Data Communications

LECTURE 2: LOCAL AREA NETWORKS

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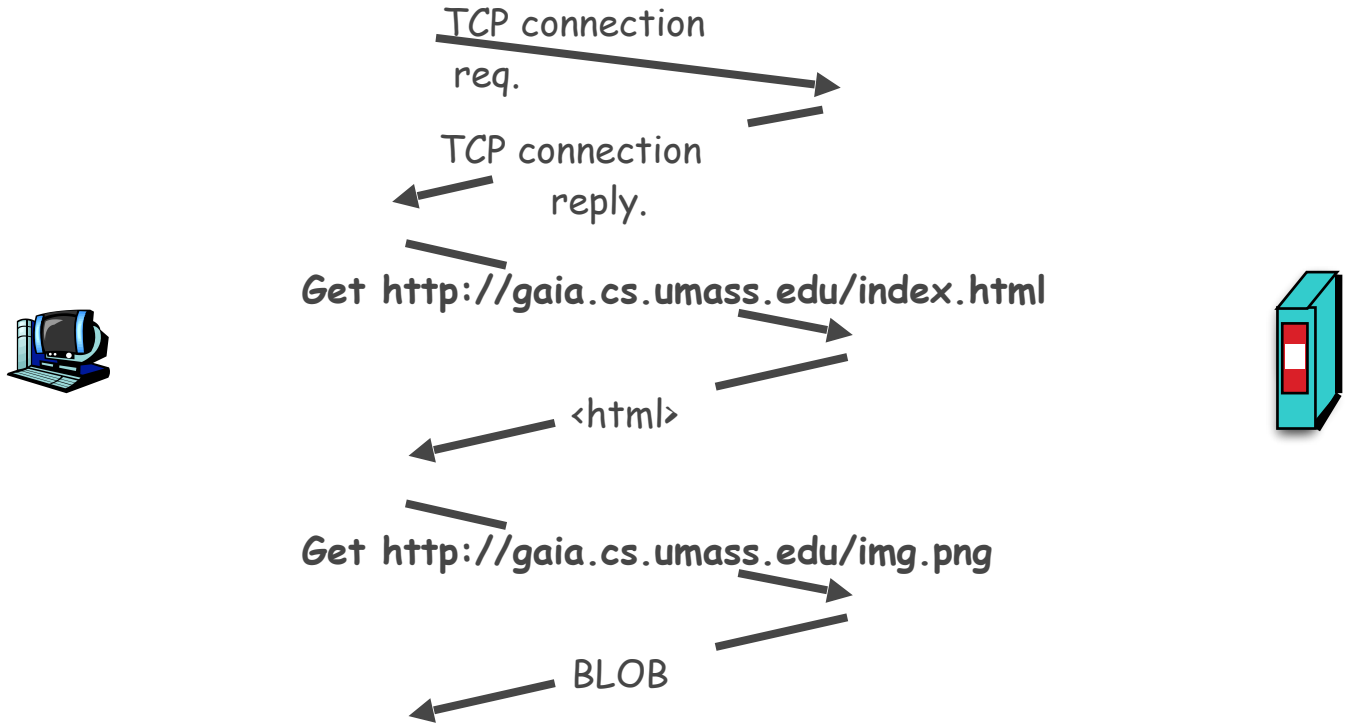
Working in Binary… your workshops and Wireshark

WHAT IS IT THAT YOU ARE LOOKING AT IN WIRESHARK?

“Give me this website please”

HOW DOES THE REQUEST HAPPEN? (WE’LL BUILD UP OVER MULTIPLE WEEKS AS WE SEE WHAT HAPPENS IN OTHER LAYERS).



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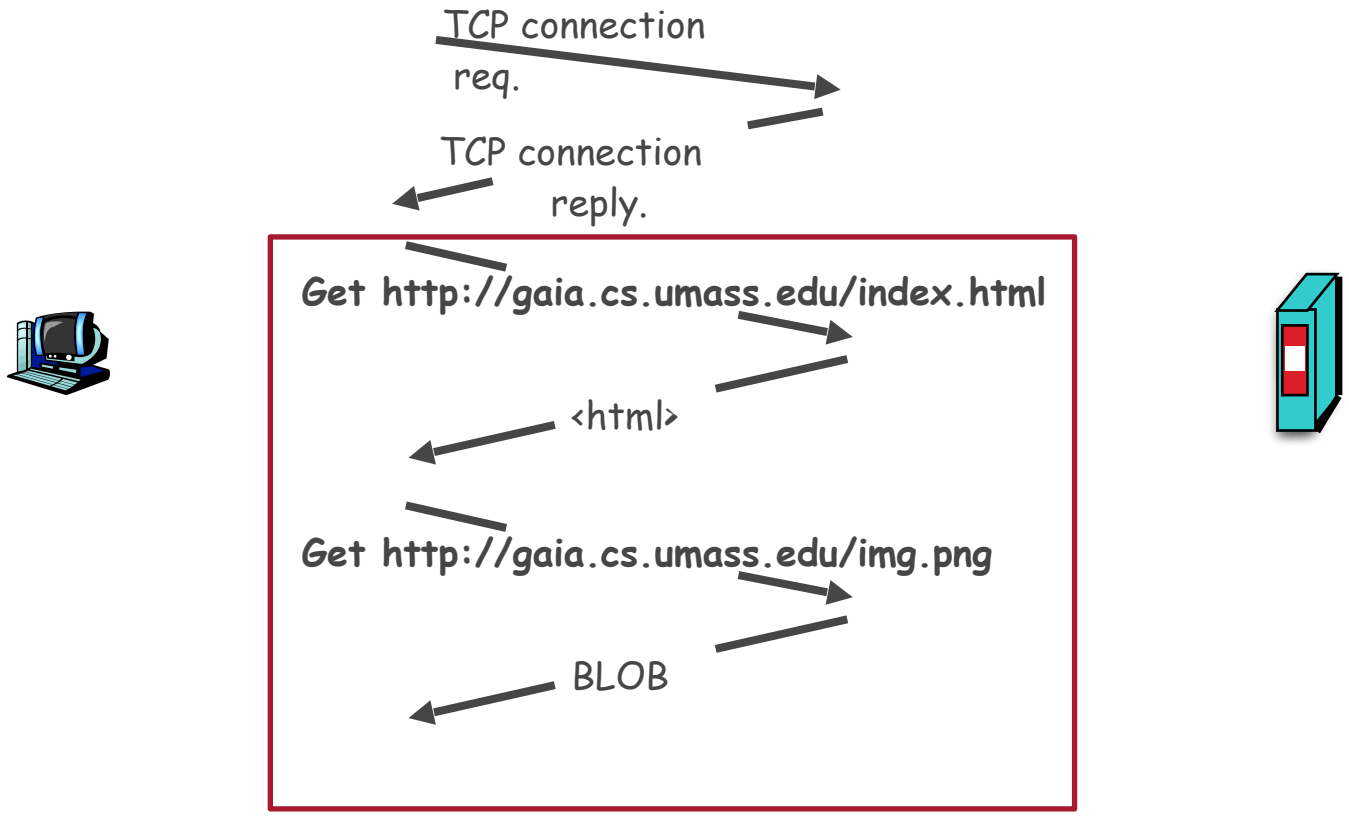


Wireshark

WHAT ARE WE LOOKING AT?

