

Summary

- Local Area Networks
 - Designed for short distance
 - Use shared media
 - Many technologies exist
- Topology refers to general shape
 - Bus
 - Ring
 - Star

Summary (continued)

- Address
 - Unique number assigned to station
 - Put in frame header
 - Recognized by hardware
- Address forms
 - Unicast
 - Broadcast
 - Multicast

Summary (continued)

- Type information
 - Describes data in frame
 - Set by sender
 - Examined by receiver
- Frame format
 - Header contains address and type information
 - Payload contains data being sent

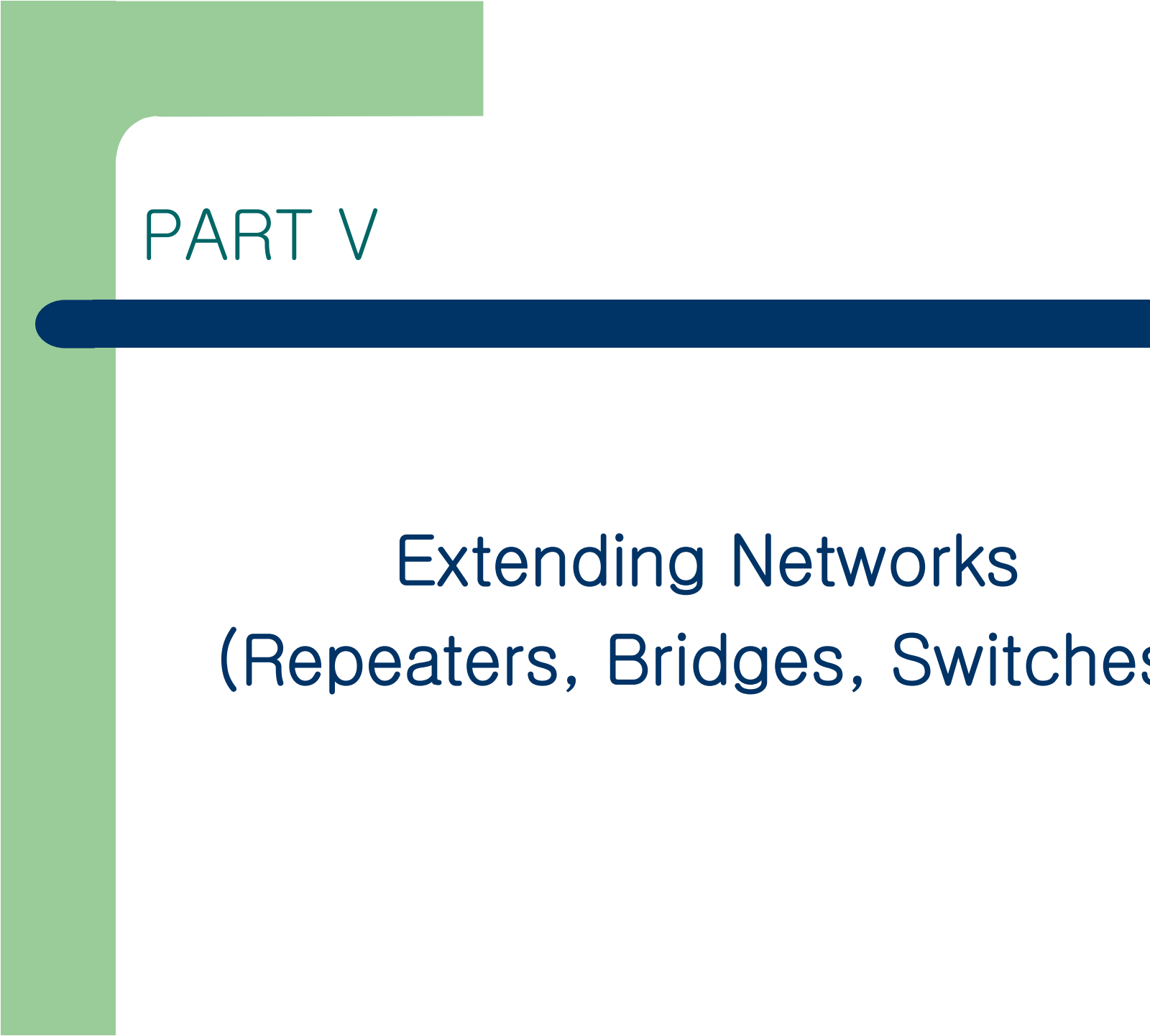
Summary (continued)

- Currently popular LAN technology
 - Ethernet (bus)
- Older LAN technologies
 - IBM Token Ring
 - FDDI (ring)
 - ATM (star)

Summary (continued)

- Wiring and topology
 - Can distinguish
 - * Logical topology
 - * Physical topology (wiring)
 - Hub allows
 - * Star-shaped bus
 - * Star-shaped ring

PART V

A decorative graphic on the left side of the slide. It consists of a light green L-shaped bar that starts at the top left and extends downwards. A dark blue horizontal bar with rounded ends is positioned across the middle of the slide, overlapping the green bar.

