Principles of Modern Communications
Switched Data Networks

based on 2011 lecture series by Dr. S. Waharte.

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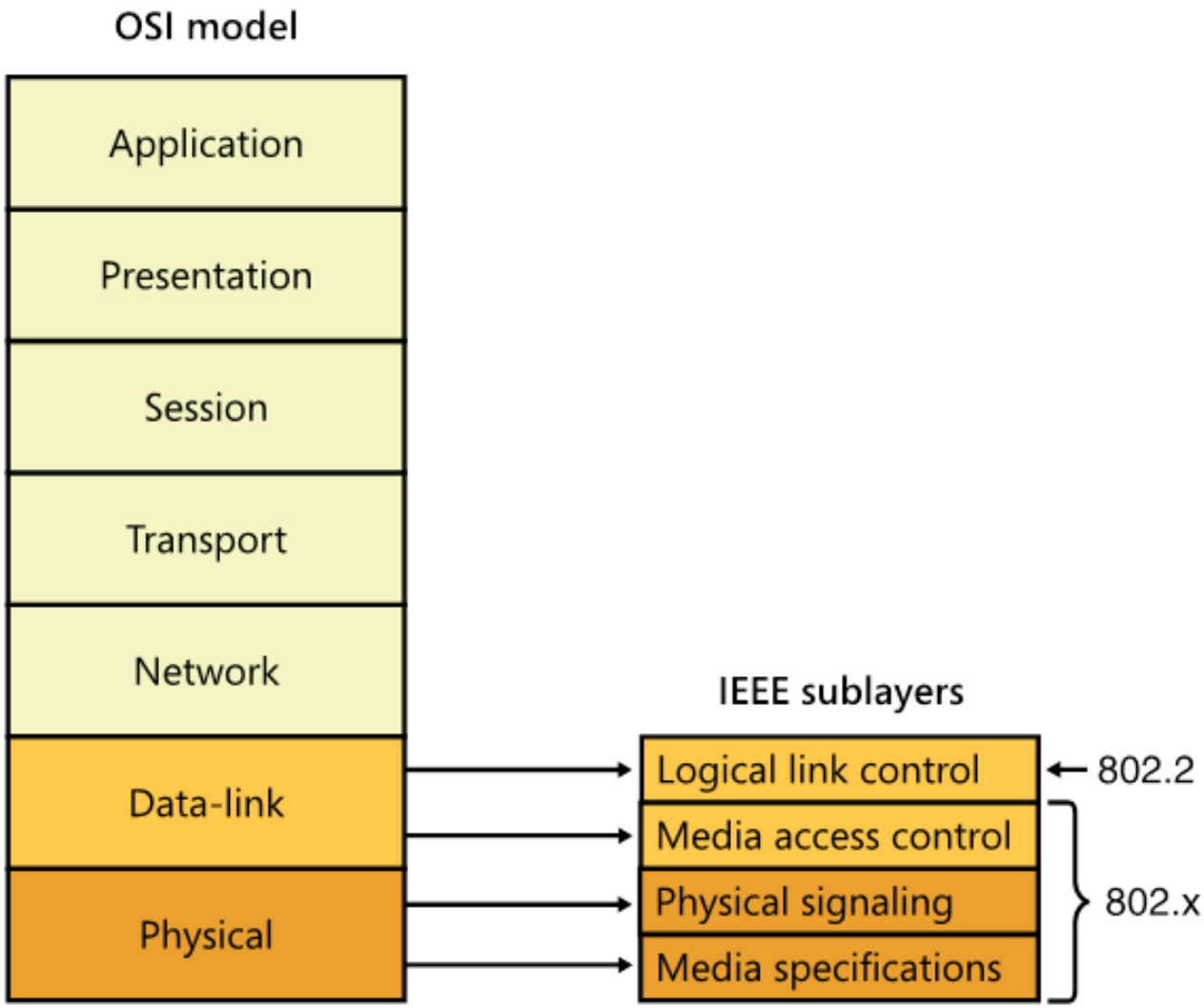
Outline

Introduction

IEEE 802 PHYSICAL AND DATA-LINK SUBLAYERS

Open Systems Interconnection (OSI)



Switched Networks

- Switched Network Standards
  - Data Link layer standards
    - Switch operation
    - Frame organization
  - Physical layer standards
    - Uses UTP and optical fiber
    - Adds standard-specific signaling

Switched Networks

- LAN Standards: Ethernet
  - Dominant in wired LANs
  - Became dominant because of its low cost and adequate performance

The Ethernet Architecture

- 1960s and 1970s: many organizations worked on methods to connect computers and share data
  - E.g., the ALOHA network at the University of Hawaii
  - 1972: Robert Metcalf and David Boggs, from Xerox's PARC, developed an early version of Ethernet
    - 1975: PARC released first commercial version (3 Mbps, up to 100 computers, max. 1 km of total cable)
- DIX developed standard based on Xerox's Ethernet (10 Mbps)
- 1990: IEEE defined the 802.3 specification
  - Defines how Ethernet networks operate at layers 1-2

Switched Networks

- Switched WANs
  - Leased line networks
    - Company leases lines to connects its sites
    - Installs switches to connect the leased lines
    - Manages the resulting networks

Switched Networks

- Switched WANs
  - Public Switched Data Networks (PSDNs)
    - PSDN vendor manages the switching cloud.
    - Firm only needs to install a single leased line from each site to the vendor's nearest point of presence (POP).
    - Frame Relay is the dominant PSDN standard.
    - Metropolitan area Ethernet is growing.

Ethernet (802.3)

Creating Ethernet Standards

- The 802 Committee
  - Committee of the Institute for Electrical and Electronics Engineers (IEEE).
  - IEEE created the 802 LAN/MAN Standards Committee for LAN standards.
  - This committee is usually called the 802 Committee.

Creating Ethernet Standards

- The 802 Committee
  - The 802 Committee creates working groups for specific types of standards.
    - 802.1 for general standards
    - 802.3 for Ethernet standards
    - 802.11 for wireless LAN standards
    - 802.16 for WiMax wireless metropolitan area network standards

Creating Ethernet Standards

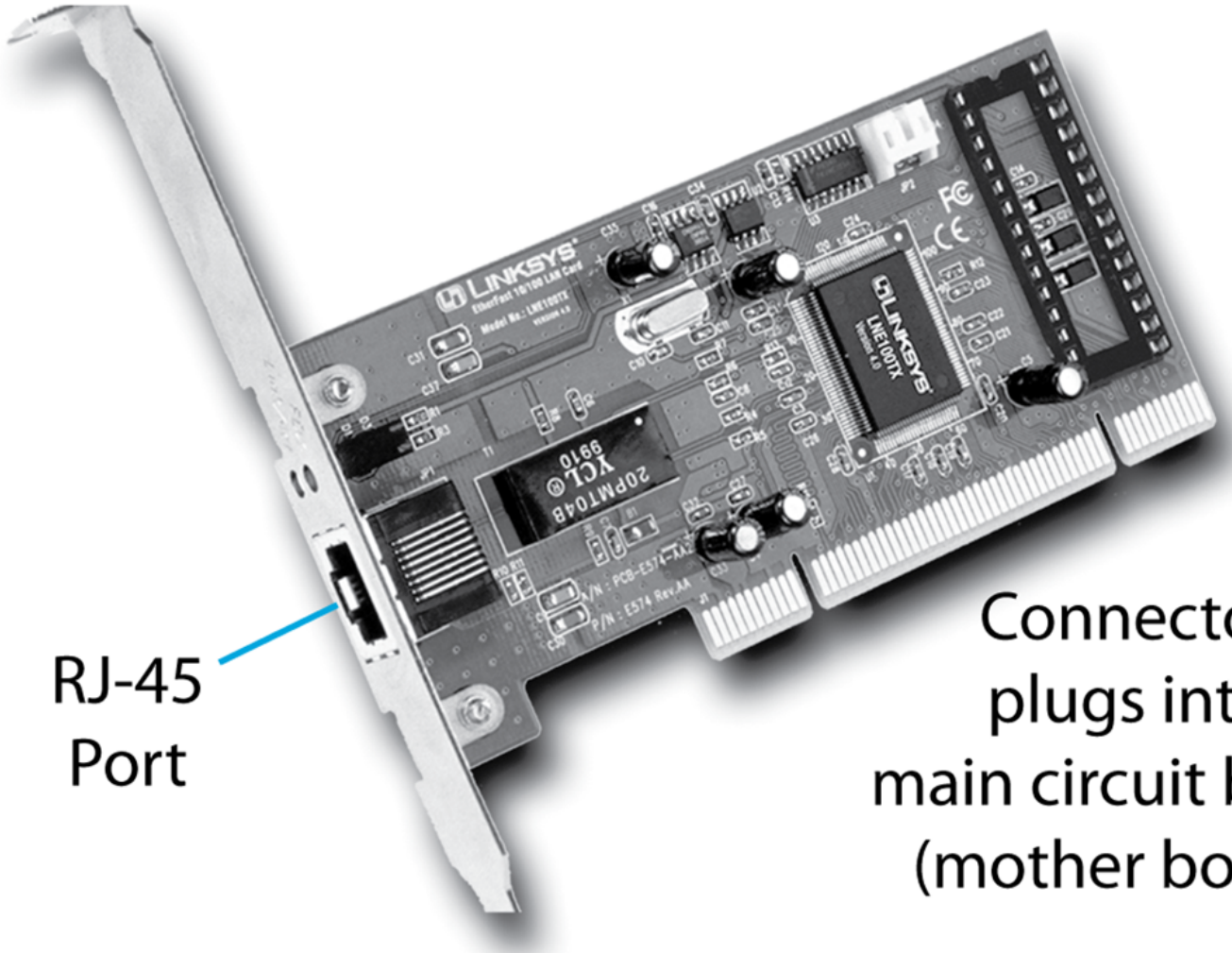
- The 802.3 Working Group
  - This group is in charge of creating Ethernet standards.
  - The terms 802.3 and Ethernet are interchangeable today.
  - Figure 6-4 shows Ethernet physical layer standards.
  - Ethernet also has data link layer standards (frame organization, switch operation, etc.)

