Institute of Electrical and Electronic Engineering, University M’Hamed BOUGARA of Boumerdes

Chapter 4
Ethernet

By: Hadjira BELAIDI

Objectives

After completing this chapter, you will be able to:

- ✓ Get an overview and understand what is Ethernet
- ✓ Describe the normal operation of the Ethernet and the Ethernet collision
- ✓ Identify the Address Resolution protocol
- ✓ Have an overview on LAN’s switches.

Chap4 Outlines

- Introduction
- Ethernet Operation
- Ethernet protocols
- Address Resolution Protocol
- LAN Switches
- Fast and Gigabit Ethernet

Outlines

- Introduction
- Ethernet Operation
- Ethernet protocols
- Address Resolution Protocol
- LAN Switches
- Fast and Gigabit Ethernet
- Experiences with Ethernet

Ethernet overview

- Most popular packet-switched LAN technology
- Bandwidths: 10Mbps, 100Mbps, 1Gbps
- Max bus length: 2500m
  - 500m segments with 4 repeaters
- Bus and Star topologies are used to connect hosts
  - Hosts attach to network via Ethernet transceiver or hub or switch
- Problem: Distributed algorithm that provides fair access

Ethernet and the OSI Model

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- Introduction
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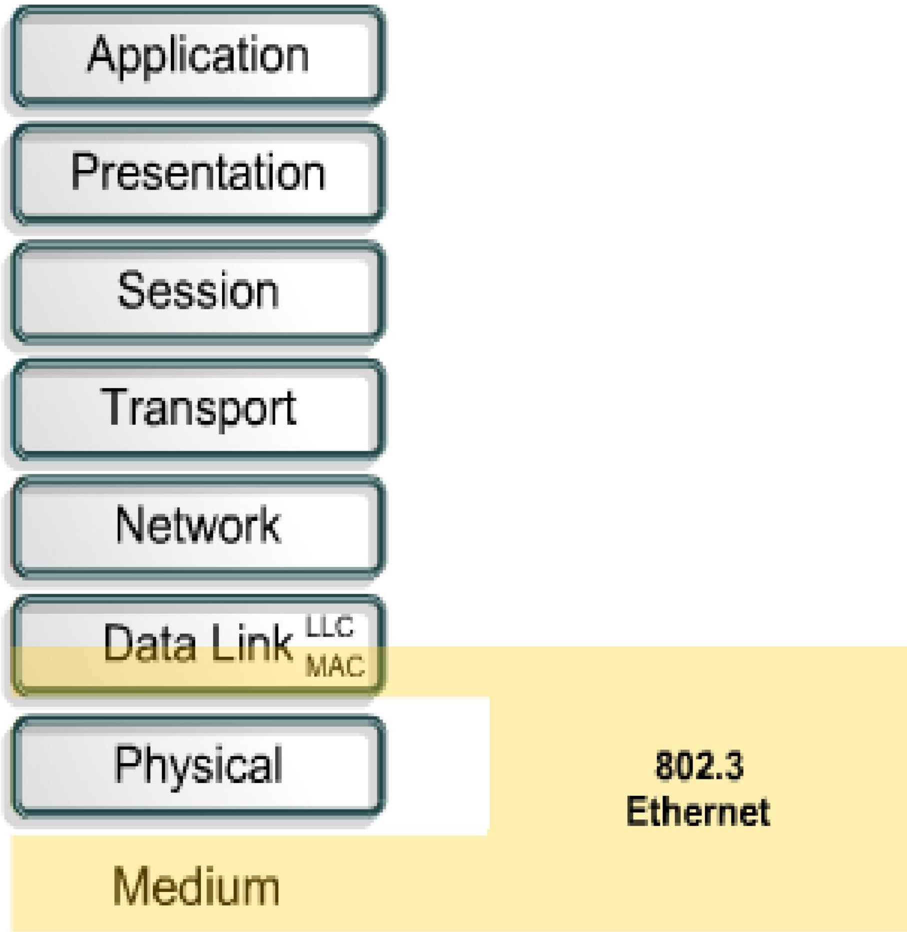
- Ethernet Problems
- Why did Ethernet Win?

Ethernet operates in two areas of the OSI model, the lower half of the data link layer, known as the MAC sublayer and the physical layer.



