled by DEBUG.

Chapter 14: Allocating memory

The kernel provides the following general purpose memory allocators: kmalloc(), kzalloc(), kcalloc(), and vmalloc(). Please refer to the API documentation for further information about them.

The preferred form for passing a size of a struct is the following:

```
p = kmalloc(sizeof(*p), ...);
```

The alternative form where struct name is spelled out hurts readability and introduces an opportunity for a bug when the pointer variable type is changed but the corresponding sizeof that is passed to a memory allocator is not.

Casting the return value which is a void pointer is redundant. The conversion from void pointer to any other pointer type is guaranteed by the C programming language.

Chapter 15: The inline disease

There appears to be a common misperception that gcc has a magic «make me faster» speedup option called «inline». While the use of inlines can be appropriate (for example as a means of replacing macros, see Chapter 12), it very often is not. Abundant use of the inline keyword leads to a much bigger kernel, which in turn slows the system as a whole down, due to a bigger icache footprint for the CPU and simply because there is less memory available for the pagecache. Just think about it; a pagecache miss causes a disk seek, which easily takes 5 milliseconds. There are a LOT of cpu cycles that can go into these 5 milliseconds.

A reasonable rule of thumb is to not put inline at functions that have more than 3 lines of code in them. An exception to this rule are the cases where a parameter is known to be a compiletime constant, and as a result of this constantness you *know* the compiler will be able to optimize most of your function away at compile time. For a good example of this later case, see the kmalloc() inline function.

Often people argue that adding inline to functions that are static and used only once is always a win since there is no space tradeoff. While this is technically correct, gcc is capable of inlining these automatically without help, and the maintenance issue of removing the inline when a second user appears outweighs the potential value of the hint that tells gcc to do something it would have done anyway.

Chapter 16: Function return values and names

Functions can return values of many different kinds, and one of the most common is a value indicating whether the function succeeded or failed. Such a value can be represented as an error-code integer (-Exxx = failure, 0 = success) or a «succeeded» boolean (0 = failure, non-zero = success).

Mixing up these two sorts of representations is a fertile source of difficult-to-find bugs. If the C language included a strong distinction between integers and booleans then the compiler would find these mistakes for us... but it doesn't. To help prevent such bugs, always follow this convention:

```
If the name of a function is an action or an imperative command,
the function should return an error-code integer.  If the name
is a predicate, the function should return a "succeeded" boolean.
```

For example, «add work» is a command, and the add_work() function returns 0 for success or -EBUSY for failure. In the same way, «PCI device present» is a predicate, and the pci_dev_present() function returns 1 if it succeeds in finding a matching device or 0 if it doesn't.

All EXPORTed functions must respect this convention, and so should all public functions. Private (static) functions need not, but it is recommended that they do.

Functions whose return value is the actual result of a computation, rather than an indication of whether the computation succeeded, are not subject to this rule. Generally they indicate failure by returning some out-of-range result. Typical examples would be functions that return pointers; they use NULL or the ERR_PTR mechanism to report failure.

Chapter 17: Don't re-invent the kernel macros

The header file include/linux/kernel.h contains a number of macros that you should use, rather than explicitly coding some variant of them yourself. For example, if you need to calculate the length of an array, take advantage of the macro

```
#define ARRAY_SIZE(x) (sizeof(x) / sizeof((x)[0]))
```

Similarly, if you need to calculate the size of some structure member, use

```
#define FIELD_SIZEOF(t, f) (sizeof(((t*)0)->f))
```

There are also min() and max() macros that do strict type checking if you need them. Feel free to peruse that header file to see what else is already defined that you shouldn't reproduce in your code.

Chapter 18: Editor modelines and other cruft

Some editors can interpret configuration information embedded in source files, indicated with special markers. For example, emacs interprets lines marked like this:

```
-*- mode: c -*-
```

Or like this:

```
/*
Local Variables:
compile-command: "gcc -DMAGIC_DEBUG_FLAG foo.c"
End:
*/
```

Vim interprets markers that look like this:

```
/* vim:set sw=8 noet */
```

Do not include any of these in source files. People have their own personal editor configurations, and your source files should not override them. This includes markers for indentation and mode configuration. People may use their own custom mode, or may have some other magic method for making indentation work correctly.