Creating Ethernet Standards

- Ethernet Standards are OSI Standards
  - Layer 1 and Layer 2 standards are almost universally OSI standards.
  - Ethernet is no exception.
  - ISO must ratify them.
  - In practice, when the 802.3 Working Group finishes standards, vendors begin building compliant products.

Ethernet physical layer standards

Network Interface Card (NIC)



Ethernet Physical Layer Standards

UTP and Fiber Media Standards

+Ethernet-Specific Signaling Standards

=Ethernet Physical Layer Standards

Ethernet Physical Layer Standards

Physical Standard	Speed	Max. Run Length	Medium
4-Pair UTP			
100BASE-TX	100 Mbps	100 m	Category 5e or higher
1000BASE-T	1 Gbps	100 m	Category 5e or higher
10GBASE-T	10 Gbps	55 m	Category 6
10GBASE-T	10 Gbps	100 m	Category 6a or Category 7

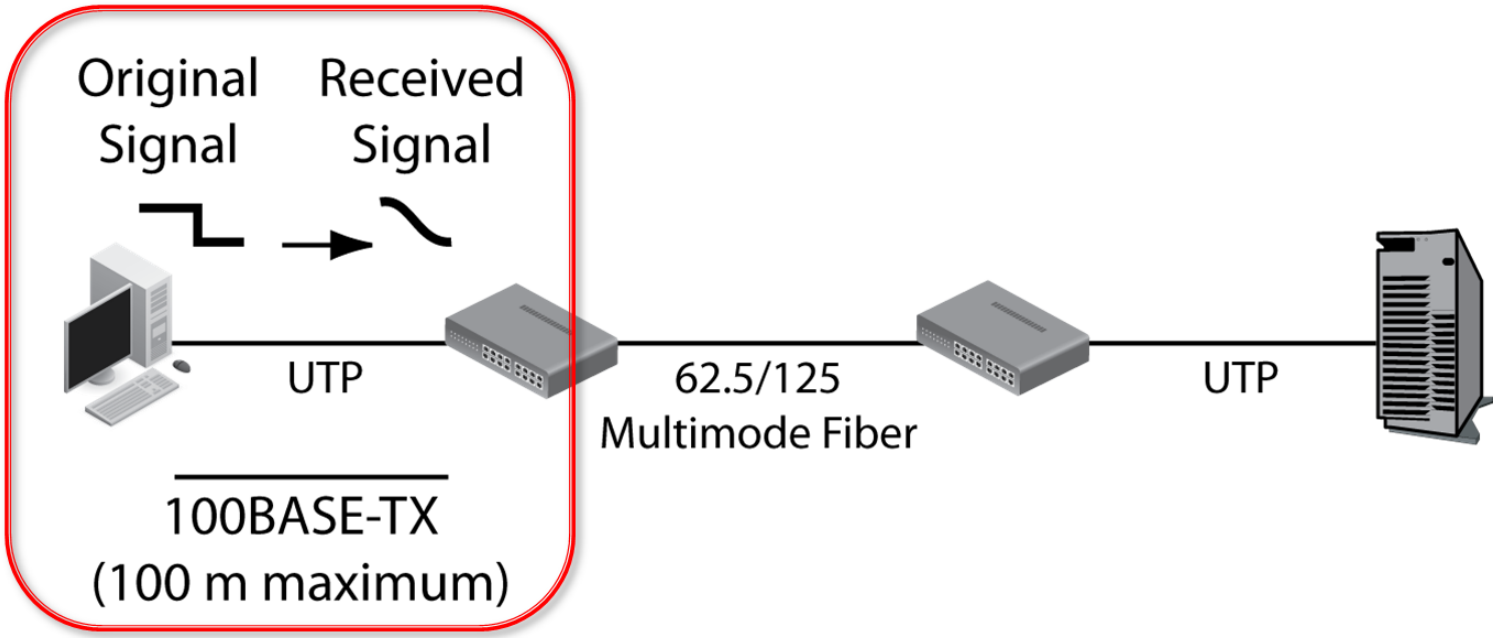
Ethernet Physical Layer Standards

Physical Standard	Speed	Max. Run Length	Core (microns)	Modal Bandwidth
Optical fiber (850 nm)				
1000BASE-SX	1 Gbps	220m	62.5	160 MHz*km
1000BASE-SX	1 Gbps	275 m	62.5	160 MHz*km
1000BASE-SX	1 Gbps	500 m	50	160 MHz*km
1000BASE-SX	1 Gbps	500 m	50	160 MHz*km

Ethernet Physical Layer Standards

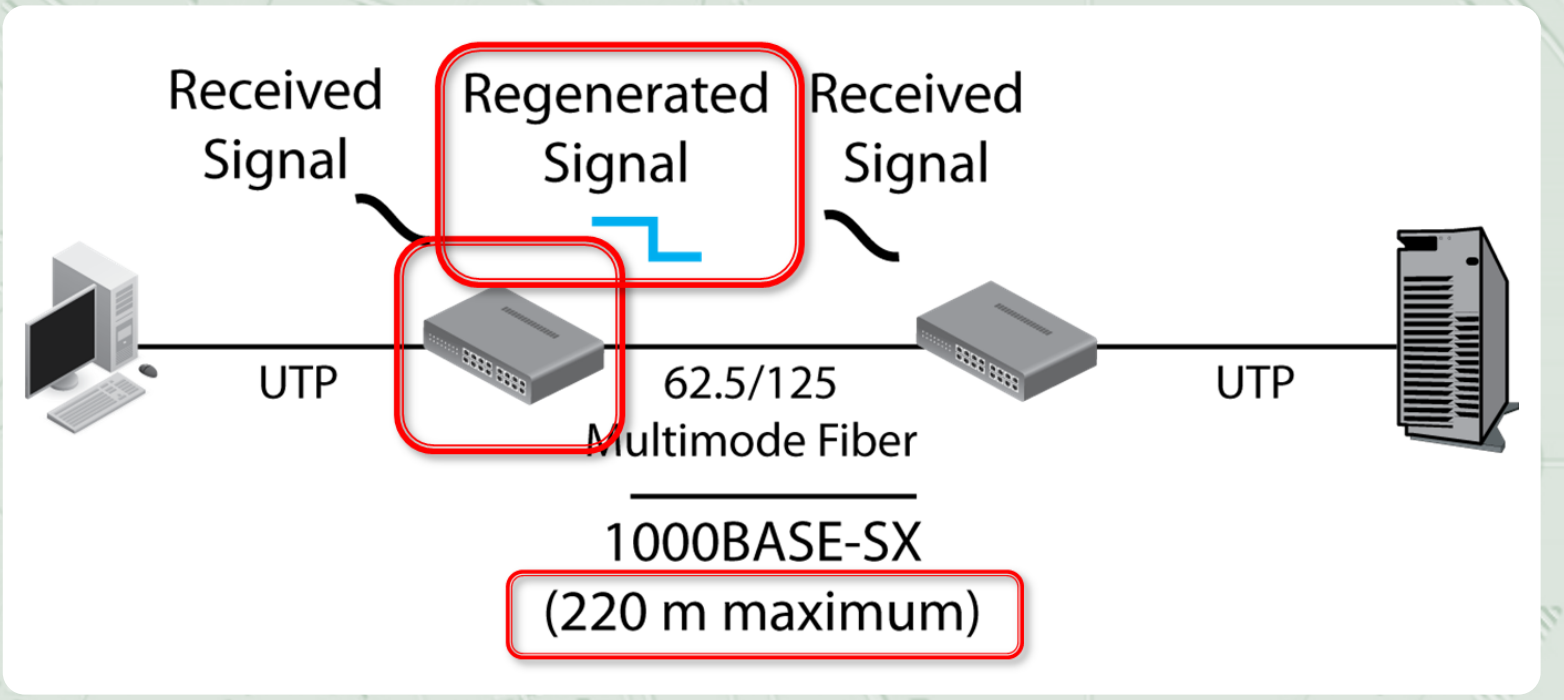
- Faster Optical Fiber
  - 1 Gbps with 1,310 nm signaling: 500 m limit
  - 10 Gbps
  - 40 Gbps
  - 100 Gbps