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1. Ethernet Operation

1.1. Normal Ethernet Operation

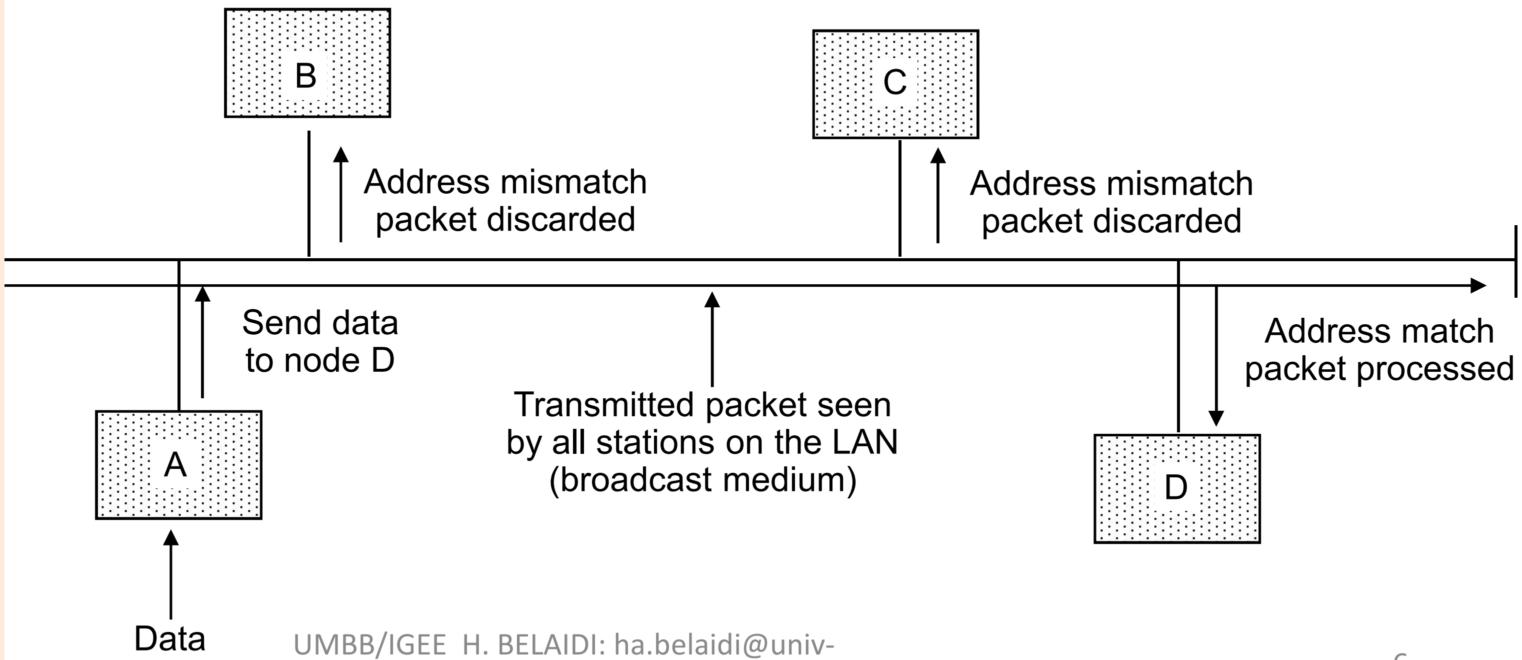
Node A needs to transmit data to Node D.

Node A builds a packet.

Node A checks to see if the cable plant is clear (no one else is currently transmitting).

Node A transmits the packet while listening to the cable.

If there were no collisions, node A returns to listen mode.



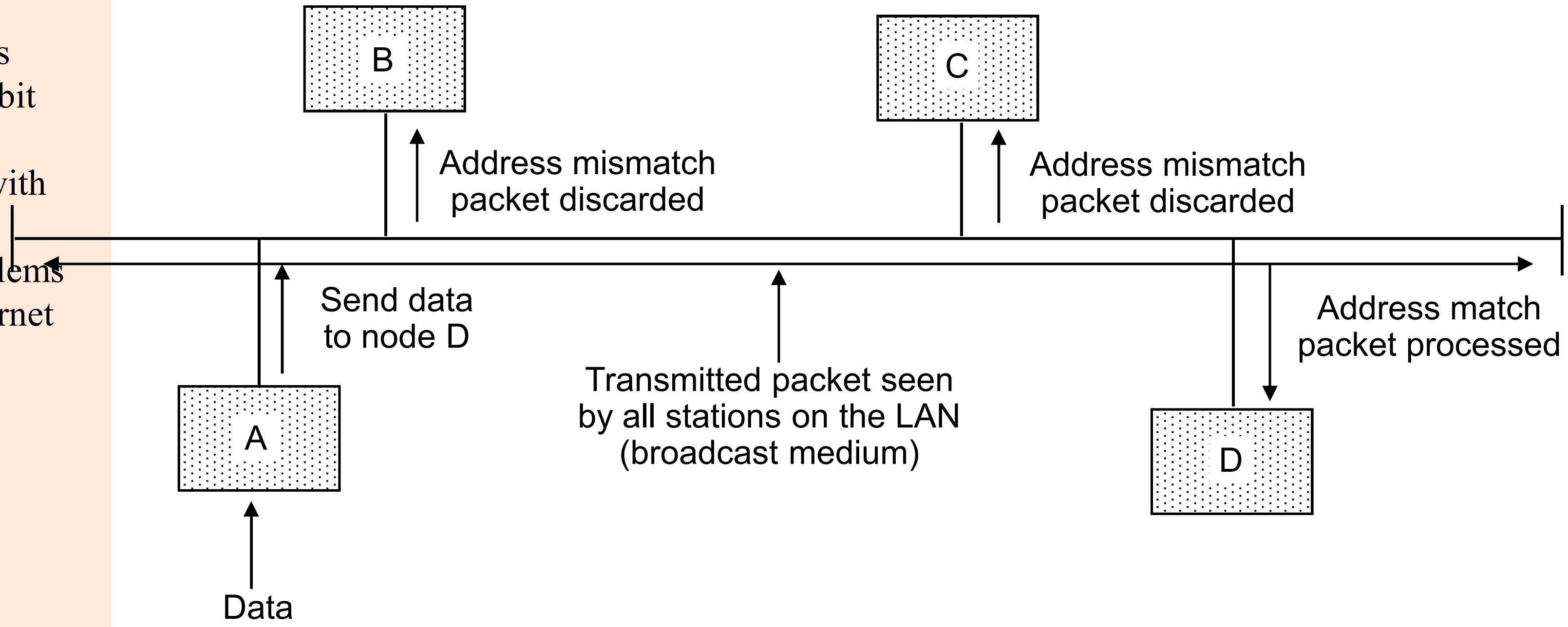
Outlines

Another station wishing to transmit should detect the cable plant is busy when node A is transmitting and enter into defer mode.

That station will try again later.

