Define an application protocol

https://github.com/heig-vd-dai-course

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Objectives

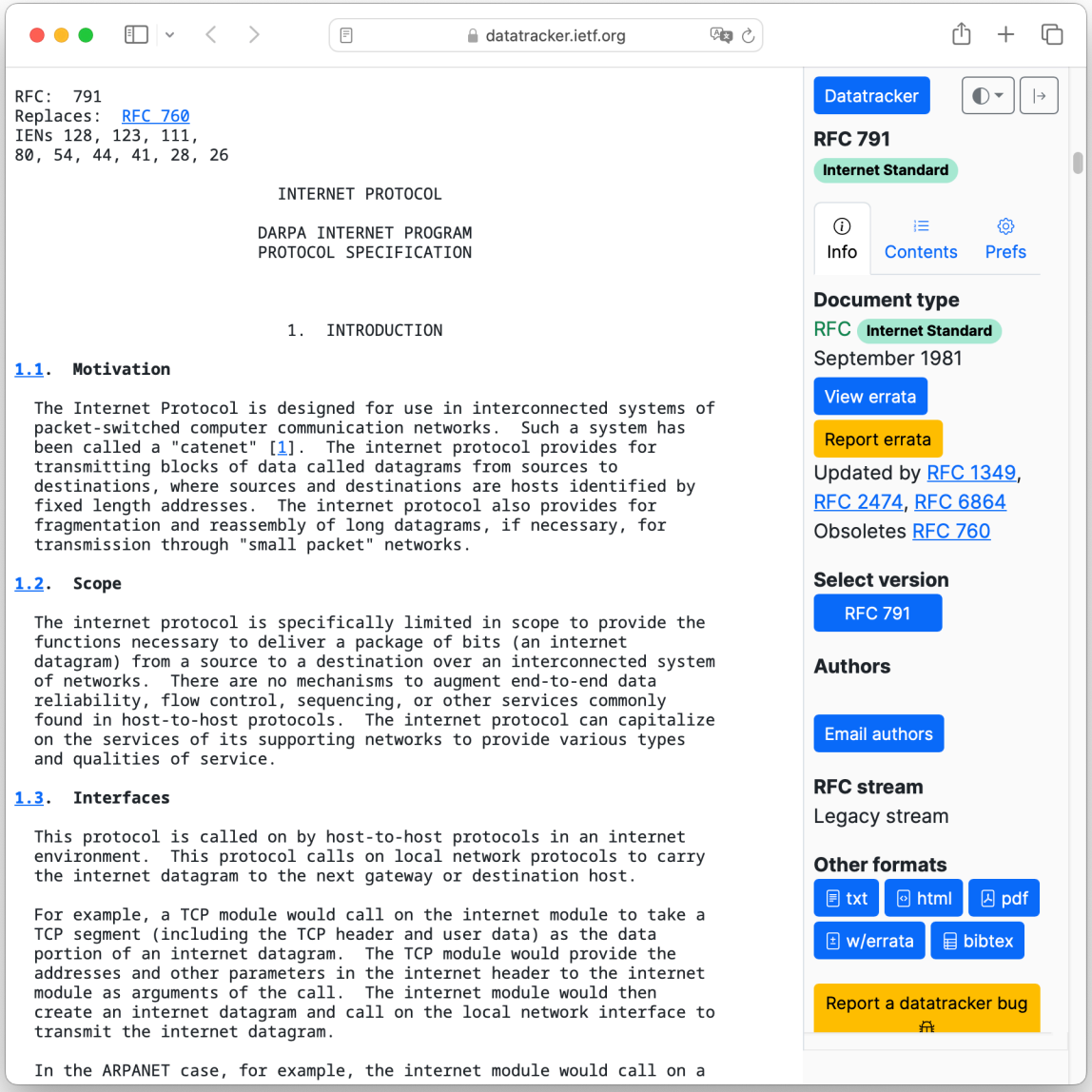
- Refresh on networking
- Learn where to find information about application protocols
- Understand application protocol
- Define application protocols
- How to use an application protocol
- **While quite short, one of the most important chapters of the course!**

A quick reminder about networking

More details for this section in the course material. You can find other resources and alternatives as well.

The Internet Protocol (IP)

- Each computer has a unique IP address
- IPv4 addresses are limited; NAT routers share IP addresses
- IPv6 fixes this issue
- IP addresses are used to route packets



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```
RFC:  791
Replaces:  RFC 760
IENs 128, 123, 111,
80, 54, 44, 41, 28, 26

                         INTERNET PROTOCOL

                      DARPA INTERNET PROGRAM
                      PROTOCOL SPECIFICATION


                         1.  INTRODUCTION

1.1.  Motivation

  The Internet Protocol is designed for use in interconnected systems of
  packet-switched computer communication networks.  Such a system has
  been called a "catenet" [1].  The internet protocol provides for
  transmitting blocks of data called datagrams from sources to
  destinations, where sources and destinations are hosts identified by
  fixed length addresses.  The internet protocol also provides for
  fragmentation and reassembly of long datagrams, if necessary, for
  transmission through "small packet" networks.

1.2.  Scope

  The internet protocol is specifically limited in scope to provide the
  functions necessary to deliver a package of bits (an internet
  datagram) from a source to a destination over an interconnected system
  of networks.  There are no mechanisms to augment end-to-end data
  reliability, flow control, sequencing, or other services commonly
  found in host-to-host protocols.  The internet protocol can capitalize
  on the services of its supporting networks to provide various types
  and qualities of service.

1.3.  Interfaces

  This protocol is called on by host-to-host protocols in an internet
  environment.  This protocol calls on local network protocols to carry
  the internet datagram to the next gateway or destination host.

  For example, a TCP module would call on the internet module to take a
  TCP segment (including the TCP header and user data) as the data
  portion of an internet datagram.  The TCP module would provide the
  addresses and other parameters in the internet header to the internet
  module as arguments of the call.  The internet module would then
  create an internet datagram and call on the local network interface to
  transmit the internet datagram.

