Tarantool

Release 1.7.2

Mar 14, 2019

Contents

CHAPTER 1

What's new?

Here is a summary of significant changes introduced in specific versions of Tarantool.

For smaller feature changes and bug fixes, see closed milestones at GitHub.

1.1 What's new in Tarantool 1.7?

The disk-based storge engine, which was called sophia or phia in earlier versions, is superseded by the vinyl storage engine.

There are new types for indexed fields.

The LuaJIT version is updated.

Automatic replication cluster bootstrap (to make it easier to configure a new replication cluster) is supported.

The space_object:inc() function is removed.

The space_object:dec() function is removed.

CHAPTER 2

Overview

2.1 An application server together with a database manager

Tarantool is a Lua application server integrated with a database management system. It has a “fiber” model which means that many Tarantool applications can run simultaneously on a single thread, while the Tarantool server itself can run multiple threads for input-output and background maintenance. It incorporates the LuaJIT – “Just In Time” – Lua compiler, Lua libraries for most common applications, and the Tarantool Database Server which is an established NoSQL DBMS. Thus Tarantool serves all the purposes that have made node.js and Twisted popular, plus it supports data persistence.

The code is free. The open-source license is BSD license. The supported platforms are GNU/Linux, Mac OS and FreeBSD.

Tarantool’s creator and biggest user is Mail.Ru, the largest internet company in Russia, with 30 million users, 25 million emails per day, and a web site whose Alexa global rank is in the top 40 worldwide. Tarantool services Mail.Ru’s hottest data, such as the session data of online users, the properties of online applications, the caches of the underlying data, the distribution and sharding algorithms, and much more. Outside Mail.Ru the software is used by a growing number of projects in online gaming, digital marketing, and social media industries. Although Mail.Ru is the sponsor for product development, the roadmap and the bugs database and the development process are fully open. The software incorporates patches from dozens of community contributors. The Tarantool community writes and maintains most of the drivers for programming languages. The greater Lua community has hundreds of useful packages most of which can become Tarantool extensions.

Users can create, modify and drop Lua functions at runtime. Or they can define Lua programs that are loaded during startup for triggers, background tasks, and interacting with networked peers. Unlike popular application development frameworks based on a “reactor” pattern, networking in server-side Lua is sequential, yet very efficient, as it is built on top of the cooperative multitasking environment that Tarantool itself uses.

One of the built-in Lua packages provides an API for the Database Management System. Thus some developers see Tarantool as a DBMS with a popular stored procedure language, while others see it as a Lua interpreter, while still others see it as a replacement for many components of multi-tier Web applications. Performance can be a few hundred thousand transactions per second on a laptop, scalable upwards or outwards to server farms.

2.2 Database features

Tarantool can run without it, but “The Box” – the DBMS server – is a strong distinguishing feature.

The database API allows for permanently storing Lua objects, managing object collections, creating or dropping secondary keys, making changes atomically, configuring and monitoring replication, performing controlled fail-over, and executing Lua code triggered by database events. Remote database instances are accessible transparently via a remote-procedure-invocation API.

Tarantool’s DBMS server uses the storage engine concept, where different sets of algorithms and data structures can be used for different situations. Two storage engines are built-in: an in-memory engine which has all the data and indexes in RAM, and a two-level B-tree engine for data sets whose size is 10 to 1000 times the amount of available RAM. All storage engines in Tarantool support transactions and replication by using a common write ahead log (WAL). This ensures consistency and crash safety of the persistent state. Changes are not considered complete until the WAL is written. The logging subsystem supports group commit.

Tarantool’s in-memory storage engine (memtx) keeps all the data in random-access memory, and therefore has very low read latency. It also keeps persistent copies of the data in non-volatile storage, such as disk, when users request “snapshots”. If a server stops and the random-access memory is lost, then restarts, it reads the latest snapshot and then replays the transactions that are in the log – therefore no data is lost.

Tarantool’s in-memory engine is lock-free in typical situations. Instead of the operating system’s concurrency primitives, such as mutexes, Tarantool uses cooperative multitasking to handle thousands of connections simultaneously. There is a fixed number of independent execution threads. The threads do not share state. Instead they exchange data using low-overhead message queues. While this approach limits the number of cores that the server will use, it removes competition for the memory bus and ensures peak scalability of memory access and network throughput. CPU utilization of a typical highly-loaded Tarantool server is under 10%. Searches are possible via secondary index keys as well as primary keys.

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 supports multi-part index keys. The possible index types are HASH, TREE, BITSET, and RTREE.

Tarantool supports asynchronous replication, locally or to remote hosts. The replication architecture can be master-master, that is, many nodes may both handle the loads and receive what others have handled, for the same data sets.

CHAPTER 3

Tutorials

3.1 Lua tutorials

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.

3.1.1 Insert one million tuples with a Lua stored procedure

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”.

The screen now looks like this:

```
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" .

The screen now looks like this:

```
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().

The screen now looks like this:

```
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()
---
```

```
- 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".

The screen now looks like this:

```
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.

The screen now looks like this:

```
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.

The screen now looks like this:

```
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() <http://www.lua.org/manual/5.1/manual.html#pdf-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'
```

The screen now looks like this:

```
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()
---
...
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.

3.1.2 Sum a JSON field for all tuples

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.

3.1.3 Indexed pattern search

Here is a generic function which takes a field identifier and a search pattern, and returns all tuples that match. |br| * The field must be the first field of a TREE index. |br| * The function will use Lua pattern matching, which allows "magic characters" in regular expressions. |br| * 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. |br| * To be cooperative, the function should yield after every 10 tuples, unless there is a reason to delay yielding. |br| 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
    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" |br| The caller has passed space_name (a string) and field_no (a number). The requirements are: |br| (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; |br| (b) field_no must be the first index part; |br| (c) the field must contain strings, because for other data types (such as "unsigned") pattern searches are not possible; |br| 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" |br| 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" |br| 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" |br| 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” |br| 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” |br| 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” |br| 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” |br| 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'}
box.space.t:insert{8,'ABCDF',''}
indexed_pattern_search("t", 2, "ABC.E.")
```

The result will be:

```
tarantool> indexed_pattern_search("t", 2, "ABC.E.")
---
- - [7, 'ABCDEF', 'a']
...
```

3.2 C tutorial

Here is one C tutorial: C stored procedures.

3.2.1 C stored procedures

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: |br| * Tarantool 1.7 |br| * A gcc compiler, any modern version should work |br| * "module.h" |br| * "msgpuck.h" |br|

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 |br| sudo apt-get install tarantool-dev |br| or on Fedora say |br| 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 |br| 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: |br| 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;
  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: |br| 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. |br| The second displayed line will be "field_count = 3" because there are three items in the table. |br| 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: |br| 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(); |br| (2) formatting a tuple using more msgpuck.h functions; |br| (3) inserting a row using box_insert.

Now, still on the client, execute this request: |br| 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.

CHAPTER 4

User's Guide

4.1 Preface

Welcome to Tarantool! This is the User's Guide. We recommend reading it first, and consulting Reference materials for more detail afterwards, if needed.

4.1.1 How to read the documentation

To get started, you can either download the whole Tarantool package as described in the first part of Chapter 2 "Getting Started", or you can skip the download and connect to the online Tarantool server running on the web at http://try.tarantool.org. Either way, as the first tryout, you can follow the introductory example "Starting Tarantool and making your first database" from the second part of Chapter 2. If you want more hands-on experience, proceed to the "Tutorials" part after you are through with Chapter 2.

Chapter 3 "Database" is about using Tarantool as a NoSQL DBMS, whereas Chapter 4 "Application server" is about using Tarantool as an application server.

Chapter 5 "Server administration" is primarily for administrators.

Chapter 6 "Connectors" is strictly for users who are connecting from a different language such as C or Perl or Python — other users will find no immediate need for this chapter.

Chapter 7 "FAQ" gives answers to some frequently asked questions about Tarantool.

For experienced users, there are also Reference materials, a Contributor's Guide and an extensive set of comments in the source code.

4.1.2 Getting in touch with the Tarantool community

Please report bugs or make feature requests at http://github.com/tarantool/tarantool/issues.

You can contact developers directly in telegram or in a Tarantool discussion group (English or Russian).

4.2 Getting started

This chapter shows how to download, how to install, and how to start Tarantool for the first time.

For production, if possible, you should download a binary (executable) package. This will ensure that you have the same build of the same version that the developers have. That makes analysis easier if later you need to report a problem, and avoids subtle problems that might happen if you used different tools or different parameters when building from source. The section about binaries is "Downloading and installing a binary package".

For development, you will want to download a source package and make the binary by yourself using a C/C++ compiler and common tools. Although this is a bit harder, it gives more control. And the source packages include additional files, for example the Tarantool test suite. The section about source is "Building from source" in Contributor's Guide.

If the installation has already been done, then you should try it out. So we've provided some instructions that you can use to make a temporary "sandbox". In a few minutes you can start the server and type in some database-manipulation statements. The section about the sandbox is "Starting Tarantool and making your first database".

4.2.1 Downloading and installing a binary package

Binary packages for two Tarantool versions – for the stable 1.6 and the latest 1.7 – are provided at http://tarantool.org/download.html. An automatic build system creates, tests and publishes packages for every push into the 1.7 branch.

To download and install the package that's appropriate for your OS, start a shell (terminal) and enter the command-line instructions provided for your OS at http://tarantool.org/download.html.

4.2.2 Starting Tarantool and making your first database

Here is how to create a simple test database after installing.

Create a new directory. It's just for tests, you can delete it when the tests are over.

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

Here is how to create a simple test database after installing.

Start the server. The server name is tarantool.

```
$ # if you downloaded a binary with apt-get or yum, say this:
$ /usr/bin/tarantool
$ # if you downloaded and untarred a binary
$ # tarball to ~/tarantool, say this:
$ ~/tarantool/bin/tarantool
$ # if you built from a source download, say this:
$ ~/tarantool/src/tarantool
```

The server starts in interactive mode and outputs a command prompt. To turn on the database, configure it. This minimal example is sufficient:

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

If all goes well, you will see the server displaying progress as it initializes, something like this:

```
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
```

Now that the server is up, you could start up a different shell and connect to its primary port with:

```
$ telnet 0 3301
```

but for example purposes it is simpler to just leave the server running in "interactive mode". On production machines the interactive mode is just for administrators, but because it's convenient for learning it will be used for most examples in this manual. Tarantool is waiting for the user to type instructions.

To create the first space and the first index, try this:

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

To insert three "tuples" (our name for "records") into the first "space" of the database try this:

```
tarantool> t = s:insert({1})
tarantool> t = s:insert({2, 'Music'})
tarantool> t = s:insert({3, 'Length', 93})
```

To select a tuple from the first space of the database, using the first defined key, try this:

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

Your terminal screen should now look like this:

```
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}
---
...
tarantool> t = s:insert{2, 'Music'}
---
...
tarantool> t = s:insert{3, 'Length', 93}
---
...
tarantool> s:select{3}
---
```

```
- - [3, 'Length', 93]
...
tarantool>
```

Now, to prepare for the example in the next section, try this:

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

4.2.3 Connecting remotely

In the previous section the first request was with box.cfg{listen = 3301}. The listen value can be any form of URI (uniform resource identifier); in this case it's just a local port: port 3301. It's possible to send requests to the listen URI via:

1. telnet,
2. a connector (which will be the subject of the "Connectors" chapter),
3. another instance of Tarantool via the console module,
4. tarantoolctl connect.

Let's try (4).

Switch to another terminal. On Linux, for example, this means starting another instance of a Bash shell. There is no need to use cd to switch to the ~/tarantool_sandbox directory.

Start the tarantoolctl utility:

$ tarantoolctl connect '3301'

This means "use tarantoolctl connect to connect to the Tarantool server that's listening on localhost:3301".

Try this request:

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

This means "send a request to that Tarantool server, and display the result". The result in this case is one of the tuples that was inserted earlier. Your terminal screen should now look like this:

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

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

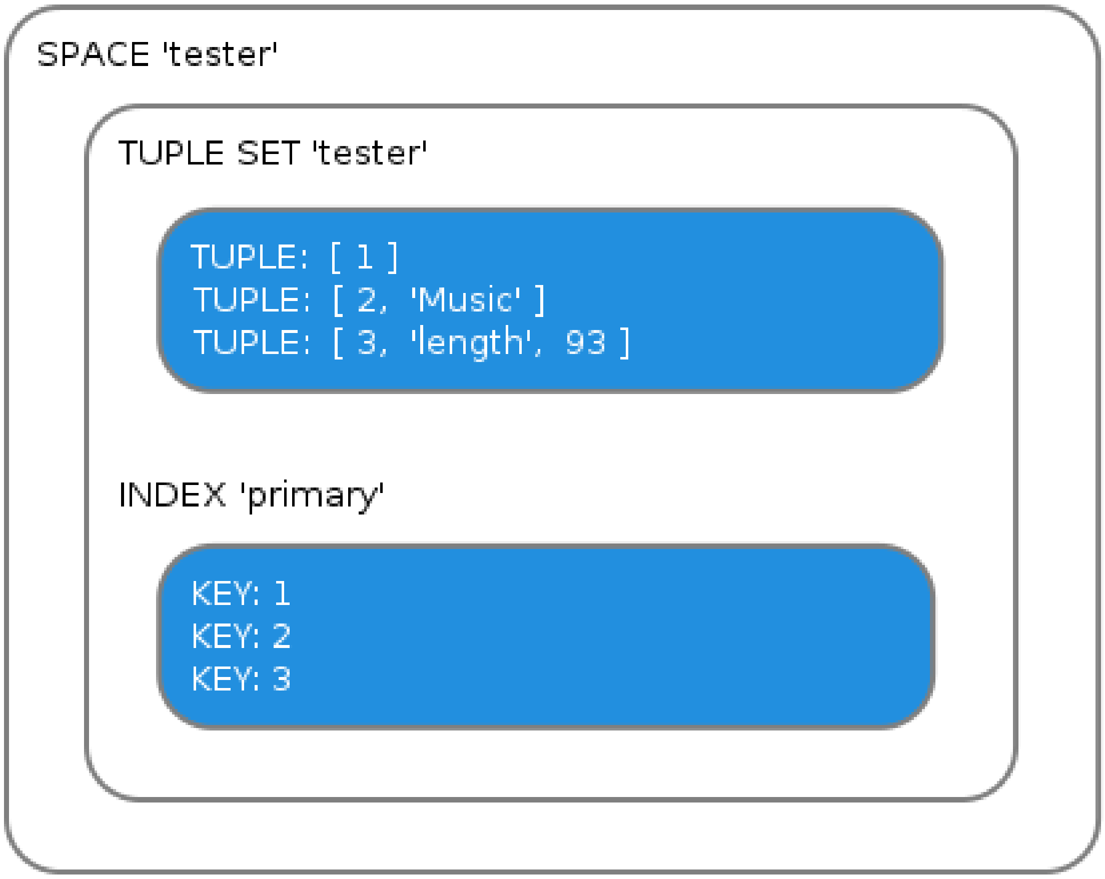
To review... If you followed all the instructions in this chapter, then so far you have: installed Tarantool from a binary repository, started up the Tarantool server, inserted and selected tuples.

4.3 Database

4.3.1 Data model

This section describes how Tarantool stores values and what operations with data it supports.

If you tried out the Starting Tarantool and making your first database exercise from the last chapter, then your database looks like this:



Here follow the descriptions of basic concepts.

Space

A space – 'tester' in the example – is a container.

When Tarantool is being used to store data, there is always at least one space. There can be many spaces. Each space has a unique name specified by the user. Each space has a unique numeric identifier which can be specified by the user but usually is assigned automatically by Tarantool. Spaces always contain one tuple set and one or more indexes.

Tuple set

A tuple set – 'tester' in the example – is a group of tuples.

There is always one tuple set in a space. The identifier of a tuple set is the same as the space name – 'tester' in the example.

A tuple fills the same role as a "row" or a "record", and the components of a tuple (which we call "fields") fill the same role as a "row column" or "record field", except that: the fields of a tuple can be composite structures, such as arrays or maps and don't need to have names. That's why there was no need to pre-define the tuple set when creating the space, and that's why each tuple can have a different number of elements. Tuples are stored as MsgPack arrays.

Any given tuple may have any number of fields and the fields may have a variety of types. The identifier of a field is the field's number, base 1. For example "1" can be used in some contexts to refer to the first field of a tuple.

When Tarantool returns a tuple value, it surrounds strings with single quotes, separates fields with commas, and encloses the tuple inside square brackets. For example: [3, `'length'`, 93].

Index

An index – 'primary' in the example – is a group of key values and pointers.

In order for a tuple set to be useful, there must always be at least one index in a space. There can be many indexes. As with spaces, the user can and should specify the index name, and let Tarantool come up with a unique numeric identifier (the "index id"). In our example there is one index and its name is "primary".

An index may be multi-part, that is, the user can declare that an index key value is taken from two or more fields in the tuple, in any order. An index may be unique, that is, the user can declare that it would be illegal to have the same key value twice. An index may have one of four types: HASH which is fast and is best for exact-equality searches with unique keys, TREE which allows partial-key searching and ordered results, BITSET which can be good for searches that contain '=' and multiple ANDed conditions, and RTREE for spatial coordinates. The first index is called the "primary key" index and it must be unique; all other indexes are called "secondary" indexes.

An index definition may include identifiers of tuple fields and their expected types. The allowed types for indexed fields are:

- unsigned (unsigned integer between 0 and 18,446,744,073,709,551,615)
- integer (signed integer between -9,223,372,036,854,775,808 and 9,223,372,036,854,775,807)
- number (unsigned integer or signed integer or floating-point value)
- string (string, any sequence of octets)
- scalar (boolean or number or string)
- array (a series of numbers for use with RTREE indexes)

Take our example, which has the request:

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

The effect is that, for all tuples in tester, field number 1 must exist and must contain an unsigned integer.

Space definitions and index definitions are stored permanently in system spaces. It is possible to add, drop, or alter the definitions at runtime, with some restrictions. See syntax details for defining spaces and indexes in reference on Tarantool's "box" module.

Data types

Tarantool can work with numbers, strings, booleans, tables, and userdata.

General type	Specific type	What Lua type() would return	Example
scalar	number	"number"	12345
scalar	string	"string"	'A B C'
scalar	boolean	"boolean"	true
scalar	nil	"nil"	nil
compound	Lua table	"table"	table: 0x410f8b10
compound	tuple	"Userdata"	12345: {'A B C'}

In Lua, a number is double-precision floating-point, but Tarantool allows both integer and floating-point values. Tarantool will try to store a 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 will be treated 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').

For database storage, Tarantool uses MsgPack rules. Storage is variable-length, so the smallest number requires only one byte but the largest number requires nine bytes. When a field has an 'unsigned' index, all values must be unsigned integers between 0 and 18,446,744,073,709,551,615.

A string is a variable-length sequence of bytes, usually represented with alphanumeric characters inside single quotes.

A boolean is either true or false.

A nil type has only one possible value, also called nil, but often displayed as null. 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 yaml.NULL or json.NULL or msgpack.NULL.

A tuple is returned in YAML format like - [120, 'a', 'b', 'c']. A few functions may return tables with multiple tuples. A scalar may be converted to a tuple with only one field. A Lua table may contain all of a tuple's fields, but not nil.

Some of the data types may be used in indexed fields.

For more tuple examples see box.tuple.

Operations

The basic operations are: the five data-change operations (insert, update, upsert, delete, replace), and the data-retrieval operation (select). There are also minor operations like "ping" which can only be used with the binary protocol. Also, there are index iterator operations, which can only be used with Lua code. (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.)

Six examples of basic operations:

```
-- Add a new tuple to tuple set tester.
-- The first field, field[1], will be 999 (type is unsigned).
-- The second field, field[2], will be 'Taranto' (type is string).
tarantool> box.space.tester:insert{999, 'Taranto'}
```

```
-- 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 the primary 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 the tuple, changing field field[2] again.
-- The syntax of upsert is similar to the syntax of update,
-- but the return value will be different.
tarantool> box.space.tester:upsert({999}, {{'=', 2, 'Tarantism'}})

-- 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'}

-- 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 the tuple.
-- Once again the clause to identify the primary-key field is mandatory.
tarantool> box.space.tester:delete{999}
```

How does Tarantool do a basic operation? Let’s take this example:

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

which, for those who know SQL, is equivalent to a statement like

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

1. If this is happening on a remote client, then the client parses the statement and changes it to a binary-protocol instruction which has already been checked, and which the server can understand without needing to parse everything again. The client ships a packet to the server.
2. The server’s “transaction processor” thread uses the primary-key index on field[1] to find the location of the tuple in memory. 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.

At this point, a yield takes place. To know the significance of that – and it’s quite significant – you have to know a few facts and a few new words.

FACT 1:

There is only one transaction processor thread. 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.

FACT 2:

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.

FACT 3:

Yields must happen, otherwise the transaction processor thread would stick permanently on the same fiber. There are 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. And there are explicit yields: in a Lua function one can and should add "yield" statements to prevent hogging. This is called cooperative multitasking.

Since all data-change operations end with an implicit yield and an implicit commit, and since no data-change operation can change more than one tuple, there is no need for any locking. Consider, for example, a Lua function that does three Tarantool operations:

```
s:select{999}             -- this does not yield and does not commit
s:update({...},{{...}})   -- this yields and commits
s:select{999}             -- this does not yield and does not commit
```

The combination "SELECT plus UPDATE" is an atomic transaction: the function holds a consistent view of the database until the UPDATE ends. For the combination "UPDATE plus SELECT" the view is not consistent, because after the UPDATE the transaction processor thread can switch to another fiber, and delete the tuple that was just updated.

Note re storage engine: vinyl handles yields differently, see differences between memtx and vinyl.

Note: Note re multi-request transactions

There is a way to delay yields. Read about execution atomicity in section Transaction control.

Since locks don't exist, and disk writes only involve the write-ahead log, transactions are usually fast. Also the Tarantool server may not be using up all the threads of a powerful multi-core processor, so advanced users may be able to start a second Tarantool server on the same processor without ill effects.

Additional examples of requests can be found in the Tarantool regression test suite (https://github.com/tarantool/tarantool/tree/1.7/test/box). A complete grammar of supported data-manipulation functions will come later in this chapter.

Since not all Tarantool operations can be expressed with the data-manipulation functions, or with Lua, to gain complete access to data manipulation functionality one must use a Perl, PHP, Python or other programming language connector. The client/server protocol is open and documented. See this annotated BNF.

Persistence

Tarantool maintains a set of write-ahead log (WAL) files. There is a separate thread – the WAL writer – which catches all requests that can change a database, such as box.schema.create or box.space.insert. Ordinarily the WAL writer writes the request, along with administrative fields and flags, to a WAL file immediately. This ensures data persistence, because, even if an in-memory database is lost when the power goes off, Tarantool recovers it automatically when it starts up again, by reading the WAL files and redoing the requests (this is called the "recovery process"). Users can change the timing of the WAL writer, or turn it off, by setting wal_mode.

Tarantool also maintains a set of snapshot files. A snapshot file is 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 snapshot and then read only the WAL files that were produced after the snapshot was made. A snapshot can be made even if there is no WAL file. Some snapshots are automatic, or users can make them at any time with the box.snapshot() request.

Details about the WAL writer and the recovery process are in the Internals section.

Data manipulation

The basic data-manipulation requests are: insert, replace, update, upsert, delete, select. All of them are part of the box library. Most of them may return data. Usually both inputs and outputs are Lua tables.

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 the examples there is an assumption that the numeric id of 'tester' is 512, which happens to be the case in our sandbox example only.

First, there are five 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 replace name with a numeric id in square brackets
tarantool> box.space[512]:select{1}
-- #4 use a variable instead of a literal for the name
tarantool> variable = 'tester'
tarantool> box.space[variable]:select{1}
-- #5 use a variable for the entire object reference
tarantool> s = box.space.tester
tarantool> s:select{1}
```

Later examples in this manual will usually have the "box.space.tester:" form (#1); however, this is a matter of user preference and all the variations exist in the wild.

Later descriptions in this manual will use the syntax "space_object:" for references to objects which are spaces as in the above examples, 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)
```

The primary-key value is enclosed in braces, and if it was a multi-part primary key then the value would be multi-part, for example ...select{1,2,3}. The braces can be enclosed inside parentheses — ...select({...}) — which are optional unless it is necessary to pass something besides the primary-key value, as in example #5. 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.

All the data-manipulation functions operate on tuple sets but, since primary keys are unique, the number of tuples in the tuple set is always 0 or 1. The only exception is box.space...select, which may accept either a primary-key value or a secondary-key value.

Complexity factors that may affect data-manipulation functions

Index size	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 use, but the number of low-level steps tends to remain constant.
Index type	Typically a HASH index is faster than a TREE index if the number of tuples in the tuple set is greater than one.
Number of indexes accessed	Ordinarily only one index is accessed to retrieve one tuple. But to update the tuple, there must be N accesses if the tuple set has N different indexes.
Number of tuples accessed	A few requests, for example select, can retrieve multiple tuples. This factor is usually less important than the others.
WAL settings	The important setting for the write-ahead log is wal_mode. If the setting causes no writing or delayed writing, this factor is unimportant. If the setting causes every data-change request to wait for writing to finish on a slow device, this factor is more important than all the others.

In the discussion of each data-manipulation function, there will be a note about which complexity factors might affect the function's resource usage.

Index operations

Index operations are automatic: if a data-manipulation request changes a tuple, then it also changes the index keys defined for the tuple. Therefore the user only needs to know how and why to define.

The simple index-creation operation which has been illustrated before is

box.space.space-name:create_index('index-name')

By default, this creates a unique "tree" index on the first field of all tuples (often called "Field#1"), which is assumed to be numeric.

These variations exist:

1. An indexed field may be a string rather than a number.

   box.space.space-name:create_index('index-name', {parts = {1, 'string'}})

   For an ordinary index, the most common data types are 'unsigned' = any non-negative integer, or 'string' = any series of bytes. Numbers are ordered according to their point on the number line – so 2345 is greater than 500 – while strings are ordered according to the encoding of the first byte then the encoding of the second byte then the encoding of the third byte and so on – so '2345' is less than '500'.

   For details about other index types see create_index.

2. There may be more than one field.

   ```
   box.space.space-name:create_index('index-name', {
       parts = {3, 'unsigned', 2, 'string'}
   })
   ```

   For an ordinary index, the maximum number of parts is 255. The specification of each part consists of a field number and a type.

3. The index does not have to be unique.

   box.space.*space-name*:create_index('index-name', { unique = false })

   The first index of a tuple set must be unique, but other indexes ("secondary" indexes) may be non-unique.

4. The index does not have to be a tree.

   box.space.*space-name*:create_index('index-name', { type = 'hash' })

   The two ordinary index types are 'tree' which is the default, and 'hash' which must be unique and which may be faster. The third type is 'bitset' which is not unique and which works best for combinations of binary values. The fourth type is 'rtree' which is not unique and which works with arrays, instead of 'string' or 'unsigned' values.

The existence of indexes does not affect the syntax of data-change requests, but does cause select requests to have more variety.

The simple select request which has been illustrated before is:

box.space.space-name:select(value)

By default, 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.

These variations exist:

1. The search can use comparisons other than equality.

   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'.

   This type of search may return more than one tuple; if so, the tuples will be in descending order by key when the comparison operator is LT or LE or REQ, otherwise in ascending order.

2. The search can use a secondary index.

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

   For a primary-key search, it is optional to specify an index name. For a secondary-key search, it is mandatory.

3. The search may be for some or all key parts.

   ```
   -- 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, '']
   ...
   ```

   The search can be for all fields, using a table for the value:

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

   or the search can be for one field, using a table or a scalar:

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

   in the second case, the result will be two tuples: {1, 'A'} and {1, 'B'}. It's even possible to specify zero fields, causing all three tuples to be returned.

Examples:

- BITSET example:

```
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'})
```

  The result will be:

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

  because (7 AND 2) is not equal to 0, and (3 AND 2) is not equal to 0.

  Searches on BITSET indexes can be for BITS_ANY_SET, BITS_ALL_SET, BITS_ALL_NOT_SET, EQ, or ALL.

- RTREE example:

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

The result will be:

```
---
- - [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.

Searches on RTREE indexes can be for GT, GE, LT, LE, OVERLAPS, or NEIGHBOR.

4.3.2 Transaction control

In several places in this manual, it's been noted that Lua processes occur in fibers on a single thread. That is why there can be a guarantee of execution atomicity. That requires emphasis.

Cooperative multitasking environment

Tarantool uses cooperative multitasking: 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": an explicit yield() request, or an implicit yield due to an operating-system call. 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. For the default memtx storage engine some of the box calls, including the data-change requests box.space...insert or box.space...update or box.space...delete, will usually cause yielding; however, box.space...select will not. A fuller description will appear in section Implicit yields.

Note re storage engine: vinyl has different rules: insert or update or delete will very rarely cause a yield, but select can cause a yield.

In the absence of transactions, any function that contains yield points may see changes in the database state caused by fibers that preempt. Then the only safe atomic functions for memtx databases would be functions which contain only one database request, or functions which contain a select request followed by a data-change request.

At this point an objection could arise: "It's good that a single data-change request will commit and yield, but surely there are times when multiple data-change requests must happen without yielding." The standard example is the money-transfer, where $1 is withdrawn from account #1 and deposited into account #2. If something interrupted after the withdrawal, then the institution would be out of balance. For such cases, the begin ... commit|rollback block was designed.

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.yield or fiber.sleep, will have the same effect.

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.

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.

Example

Assuming that in tuple set 'tester' there are tuples in which the third field represents a positive dollar amount ... 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"
...
```

Implicit yields

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

The implicit yield requests are: insert replace update upsert delete (the "data-change" requests), and functions in module fio, net_box, console, or socket (the "os" and "network" requests).

Note re storage engine: vinyl causes select to be an implicit yield request, but data-change requests may not be.

The yield occurs just before a blocking syscall, such as a write to the Write-Ahead Log (WAL) or a network message reception.

Implicit yield requests are disabled by box.begin, and enabled again by commit. Therefore the sequence

```
begin
implicit yield request #1
implicit yield request #2
implicit yield request #3
commit
```

will not cause implicit yield until the commit occurs (specifically: just before the writes to the WAL, which are delayed until commit time). The commit request is not itself an implicit yield request, it only enables yields caused by earlier implicit yield requests.

Despite their resemblance to implicit yield requests, truncate and drop do not cause implicit yield. Despite their resemblance to functions of the fio module, functions of the standard Lua module os do not cause implicit yield. Despite its resemblance to commit, rollback does not enable yields.

If wal_mode = 'none', then implicit yielding is disabled, 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 if it is inside a function or Lua program being executed on the server, but causes yielding 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.

4.3.3 Access control

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

Briefly: there is a method to guarantee with password checks that users really are who they say they are ("authentication"). There is a _user space where user names and password-hashes are stored. There are functions for saying that certain users are allowed to do certain things ("privileges"). There is a _priv 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").

Passwords

Each user may have a password. The password is any alphanumeric string. Administrators should advise users to choose long unobvious passwords, but it is ultimately up to the users to choose or change their own passwords.

Tarantool passwords are stored in the _user space with a Cryptographic hash function so that, if the password is 'x', the stored hashed-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. 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.

Note: To get the hash-password of a string 'X', say box.schema.user.password('X'). To see more about the details of the algorithm for the purpose of writing a new client application, read the scramble.h header file.

Users and the _user space

The fields in the _user space are:

- the numeric id of the tuple
- the numeric id of the tuple's creator
- the user name
- the type
- optional password

There are four special tuples in the _user space: 'guest', 'admin', 'public', and 'replication'.

Name	ID	Type	Description
guest	0	user	Default when connecting remotely. Usually an untrusted user with few privileges.
admin	1	user	Default when using tarantool as a console. Usually an administrative user with all privileges.
public	2	role	Not a user in the usual sense. Described later in section Roles.
replication	3	role	Not a user in the usual sense. Described later in section Roles.

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']
...
```

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, say:

```
box.schema.user.create(user-name)
box.schema.user.create(user-name, {if_not_exists = true})
box.schema.user.create(user-name, {password = password}).
```

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.

To change the user's password, say:

```
-- To change the current user's password
box.schema.user.passwd(password)

-- To change a different user's password
```

box.schema.user.passwd(user-name, password)

(Usually it is only the admin user who can change a different user's password.)

To drop a user, say:

box.schema.user.drop(user-name).

To check whether a user exists, say:

box.schema.user.exists(user-name)

which returns true or false.