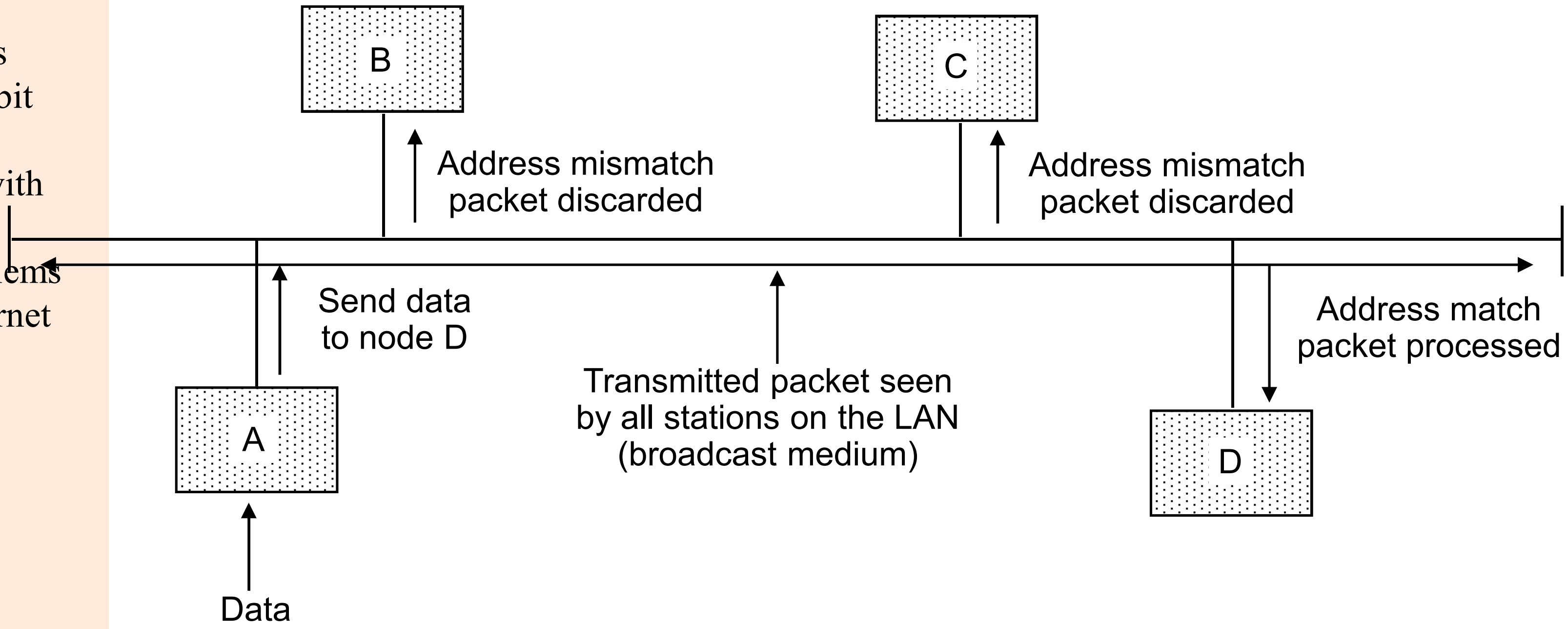
There is no priority scheme used with Ethernet.

All stations have equal access to the cable plant.



Outlines

An Ethernet station is allowed to transmit a packet as small as 64 bytes, as large as 1518 bytes (18 bytes of MAC header or trailer information) or any size in between.



Outlines

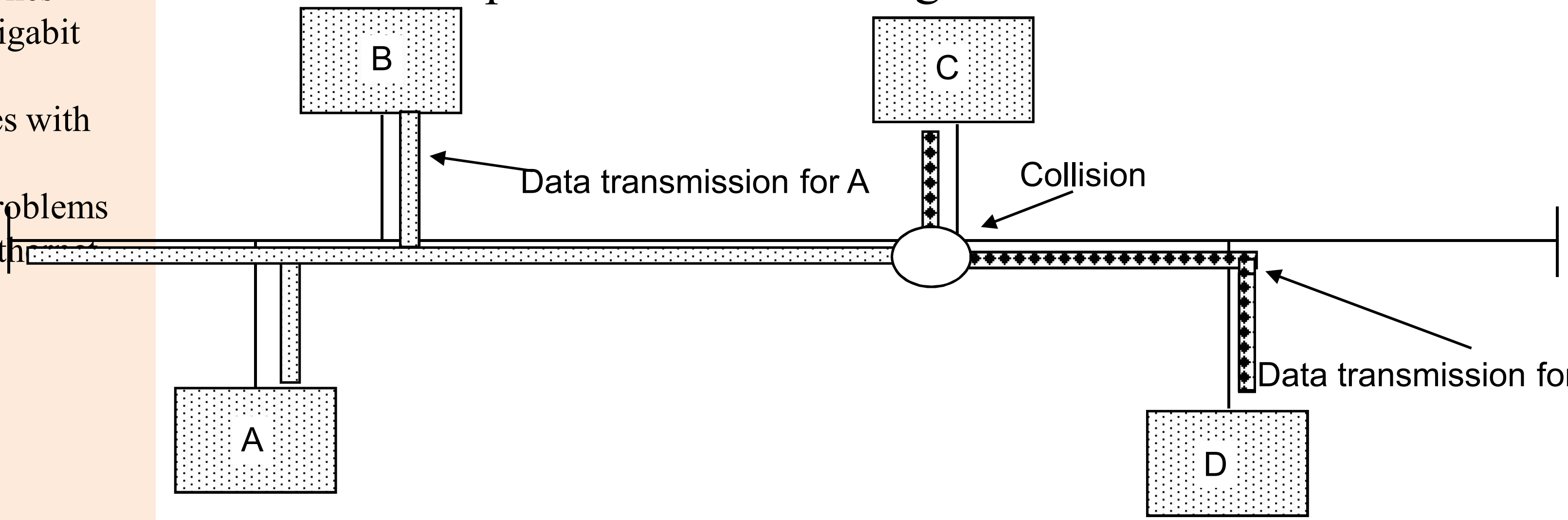
1.2. Ethernet Collisions

Node A needs to transmit data to Node D.