Data Link Using Multiple Switches



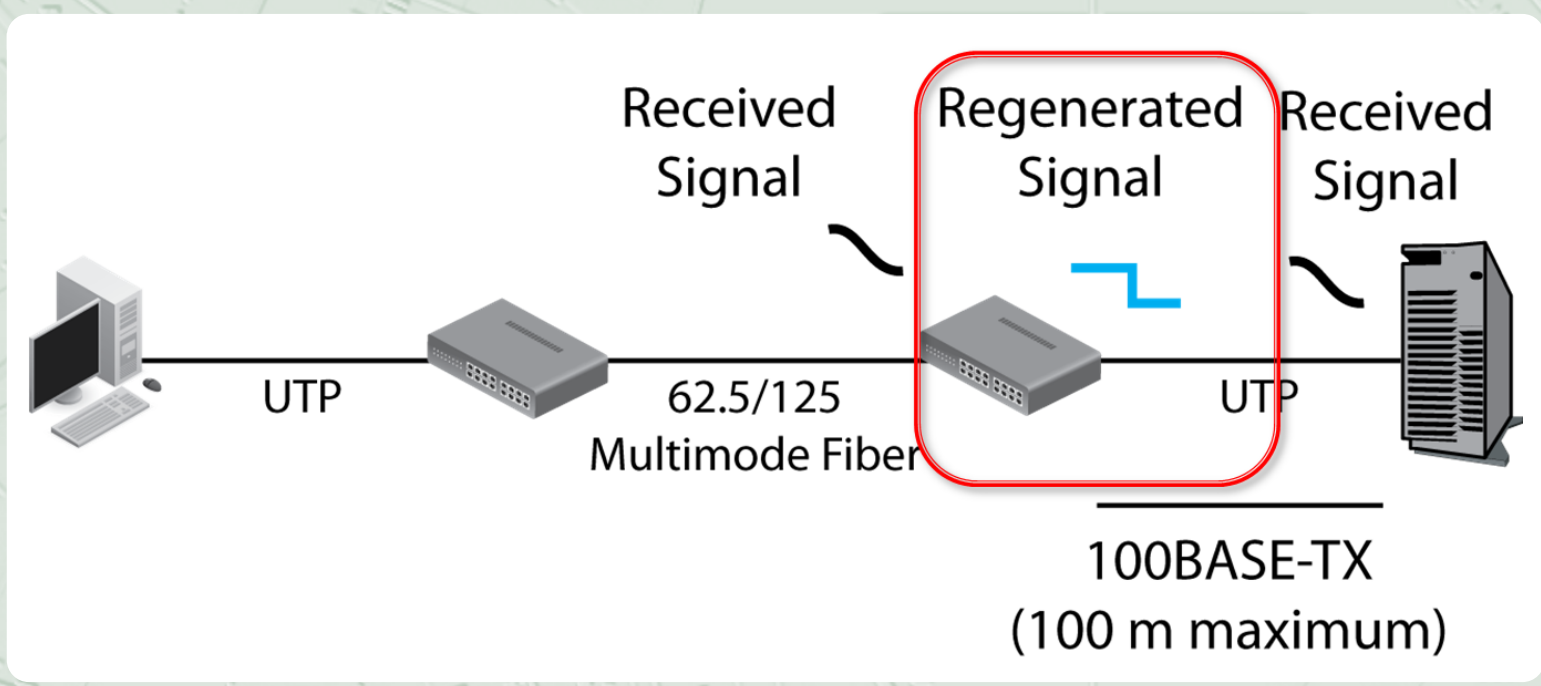
- The first physical link is 100BASE-TX, so the maximum physical span is 100 meters.

Data Link Using Multiple Switches



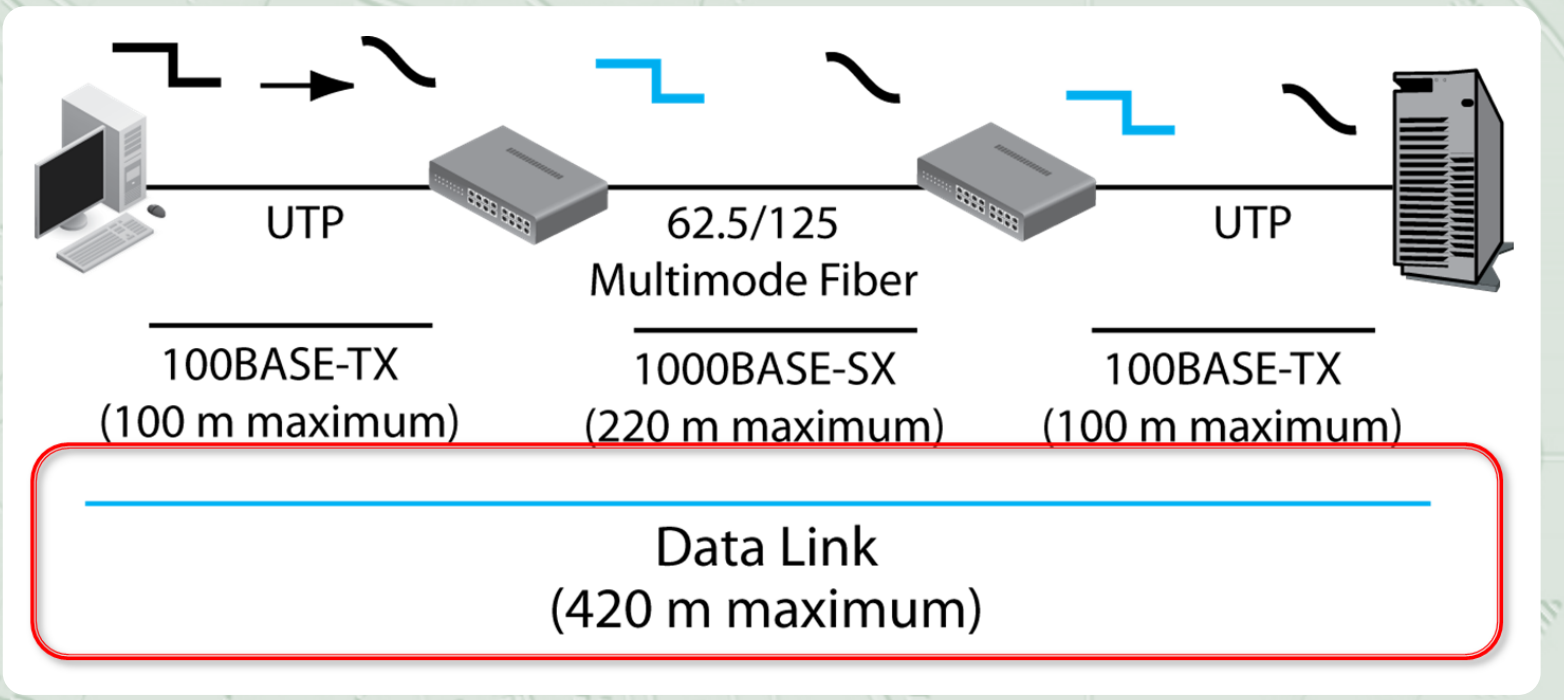
- The switch regenerates the received signal.
- On a 1000BASE-SX link, the clean new signal can travel up to another 220 meters.

Data Link Using Multiple Switches



- The second switch also regenerates the signal.
- The clean regenerated signal goes on.

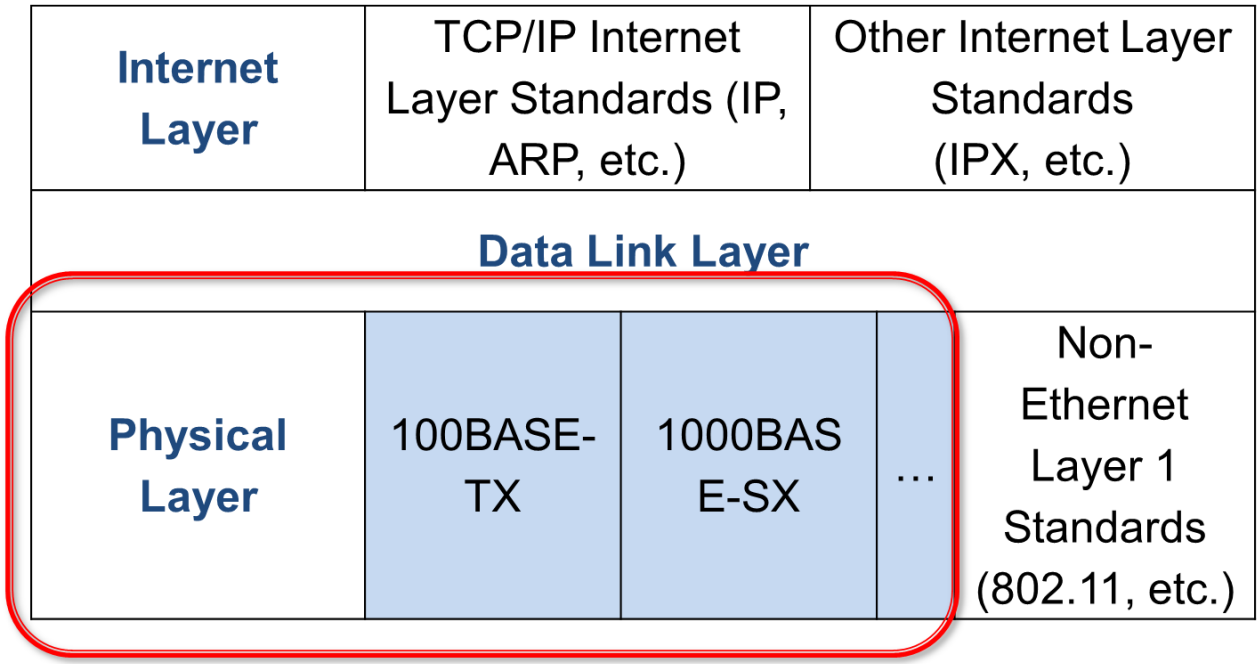
Data Link Using Multiple Switches



- Physical links have maximum distance spans, but thanks to regeneration, there is no maximum size to Ethernet network data links.

