Computer Networks

Lecture on

Ethernet

Plan of This Lecture

- Ethernet features
- History of Ethernet
- CSMA/CD basis
- Differences between Ethernet varieties
- Ethernet frame structure
- Virtual local networks
- Ethernet switches
- Industrial Ethernet
- Ethernet Passive Optical Network

Features of Today's Ethernet

- Used in LANs, MANs, WANs
  and even between printed boards in one chassis
- Different speeds: 10, 100 Mb/s, 1, 10, 40, 100, 400 Gb/s
- Different ranges: 15 m - 100 km
- Different copper and optical interfaces
- 48-bit flat addressing, i.e. no subnets
- Point-to-point or bus topology
- Half- or full-duplex
- Speed and duplex auto-configuration possible
- Transmission media sharing possible for interfaces up to 1Gb/s
  - CSMA/CD
  - collisions, back-off, retransmissions, saturation

- Basic frame size – min. 46, max. 1500 bytes of payload
- Jumbo frames – up to 9000 bytes
- Flow-control possible
- Power supply via Ethernet interfaces (PoE) possible
- Virtual LANs
- Frame prioritization
- Ethernet-in-Ethernet tunnelling
- Link aggregation – EtherChannel, IEEE 802.3ad
- Ethernet switches allow for:
    - frame transmission between interfaces with different speeds
    - redundancy without loop – dynamic formation of tree topology

History of Ethernet

- Was developed at Xerox PARC between 1973 and 1974
  stiff coaxial cable as a shared medium
- Upgrade from 2.94 Mbit/s to 10 Mbit/s 1980
- Digital Equipment Corporation (DEC), Intel, and Xerox cooperation
- Frame specification called Ethernet II – used nowadays
- IEEE 802.3 draft/standard 1983/1985
  a bit different frame – used nowadays
- Shift to inexpensive thin coaxial cable and then ubiquitous twisted pair wiring
- Ethernet competed with Token Ring and other LAN technologies in 80's
- Ethernet became prevalent, must-have interface in 90's

- Coaxial cable replaced with point-to-point links
  connected by Ethernet repeaters or switches — in 90's
- First optical interfaces — 1993
- Fast Ethernet, i.e. 100 Mbit/s — 1995
- Gigabit Ethernet, i.e. 1 Gbit/s — 1998
- 10 Gigabit Ethernet — 2002
- 100 Gigabit Ethernet — 2010
- 400 Gbit/s — 2017

CSMA/CD Basis

Carrier-Sense Multiple Access with Collision Detection
is a media access control method

It is like a human conversation

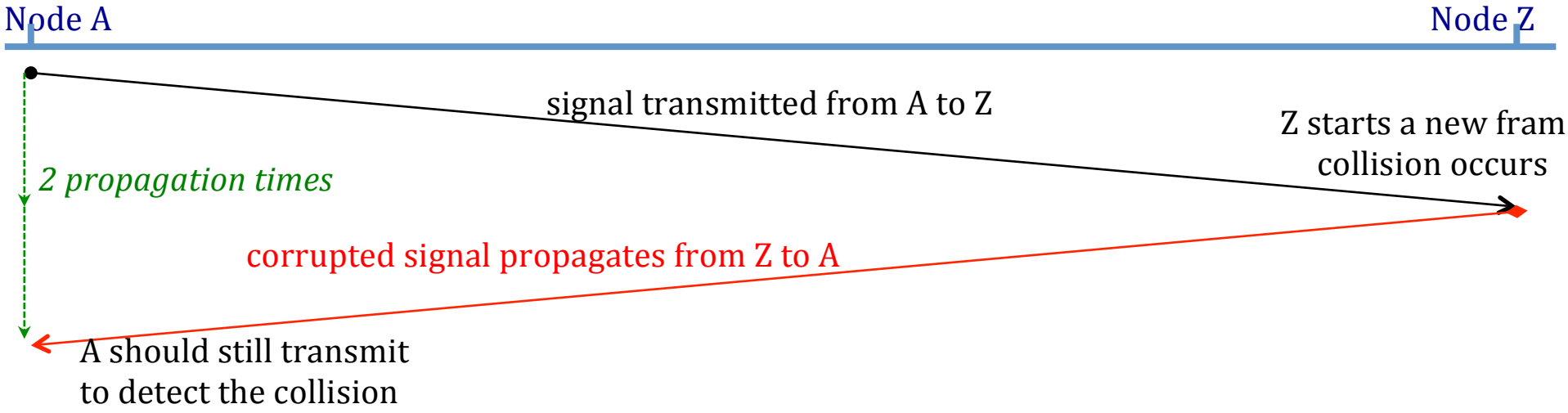
- I can speak if nobody speaks
  otherwise I am waiting
- If I started simultaneously with someone else
  - than we stop both
  - after a random delay I start again