To find what privileges a user has, say:

box.schema.user.info(user-name)

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')
---
...
```

Note: The maximum number of users is 32.

Privileges and the _priv space

The fields in the _priv space are:

- 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" or "function" or "universe",
- the numeric id of the object,
- the type of operation - "read" = 1, or "write" = 2, or "execute" = 4, or a combination such as "read,write,execute".

The function for granting a privilege is:

box.schema.user.grant(grantee, operation, object-type, object-name*[, *options])
-- OR
box.schema.user.grant(grantee, operation, 'universe' [, nil, options])

where 'universe' means 'all objects', and the optional grant-option can be:

- grantor=grantor_name_or_id - string or number, for custom grantor
- if_not_exists=true|false - bool, do not throw error if user already has the privilege

The function for revoking a privilege is:

box.schema.user.revoke(grantee, operation, object-type, object-name*[, *options])
box.schema.user.revoke(grantee, operation, 'universe'[, nil, options])

where 'universe' means 'all objects', and the optional grant-option can be:

- if_not_exists=true|false - bool, do not throw error if user already lacks the privilege

For example, here is a session where the admin user gave the guest user the privilege to read from a space named space55, and then took the privilege away:

```
tarantool> box.schema.user.grant('guest', 'read', 'space', 'space55')
---
...
tarantool> box.schema.user.revoke('guest', 'read', 'space', 'space55')
---
...
```

Note: 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, steps should be taken to ensure that all their associated privileges have been revoked.

Note: Only the 'admin' user can grant privileges for the 'universe'.

Note: Only the creator of a space can drop, alter, or truncate the space. Only the creator of a user can change a different user's password.

Functions and the _func space

The fields in the _func space are:

- the numeric function id, a number,
- the function name
- flag
- possibly a language name.

The _func space does not include the function's body. One continues 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.

The function for creating a _func tuple is:

box.schema.func.create(function-name [, options])

The possible options are:

- if_not_exists = true|false - default = false,
- setuid = true|false - default = false,
- language = 'LUA'|'C' - default = 'LUA'.

Example:

```
box.schema.func.create('f', {language = 'C', setuid = false})
```

Specifying if_not_exists=false would cause error: Function '...' already exists if the _func tuple already exists.

Specifying setuid=true would cause the setuid flag (the fourth field in the _func tuple) to have a value meaning "true", and the effect of that is that the function's caller is treated as the function's creator, with full privileges. The setuid behavior does not apply for users who connect via console.connect.

Specifying language='C' would cause the language field (the fifth field in the _func tuple) to have a value 'C', which means the function was written in C. Tarantool functions are normally written in Lua but can be written in C as well.

The function for dropping a _func tuple is:

box.schema.func.drop(function-name)

The function for checking whether a _func tuple exists is:

box.schema.func.exists(function-name)

In the following example, a function named 'f7' is created, then it is put in the _func space, then it is used in a box.schema.user.grant function, then it is dropped:

```
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')
---
...
tarantool> box.schema.func.drop('f7')
---
...
```

box.session and security

After a connection has taken place, the user has access to a "session" object which has several functions. The ones which are of interest for security purposes are:

```
box.session.uid()          -- returns the id of the current user
box.session.user()         -- returns the name of the current user
box.session.su(user-name) -- allows changing current user to 'user-name'
```

If a user types requests directly on the Tarantool server in its interactive mode, or if a user connects to the admin port, then the user by default is 'admin' and has many privileges. If a user connects from an application program via one of the connectors, then the user by default is 'guest' and has few privileges. Typically an admin user will set up and configure objects, then grant privileges to appropriate non-admin users. Typically a guest user will use box.session.su() to change into a non-generic user to whom admin has granted more than the default privileges. For example, admin might say:

```
box.space._user:insert{123456,0,'manager','user'}
box.schema.user.grant('manager', 'read', 'space', '_space')
box.schema.user.grant('manager', 'read', 'space', 'payroll')
```

and later a guest user, who wishes to see the payroll, might say:

```
box.session.su('manager')
box.space.payroll:select{'Jones'}
```

Roles

A role is a container for privileges which can be granted to regular users. Instead of granting and revoking individual privileges, one can put all the privileges in a role and then grant or revoke the role. Role information is in the _user space but the third field - the type field - is 'role' rather than 'user'.

If a role R1 is granted a privilege X, and user U1 is granted a privilege "role R1", then user U1 in effect has privilege X. Then if a role R2 is granted a privilege Y, and role R1 is granted a privilege "role R2", then user U1 in effect has both privilege X and privilege Y. In other words, a user gets all the privileges that are granted to a user's roles, directly or indirectly.

box.schema.role.create(role-name[, {if_not_exists=true}])
    Create a new role.

box.schema.role.grant(role-name, privilege)
    Put a privilege in a role.

box.schema.role.revoke(role-name, privilege)
    Take a privilege out of a role.

box.schema.role.drop(role-name)
    Drop a role.

box.schema.role.grant(role-name, 'execute', 'role', role-name)
    Grant a role to a role.

box.schema.role.revoke(role-name, 'execute', 'role', role-name)
    Revoke a role from a role.

box.schema.role.exists(role-name)
    Check whether a role exists. Returns (type = boolean) true if role-name identifies a role, otherwise false.

box.schema.user.grant(user-name, 'execute', 'role', role-name)
    Grant a role to a user.

box.schema.user.revoke(user-name, 'execute', 'role', role-name)
    Revoke a role from a user.

There are two predefined roles. The first predefined role, named 'public', is 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: box.schema.role.grant('public','read','space','t'). The second predefined role, named 'replication', can be assigned by the 'admin' user to users who need to use replication features.

Example showing a role within a role

In this example, a new user named U1 will insert a new tuple into a new space named T, and will succeed even though user U1 has no direct privilege to do such an insert – that privilege is inherited from role R1, which in turn inherits from role R2.

```
-- This example will work for a user with many privileges, such as 'admin'
box.schema.space.create('T')
box.space.T:create_index('primary', {})
-- Create a user U1 so that later it's possible to say box.session.su('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 U1 (order doesn't matter)
box.schema.role.grant('R1', 'execute', 'role', 'R2')
box.schema.user.grant('U1', 'execute', 'role', 'R1')
-- Grant read and execute privileges to R2 (but not to R1 and not to U1)
box.schema.role.grant('R2', 'read,write', 'space', 'T')
box.schema.role.grant('R2', 'execute', 'universe')
-- Use box.session.su to say "now become user U1"
box.session.su('U1')
-- Next insert succeeds because U1 in effect has write privilege on T
box.space.T:insert{1}
```

4.3.4 Triggers

Triggers, also known as callbacks, are functions which the server executes when certain events happen. Currently the main types of triggers are connection triggers, which are executed when a session begins or ends, and replace triggers, which are for database events.

All triggers have the following characteristics:

- They associate a function with an event. The request to "define a trigger" consists of passing the name of the trigger's function to one of the "on_event-name()" functions: on_connect(), on_auth(), on_disconnect(), or on_replace().
- They are defined by any user. There are no privilege requirements for defining triggers.
- They are called after the event. They are not called if the event ends prematurely due to an error. (Exception: on_auth() is called before the event.)
- They are in server memory. They are not stored in the database. Triggers disappear when the server is shut down. If there is a requirement to make them permanent, then the function definitions and trigger settings should be part of an initialization script.
- They 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.
- They can be multiple for one event. Triggers are executed in the reverse order that they were defined in.
- They must work within the event context. If the function contains requests which normally could not occur immediately after the event but before the return from the event, effects are undefined. For example, putting os.exit() or box.rollback() in a trigger function would be bringing in requests outside the event context.

- They are replaceable. The request to "redefine a trigger" consists of passing the names of a new trigger function and an old trigger function to one of the "on event-name . . . " functions.

Connection triggers

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.

Parameters

- 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)
```

Warning: 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.

Parameters

- 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_disconnect(f)
```

Example

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
```

Authentication triggers

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.

Parameters

- 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)
```

Replace triggers

object space_object

space_object:on_replace(trigger-function[, old-trigger-function-name])
Create a "replace trigger". The function-name will be executed whenever a replace() or insert() or update() or upsert() or delete() happens to a tuple in <space-name>.

Parameters

- 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.space.X:on_replace(f)
```

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:

```
tarantool> box.space.X:run_triggers(false)
```

Example

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
```

Another example

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)
```

Getting 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.

In the following example, we find that there are three functions associated with on_connect triggers, and execute the third function, which happens to contain the line "print('function #3')". Then we delete the third trigger.

```
tarantool> box.session.on_connect()
---
- - 'function: 0x416ab6f8'
  - 'function: 0x416ab6f8'
  - 'function: 0x416ad800'
...

tarantool> box.session.on_connect()[3]()
function #3
---
...
tarantool> box.session.on_connect(nil, box.session.on_connect()[3])
---
...
```

4.3.5 Limitations

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. 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 2147483647 (box.schema.FIELD_MAX). The practical maximum is whatever is specified by the space's field_count member, or the maximum tuple length.

Number of bytes in a tuple

By default the value of slab_alloc_maximal is 1048576, and the maximum tuple length is approximately one quarter of that: approximately 262,000 bytes. To increase it, when starting the server, specify a larger value. For example box.cfg{slab_alloc_maximal=2*1048576}.

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 2147483647 (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).

For additional limitations which apply only to the vinyl storage engine, see section Differences between memtx and vinyl.

4.3.6 Vinyl storage engine

A storage engine is a set of very-low-level routines which actually store and retrieve tuple values. Tarantool offers a choice of two storage engines:

- memtx (the in-memory storage engine) is the default and was the first to arrive.
- vinyl (the on-disk storage engine) is a working key-value engine and will especially appeal to users who like to see data go directly to disk, so that recovery time might be shorter and database size might be larger. On the other hand, vinyl lacks some functions and options that are available with memtx. Where that is the case, the relevant description in this manual will contain a note beginning with the words "Note re storage engine". See also a coverage for all the differences between memtx and vinyl further on this page.

To specify that the engine should be vinyl, add the clause engine = `'vinyl'` when creating a space, for example: space = box.schema.space.create(`'name'`, {engine=`'vinyl'`}).

Differences between memtx and vinyl storage engines

The primary difference between memtx and vinyl is that memtx is an "in-memory" engine while vinyl is an "on-disk" engine. An in-memory storage engine is generally faster, and the memtx engine is justifiably the default for Tarantool, but there are two situations where an on-disk engine such as vinyl would be preferable:

1. when the database is larger than the available memory and adding more memory is not a realistic option;
2. when the server frequently goes down due to errors or a simple desire to save power – bringing the server back up and restoring a memtx database into memory takes time.

Here are behavior differences which affect programmers. All of these differences have been noted elsewhere in sentences that begin with the words "Note re storage engine: vinyl".

- With memtx, the index type can be TREE or HASH or RTREE or BITSET. |br| With vinyl, the only index type is TREE.
- With memtx, create_index can be done at any time. |br| With vinyl, secondary indexes must be created before tuples are inserted.
- With memtx, for index searches, nil is considered to be equal to any scalar. |br| With vinyl, nil or missing parts are not allowed.
- With memtx, temporary spaces are supported. |br| With vinyl, they are not.
- With memtx, the alter() and len() and random() and auto_increment() and truncate() functions are supported. |br| With vinyl, they are not.
- With memtx, the count() function takes a constant amount of time. |br| With vinyl, it takes a variable amount of time depending on index size.
- With memtx, delete will return deleted tuple, if any. |br| With vinyl, delete will always return nil.

It was explained earlier that memtx does not "yield" on a select request, it yields only on data-change requests. However, vinyl does yield on a select request, or on an equivalent such as get() or pairs(). This has significance for cooperative multitasking.

Vinyl features

- Full ACID compliance
- Multi-Version Concurrency Control (MVCC)
- Pure Append-Only
- Multi-threaded (Client access and Engine scalability)
- Multi-databases support (Single environment and WAL)
- Multi-Statement and Single-Statement Transactions (Snapshot Isolation (SI), multi-databases)
- Asynchronous or synchronous transaction execution (Callback triggered versus blocking)
- Separate storage formats: key-value (Default), or document (Keys are part of value)
- Update without read
- Consistent Cursors

- Prefix search
- Point-in-Time Snapshots
- Versional database creation and asynchronous shutdown/drop
- Asynchronous Online/Hot Backup
- Compression (Per region, both lz4 and zstd are supported)
- Metadata Compression (By default)
- Key Compression (Compress key duplicates, including suffixes)
- Easy to use (Minimalist API)
- Easy to integrate (Native support of using as storage engine)
- Easy to write bindings (Very FFI-friendly, API designed to be stable in future)
- Easy to build in (Amalgamated, compiles into two C files)
- Event loop friendly
- Zero-Configuration (Tuned by default)
- Implemented as a small library written in C with zero dependencies
- BSD Licensed

It is appropriate for databases that cannot fit in memory, where access via secondary keys is not required.

In vinyl terminology:

- There is one Environment.
- An Environment has N Databases - a vinyl database is like a Tarantool space.
- A Database has N Ranges.
- A Range has one Range File.
- A Range File has N Runs.
- A Run has N Regions - a vinyl Region is like a B-tree page.
- A Region has keys and values - a vinyl key-value is like a Tarantool tuple.

A key and its associated value are together, so when one accesses a key one gets the whole tuple. In other words, in vinyl the data is stored in the index. There are up to two in-memory copies of an index, as well as the copy in the Range File.

For operations that insert or update tuples - called Set operations in vinyl - vinyl makes changes to in-memory copies of the index, and writes to Tarantool's Write-ahead Log. A scheduler assigns tasks to multiple background threads for transferring index data from memory to disk, and for reorganizing Runs. To support transactions, Set operations can be delayed until an explicit commit. If multiple users access the same tuples simultaneously, the concurrency control method is MVCC and the isolation level is Snapshot.

Formally, in terms of disk accesses, vinyl has the following algorithmic complexity:

- Set - the worst case is O(1) append-only key writes to the Write-Ahead Log + in-memory Range index searches + in-memory index inserts
- Delete - the worst case is O(1) key writes and in-memory index inserts (the same as Set)
- Get - the worst case is amortized O(max_run_count_per_node) random Region reads from a single Range file, which itself does in-memory index search + in-memory Region search

- Range - queries, the worst case of full Database scan is amortized O(total_Region_count) + in-memory key-index searches for each Range

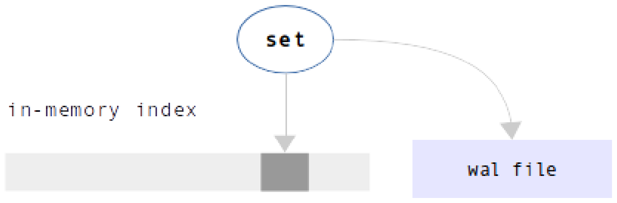
Under the hood

In this section, to illustrate internals, we will discuss this example:

1. filling an empty database with one million tuples (we'll call them "keys" to emphasize the indexed nature)
2. reading all stored tuples in the original order.

Inserting the first 200.000 keys

During the first 200,000 Set operations, inserted keys first go to the in-memory index. To maintain persistence, information about each Set operation is written to Tarantool's Write-ahead Log.

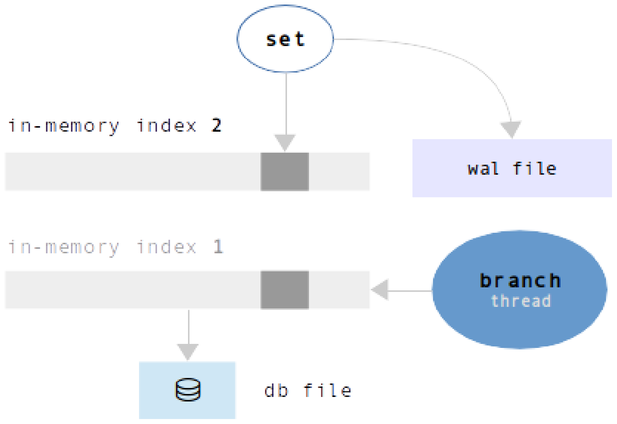


At this point, we have keys in an in-memory index and records in the Write-ahead Log.

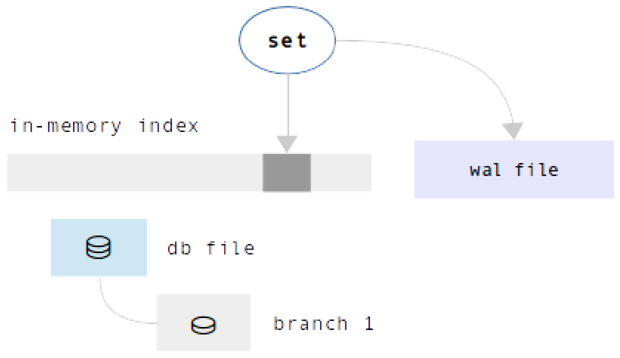
Inserting the next 300.000 keys

As the in-memory index becomes too large for available memory, the index must be copied from memory to disk. The on-disk copy of the in-memory index is called a Run. To save the Run, a new file is created, the Range File. We will call it db file for this example.

The scheduler wakes a worker thread in the background, a Run Creation Thread. The thread creates a second in-memory index. If there are Set operations taking place while the thread is working, their contention effect will be small because they will operate on the second in-memory index.