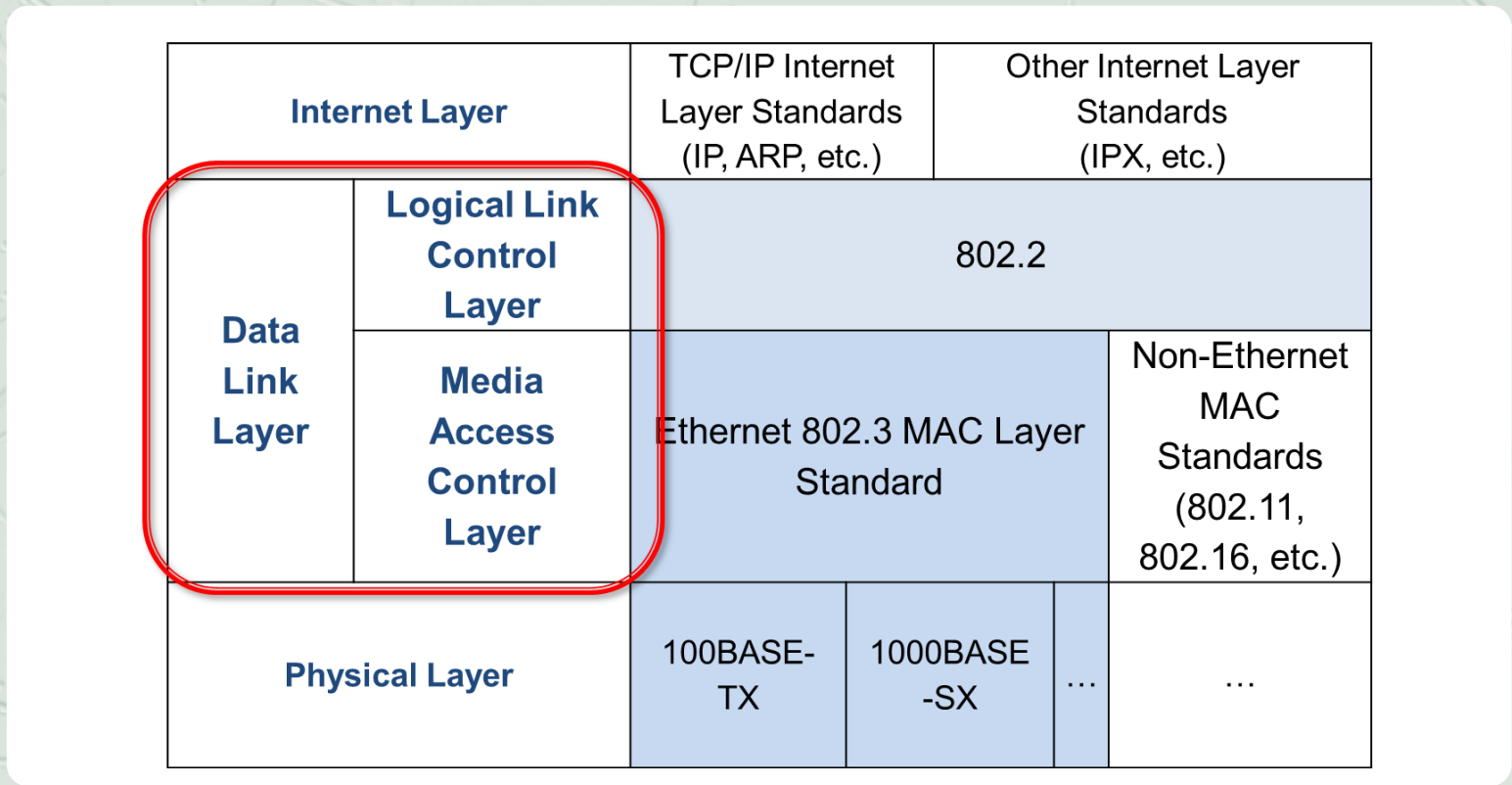
Ethernet data link layer (MAC) Standards

Layering in 802 Networks



- Ethernet has many physical layer standards.

Layering in 802 Networks



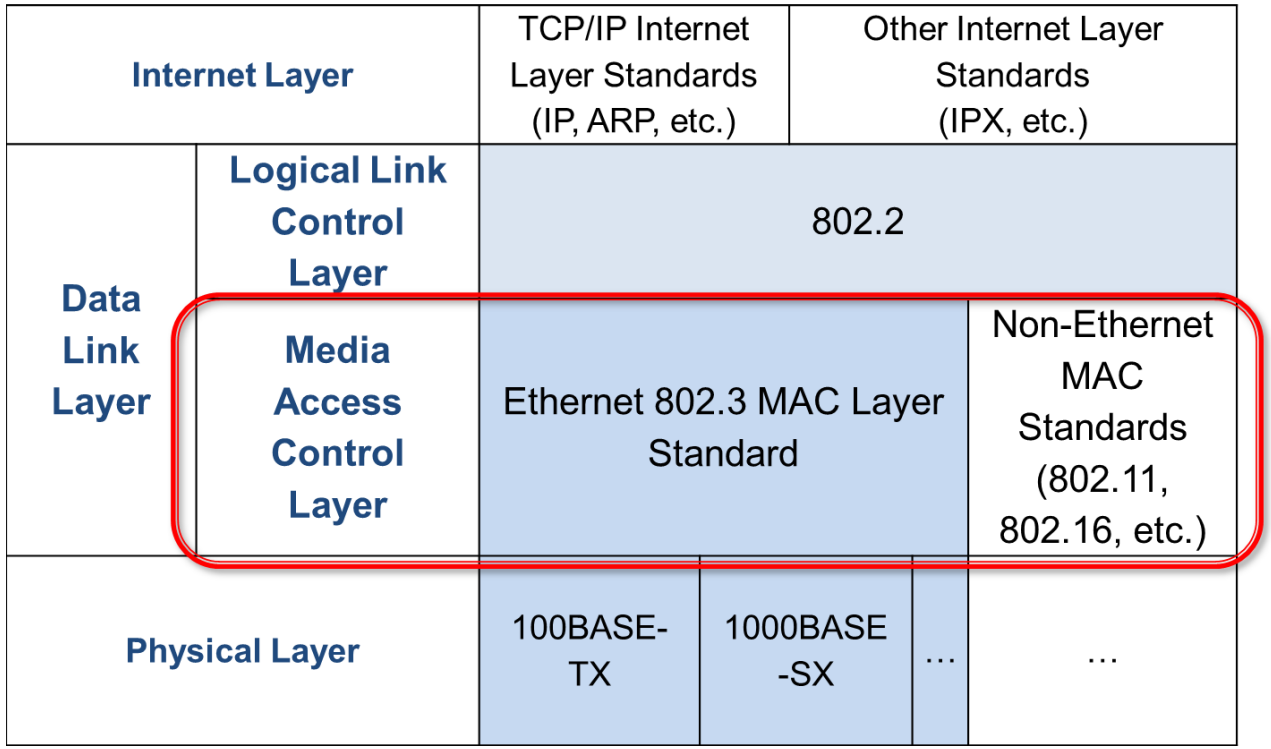
- The 802 Committee divided the data link layer into logical link control and media access control layers.

