`net2`
Technical Specification

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Abstract

This is a technical specification for `net2`, a networking abstraction for URL-addressable agents communicating via byte streams. Its purpose is to drive the engineering design process.

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Chapter 1

Introduction

This report defines an abstract model for `net2`.

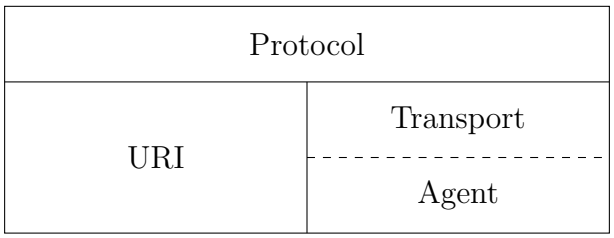

Figure 1.1: The `net2` API stack

Chapter 2

URI

- Explain how URIs work in `net2`.

  "A URI has several parts. The authority defines *who* you are talking to. The scheme defines *how* you talk to them. The path and query define *what resource* you're talking to them about."

- We roll our own URI sub-system.

$\mathcal{S}$ = schemes $\quad$ $\mathcal{A}$ = authorities $\quad$ $\mathcal{P}$ = paths $\quad$ $\mathcal{Q}$ = queries

$\mathsf{scheme} : \mathcal{U} \to \mathcal{S}$ $\quad$ $\mathsf{authority} : \mathcal{U} \to \mathcal{A}$ $\quad$ $\mathsf{path} : \mathcal{U} \to \mathcal{P}$ $\quad$ $\mathsf{query} : \mathcal{U} \to \mathcal{Q}$

Chapter 3

Transport

A *byte stream* is a one-way communications channel. A *connection* is a pair of opposing byte streams.

3.1 Primitive types

References

$\mathcal{L}$ = listeners $\qquad$ $\mathcal{T}$ = transports

A *reference* is an opaque token that represents a portion of run-time state. A listener represents a connection request queue. A transport represents a connection.

Ports

$\mathcal{I}$ = input ports $\qquad$ $\mathcal{O}$ = output ports

A *port* is a host platform object that represents one end of a byte stream. Ports come in pairs—an input port and an output port. An output port sends bytes to the byte stream. An input port receives bytes from the byte stream.

Literals

$\mathcal{B}$ = byte arrays $\qquad$ $\varnothing$ = void

A *literal* is a fixed unit of data. A byte array is a unit of data exchange. The void literal is returned by operations with a side effect and no useful result.

$[k \mapsto v]\mathrm{D}$	associate k with v in D.
$\mathrm{D} \setminus \{k \mapsto \cdot\}$	remove from D the association keyed by k.
$\mathrm{D}(k)$	lookup k in D.

Figure 3.1: Dictionary notation

3.2 Run-time state

$$\mathrm{L} : \mathcal{L} \to \mathcal{A} \qquad\qquad \mathrm{T} : \mathcal{T} \to \mathcal{A} \times \mathcal{A} \times \mathcal{I} \times \mathcal{O}$$

The run-time state is modeled as a set of dictionaries. A *dictionary* is an associative array. Dictionaries associate references to some underlying data. Associations can be added, removed, or looked up. All side effects occur during operations on dictionaries in the run-time state.

L records the addresses of listeners. Given listener ℓ and local authority authority a_L, the host platform queues requests to connect to a_L under ℓ for as long as $\mathrm{L}(\ell) = a_L$.

T records the addresses and ports of established connections. Given transport t, addresses a_L, a_R, and ports p_I, p_O, the host platform establishes a connection between local authority a_L and remote authority a_R for as long as $\mathrm{T}(t) = (a_L, a_R, p_I, p_O)$. Updating p_I or p_O will exchange bytes over the connection.

3.3 The Agent API

A registered name driver implements the operations defined in this section.

$$\text{listener} : \mathcal{A} \to \mathcal{L} \qquad\qquad \text{listener}(a_L) = \ell$$

Creates a reference ℓ to a connection request queue associated with local authority a_L.

$$\text{accepter} : \mathcal{L} \to \mathcal{T} \times \mathcal{A} \times \mathcal{I} \times \mathcal{O} \qquad\qquad \text{accepter}(\ell) = \langle t, a_R, p_I, p_O \rangle$$

Creates a reference t to a connection request from remote authority a_R queued under listener ℓ. Opens ports p_I, p_O for exchanging bytes over the connection.

$$\text{connector} : \mathcal{A} \to \mathcal{T} \times \mathcal{A} \times \mathcal{I} \times \mathcal{O} \qquad\qquad \text{connector}(a_R) = \langle t, a_L, p_I, p_O \rangle$$

Creates a reference t to a connection from local authority a_L to remote authority a_R. Opens ports p_I, p_O for exchanging bytes over the connection.