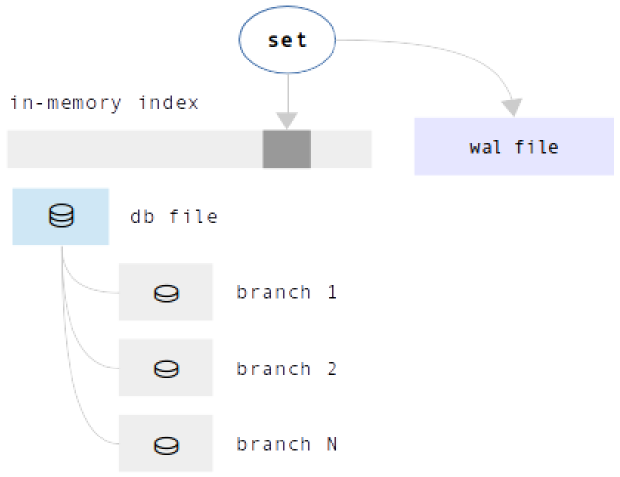


When the Run Creation Thread finishes the task, the first in-memory index is freed.

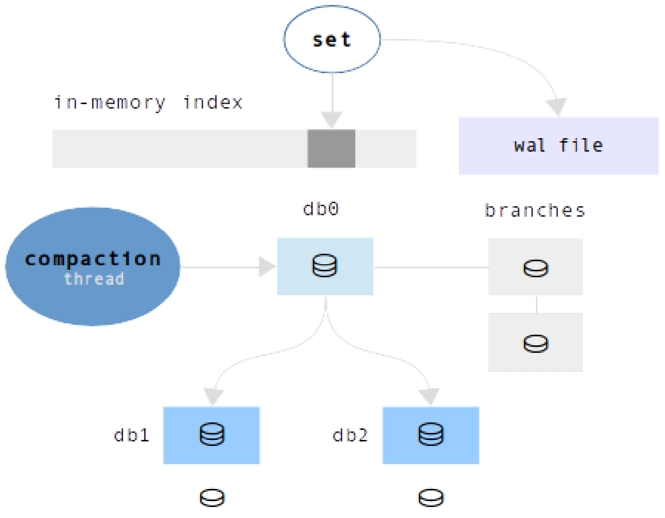


Inserting the next 200.000 keys

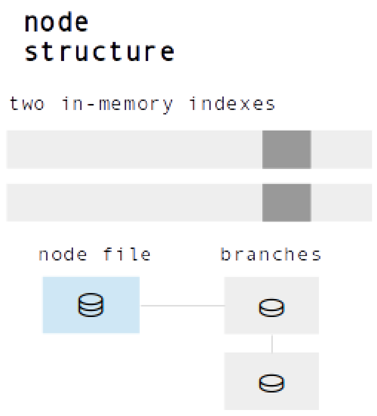
Several times, the in-memory index becomes too large and a Run Creation Thread transfers the keys to a Run. The Runs have been appended to the end of db file. The number of created Runs becomes large.



There is a user-settable maximum number of Runs per Range. When the number of Runs reaches this maximum, the vinyl scheduler wakes a Compaction Thread for the db file. The Compaction Thread merges the keys in all the Runs, and creates one or more new db files.



Now there are multiple pairs of in-memory indexes, and each pair has an associated db file. The combination of the in-memory indexes and the db file is called a Range, and the db file is called a Range File.



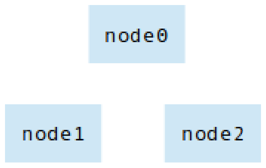
Thus the contents of a Range are: a range of sorted key values, stored in Runs of a Range File and (when necessary) in memory. Since the ranges do not overlap, each Range can be handled independently. Therefore, while one of the background threads is working on Range 1, another background thread can be working on Range 2, without contention. That means that all the background operations (Run Creation, Compaction, Garbage Collection, and Backup) can take place in parallel on multiple threads.

The foregoing explanation will now be repeated with different wording.

Before the Compaction there was one Range, which was created automatically when the Database was initialized. The Range had:

1. an in-memory index with some keys in it,
2. a Range File with several Runs,
3. a Write-Ahead Log file recording the Set operations, in the order they happened.

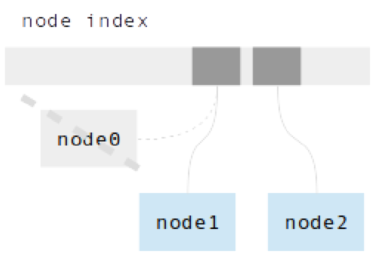
The number of Runs became too big, so the vinyl scheduler starts the Compaction Thread and creates two new Ranges.



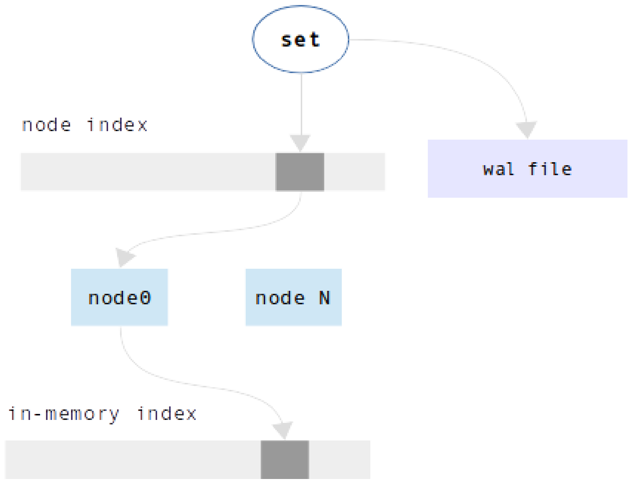
So, each of the two new Range Files contains half of the keys that were in the original Range. The Range's in-memory indexes are split in the same way.

After the splitting, vinyl must take into account that: while the Compaction was going on in the background, there might have been more Set operations taking place in parallel. These Set operations would have changed one of the in-memory indexes, and these changes too will be merged.

When the Compaction Thread finishes, the original Range is deleted, and information about the new Ranges is inserted into an in-memory Range Index.

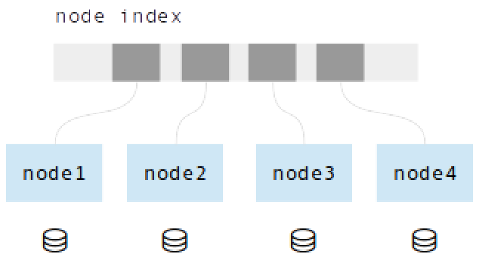


This Range Index is used for all Set operations and all searches. Since the Range Index has the minimum and maximum key values that are in each Range, it is straightforward to scan it to find what Range would contain a particular key value.



Inserting the last 300.000 keys

The final 300,000 Set operations take place; the background threads continue to create new Runs and do more Compactions. After the millionth insertion, the Database has four Ranges.



The inserting is done. Now, because the words "memory" and "disk" have appeared in this explanation several times, here are a few words about how vinyl is designed to use these resources most efficiently:

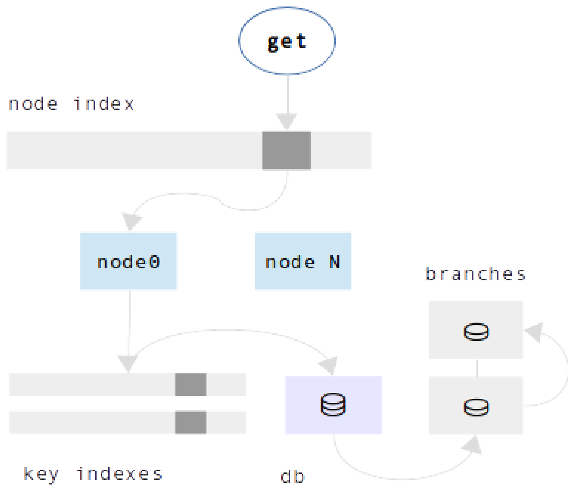
- If there is more memory available, then Run Creation and Compaction will be less frequent, and there will be fewer disk accesses.
- The best vinyl performance will occur if there is no setting of a memory limit, but this must be balanced against other considerations, such as requirements for the memtx storage engine. If there is a setting of a memory limit, the vinyl scheduler will give priority to the Ranges that have the largest in-memory indexes, so that the largest memory blocks are freed first.
- To make the most of hard drives and Flash, vinyl will delay operations that require disk access (except

the writing of the Write-ahead Log which is specially tunable), so that the accesses are done in large sequential blocks.

- Overwriting does not occur; vinyl is an "append-only" engine.

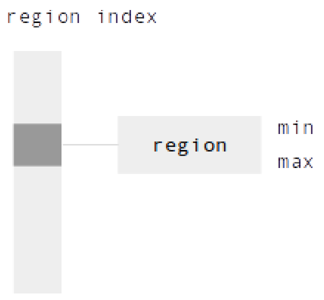
Reading million keys

We will now start to read the million rows in the order that they were inserted, which was random.

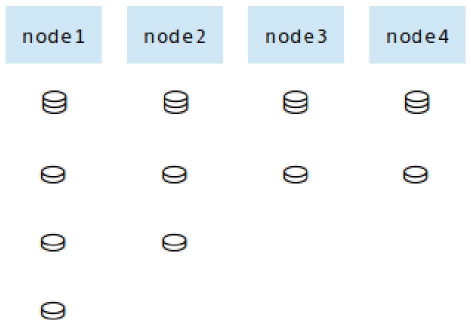


During the Get (search), vinyl first finds the correct Range by looking in the Range Index. Then it searches the Range's first in-memory index, and/or the Range's second in-memory index, and/or each Run of the Range, starting from the end of the Range File.

Remember that a Run is divided into Regions, which are like what would be called "pages" or "blocks" in a B-tree. For each Run, there is a list of the Regions and their minimum/maximum key values - the Region Index - as well as some metadata.



Region Indexes are loaded into memory when the Database is opened. Since the Database's Range Index and the Region Indexes are normally in-memory, searching and retrieving a tuple might require only zero or one disk accesses. However, when memory is limited and there are many Runs, search time may rise. For each additional Run there is a possible additional disk access during a search. Also, it is impossible to maintain memory limits without doing a Run Creation process, because new Set operations might occur more quickly than the Compaction process can run.



Vinyl is read optimized. It is very likely that the most recently created Runs (hot data) will be in the file system cache. The scheduler will give priority to the Ranges which have the largest in-memory indexes and the most Runs.

The scheduler may also try to arrange that a Range will have only one Run, which will ensure the average number of disk seeks for each search is O(1).

4.4 Application server

4.4.1 About modules/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.

4.4.2 Installing an existing module

Modules that come from Tarantool developers and community contributors are available at rocks.tarantool.org. Some of them – expirationd, mysql, postgresql, shard – are discussed elsewhere in this manual.

Step 1: Install LuaRocks. A general description of installing LuaRocks on a Unix system is given in the LuaRocks Quick Start Guide. For example, on Ubuntu you could say:

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

Step 2: Add the Tarantool repository to the list of rocks servers. This is done by putting rocks.tarantool.org in the .luarocks/config.lua file:

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

Once these steps are complete, you can:

- search the repositories with

  $ luarocks search module-name

- add new modules to the local repository with

  $ luarocks install module-name --local

- load any module for Tarantool with

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

... and that is why examples in this manual often begin with require requests.

See "tarantool/rocks" repository at GitHub for more examples and information about contributing.

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

4.4.3 Creating a new Lua module locally

As an example, let's create a new Lua file named mymodule.lua, containing a named function which will be exported. Then, in Tarantool: load, examine, and call.

The Lua file should look like this:

```lua
-- mymodule - a simple Tarantool module
local exports = {}
exports.myfun = function(input_string)
   print('Hello', input_string)
end
return exports
```

The requests to load, examine and call look like this:

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

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

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

4.4.4 Creating a new C/C++ module locally

As an example, let's create a new C file named mycmodule.c, containing a named function which will be exported. Then, in Tarantool: load, examine, and call.

Prerequisite: install tarantool-dev first.

The C file should look like this:

```c
/* mycmodule - a simple Tarantool module */
#include <lua.h>
#include <lauxlib.h>
#include <lualib.h>
#include <tarantool.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;
}
```

Use gcc to compile the code for a shared library (without a “lib” prefix), then use ls to examine it:

```
$ 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
```

Tarantool’s developers recommend using Tarantool’s CMake scripts which will handle some of the build steps automatically.

The requests to load, examine and call look like this:

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

You can also create modules with C++, provided that the code does not throw exceptions.

4.4.5 Creating a mixed Lua/C module locally

1. Create a Lua module and name it as you like, say myfunmodule.
2. Create a C module (submodule) and name it myfunmodule.internal or something like that.
3. Load the C module from your Lua code using require('myfunmodule.internal') and then wrap or use it.

For a sample of a mixed Lua/C module, see “tarantool/http” repository at GitHub.

4.4.6 Tips for special situations

- Lua caches all loaded modules in the package.loaded table. To reload a module from disk, set its key to nil:

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

- Use package.path to search for .lua modules, and use package.cpath to search for C binary modules.

  ```
  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
  ...
  ```

  Question-marks stand for the module name that was specified earlier when saying require('modulename').

- To see the internal state from within a Lua module, use state and create a local variable inside the scope of the file:

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

- Notice that Lua examples in this manual use local variables. Use global variables with caution, since the module's users may be unaware of them.

4.4.7 Cookbook recipes

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” |br| #!/usr/bin/env tarantool |br| 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 = {
    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)
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

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
        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 }
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>
```

4.5 Server administration

Typical server administration tasks include starting and stopping the server, reloading configuration, taking snapshots, log rotation.

4.5.1 Using tarantool as a client

If tarantool is started without an initialization file, or if the initialization file contains console.start(), then tarantool enters interactive mode. There will be a prompt ("tarantool>") and it will be possible to enter requests. When used this way, tarantool can be a client for a remote server.

This section shows all legal syntax for the tarantool program, with short notes and examples. Other client programs may have similar options and request syntaxes. Some of the information in this section is duplicated in the chapter Configuration reference.

Conventions used in this section

Tokens are character sequences which are treated as syntactic units within requests. Square brackets [and] enclose optional syntax. Three dots in a row ... mean the preceding tokens may be repeated. A vertical bar | means the preceding and following tokens are mutually exclusive alternatives.

Options when starting client from the command line

General form:

$ tarantool
OR
$ tarantool options
OR
$ tarantool lua-initialization-file [arguments]

Here lua-initialization-file can be any script containing code for initializing. Effect: The code in the file is executed during startup. Example: init.lua. |br| Notes: If a script is used, there will be no prompt. The script should contain configuration information including box.cfg...listen=... or box.listen(...) so that a separate program can connect to the server via one of the ports.

Option is one of the following (in alphabetical order by the long form of the option):

-?, -h, --help
: Client displays a help message including a list of options. Example: tarantool --help The program stops after displaying the help.

-V, --version
: Client displays version information. Example: tarantool --version. The program stops after displaying the version.

Tokens, requests, and special key combinations

Procedure identifiers are: Any sequence of letters, digits, or underscores which is legal according to the rules for Lua identifiers. Procedure identifiers are also called function names. |br| Note: function names are case sensitive so insert and Insert are not the same thing.

String literals are: Any sequence of zero or more characters enclosed in single quotes. Double quotes are legal but single quotes are preferred. Enclosing in double square brackets is good for multi-line strings as described in Lua documentation. |br| Examples: 'Hello, world', 'A', [[A\B!]].

Numeric literals are: Any sequence of one or more digits, not enclosed in quotes, optionally preceded by - (minus sign). Large or floating-point numeric literals may include decimal points, exponential notation, or suffixes.|br| Examples: 500, -500, 5e2, 500.1, 5LL, 5ULL.

Single-byte tokens are: , or (or) or arithmetic operators. |br| Examples: * , ( ).

Tokens must be separated from each other by one or more spaces, except that spaces are not necessary around single-byte tokens or string literals.

Requests

Generally requests are entered following the prompt in interactive mode while tarantool is running. (A prompt will be the word 'tarantool' and a greater-than sign, for example tarantool>). The end-of-request marker is by default a newline (line feed).

For multi-line requests, it is possible to change the end-of-request marker. Syntax: console = require('console'); console.delimiter(string-literal). The string-literal must be a value in single quotes. Effect: string becomes end-of-request delimiter, so newline alone is not treated as end of request. To go back to normal mode: console.delimiter('')string-literal. Delimiters are usually not necessary because Tarantool can tell when a multi-line request has not ended (for example, if it sees that a function declaration does not have an end keyword). Example:

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

See here a condensed Backus-Naur Form [BNF] description of the suggested form of client requests.

In interactive mode, one types requests and gets results. Typically the requests are typed in by the user following prompts. Here is an example of an interactive-mode Tarantool client session:

```
$ tarantool
[ tarantool will display an introductory message
  including version number here ]
tarantool> box.cfg{listen = 3301}
[ tarantool will display configuration information here ]
tarantool> s = box.schema.space.create('tester')
[ tarantool may display an in-progress message here ]
---
...
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
$
```

Explanatory notes about what Tarantool displayed in the above example:

- Many requests return typed objects. In the case of box.cfglisten=3301, this result is displayed on the screen. If the request had assigned the result to a variable, for example c = box.cfglisten=3301, then the result would not have been displayed on the screen.
- A display of an object always begins with "---" and ends with "...".
- The insert request returns an object of type = tuple, so the object display line begins with a single dash ('-'). However, the select request returns an object of type = table of tuples, so the object display line begins with two dashes ('- -').

4.5.2 Utility 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.

Configuration for tarantoolctl

The tarantoolctl script will look for a configuration file in the current directory ($PWD/.tarantoolctl). If that fails, it looks in the current user's home directory ($HOME/.config/tarantool/tarantool). If that fails, it looks in the SYSCONFDIR directory (usually /etc/sysconfig/tarantool, but it may be different on some platforms). Most of the settings are similar to the settings used by box.cfg...; however, tarantoolctl adjusts some of them by adding an application name. A copy of usr/local/etc/default/tarantool, with defaults for all settings, would look like this:

```
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"
```

The settings in the above script are:

pid_file The directory for the pid file and control-socket file. The script will add "/instance-name" to the directory name.

wal_dir The directory for the write-ahead *.xlog files. The script will add "/instance-name" to the directory-name.

snap_dir The directory for the snapshot *.snap files. The script will add "/instance-name" to the directory-name.

vinyl_dir The directory for the vinyl-storage-engine files. The script will add "/vinyl/instance-name" to the directory-name.

logger The place where the application log will go. The script will add "/instance-name.log" to the name.

username The user that runs the Tarantool server. This is the operating-system user name rather than the Tarantool-client user name.

instance_dir The directory where all applications for this host are stored. The user who writes an application for tarantoolctl must put the application's source code in this directory, or a symbolic link. For examples in this section the application name my_app will be used, and its source will have to be in instance_dir/my_app.lua.

Commands for tarantoolctl

The command format is tarantoolctl operation application_name, where operation is one of: start, stop, enter, logrotate, status, eval. Thus ...

start <application>
Start application <application>

stop <application>
Stop application

enter <application>
Show application's admin console

logrotate <application>
Rotate application's log files (make new, remove old)

status <application>
Check application's status

eval <application> <scriptname>
Execute code from <scriptname> on an instance of application

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

Typical code snippets for tarantoolctl

A user can check whether my_app is running with these lines:

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

A user can initiate, for boot time, an init.d set of instructions:

```
for (each file mentioned in the instance_dir directory):
    tarantoolctl start `basename $ file .lua`
```

A user can set up a further configuration file for log rotation, like this:

```
/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
}
```

A detailed example for tarantoolctl

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

The assumptions are: the root password is known, the computer is only being used for tests, the Tarantool server is ready to run but is not currently running, tarantoolctl is installed along the user's path, and there currently is no directory named tarantool_test.

Create a directory named /tarantool_test:

```
$ sudo mkdir /tarantool_test
```

Edit /usr/local/etc/default/tarantool. It might be necessary to say sudo mkdir /usr/local/etc/default first. Let the new file contents be:

```
default_cfg = {
    pid_file = "/tarantool_test/my_app.pid",
    wal_dir = "/tarantool_test",
    snap_dir = "/tarantool_test",
    vinyl_dir = "/tarantool_test",
    logger = "/tarantool_test/log",
    username = "tarantool",
}
instance_dir = "/tarantool_test"
```

Make the my_app application file, that is, /tarantool_test/my_app.lua. Let the file contents be:

```
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
```

Tell tarantoolctl to start the application ...

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

... expect to see messages indicating that the instance has started. Then ...

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

... expect to see the .snap file and the .xlog file. Then ...

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

... expect to see the contents of my_app's log, including error messages, if any. Then ...

```
$ cd /tarantool_test
$ # assume that 'tarantool' invokes the tarantool server
$ sudo tarantool
tarantool> box.cfg{}
tarantool> console = require('console')
tarantool> console.connect('localhost:3301')
tarantool> box.space.tester:select({0}, {iterator = 'GE'})
```

... expect to see several tuples that my_app has created.

Stop. The only clean way to stop my_app is with tarantoolctl, thus:

```
$ sudo tarantoolctl stop my_app
```

Clean up. Restore the original contents of /usr/local/etc/default/tarantool, and ...

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

An example for tarantoolctl connect

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

Note: 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.

4.5.3 Administrative ports

“Admin port”, “admin console”, and “text protocol” all refer to the same thing: a connection which is set up with console.listen(...) for entry of requests by administrators.

“Binary port”, “binary protocol”, and “primary port” all refer to a different thing: a connection which is set up with box.cfg{listen=...} for entry of requests by anyone.

Ordinary connections to the Tarantool server should go via a binary port. But admin ports are useful for special cases involving security.

When you connect to an admin port:

- No password is necessary
- The user is automatically ‘admin’, a user with many privileges.

Therefore you must set up admin ports very cautiously. If it is a TCP port, it should only be opened for a specific IP. Ideally it should not be a TCP port at all, it should be a Unix domain socket, so that access to the server machine is required. Thus a typical setup for an admin port is:

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

and a typical connection URI is:

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

if the listener has the privilege to write on /var/lib/tarantool and the connector has the privilege to read on /var/lib/tarantool. Alternatively both setup and connection can be done with tarantoolctl.

If no administrator password exists which could be given out to users, and admin ports are restricted or are sockets, then requests which require ‘admin’ privileges can only occur locally, and are subject to Unix security and monitoring.

For additional security, some requests are illegal. For example, “conn:eval” will result in the error message “-error: console does not support this request type” because conn:eval requires the binary protocol.

If security via admin ports is not necessary, it is still possible to be an admin user by using the tarantool server as a client, or by connecting to a binary port with a valid password.

To find out whether a TCP port is an admin port, use telnet. For example:

```
$ 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
```

In this example the response does not include the word "binary" and does include the words "Lua console". Therefore it is clear that this is a successful connection to an admin port, and admin requests can now be entered on this terminal.

4.5.4 Administrative requests

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()
---
- 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.

4.5.5 Server introspection

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.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: 158
    ro: false
    uuid: a2684219-b2b1-4334-88ab-50b0722283fd
    id: 1
  version: 1.7.2-435-g6ba8500
  pid: 12932
  status: running
  vclock:
  - 158
  replication:
    status: off
  uptime: 908
...
tarantool> box.info.pid
---
- 12932
...
tarantool> box.info.status
---
- running
...
tarantool> box.info.uptime
---
- 1065
...
tarantool> box.info.version
---
- 1.7.2-435-g6ba8500
...
```

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 use and memory fragmentation.

The display of slabs is broken down by the slab size – 64-byte, 136-byte, and so on. The example omits the slabs which are empty. The example display is saying that: there are 16 items stored in the 64-byte slab (and 16*64=102 so bytes_used = 1024); there is 1 item stored in the 136-byte slab (and 136*1=136 so bytes_used = 136); the arena_used value is the total of all the bytes_used values (1024+136 = 1160); the arena_size value is the arena_used value plus the total of all the bytes_free values (1160+4193200+4194088 = 8388448). The arena_size and arena_used values are the amount of the % of slab_alloc_arena that is already distributed to the slab allocator.

Example:

```
tarantool> box.slab.info().arena_used
---
- 4194304
...
tarantool> box.slab.info().arena_size
---
- 104857600
...
tarantool> box.slab.stats()
---
- - mem_free: 16248
    mem_used: 48
    item_count: 2
    item_size: 24
    slab_count: 1
    slab_size: 16384
  - mem_free: 15736
    mem_used: 560
    item_count: 14
    item_size: 40
    slab_count: 1
    slab_size: 16384
    <...>
...
tarantool> box.slab.stats()[1]
---
- mem_free: 15736
  mem_used: 560
  item_count: 14
  item_size: 40
  slab_count: 1
  slab_size: 16384
...
```

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
    rps: 0
  EVENTS:
    total: 2
    rps: 0
  LOCKS:
    total: 6
    rps: 0
  RECEIVED:
    total: 0
    rps: 0
...
```

4.5.6 Replication

Replication allows multiple Tarantool servers to work on copies of the same databases. The databases are kept in synch because each server can communicate its changes to all the other servers. Servers which share the same databases are a "cluster". Each server in a cluster also has a numeric identifier which is unique within the cluster, known as the "server id".

To set up replication, it's necessary to set up the master servers which make the original data-change requests, set up the replica servers which copy data-change requests from masters, and establish procedures for recovery from a degraded state.

Replication architecture

A replica gets all updates from the master by continuously fetching and applying its write-ahead log (WAL). Each record in the WAL represents a single Tarantool data-change request such as INSERT or UPDATE or DELETE, and is assigned a monotonically growing log sequence number (LSN). In essence, Tarantool replication is row-based: each data change command is fully deterministic and operates on a single tuple.

A stored program invocation is not written to the write-ahead log. Instead, log events for actual data-change requests, performed by the Lua code, are written to the log. This ensures that possible non-determinism of Lua does not cause replication to go out of sync.

Setting up a master

To prepare the master for connections from the replica, it's only necessary to include "listen" in the initial box. cfg request, for example box.cfg{listen=3301}. A master with enabled "listen" URI can accept connections from as many replicas as necessary on that URI. Each replica has its own replication state.

Setting up a replica

A server requires a valid snapshot (.snap) file. A snapshot file is created for a server the first time that box.cfg occurs for it. If this first box.cfg request occurs without a "replication source" clause, then the server is a master and starts its own new cluster with a new unique UUID. If this first box.cfg request occurs with a "replication source" clause, then the server is a replica and its snapshot file, along with the cluster information, is constructed from the write-ahead logs of the master. Therefore, to start replication, specify replication_source in a box.cfg request. When a replica contacts a master for the first time, it becomes part of a cluster. On subsequent occasions, it should always contact a master in the same cluster.

Once connected to the master, the replica requests all changes that happened after the latest local LSN. It is therefore necessary to keep WAL files on the master host as long as there are replicas that haven't applied them yet. A replica can be "re-seeded" by deleting all its files (the snapshot .snap file and the WAL .xlog files), then starting replication again - the replica will then catch up with the master by retrieving all the master's tuples. Again, this procedure works only if the master's WAL files are present.

Note: Replication parameters are "dynamic", which allows the replica to become a master and vice versa with the help of the box.cfg statement.

Note: The replica does not inherit the master's configuration parameters, such as the ones that cause the snapshot daemon to run on the master. To get the same behavior, one would have to set the relevant parameters explicitly so that they are the same on both master and replica.

Note: 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.

Recovering from a degraded state

"Degraded state" is a situation when the master becomes unavailable - due to hardware or network failure, or due to a programming bug. There is no automatic way for a replica to detect that the master is gone forever, since sources of failure and replication environments vary significantly. So the detection of degraded state requires a human inspection.

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

Step 1. Start the first server thus:

```
box.cfg{listen = uri#1}
-- replace with more restrictive request
box.schema.user.grant('guest', 'read,write,execute', 'universe')
box.snapshot()
```

... Now a new cluster exists.

Step 2. Check where the second server's files will go by looking at its directories (snap_dir for snapshot files, wal_dir for .xlog files). They must be empty - when the second server joins for the first time, it has to be working with a clean state so that the initial copy of the first server's databases can happen without conflicts.

Step 3. Start the second server thus:

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

... where uri#1 = the URI that the first server is listening on.

That's all.

In this configuration, the first server is the "master" and the second server is the "replica". Henceforth every change that happens on the master will be visible on the replica. A simple two-server cluster with the master on one computer and the replica on a different computer is very common and provides two benefits: FAILOVER (because if the master goes down then the replica can take over), or LOAD BALANCING (because clients can connect to either the master or the replica for select requests). Sometimes the replica may be configured with the additional parameter read_only = true.

Monitoring a replica's actions

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

In the log there is a record of replication activity. If a primary server is started with:

```
box.cfg{
  <...>,
  logger = log file name,
  <...>
}
```

then there will be lines in the log file, containing the word "relay", when a replica connects or disconnects.

Preventing duplicate actions

Suppose that the replica tries to do something that the master has already done. For example: |br| box.schema.space.create('X') |br| This would cause an error, "Space X exists". For this particular situation, the code could be changed to: |br| box.schema.space.create('X', {if_not_exists=true}) |br| But there is a more general solution: the box.once(key, function) method. If box.once() has been called before with the same key value, then function is ignored; otherwise function is executed. Therefore, actions which should only occur once during the life of a replicated session should be placed in a function which is executed via box.once(). For example:

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

Master-master replication

In the simple master-replica configuration, the master's changes are seen by the replica, but not vice versa, because the master was specified as the sole replication source. In the master-master configuration, also sometimes called multi-master configuration, it's possible to go both ways. Starting with the simple configuration, the first server has to say:

box.cfg{ replication_source = uri#2 }

This request can be performed at any time – replication_source is a dynamic parameter.

In this configuration, both servers are "masters" and both servers are "replicas". Henceforth every change that happens on either server will be visible on the other. The failover benefit is still present, and the load-balancing benefit is enhanced (because clients can connect to either server for data-change requests as well as select requests).

If two operations for the same tuple take place "concurrently" (which can involve a long interval because replication is asynchronous), and one of the operations is delete or replace, there is a possibility that servers will end up with different contents.

All the "What If?" questions

Q: What if there are more than two servers with master-master? |br| A: On each server, specify the replication_source for all the others. For example, server #3 would have a request: |br| box.cfg{ |br| replication_source = {uri#1, uri#2} |br| }

Q: What if a server should be taken out of the cluster? |br| A: For a replica, run box.cfg{} again specifying a blank replication source: |br| box.cfg{replication_source=''}

Q: What if a server leaves the cluster? |br| 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? |br| 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? |br| 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? |br| 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? |br| 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? |br| 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? |br| 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? |br| 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 |br| replication_source='username:password@host:port'

Q: What if advanced users want to understand better how it all works? |br| A: See the description of server startup with replication in the Internals section.

Hands-on replication tutorial

After following the steps here, an administrator will have experience creating a cluster and adding a replica.

Start two shells. Put them side by side on the screen. (This manual has a tabbed display showing "Terminal #1". Click the "Terminal #2" tab to switch to the display of the other shell.)

```
$
```

```
$
```

On the first shell, which we'll call Terminal #1, execute these commands:

```
$ # 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'})
```

The result is that a new cluster is set up, and the server's UUID is displayed. Now the screen looks like this: (except that UUID values are always different):

```
$ # 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']
...
```

```
$
```

On the second shell, which we'll call Terminal #2, execute these commands:

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

The result is that a replica is set up. Messages appear on Terminal #1 confirming that the replica has connected and that the WAL contents have been shipped to the replica. Messages appear on Terminal #2 showing that replication is starting. Also on Terminal#2 the _cluster UUID values are displayed, and one of them is the same as the _cluster UUID value that was displayed on Terminal #1, because both servers are in the same cluster.

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

On Terminal #1, execute these requests:

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

Now the screen looks like this:

```
<... ...>
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
<...> [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']
...
```

The creation and insertion were successful on Terminal #1. Nothing has happened on Terminal #2.

On Terminal #2, execute these requests:

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

Now the screen looks like this (remember to click on the “Terminal #2” tab when looking at Terminal #2 results):

```
<... ...>
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']
...
```

The selection and insertion were successful on Terminal #2. Nothing has happened on Terminal #1.

On Terminal #1, execute these Tarantool requests and shell commands:

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

Now Tarantool #1 is stopped. Messages appear on Terminal #2 announcing that fact. The ls -l commands show that both servers have made snapshots, which have similar sizes because they both contain the same tuples.

