Introduction to Networks

Ethernet

Wolfgang Tremmel
academy@de-cix.net
Networking Basics
DE-CIX Academy

01 - Introduction to Networks

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
Ethernet
A Modern Ethernet Device
Nokia 7950

• As used by DE-CIX
• Connects 100s of devices
• using optical interfaces
• with speeds up to 100Gbps
Another Modern Ethernet Device

Fritzbox

- as used at home
- connects 4 devices directly
- using copper interfaces
- with speeds up to 1Gbps
So why does the symbolic drawing of Ethernet look like this?
1971

It began in Hawaii: ALOHA-Net
ALOHA-Net
University of Hawaii, 1971

• Radio based network
• To interconnect sites
• Simple principle:
  • If you have data to send, send it
  • If you receive something while sending, stop and try again later
1973

Robert Metcalfe - Xerox PARC
Ethernet
Xerox PARC, 1973

• Instead of radio, uses a coax cable
  • For higher bandwidth
  • And more reliability
• Inspired by ALOHAnet
• Standardized in 1980
• Ethernet II in 1982, standardized as IEEE 802.3 in 1983

Attribution: Coolcaesar at the English language Wikipedia
https://commons.wikimedia.org/wiki/File:Parcentrance.jpg
10BASE5
10 Mbit/s Ethernet

• 10 - Mbit/s
• BASE - uses baseband modulation
• 5 - 500m max. segment length
• Hardware:
  • 1cm thick coax cable
  • "Vampire-Tap" Transceivers
10Base5 Ethernet
Remember the drawing
10Base5 Ethernet
Remember the drawing

50Ω Coax Cable
10Base5 Ethernet
Remember the drawing

50Ω Coax Cable

Author: Alistair1978 (based on copyright claims). / CC BY-SA (https://creativecommons.org/licenses/by-sa/2.5) https://commons.wikimedia.org/wiki/File:ThicknetTransceiver.jpg
10BASE2 still only 10 Mbit/s Ethernet

- Hardware:
  - thin coax cable
  - BNC-"T"-connectors
  - Up to 200m total length
  - "Cheapernet"
  - mid to late 1980s
10Base-T
still only 10 Mbit/s Ethernet

- Hardware:
  - two pairs of twisted copper wires
  - 8P8C (RJ45) plastic connector
- Since 1988
- Needs an active component (hub or switch) to interconnect
Competing standards
Token Ring
1984 - 1990s

• Developed by IBM
• 4Mbit/s, later 16Mbit/s
• Deterministic access
• Needs central Multistation Access Unit
• More complex than Ethernet
• More expensive than Ethernet
FDDI
late 1980s - 1990s

• Fiber Distributed Data Interface
• Optical network
• 100Mbit/s speed, up to 200km size
• Frame-size of 4352 bytes
• double ring topology
• made obsolete by GigabitEthernet
Back to Ethernet
Ethernet is a *broadcast* network where all devices are connected to a *shared* medium.
Broadcast network

One is sending, everybody is receiving

- All stations share one medium
- Only one station at a time can send data
- If two stations start sending at the same time, a collision occurs
  - Both stop sending, wait for a random time, then retry
  - This was one of the main criticisms (no guaranteed delivery)
Broadcast network
One is sending, **everybody is receiving**

- Everybody is receiving everything
- How to avoid overload / unnecessary processing of data?
  - Each station has a unique 48-Bit address
  - Receivers address is at the beginning of each frame
  - And can be processed by the network card
- Only frames with matching address or broadcast frames are forwarded to the CPU
# Ethernet Frame Structure

<table>
<thead>
<tr>
<th>Preamble</th>
<th>SF</th>
<th>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>10101010</td>
<td>10101010</td>
<td>10101010</td>
<td>10101010</td>
<td>10101011</td>
<td>48 Bits</td>
<td>6 Octets</td>
<td>16 Bits</td>
</tr>
</tbody>
</table>
**Ethernet Frame Structure**

- Preamble - 56 bits of 10101010....
- Start of frame marker - 8 bits: 10101011
- Destination MAC address
- Source MAC address
- EtherType (or length)
- Payload
- 32 bit checksum

<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>10101010</td>
<td></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>
</tr>
</tbody>
</table>
**Ethernet Addressing**

- 48 Bit address - 6 octets
- 281 trillion possible addresses
- managed by IEEE
  - you can purchase blocks of addresses
- notation examples:
  - 00:26:b0:d8:3d:8a
  - 0026.b0d8.3d8a
  - 00-26-b0-d8-3c-8a

<table>
<thead>
<tr>
<th>Preamble</th>
<th>SF</th>
<th>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>10101010</td>
<td>10101010</td>
<td>10101010</td>
<td>10101011</td>
<td>48 Bits 6 Octets</td>
<td>48 Bits 6 Octets</td>
<td>16 Bits 2 Octets</td>
<td>46 - 1500 Octets</td>
</tr>
</tbody>
</table>
**Ethernet Addressing**