Extending Networks (Repeaters, Bridges, Switches)

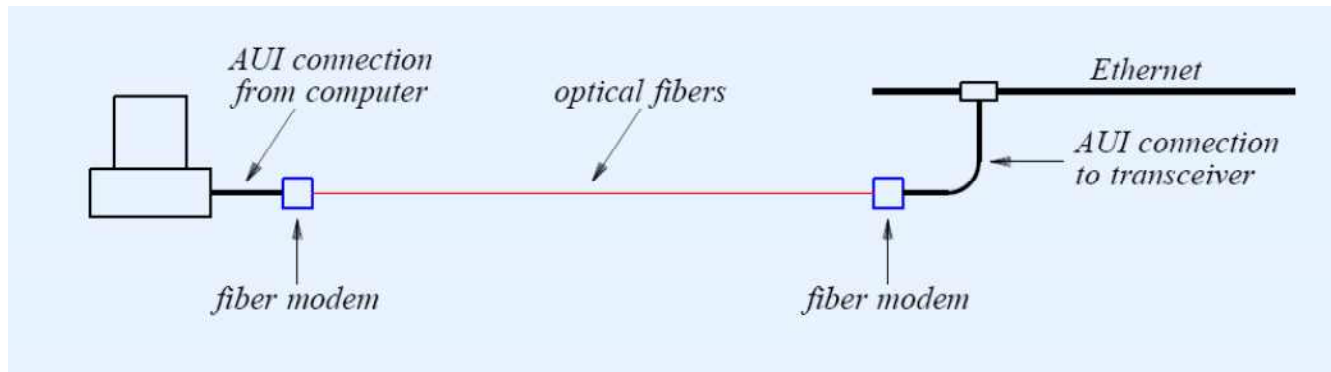
Motivation

- Recall
 - Each LAN technology has a distance limitation
 - Example: CSMA/CD & Token Ring cannot work across arbitrary distance (Also each station has power limit) → The reason for LAN length limit
- However
 - Users desire arbitrary distance connections
 - Example: two computers across a corporate campus are part of one workgroup

Extension Techniques

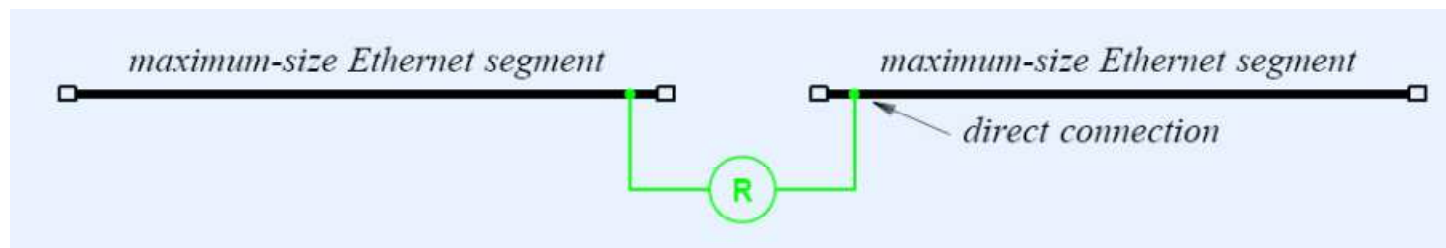
- Must not violate design assumptions
- Often part of original design
- Example technique
 - Use connection with lower delay than copper

Illustration Of Extension For One Computer



- Optical fiber
 - Has lower delay
 - can overcome the length limit
 - Has high bandwidth
 - Can pass signals within specified bounds (few Km)

Repeater



→Solution for station power consumption budget not delay

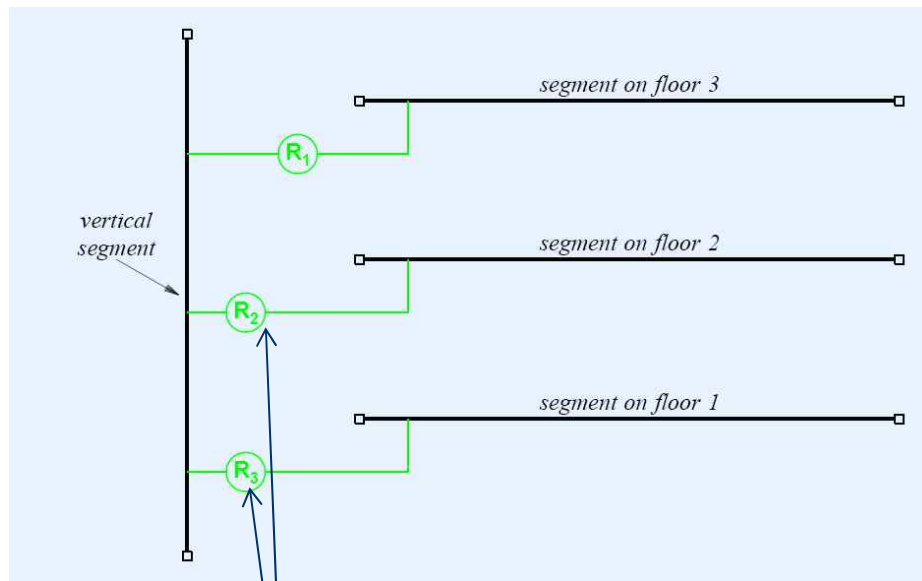
→For delay, there are MAX # of repeaters allowed.