Layering in 802 Networks

<table>
<tr><td colspan="2">Internet Layer</td><td colspan="2">TCP/IP Internet Layer Standards (IP, ARP, etc.)</td><td>Other Internet Layer Standards (IPX, etc.)</td></tr>
<tr><td rowspan="2">Data Link Layer</td><td>Logical Link Control Layer</td><td colspan="3">802.2</td></tr>
<tr><td>Media Access Control Layer</td><td colspan="2">Ethernet 802.3 MAC Layer Standard</td><td>Non-Ethernet MAC Standards (802.11, 802.16, etc.)</td></tr>
<tr><td colspan="2">Physical Layer</td><td>100BASE-TX</td><td>1000BASE-SX</td><td>…</td><td>…</td></tr>
</table>

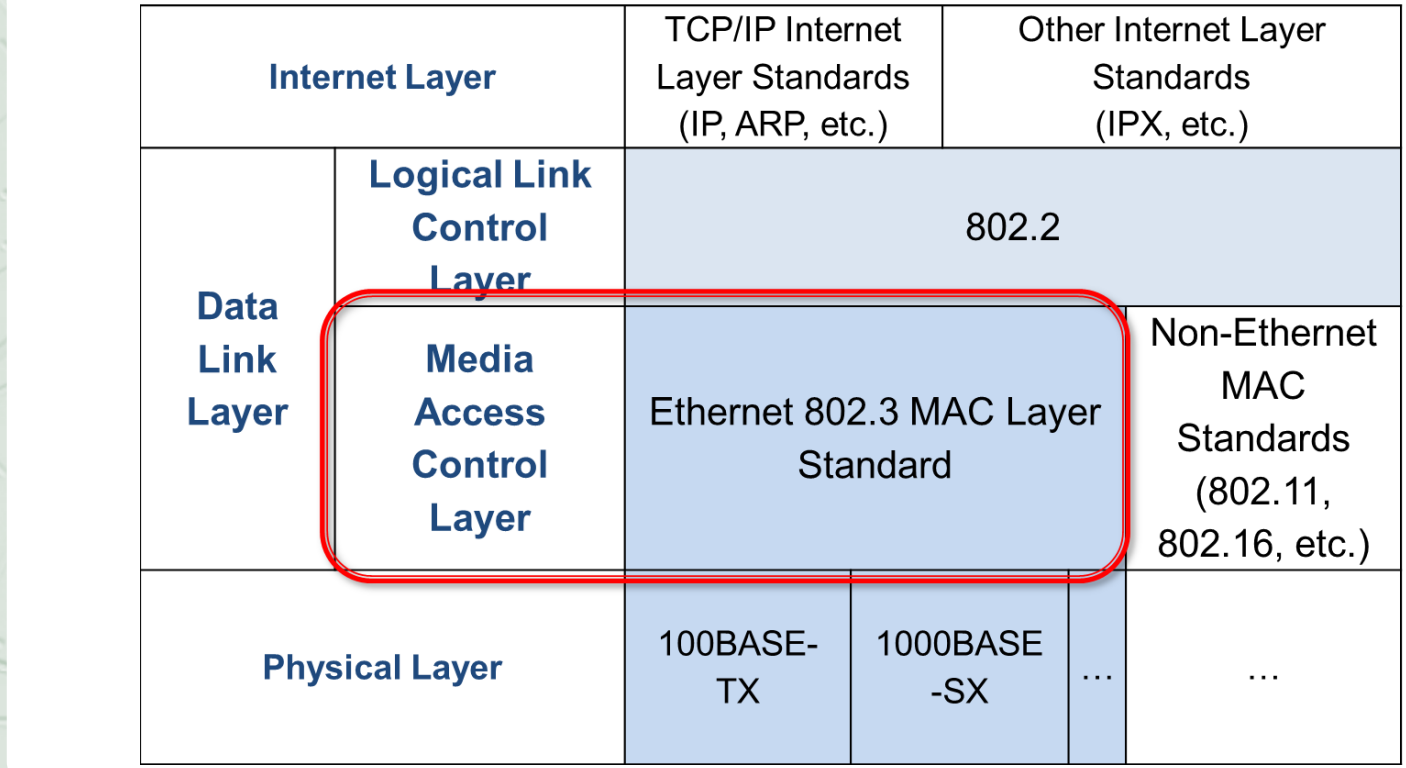
- The logical link control layer handles general work for all 802 standards.
- There is a single LLC standard, 802.2. In practice, it has no significance for Ethernet LAN managers.

Layering in 802 Networks



- The MAC layer handles standard-specific matters.
- Implementers must understand MAC layer standards.

Layering in 802 Networks



- Ethernet only has a single MAC layer standard.

Ethernet MAC Layer Frame

Field
Preamble (7 octets of 10101010 for synchronization)
Start Frame Delimiter (10101011 to end synch)
Destination MAC address (48 bits)
Source MAC address (48 bits)
Tag Protocol ID (TPID, Optional, 2 octets)
Tag Control Information (TCI, optional, 2 octets)

- The first two fields synchronize the receiver's clock with the senders clock.
- If this was not done, the receiver might read bit 1,012 when it is really bit 1,102.

Ethernet MAC Layer Frame

Field
Preamble (7 octets of 10101010 for synchronization)
Start Frame Delimiter (10101011 to end synch)
Destination MAC address (48 bits)
Source MAC address (48 bits)
Tag Protocol ID (TPID, Optional, 2 octets)
Tag Control Information (TCI, optional, 2 octets)

- The MAC address fields are 48 bits long.
- They are represented for humans in hexadecimal notation (Base 16).

Hexadecimal Notation

4 Bits	Decimal (Base 10)	Hexadecimal (Base 16)
0000	0	0 hex
0001	1	1 hex
0010	2	2 hex
0011	3	3 hex
0100	4	4 hex
0101	5	5 hex
0110	6	6 hex
0111	7	7 hex

4 Bits	Decimal (Base 10)	Hexadecimal (Base 16)
1000	8	8 hex
1001	9	9 hex
1010	10	A hex
1011	11	B hex
1100	12	C hex
1101	13	D hex
1110	14	E hex
1111	15	F hex

Hexadecimal Notation

- Divide a 48-bit Ethernet address into 12 four-bit "nibbles".
- Convert each nibble into a Hex symbol.
- Combine two hex symbols into pairs and place a dash between pairs.
- For example, A1-36-CD-7B-DF hex begins with 10100001 for A1, followed by 00110110 for 36.

Ethernet MAC Layer Frame

Field
Preamble (7 octets of 10101010 for synchronization
Start Frame Delimiter (10101011 to end synch)
Destination MAC address (48 bits)
Source MAC address (48 bits)
Tag Protocol ID (TPID, Optional, 2 octets)
Tag Control Information (TCI, optional, 2 octets)
Length (2 octets)
Logical Link Control (LLC subheader, 8 octets)
Packet (variable length)
PAD (Situation-Specific)
Frame Check Sequence

- The TPID and TCI fields are optional. They are used to add priority levels of VLAN numbers.

Ethernet MAC Layer Frame

Field
Preamble (7 octets of 10101010 for synchronization
Start Frame Delimiter (10101011 to end synch)
Destination MAC address (48 bits)
Source MAC address (48 bits)
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Tag Control Information (TCI, optional, 2 octets)
Length (2 octets)
Logical Link Control (LLC subheader, 8 octets)
Packet (variable length)
PAD (Situation-Specific)
Frame Check Sequence

- The length field gives the length of the data field, not the total length of the frame.

Ethernet MAC Layer Frame

Field
Preamble (7 octets of 10101010 for synchronization
Start Frame Delimiter (10101011 to end synch)
Destination MAC address (48 bits)
Source MAC address (48 bits)
Tag Protocol ID (TPID, Optional, 2 octets)
Tag Control Information (TCI, optional, 2 octets)
Length (2 octets)
Logical Link Control (LLC subheader, 8 octets)
Packet (variable length)
PAD (Situation-Specific)
Frame Check Sequence

- The data field has two fields.
- The LLC subheader identifies the type of packet in the data field.
- The packet has variable length.

Ethernet MAC Layer Frame

Field
Preamble (7 octets of 10101010 for synchronization
Start Frame Delimiter (10101011 to end synch)
Destination MAC address (48 bits)
Source MAC address (48 bits)
Length (2 octets)
Logical Link Control (LLC subheader, 8 octets)
Packet (variable length)
PAD (Situation-Specific)
Frame Check Sequence