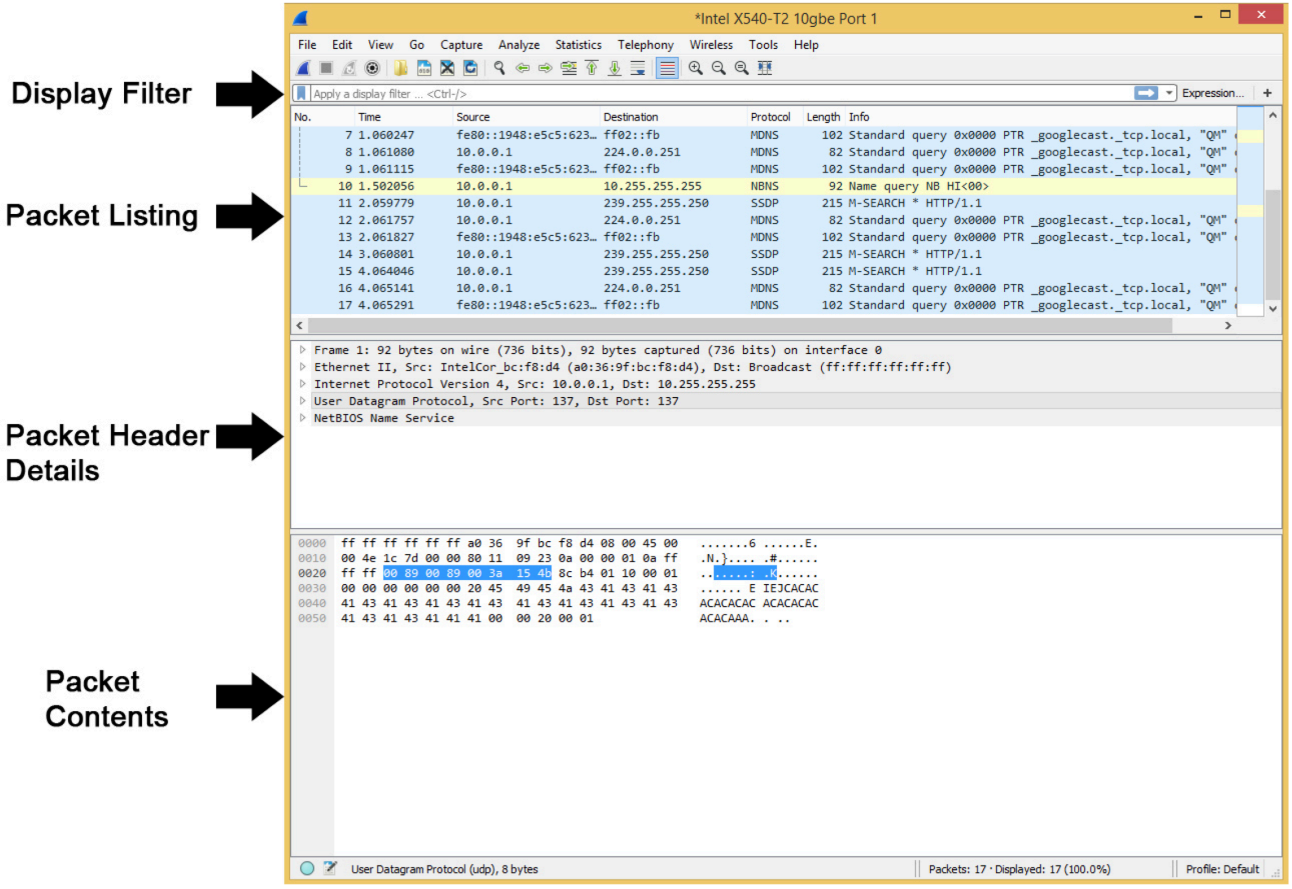
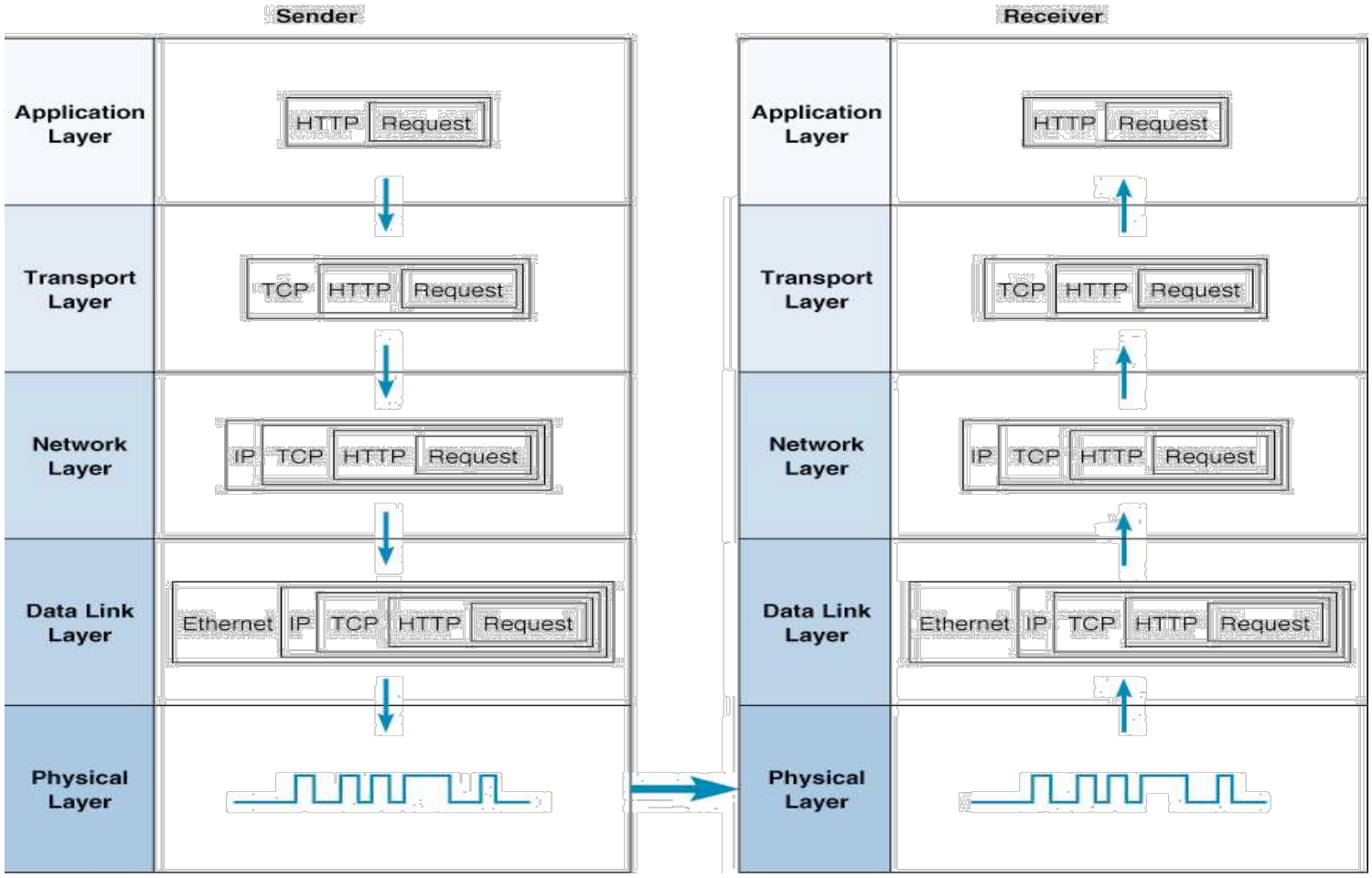


Figure 1: WireShark Graphical User Interface

Wireshark

(FROM SLIDE 40 LAST WEEK)



Local Area Networks

WHAT ARE THEY AND HOW CAN THEY BE ARRANGED?

Local Area Networks

WHAT ARE WE LOOKING AT?

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	protocol data unit	layer
Host Layers	data	application
		Network process to application
	data	presentation
		Data Representation and Encryption
	data	session
		Internet Communication
	segment	transport
		End-to-end Connections and Reliability
Media Layers	datagram	network
		Path determination and Logical Addressing
	frame	data-link
		Physical Addressing and Media Access
	bit	physical
		Media, Signal, and Binary Tranmission

LAYER OF OPERATION

- Local networks operate primary at the data-link layer.
- Nodes still have layer-3 connectivity, but the services provided by layer-3 are sufficient but not necessary in order to talk to another node on the local network

What is a LAN?

LOCAL AREA NETWORK

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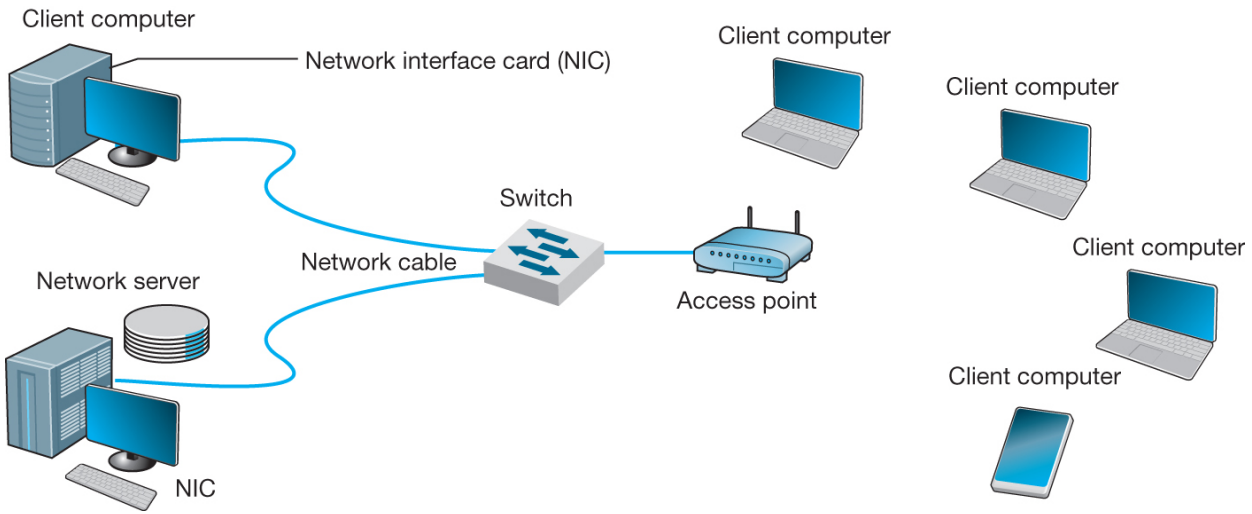
TYPICALLY

- Covers geographically small area
- Owned and managed by one organisation
- Simple physical and logical topology
- Some components: NIC, Cables, Hubs, Switches, ...



Services

WHY USE A LAN?

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INFORMATION SHARING

- Email
- Files
- Databases
- Improves productivity

SERVICE SHARING

- Printers
- Internet
- Software packages
- Reduces Costs

NIC

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NETWORK INTERFACE CONTROLLER

- Sometimes referred to as Network Interface Card
- Each computer has one NIC for each network it is connected to.
- For example Ethernet and WiFi
- The NIC deals with the physical characteristics of the connection
- Provides data-link layer software (firmware)

Remember Topologies from last week?