- Hardware device
- Connects two LAN segments
(segment limit ~ 500m)
- Copies signal from one segment to the other
- Connection can be extended with Fiber Optic Intra-Repeater Link (FOIRL) – low delay

Repeater (continued)

- Amplifies signals from one segment and sends to the other
- Operates in two directions simultaneously
- Propagates noise and collisions (collision occurs in the other segments, too)
- Max. 4 repeaters btw. pair of station allowed (hub counts as a repeater)

Repeaters And The Original Ethernet Wiring Scheme



- Designed for office
- Only two repeaters between any pair of stations

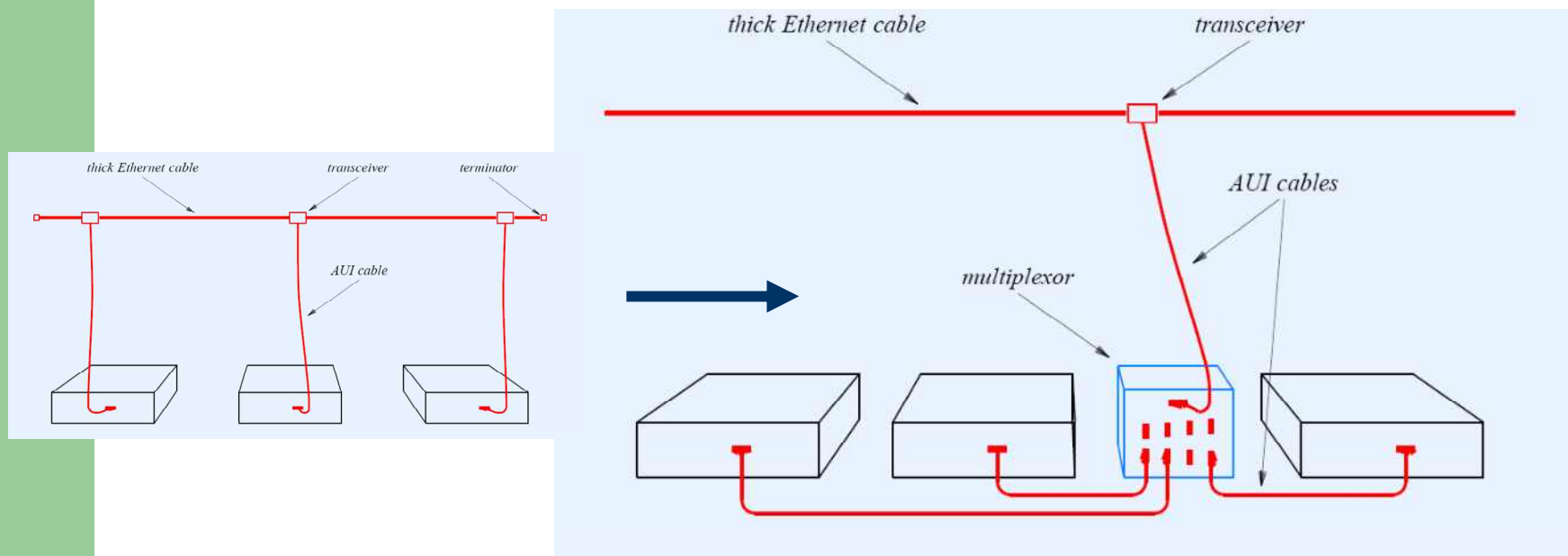
Hub

- Physically
 - Small electronic device
 - Has connections for several computers (e.g., 4 or 20)
- Logically
 - Operates on signals
 - Propagates each incoming signal to all connections
 - Similar to connecting segments with repeaters
 - Does not understand packets
- Extremely low cost

Connection Multiplexing

- Concept
 - Multiple stations share one network connection
- Motivation
 - Cost
 - Convenience of wiring
- Hardware device required

Illustration of Connection Multiplexing



- Multiplexing device attached to network
- Stations attach to device
- Predates (occur at earlier date) hubs

Modern Equivalent of Connection Multiplexing

- Hubs used now
- Connections on a hub
 - One for each attached computer
 - One for another hub
- Multiple hubs
 - Can be interconnected in a *daisy chain*
 - Operate as one giant hub
 - Called *stacking*