Collision in Ethernet

- Jam signal is generated by the first node who recognizes a collision
  – to ensure that any receiving node drops the corrupted frame
- Time slot for random delay grows exponentially after subsequent collisions (max. 10 times)
- No more attempts after 16 subsequent collisions
  - network is reported as unused / saturated

Collision Detection is possible only if

transmission time of a frame > 2 * time of signal propagation in the medium



Min. Ethernet frame length = 64 B (51,2 µs)

= 512 B for 1 Gb/s

- carrier extension
- or more than 1 standard frame

CSMA/CD used only on electrical 10 Mb/s, 100 Mb/s and 1 Gb/s

Higher speed ⇒ shorter cable

Max. cable length

for many Ethernet varieties = 100 m – cabling in a building

200 m, 500 m for some 10 Mb/s interfaces

Differences Between Ethernet Varieties

Selected Ethernet variants

Name	Speed	Cabling Topology	Cable	Range
10Base-5	10 Mbps	bus	thick coax	500 m
10Base-2	10 Mbps	bus	thin coax	200 m
10Base-T	10 Mbps	star	UTP cat 3	100 m
100Base-TX	100 Mbps	star	UTP cat 5	100 m
1000Base-T	1 Gbps	star	UTP cat 5e	100 m
1000Base-SX	1 Gbps	star	MM fiber	300 m
1000Base-LX	1 Gbps	star	SM fiber	10 km
10GBase-T	10 Gbps	star	UTP cat6	100 m
10GBase-SR	10 Gbps	star	MM fiber	300 m
10GBase-LR	10 Gbps	star	SM fiber	10km

UTP – unshielded twisted pair, MM – multi-mode, SM – single-mode

Ethernet frame variations

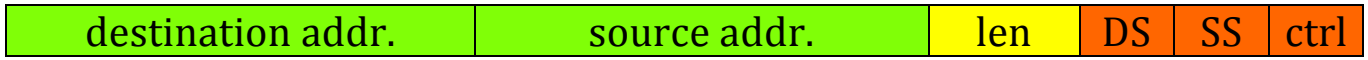
Ethernet II

is the most common

IEEE 802.3

was used in Novell NetWare

IEEE 802.3 + IEEE 802.2



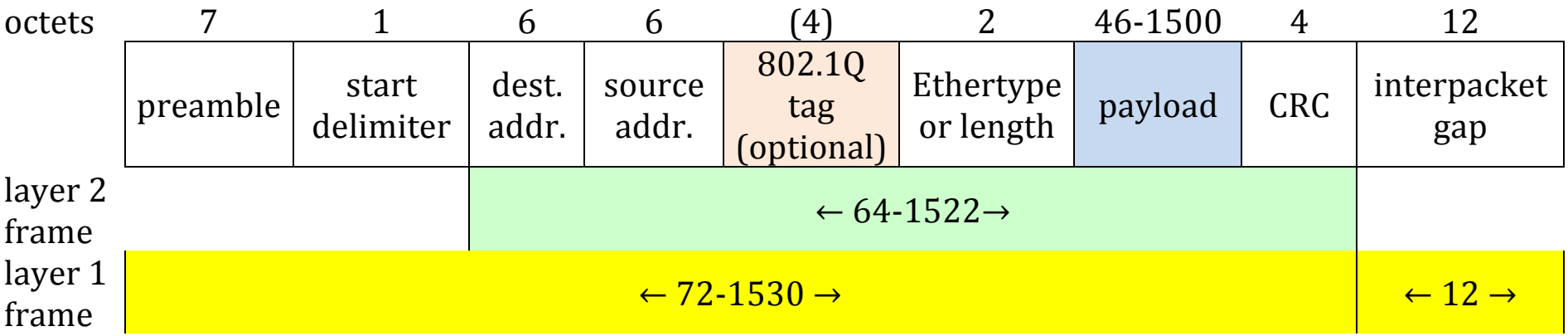
is used on FDDI, Token Ring, IEEE 802.11, …

IEEE 802.3 + SNAP

is used on AppleTalk v2

SNAP – IEEE 802.2 Subnetwork Access Protocol

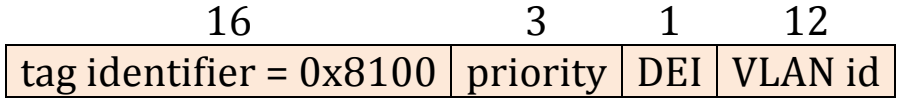
Ethernet Frame Structure



Preamble – to synchronize the receiver with incoming signal 1010…1010

Start delimiter = 10101011

802.1Q tag – virtual LAN header



DEI – drop eligible indicator

VLAN tags can be added, removed and modified by switches

Frame Standards for Network Service Providers

Q-in-Q

- allows for multiple VLAN tags
- one VLAN can be tunnelled by another one
- used in big enterprise networks