  In the ARPANET case, for example, the internet module would call on a
```

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RFC 791

Internet Standard

Info | Contents | Prefs

Document type

RFC Internet Standard

September 1981

View errata

Report errata

Updated by RFC 1349, RFC 2474, RFC 6864

Obsoletes RFC 760

Select version

RFC 791

Authors

Email authors

RFC stream

Legacy stream

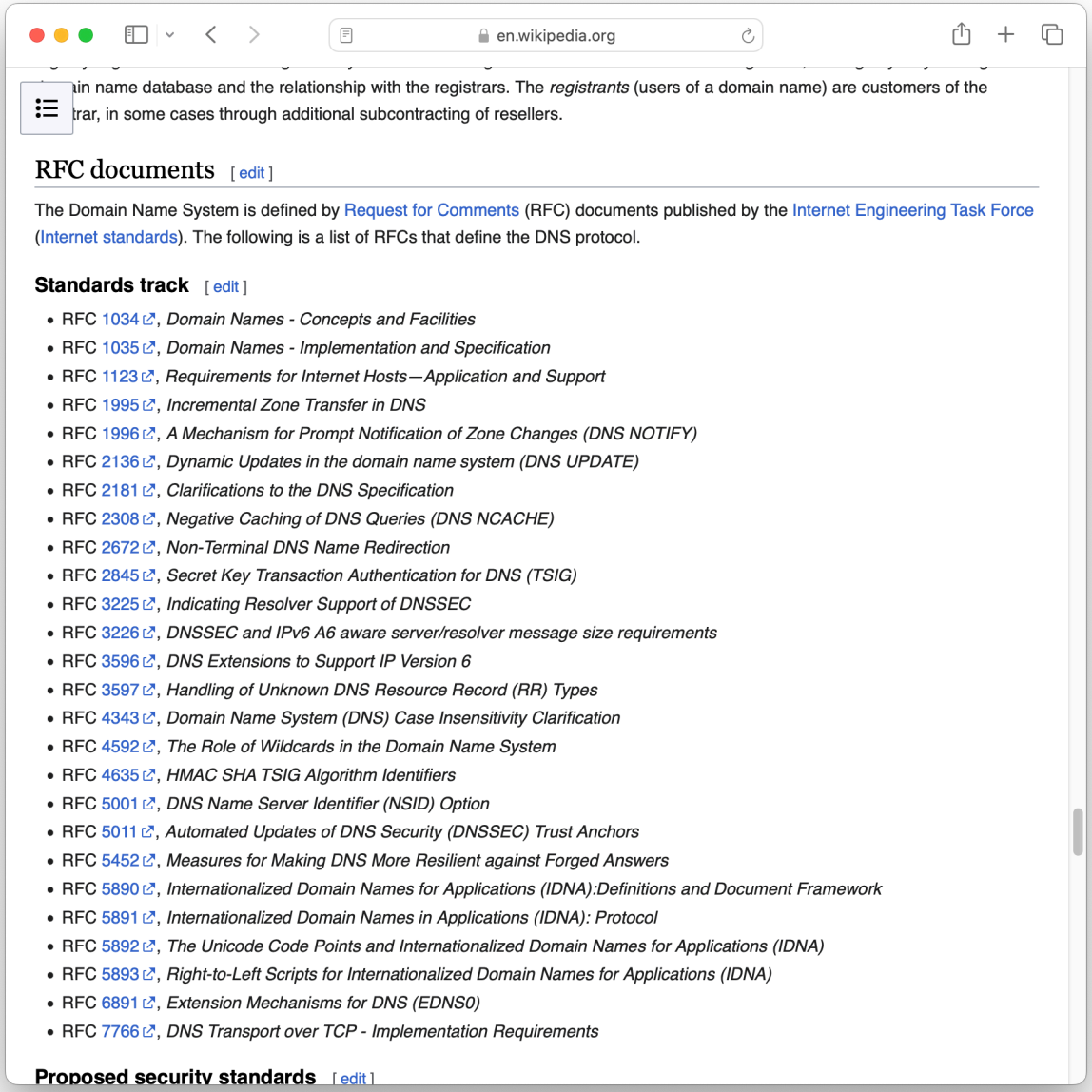
Other formats

txt | html | pdf | w/errata | bibtex

Report a datatracker bug

The Domain Name System (DNS)

- DNS maps domain names to IP addresses
- Example: `heig-vd.ch` → `193.134.223.20`
- dig and nslookup are useful tools to query DNS servers



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in name database and the relationship with the registrars. The *registrants* (users of a domain name) are customers of the rar, in some cases through additional subcontracting of resellers.

RFC documents [edit]

The Domain Name System is defined by Request for Comments (RFC) documents published by the Internet Engineering Task Force (Internet standards). The following is a list of RFCs that define the DNS protocol.

Standards track [edit]

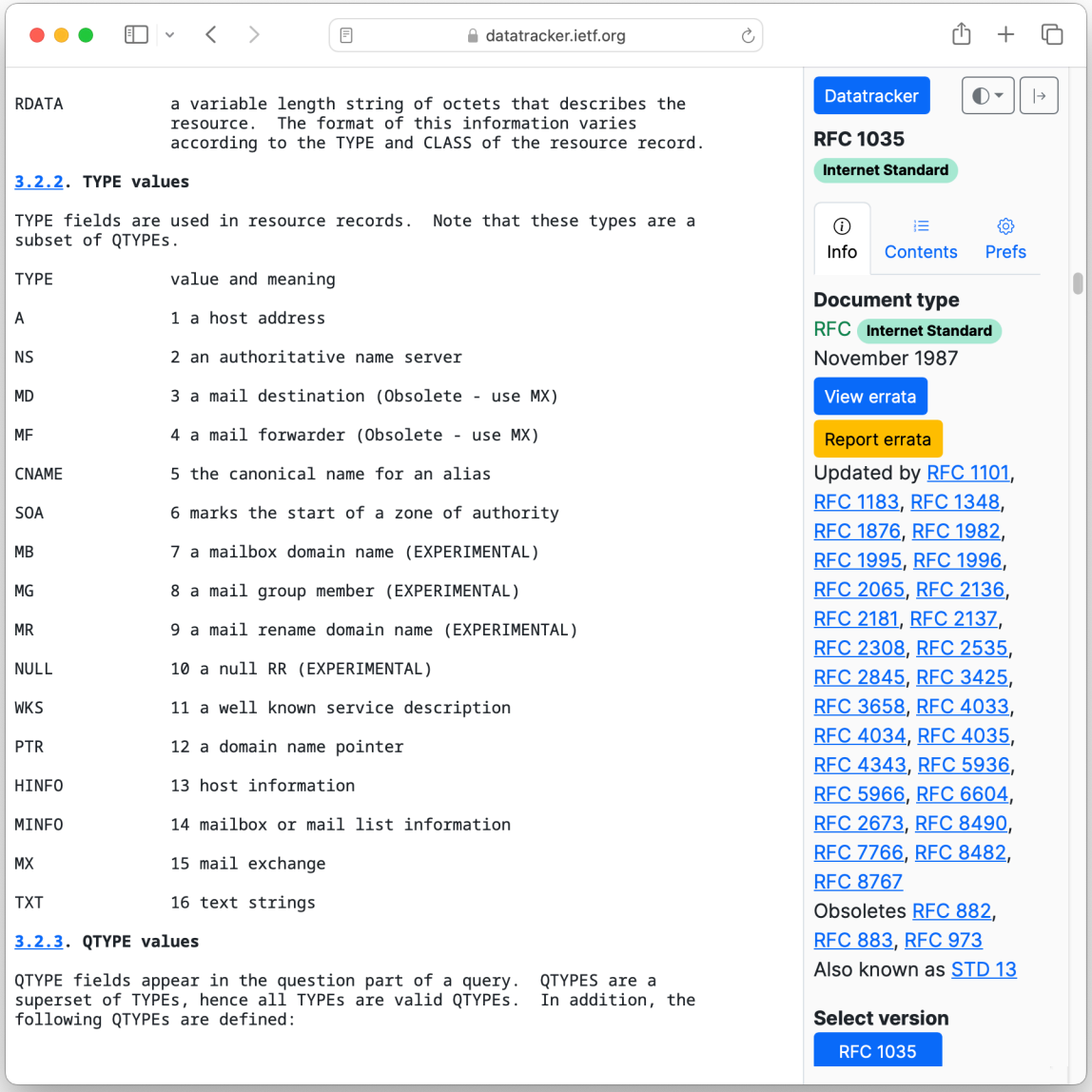
- RFC 1034, *Domain Names - Concepts and Facilities*
- RFC 1035, *Domain Names - Implementation and Specification*
- RFC 1123, *Requirements for Internet Hosts—Application and Support*
- RFC 1995, *Incremental Zone Transfer in DNS*
- RFC 1996, *A Mechanism for Prompt Notification of Zone Changes (DNS NOTIFY)*
- RFC 2136, *Dynamic Updates in the domain name system (DNS UPDATE)*
- RFC 2181, *Clarifications to the DNS Specification*
- RFC 2308, *Negative Caching of DNS Queries (DNS NCACHE)*
- RFC 2672, *Non-Terminal DNS Name Redirection*
- RFC 2845, *Secret Key Transaction Authentication for DNS (TSIG)*
- RFC 3225, *Indicating Resolver Support of DNSSEC*
- RFC 3226, *DNSSEC and IPv6 A6 aware server/resolver message size requirements*
- RFC 3596, *DNS Extensions to Support IP Version 6*
- RFC 3597, *Handling of Unknown DNS Resource Record (RR) Types*
- RFC 4343, *Domain Name System (DNS) Case Insensitivity Clarification*
- RFC 4592, *The Role of Wildcards in the Domain Name System*
- RFC 4635, *HMAC SHA TSIG Algorithm Identifiers*