- Two bits in first octect have special meaning
  - one for local vs. globally unique addresses
    - unique: usually "burned" into the hardware by manufacturer
  - one for unicast vs. multicast

<table>
<thead>
<tr>
<th>Preamble</th>
<th>SFD</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>10101010</td>
<td>10101010</td>
<td>10101010</td>
<td>10101010</td>
<td>10101011</td>
<td>48 Bits 6 Octets</td>
<td>16 Bits 2 Octets</td>
</tr>
</tbody>
</table>
## Ethernet

### Special Addresses

- **FF:FF:FF:FF:FF:FF**
  - The *broadcast* address
- Received by all nodes

---

<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>10101010</td>
<td>10101010</td>
<td>10101010</td>
<td>10101010</td>
<td>10101011</td>
<td>48 Bits 6 Octets</td>
<td>16 Bits 2 Octets</td>
</tr>
</tbody>
</table>

- Payload: 46 - 1500 Octets
- Checksum: 32 Bits 4 Octets
**Ethernet**

**Ethertype**

- Was once used to indicate size of payload
- Using values up to 1500
- → Ethertype values start at 1536
- Some well-known values:
  - 0x0800: IPv4
  - 0x86dd: IPv6
  - 0x0806: ARP
  - 0x8100: VLAN Tagged

---

<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>10101010</td>
<td>10101010</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>
</tr>
</tbody>
</table>
Ethernet Today
In data centers

• Usually optical fibres are used

• Various types exist (single mode, multi mode)

• Speeds are 1 GBit/s, 10 GBit/s, 100 GBit/s or 400 GBit/s

• Connections are between a switch and an end device
Ethernet at home
10Base-T

• Only wire-based connections are in use
• Speeds are 100Mbit/s or 1Gbit/s
• With a switch as a center
• Wireless Ethernet - WIFI is most common
Ethernet at home

10Base-T

- 10Base-T (twisted pair) requires a central device
- To replace the yellow coax cable
- Early devices: a *hub*
  - Function: What is received on one port is broadcasted out on all other ports
  - Just like the yellow coax cable
Ethernet Switch

Ethernet today

• Instead of a hub, a switch is common today

• Advantage:
  • a switch learns which devices are connected to which port
  • and only sends frames on ports they are destined to
  • fallback: unknown destinations are still broadcasted on all ports

Attribution: Wolfgang Tremmel
But...

Ethernet still....

- ...usually has a max payload size of 1500 octets
  - "jumbo frames" with 9000 octets exist, but are not commonly used
- ...uses 48-bit addresses
- ...is a broadcast medium.
  - but today *switches* are used and connections are point-to-point
Network layers - Internet Model

Ethernet: Link Layer

- Data units are called "Frames"
- Provides node-to-node data transfer
- Examples:
  - Point-to-Point Protocol (PPP)
  - Ethernet
Conclusion
Please remember....

Facts about Ethernet

• Ethernet is a broadcast network

• It uses 48-Bit addresses
  • Which are globally unique

• Ethernet frames have usually max. 1500 octets payload

• Today switches interconnect devices
Thank you!

academy@de-cix.net

Interested in more webinars? Please subscribe to our mailing list at https://lists.de-cix.net/wws/subscribe/academy
Links used in the presentation
History of Ethernet

- ALOHAnet
- Robert Metcalfe and Xerox PARC
- Ethernet
  - Wikipedia entry for Ethernet
  - IEEE Standard for Ethernet
- Various types of Ethernet
  - 10Base5
  - 10Base2
  - 10Base-T
- more speed
  - FastEthernet - 100Mbit/s
  - GigabitEthernet - 1000Mbit/s / 1GBit/s
  - 10 Gigabit Ethernet - 10GBit/s
  - 100 Gigabit Ethernet (and 40 Gigabit Ethernet)
Other protocols
Now mostly obsolete

- Token Ring
- FDDI
- Arcnet
- Econet
- AppleTalk
Ethernet hardware
Then and now

- **Historical hardware**
  - *Vampire tap* for 10Base5
  - *Attachment Unit Interface*
  - *Coax cable* and *BNC-Connector* for 10Base2
  - *Ethernet Hub* for 10Base-T

- **Currently used hardware**
  - *Twisted pair* cables: *Cat5*, *Cat6*, *RJ45* connector
  - *Optical fibres*: *Single-mode* and *multi-mode*
  - *Ethernet switch*
Standards

• IEEE standards
  • 802.3-2018 current standard, also here
  • IEEE 802 committee website

• Registered information:
  Ethertype list at IANA, Public register at IEEE

• Some Internet RFCs regarding Ethernet
  • IP over Ethernet: RFC894, RFC895
  • IPv6 over Ethernet: RFC1972, RFC2464

Software

• Wireshark

• TCPDump