Networking Basics

03a - The Internet Protocol (IP)

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Networking Basics
DE-CIX Academy

01 - Protocols and Packets
02 - Ethernet
02a - VLANs
03 - IP - the Internet Protocol
03a - IP Addresses, Prefixes, and Routing
03b - Global IP routing
04 - UDP
05 - TCP and more
06 - Higher protocols - http, smtp, and more
Protocol
What is a "Protocol"?

- If you want to communicate, you need to speak a common language
- Otherwise you will not understand each other

PS: I used Google Translate. Hope it says "I do not understand"
What is a "Protocol"?

• If you want to communicate, you need to speak a common language

• Otherwise you will not understand each other

• The same is true for computers or other network devices
Protocol Stack

Multiple protocols building on each other
Internet Model
Physical Layer

- Light pulses and electrical signals
- Lasers and fibres
- Electrical cables

<table>
<thead>
<tr>
<th>Layer</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Application</td>
</tr>
<tr>
<td>4</td>
<td>Transport</td>
</tr>
<tr>
<td>3</td>
<td>Internet</td>
</tr>
<tr>
<td>2</td>
<td>Link</td>
</tr>
<tr>
<td>1</td>
<td>Physical</td>
</tr>
</tbody>
</table>

Attribution: Cjp24
https://commons.wikimedia.org/wiki/File:12_Optical_fibers_(1).jpg
Internet Model
Link Layer

• Data units are called "Frames"

• Provides hop-to-hop (node-to-node) data transfer

• Examples:
  • Ethernet
# Ethernet Frame Structure

- **EtherType**
- **Payload**

<table>
<thead>
<tr>
<th>Preamble</th>
<th>SF D</th>
<th>Destination MAC Address</th>
<th>Source MAC Address</th>
<th>Ethertype</th>
<th>Payload</th>
<th>Checksum</th>
</tr>
</thead>
<tbody>
<tr>
<td>101010101010101010101010101010101010101010101011</td>
<td>48 Bits 6 Octets</td>
<td>48 Bits 6 Octets</td>
<td>16 Bits 2 Octets</td>
<td>46 - 1500 Octets</td>
<td>32 Bits 4 Octets</td>
<td></td>
</tr>
</tbody>
</table>
## Ethernet Frame Structure

<table>
<thead>
<tr>
<th>Ethertype</th>
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</tr>
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<td></td>
<td>4 Octets</td>
</tr>
<tr>
<td>48 Bits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Encapsulation
Packets inside packets

• The payload of Ethernet is IP
• Encapsulation is like Russian dolls
• So we have an IP packet inside an Ethernet frame
Internet Model
IP / Internet Layer

• Data units are called "Packets"

• Provides source to destination (end-to-end) transport

• Needs addresses for entities

• Examples:
  • IPv4
  • IPv6
### IP - Version 4 (IPv4)

Header + Payload

<table>
<thead>
<tr>
<th>Ethernet Payload</th>
<th>IPv4 Header</th>
<th>IP Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20-60 Bytes</td>
<td>1440-1480 Bytes</td>
</tr>
</tbody>
</table>
### IPv4 Header

**Some parts to point out**

- Starts with version and length
- Total length of packet
- Important: Time to live (TTL)
- Protocol: Type of payload
- Source / Destination address 32 bits
- Options (optional)

<table>
<thead>
<tr>
<th>Byte</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Version</td>
<td>Header Length</td>
<td>DSCP / ECN</td>
<td>Total Length (20..65535)</td>
</tr>
<tr>
<td></td>
<td>always 4</td>
<td>5..15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Identification</td>
<td>Flags / Fragment Offset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Time To Live</td>
<td>Protocol</td>
<td>Header Checksum</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Source IPv4 Address</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Destination IPv4 Address</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td>Optional (if HeaderLength &gt; 5)</td>
</tr>
</tbody>
</table>
IP - Version 6 (IPv6)
Header + Payload

<table>
<thead>
<tr>
<th>Ethernet Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IPv6 Fixed</strong>*) Header</td>
</tr>
<tr>
<td><strong>IP Payload</strong></td>
</tr>
<tr>
<td>40 Bytes</td>
</tr>
<tr>
<td>1460 Bytes</td>
</tr>
</tbody>
</table>

*) IPv6 packets can contain "extension headers" after the fixed header.
Looks less complicated!