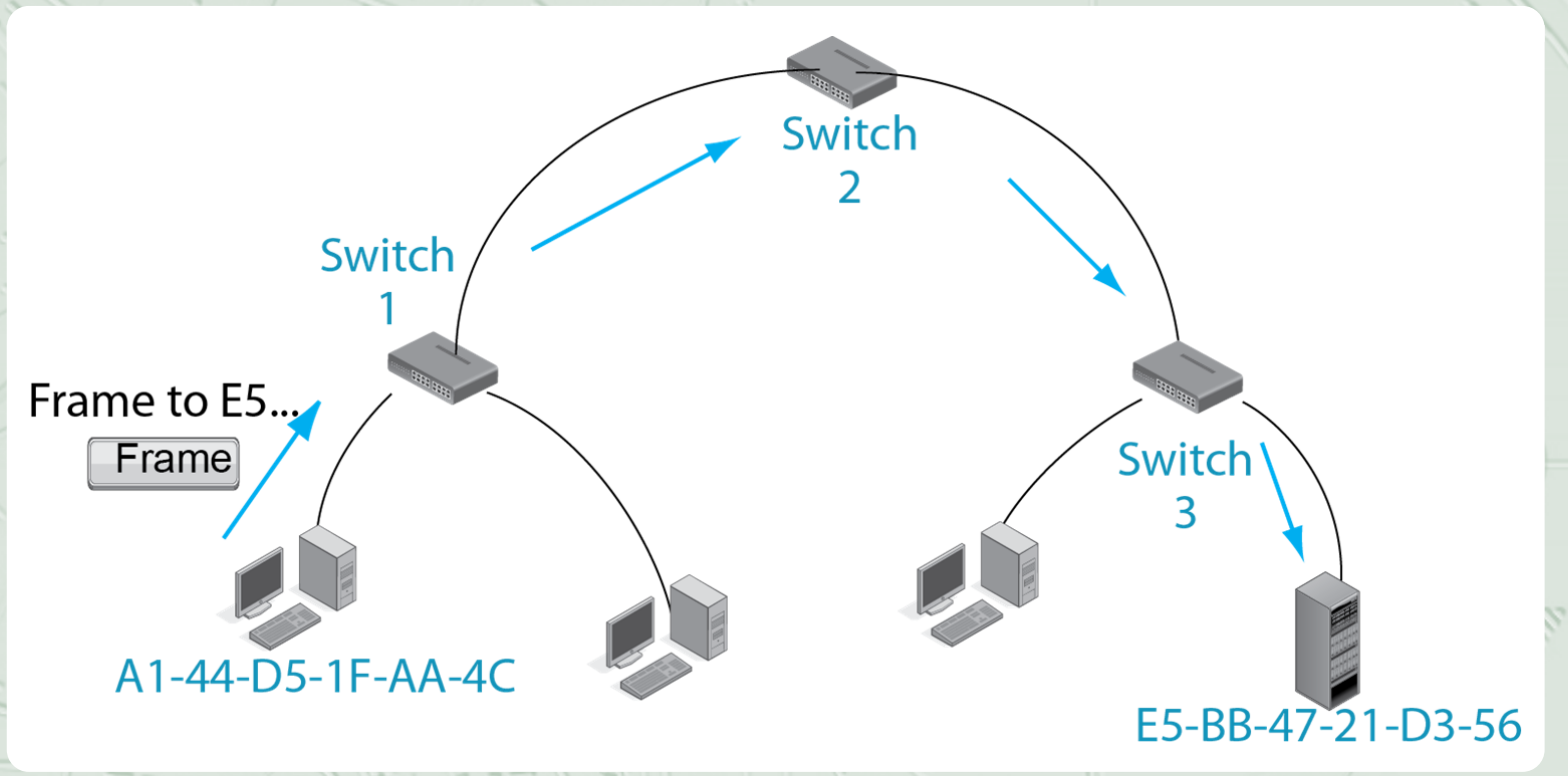
- The PAD field is added by the sender only if the data field is less than 46 octets.
- The PAD field is selected so that the total of the length field and the pad is 46 octets.

Ethernet MAC Layer Frame

Field
Preamble (7 octets of 10101010 for synchronization
Start Frame Delimiter (10101011 to end synch)
Destination MAC address (48 bits)
Source MAC address (48 bits)
Length (2 octets)
Logical Link Control (LLC subheader, 8 octets)
Packet (variable length)
PAD (Situation-Specific)
Frame Check Sequence

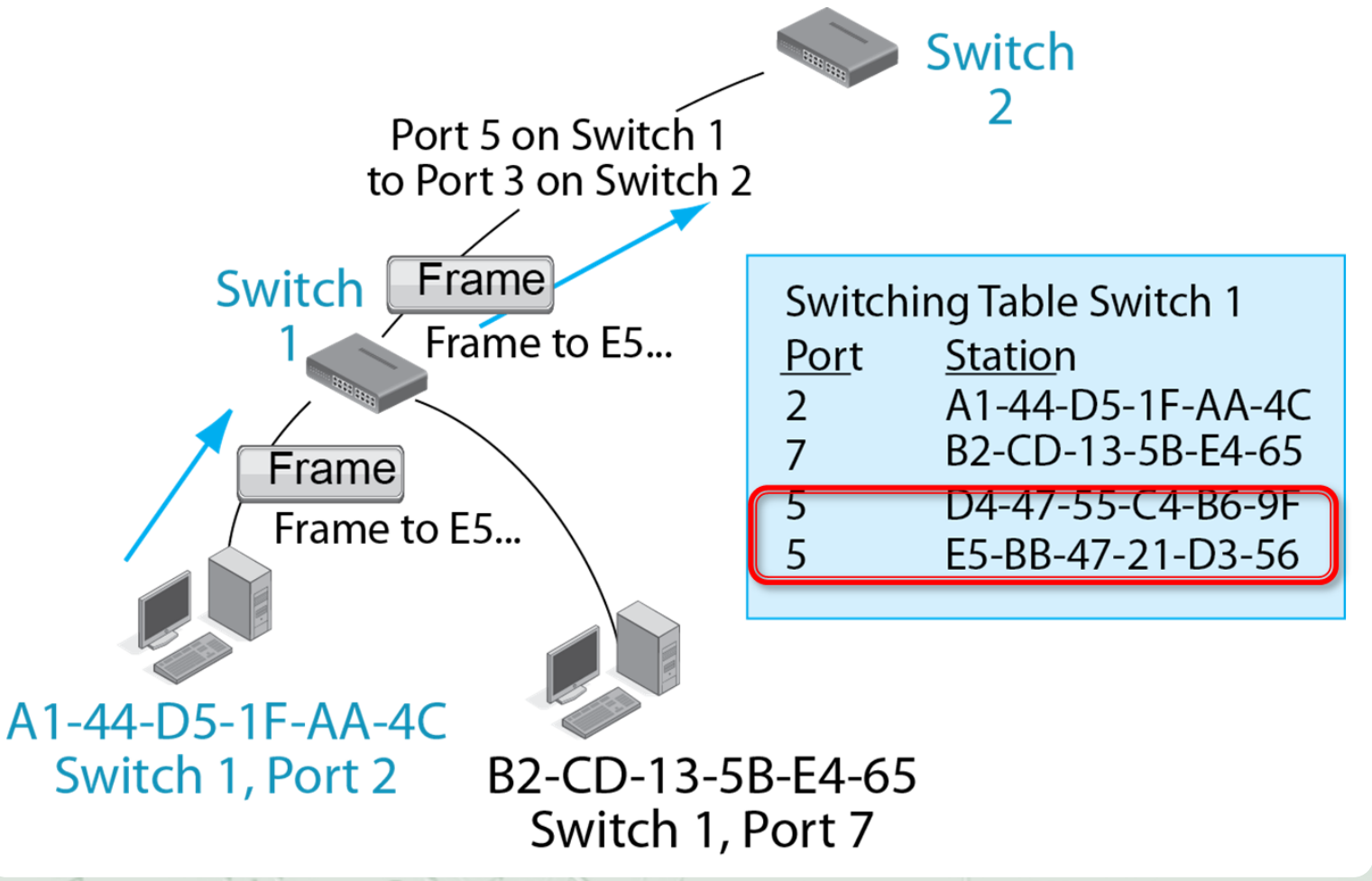
- The Frame Check Sequence field is for error detection.
- If an error is found, the frame is discarded.
- There is no error message or request for transmission.
- Ethernet is not reliable.

Multiswitch Ethernet LAN



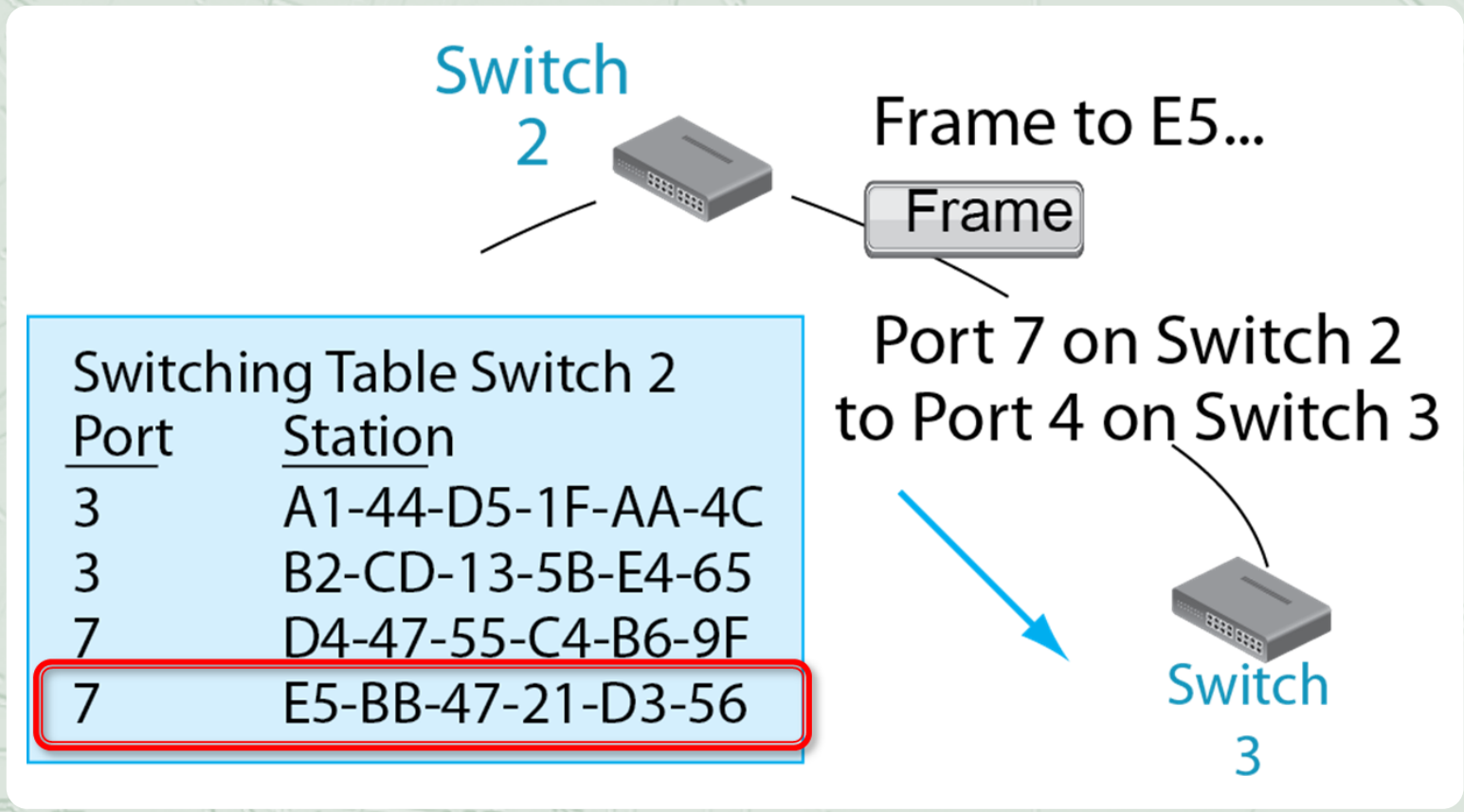
- A packet from A1...to E5...Must pass through Switches 1, 2, and 3.