- RFC 5001, *DNS Name Server Identifier (NSID) Option*
- RFC 5011, *Automated Updates of DNS Security (DNSSEC) Trust Anchors*
- RFC 5452, *Measures for Making DNS More Resilient against Forged Answers*
- RFC 5890, *Internationalized Domain Names for Applications (IDNA):Definitions and Document Framework*
- RFC 5891, *Internationalized Domain Names in Applications (IDNA): Protocol*
- RFC 5892, *The Unicode Code Points and Internationalized Domain Names for Applications (IDNA)*
- RFC 5893, *Right-to-Left Scripts for Internationalized Domain Names for Applications (IDNA)*
- RFC 6891, *Extension Mechanisms for DNS (EDNS0)*
- RFC 7766, *DNS Transport over TCP - Implementation Requirements*

Proposed security standards [edit]

Common DNS records

Records map a domain name to an IP address.

- `NS` : Name Server
- `CNAME` : Alias
- `A` : IPv4 address
- `AAAA` : IPv6 address



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```
RDATA           a variable length string of octets that describes the
                resource.  The format of this information varies
                according to the TYPE and CLASS of the resource record.

3.2.2. TYPE values

TYPE fields are used in resource records.  Note that these types are a
subset of QTYPEs.

TYPE            value and meaning

A               1 a host address

NS              2 an authoritative name server

MD              3 a mail destination (Obsolete - use MX)

MF              4 a mail forwarder (Obsolete - use MX)

CNAME           5 the canonical name for an alias

SOA             6 marks the start of a zone of authority

MB              7 a mailbox domain name (EXPERIMENTAL)

MG              8 a mail group member (EXPERIMENTAL)

MR              9 a mail rename domain name (EXPERIMENTAL)

NULL            10 a null RR (EXPERIMENTAL)

WKS             11 a well known service description

PTR             12 a domain name pointer

HINFO           13 host information

MINFO           14 mailbox or mail list information

MX              15 mail exchange

TXT             16 text strings

3.2.3. QTYPE values

QTYPE fields appear in the question part of a query.  QTYPES are a
superset of TYPEs, hence all TYPEs are valid QTYPEs.  In addition, the
following QTYPEs are defined:
```