$\tau ::= \mathsf{listen}(\tau)$	bind authority		$v ::= a$	authority
$\mid \mathsf{accept}(\tau)$	accept connection		$\mid b$	byte array
$\mid \mathsf{connect}(\tau)$	connect to authority		$\mid \ell$	listener
$\mid \mathsf{release}(\tau)$	unbind / disconnect		$\mid t$	transport
$\mid \mathsf{send}(\tau, \tau)$	send bytes		$\mid u$	URI
$\mid \mathsf{receive}(\tau)$	receive bytes		$\mid \varnothing$	void

Figure 3.2: Transport syntax

$$\text{sender} : \mathcal{B} \times \mathcal{O} \to \mathcal{O} \qquad \text{sender}(b, p_O) = p'_O$$

Creates a port update p'_O that writes byte array b to port p_O.

$$\text{receiver} : \mathcal{I} \to \mathcal{B} \times \mathcal{I} \qquad \text{receiver}(p_I) = \langle b, p'_I \rangle$$

Creates a port update p'_I that reads byte array b from port p_I.

3.4 Creating and destroying connections

$$\mathsf{listen} : \mathcal{A} \to \mathcal{L} \qquad \mathsf{listen}(a_L) = \ell \qquad \frac{\text{listener}(a_L) = \ell}{\mathrm{L} \vdash \mathsf{listen}(a_L) \rightsquigarrow [\ell \mapsto a_L]\mathrm{L} \vdash \ell} \textsc{Lsn}$$

Creates a listener ℓ on local authority a_L.

$$\mathsf{accept} : \mathcal{L} \to \mathcal{T} \qquad \mathsf{accept}(\ell) = t \qquad \frac{\mathrm{L}(\ell) = u_L \qquad \text{accepter}(\ell) = \langle t, a_R, p_I, p_O \rangle}{\mathrm{T} \vdash \mathsf{accept}(\ell) \rightsquigarrow [t \mapsto \langle a_L, a_R, p_I, p_O \rangle]\mathrm{T} \vdash t} \textsc{Acc}$$

Accepts a transport t from listener ℓ.

$$\mathsf{connect} : \mathcal{A} \to \mathcal{T} \qquad \mathsf{connect}(a) = t \qquad \frac{\text{connector}(a_R) = \langle t, a_L, p_I, p_O \rangle}{\mathrm{T} \vdash \mathsf{connect}(a_R) \rightsquigarrow [t \mapsto \langle a_L, a_R, p_I, p_O \rangle]\mathrm{T} \vdash t} \textsc{Con}$$

Connects a transport t from local authority a_L to remote authority a_R.

$$\mathsf{release} : X \to \varnothing \qquad \mathsf{release}(x) = \varnothing \qquad \frac{\{x \mapsto \cdot\} \in X}{X \vdash \mathsf{release}(x) \rightsquigarrow X \setminus \{x \mapsto \cdot\} \vdash \varnothing} \textsc{Rls}$$

Stops listening when x is a listener. Closes the connection when x is a transport.

3.5 Exchanging bytes

$$\mathsf{send} : \mathcal{B} \times \mathcal{T} \to \varnothing \qquad \mathsf{send}(b, t) = \varnothing \qquad \frac{\mathrm{T}(t) = \langle a_L, a_R, p_I, p_O \rangle \qquad \mathrm{sender}(b, p_O) = p'_O}{\mathrm{T} \vdash \mathsf{send}(b, t) \rightsquigarrow [t \mapsto \langle a_L, a_R, p_I, p'_O \rangle]\mathrm{T} \vdash \varnothing}\ \textsc{Snd}$$

Sends byte array b over transport t.

$$\mathsf{receive} : \mathcal{T} \to \mathcal{B} \qquad \mathsf{receive}(t) = b \qquad \frac{\mathrm{T}(t) = \langle a_L, a_R, p_I, p_O \rangle \qquad \mathrm{receiver}(p_I) = \langle b, p'_I \rangle}{\mathrm{T} \vdash \mathsf{receive}(t) \rightsquigarrow [t \mapsto \langle a_L, a_R, p'_I, p_O \rangle]\mathrm{T} \vdash b}\ \textsc{Rcv}$$

Receives byte array b over transport t.

Chapter 4

Protocol

$\mathcal{C} = \text{codecs}$ $\mathcal{D} = \text{decoders}$ $\mathcal{E} = \text{encoders}$

$\mathcal{C} : \{X \to Y\}$ $\mathcal{D} : \{\mathcal{B} \to X\}$ $\mathcal{E} : \{X \to \mathcal{B}\}$

4.1 Codecs

A *codec* is a function for restructuring data. A *decoder* is a codec that consumes byte arrays. An *encoder* is a codec that produces byte arrays.