Bridge

- Hardware device
- Connects two LAN segments
- Forwards frames (same interface as NIC)
 - Promiscuous mode listening
- Does not forward noise or collisions
 - isolates the problems on each segment
 - discard the frame with error and collisions
- Learns addresses and filters
- Allows independent transmission on each segment after bridge knows the node attached on each segment
- Usually Embedded system with code ROM with processor, memory, two network interface

Bridge Algorithm

- Listen in promiscuous mode
- Watch source address in incoming frames
- Make list of computers on each segment
- Only forward if necessary
- Always forward broadcast/multicast

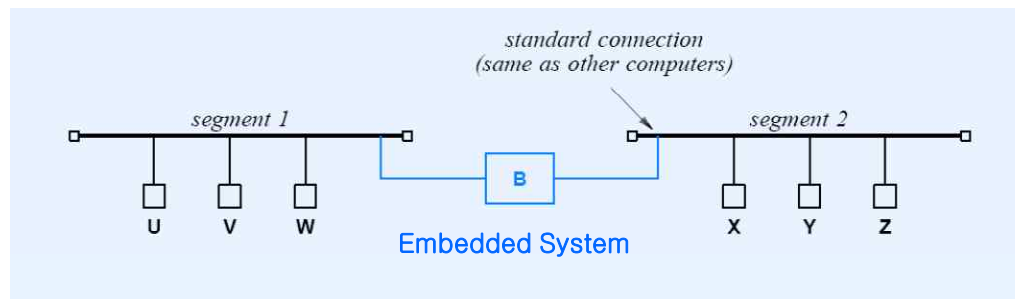
Illustration Of A Bridge

U, V, W and X, Y, Z

Can communicate

In parallel ! →

Computers which interacts frequently are placed on the same segment.

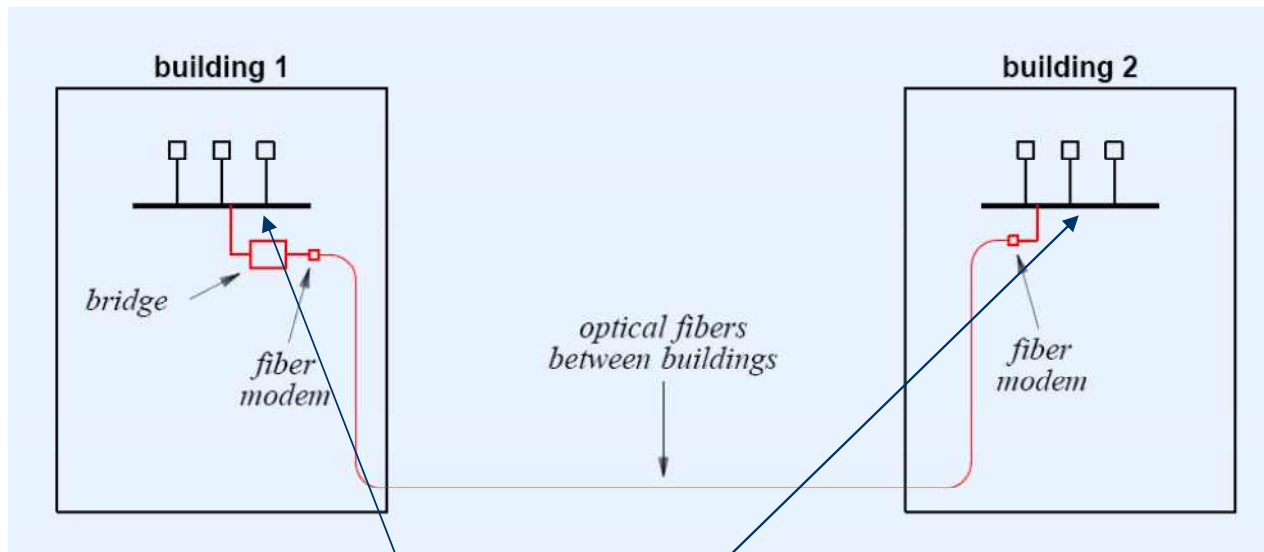


Event List	Segment 1 List	Segment 2
Bridge boots	—	—
U sends to V	U	—
V sends to U	U, V	—
Z broadcasts	U, V	Z
Y sends to V	U, V	Z, Y
Y sends to X	U, V	Z, Y
X sends to W	U, V	Z, Y, X
W sends to Z	U, V, W	Z, Y, X

← (Only by checking source address in packets)