Mac-in -Mac aka Provider Backbone Bridges (PBB)

- Customer Eth. frames are tunnelled by a backbone Eth. network

octets	6	6	2	16	2	8	3	64-1522
	backbone dest. addr.	backbone src. addr.	EtherType = 0x88A8	backbone VLAN tag	EtherType = 0x88E7	flags & priority	service identifier	original Ethernet frame
	Backbone component				Service component			Customer component

Virtual Local Network – VLAN

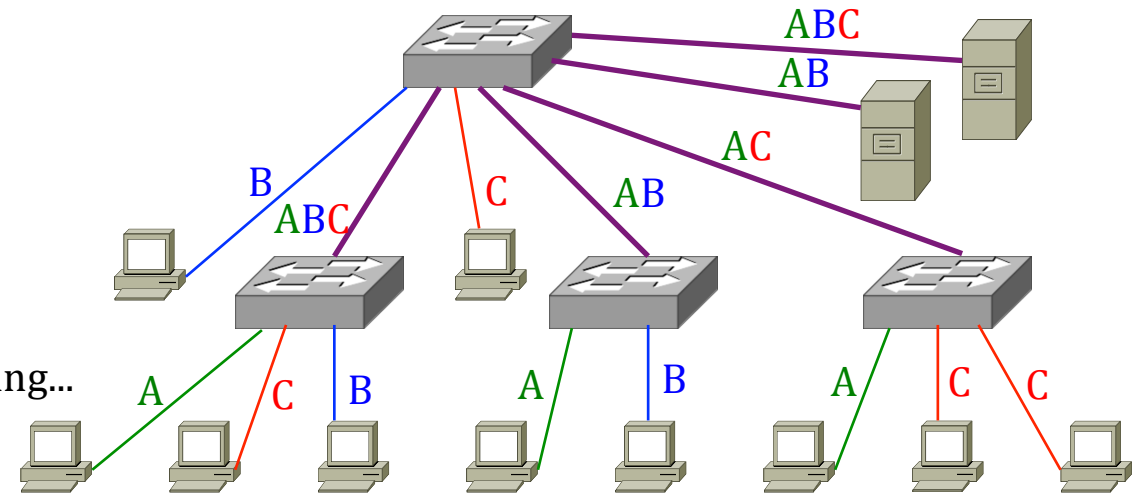
What for?

Physical vs. Logical Topology

- Locations
  buildings, floors, rooms...

vs.

- Organizational units
  production, management, accounting...



Advantages of VLANs

- Independence of logical and physical topologies
- Manageability
- Scalability
  - smaller broadcast domains
- Security
  - impossible to intercept a frame from other VLAN

Example of usage

- Production
- Network management
- Voice over IP
- Storage area network (SAN)
- Guest Internet access
- Demilitarized zone (DMZ)
- Separation of TV content in hotel networks

Routers can exchange of data between VLANs

Static vs. Dynamic VLANs

- Static – port-based
  - administrator configures port assignments
- Dynamic – based on MAC addresses or usernames
  - administrator configures port assignment rules
  - a trunking protocol propagates them

    Trunk – is a set of VLANs

    Trunk port – is an uplink port

Protocol-based VLANs – e.g. ARP, IP, IPX switched to selected interfaces

Enabling standards:

- IEEE 802.1Q 4,096 VLANs
- IEEE 802.1ad (QinQ) 4,096 x 4,096 VLANs x … – manufacturer dependent
- IEEE 802.1aq (Shortest Path Bridging) expands the VLAN limit to 16 million

Ethernet Switches

Aim: enlarge LAN span

Hubs passive & active do the same but

switch separates collision domains

Flooding switch

- each frame is forwarded to all interfaces without the input one

Learning switch

- Stores MAC addresses heard on each interface
- If destination address is in the table
  - then the frame is forwarded only to the pointed interface
  - otherwise to all interfaces without the input one