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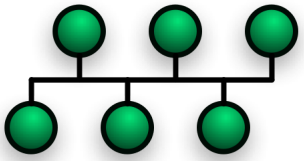
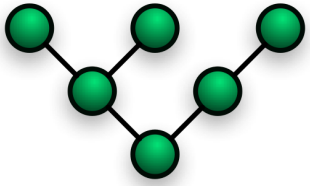
"KINDS OF NETWORKS"

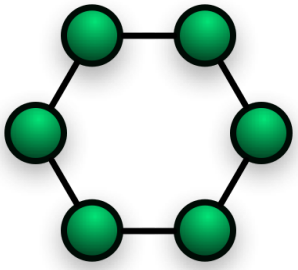
Point-to-point



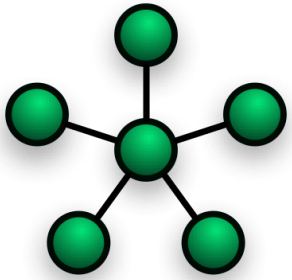
Bus (multi-drop)



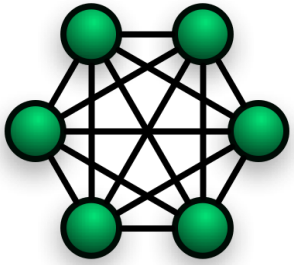
Tree



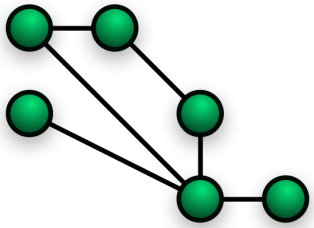
Ring



Star



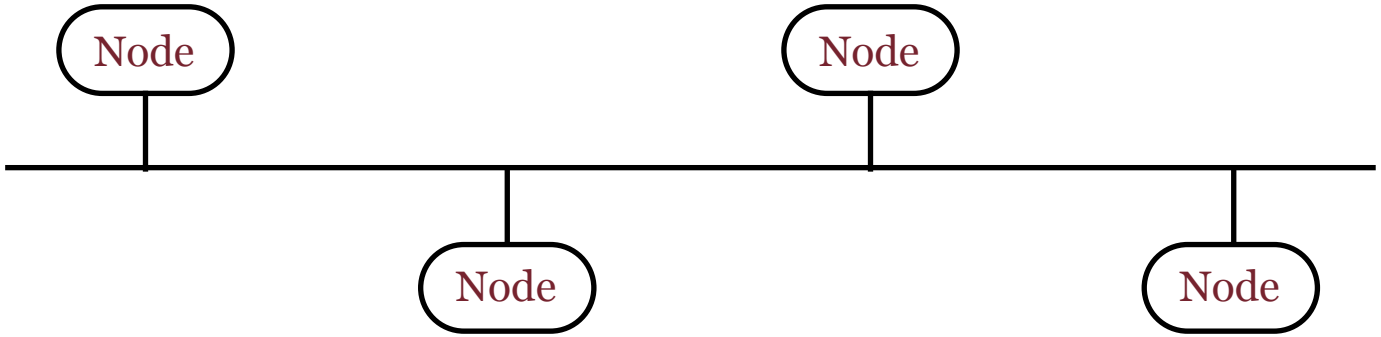
(Full) Mesh



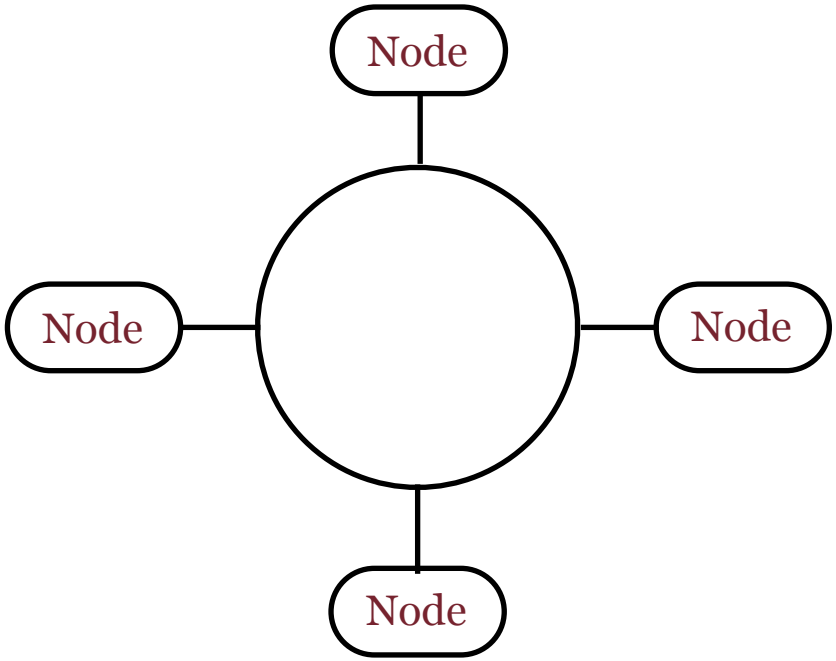
Partial mesh

Bus

Sometimes draw as:

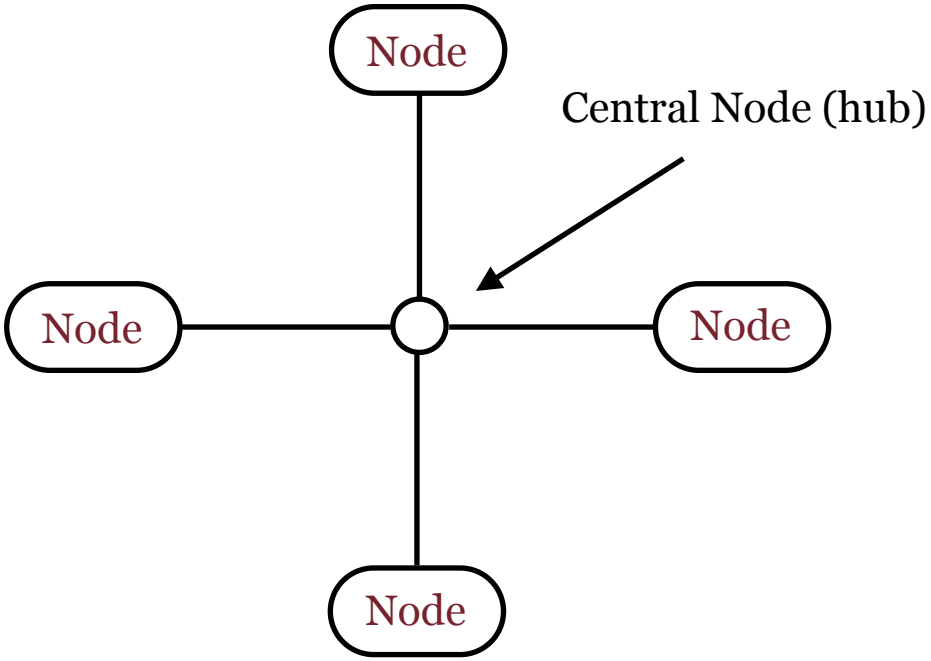


Ring



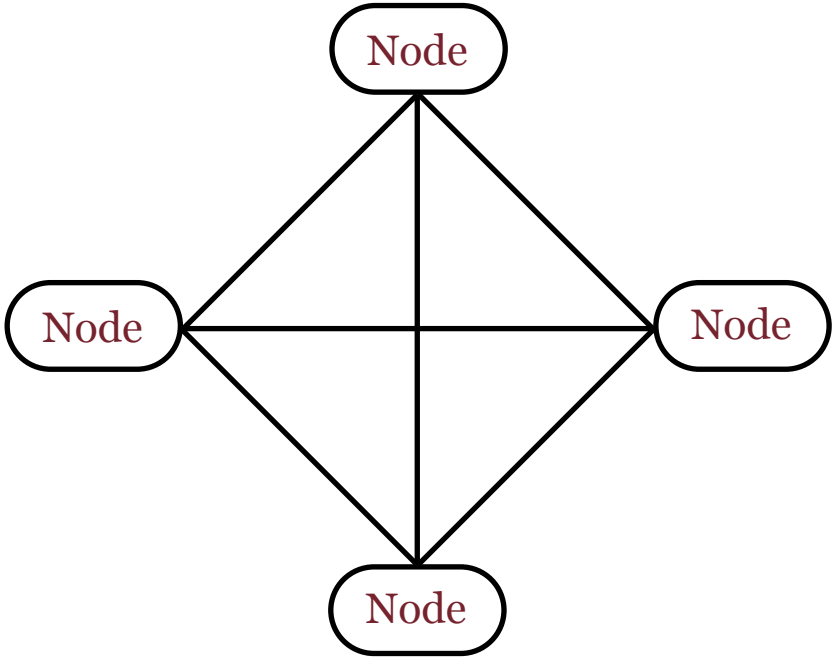
Star

All nodes connected to a single central point



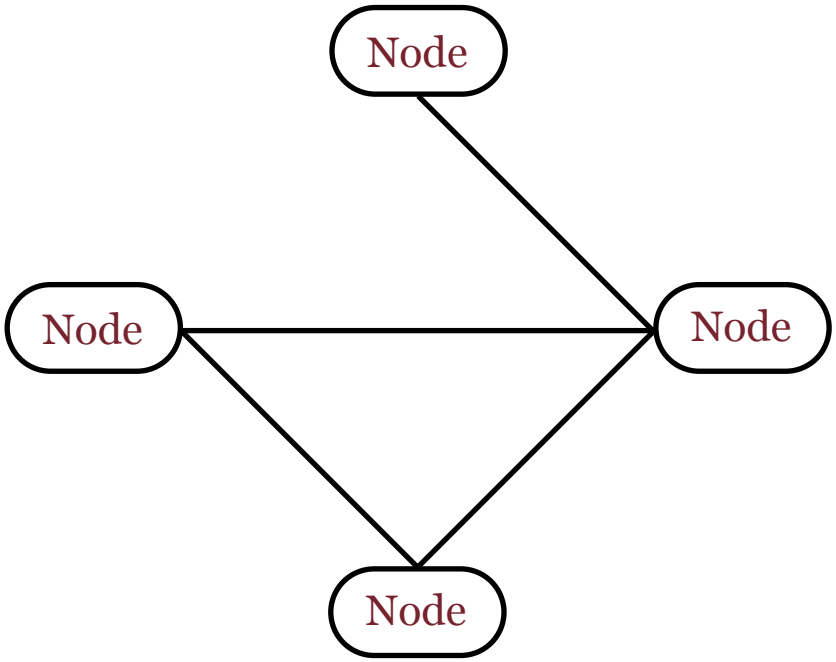
Full Mesh

ALL NODES TO EACH OTHER OVER A SINGLE LINK



Partial Mesh

THE MOST GENERAL TOPOLOGICAL FORM



Network Topologies

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PHYSICAL TOPOLOGY

How the network is physically installed (hardware and cabling)