Multiswitch Ethernet LAN



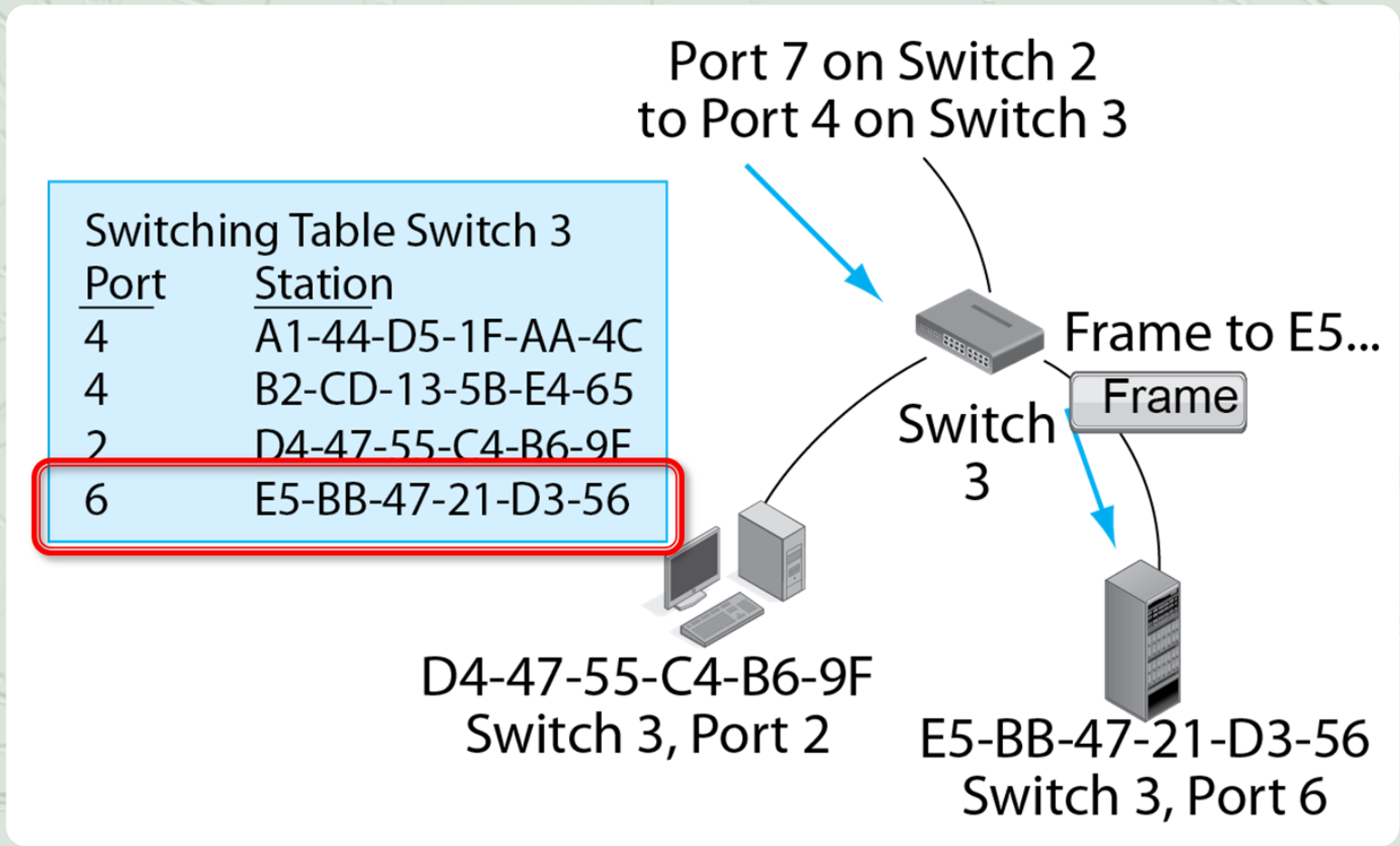
- Switch 1 sees that it should send the frame to E5 out Port 5.

Multiswitch Ethernet LAN



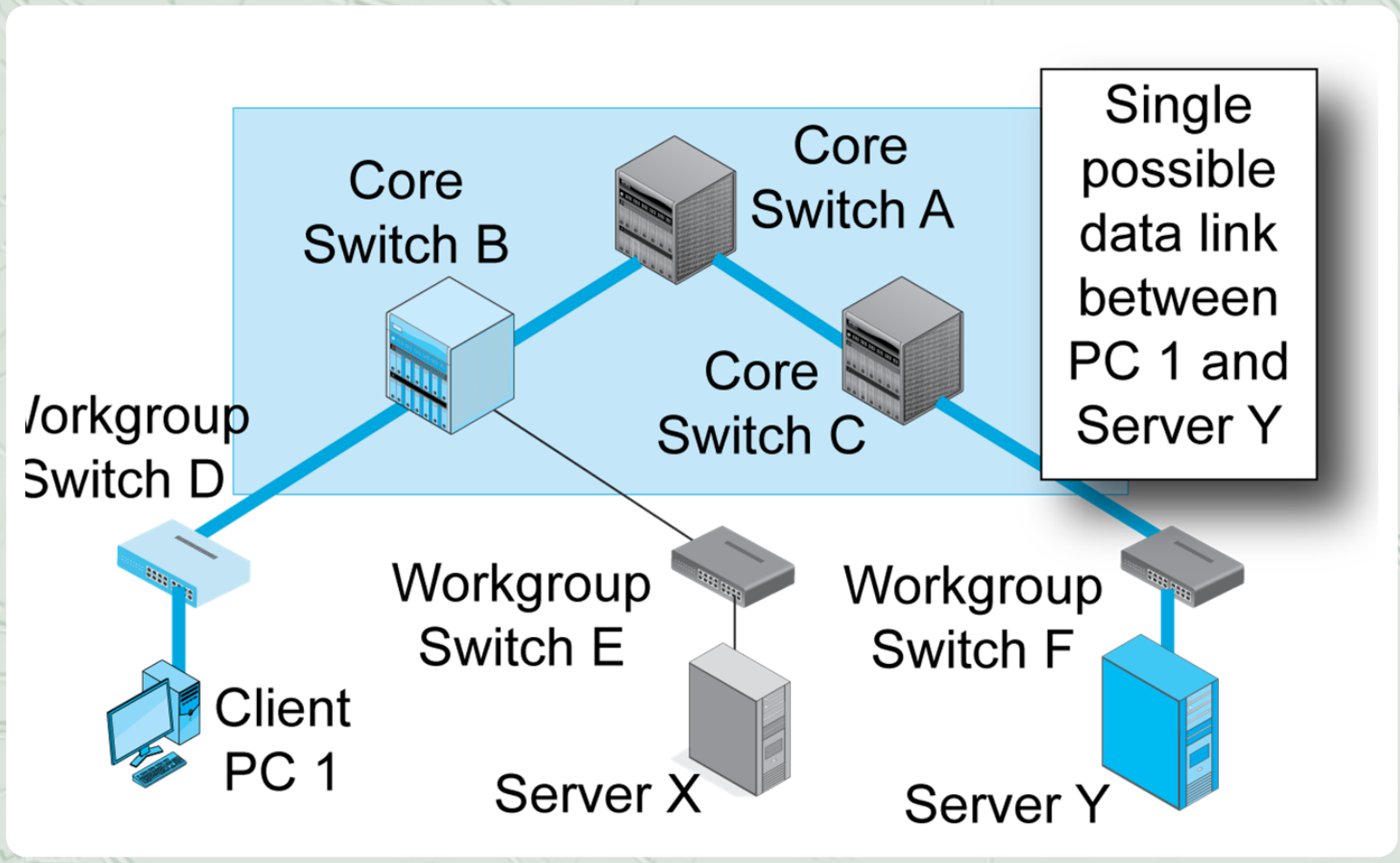
- Switch 2 sees that it should send the frame to E5 out Port 7.