Node A builds a packet.

Checks to see if the cable plant is clear (no one else is currently transmitting).

Transmits packet while listening to the cable.



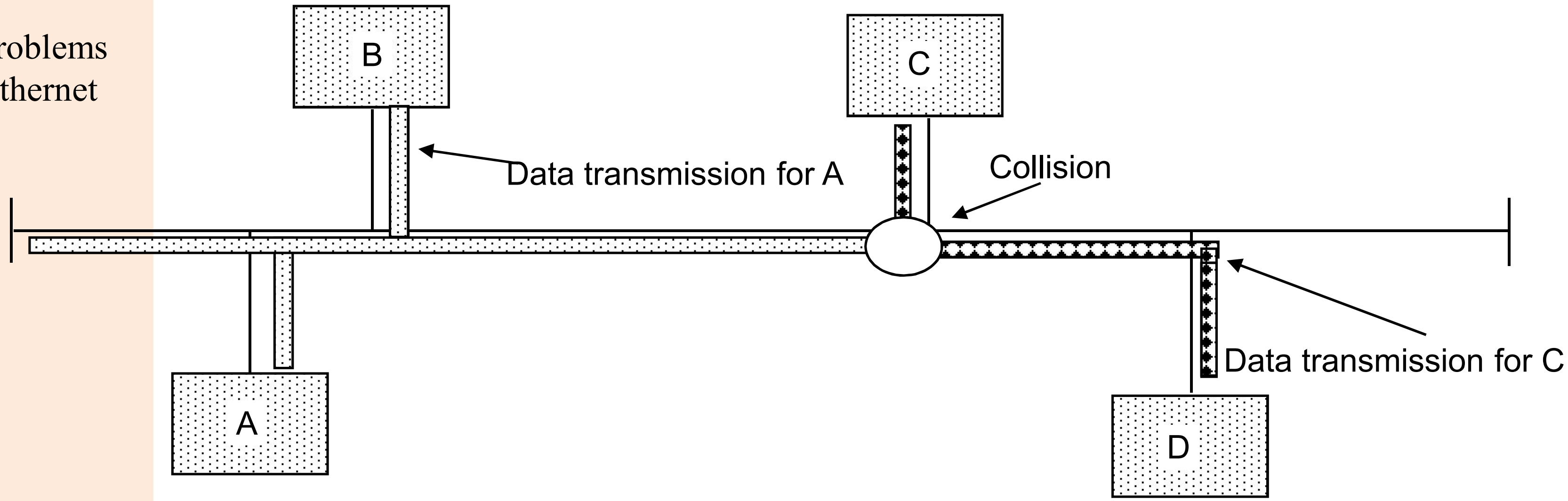
Outlines

Before Node A's transmission reaches node C, node C accomplishes the above steps and also starts to transmit.

There is a collision on the cable plant caused by node A and C.

All stations invoke the backoff algorithm.

- This deference should allow the cable plant to stabilize.
- When the cable is clear, it will be available for any station to transmit.
- No special treatment is given to the stations that were involved in the collision.



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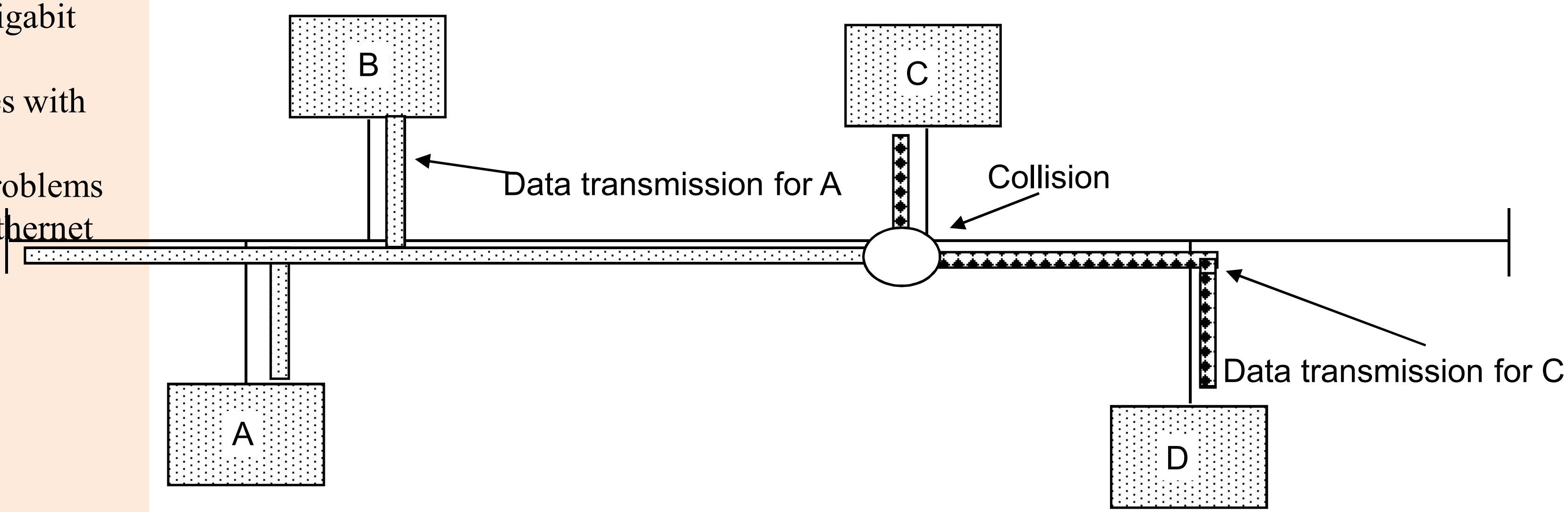
It is the hope of the backoff algorithm that no two controllers will generate the same two backoff times and attempt to simultaneously transmit.

