Going low level with TCP sockets and `:gen_tcp`

Orestis Markou

@orestis

orestis.gr

About

Orestis Markou

@orestis

orestis.gr

Why?

External hardware control
^ PJLink protocol for projectors
^ Obscure IP-powerbars
^ Terse official docs
^ Foundation of the Internet
^ Will make you wonder how everything even *works*
^ Will make you appreciate the engineers that designed it

Internet Protocol (IP in TCP/IP)

- Like passing notes in school
- Put data in a packet, pass it on
- Hope for the best!

Packet arrived?

^ Data too big?

^ Ordering?

Transport Control Protocol (TCP in TCP/IP)

Photo by Annie Spratt on Unsplash

TCP/IP

- **Point-to-point**,
- **stream**
- **two-way**

make connection/dial phone
^ just talk / listen (write data/read data)

BSD Sockets API

- `socket()`
- `bind()`
- `listen()`
- `accept()`
- `connect()`
- …

1983

^ network as file

^ POSIX standard

^ Most common TCP/IP API

^ Implemented by your OS

^ Slightly breaks the illusion

:gen_tcp

- accept/1,2
- close/1
- connect/3,4
- listen/2
- recv/2,3
- send/2
- shutdown/2
- controlling_process/2

BSD Sockets in the BEAM

^ Arcane & intricate
^ reflects the intricacies of BSD & BEAM together

Hello world, server

- Accept connections on port 4001
- Send the current datetime
- Close the connection

Demo

example1.exs

Server Code

```elixir
def server do
  {:ok, listen_socket} = :gen_tcp.listen(4001, [:binary,
                                                reuseaddr: true])
  server_handler(listen_socket)
end

def server_handler(listen_socket) do
  {:ok, socket} = :gen_tcp.accept(listen_socket)
  d = DateTime.utc_now() |> DateTime.to_string()
  :ok = :gen_tcp.send(socket, d <> "\r\n")
  :ok = :gen_tcp.shutdown(socket, :read_write)
  server_handler(listen_socket)
end
```

Server Code

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def server do
  {:ok, listen_socket} = :gen_tcp.listen(4001, [:binary,
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  :ok = :gen_tcp.shutdown(socket, :read_write)
  server_handler(listen_socket)
end
```

- `:binary` vs charlist for data
- `reuseaddr` useful for demo purposes

Server Code

```
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  d = DateTime.utc_now() |> DateTime.to_string()
  :ok = :gen_tcp.send(socket, d <> "\r\n")
  :ok = :gen_tcp.shutdown(socket, :read_write)
  server_handler(listen_socket)
end
```

Listen socket vs actual socket

^ accept is blocking

^ shutdown is more gentle

^ recurse for the next connection

Client code

```
def client do
  {:ok, socket} = :gen_tcp.connect('localhost', 4001,
                    [:binary, active: true])
  client_handler(socket)
end

def client_handler(socket) do
  receive do
    {:tcp, ^socket, data} ->
      IO.write data
      client_handler(socket)
    {:tcp_closed, ^socket} -> IO.puts "== CLOSED =="
  end
end
```

Client code

```elixir
def client do
  {:ok, socket} = :gen_tcp.connect('localhost', 4001,
                    [:binary, active: true])
  client_handler(socket)
end

def client_handler(socket) do
  receive do
    {:tcp, ^socket, data} ->
      IO.write data
      client_handler(socket)
    {:tcp_closed, ^socket} -> IO.puts "== CLOSED =="
  end
end
```

Host is always a charlist

^ `active` mode turns incomning data into erlang messages (default)

Client code

```elixir
def client do
  {:ok, socket} = :gen_tcp.connect('localhost', 4001,
                    [:binary, active: true])
  client_handler(socket)
end

def client_handler(socket) do
  receive do
    {:tcp, ^socket, data} ->
      IO.write data
      client_handler(socket)
    {:tcp_closed, ^socket} -> IO.puts "== CLOSED =="
  end
end
```

One server, many clients

Server Code