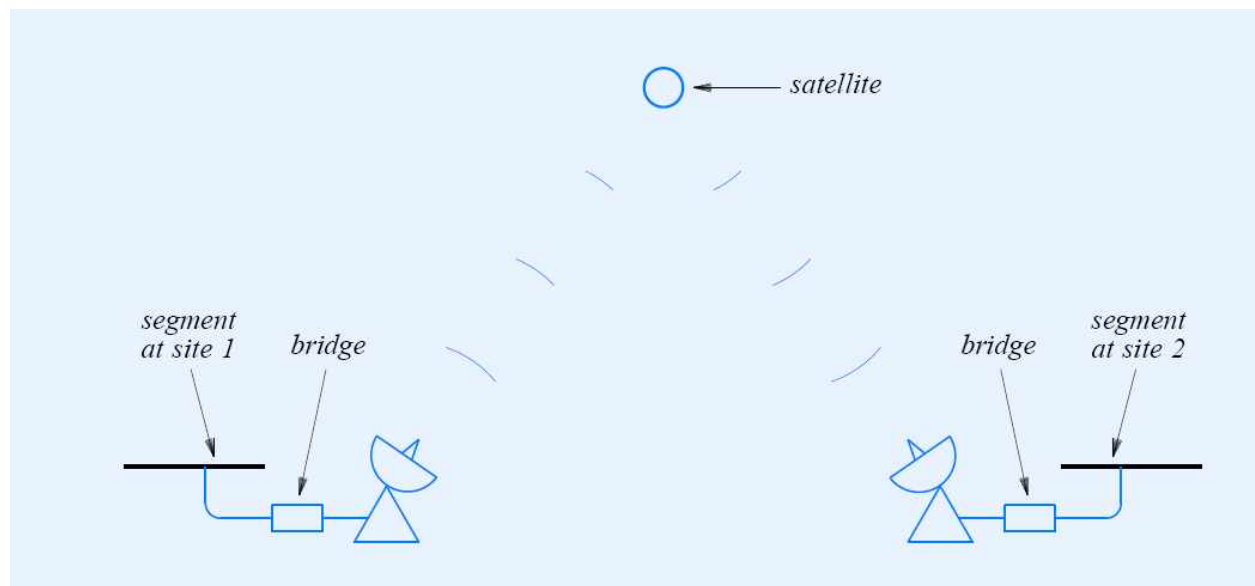
Bridge uses source address to learn location of computers
Learning is completely automated

Extending A Bridge



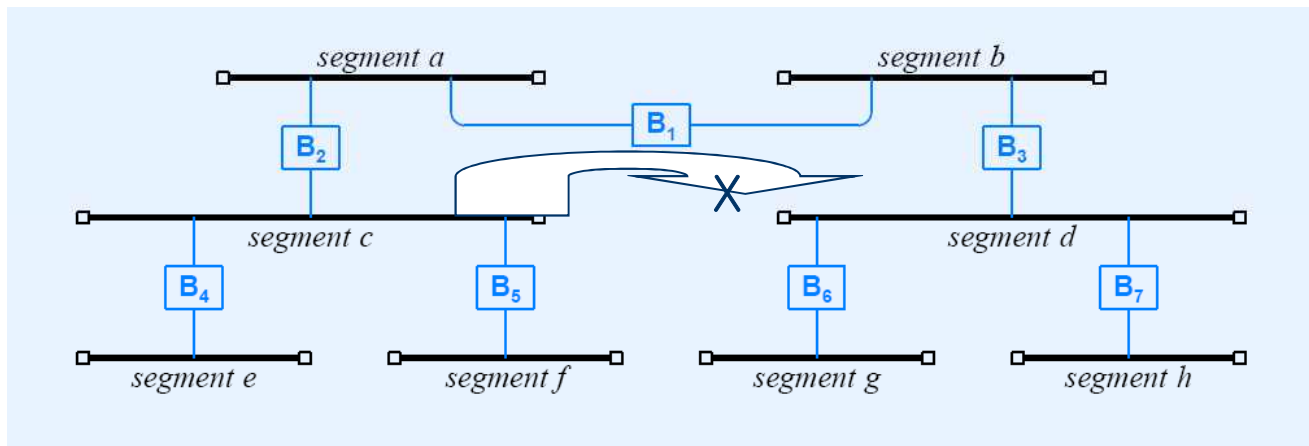
- Typically optical fiber
- Can span buildings
- Individual computer can be added or removed without wiring change (segment based maintenance)

Satellite Bridging



- Can span arbitrary distance
- Unnecessary frame forwarding should be avoided due to Low BW
→ Each bridge should know the address of the sites
- Buffering is necessary to balance the LAN and satellite channel speed. Usually sender waits for response → No overflow

Apparent Problem



- Complex bridge connections may not be apparent
- Adding one more bridge inadvertently introduces a cycle
- Consider a broadcast frame