Even if they do, it is not a fatal error.

Each controller's backoff algorithm will generate a longer backoff with each successive collision.



1.3. Ethernet Transmission Flowchart

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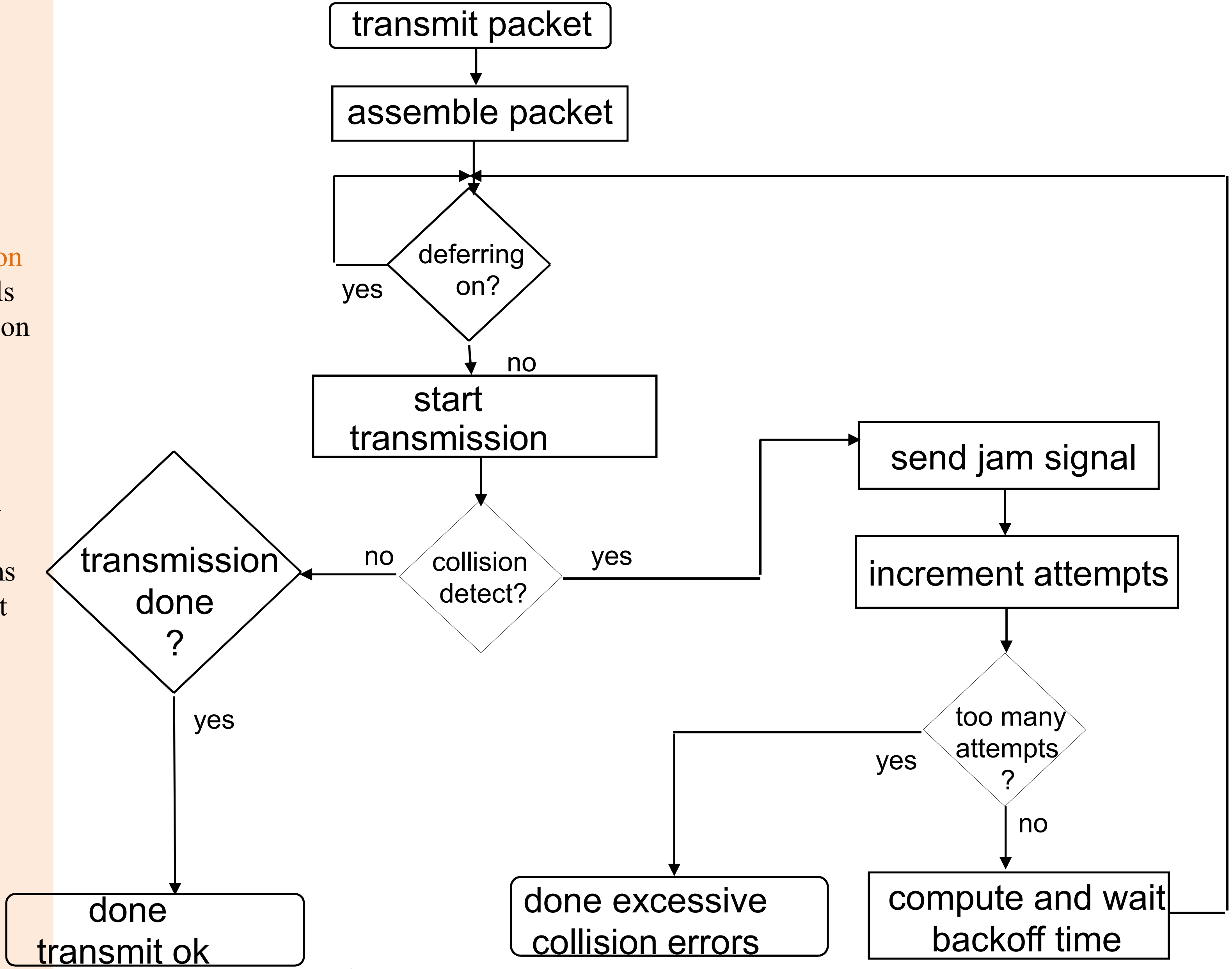

1.4. Collision Domains

Outlines

To move data between one Ethernet station and another, the data often passes through a repeater.

All other stations in the same collision domain see traffic that passes through a repeater.

A collision domain is then a shared resource. Problems originating in one part of the collision domain will usually impact the entire collision domain.

Outlines

2. Ethernet protocols

2.1. Aloha (Aloha method)

- Aloha, also called the *Aloha method*, refers to a simple communications scheme in which each source (transmitter) in a network sends data whenever there is a frame to send.
- If the frame successfully reaches the destination (receiver), the next frame is sent.
- If the frame fails to be received at the destination, it is sent again.
- This protocol was originally developed at the University of Hawaii for use with satellite communication systems in the Pacific.

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- In a wireless broadcast system or a half-duplex two-way link, Aloha works perfectly.
- But as networks become more complex, for example in an Ethernet system involving multiple sources and destinations that share a common data path, trouble occurs because data frames collide (conflict).
- The heavier the communications volume, the worse the collision problems become.
- The result is degradation of system efficiency, because when two frames collide, the data contained in both frames is lost.