LOGICAL TOPOLOGY

How the network works conceptually using protocols (software)

LOGICAL TOPOLOGIES OF LANS

- Bus topology – only one transmitter at a time and message goes to all other nodes
- Star topology – multiple messages at one time, message only seen by destination
- Ring – message travels around ring, not passed on by destination (intervening nodes see it and pass it on).

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LAN Topologies

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Topology	Advantages	Disadvantages
Bus	Economical wiring Simple Easy to extend	Reliability – bus disabled if a single wire cut Heavy traffic slows network More nodes – more contention
Ring	Economical wiring Easy coordination (token)	Reliability – whole ring disabled if a single wire cut
Star	Multiple messages at one time Reliable - cable cut only isolates one machine Secure	Lots of wiring Central point of failure

Media Access

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NETWORK SEGMENTS

- Shared resource
- Multiple nodes vying for access to link
- Need a mechanism to avoid collisions

Access Strategies

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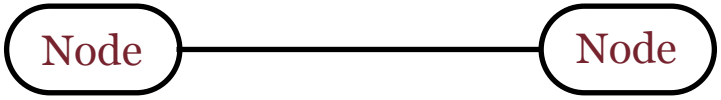
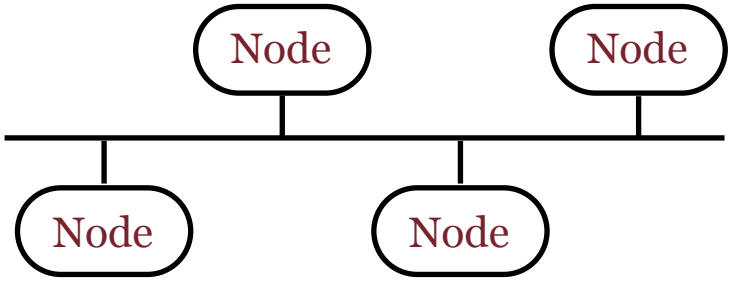
POINT-TO-POINT

- Exclusive access
- Can transmit any time
- No need for access control
- No need for addresses (destination is implicit)



MULTIPOINT NETWORK

- Shared access
- Can only transmit when clear
- Access control required
- Need for addresses to identify recipient



Multipoint networks

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MULTI-ACCESS PROTOCOLS

- Controlled access protocols: Reservation, Polling, Token Passing
- Multiplexing protocols: FDMA, TDMA, CDMA
- Random access protocols: ALOHA, CSMA/CD, CSMA/CA

Controlled Access Protocols

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RESERVATION

- Reserve the medium for exclusive access for a time period
- eg. aircraft on runway at airport, or a table at a restaurant

POLLING

- Coordinator asks each participant if they need resource
- eg. teacher asks each student in turn a question

TOKEN PASSING

- No coordinator — there is one token which arbitrates access to resource
- eg. speaking stick, or dice (player that has dice has turn)

Multiplexing Protocols

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FREQUENCY DIVISION MULTIPLE ACCESS (FDMA)

- Each participant is assigned a particular frequency
- eg. Radio or TV stations divide radio spectrum

TIME DIVISION MULTIPLE ACCESS (TDMA)

- Each participant is assigned a time slot
- eg. pistons firing in an engine

CODE DIVISION MULTIPLE ACCESS (CDMA)

- Each participant uses medium at the same time
- eg. People sharing a train carriage

Random Access Protocols

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ALOHA

- Early (prior to Internet) radio network set up in Hawaii
- Central station coordinated access

CSMA/CD

- CS - Carrier Sense, MA - Multiple Access, with CD - Collision Detect

CSMA/CA

- CS - Carrier Sense, MA - Multiple Access, with CA - Collision Avoidance

Random Access Protocols

A CLOSER LOOK AT CSMA/CD

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CAN BE THOUGHT OF AS "ORDERED CHAOS"

- Computers can test to see if the line is free (Carrier Sense)
  - If no other computer is currently transmitting then it's okay to send
- Frames can still be sent by two computers at the same time
  - They will collide and become garbled
- Computers can see when this happens (Collision Detect)
  - If a collision occurs, the computer will wait a random amount of time and then try again
  - If the link is congested, wait again for twice as long (exponential back off)

Ethernet

IEEE 802.3

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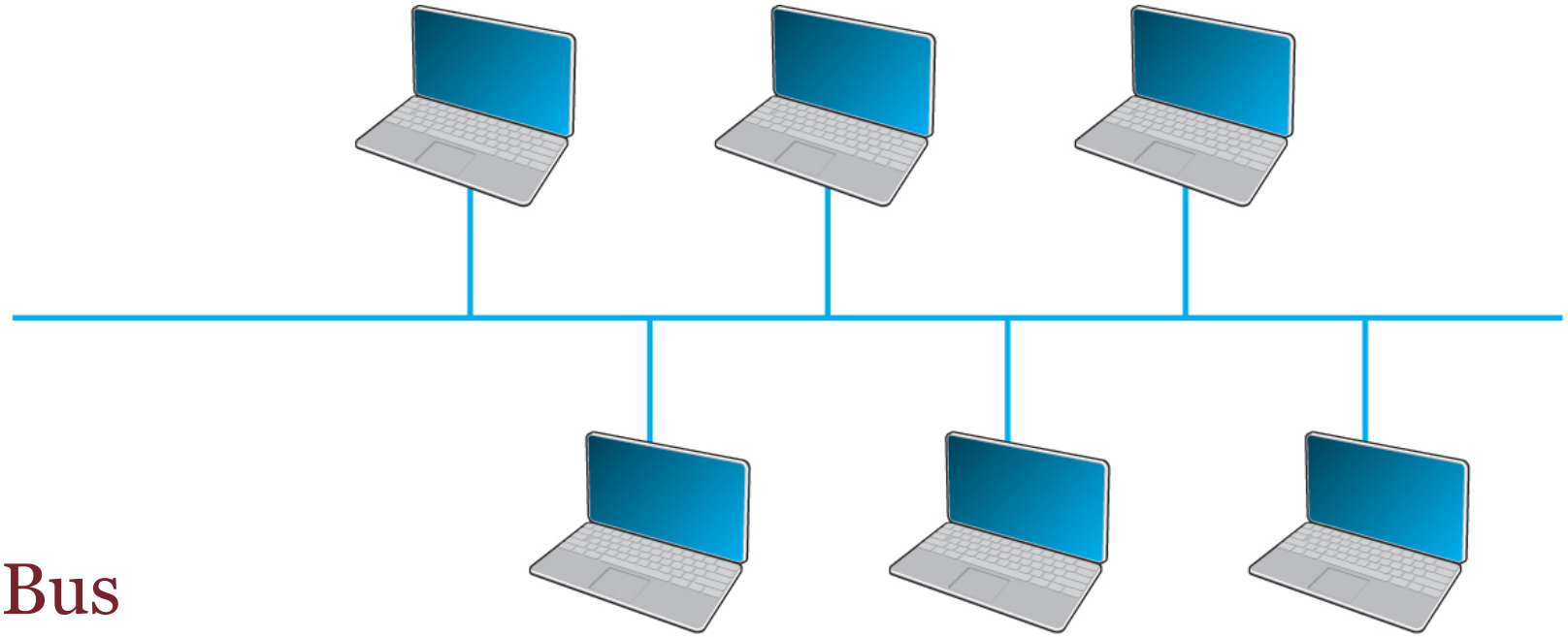
A CSMA/CD BASED PROTOCOL

- Used by almost all LANs today (de facto standard)
- Originally developed by a consortium of Digital Equipment Corp., Intel and Xerox (DIX)
- Standardised as IEEE 802.3
- Types of Ethernet
  - Bus Ethernet — on a single cable (deprecated)
  - Shared Ethernet — using hubs (deprecated)
  - Switched Ethernet — using switches