Appendix I: References

- The C Programming Language, Second Edition by Brian W. Kernighan and Dennis M. Ritchie. Prentice Hall, Inc., 1988. ISBN 0-13-110362-8 (paperback), 0-13-110370-9 (hardback).
- The Practice of Programming by Brian W. Kernighan and Rob Pike. Addison-Wesley, Inc., 1999. ISBN 0-201-61586-X.
- GNU manuals - where in compliance with K&R and this text - for **cpp**, **gcc**, **gcc internals** and **indent**
- WG14 International standardization workgroup for the programming language C
- Kernel CodingStyle, by greg@kroah.com at OLS 2002

6.4.4 Python Style Guide

Introduction

This document gives coding conventions for the Python code comprising the standard library in the main Python distribution. Please see the companion informational PEP describing style guidelines for the C code in the C implementation of Python[1].

This document and PEP 257 (Docstring Conventions) were adapted from Guido's original Python Style Guide essay, with some additions from Barry's style guide[2].

A Foolish Consistency is the Hobgoblin of Little Minds

One of Guido's key insights is that code is read much more often than it is written. The guidelines provided here are intended to improve the readability of code and make it consistent across the wide spectrum of Python code. As PEP 20 says, «Readability counts».

A style guide is about consistency. Consistency with this style guide is important. Consistency within a project is more important. Consistency within one module or function is the most important.

But most importantly: know when to be inconsistent – sometimes the style guide just doesn't apply. When in doubt, use your best judgment. Look at other examples and decide what looks best. And don't hesitate to ask!

[1] PEP 7, Style Guide for C Code, van Rossum
[2] Barry's GNU Mailman style guide

Two good reasons to break a particular rule:

1. When applying the rule would make the code less readable, even for someone who is used to reading code that follows the rules.
2. To be consistent with surrounding code that also breaks it (maybe for historic reasons) – although this is also an opportunity to clean up someone else's mess (in true XP style).

Code lay-out

Indentation

Use 4 spaces per indentation level.

For really old code that you don't want to mess up, you can continue to use 8-space tabs.

Continuation lines should align wrapped elements either vertically using Python's implicit line joining inside parentheses, brackets and braces, or using a hanging indent. When using a hanging indent the following considerations should be applied; there should be no arguments on the first line and further indentation should be used to clearly distinguish itself as a continuation line.

Yes:

```
# Aligned with opening delimiter
foo = long_function_name(var_one, var_two,
                         var_three, var_four)

# More indentation included to distinguish this from the rest.
def long_function_name(
        var_one, var_two, var_three,
        var_four):
    print(var_one)
```

No:

```
# Arguments on first line forbidden when not using vertical alignment
foo = long_function_name(var_one, var_two,
    var_three, var_four)

# Further indentation required as indentation is not distinguishable
def long_function_name(
    var_one, var_two, var_three,
    var_four):
    print(var_one)
```

Optional:

```
# Extra indentation is not necessary.
foo = long_function_name(
  var_one, var_two,
  var_three, var_four)
```

The closing brace/bracket/parenthesis on multi-line constructs may either line up under the first non-whitespace character of the last line of list, as in:

```
my_list = [
    1, 2, 3,
```

(continues on next page)

(продолжение с предыдущей страницы)

```
    4, 5, 6,
    ]
result = some_function_that_takes_arguments(
    'a', 'b', 'c',
    'd', 'e', 'f',
    )
```

or it may be lined up under the first character of the line that starts the multi-line construct, as in:

```
my_list = [
    1, 2, 3,
    4, 5, 6,
]
result = some_function_that_takes_arguments(
    'a', 'b', 'c',
    'd', 'e', 'f',
)
```

Tabs or Spaces?

Never mix tabs and spaces.

The most popular way of indenting Python is with spaces only. The second-most popular way is with tabs only. Code indented with a mixture of tabs and spaces should be converted to using spaces exclusively. When invoking the Python command line interpreter with the `-t` option, it issues warnings about code that illegally mixes tabs and spaces. When using `-tt` these warnings become errors. These options are highly recommended!

For new projects, spaces-only are strongly recommended over tabs. Most editors have features that make this easy to do.

Maximum Line Length

Limit all lines to a maximum of 79 characters.