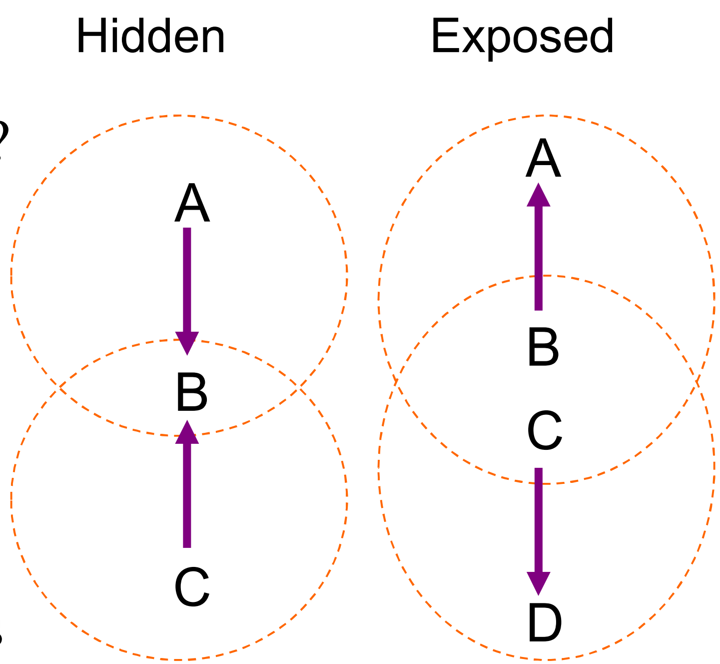
Outlines

- To minimize the number of collisions, thereby optimizing network efficiency and increasing the number of subscribers that can use a given network, a scheme called *slotted Aloha* was developed.
- This system employs signals called beacons that are sent at precise intervals and tell each source when the channel is clear to send a frame.
- Further improvement can be realized by a more sophisticated protocol called Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

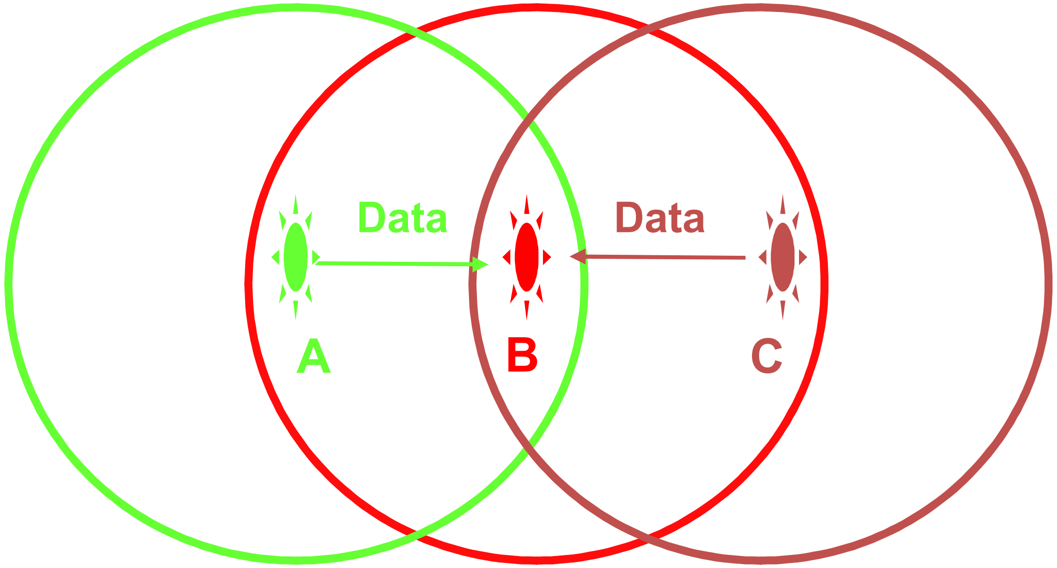
Outlines

2.2. Ethernet MAC – Carrier Sense

- Basic idea:
  - Listen to wire before transmission
  - Avoid collision with active transmission
- Why didn't ALOHA have this?
  - In wireless, relevant contention at the receiver, not sender
    - Hidden terminal
    - Exposed terminal
- Carrier Sense Multiple Access
  - Ethernet (CSMA/CD) is not enough for wireless (collision at receiver cannot detect at sender)



Outlines



A and C want to send data to B

1. A senses medium idle and sends data
2. C senses medium idle and sends data
3. Collision occurs at B

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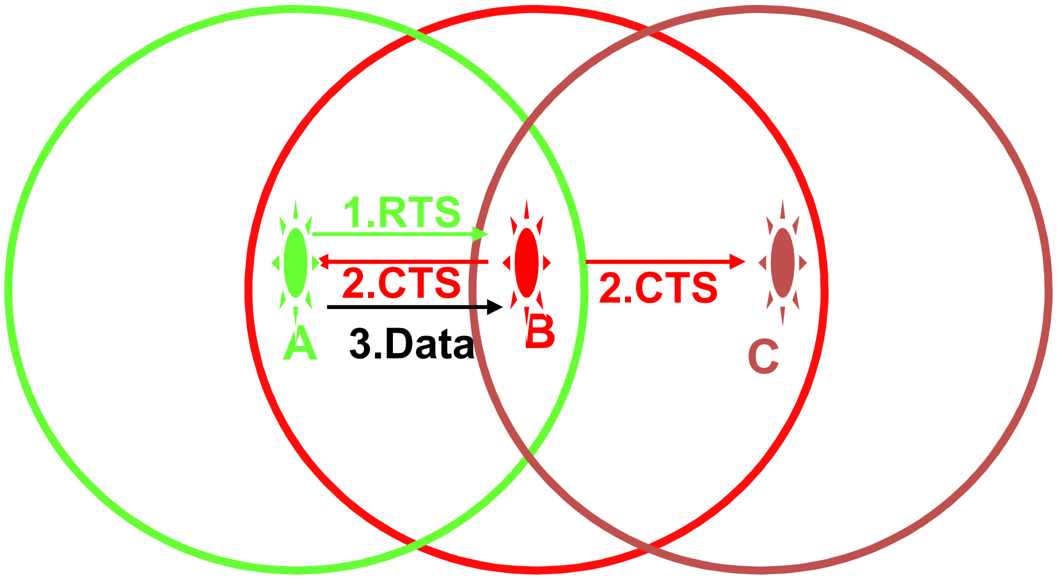