Datatracker

RFC 1035

Internet Standard

Info Contents Prefs

Document type

RFC Internet Standard

November 1987

View errata

Report errata

Updated by RFC 1101, RFC 1183, RFC 1348, RFC 1876, RFC 1982, RFC 1995, RFC 1996, RFC 2065, RFC 2136, RFC 2181, RFC 2137, RFC 2308, RFC 2535, RFC 2845, RFC 3425, RFC 3658, RFC 4033, RFC 4034, RFC 4035, RFC 4343, RFC 5936, RFC 5966, RFC 6604, RFC 2673, RFC 8490, RFC 7766, RFC 8482, RFC 8767

Obsoletes RFC 882, RFC 883, RFC 973

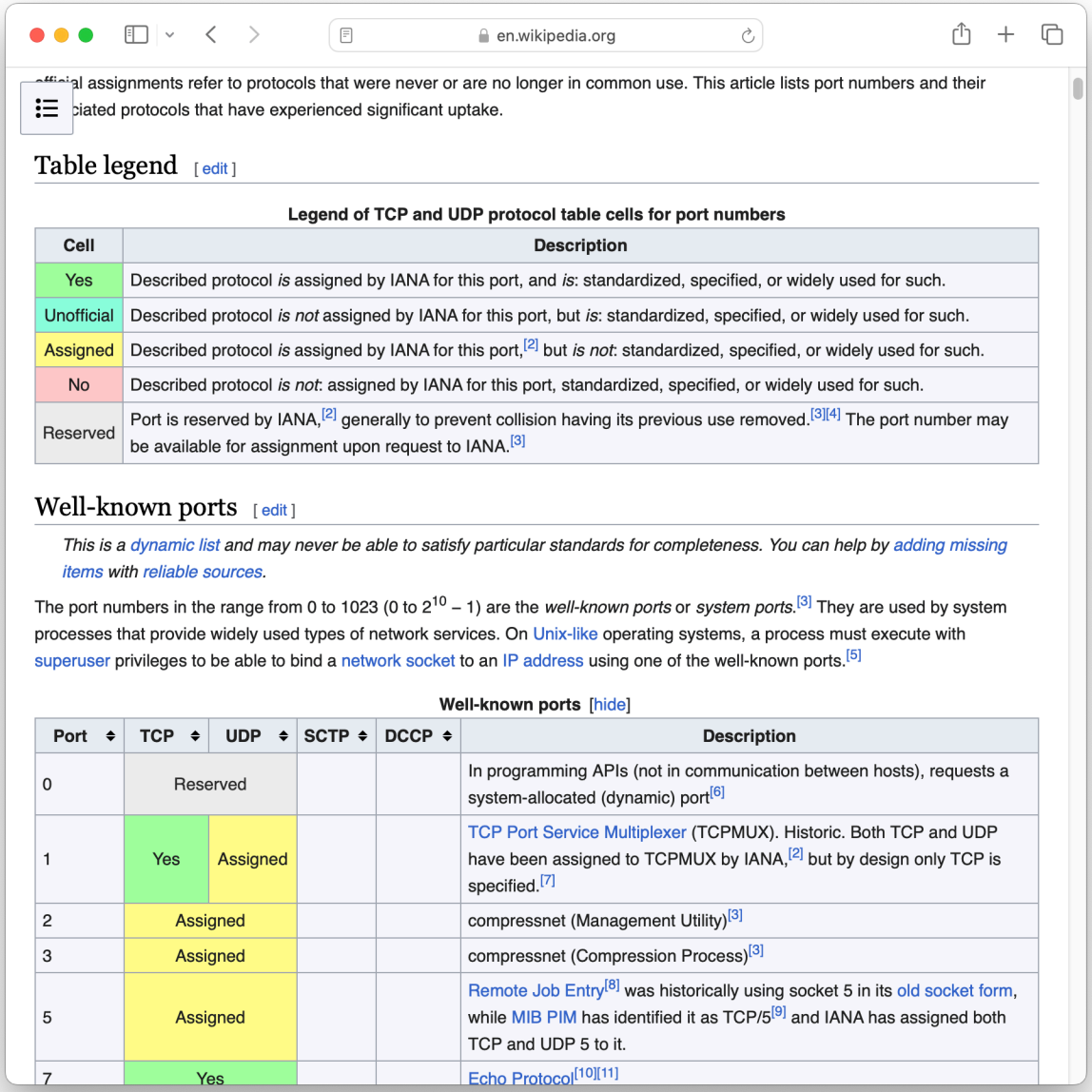
Also known as STD 13

Select version

RFC 1035

Reserved ports

- Ports identify processes or services
- Analogy: an IP address is like a street address, a port is like an apartment number
- Ports are 16-bit unsigned numbers, maximum 65535
- Reserved ports: 0-1023
- Other ports: far west



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ficial assignments refer to protocols that were never or are no longer in common use. This article lists port numbers and their ciated protocols that have experienced significant uptake.

Table legend [edit]

Legend of TCP and UDP protocol table cells for port numbers

Cell	Description
Yes	Described protocol *is* assigned by IANA for this port, and *is*: standardized, specified, or widely used for such.
Unofficial	Described protocol *is not* assigned by IANA for this port, but *is*: standardized, specified, or widely used for such.
Assigned	Described protocol *is* assigned by IANA for this port,[2] but *is not*: standardized, specified, or widely used for such.
No	Described protocol *is not*: assigned by IANA for this port, standardized, specified, or widely used for such.
Reserved	Port is reserved by IANA,[2] generally to prevent collision having its previous use removed.[3][4] The port number may be available for assignment upon request to IANA.[3]

Well-known ports [edit]

This is a dynamic list and may never be able to satisfy particular standards for completeness. You can help by adding missing items with reliable sources.

The port numbers in the range from 0 to 1023 (0 to $2^{10} - 1$) are the *well-known ports* or *system ports*.[3] They are used by system processes that provide widely used types of network services. On Unix-like operating systems, a process must execute with superuser privileges to be able to bind a network socket to an IP address using one of the well-known ports.[5]

Well-known ports [hide]