```elixir
def server do
  {:ok, listen_socket} = :gen_tcp.listen(4001, [:binary,
                                                reuseaddr: true])
  for _ <- 0..10, do: spawn(fn -> server_handler(listen_socket) end)
  Process.sleep(:infinity)
end

def server_handler(listen_socket) do
  {:ok, socket} = :gen_tcp.accept(listen_socket)
  :ok = :gen_tcp.send(socket, "Hello!\r\n")
  :ok = :gen_tcp.shutdown(socket, :read_write)
  server_handler(listen_socket)
end
```

One process listens, multiple processes accept

^ Use Ranch for this: https://github.com/ninenines/ranch

Two-way stream - server

- Accept connections
- Send **`"HELLO?"`**
- Wait for name
- Send **`"Hello, <name>!"`**
- Close the connection

Two-way stream - client

- Connect
- Wait for **`"HELLO?"`**
- Send name
- Read all data
- Wait until connection is closed

Two way - demo

example2b.exs

Two-way - server

```
def server_handler(listen_socket) do
  {:ok, socket} = :gen_tcp.accept(listen_socket)
  :ok = :gen_tcp.send(socket, "HELLO?")
  receive do
    {:tcp, ^socket, data} ->
      :ok = :gen_tcp.send(socket, "Hello, #{data}!\r\n")
  end
  :ok = :gen_tcp.shutdown(socket, :read_write)
  server_handler(listen_socket)
end
```

two way communications

Two-way - client

```elixir
def client_handler(socket) do
  receive do
    {:tcp, ^socket, "HELLO?"} ->
      d = IO.gets("Enter your name: ") |> String.trim()
      :ok = :gen_tcp.send(socket, d)
      client_handler(socket)
    {:tcp, ^socket, data} ->
      IO.write data
      client_handler(socket)
    {:tcp_closed, ^socket} -> IO.puts "== CLOSED =="
  end
end
```

Two-way - client

```elixir
def client_handler(socket) do
  receive do
    {:tcp, ^socket, "HELLO?"} ->
      d = IO.gets("Enter your name: ") |> String.trim()
      :ok = :gen_tcp.send(socket, d)
      client_handler(socket)
    {:tcp, ^socket, data} ->
      IO.write data
      client_handler(socket)
    {:tcp_closed, ^socket} -> IO.puts "== CLOSED =="
  end
end
```

Passive mode

- Closer to the original BSD API
- Read/write to a "file"
- Blocking API with timeouts
- Provides back-pressure

send is the same

^ recv is changing

Passive mode server

```
def server do
  {:ok, listen_socket} = :gen_tcp.listen(4001, [:binary, reuseaddr: true
                                                active: false])
  server_handler(listen_socket)
end

def server_handler(listen_socket) do
  {:ok, socket} = :gen_tcp.accept(listen_socket)
  :ok = :gen_tcp.send(socket, "HELLO?")
  {:ok, data} = :gen_tcp.recv(socket, 0)
  :ok = :gen_tcp.send(socket, "Hello, #{data}!\r\n")
  :ok = :gen_tcp.shutdown(socket, :read_write)
  server_handler(listen_socket)
end
```

Passive mode server

```elixir
def server do
  {:ok, listen_socket} = :gen_tcp.listen(4001, [:binary, reuseaddr: true
                                                active: false])
  server_handler(listen_socket)
end

def server_handler(listen_socket) do
  {:ok, socket} = :gen_tcp.accept(listen_socket)
  :ok = :gen_tcp.send(socket, "HELLO?")
  {:ok, data} = :gen_tcp.recv(socket, 0, 5000)
  :ok = :gen_tcp.send(socket, "Hello, #{data}!\r\n")
  :ok = :gen_tcp.shutdown(socket, :read_write)
  server_handler(listen_socket)
end
```

active: false (default is true even for servers)
^ read zero bytes, blocking call, timeout
5000 millis
^ default timeout infinity

Passive mode client

```elixir
def client do
  {:ok, socket} = :gen_tcp.connect('localhost', 4001,
    [:binary, active: false])
  client_handler(socket)
end

def client_handler(socket) do
  case :gen_tcp.recv(socket, 0, 5000) do
    {:ok, "HELLO?"} ->
      d = IO.gets("Enter your name: ") |> String.trim()
      :ok = :gen_tcp.send(socket, d)
      client_handler(socket)
    {:ok, data} ->
      IO.write data
      client_handler(socket)
    {:error, :closed} -> IO.puts "== CLOSED =="
  end
end
```

Passive mode client

```
def client do
  {:ok, socket} = :gen_tcp.connect('localhost', 4001,
    [:binary,
    active: false])
  client_handler(socket)
end
```

Passive mode client