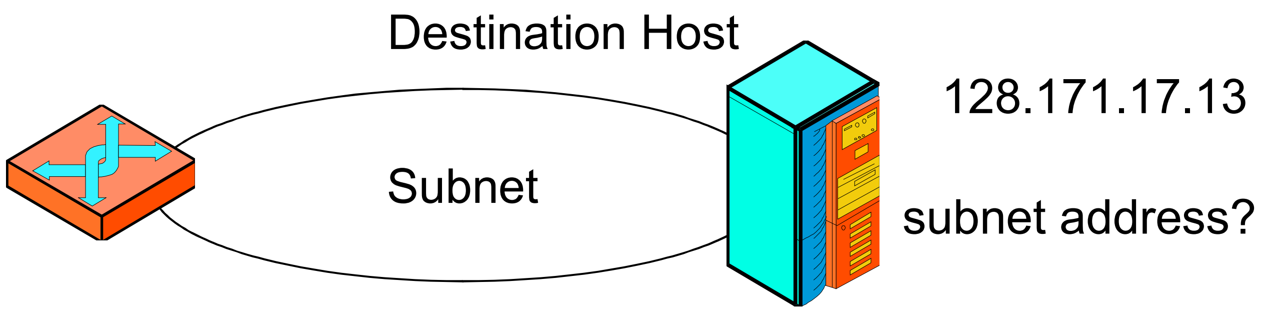
A and C want to send to B

1. A sends RTS (Request To Send) to B
2. B sends CTS (Clear To Send) to A
   C "overhears" CTS from B
3. C waits for duration of A's transmission

3.2. Address Resolution

Outlines

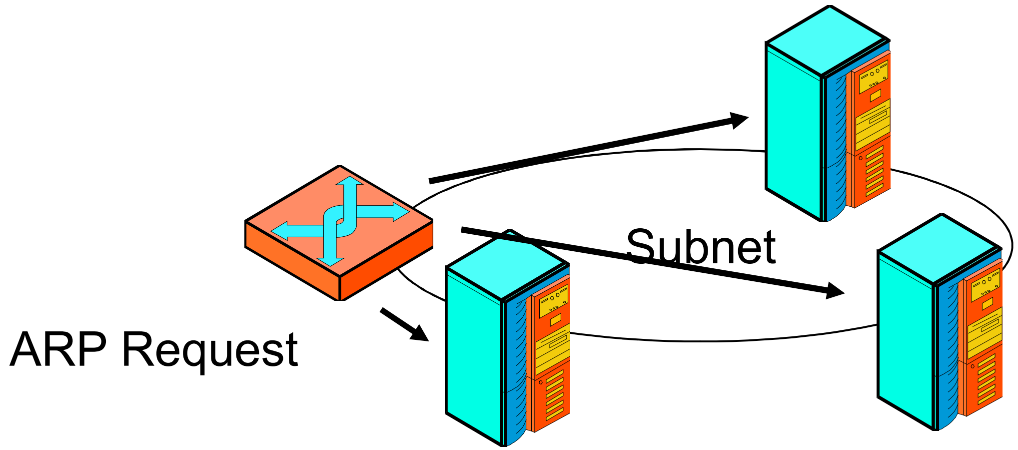
- Problem
  - Router knows that destination host is on its subnet based on the IP address of an arriving packet
  - Does not know the destination host's subnet address, *so cannot deliver the packet across the subnet*



Outlines

Router creates an ARP Request message to be sent to all hosts on the subnet.

- Address resolution protocol message asks "Who has IP address 128.171.17.13?"
- Passes ARP request to data link layer process for delivery



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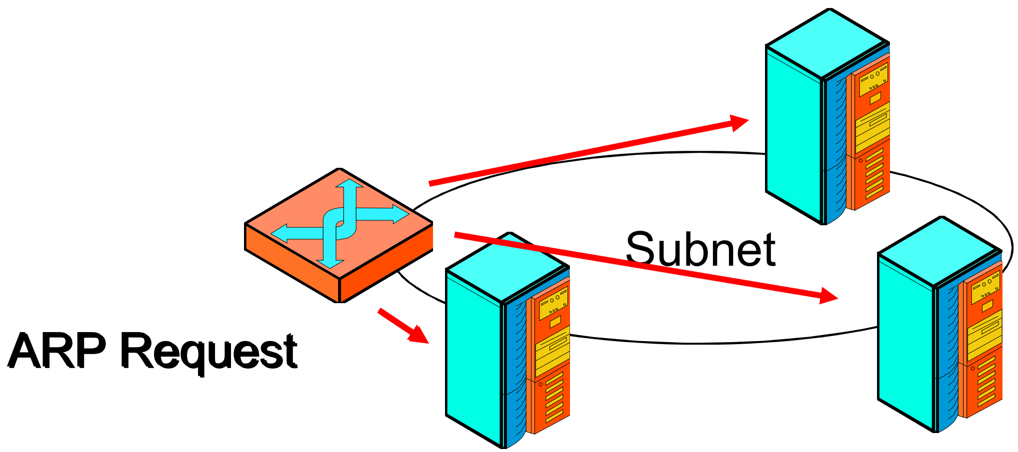
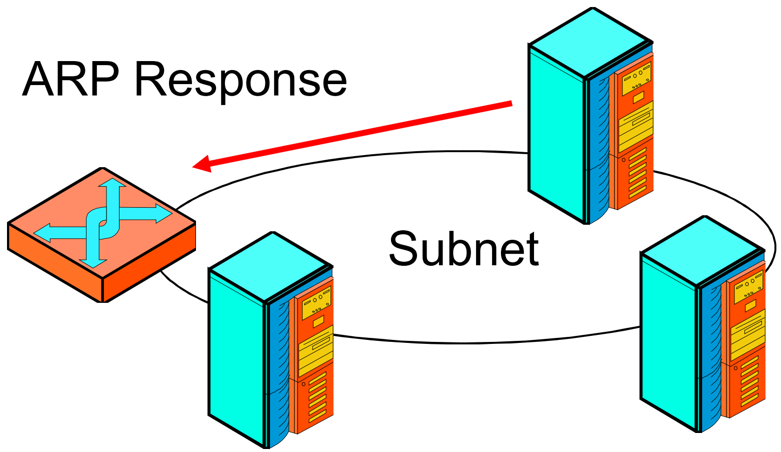
- Data link process of router broadcasts the ARP Request message to all hosts on the subnet.
  - On a LAN, MAC address of 48 ones tells all stations to pay attention to the frame