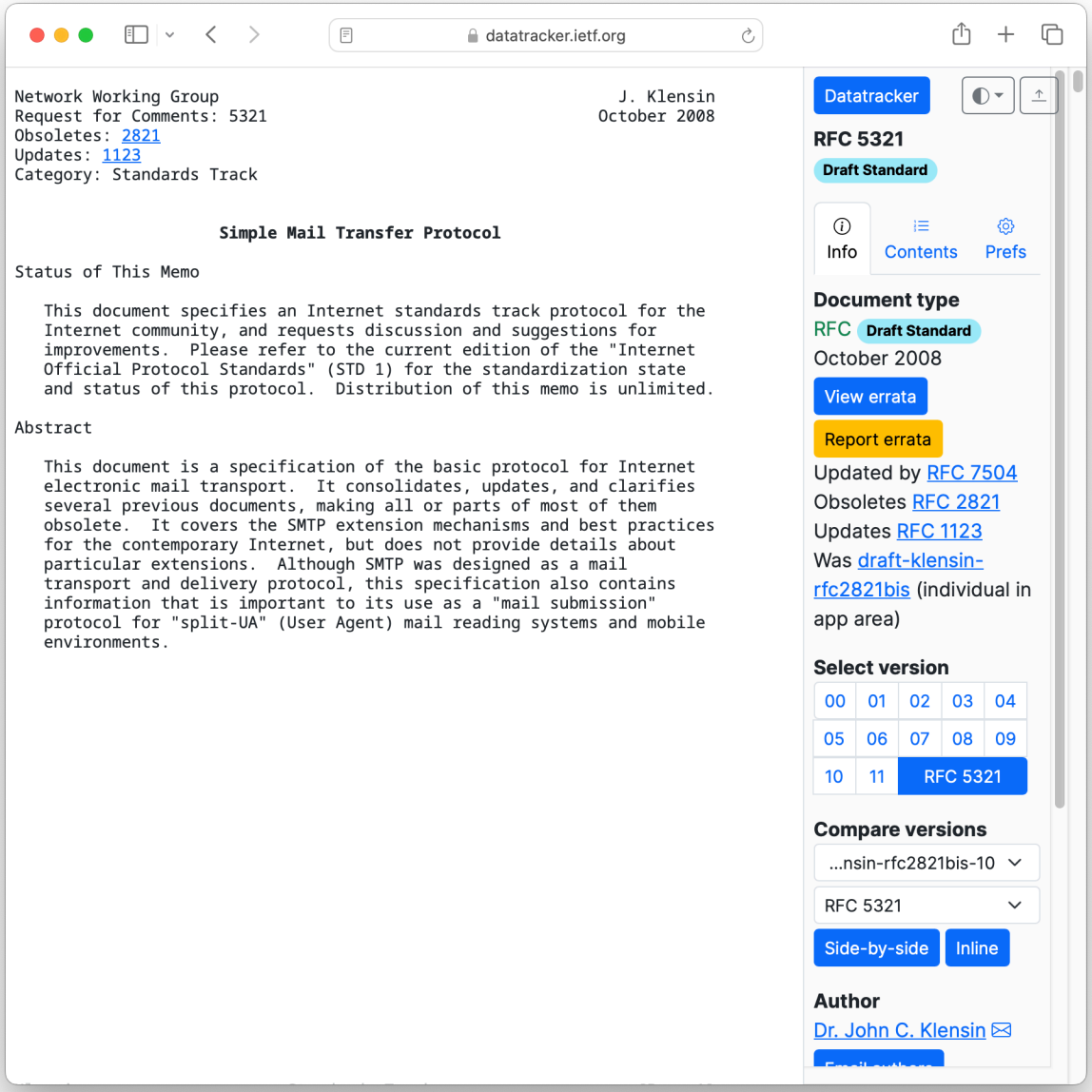
Port	TCP	UDP	SCTP	DCCP	Description
0	Reserved				In programming APIs (not in communication between hosts), requests a system-allocated (dynamic) port[6]
1	Yes	Assigned			TCP Port Service Multiplexer (TCPMUX). Historic. Both TCP and UDP have been assigned to TCPMUX by IANA,[2] but by design only TCP is specified.[7]
2	Assigned				compressnet (Management Utility)[3]
3	Assigned				compressnet (Compression Process)[3]
5	Assigned				Remote Job Entry[8] was historically using socket 5 in its old socket form, while MIB PIM has identified it as TCP/5[9] and IANA has assigned both TCP and UDP 5 to it.
7	Yes				Echo Protocol[10][11]

What is an application protocol

More details for this section in the course material. You can find other resources and alternatives as well.

What is an application protocol

- Defines application communication
- RFCs on the IETF website:
  - Relies on transport and network protocols
  - Multiple revisions exist