Multiswitch Ethernet LAN



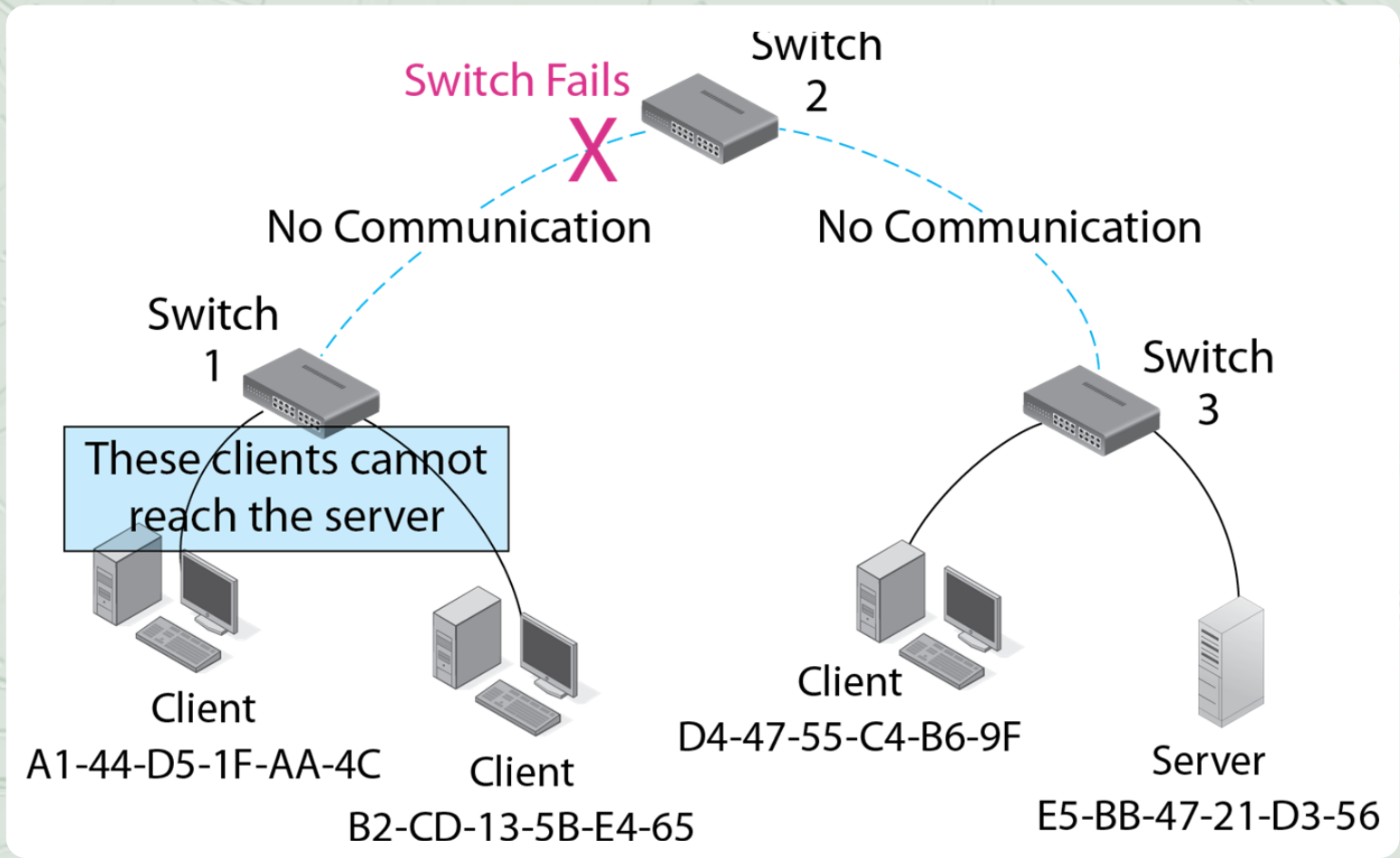
- Switch 3 sees that it should send the frame to E5 out Port 6.

Hierarchical Ethernet LAN



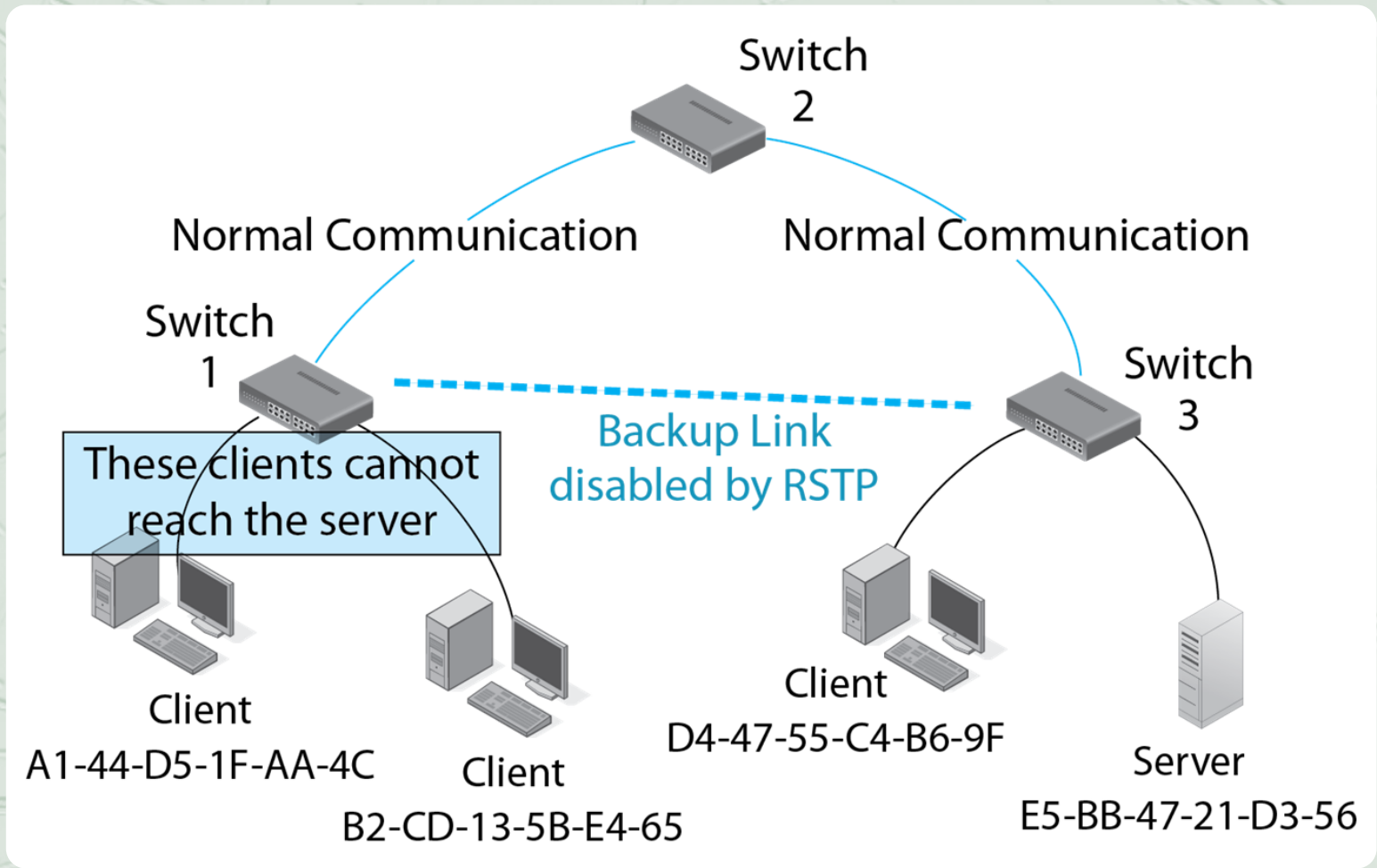
Advanced Ethernet concepts

Single Point of Failure and the Rapid Spanning Tree Protocol



- Ethernet's hierarchy creates single points of failure.

Single Point of Failure and the Rapid Spanning Tree Protocol



- RSTP allows backup links to be added.
- These are disabled until needed.

Switched Wide Area Networks (WANs)

Wide Area Networks

- Wide Area Networks (WANs)
  - Connect different sites.
- WAN Purposes
  - Provide remote access to individuals who are off site.
  - Link sites within the same corporation.
  - Provide Internet access.

Wide Area Networks

- Carriers
  - Beyond their physical premises, companies must use the services of regulated carriers.
  - Carriers have rights of way for transmission in public areas.
  - Companies are limited to whatever services the carriers provide.
  - Prices for carrier services change abruptly and without technological reasons.
  - Prices and service availability vary from country to country.

Wide Area Networks

- High Costs and Low Speeds
  - High cost per bit transmitted, compared with LANs
  - Consequently, lower speeds (most commonly 256 kbps to about 50 megabits per second)