Shared Ethernet

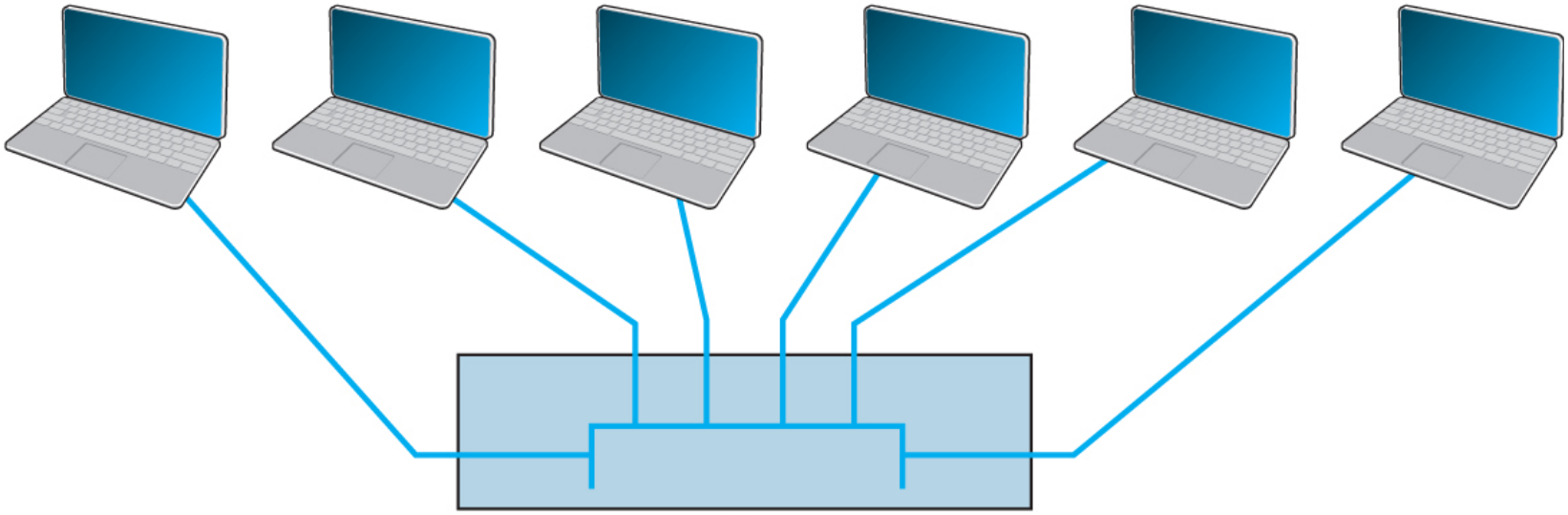
LOGICAL TOPOLOGY



Bus

Shared Ethernet

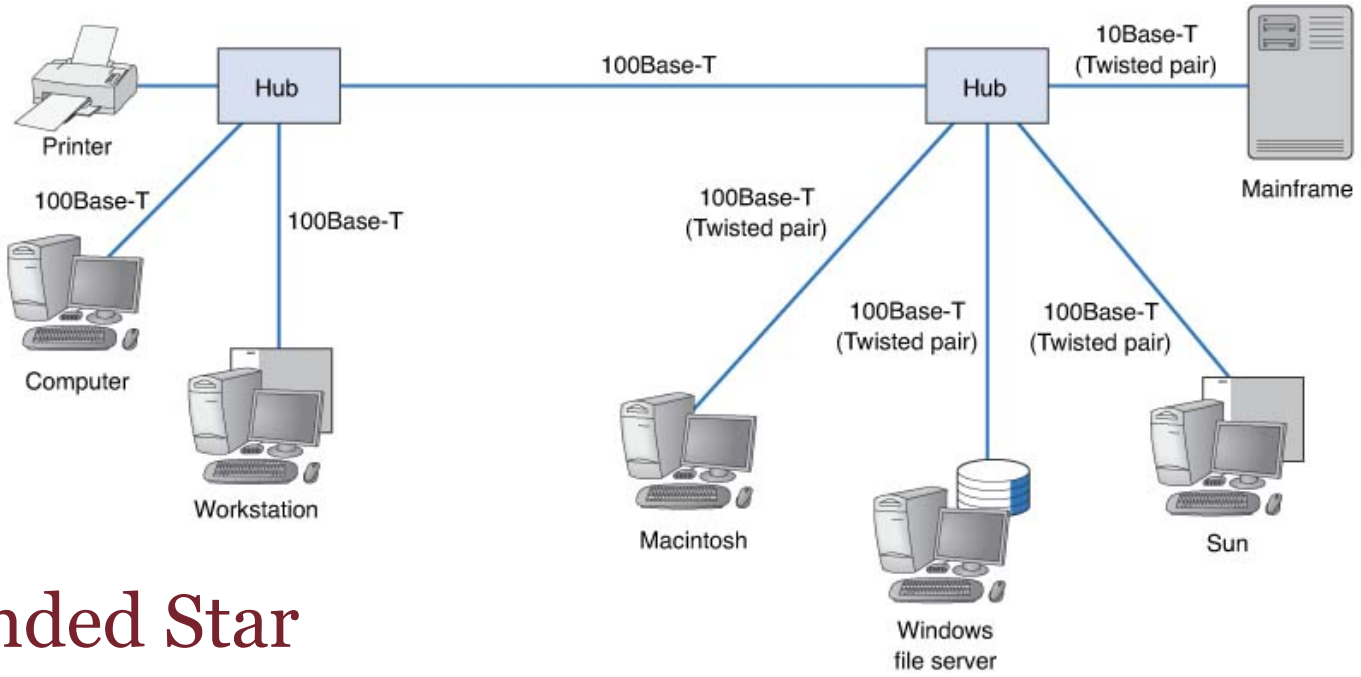
PHYSICAL TOPOLOGY



Star

Multiple Hubs…

PHYSICAL TOPOLOGY



Extended Star

Back to Wireshark for a moment

WHAT ARE WE LOOKING AT?

Wireshark

WHAT ARE WE LOOKING AT NEXT?

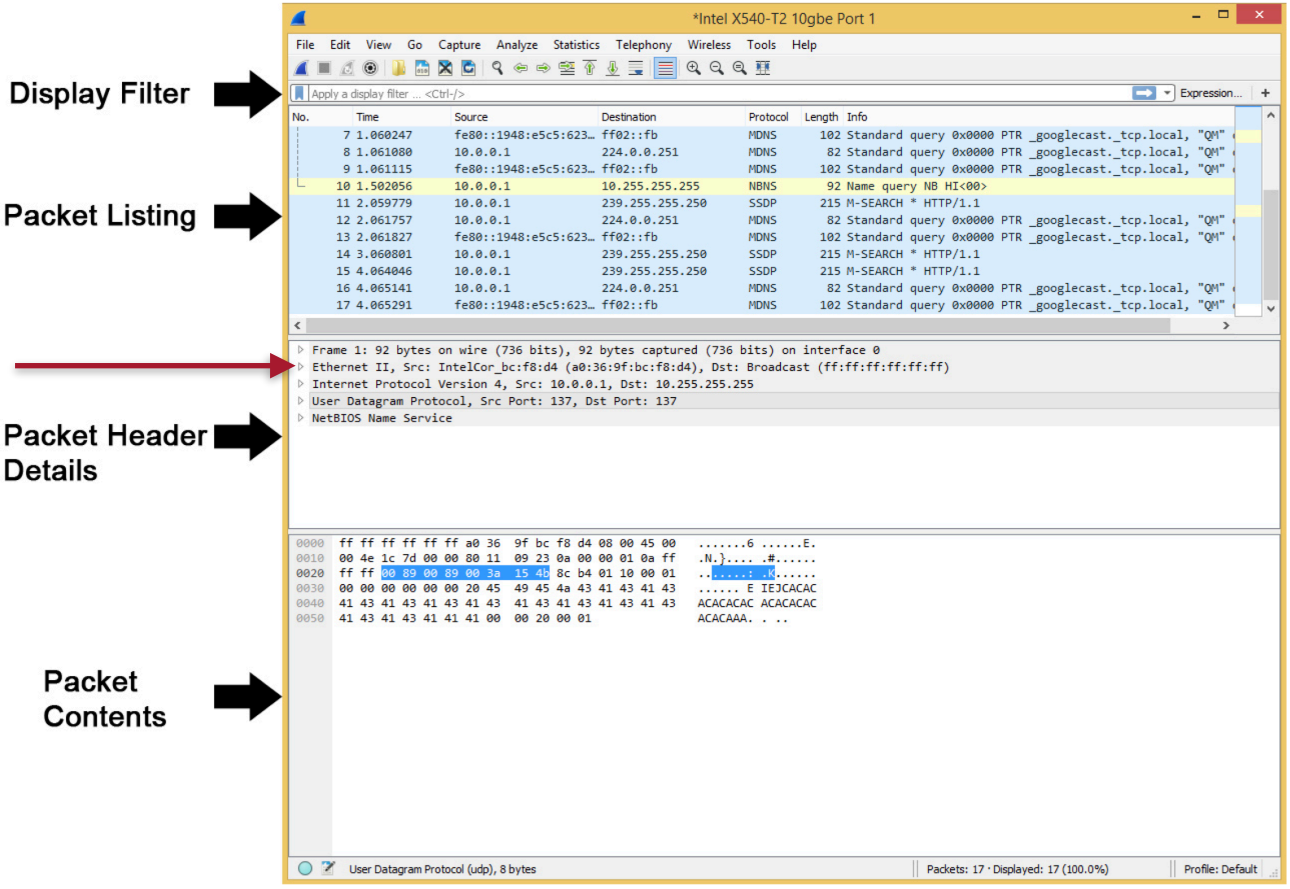


Figure 1: WireShark Graphical User Interface

Thinking about the “addresses”

AND ABOUT THE PACKET

Ethernet Address

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ADDRESSING SYSTEM FOR LAYER-2