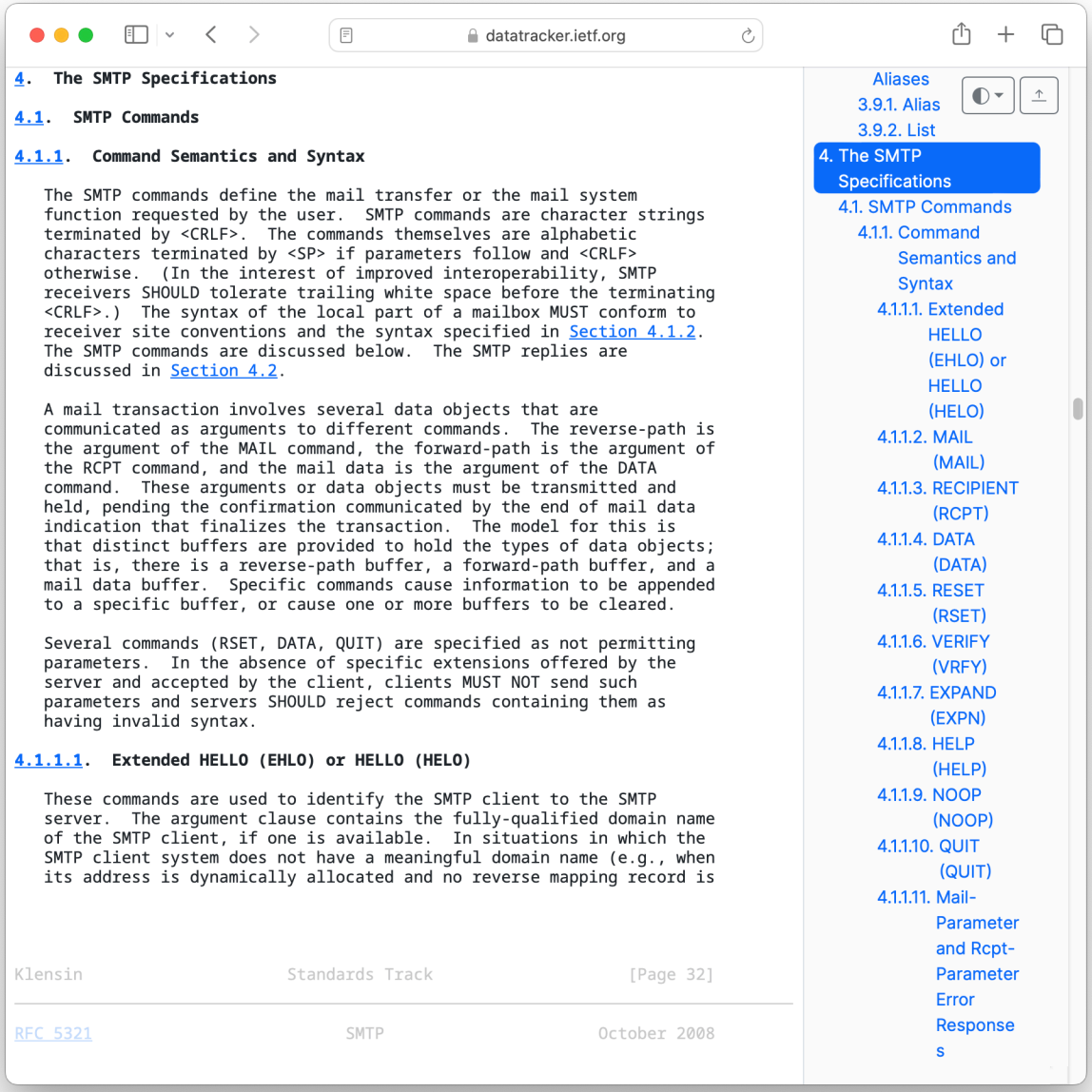


How is structured an application protocol

More details for this section in the course material. You can find other resources and alternatives as well.

How is structured an application protocol

- Defined by a set of rules to follow in a RFC
- Rules define:
  - Transport protocol
  - Messages order
  - Examples and errors



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4. The SMTP Specifications

4.1. SMTP Commands

4.1.1. Command Semantics and Syntax

The SMTP commands define the mail transfer or the mail system function requested by the user. SMTP commands are character strings terminated by <CRLF>. The commands themselves are alphabetic characters terminated by <SP> if parameters follow and <CRLF> otherwise. (In the interest of improved interoperability, SMTP receivers SHOULD tolerate trailing white space before the terminating <CRLF>.) The syntax of the local part of a mailbox MUST conform to receiver site conventions and the syntax specified in Section 4.1.2. The SMTP commands are discussed below. The SMTP replies are discussed in Section 4.2.

A mail transaction involves several data objects that are communicated as arguments to different commands. The reverse-path is the argument of the MAIL command, the forward-path is the argument of the RCPT command, and the mail data is the argument of the DATA command. These arguments or data objects must be transmitted and held, pending the confirmation communicated by the end of mail data indication that finalizes the transaction. The model for this is that distinct buffers are provided to hold the types of data objects; that is, there is a reverse-path buffer, a forward-path buffer, and a mail data buffer. Specific commands cause information to be appended to a specific buffer, or cause one or more buffers to be cleared.

Several commands (RSET, DATA, QUIT) are specified as not permitting parameters. In the absence of specific extensions offered by the server and accepted by the client, clients MUST NOT send such parameters and servers SHOULD reject commands containing them as having invalid syntax.

4.1.1.1. Extended HELLO (EHLO) or HELLO (HELO)

These commands are used to identify the SMTP client to the SMTP server. The argument clause contains the fully-qualified domain name of the SMTP client, if one is available. In situations in which the SMTP client system does not have a meaningful domain name (e.g., when its address is dynamically allocated and no reverse mapping record is

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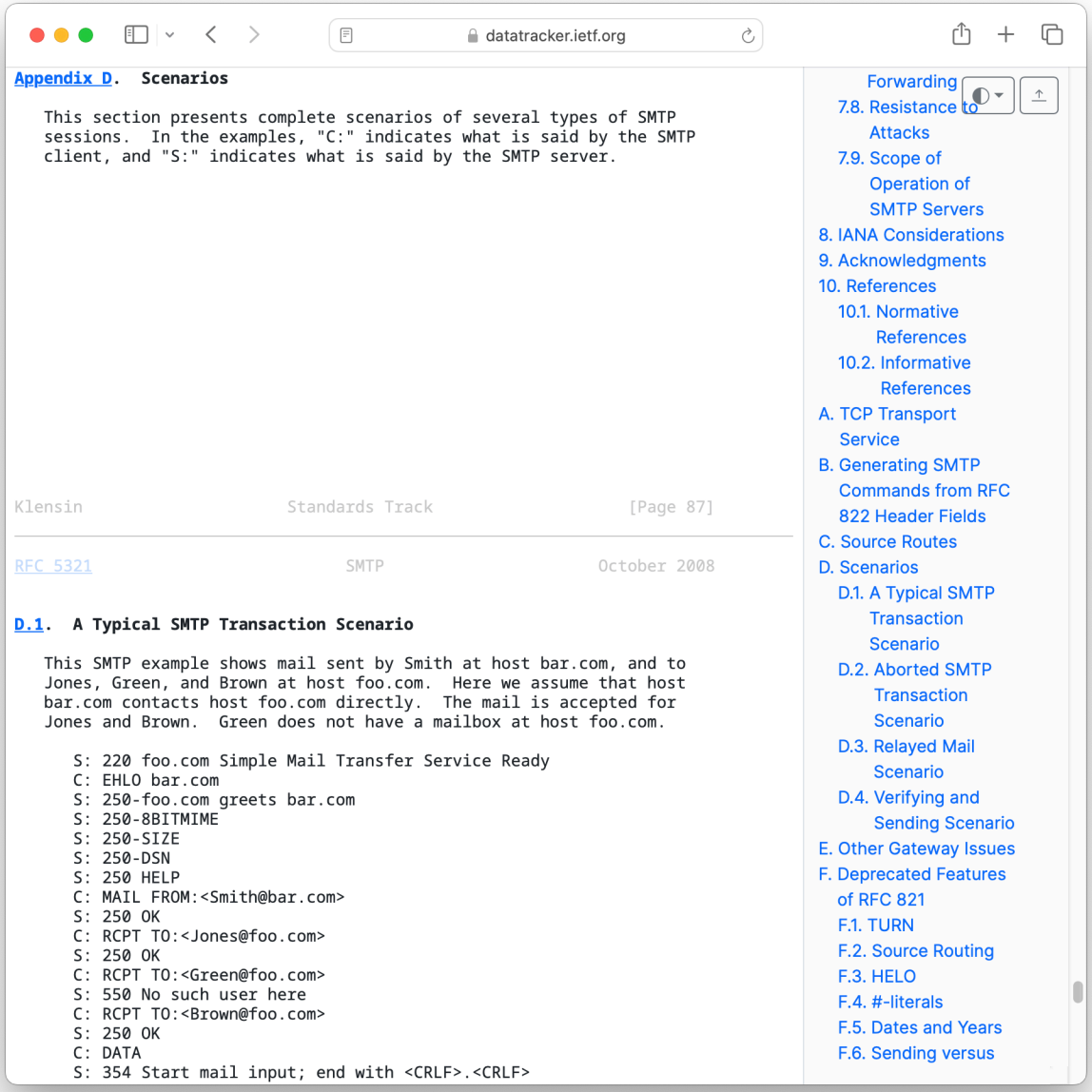
RFC 5321 SMTP October 2008

How to define an application protocol

More details for this section in the course material. You can find other resources and alternatives as well.