There are still many devices around that are limited to 80 character lines; plus, limiting windows to 80 characters makes it possible to have several windows side-by-side. The default wrapping on such devices disrupts the visual structure of the code, making it more difficult to understand. Therefore, please limit all lines to a maximum of 79 characters. For flowing long blocks of text (docstrings or comments), limiting the length to 72 characters is recommended.

The preferred way of wrapping long lines is by using Python's implied line continuation inside parentheses, brackets and braces. Long lines can be broken over multiple lines by wrapping expressions in parentheses. These should be used in preference to using a backslash for line continuation.

Backslashes may still be appropriate at times. For example, long, multiple `with`-statements cannot use implicit continuation, so backslashes are acceptable:

```
with open('/path/to/some/file/you/want/to/read') as file_1, \
        open('/path/to/some/file/being/written', 'w') as file_2:
    file_2.write(file_1.read())
```

Another such case is with `assert` statements.

Make sure to indent the continued line appropriately. The preferred place to break around a binary operator is *after* the operator, not before it. Some examples:

```
class Rectangle(Blob):

    def __init__(self, width, height,
                 color='black', emphasis=None, highlight=0):
        if (width == 0 and height == 0 and
            color == 'red' and emphasis == 'strong' or
            highlight > 100):
            raise ValueError("sorry, you lose")
        if width == 0 and height == 0 and (color == 'red' or
                                           emphasis is None):
            raise ValueError("I don't think so -- values are %s, %s" %
                             (width, height))
        Blob.__init__(self, width, height,
                      color, emphasis, highlight)
```

Blank Lines

Separate top-level function and class definitions with two blank lines.

Method definitions inside a class are separated by a single blank line.

Extra blank lines may be used (sparingly) to separate groups of related functions. Blank lines may be omitted between a bunch of related one-liners (e.g. a set of dummy implementations).

Use blank lines in functions, sparingly, to indicate logical sections.

Python accepts the control-L (i.e. ^L) form feed character as whitespace; Many tools treat these characters as page separators, so you may use them to separate pages of related sections of your file. Note, some editors and web-based code viewers may not recognize control-L as a form feed and will show another glyph in its place.

Encodings (PEP 263)

Code in the core Python distribution should always use the ASCII or Latin-1 encoding (a.k.a. ISO-8859-1). For Python 3.0 and beyond, UTF-8 is preferred over Latin-1, see PEP 3120.

Files using ASCII should not have a coding cookie. Latin-1 (or UTF-8) should only be used when a comment or docstring needs to mention an author name that requires Latin-1; otherwise, using `\x`, `\u` or `\U` escapes is the preferred way to include non-ASCII data in string literals.

For Python 3.0 and beyond, the following policy is prescribed for the standard library (see PEP 3131): All identifiers in the Python standard library MUST use ASCII-only identifiers, and SHOULD use English words wherever feasible (in many cases, abbreviations and technical terms are used which aren't English). In addition, string literals and comments must also be in ASCII. The only exceptions are (a) test cases testing the non-ASCII features, and (b) names of authors. Authors whose names are not based on the latin alphabet MUST provide a latin transliteration of their names.

Open source projects with a global audience are encouraged to adopt a similar policy.

Imports

- Imports should usually be on separate lines, e.g.:

```
Yes: import os
     import sys

No:  import sys, os
```

It's okay to say this though:

```
from subprocess import Popen, PIPE
```

- Imports are always put at the top of the file, just after any module comments and docstrings, and before module globals and constants.

  Imports should be grouped in the following order:

  1. standard library imports
  2. related third party imports
  3. local application/library specific imports

  You should put a blank line between each group of imports.

  Put any relevant `__all__` specification after the imports.

- Relative imports for intra-package imports are highly discouraged. Always use the absolute package path for all imports. Even now that PEP 328 is fully implemented in Python 2.5, its style of explicit relative imports is actively discouraged; absolute imports are more portable and usually more readable.

- When importing a class from a class-containing module, it's usually okay to spell this:

```
from myclass import MyClass
from foo.bar.yourclass import YourClass
```

  If this spelling causes local name clashes, then spell them

```
import myclass
import foo.bar.yourclass
```

  and use «myclass.MyClass» and «foo.bar.yourclass.YourClass».