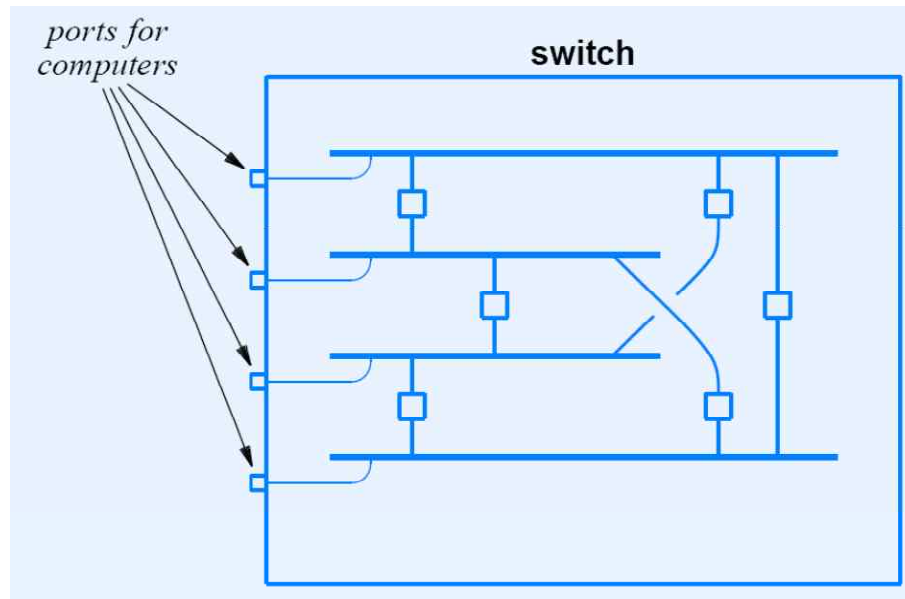
Spanning Tree Algorithm

- To break the cycles
 1. really break the bridge connection cycle
 2. prohibits a bridge to forward (*****)
 - Allows cycles
 - Used by all bridges to
 - Discover one another
 - Break cycle(s)
 - Known as *Distributed Spanning Tree (DST)*
 - allows a bridge to determine whether forwarding will introduce a cycle
- 

Switch

- Electronic device
- Physically similar to a hub (one port to many ports)
- Logically similar to a bridge
 - Switch: One computer per segment
(similar to multiple segment connected by bridge)
on the contrary, hub: shared media
 - Operates on packets
 - Understands addresses
 - Only forwards when necessary
- Permits separate pairs of computers to communicate at the same time
 - $RN/2$
(R: rate at which a given computer can transmit data,
N: total number of computers connected to switch) – HUB: R
 - Like the bridge, independent segment basis
(Processor + Interconnections)
- Higher cost than hub
 - Read TEXT (Performance) pp.173

Conceptual Switch Function



HUB & Switch Combo
is possible.

HUB: Single Segment
with many computers (shared)

Switch: Multiple Segment (parallel)
Compromised Solution

- Conceptual operation
 - One LAN segment per host
 - Bridge interconnects each pair of segments
- NOT an actual implementation

Summary

- LANs
 - Have distance limitations
 - Can be extended
- Fiber can be used between computer and LAN (Due to low delay)
- Repeater
 - Connects two LAN segments (extend segment)
 - Repeats and amplifies all signals
 - Forwards noise and collisions

Summary (continued)

- Bridge
 - Connects two LAN segments
 - Understands frames
 - Uses addresses
 - Does not forward noise or collisions
 - Allows simultaneous transmission on segments

Summary (continued)

- Hub
 - Central facility in star-shaped network
 - Operates like a repeater
- Switch
 - Central facility in star-shaped network
 - Operates like a set of bridged segments

PART VI

Long-Distance and Local Loop Digital Connection Technologies

(To overcome
the # of computers that LAN can handle
and
distance limit of LAN
→ WAN)

Motivation

- Connect computers across

- Large geographic distance

- Public right-of-way

- * Streets

- * Buildings

- * Railroads

A right of way is a form of an easement granted by the property owner that gives the right to travel over your land and to have the reasonable use and enjoyment of your property to others as long as it is not inconsistent with your use and enjoyment of the land.

Long-Distance Transmission Technologies

- General solution: lease transmission facilities from telephone company
 - Point-to-point topology
 - NOT part of conventional telephone system
 - Copper, fiber, microwave, or satellite channels available
 - Customer chooses analog or digital

Equipment For Leased Connections

- Analog circuit
 - Modem required at each end
- Digital circuit
 - DSU/CSU required at each end

(Digital (or Data) Service Unit/Channel Service Unit) A pair of communications devices that connect an inhouse line to an external digital circuit (T1, DDS, etc.). It is similar to a modem, but connects a digital circuit rather than an analog one.