How to define an application protocol

- Lot of work and thinking
- A protocol is never perfect
- The more you take your time to think and design it, the less you will have to change it later



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Appendix D. Scenarios

This section presents complete scenarios of several types of SMTP sessions. In the examples, "C:" indicates what is said by the SMTP client, and "S:" indicates what is said by the SMTP server.

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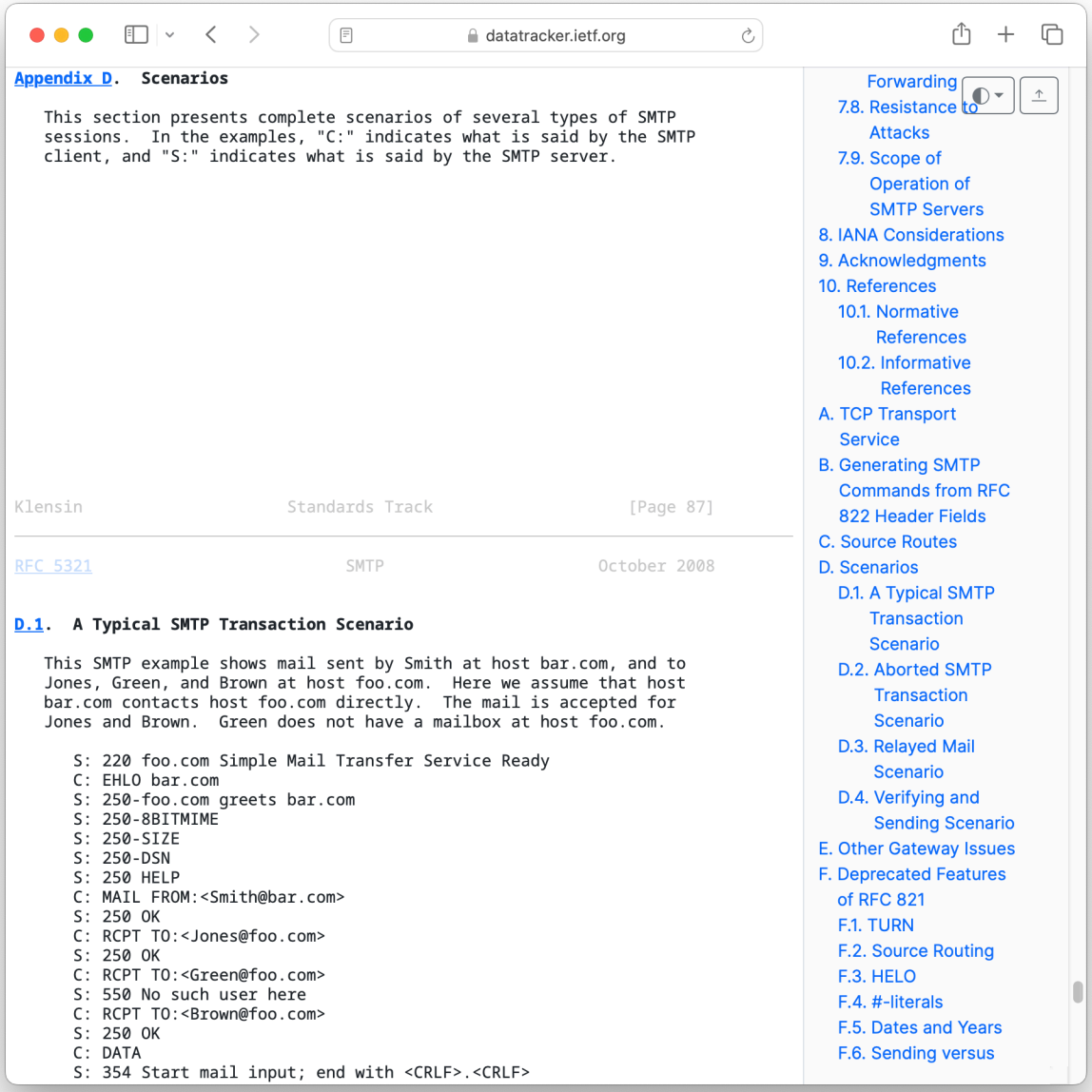
D.1. A Typical SMTP Transaction Scenario

This SMTP example shows mail sent by Smith at host bar.com, and to Jones, Green, and Brown at host foo.com. Here we assume that host bar.com contacts host foo.com directly. The mail is accepted for Jones and Brown. Green does not have a mailbox at host foo.com.

```
S: 220 foo.com Simple Mail Transfer Service Ready
C: EHLO bar.com
S: 250-foo.com greets bar.com
S: 250-8BITMIME
S: 250-SIZE
S: 250-DSN
S: 250 HELP
C: MAIL FROM:<Smith@bar.com>
S: 250 OK
C: RCPT TO:<Jones@foo.com>
S: 250 OK
C: RCPT TO:<Green@foo.com>
S: 550 No such user here
C: RCPT TO:<Brown@foo.com>
S: 250 OK
C: DATA
S: 354 Start mail input; end with <CRLF>.<CRLF>
```

- Simplified structure for this course:
  - Section 1 - Overview
  - Section 2 - Transport protocol
  - Section 3 - Messages
  - Section 4 - Examples