- Bigger overall throughput of the LAN segment

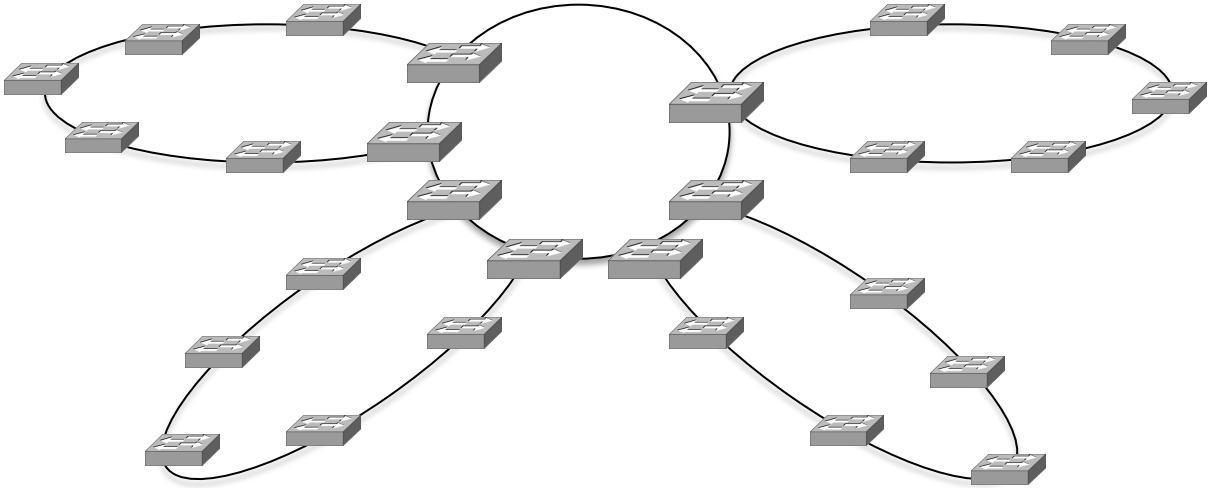
Different speed interfaces

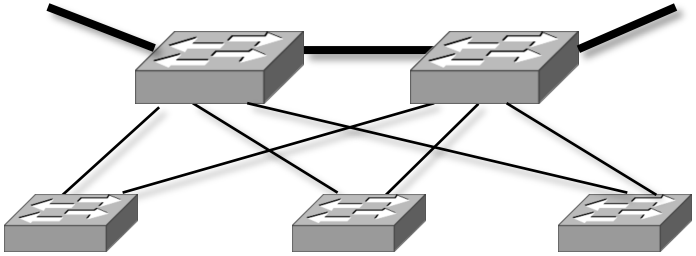
- Slower (often downlink ports)
  - to workstations
  - to LANs
- Faster
  - to servers
  - uplink ports
    - to aggregation switches
    - to WANs

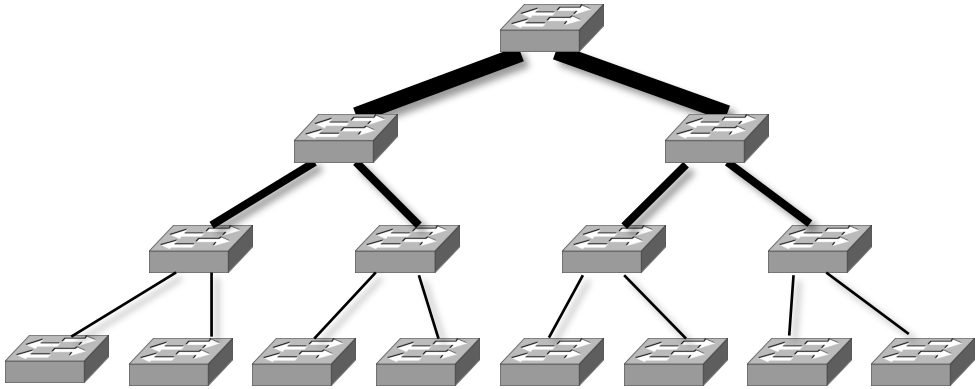
Ethernet network topologies

- Mesh
- Hierarchical
  - access
  - aggregation
  - core
- Ring
- Some data centre topologies, e.g. Fat Tree Topology,

Exemplary Topologies







Main Management Features of an Ethernet Switch

- Enable and disable ports
- Network Access Control
  - e. g. MAC address filtering
- Link bandwidth settings
- QoS configuration and monitoring
- VLAN configuration
- Configuration of Spanning Tree Protocol (STP) and Shortest Path Bridging (SPB) features
- Monitoring of device and link health
- Port mirroring for monitoring traffic and troubleshooting
- Link aggregation configuration

Redundant Topology

- Good because of
  - increased reliability
- Bad, because of
  - broadcast storms
  - multiple frame retransmissions
  - MAC address tables instabilities
- Redundant physical and non-redundant logical topology

Spanning Tree Protocol (STP) – prevents loops

- elects the root switch
- disables redundant links
- switches communicate with each other using Bridge Protocol
- the best path to the root bridge is calculated based on
  - port cost
  - path cost
  - port priority