```
def client_handler(socket) do
  case :gen_tcp.recv(socket, 0, 5000) do
    {:ok, "HELLO?"} ->
      d = IO.gets("Enter your name: ") |> String.trim()
      :ok = :gen_tcp.send(socket, d)
      client_handler(socket)
    {:ok, data} ->
      IO.write data
      client_handler(socket)
    {:error, :closed} -> IO.puts "== CLOSED =="
  end
end
```

Passive mode

- `recv(socket, length)`
- `recv(socket, length, timeout)`
- `timeout` defaults to `:infinity`
- When `length > 0`, "read exactly `length` bytes"
- When `length == 0`, "read all available"

Major gotchas

- *Passive:* How many bytes to read?
- *Active:* Will "HELLO?" arrive in a single message?
- **This is by design!**

Something like race condition!
^ Depends on various arcane parameters (OS/BEAM)
^ Works most of the time with tiny payloads like this
^ Will break on real-world usage
^ Another level of abstraction is needed

Protocols

- Give shape to the data packets
- Common or niche or your own!

Some are even provided by `:gen_tcp`

Protocol specifications

- What comes next?
- What form does it come in?
- Who is responsible for the next transmission?
- (Distributed state machine)

Protocol specifications

e.g. Daytime protocol (RFC 867)

TCP Based Daytime Service
One daytime service is defined as a connection based application on TCP. A server listens for TCP connections on TCP port 13. Once a connection is established the current date and time is sent out the connection as a ascii character string (and any data received is thrown away). The service closes the connection after sending the quote.

Protocol specifications

e.g. HTTP/1.1 protocol (RFC 2616)

<176 pages>

e.g. Memcached protocol

<1200 lines>

Built-in protocols

- Provided by :gen_tcp
- Limited in scope, non-extensible
- Might be useful

Prefix header length

`[packet: 2]`

- Transparently add/strip header
- 1, 2 or 4 byte header length
- Support up to 2GB messages
- Very useful when you control both ends

Line-based messages

```
[packet: :line,
line_delimiter: ?\n,
packet_size: 255]
```

- Split incoming messages by newline
- Outgoing messages are your responsibility
- A few gotchas, must evaluate

unfortunately can't set CRLF as delimiter
^ might not be as bullet proof as needed

Demo

protocols.exs

`/usr/local/opt/memcached/bin/memcached`

Mutable sockets

- Can change mode on-the-fly (binary, active)
- Active mode can be one shot or N-shot or permanent
- Can change protocols on the fly
- Read a line, extract content length, read raw bytes

```elixir
def memcached_client_get do
  {:ok, socket} = :gen_tcp.connect('localhost', 11211,
    [:binary,  active: false,
      packet: :line])
  :gen_tcp.send(socket, "get elixirconf\r\n")
  {:ok, response} = :gen_tcp.recv(socket, 0, 5000)
  IO.puts "Raw response:"
  IO.inspect response
  <<"VALUE elixirconf ", resp::binary>> = response
  [_, length] = resp |> String.trim() |> String.split()
    |> Enum.map(&String.to_integer/1)
  :inet.setopts(socket, [packet: 0])
  {:ok, data} = :gen_tcp.recv(socket, length, 5000)
  IO.puts "Actual data:"
  IO.inspect data
end
```

```elixir
def memcached_client_get do
  {:ok, socket} = :gen_tcp.connect('localhost', 11211,
    [:binary,  active: false,
      packet: :line])
  :gen_tcp.send(socket, "get elixirconf\r\n")
  {:ok, response} = :gen_tcp.recv(socket, 0, 5000)
  IO.puts "Raw response:"
  IO.inspect response
  <<"VALUE elixirconf ", resp::binary>> = response
  [_, length] = resp |> String.trim() |> String.split()
    |> Enum.map(&String.to_integer/1)
  :inet.setopts(socket, [packet: 0])
  {:ok, data} = :gen_tcp.recv(socket, length, 5000)
  IO.puts "Actual data:"
  IO.inspect data
end
```

Pain point: Untangle the protocol logic from the socket logic

- Abstract the "transport" out
- Provide a dummy transport for testing
- Transparently adapt to TLS/SSL, tunnels etc.

Resources

- TCP/IP Illustrated, Volume 1 [Fall & Stevens]
- http://erlang.org/doc/man/gen_tcp.html
- http://erlang.org/doc/man/inet.html
- https://ninenines.eu/docs/en/ranch/1.4/guide/
- https://github.com/orestis/elixir_tcp

Thank you!

Questions?

https://github.com/orestis/elixir_tcp

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