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```
S: 220 foo.com Simple Mail Transfer Service Ready
C: EHLO bar.com
S: 250-foo.com greets bar.com
S: 250-8BITMIME
S: 250-SIZE
S: 250-DSN
S: 250 HELP
C: MAIL FROM:<Smith@bar.com>
S: 250 OK
C: RCPT TO:<Jones@foo.com>
S: 250 OK
C: RCPT TO:<Green@foo.com>
S: 550 No such user here
C: RCPT TO:<Brown@foo.com>
S: 250 OK
C: DATA
S: 354 Start mail input; end with <CRLF>.<CRLF>
```

Section 1 - Overview

This section defines the purpose of the protocol:

- What is the goal of the protocol?
- What is the problem that it tries to solve?
- What the application protocol is used for?

Section 2 - Transport protocol

This section defines the transport protocol used by the application protocol:

- What protocol(s) is/are involved? On which port(s)?
- How are messages/actions encoded?
- How are messages/actions delimited?
- How are messages/actions treated (text or binary)?
- Who initiates/closes the communication?
- What happens on an unknown message/action/exception?

Section 3 - Messages

This section defines the messages that can be exchanged between the client and the server.

- What are the messages/actions?
- What are the parameters?
- What are the return values?
- What are the exceptions?

Try to describe these for a given context, not from each point of view. It makes it way easier to understand and to implement.

Section 4 - Examples

This section defines examples of messages that can be exchanged between the client and the server and the exchange order:

- What are the examples of messages/actions?
- What are the examples of exceptions?

It is important to define these examples to illustrate the protocol and to help the reader to understand the protocol using sequence or state diagrams.

Example - The SMS protocol

More details for this section in the course material. You can find other resources and alternatives as well.

Example - The SMS protocol

“ *You are working for a startup that wants to create a new communication app.*

The app is simple: it allows users (with unique usernames) to send small text messages (maximum 100 characters) to each other. The server is in charge of sending the messages to the recipients.

You are asked to define the application protocol that will be used by the clients and the server. ”

Questions

Do you have any questions?

Practical content

What will you do?

- Define two custom application protocols:
  - *"Guess the number"* game
  - *"Temperature monitoring"* application

These application protocols will be used in the next chapters to implement them!

Find the practical content

You can find the practical content for this chapter on GitHub.

Finished? Was it easy? Was it hard?

Can you let us know what was easy and what was difficult for you during this chapter?

This will help us to improve the course and adapt the content to your needs. If we notice some difficulties, we will come back to you to help you.

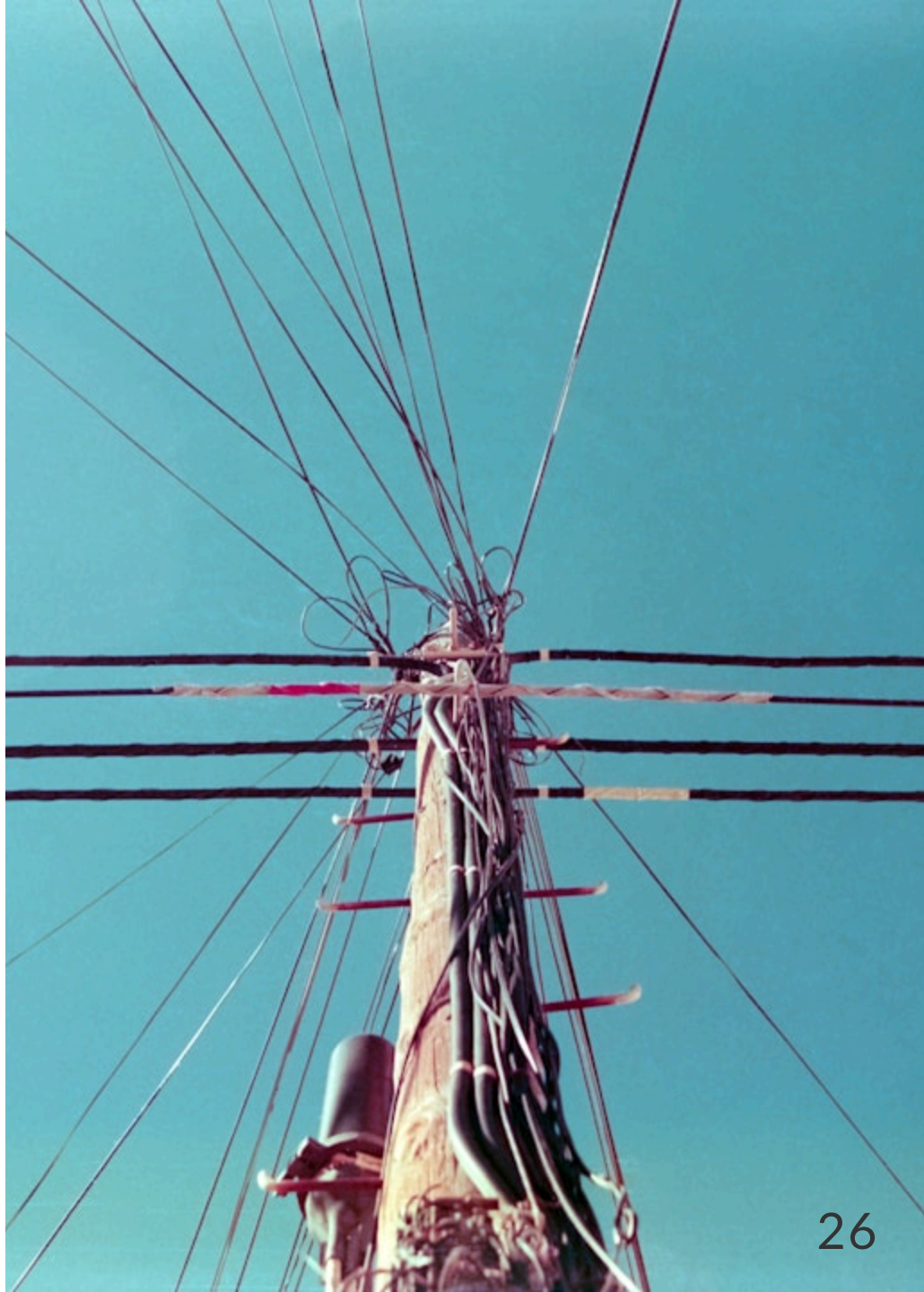
➡️ GitHub Discussions

You can use reactions to express your opinion on a comment!

What will you do next?

In the next chapter, you will learn the following topics:

- Java TCP programming
  - How to create a TCP server
  - How to create a TCP client
  - Implement the *"Guess the number"* game using TCP (optional)



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