Spanning Tree Protocols

- STP — 1985 (DEC), 1990 (IEEE) — 50 s convergence
- RSTP – Rapid STP — 2001 (IEEE) — 5 s
- PVST – Per-VLAN STP — CISCO — many trees
- R-PVST – Rapid PVST — CISCO & other proprietary protocols
- MSTP – Multiple STP — 2005 (IEEE)
  - spanning tree can be defined for individual VLANs or for groups of VLANs
  - interworks with RSTP switches

- Shortest Path Bridging (SPB) 2012 (IEEE) for big networks
  - routing but using MAC addresses
  - builds shortest path trees
  - can support up to 1000 switches
  - can provide tens of thousands of layer-2 E-LAN services
    - E-LINE – Ethernet virtual private line
      connects two customer Ethernet ports
    - E-LAN – Ethernet Virtual Private LAN
      connects a set of customer endpoints
    - E-TREE – Ethernet Virtual Private Tree
      multipoint service, preventing inter-leaf communication
  - interworks with RSTP & MSTP switches

Industrial Ethernet

Idea: use Ethernet as the link-layer protocol

with one of industry standards as the application-layer:

- Modbus
- Profibus
- DeviceNet
- Foundation Fieldbus

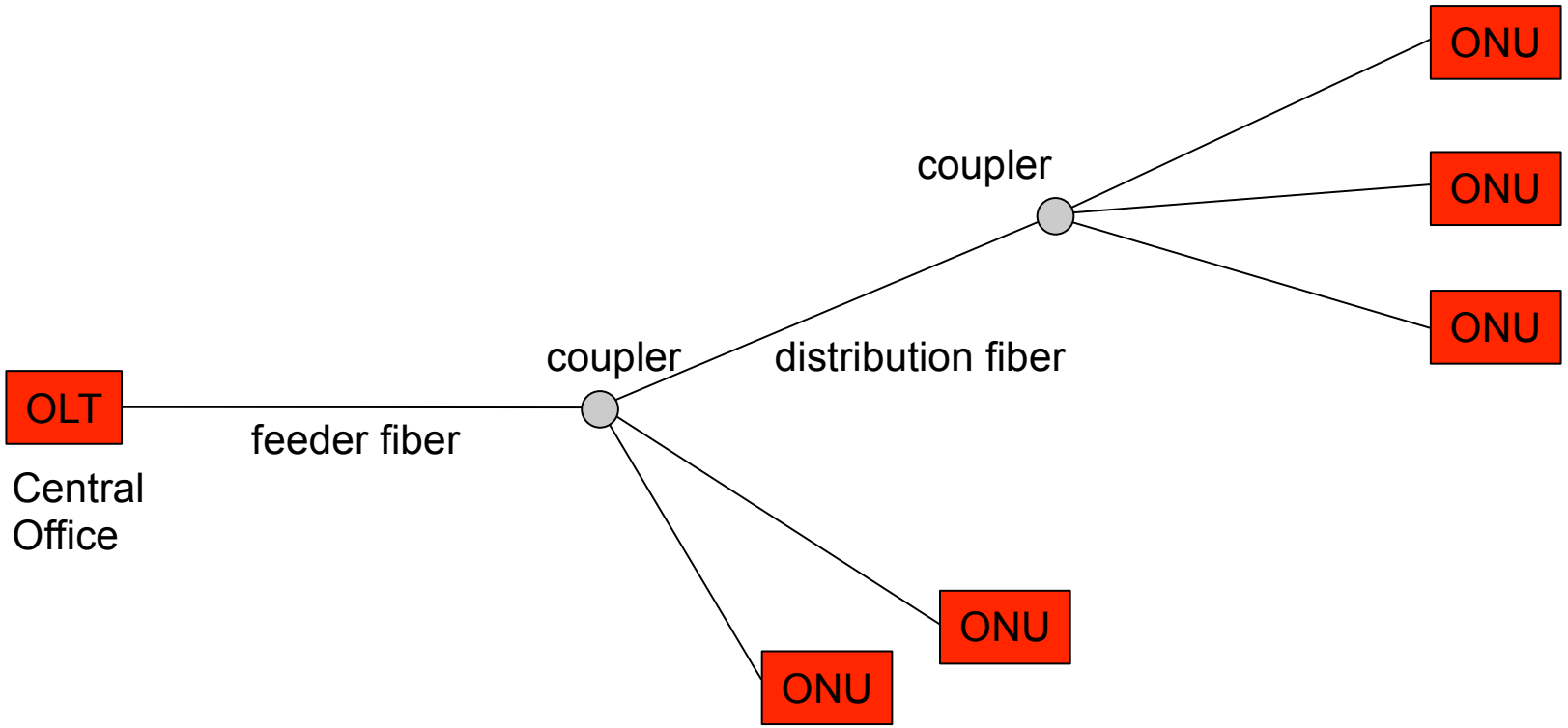
Advantages

- Increased speed and overall performance
- Increased distance
- Ability to use standard access points, routers, switches, hubs, cables and optical fibre
- Immensely cheaper than equivalent serial-port devices