```
<... ...>
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
```

On Terminal #2, ignore the error messages, and execute these requests:

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

Now the screen looks like this (ignoring the error messages):

```
<... ...>
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: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']
```

```
...
```

Terminal #2 has done a select and an insert, even though Terminal #1 is down.

On Terminal #1 execute these commands:

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

Now the screen looks like this:

```
<... ...>
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/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
```

The master has reconnected to the cluster, and has NOT found what the replica wrote while the master was away. That is not a surprise – the replica has not been asked to act as a replication source.

On Terminal #1, say:

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

The screen now looks like this:

```
<... ...>
$ ~/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> 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'
```

This shows that the two servers are once again in synch, and that each server sees what the other server wrote.

To clean up, say "os.exit()" on both Terminal #1 and Terminal #2, and then on either terminal say:

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

4.5.7 Backups

The exact procedure for backing up a database depends on: how up-to-date the database must be, how frequently backups must be taken, whether it is okay to disrupt other users, and whether the procedure should be optimized for size (saving disk space) or for speed (saving time). So there is a spectrum of possible policies, ranging from cold-and-simple to hot-and-difficult.

Cold backup

In essence: The last snapshot file is a backup of the entire database; and the WAL files that are made after the last snapshot are incremental backups. Therefore taking a backup is a matter of copying the snapshot and WAL files.

1. Prevent all users from writing to the database. This can be done by shutting down the server, or by saying box.cfg{read_only=true} and then ensuring that all earlier writes are complete (fsync can be used for this purpose).
2. If this is a backup of the whole database, say box.snapshot().
3. Use tar to make a (possibly compressed) copy of the latest .snap and .xlog files on the snap_dir and wal_dir directories.
4. If there is a security policy, encrypt the tar file.
5. Copy the tar file to a safe place.

... Later, restoring the database is a matter of taking the tar file and putting its contents back in the snap_dir and wal_dir directories.

Continuous remote backup

In essence: replication is useful for backup as well as for load balancing. Therefore taking a backup is a matter of ensuring that any given replica is up to date, and doing a cold backup on it. Since all the other replicas continue to operate, this is not a cold backup from the end user's point of view. This could be done on a regular basis, with a cron job or with a Tarantool fiber.

Hot backup

In essence: The logged changes done since the last cold backup must be secured, while the system is running.

For this purpose you need a "file copy" utility that will do the copying remotely and continuously, copying only the parts of a file that are changing. One such utility is rsync.

Alternatively, you need an ordinary file copy utility, but there should be frequent production of new snapshot files or new WAL files as changes occur, so that only the new files need to be copied.

Note re storage engine: vinyl databases require additional steps.

4.5.8 Updates/upgrades

Updating Tarantool in production

First, put your application's business logic in a Tarantool-Lua module that exports its functions for CALL.

For example, /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;
}
```

This file is maintained by the application's developers. On its side, Tarantool Team provides templates for you to assemble deb/rpm packages and utilities to quickly assemble packages for specific platforms. If needed, you can split applications into standalone files and/or modules.

Second, put an initialization script to the /etc/tarantool/instances.available directory.

For example, /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})
```

As a more detailed example, you can take the example.lua script that ships with Tarantool and defines all configuration options.

This initialization script is actually a configuration file and should be maintained by system administrators, while developers only provide a template.

Now update your app file in /usr/share/tarantool. Replace your application file (for example, /usr/share/tarantool/myapp.lua) and manually reload the myappcfg.lua initialization script using tarantoolctl:

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

After that, you need to manually flush the cache of package.loaded modules.

For deb/rpm packages, you can add the tarantoolctl eval instruction directly into Tarantool's specification in RPM.spec and the /debian directory.

Finally, clients make a CALL to myapp.api_for_call and other API functions.

In the case of tarantool-http, there is no need to start the binary protocol at all.

Upgrading a Tarantool database

This information applies for users who created databases with older versions of the Tarantool server, and have now installed a newer version. The request to make in this case is: box.schema.upgrade().

For example, here is what happens when one runs box.schema.upgrade() with a database that was created in early 2015. Only a small part of the output is shown.

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

4.5.9 Server signal handling

The server processes these signals during the main thread event loop:

SIGHUP may cause log file rotation, see the example in section "Logging".

SIGUSR1 may cause saving of a snapshot, see the description of box.snapshot.

SIGTERM may cause graceful shutdown (information will be saved first).

SIGINT (also known as keyboard interrupt) may cause graceful shutdown.

SIGKILL causes shutdown.

Other signals will result in behavior defined by the operating system. Signals other than SIGKILL may be ignored, especially if the server is executing a long-running procedure which prevents return to the main thread event loop.

4.5.10 Process title

Linux and FreeBSD operating systems allow a running process to modify its title, which otherwise contains the program name. Tarantool uses this feature to help meet the needs of system administration, such as figuring out what services are running on a host, their status, and so on.

A Tarantool server's process title has these components:

program_name [initialization_file_name] <role_name> [custom_proc_title]

- program_name is typically "tarantool".
- initialization_file_name is the name of an initialization file, if one was specified.
- role_name is:
  - "running" (ordinary node "ready to accept requests"),
  - "loading" (ordinary node recovering from old snap and wal files),
  - "orphan" (not in a cluster),
  - "hot_standby", or
  - "dumper" + process-id (saving a snapshot).
- custom_proc_title is taken from the custom_proc_title configuration parameter, if one was specified.

For example:

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

4.5.11 System-specific administration notes

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

Setting up an instance:

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

Starting all instances:

```
$ service tarantool start
```

Stopping all instances:

```
$ service tarantool stop
```

Starting/stopping one instance:

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

Fedora, RHEL, CentOS

There are no known permanent issues. For transient issues, go to http://github.com/tarantool/tarantool/issues and enter "RHEL" or "CentOS" or "Fedora" or "Red Hat" in the search box.

FreeBSD

There are no known permanent issues. For transient issues, go to http://github.com/tarantool/tarantool/issues and enter "FreeBSD" in the search box.

Mac OS X

There are no known permanent issues. For transient issues, go to http://github.com/tarantool/tarantool/issues and enter "OS X" in the search box.

4.5.12 Notes for systemd users

Tarantool fully supports systemd for managing instances and supervising database daemons.

Instance management

Tarantool was designed to have multiple running instances of Tarantool on the same machine. Use systemctl start|stop|restart|status tarantool@$MYAPP to manage your databases and Lua applications.

Creating instances

Simply put your Lua configuration to /etc/tarantool/instances.available/$MYAPP.lua:

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

(this minimal example is sufficient).

Another starting point could be the example.lua script that ships with Tarantool and defines all options.

Starting instances

Use systemctl start tarantool@$MYAPP to start ${MYAPP} instance:

```
$ 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>
```

(console examples here and further on are for Fedora).

Use systemctl enable tarantool@$MYAPP to enable ${MYAPP} instance for auto-load during system startup.

Monitoring instances

Use systemctl status tarantool@$MYAPP to check information about ${MYAPP} instance:

```
$ 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>
```

Use journalctl -u tarantool@$MYAPP to check the boot log:

```
$ 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
```

Attaching to instances

You can attach to a running Tarantool instance and evaluate some Lua code using the tarantoolctl utility:

```
$ 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>
```

Checking logs

Tarantool logs important events to /var/log/tarantool/$MYAPP.log.

Let's write something to the log file:

```
$ 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")
---
...
```

Then check the logs:

```
$ 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
```

Log rotation is enabled by default if you have logrotate installed. Please configure /etc/logrotate.d/tarantool to change the default behavior.

Stopping instances

Use systemctl stop tarantool@$MYAPP to see information about the running ${MYAPP} instance.

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

Daemon supervision

All instances are automatically restarted by systemd in case of failure.

Let's try to destroy an instance:

```
$ 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
```

Now let's make sure that systemd has revived our Tarantool instance:

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

Finally, let's check the boot logs:

```
$ 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.
```

Customizing the service file

Please don't modify the tarantool@.service file in-place, because it will be overwritten during package upgrades. It is recommended to copy this file to /etc/systemd/system and then modify the required settings. Alternatively, you can create a directory named unit.d/ within /etc/systemd/system and put there a drop-in file name.conf that only changes the required settings. Please see systemd.unit(5) manual page for additional information.

Debugging

coredumpctl automatically saves core dumps and stack traces in case of a crash. Here is how it works:

```
$ # !!! please never do this on the production system !!!
$ 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
```

coredumpctl list /usr/bin/tarantool displays the latest crashes of the Tarantool daemon:

```
$ 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
```

coredumpctl info <pid> shows the stack trace and other useful information:

```
$ 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)
                ...
```

coredumpctl -o filename.core info <pid> saves the core dump into a file.

coredumpctl gdb <pid> starts gdb on the core dump.

It is highly recommended to install the tarantool-debuginfo package to improve gdb experience. Example:

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

gdb also provides information about the debuginfo packages you need to install:

```
$ # 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
```

Symbol names are present in stack traces even if you don't have the tarantool-debuginfo package installed.

For additional information, please refer to the documentation provided with your Linux distribution.

Precautions

- Please don't use tarantoolctl {start,stop,restart} to control instances started by systemd. It is still possible to use tarantoolctl to start and stop instances from your local directories (e.g. $HOME) without obtaining ROOT access.

- tarantoolctl is configured to work properly with systemd. Please don't modify system-wide settings of tarantoolctl, such as paths, directory permissions and usernames. Otherwise, you have a chance to shoot yourself in the foot.
- systemd scripts are maintained by the Tarantool Team (http://tarantool.org). Please file tickets directly to the upstream's bug tracker (https://github.com/tarantool/tarantool/issues/) rather than to your Linux distribution.

Limitations

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/: |br| #To enable the instance to be automatically loaded by systemd: |br| systemctl enable tarantool@instancename

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

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

4.6 Connectors

This chapter documents APIs for various programming languages.

4.6.1 Protocol

Tarantool's binary protocol was designed with a focus on asynchronous I/O and easy integration with proxies. Each client request starts with a variable-length binary header, containing request id, request type, server id, log sequence number, and so on.

The mandatory length, present in request header simplifies client or proxy I/O. A response to a request is sent to the client as soon as it is ready. It always carries in its header the same type and id as in the request. The id makes it possible to match a request to a response, even if the latter arrived out of order.

Unless implementing a client driver, you needn't concern yourself with the complications of the binary protocol. Language-specific drivers provide a friendly way to store domain language data structures in

Tarantool. A complete description of the binary protocol is maintained in annotated Backus-Naur form in the source tree: please see the page about Tarantool's binary protocol.

4.6.2 Packet example

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.

Component	Byte #0	Byte #1	Byte #2	Byte #3
code for insert	02			
rest of header	...	...	...	...
2-digit number: space id	cd	02	01	
code for tuple	21			
1-digit number: field count = 2	92			
1-character string: field[1]	a1	41		
2-character string: field[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.

4.6.3 Setting up the server for connector examples

This chapter has examples that show how to connect to the Tarantool server via the Perl, PHP, Python, 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"),
- user 'guest' has privileges for reading and writing.

It is easy to meet all the conditions by starting the server and executing this script:

```
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')
```

4.6.4 Java

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

4.6.5 Go

Please see https://github.com/mialinx/go-tarantool.

4.6.6 R

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

4.6.7 Perl

The most commonly used Perl driver is DR::Tarantool. It is not supplied as part of the Tarantool repository; it must be installed separately. The most common way to install it is with CPAN, the Comprehensive Perl Archive Network. DR::Tarantool requires other modules which should be installed first. For example, on Ubuntu, the installation could look like this:

```
$ 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
```

Here is a complete Perl program that inserts [99999,'BB'] into space[999] via the Perl 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.pl and say perl example.pl. 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 displaying any messages. If Tarantool is not running on localhost with listen port = 3301, the program will print "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',                      # look for tarantool on localhost
  port    => 3301,                             # on port 3301
  user    => 'guest',                          # username. one could also say 'password=>...'

  spaces  => {
    999 => {                                   # definition of space[999] ...
      name => 'examples',                      #   space[999] name = 'examples'
      default_type => 'STR',                   #   space[999] field type is 'STR' if undefined
      fields => [ {                            #   definition of space[999].fields ...
          name => 'field1', type => 'NUM' } ], #     space[999].field[1] name='field1',type='NUM'
      indexes => {                             #   definition of space[999] indexes ...
        0 => {
          name => 'primary', fields => [ 'field1' ] } } } } );

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

The example program uses field type names 'STR' and 'NUM' instead of 'string' and 'unsigned', due to a temporary Perl limitation.

The example program only shows one request and does not show all that's necessary for good practice. For that, please see DR::Tarantool CPAN repository.

4.6.8 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 :ref:'installation instructions <https://github.com/tarantool/tarantool-php/blob/master/#installing-and-building>'_. 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
<?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).

4.6.9 Python

Here is a complete Python program that inserts [99999,'Value','Value'] into space examples via the high-level Python API.

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

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

To prepare, paste the code into a file named example.py and install the tarantool-python connector with either pip install tarantool>0.4 to install in /usr (requires root privilege) or pip install tarantool>0.4 --user to install in ~ i.e. user's default directory. Before trying to run, check that the server is listening at localhost:3301 and that the space examples exists, as described earlier. To run the program, say python example.py. The program will connect to the server, will send the request, and will not throw any exception if all went well. If the tuple already exists, the program will throw 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.

4.6.10 C

Here follow two examples of using Tarantool's high-level C API.

Example 1

Here is a complete C program that inserts [99999,'B'] into space examples via the high-level C API.

```
#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);          /* See note = SETUP */
   tnt_set(tnt, TNT_OPT_URI, "localhost:3301");
   if (tnt_connect(tnt) < 0) {                       /* See note = CONNECT */
       printf("Connection refused\n");
       exit(-1);
   }
   struct tnt_stream *tuple = tnt_object(NULL);      /* See note = MAKE REQUEST */
   tnt_object_format(tuple, "[%d%s]", 99999, "B");
   tnt_insert(tnt, 999, tuple);                      /* See note = SEND REQUEST */
   tnt_flush(tnt);
   struct tnt_reply reply;  tnt_reply_init(&reply); /* See note = GET REPLY */
   tnt->read_reply(tnt, &reply);
   if (reply.code != 0) {
       printf("Insert failed %lu.\n", reply.code);
   }
   tnt_close(tnt);                                   /* See below = TEARDOWN */
   tnt_stream_free(tuple);
   tnt_stream_free(tnt);
}
```

Paste the code into a file named example.c and install tarantool-c. One way to install tarantool-c (using Ubuntu) is:

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

To compile and link the program, say:

```
$ # sometimes this is necessary:
$ export LD_LIBRARY_PATH=/usr/local/lib
$ gcc -o example example.c -ltarantool
```

Before trying to run, check that the server is listening at localhost:3301 and that the space examples exists, as described earlier. To run the program, say ./example. The program will connect to the server, and will send the request. If Tarantool is not running on localhost with listen address = 3301, the program will print "Connection refused". If the insert fails, the program will print "Insert failed" and an error number (see all error codes in the source file /src/box/errcode.h).

Here are notes corresponding to comments in the example program.

SETUP: The setup begins by creating a stream.

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

In this program, the stream will be named tnt. Before connecting on the tnt stream, some options may have to be set. The most important option is TNT_OPT_URI. In this program, the URI is localhost:3301, since that is where the Tarantool server is supposed to be listening.

Function description:

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

CONNECT: Now that the stream named tnt exists and is associated with a URI, this example program can connect to the server.

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

Function description:

int tnt_connect(struct tnt_stream *s)

The connection might fail for a variety of reasons, such as: the server is not running, or the URI contains an invalid password. If the connection fails, the return value will be -1.

MAKE REQUEST: Most requests require passing a structured value, such as the contents of a tuple.

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

In this program, the request will be an INSERT, and the tuple contents will be an integer and a string. This is a simple serial set of values, that is, there are no sub-structures or arrays. Therefore it is easy in this case to format what will be passed using the same sort of arguments that one would use with a C printf() function: %d for the integer, %s for the string, then the integer value, then a pointer to the string value.

Function description:

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

SEND REQUEST: The database-manipulation requests are analogous to the requests in the box library.

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

In this program, the choice is to do an INSERT request, so the program passes the tnt_stream that was used for connection (tnt) and the tnt_stream that was set up with tnt_object_format() (tuple).

Function description:

```
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)
```

GET REPLY: For most requests, the client will receive a reply containing some indication whether the result was successful, and a set of tuples.

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

This program checks for success but does not decode the rest of the reply.

Function description:

```
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)
```

TEARDOWN: When a session ends, the connection that was made with tnt_connect() should be closed, and the objects that were made in the setup should be destroyed.

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

Function description:

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

Example 2

Here is a complete C program that selects, using index key [99999], from space examples via the high-level C API. To display the results, the program uses functions in the MsgPuck library which allow decoding of MessagePack arrays.

```
#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); /* tuple = search key */
    tnt_select(tnt, 999, 0, (2^32) - 1, 0, 0, tuple);
    tnt_flush(tnt);
    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);
}
```

Similarly to the first example, paste the code into a file named example2.c.

To compile and link the program, say:

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

To run the program, say ./example2.

The two example programs only show a few requests and do not show all that's necessary for good practice. See more in the tarantool-c documentation at GitHub.

4.6.11 Interpreting function return values

For all connectors, calling a function via Tarantool causes a return in the MsgPack format. If the function is called using the connector's API, some conversions may occur. All scalar values are returned as tuples (with a MsgPack type-identifier followed by a value); all non-scalar values are returned as a group of tuples (with a MsgPack array-identifier followed by the scalar values). If the function is called via the binary protocol command layer – "eval" – rather than via the connector's API, no conversions occur.

In the following example, a Lua function will be created. Since it will be accessed externally by a 'guest' user, a grant of an execute privilege will be necessary. The function returns an empty array, a scalar string, two booleans, and a short integer. The values are the ones described in the table Common Types and MsgPack Encodings.