- Used on the local network as part of media access
  - Also know as a MAC address, or sometimes as a hardware address
- Ethernet addresses are ***48-bits in size*** and are written in ***hexadecimal***
  - Normally each ***octet*** is separated by a colon, `B6:CD:35:3B:C7:6F`
  - However it may be a dash instead, `B6-CD-35-3B-C7-6F`
- The case of the digits doesn't matter, `b6:cd:35:3b:c7:6f` is also valid

Ethernet Address

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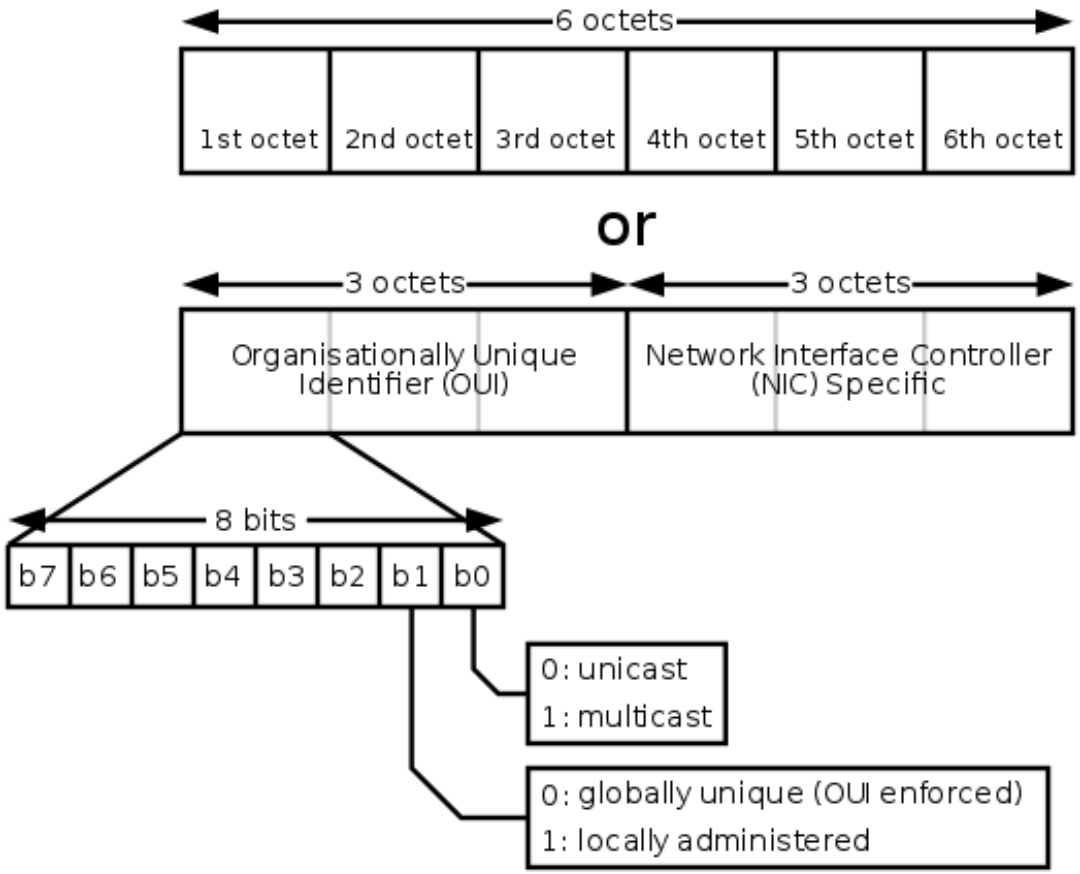
ADDRESS ALLOCATION

- Every device in the world is assigned a unique Ethernet address.
  - Each NIC in your computer has an individual address
- IEEE assigns each manufacturer a 24-bit (3-byte) code:
  - Organisationally Unique Identifier (OUI). This is the first three octets of the address.
- Each manufacturer assigns the bottom 3 octets in a unique fashion.
- What's weird is that hardware (Ethernet addresses) only apply on a local level, so this is rather overkill

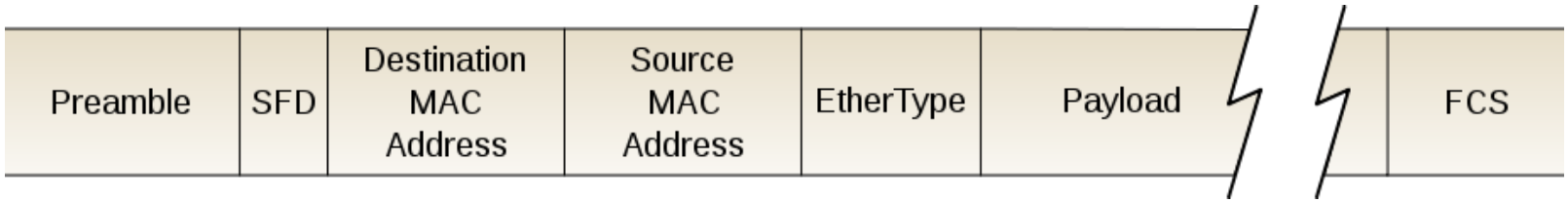
MAC address

FRAME STRUCTURE



Ethernet Frame

ADDRESS STRUCTURE



How can we set up communications?

MODES OF COMMUNICATION AND “NETWORK SEGMENTS”

No Communication

MODES OF COMMUNICATION

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TWO ISOLATED COMPUTERS

- No communication

Directly attached

MODES OF COMMUNICATION

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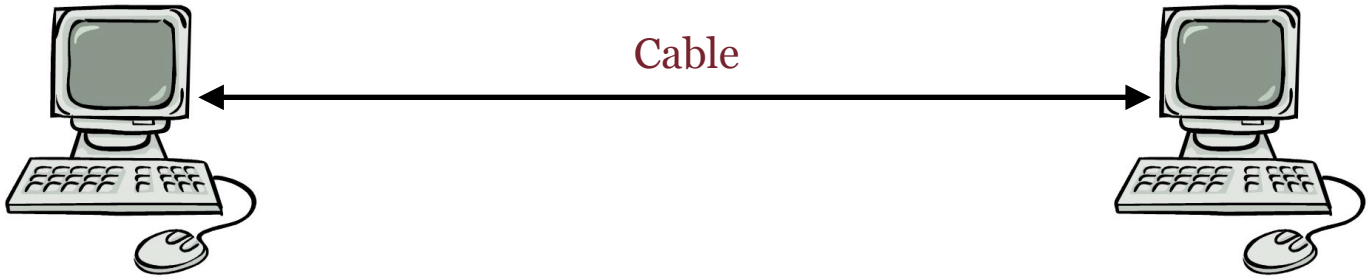
TWO COMPUTERS WITH A SINGLE CABLE

- Direct communication



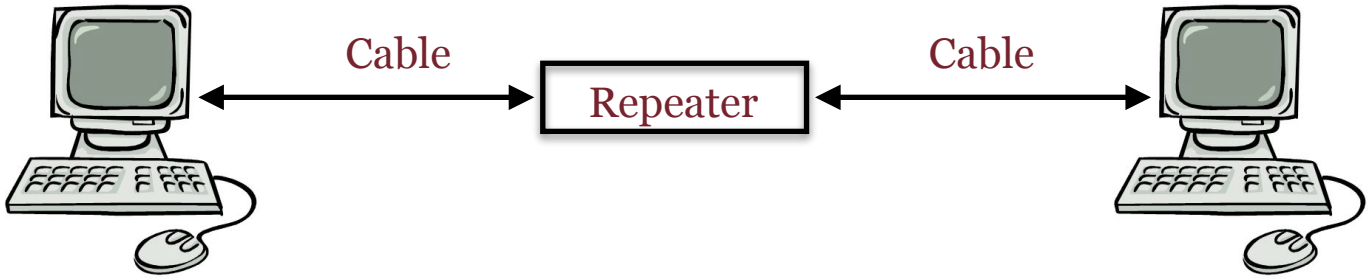
- No addresses needed
- Message sent directly to destination node