Decoders

$\mathsf{decode} : \mathcal{D} \times \mathcal{T} \to X$ $\mathsf{decode}(d, t) = x$ $\dfrac{\mathrm{T} \vdash \mathsf{receive}(t) \rightsquigarrow \mathrm{T}' \vdash b \qquad d(b) = x}{\mathrm{T} \vdash \mathsf{decode}(d, t) \rightsquigarrow \mathrm{T}' \vdash x}$ DEC

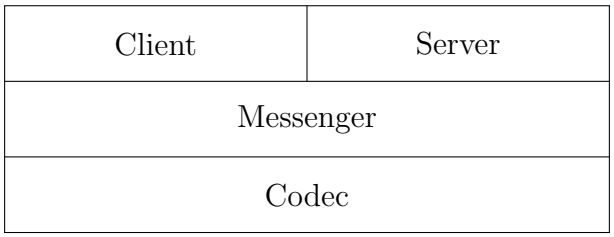

Figure 4.1: The Protocol API stack

Encoders

$$\mathsf{encode} : X \times \mathcal{E} \times \mathcal{T} \to \varnothing \qquad \mathsf{encode}(x, e, t) = \varnothing \qquad \frac{e(x) = b}{\mathsf{encode}(x, e, t) \rightsquigarrow \mathsf{send}(b, t)}\ \textsc{Enc}$$

Composites

$$c : X \to Y \qquad d : \mathcal{B} \to X \qquad e : Y \to \mathcal{B} \qquad c \circ d : \mathcal{B} \to Y \qquad e \circ c : X \to \mathcal{B}$$

4.2 Messengers

Primitive types

$$\mathcal{M} = \text{messengers}$$

Run-time state

$$\mathrm{M} : \mathcal{M} \to \mathcal{D} \times \mathcal{E} \times \mathcal{T}$$

Creating and destroying messengers

$$\mathsf{messenger} : \mathcal{D} \times \mathcal{E} \times \mathcal{T} \to \mathcal{M} \qquad \mathsf{messenger}(d, e, t) = m$$

$$\frac{}{\mathrm{M} \vdash \mathsf{messenger}(d, e, t) \rightsquigarrow [m \mapsto \langle d, e, t \rangle]\mathrm{M} \vdash m}\ \textsc{Msn}$$

$$\frac{\mathrm{M}(m) = \langle d, e, t \rangle \qquad \mathrm{T} \vdash \mathsf{release}(t) \rightsquigarrow \mathrm{T}' \vdash \varnothing}{\mathrm{M}, \mathrm{T} \vdash \mathsf{release}(m) \rightsquigarrow \mathrm{M} \setminus \{m \mapsto \cdot\}, \mathrm{T}' \vdash \varnothing}\ \textsc{RlsM}$$

Reading and writing messages

$$\mathsf{read} : \mathcal{M} \to \mathcal{B} \qquad \mathsf{read}(m) = b \qquad \frac{\mathrm{M}(m) = \langle d, e, t \rangle}{\mathsf{read}(m) \rightsquigarrow \mathsf{decode}(d, t)}\ \textsc{Rd}$$

$$\mathsf{write} : \mathcal{B} \times \mathcal{M} \to \varnothing \qquad \mathsf{write}(b, m) = \varnothing \qquad \frac{\mathrm{M}(m) = \langle d, e, t \rangle}{\mathsf{write}(x, m) \rightsquigarrow \mathsf{encode}(x, e, t)}\ \textsc{Wr}$$

4.3 Clients and servers

Appendix A

Mathematical Reference

Sets	
$\mathcal{A}$	URI authorities
$\mathcal{B}$	byte arrays
$\mathcal{C}$	codecs
$\mathcal{D}$	decoders
$\mathcal{E}$	encoders
$\mathcal{I}$	input ports
$\mathcal{L}$	listeners
$\mathcal{M}$	messengers
$\mathcal{O}$	output ports
$\mathcal{P}$	URI paths
$\mathcal{Q}$	URI queries
$\mathcal{S}$	URI schemes
$\mathcal{T}$	transports
$\varnothing$	void

Appendix B

Glossary

agent A URL-addressable process capable of exchanging bytes.

authority The authority component of a URI. This could be an IP address and port number, or other kinds of extensible registered names [BLFM14].

byte array A finite sequence of bytes.

byte stream A one-way communications channel.

connection A two-way communications channel.

connector A means of requesting a connection to another agent.

dictionary A binary relation between references and run-time state.

host platform The programming platform implementing `net2`.

input port A port that receives bytes.

listener A means of accepting connection requests from other agents.

output port A port that sends bytes.

port One end of a byte stream.

reference An opaque token that identifies a set of related objects.

scheme The scheme component of a URI.

transport A reliable, buffered, and ordered means of exchanging bytes with other agents.

URL A URI, as defined in RFC 3986 [BLFM14], that locates an agent.

References

[BLFM14] Tim Berners-Lee, Roy Fielding, and Larry Masinter. Rfc 3986, uniform resource identifier (uri): Generic syntax, 2005. *URL: http://www. faqs. org/rfcs/rfc3986. html*, 2014.

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