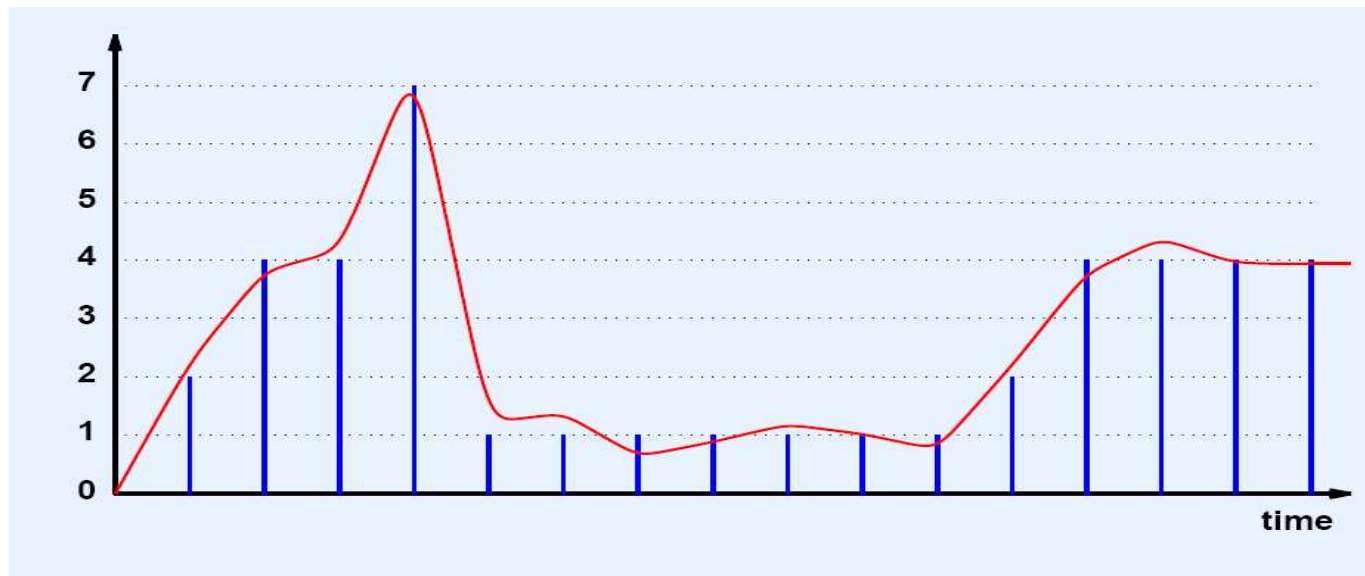
Digital Circuit Technology

- Developed by telephone companies
- Designed for use in voice system
 - Analog audio from user's telephone converted to digital format
 - Digital format sent across network
 - Digital format converted back to analog audio

(Digitization overview in the TEXT – pp.178)

4000Hz needs 8000 samples/sec. every 125us period

Illustration Of Digitized Signal

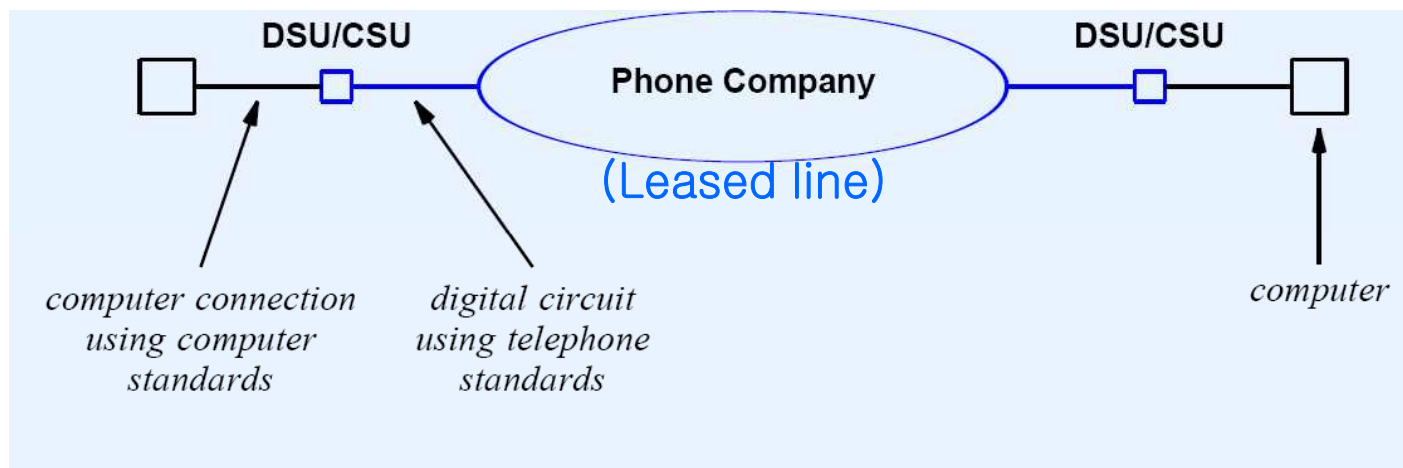


- Pick nearest digital value for each sample
- Telephone standard known as *Pulse Code Modulation (PCM)*
- Digital voice requires synchronous & isochronous network
- Study DPCM. ADPCM