Network repeater

MODES OF COMMUNICATION

TWO COMPUTERS WITH A REPEATER

- If the distance between nodes is too far…



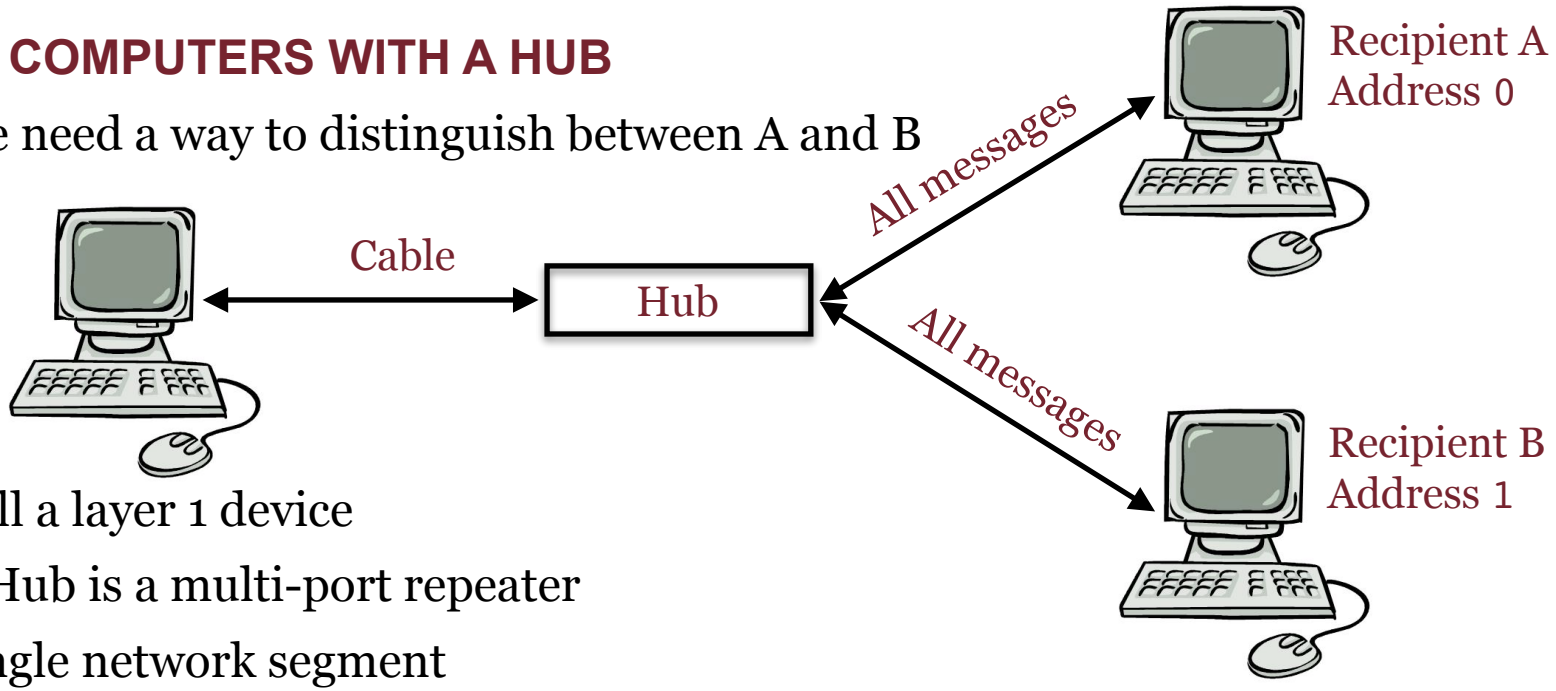
- The signal decays and we need to boost it with a repeater
- The repeater and the two nodes are on the same network segment
- The cable and the repeater are layer 1 physical devices

Network with a Hub

MODES OF COMMUNICATION

THREE COMPUTERS WITH A HUB

- We need a way to distinguish between A and B



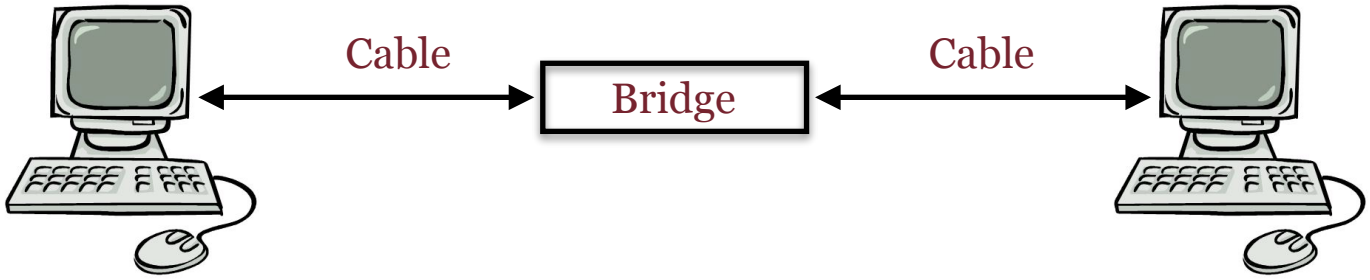
- Still a layer 1 device
- A Hub is a multi-port repeater
- Single network segment

Bridged Network

MODES OF COMMUNICATION

TWO COMPUTERS WITH A BRIDGE

- If the distance between nodes is too far…



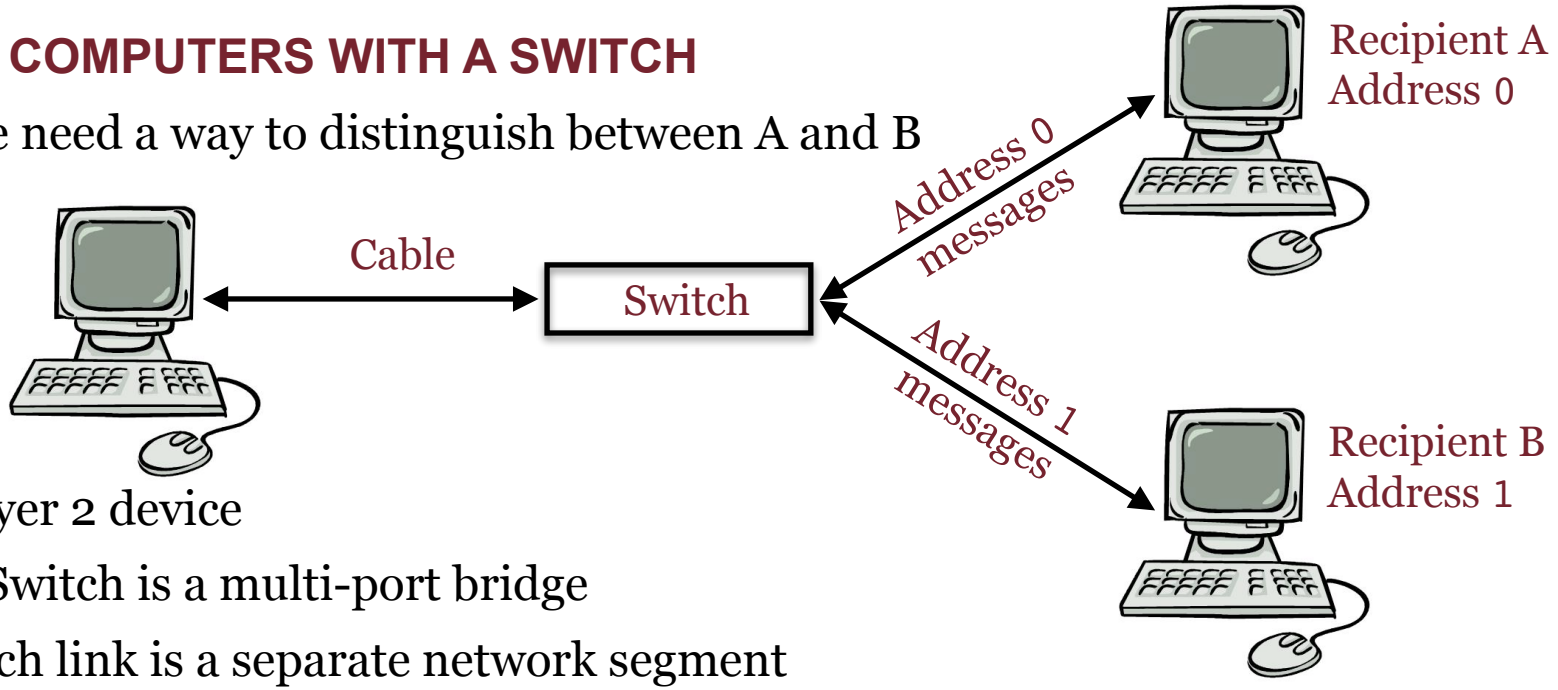
- The frame is read into the bridge's memory and then retransmitted
- **Each side of the bridge is a different network segment**
- The bridge is a layer 2 device

Switched Network

MODES OF COMMUNICATION

THREE COMPUTERS WITH A SWITCH

- We need a way to distinguish between A and B

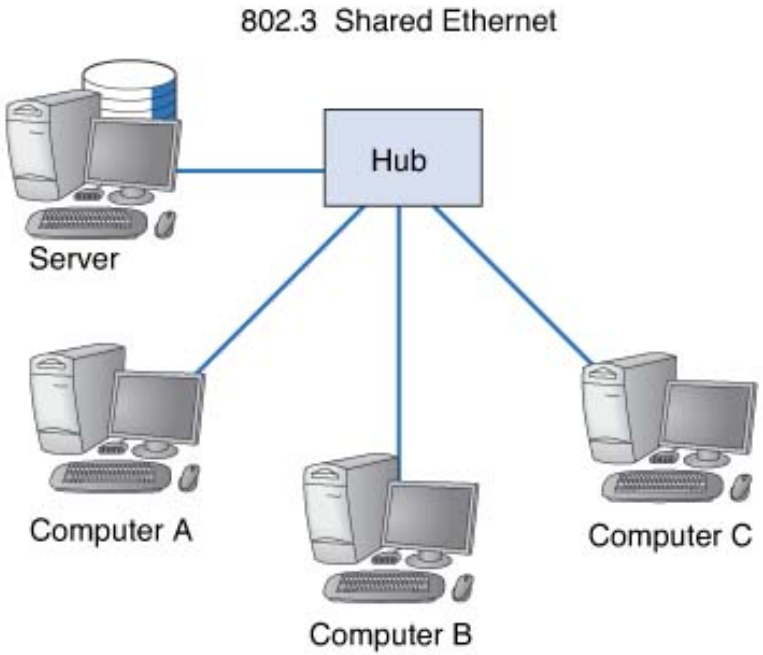


- Layer 2 device
- A Switch is a multi-port bridge
- Each link is a separate network segment