Whitespace in Expressions and Statements

Pet Peeves

Avoid extraneous whitespace in the following situations:

- Immediately inside parentheses, brackets or braces.

```
Yes: spam(ham[1], {eggs: 2})
No:  spam( ham[ 1 ], { eggs: 2 } )
```

- Immediately before a comma, semicolon, or colon:

```
Yes: if x == 4: print x, y; x, y = y, x
No:  if x == 4 : print x , y ; x , y = y , x
```

- Immediately before the open parenthesis that starts the argument list of a function call:

```
Yes: spam(1)
No:  spam (1)
```

- Immediately before the open parenthesis that starts an indexing or slicing:

```
Yes: dict['key'] = list[index]
No:  dict ['key'] = list [index]
```

- More than one space around an assignment (or other) operator to align it with another.

  Yes:

```
x = 1
y = 2
long_variable = 3
```

  No:

```
x             = 1
y             = 2
long_variable = 3
```

Other Recommendations

- Always surround these binary operators with a single space on either side: assignment (`=`), augmented assignment (`+=`, `-=` etc.), comparisons (`==`, `<`, `>`, `!=`, `<>`, `<=`, `>=`, `in`, `not in`, `is`, `is not`), Booleans (`and`, `or`, `not`).
- If operators with different priorities are used, consider adding whitespace around the operators with the lowest priority(ies). Use your own judgement; however, never use more than one space, and always have the same amount of whitespace on both sides of a binary operator.

  Yes:

```
i = i + 1
submitted += 1
x = x*2 - 1
hypot2 = x*x + y*y
c = (a+b) * (a-b)
```

  No:

```
i=i+1
submitted +=1
x = x * 2 - 1
hypot2 = x * x + y * y
c = (a + b) * (a - b)
```

- Don't use spaces around the `=` sign when used to indicate a keyword argument or a default parameter value.

  Yes:

```
def complex(real, imag=0.0):
    return magic(r=real, i=imag)
```

  No:

```
def complex(real, imag = 0.0):
    return magic(r = real, i = imag)
```

- Compound statements (multiple statements on the same line) are generally discouraged.

  Yes:

```
if foo == 'blah':
    do_blah_thing()
do_one()
do_two()
do_three()
```

  Rather not:

```
if foo == 'blah': do_blah_thing()
do_one(); do_two(); do_three()
```

- While sometimes it's okay to put an if/for/while with a small body on the same line, never do this for multi-clause statements. Also avoid folding such long lines!

  Rather not:

```
if foo == 'blah': do_blah_thing()
for x in lst: total += x
while t < 10: t = delay()
```

  Definitely not:

```
if foo == 'blah': do_blah_thing()
else: do_non_blah_thing()

try: something()
finally: cleanup()

do_one(); do_two(); do_three(long, argument,
                             list, like, this)

if foo == 'blah': one(); two(); three()
```

Comments

Comments that contradict the code are worse than no comments. Always make a priority of keeping the comments up-to-date when the code changes!

Comments should be complete sentences. If a comment is a phrase or sentence, its first word should be capitalized, unless it is an identifier that begins with a lower case letter (never alter the case of identifiers!).

If a comment is short, the period at the end can be omitted. Block comments generally consist of one or more paragraphs built out of complete sentences, and each sentence should end in a period.

You should use two spaces after a sentence-ending period.

When writing English, Strunk and White apply.

Python coders from non-English speaking countries: please write your comments in English, unless you are 120% sure that the code will never be read by people who don't speak your language.

Block Comments

Block comments generally apply to some (or all) code that follows them, and are indented to the same level as that code. Each line of a block comment starts with a # and a single space (unless it is indented text inside the comment).

Paragraphs inside a block comment are separated by a line containing a single #.

Inline Comments

Use inline comments sparingly.

An inline comment is a comment on the same line as a statement. Inline comments should be separated by at least two spaces from the statement. They should start with a # and a single space.

Inline comments are unnecessary and in fact distracting if they state the obvious. Don't do this:

```
x = x + 1                 # Increment x
```

But sometimes, this is useful:

```
x = x + 1                 # Compensate for border
```

Documentation Strings

Conventions for writing good documentation strings (a.k.a. «docstrings») are immortalized in PEP 257.