DSU/CSU

- Performs two functions; usually a single “box”
- Needed because telephone industry digital encoding differs from computer industry digital encoding
- DSU portion (→ To computer side)
 - Translates between two encodings
- CSU portion (→ To phone line or company)
 - Terminates line + diagnostics + loop back test
 - Allows for maintenance
 - Bit stuffing or balanced encoding to prevent excessive and contiguous 1's

Illustration Of DSU/CSU



- Cost of digital circuit depends on
 - Distance
 - Capacity

Telephone Standards For Digital Circuits

- Specified by the telephone industry in each country
- Differs around the world
- Are known by two-character standard name
- Note: engineers refer to circuit capacity as “speed”

Voice channel: 8000 X (by Nyquist Theorem) 8bit samples/sec.=64Kbps

Example Circuit Capacities

Name	Bit Rate	Voice calls	Location
—	0.064 Mbps	1	
<u>T1</u>	<u>1.544 Mbps</u>	<u>24</u>	<u>North America</u>
T2	6.312 Mbps	96	North America
T3	44.736 Mbps	672	North America
E1	2.048 Mbps	30	Europe
E2	8.448 Mbps	120	Europe
E3	34.368 Mbps	480	Europe

Note: T2 is not popular

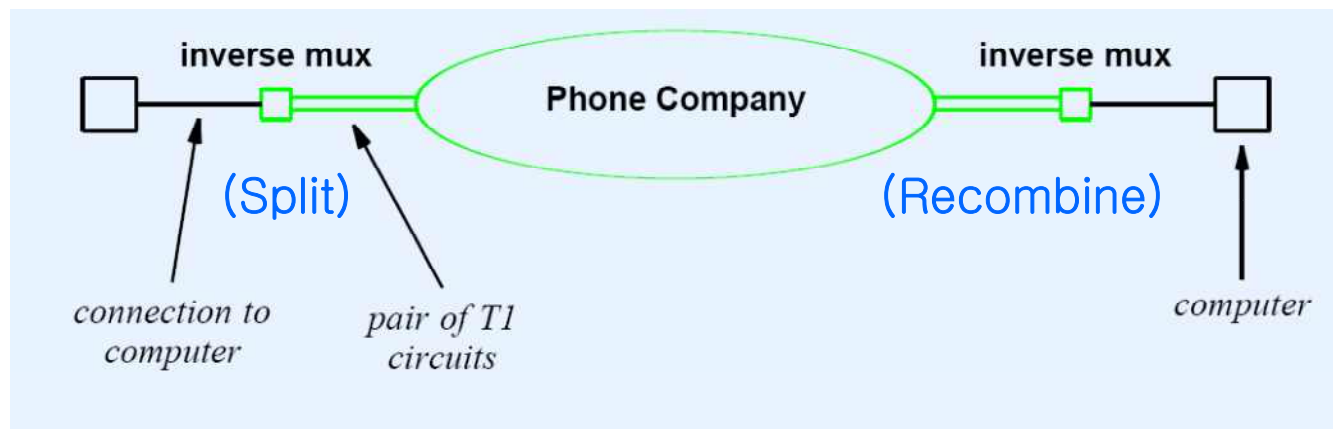
Common Digital Circuit Terminology

- Multiples of a single voice channel 64 Kbps (8000 X 8bit samples)
- Most common in North America
 - T1 circuit (24 times a single voice channels)
 - T3 circuit (28 times T1)
- Also available
 - Fractional T1 (e.g., 64 Kbps circuit– DS0 rate)
 - ← By Time Division Multiplexing

Inverse Multiplexing

- Combines two or more circuits
- Produces intermediate capacity (e.g. $T1 < x < T3$ needed) circuit
- Special hardware required
 - Needed at each end
 - Called *inverse multiplexor*

Example Of Inverse Multiplexing



- Can alternate between circuits for
 - Every other bit
 - Every other byte

High-Capacity Digital Circuits

- Called Trunk
- Also available from phone company
- Use optical fiber
- Electrical standards called *Synchronous Transport Signal (STS)*
- Optical standards called *Optical Carrier (OC)*

High-Capacity Circuits

Standard Name	Optical Name	Bit Rate	Voice Calls
STS-1	OC-1	51.840 Mbps	810
STS-3	OC-3	155.520 Mbps	2430
STS-12	OC-12	622.080 Mbps	9720
STS-24	OC-24	1,244.160 Mbps	19440
STS-48	OC-48	2,488.320 Mbps	38880

C: Concatenated
for single circuit
not inverse
multiplexed

3 OC-1

- *STS*– is standard for electrical signals
- *OC*– is standard for optical signals
- Engineers usually use *OC*– terminology for everything
- *OC-3* popular

Local Loop

- Telephone terminology
- Refers to connection between residence/business (subscriber) and central office (CO) (provider)
- Crosses public right-of-way
- Originally for analog POTS (Plain Old Telephone Service)