```
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')
---
...
```

Here is a C program which calls the function. Although C is being used for the example, the result would be precisely the same if the calling program was written in Perl, PHP, Python, Go, or 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);            /* SETUP */
 tnt_set(tnt, TNT_OPT_URI, "localhost:3301");
  if (tnt_connect(tnt) < 0) {                       /* CONNECT */
      printf("Connection refused\n");
      exit(-1);
  }
  struct tnt_stream *tuple = tnt_object(NULL);       /* MAKE REQUEST */
  struct tnt_stream *arg; arg = tnt_object(NULL);
  tnt_object_add_array(arg, 0);
  struct tnt_request *req1 = tnt_request_call(NULL); /* CALL 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);                                   /* SEND REQUEST */
  struct tnt_reply reply;  tnt_reply_init(&reply);   /* GET REPLY */
  tnt->read_reply(tnt, &reply);
  if (reply.code != 0) {
    printf("Call failed %lu.\n", reply.code);
    exit(-1);
  }
  const unsigned char *p= (unsigned char*)reply.data;/* PRINT REPLY */
  while (p < (unsigned char *) reply.data_end)
  {
    printf("%x ", *p);
    ++p;
  }
  printf("\n");
  tnt_close(tnt);                                  /* TEARDOWN */
  tnt_stream_free(tuple);
  tnt_stream_free(tnt);
}
```

When this program is executed, it will print:

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

The first five bytes – dd 0 0 0 5 – are the MsgPack encoding for “32-bit array header with value 5” (see MsgPack specification). The rest are as described in the table Common Types and MsgPack Encodings.

4.7 FAQ

Q: |br| A: |br|	Why Tarantool? |br| 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: |br| A: |br|	Why Lua? |br| 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: |br| A: |br|	What's the key advantage of Tarantool? |br| 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. |br| 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: |br| A: |br|	What are your development plans? |br| 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: |br| A: |br|	Who is developing Tarantool? |br| 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: |br| A: |br|	How serious is Mail.Ru about Tarantool? |br| 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: |br| A: |br|	Are there problems associated with being an in-memory server? |br| 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.

CHAPTER 5

Reference

5.1 Built-in library reference

This reference covers Tarantool's built-in Lua modules.

Note: 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.

5.1.1 Module 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: box.schema, box.tuple, box.space, box.index, box.cfg, box.info, box.slab, box.stat. 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).

Submodule 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.

Parameters

- 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 five 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().

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 the _user space.

Parameters

- 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

Examples:

```
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 the _user space.

Parameters

- user-name (string) – the name of the user
- options (table) – if_exists

Examples:

```
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.

Parameters

- 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.

Parameters

- 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'.

Variation: instead of privilege, object-type, object-name say role-name (see section Roles).

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)

Revoke privileges from a user.

Parameters

- 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 password.

Parameters

- 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).

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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])

Grant privileges to a role.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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 section Functions and the _func space.

Parameters

- 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 section Functions and the _func space.

Parameters

- 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.

Parameters

- func-name (string) – the name of the function

Rtype bool

Example:

```
box.schema.func.exists('calculate')
```

Submodule 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.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 tuple set 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.

Parameters: space_object = an object reference; index_name (type = string) = name of index, which should not be a number and should not contain special characters; options.

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.

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: |br| The six index field types (unsigned | string | integer | number | array | scalar) differ depending on what values are allowed, and what index types are allowed. |br| 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. |br| 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. |br| integer: integers between -9223372036854775808 and 18446744073709551615. May also be called ‘int’. Legal in memtx TREE or HASH indexes, and in vinyl TREE indexes. |br| 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. |br| array: array of integers between -9223372036854775808 and 9223372036854775807. Legal in memtx RTREE indexes. |br| 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

Index field type	What can be in it	Where is it legal	Examples
unsigned	integers between 0 and 18446744073709551615	memtx TREE or HASH indexes, |br| vinyl TREE indexes	123456 |br|
string	strings – any set of octets	memtx TREE or HASH indexes |br| vinyl TREE indexes	'A B C' |br| '\65 \66 \67'
integer	integers between -9223372036854775808 and 18446744073709551615	memtx TREE or HASH indexes, |br| vinyl TREE indexes	-2^63 |br|
number	integers between -9223372036854775808 and 18446744073709551615, single-precision floating point numbers, double-precision floating point numbers	memtx TREE or HASH indexes, |br| vinyl TREE indexes	1.234 |br| -44 |br| 1.447e+44
array	array of integers between -9223372036854775808 and 9223372036854775807	memtx RTREE indexes	{10, 11} |br| {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, |br| vinyl TREE indexes	true |br| -1 |br| 1.234 |br| '' |br| ''

space_object:insert(tuple)

Insert a tuple into a space.

Parameters: space_object = an object reference; tuple (type = Lua table or tuple) = 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.

Parameters: space_object = an object reference; key (type = Lua table or scalar) = key to be matched against the index key, which may be multi-part.

Return the tuples whose primary-key fields are equal to the passed field-values. If the number of passed field-values is less than the number of fields in the primary key, then only the passed field-values 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.

Parameters: space_object = an object reference; key (type = Lua table or scalar) = key to be matched against the index key, which may be multi-part.

Return the tuple whose index key matches key, or null.

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 tuple set 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.

Parameters: 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.

Parameters:space_object = an object reference; space-name (type = 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().

Parameters: space_object = an object reference; tuple (type = Lua table or 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.

Parameters: space_object = an object reference; key (type = Lua table or scalar) = primary-key field values, must be passed as a Lua table if key is multi-part; {operator, field_no, value} (type = table): a group of arguments for each operation, indicating what the operation is, what field the operation will apply to, and what value will be applied. The field number can be negative, meaning the position from the end of tuple (#tuple + negative field number + 1).

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: |br| box.space.tester:update(999, {{`'='`, 2, `'B'`}}) |br| 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: |br| box.space.tester:update({999}, {{`'='`, 2, `'B'`}}) |br| 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: |br| box.space.tester:update({999}, {{`'='`, 3, 1}}) |br| 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: |br| box.space.tester:update({999}, {{`'+'`, 3, 1}}) |br| 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: |br| box.space.tester:update({999}, {{`'|'`, 3, 1}, {`'='`, 2, `'C'`}}) |br| 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: |br| box.space.tester:update({999}, {{`'#'`, 2, 1}, {`'-'`, 2, 3}}) |br| 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: |br| box.space.tester:update({999}, {{`'='`, 2, `'XYZ'`}}) |br| 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: |br| box.space.tester:update({999}, {{`':'`, 2, 2, 1, `'!!'`}}) |br| 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.

Parameters: space_object = an object reference; tuple_value (type = Lua table or scalar) = field values, must be passed as a Lua table; {operator, field_no, value} (type = Lua table) = a group of arguments for each operation, indicating what the operation is, what field the operation will apply to, and what value will be applied. The field number can be negative, meaning the position from the end of the tuple (#tuple + negative field number + 1).

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.

Parameters: space_object = an object reference key (type = Lua table or scalar) = key to be matched against the index key, which may be multi-part.

Return the deleted tuple

Rtype tuple

Complexity Factors: Index size, Index type

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.

Parameters: space_object = an object reference.

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.

Parameters: space_object = an object reference.

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.

Parameters: space_object = an object reference.

Example:

```
tarantool> box.space.tester.field_count
---
- 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.

Parameters: space_object = an object reference.

Rtype table

Example:

```
tarantool> #box.space.tester.index
---
- 1
...
tarantool> box.space.tester.index.primary.type
---
- TREE
...
```

space_object:count([key][, iterator])

Parameters: space_object = an object reference; key (type = Lua table or scalar) = key to be matched against the primary index key, which may be multi-part; iterator = comparison method.

Return Number of tuples.

Example:

```
tarantool> box.space.tester:count(2, {iterator='GE'})
---
- 1
...
```

space_object:len()

Parameters: space_object = an object reference.

Return Number of tuples in the space.

Example:

```
tarantool> box.space.tester:len()
---
- 2
...
```

Note re storage engine: vinyl does not support len(). One possible workaround is to say #select(...).

space_object:truncate()

Deletes all tuples. .

Parameters: space_object = an object reference.

Complexity Factors: Index size, Index type, Number of tuples accessed.

Return nil

Note: 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 here

---

Note re storage engine: vinyl does not support truncate().

Example:

```
tarantool> box.space.tester:truncate()
---
...
tarantool> box.space.tester:len()
---
- 0
...
```

space_object:auto_increment(field-value[, field-value ...])

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.

Note re storage engine: vinyl does not support auto_increment().

Parameters: space_object = an object reference; field-value(s) (type = Lua table or scalar) = 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()

A helper function to prepare for iterating over all tuples in a space.

Parameters: space_object = an object reference.

Return function which can be used in a for/end loop. Within the loop, a value is returned for each iteration.

Rtype function, tuple

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
...
```

box.space._schema

_schema is a system tuple set. Its single tuple contains these 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 tuple set. Its tuples contain these 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:

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:

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
  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 tuple set. Its tuples contain these 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 '
  - '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 tuple set for support of the authorization feature.

box.space._priv
: _priv is a system tuple set for support of the authorization feature.

box.space._cluster
: _cluster is a system tuple set for support of the replication feature.

box.space._func
: _func is a system tuple set with function tuples made by box.schema.func.create.

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 tuple set, 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
  - _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: |br| box.space._space:select{288} |br| or |br| box.space._space:select{box.schema.SPACE_ID} |br|

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: |br| box.space._space.index.name:select{'_space'}

However, the retrieved tuple is not easy to read: |br| tarantool> box.space._space.index.name:select{'_space'} |br| — |br| - - [280, 1, '_space', 'memtx', 0, '', [{'name': 'id', |br| 'type': 'num'}, {'name': 'owner','type': 'num'}, |br| {'name': 'name','type': 'str'}, {'name': 'engine', |br| 'type': 'str'},{'name': 'field_count', 'type': 'num'}, |br| {'name': 'flags','type': 'str'}, {'name': 'format', |br| 'type': '*'}]] |br| ...

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: |br| local tuple_of_space, field_name, field_type |br| tuple_of_space = box.space._space.index.name:select{'_space'}[1] |br| for i = 1, #tuple_of_space[7], 1 |br| do |br| field_name = tuple_of_space[7][i]['name'] |br| field_type = tuple_of_space[7][i]['type'] |br| print(field_name .. ',' ..field_type) |br| end

And here is what happens when one executes the for loop: |br| id,num |br| owner,num |br| name,str |br| engine,str |br| field_count,num |br| flags,str |br| format,*

Submodule 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.

Parameters:

- index_object = an object reference.

Rtype boolean

index_object.type
Index type, 'TREE' or 'HASH' or 'BITSET' or 'RTREE'.

Parameters:

- index_object = an object reference.

index_object.parts
An array describing index key fields.

Parameters:

- index_object = an object reference.

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(bitset-value | search-value, iterator-type)

This method provides iteration support within an index. The bitset-value or search-value parameter specifies what must match within the index. The iterator-type 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.

Parameters:

- index_object = an object reference;
- bitset-value | search-value... = what to search for
- iterator-type = as defined in tables below.

Return this method returns an iterator closure, i.e. a function which can be used to get the next value on each invocation

Rtype function, tuple

Possible errors: Selected iteration type is not supported for the index type, or search value is not supported for the iteration type.

Complexity Factors: Index size, Index type, Number of tuples accessed.

A search-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 search-value will be compared to each part of an index key.

Iterator types for TREE indexes

Note: Formally the logic for TREE index searches is: |br| 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']
...
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).

Parameters:

- index_object = an object reference;
- search-key = values to be matched against the index key;
- option(s) any or all of
  - iterator = iterator-type,
  - limit = maximum-number-of-tuples,
  - offset = 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']
...
```

Note: 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.

Note: iterator = iterator-type is optional. If it is omitted, then iterator = 'EQ' is assumed.

Note: 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.

Note: 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.

Parameters: space_object = an object reference; key (type = Lua table or scalar) = key to be matched against the index key, which may be multi-part.

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-value])

Find the minimum value in the specified index.

Parameters:

- index_object = an object reference;
- key-value.

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-value])

Find the maximum value in the specified index.

Parameters:

- index_object = an object reference;
- key-value.

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(random-value)

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.

Parameters:

- index_object = an object reference;
- random-value (type = number) = an arbitrary non-negative integer.

Return the tuple for the random key in the index.

Rtype tuple

Complexity Factors: Index size, Index type.

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.

Parameters:

- index_object = an object reference;
- key-value (type = Lua table or scalar) = the value which must match the key(s) in the specified index. The type may be a list of field-values, or a tuple containing only the field-values; 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.

Parameters:

- index_object = an object reference;
- key (type = Lua table or scalar) = key to be matched against the index key;
- operator, field_no, value (type = Lua table) = update operations (see: box.space...update()).

  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.

Parameters:

- index_object = an object reference;
- key (type = Lua table or scalar) = key to be matched against the index key.

  Return the deleted tuple.

  Rtype tuple

Note re storage engine: vinyl will return nil, rather than the deleted tuple.

index_object:alter({options})

Alter an index.

Parameters:

- index_object = an object reference;

- options = 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.

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.

Parameters:

- 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.

Parameters:

- index_object = an object reference;
- index-name (type = 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.

Parameters:

- 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', {
         >   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.

Submodule 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.storage

A Lua table that can hold arbitrary unordered session-specific names and values, which will last until the session ends.

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. '
...
```

See the section Triggers for instructions about defining triggers for connect and disconnect events with box.session.on_connect() and box.session.on_disconnect(). See the section Access control for instructions about box.session functions that affect user identification and security.

Submodule 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.

Parameters

- 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.

Parameters

- 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 = ''
---
...
tarantool> for k, v in t:pairs() do
         >   tmp = tmp .. v
         > end
---
...
tarantool> tmp
---
- Fld#1Fld#2Fld#3Fld#4Fld#5
...
```

tuple_object:update({{format, field_number, 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_number, value}...), which updates a tuple in a space.

Parameters: briefly: format indicates the type of update operation such as '=' for 'assign new value', field_number indicates the field number to change such as 2 for field number 2, value indicates the string which operates on the field such as 'B' for a new assignable value = 'B'.

For details: see the description for format, field_number, and value in the section box.space.space-name:update{key, format, {field_number, value}. . .).

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']
...
```

Example

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
...
```

5.1.2 Module 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[, function parameters ...])

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.

Parameters:

- function = function or function reference;
- function parameters = whatever values are required by the function.

Return table. first element = seconds of CPU time; second element = whatever the function returns.

Rtype table

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)
```

5.1.3 Module 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').

Parameters

- 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.

Parameters

- 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:

```
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, then hitting the TAB key may cause tarantool to complete a word automatically. The default auto-completion value is true.

5.1.4 Module 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 Module 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')
```

5.1.5 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 – single-byte character to designate end-of-field, default = comma
- quote_char = string – single-byte character to designate encloser of string, default = quote mark
- chunk-size = number – number of characters to read at once (usually for file-IO efficiency), default = 4096
- skip_head_lines = number – number of lines to skip at the start (usually for a header), default 0

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.

Parameters

- 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().

Parameters

- 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')
---
...
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).

Parameters

- 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
...
```

5.1.6 Module 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())
```

Example

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_insert('Secret Password')
---
- 'Password is not valid'
...
```

5.1.7 Submodule 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.

Parameters

- 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.

Parameters

- code (number) – number of a pre-defined error
- errtext(s) (string) – part of the message which will accompany the error

For example:

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()
---
...
tarantool> box.error.last()
---
- null
...
```

5.1.8 Module 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.

Parameters

- 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)
         > 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)

Parameters

- 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.

Parameters

- 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().

Parameters

- 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()

Parameters

- 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()

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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'
---
```

```
...
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
         >     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
---
...
```

5.1.9 Submodule fiber-ipc

The fiber-ipc submodule allows sending and receiving messages between different processes. 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).

fiber.channel([capacity])

Create a new communication channel.

Parameters

- 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

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.

Parameters

- 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.

Parameters

- 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

Example

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

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
```

5.1.10 Submodule fiber-cond

The fiber-cond submodule has a synchronization mechanism for fibers, similar to "Condition Variables" and similar to operating-system functions such as pthread_cond_wait() plus pthread_cond_signal().

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().

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().

    Parameters

    - 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

Example

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'
fiber = require('fiber')
cond = fiber.cond()
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'
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.

5.1.11 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.

Parameters

- 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.

Parameters

- 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).

Parameters

- 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".

Parameters

- 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".

Parameters

- 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".

Parameters

- 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".

Parameters

- 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”..

Parameters

- 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
...
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".

Parameters

- 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".

Parameters

- 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".

Parameters

- 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.

Parameters

- 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".

Parameters

- 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".

Parameters

- 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".

Note: 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.

Parameters

- 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')
---
- 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.

Parameters

- 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".

Parameters

- 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".

Parameters

- 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".

Parameters

- fh (userdata) – file-handle as returned by fio.open().

Return true if success, false if failure.