- Write docstrings for all public modules, functions, classes, and methods. Docstrings are not necessary for non-public methods, but you should have a comment that describes what the method does. This comment should appear after the `def` line.
- PEP 257 describes good docstring conventions. Note that most importantly, the `"""` that ends a multiline docstring should be on a line by itself, and preferably preceded by a blank line, e.g.:

  ```
  """Return a foobang

  Optional plotz says to frobnicate the bizbaz first.

  """
  ```

- For one liner docstrings, it's okay to keep the closing `"""` on the same line.

Version Bookkeeping

If you have to have Subversion, CVS, or RCS crud in your source file, do it as follows.

```
__version__ = "$Revision$"
# $Source$
```

These lines should be included after the module's docstring, before any other code, separated by a blank line above and below.

Naming Conventions

The naming conventions of Python's library are a bit of a mess, so we'll never get this completely consistent – nevertheless, here are the currently recommended naming standards. New modules and packages (including third party frameworks) should be written to these standards, but where an existing library has a different style, internal consistency is preferred.

Descriptive: Naming Styles

There are a lot of different naming styles. It helps to be able to recognize what naming style is being used, independently from what they are used for.

The following naming styles are commonly distinguished:

- `b` (single lowercase letter)
- `B` (single uppercase letter)
- `lowercase`
- `lower_case_with_underscores`
- `UPPERCASE`
- `UPPER_CASE_WITH_UNDERSCORES`
- `CapitalizedWords` (or CapWords, or CamelCase – so named because of the bumpy look of its letters[3]). This is also sometimes known as StudlyCaps.

  Note: When using abbreviations in CapWords, capitalize all the letters of the abbreviation. Thus HTTPServerError is better than HttpServerError.
- `mixedCase` (differs from CapitalizedWords by initial lowercase character!)
- `Capitalized_Words_With_Underscores` (ugly!)

There's also the style of using a short unique prefix to group related names together. This is not used much in Python, but it is mentioned for completeness. For example, the `os.stat()` function returns a tuple whose items traditionally have names like `st_mode`, `st_size`, `st_mtime` and so on. (This is done to emphasize the correspondence with the fields of the POSIX system call struct, which helps programmers familiar with that.)

The X11 library uses a leading X for all its public functions. In Python, this style is generally deemed unnecessary because attribute and method names are prefixed with an object, and function names are prefixed with a module name.

In addition, the following special forms using leading or trailing underscores are recognized (these can generally be combined with any case convention):

- `_single_leading_underscore`: weak «internal use» indicator. E.g. `from M import *` does not import objects whose name starts with an underscore.
- `single_trailing_underscore_`: used by convention to avoid conflicts with Python keyword, e.g.

```
Tkinter.Toplevel(master, class_='ClassName')
```

- `__double_leading_underscore`: when naming a class attribute, invokes name mangling (inside class FooBar, `__boo` becomes `_FooBar__boo`; see below).

[3] CamelCase Wikipedia page

- `__double_leading_and_trailing_underscore__`: «magic» objects or attributes that live in user-controlled namespaces. E.g. `__init__`, `__import__` or `__file__`. Never invent such names; only use them as documented.

Prescriptive: Naming Conventions

Names to Avoid

Never use the characters „l" (lowercase letter el), „O" (uppercase letter oh), or „I" (uppercase letter eye) as single character variable names.

In some fonts, these characters are indistinguishable from the numerals one and zero. When tempted to use „l", use „L" instead.

Package and Module Names

Modules should have short, all-lowercase names. Underscores can be used in the module name if it improves readability. Python packages should also have short, all-lowercase names, although the use of underscores is discouraged.

Since module names are mapped to file names, and some file systems are case insensitive and truncate long names, it is important that module names be chosen to be fairly short – this won't be a problem on Unix, but it may be a problem when the code is transported to older Mac or Windows versions, or DOS.

When an extension module written in C or C++ has an accompanying Python module that provides a higher level (e.g. more object oriented) interface, the C/C++ module has a leading underscore (e.g. `_socket`).

Class Names

Almost without exception, class names use the CapWords convention. Classes for internal use have a leading underscore in addition.

Exception Names

Because exceptions should be classes, the class naming convention applies here. However, you should use the suffix «Error» on your exception names (if the exception actually is an error).