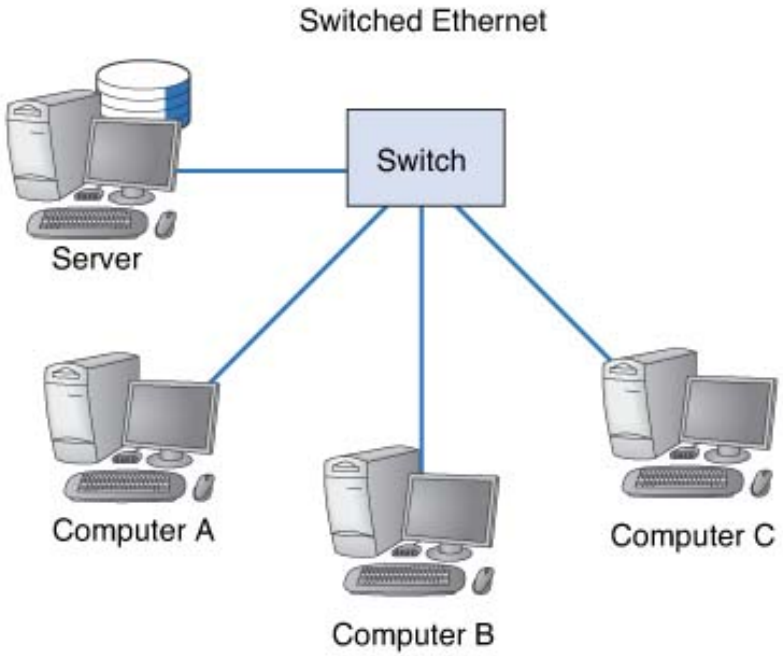
Comparing Hub vs Switched

MODES OF COMMUNICATION

Performance



Capable of using about only 50% of capacity before collisions become a problem



Runs at up to 90% capacity

Sending Messages

NETWORK SEGMENTS, DOMAINS, COLLISIONS, AND TYPES OF TRANSMISSION (CASTING)

Casting

WHO GETS THE MESSAGE?

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UNICAST

- Destination is a single node

MULTICAST

- Destination is a group of nodes

BROADCAST

- Destination is all nodes on the network

ANYCAST

- Destination is the closest node that provides the service

Collision Domain

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HOW BIG CAN MY NETWORK GET?

- Collision Domain: If two stations want to transmit at the same time, there is a collision, so they need to backoff and retransmit later.
- This means they are on the same LAN and thus on the same collision domain.
- So the LAN technology that we have studied so far represents a collision domain.

Broadcast Domain

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HOW BIG CAN MY NETWORK GET?

- Broadcast Domain: A logical division of a computer network, in which all nodes can reach each other by broadcast at the data link layer.
  - That is, all those devices that will receive a broadcast message
  - A broadcast domain can be within the same LAN segment or it can be bridged/switched to other LAN segments.
- Some layer-two network devices are able to divide the collision domains
  - however, broadcast domains are only divided by layer-3 network devices such as routers or layer-3 switches.

Domains

WHICH IS WHICH?

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COLLISION AND BROADCAST DOMAINS

- Collision domains are generally smaller than, and contained within, broadcast domains.
- You will be able to understand these concepts better once we discuss layer-2 and layer-3 devices such as switches/bridges and routers in detail.
- In this lecture, we will focus on layer 2 devices – Switches.

Point-to-point collisions?

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INDIVIDUAL LINKS COME IN THREE DIFFERENT FORMS

- **Simplex** – transmit in single direction only
  - Like TV or Radio
- **(Full) duplex** – transmit in both directions at the same time
- **Half duplex** – transmit in both directions but not at the same time
  - Like CB Radio
- **Multiplex** – put transmissions from multiple sources on the line (share)

A closer look at “Switching”

WHAT HAPPENS UNDER THE HOOD?

Backwards Learning

HOW DO SWITCHES WORK?

- When the switch is first powered on it knows nothing about the network
- As frames arrive it starts to learn which ports relate to which addresses
  - It stores the addresses in a table, called the MAC table
  - When new frames arrive it checks the MAC table for the address
    - If there's a matching entry it sends the frame out of the relevant port
    - If there's no match it sends it out of every port (except the ingress port)

Switched Ethernet

HOW DO SWITCHES WORK?

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- A switch unlike a hub allows for the logical separation of a collision domain.
  - Switches replace the shared medium of legacy Ethernet with a dedicated segment for each station.
  - These segments connect to a switch
  - A Switch can connect many of these single station segments. Some switches today can support hundreds of dedicated segments.
- Both logical and physical topology of the network becomes a star topology
  - Switches operate at the data-link layer

What do they do?

HOW DO SWITCHES WORK?

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- Listen to all traffic
- Checks source and destination addresses of each packet
- Builds a forwarding table as information becomes available
- Forwards frames in the following manner:
  - If the destination is not listed in the forwarding table, the switch forwards packets to all segments
  - If the destination is listed in the forwarding table, the switch forwards packets to that segment.

“Switching modes”

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CUT-THROUGH SWITCHING

- Read destination address and start transmitting
  - Without waiting for the entire message is received
- Low latency – but may waste capacity (error messages)
- Only on the same speed incoming and outgoing circuits

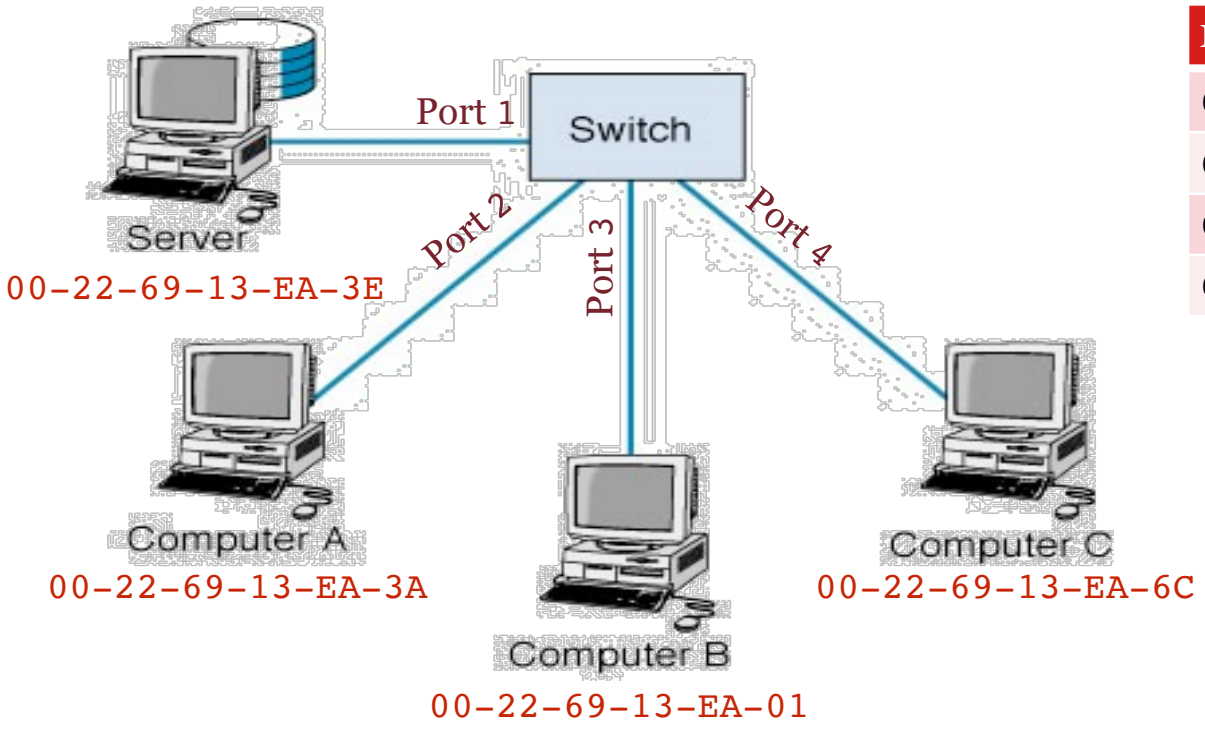
STORE-AND-FORWARD SWITCHING

- Wait until the whole message is received, perform error control, and then transmit it
- Less wasted capacity – slower network (latency)
- Circuit speeds may be different

FRAGMENT-FREE SWITCHING

- Read the first 64-byte segment (contains the header)
- Perform error check, if it is okay then start transmitting
- Compromise between previous two modes

Shared Ethernet



MAC	Port
00-22-69-13-EA-3E	1
00-22-69-13-EA-3A	2
00-22-69-13-EA-01	3
00-22-69-13-EA-6C	4

Ethernet Comparison

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Ethernet	Bus	Shared (Hub)	Switched (Switch)
Physical Topology	Bus	Star	Star
Logical Topology	Bus	Bus	Star
Cable	Single cable Less wiring	Cable between every node and hub	Cable between every node and Switch
Level	Electrical Signal	Electrical Signal	Packet (Examines destination address)
Messages	Only one on bus at a time	Only one through hub at a time	Multiple messages to different destination
Buffering	None	None	Buffers message (at least up to address)

Yes - that's right, bus!

Big Ideas from today

WHAT HAVE WE BEEN FOCUSING ON?

MACQUARIE University

1) What happens at “Layer 2”?
2) How can we organise who sends what down communication paths?
3) What are the differences between hubs and switches?
4) Ethernet Frame structure + MAC Addresses
5) Comparisons between some modes of communication
6) Collision Domains and Broadcast Domains (How many in a network?)
7) How does switching work?

Next week, we are going to cheat and look at how to add more ipv4 addresses without adding more ipv4 addresses :)

Also, Mike is no longer at that office location, what would happen to the coffee message?