Devices can be manufactured for outdoor conditions

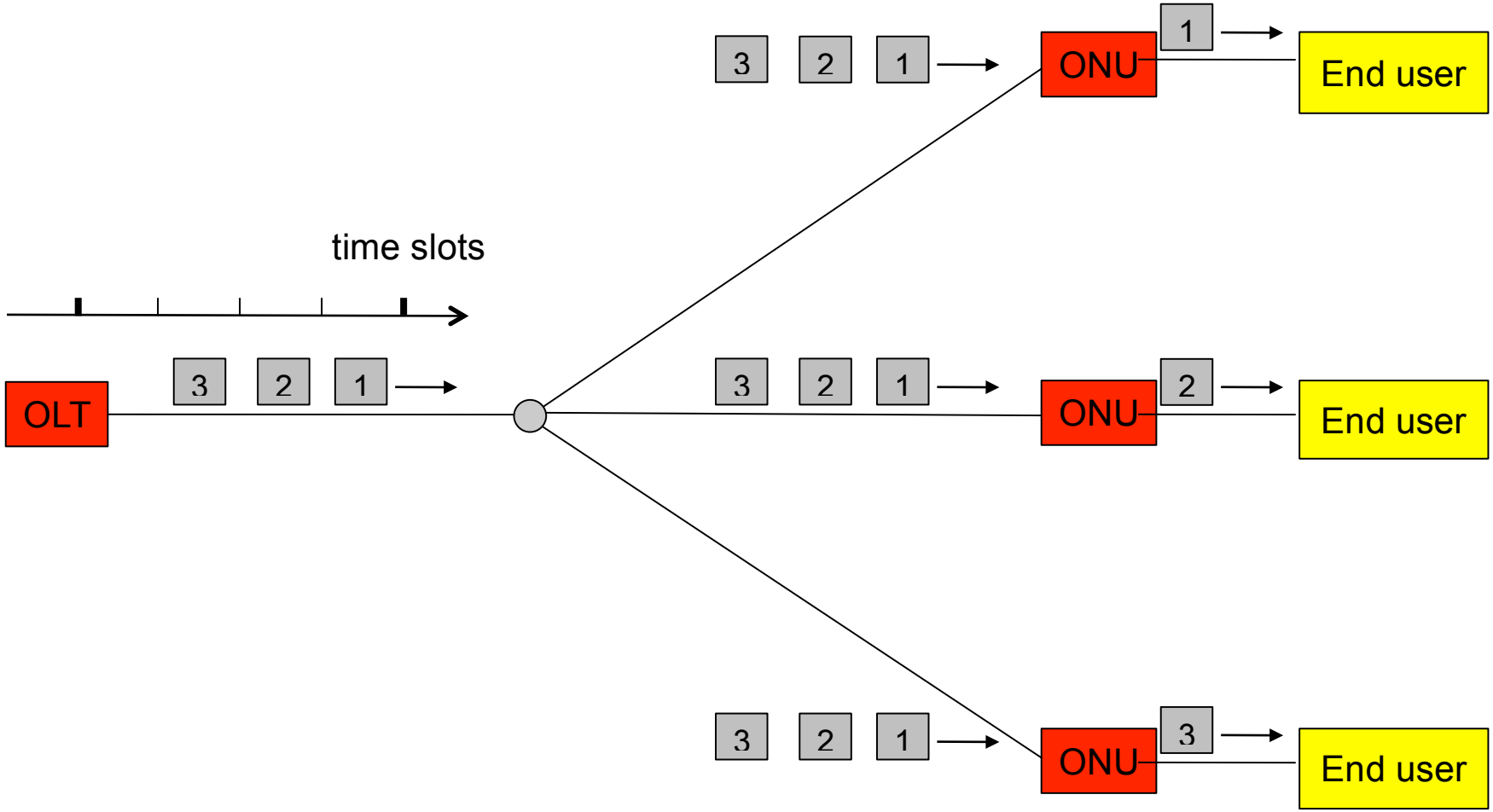
Switches can have very fast STP convergence, e.g. 10 ms (proprietary protocols)