Example:

```
tarantool> fh:fsync()
---
- true
...
```

5.1.12 Module fun

Lua fun, 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
1
2
3
---
...
```

5.1.13 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.

Parameters

- 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.

Parameters

- 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"}'
...
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 - allow nan and inf (default is true)
- cfg.encode_use_tostring - use tostring for unrecognizable types (default is false)
- cfg.encode_invalid_as_nil - use null for all unrecognizable types (default is false)
- cfg.encode_load_metatables - load metatables (default is false)

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. >>>>>>> Fix every NOTE to be highlighted on site + JSON cfg rewritten

5.1.14 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_name 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.

Parameters

- 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()

Example

```
$ ~/tarantool/src/tarantool
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()
$ less tarantool.txt
```

```
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.

5.1.15 Module 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.

Parameters

- 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.

Parameters

- string – a string formatted as MsgPack.

Return

- the original contents formatted as a Lua table;
- the number of bytes that were decoded.

Rtype table

msgpack.NULL

A value comparable to Lua “nil” which may be useful as a placeholder in a tuple.

Example

```
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
msg-pack.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.

5.1.16 Module net.box

The net.box module contains connectors to remote database systems. One variant, to be discussed later, is for connecting to MySQL or MariaDB or PostgreSQL — that variant is the subject of the SQL DBMS modules appendix. In this section the subject is the built-in variant, net.box. This is for connecting to tarantool servers via a network.

Call require('net.box') to get a net.box object, which will be called net_box for examples in this section. Call net_box.new() to connect and get a connection object, which will be called conn for examples in this section. Call the other net.box() routines, passing conn:, to execute requests on the remote box. Call 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.

net_box.new(URI[, {option[s]}])

Create a new connection. The connection is established on demand, at the time of the first request. It is re-established automatically after a disconnect. The returned conn object supports methods for making remote requests, such as select, update or delete.

For the 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.new('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.

Parameters

- URI (string) – the URI of the target for the connection
- options – a possible option is wait_connect

Return conn object

Rtype userdata

Example:

```
conn = net_box.new('localhost:3301')
conn = net_box.new('127.0.0.1:3306', {wait_connect = false})
```

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.

Parameters

- timeout (number) –

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: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{...}.

Note: 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.

Example showing use of most of the net.box methods

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. Assume that the database is nearly empty. Assume that the tarantool server is running on localhost 127.0.0.1:3301.

```
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.new('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
...
```

5.1.17 Function 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.

Parameters

- key (string) – a value that will be checked
- function (function) – a function
- ... – arguments, that must be passed to function

5.1.18 Module 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

Parameters

- 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.

Parameters

- 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])
---
- 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'))
---
...
```

5.1.19 Module 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.

Parameters

- host (string) – URL or IP address
- port (number) – port number
- timeout (number) – timeout

Return a connected socket, if no error.

Rtype userdata

Example:

```
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)

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=...).

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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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 all available data from the socket buffer if non-blocking. Rarely used. For details see this description.

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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Return 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)

Example

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". 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/1.0rnHost: tarantool.orgrnrn")
---
- true
...
tarantool> sock:read(17)
---
- "HTTP/1.1 200 OKrn"
...
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. |br| 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
        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.

5.1.20 Module 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
---
...
```

5.1.21 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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
...
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.

Parameters

- 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.

Parameters

- 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.

Parameters

- 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(...).

Parameters

- 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.

Parameters

- 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

Parameters

- got (lua-value) – actual result
- expected (lua-value) – expected result
- test-name (string) – name of test

Example

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
```

5.1.22 Module 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
...
```

5.1.23 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)

Parameters

- uuid_str – UUID in 36-byte hexadecimal string

Return converted UUID

Rtype cdata

uuid.frombin(uuid_bin)

Parameters

- 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

Parameters

- 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

Example

```
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
...
```

5.1.24 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.

Parameters

- 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.

Parameters

- 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.

Example

```
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'}
  ...
...
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.

5.1.25 Miscellaneous

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.

Parameters

- 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
...
```

5.1.26 Database error codes

In the current version of the binary protocol, error message, which is normally more descriptive than error code, is not present in server response. 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 follow only 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.

5.2 Rocks reference

This reference covers third-party Lua modules for Tarantool.

5.2.1 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]
```

For example:

```
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
---
...
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.

Example

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"
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
---
...
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]
```

For example:

```
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
---
...
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.

Example

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)
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.

5.2.2 Module 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.

5.2.3 Module 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' },
         >     { 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 ...
---
...
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.

On Terminal #1, say:

```
$ 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 = {
         >   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.

5.2.4 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.

5.3 Configuration reference

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 ]
```

5.3.1 Command options

-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.

Note: 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.

5.3.2 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	Example
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.

5.3.3 Initialization file

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().

5.3.4 Configuration parameters

Configuration parameters have the form: |br| 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

Run the server as a background task. The logger and pid_file parameters must be non-null for this to work.

Type: boolean |br| Default: false |br| Dynamic: no |br|

coredump

Deprecated. Do not use.

Type: boolean |br| Default: false |br| Dynamic: no |br|

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 |br| Default: null |br| Dynamic: yes |br|

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.

Note: 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 |br| Default: null |br| Dynamic: yes |br|

pid_file
: Store the process id in this file. Can be relative to work_dir. A typical value is "tarantool.pid".

  Type: string |br| Default: null |br| Dynamic: no |br|

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 |br| Default: false |br| Dynamic: yes |br|

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 |br| Default: "." |br| Dynamic: no |br|

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 |br| Default: "." |br| Dynamic: no |br|

username
: UNIX user name to switch to after start.

  Type: string |br| Default: null |br| Dynamic: no |br|

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 |br| Default: "." |br| Dynamic: no |br|

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 |br| box.cfg{work_dir='/home/user/A',wal_dir='B',snap_dir='C'} |br| 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 |br| Default: null |br| Dynamic: no |br|

Configuring the storage

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 |br| Default: 1.0 |br| Dynamic: no |br|

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 |br| Default: 1.1 |br| Dynamic: no |br|

slab_alloc_maximal

Size of the largest allocation unit. It can be increased if it is necessary to store large tuples.

Type: integer |br| Default: 1048576 |br| Dynamic: no |br|

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 |br| Default: 16 |br| Dynamic: no |br|

vinyl

The default vinyl configuration can be changed with
vinyl = {
  run_age_wm = number,
  run_age_period = number of seconds,
  memory_limit = number of gigabytes,
  compact_wm = number,
  threads = number,
  run_age = number,
  run_prio = number,
}
This method may change in the future.

Default values are:

```
vinyl = {
  run_age_wm = 0,
  run_age_period = 0,
  memory_limit = 1,
  compact_wm = 2,
  threads = 5,
  run_age = 0,
  run_prio = 2,
}
```

Snapshot daemon

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 |br| Default: 0 |br| Dynamic: yes |br|

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 |br| Default: 6 |br| Dynamic: yes |br|

Binary logging and snapshots

panic_on_snap_error, |br| panic_on_wal_error, |br| rows_per_wal, |br| snap_io_rate_limit, |br| wal_mode, |br| wal_dir_rescan_delay |br|

panic_on_snap_error
: If there is an error while reading the snapshot file (at server start), abort.

Type: boolean |br| Default: true |br| Dynamic: no |br|

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 |br| Default: true |br| Dynamic: yes |br|

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 |br| Default: 500000 |br| Dynamic: no |br|

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 |br| Default: null |br| Dynamic: yes |br|

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 |br| Default: "write" |br| Dynamic: yes |br|

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 |br| Default: 2 |br| Dynamic: no |br|

Replication

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 |br| box.cfg{replication_source = {uri#1,uri#2}} |br|

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 |br| Default: null |br| Dynamic: yes |br|

Networking

io_collect_interval, |br| readahead |br|

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 |br| Default: null |br| Dynamic: yes |br|

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 |br| Default: 16320 |br| Dynamic: yes |br|

Logging

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 |br| Default: 5 |br| Dynamic: yes |br|

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 |br| Default: null |br| Dynamic: no |br|

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 |br| Default: true |br| Dynamic: no |br|

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 |br| Default: 0.5 |br| Dynamic: yes |br|

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. |br|

```
mv Log_file Log_file.bak
```

On Terminal #1: put a message "Log Line #2" in the log file. |br|

```
log.info('Log Line #2')
```

On Terminal #2: use ps to find the process ID of the Tarantool server. |br|

```
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.) |br|

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
```

CHAPTER 6

Contributor's Guide

6.1 C API reference

6.1.1 Module 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.

    Parameters

    - ctx (box_funtion_ctx_t*) – an opaque structure passed to the stored C procedure by Tarantool
    - tuple (box_tuple_t*) – a tuple to return

    Returns -1 on error (perhaps, out of memory; check box_error_last())

    Returns 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.

    Parameters

    - char* name (const) – space name
    - len (uint32_t) – length of name

    Returns BOX_ID_NIL on error or if not found (check box_error_last())

    Returns 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.

Parameters

- space_id (uint32_t) – space identifier
- char* name (const) – index name
- len (uint32_t) – length of name

Returns BOX_ID_NIL on error or if not found (check box_error_last())

Returns 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.

Parameters

- 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

Returns -1 on error (check box_error_last())

Returns 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.

Parameters

- 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

Returns -1 on error (check box_error_last())

Returns 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.

Parameters

- 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

Returns -1 on error (check box_error_last())

Returns 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.

Parameters

- 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

Returns -1 on error (check box_error_last())

Returns 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.

Parameters

- 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

Returns -1 on error (check :box_error_last())

Returns 0 otherwise

See also space_object.upsert()

6.1.2 Module 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 Module 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.

Parameters

- 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.

Returns 0 - timeout

Returns >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.

Returns -1 and errno = ENOMEM if failed to create a task

Returns 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 Module 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.

Parameters

- error (box_error_t*) – error

Returns not-null string

uint32_t box_error_code(const box_error_t *error)
Return IPROTO error code

Parameters

- error (box_error_t*) – error

Returns enum box_error_code

const char * box_error_message(const box_error_t *error)
Return the error message

Parameters

- error (box_error_t*) – error

Returns 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.

Returns 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.

Parameters

- 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 Module 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.

Parameters

- 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.

Parameters

- 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

Parameters

- 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()).

Parameters

- 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.

Parameters

- fiber* f (struct) – fiber
- yesno (bool) – status to set

Returns previous state

void fiber_set_joinable(struct fiber *fiber, bool yesno)
Set fiber to be joinable (false by default).

Parameters

- 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.

Parameters

- 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.

Parameters

- 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 Module 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.

Parameters

- 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

Returns NULL on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Returns 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.

Parameters

- 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.

Returns -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Returns 0 on success. The end of data is not an error.

void box_iterator_free(box_iterator_t *iterator)
Destroy and deallocate iterator.

Parameters

- 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.

Parameters

- space_id (uint32_t) – space identifier
- index_id (uint32_t) – index identifier

Returns -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Returns >= 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.

Parameters

- space_id (uint32_t) – space identifier
- index_id (uint32_t) – index identifier

Returns -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Returns >= 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).

Parameters

- 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.

Parameters

- 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

Returns -1 on error (check :ref:box_error_last‘c_api-error-box_error_last>‘)

Returns 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.

Parameters

- 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

Returns -1 on error (check :ref:box_error_last()‘c_api-error-box_error_last>‘)

Returns 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.

Parameters

- 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

Returns -1 on error (check :ref:box_error_last()‘c_api-error-box_error_last>‘)

Returns 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.

Parameters

- 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

Returns -1 on error (check :ref:box_error_last()‘c_api-error-box_error_last>‘)

Returns 0 on success

See also: index_object.count()

6.1.7 Module latch

box_latch_t

A lock for cooperative multitasking environment

box_latch_t *box_latch_new(void)
Allocate and initialize the new latch.

Returns allocated latch object

Return type box_latch_t *

void box_latch_delete(box_latch_t *latch)
Destroy and free the latch.

Parameters

- 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.

Parameters

- latch (box_latch_t*) – latch to lock

Returns status of operation. 0 - success, 1 - latch is locked

Return type int

void box_latch_unlock(box_latch_t *latch)
Unlock a latch. The fiber calling this function must own the latch.

Parameters

- latch (box_latch_t*) – latch to unlock

6.1.8 Module 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.

Parameters

- L (lua_State*) – Lua State
- ctypeid (uint32_t) – FFI's CTypeID of this cdata

Returns 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

Parameters

- L (lua_State*) – Lua State
- idx (int) – stack index
- ctypeid (uint32_t*) – output argument. FFI's CTypeID of returned cdata

Returns 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.

Parameters

- 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

Parameters

- L (lua_State*) – Lua State
- char* ctypename (const) – C type name as string (e.g. "struct request" or "uint32_t")

Returns CTypeID

See also: luaL_pushcdata(), luaL_checkcdata()

int luaL_cdef(struct lua_State *L, const char *ctypename)
Declare symbols for FFI

Parameters

- L (lua_State*) – Lua State
- char* ctypename (const) – C definitions (e.g. "struct stat")

Returns 0 on success

Returns 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

Parameters

- 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

Parameters

- 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.

Returns 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.

Returns the converted number or 0 of argument can't be converted

6.1.9 Module say (logging)

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.

Parameters

- 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.

Parameters

- 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 Module 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 Module 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 Module 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.

Parameters

- 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

Returns NULL on out of memory

Returns 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.

Parameters

- tuple (box_tuple_t*) – a tuple

Returns -1 on error

Returns 0 otherwise

See also: box_tuple_unref()

void box_tuple_unref(box_tuple_t *tuple)

Decrease the reference counter of tuple.

Parameters

- tuple (box_tuple_t*) – a tuple

Returns -1 on error

Returns 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).

Parameters

- 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).

Parameters

- 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.

Returns -1 on error

Returns number of bytes written on success.

box_tuple_format_t *box_tuple_format(const box_tuple_t *tuple)
Return the associated format.

Parameters

- tuple (box_tuple_t*) – a tuple

Returns 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.

Parameters

- tuple (box_tuple_t*) – a tuple
- field_id (uint32_t) – zero-based index in MsgPack array.

Returns NULL if i >= box_tuple_field_count()

Returns 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.

Parameters

- it (box_tuple_iterator_t*) – a tuple iterator

Returns position

void box_tuple_rewind(box_tuple_iterator_t *it)
Rewind iterator to the initial position.

Parameters

- 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).

Parameters

- 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.

Parameters

- it (box_tuple_iterator_t*) –

Returns NULL if there are no more fields

Returns 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 Module 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.

Returns 0 on success

Returns -1 on error. Perhaps a transaction has already been started

int box_txn_commit(void)
    Commit the current transaction.

        Returns 0 on success

        Returns -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.

        Returns 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

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
<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;
    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_STRING | |
|                  |        +-------------+-----------+ |
|                  |                   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.

Requests

- 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:

+==================+==================+
|                  |                  |
|   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
+-----------+==========+===========+
|           |          |           |
|    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 |
|                       |                  |
+=======================+==================+
                    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
+================+================+===================++-------+
|                |                |    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 have the same format. They start with:

```
SNAP\n
0.12\n
Server: e6eda543-eda7-4a82-8bf4-7ddd442a9275\n
VClock: {1: 0}\n
\n
...
```

So, Header of an SNAP/XLOG consists of:

```
<format>\n
<format_version>\n
Server: <server_uuid>\n
VClock: <vclock_map>\n
\n
```

There are two markers: tuple beginning - 0xd5ba0bab and EOF marker - 0xd510aded. So, next, between Header and EOF marker there's data with the following schema:

```
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
```

6.2.2 Data persistence and the WAL file format

To maintain data persistence, Tarantool writes each data change request (INSERT, UPDATE, DELETE, REPLACE) 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 (its format is the same 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             File header: "XLOG\n"
30 2e 31 32 0a             File header: "0.12\n" = version
...                        (not shown = more header + tuples for system spaces)
d5 ba 0b ab                Magic row marker always = 0xab0bbad5 if version 0.12
19 00                      Length, not including length of header, = 25 bytes
ce 16 a4 38 6f             Record header: previous crc32, current crc32,
a7 cc 73 7f 00 00 66 39
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 "Double"
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: |br| 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: |br| 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. |br| 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: |br| 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: |br|

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. |br| 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: |br| 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. |br| 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. |br| 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. |br| 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). |br| 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 |br| where: |br| c_api is the directory name, |br| box_index is the file name (without ".rst"), and |br| 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.

Parameters

- 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.

Parameters

- 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.

1. 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.
2. 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:

1. 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.

2. 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.

3. when you use sparse to literally create a _new_ type for type-checking.

4. 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.

5. 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. |br| Prentice Hall, Inc., 1988. |br| ISBN 0-13-110362-8 (paperback), 0-13-110370-9 (hardback).
- The Practice of Programming by Brian W. Kernighan and Rob Pike. |br| Addison-Wesley, Inc., 1999. |br| 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!

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).

[1] PEP 7, Style Guide for C Code, van Rossum
[2] Barry's GNU Mailman style guide

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,
    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).
- __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

[3] CamelCase Wikipedia page

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>
- genindex

Lua Module Index