- Starts with version and some labels
- Payload length in bytes (0-65535)
- Next Header - you can chain more headers
  - replaces protocol field
- Hop Limit replaces TTL
- Addresses are now 128bits
IP Addresses - IPv4
IP Addresses
IPv4

• 32 bit in length

• you might have heard of Class-A, -B, -C addresses

• there is no such thing anymore!

• since 1993!

• all usable IP addresses are equal

• more about this in another webinar
IP Addresses
IPv4

• 32 bit in length
  • 4.294.967.296 possible addresses
  • written as 4 decimal numbers separated by dots "."
  • some addresses are reserved / not usable
  • all usable IPv4 addresses have been assigned to users

192.0.2.123

IPv6!
Development started: 1994
First published: 1995
IP Addresses - IPv6
IP Addresses

IPv6

- 128 bit in length - possible addresses:
  340282366920938463463374607431768211456
- there are lots of IPv6 addresses available
- written as hexadecimal numbers separated by colons ":" 
  • double-colon ":::" means fill up with zeros here
- some addresses are reserved / not usable

2001:db8:274f:400:226:b0ff:fed8:3d8a

2001:db8::1

2001:db8:0:0:0:0:0:1

2001:0db8:0000:0000:0000:0000:0000:1
Internet Protocol

How did it all start?
History of IP
It started in the 60s

• To debunk a myth:
  • It was not invented to survive a nuclear war!

• But it was funded by DARPA - a military research agency

• To connect research facilities to share (computing) resources

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Timeline
Some days in the early history of IP

- 1961 - concept of packet switching network
- 1967 - Plan for "ARPAnet"
- 1969 - first ARPAnet node, first RFC published
- 1972 - first public demonstration of ARPAnet
- 1974 - TCP/IP protocol described, "Internet" first used
- 1983 - ARPAnet switches from NCP to TCP/IP
Why was IP so successful?
The role of documentation

• There were other, competing protocols
  • Do you remember BITnet, DECnet? OSI?
  • Either vendor-proprietary or just theory
• IP Protocols were evolving more quickly
• Everything was open - and still is
  • 1969 - first Request for comments (RFC) published
  • Memos, best practices, standards - published as RFC
• Today: Well established and open standard for publishing

Attribution: Public Domain
Conclusion
Things you should remember
The IP Protocol(s)

- Internet Protocol (IP) takes care of **end-to-end** communication
- IPv4 and IPv6 coexist
- IP packets consist of **header** and **payload**
- IPv4 and IPv6 headers are different
  - But both contain source- and destination **addresses**
  - IPv4 addresses are 32 bit long, IPv6 addresses are 128 bit long
- **Payload** can yet be another protocol
Thank you!

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Links and further reading
Links and further reading

- IP Version Numbers https://www.iana.org/assignments/version-numbers/version-numbers.xhtml#version-numbers-1
  - IPv4
    - IPv4 address exhaustion - https://en.wikipedia.org/wiki/IPv4_address_exhaustion
  - IPv6
    - First standard: RFC1884, current standard: RFC8200
- History of Internet and IP
  - Internet Hall of Fame - https://internethalloffame.org
  - Defense Advanced Research Projects Agency (DARPA) - https://www.darpa.mil

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Internet RFCs (Standards)

- There are too many RFCs dealing with IPv4 and IPv6 to be listed here
- Just go to https://tools.ietf.org/html/ and use the search field
- The IETF - Internet Engineering Task Force

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