Global Variable Names

(Let's hope that these variables are meant for use inside one module only.) The conventions are about the same as those for functions.

Modules that are designed for use via `from M import *` should use the `__all__` mechanism to prevent exporting globals, or use the older convention of prefixing such globals with an underscore (which you might want to do to indicate these globals are «module non-public»).

Function Names

Function names should be lowercase, with words separated by underscores as necessary to improve readability.

mixedCase is allowed only in contexts where that's already the prevailing style (e.g. threading.py), to retain backwards compatibility.

Function and method arguments

Always use `self` for the first argument to instance methods.

Always use `cls` for the first argument to class methods.

If a function argument's name clashes with a reserved keyword, it is generally better to append a single trailing underscore rather than use an abbreviation or spelling corruption. Thus `class_` is better than `clss`. (Perhaps better is to avoid such clashes by using a synonym.)

Method Names and Instance Variables

Use the function naming rules: lowercase with words separated by underscores as necessary to improve readability.

Use one leading underscore only for non-public methods and instance variables.

To avoid name clashes with subclasses, use two leading underscores to invoke Python's name mangling rules.

Python mangles these names with the class name: if class Foo has an attribute named `__a`, it cannot be accessed by `Foo.__a`. (An insistent user could still gain access by calling `Foo._Foo__a`.) Generally, double leading underscores should be used only to avoid name conflicts with attributes in classes designed to be subclassed.

Note: there is some controversy about the use of __names (see below).

Constants

Constants are usually defined on a module level and written in all capital letters with underscores separating words. Examples include `MAX_OVERFLOW` and `TOTAL`.

Designing for inheritance

Always decide whether a class's methods and instance variables (collectively: «attributes») should be public or non-public. If in doubt, choose non-public; it's easier to make it public later than to make a public attribute non-public.

Public attributes are those that you expect unrelated clients of your class to use, with your commitment to avoid backward incompatible changes. Non-public attributes are those that are not intended to be used by third parties; you make no guarantees that non-public attributes won't change or even be removed.

We don't use the term «private» here, since no attribute is really private in Python (without a generally unnecessary amount of work).

Another category of attributes are those that are part of the «subclass API» (often called «protected» in other languages). Some classes are designed to be inherited from, either to extend or modify aspects of the class's behavior. When designing such a class, take care to make explicit decisions about which attributes are public, which are part of the subclass API, and which are truly only to be used by your base class.

With this in mind, here are the Pythonic guidelines:

- Public attributes should have no leading underscores.
- If your public attribute name collides with a reserved keyword, append a single trailing underscore to your attribute name. This is preferable to an abbreviation or corrupted spelling. (However, not withstanding this rule, „cls" is the preferred spelling for any variable or argument which is known to be a class, especially the first argument to a class method.)

  Note 1: See the argument name recommendation above for class methods.

- For simple public data attributes, it is best to expose just the attribute name, without complicated accessor/mutator methods. Keep in mind that Python provides an easy path to future enhancement, should you find that a simple data attribute needs to grow functional behavior. In that case, use properties to hide functional implementation behind simple data attribute access syntax.

  Note 1: Properties only work on new-style classes.

  Note 2: Try to keep the functional behavior side-effect free, although side-effects such as caching are generally fine.

  Note 3: Avoid using properties for computationally expensive operations; the attribute notation makes the caller believe that access is (relatively) cheap.

- If your class is intended to be subclassed, and you have attributes that you do not want subclasses to use, consider naming them with double leading underscores and no trailing underscores. This invokes Python's name mangling algorithm, where the name of the class is mangled into the attribute name. This helps avoid attribute name collisions should subclasses inadvertently contain attributes with the same name.

  Note 1: Note that only the simple class name is used in the mangled name, so if a subclass chooses both the same class name and attribute name, you can still get name collisions.

  Note 2: Name mangling can make certain uses, such as debugging and `__getattr__()`, less convenient. However the name mangling algorithm is well documented and easy to perform manually.

  Note 3: Not everyone likes name mangling. Try to balance the need to avoid accidental name clashes with potential use by advanced callers.

References

Copyright

Author:

- Guido van Rossum <guido@python.org>
- Barry Warsaw <barry@python.org>

Lua Module Index