Ethernet Passive Optical Network

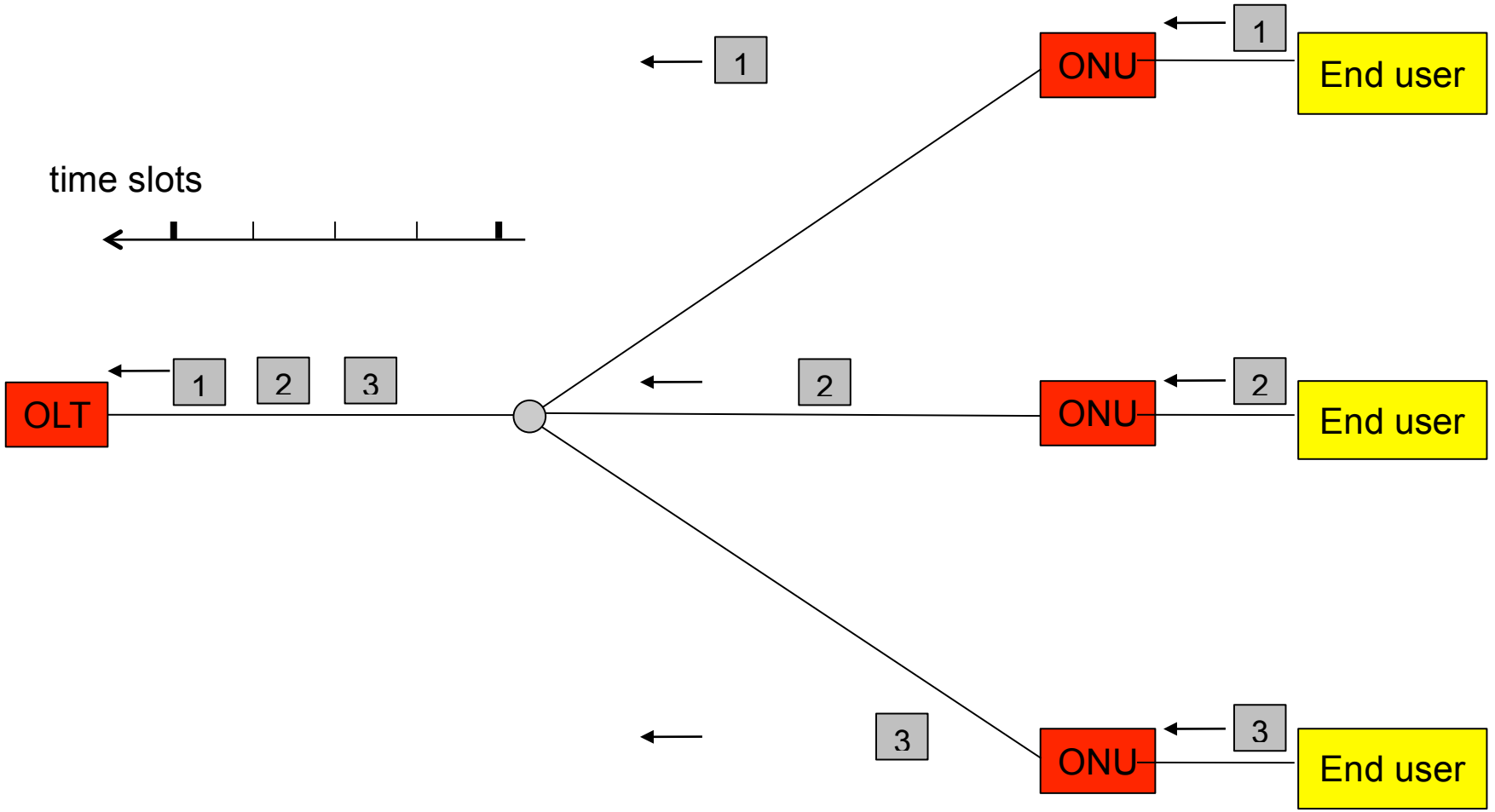


OLT – Optical Line Termination
ONU – Optical Network Unit

OLT sends Ethernet frames to the end-users

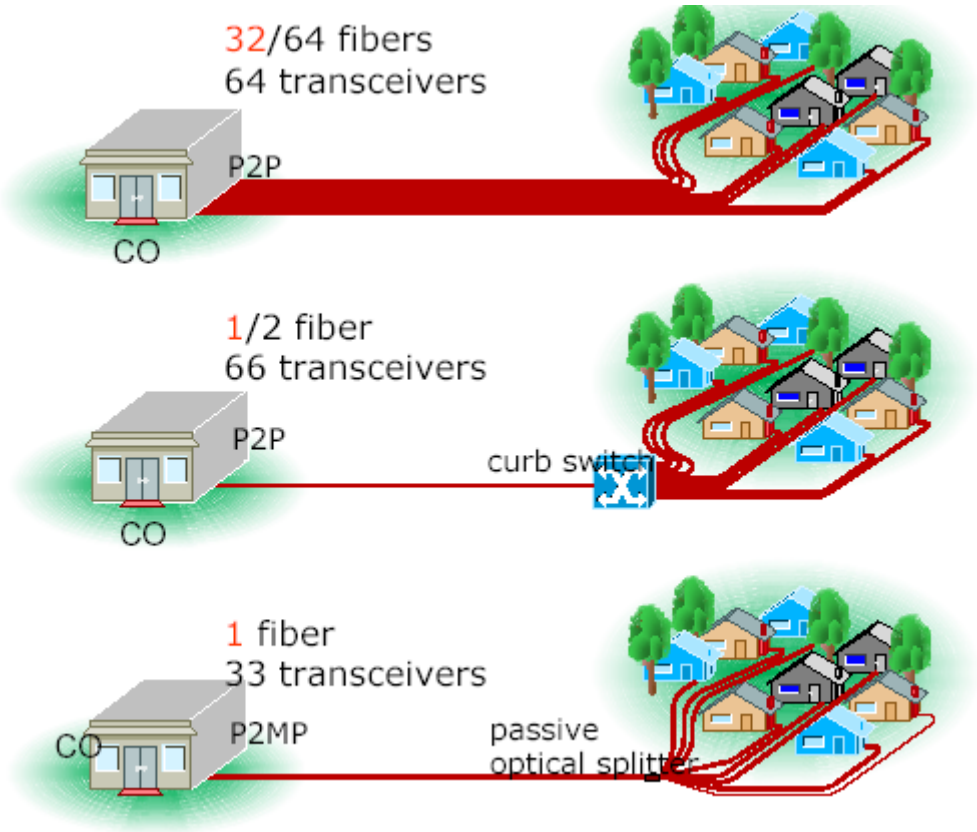


End-users send Ethernet frames to OLT



Advantages:

- less fibers
- less optical ports
- no power supply for a splitter
- easier to manage
- cheaper to maintain
- separate frequency window for cable TV



Disadvantages:

- limited scalability
- lack of redundancy
- less bandwidth for end user
- difficult DWDM upgrade in the future
- lack of widely accepted standards
- technology provider gets control over network owner
- still expensive

Summary

- Ethernet features
- History of Ethernet
- CSMA/CD basis
- Ethernet varieties
  - Physical interfaces
  - Frame variations
- Ethernet frame structure
  - standard frame
  - VLAN tag
  - Q-in-Q
  - Mac-in-Mac
- Virtual local networks
- Ethernet switches
  - What for are they?
  - Learning switch
  - Main management features
  - Exemplary topologies
  - Spanning tree protocols
- Industrial Ethernet
- Ethernet Passive Optical Network

Questions

1. What is the scope of usage of the Ethernet technology?
2. What are the main features of the Ethernet technology?
3. What for Ethernet-in-Ethernet tunneling is used?
4. What is the advantage of using jumbo frames?
5. What is the disadvantage of using jumbo frames?
6. What are standard sizes of min and max Ethernet frames?
7. What is the jumbo frame size?
8. What is EtherChannel and when it is used?
9. What do the Ethernet header contains in its fields?
10. What are the distance ranges of Ethernet interfaces?
11. What is the standard range of electrical Ethernet interfaces (from 100-megabit to 10-gigabit)?
12. What are the transmission speeds of Ethernet interfaces?
13. What is the difference between multimode and single mode fibers?
14. Can one fiber be used to transmit and receive signals? Why?
15. What is the principle of CSMA/CD mechanism?
16. Why do a preamble have to start a frame in CSMA and CSMA/CD protocols?
17. Is a frame collision possible when only 2 Ethernet interfaces are connected by a half-duplex link? Why?
18. What is the reason for minimum length of Ethernet frame?
19. What does happen when a frame collision is discovered on the Ethernet link?
20. Does the full-duplex point-to-point Ethernet use CSMA/CD mechanism? Why?

21. When a switch having interfaces with different speeds should be installed?
22. What is it the fat tree network? Where is it applied?
23. What is it the hierarchical internetworking model?
24. What is the aim of Spanning-Tree protocols in Ethernet networks?
25. What is the aim of VLANs (Virtual Local Area Network)?
26. What is the purpose of VLAN trunking protocols?
27. How does an Ethernet switch process frame priorities?
28. What are the pros for Industrial Ethernet deployment?
29. How an EPON network works?
30. What are the advantages of EPON (Ethernet Passive Optical Network)?

Questions for curious minds

1. What is the Sneakernet throughput?
2. Why copper cables are used more frequently than fiber cables inside buildings, in spite of being sensitive to interference and radio noises?
3. Why can Ethernet be used in real time industry networks?
4. How many times one can look into a light beam from a telecommunication fiber?