3.3. Address Resolution Protocol (ARP)

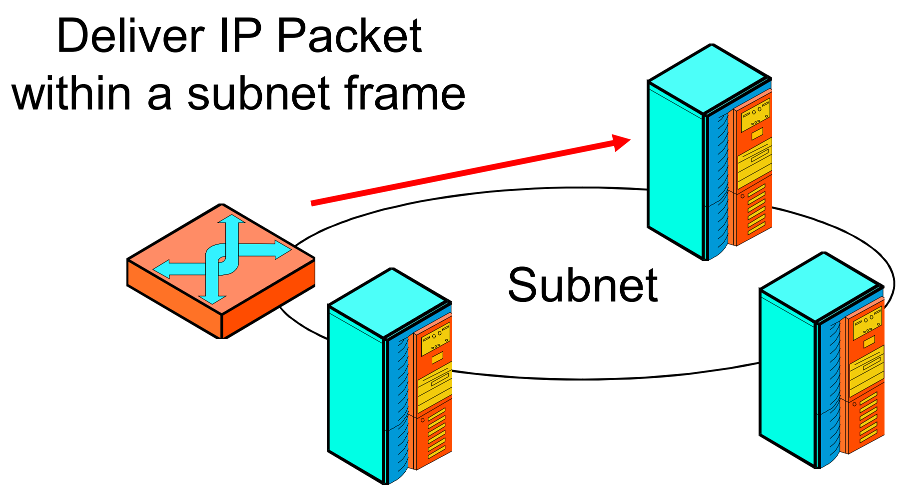
Outlines

- Host with IP address 128.171.17.13 responds
  - Internet process creates an ARP response message
  - Contains the destination host's subnet address (48-bit MAC address on a LAN)



Outlines

- Router delivers the IP packet to the destination host
  - Places the IP packet in the subnet frame
  - Puts the *destination host's subnet address* in the destination address field of the frame



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4. LAN Switches

- Ethernet networks used to be built using **repeaters**.
- When the performance of these networks began to suffer because too many devices shared the same segment, network engineers added bridges to create multiple collision domains.
- As networks grew in size and complexity, the **bridge evolved into the modern switch**, allowing micro-segmentation of the network.
- Today's networks typically are built using **switches and routers**, often with the routing and switching function in the same device.

4.1. Sending and receiving Ethernet frames via a hub

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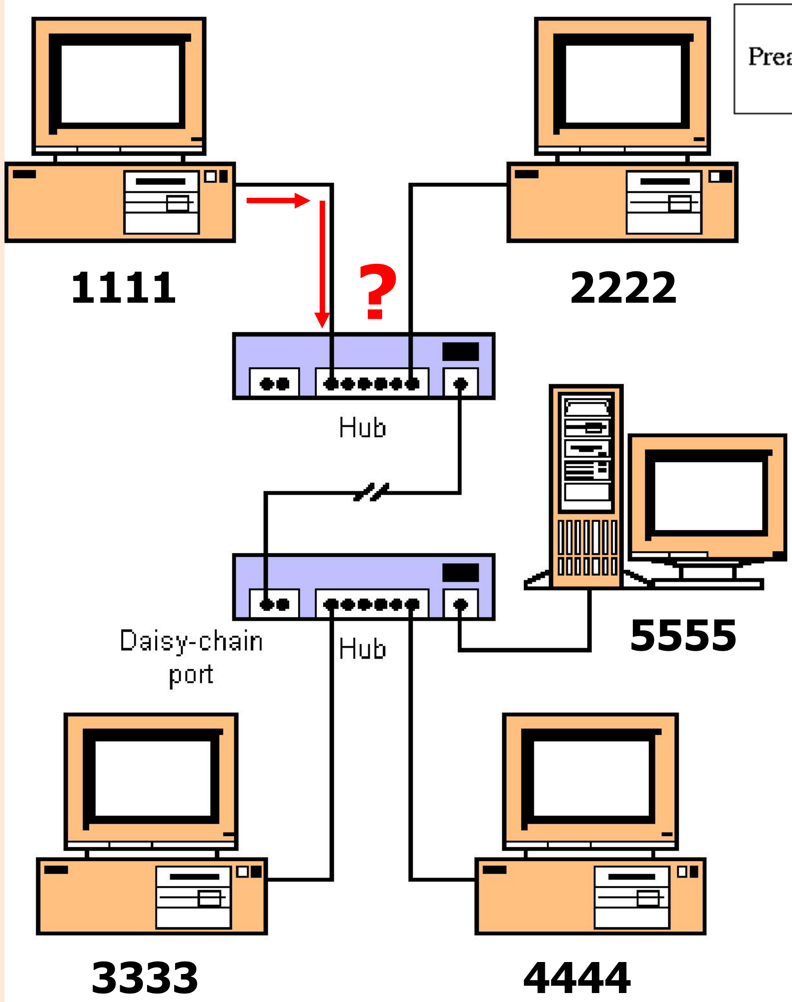

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC

3333 1111

- So, what does a hub do when it receives information?
- Remember, a hub is nothing more than a multiport repeater.

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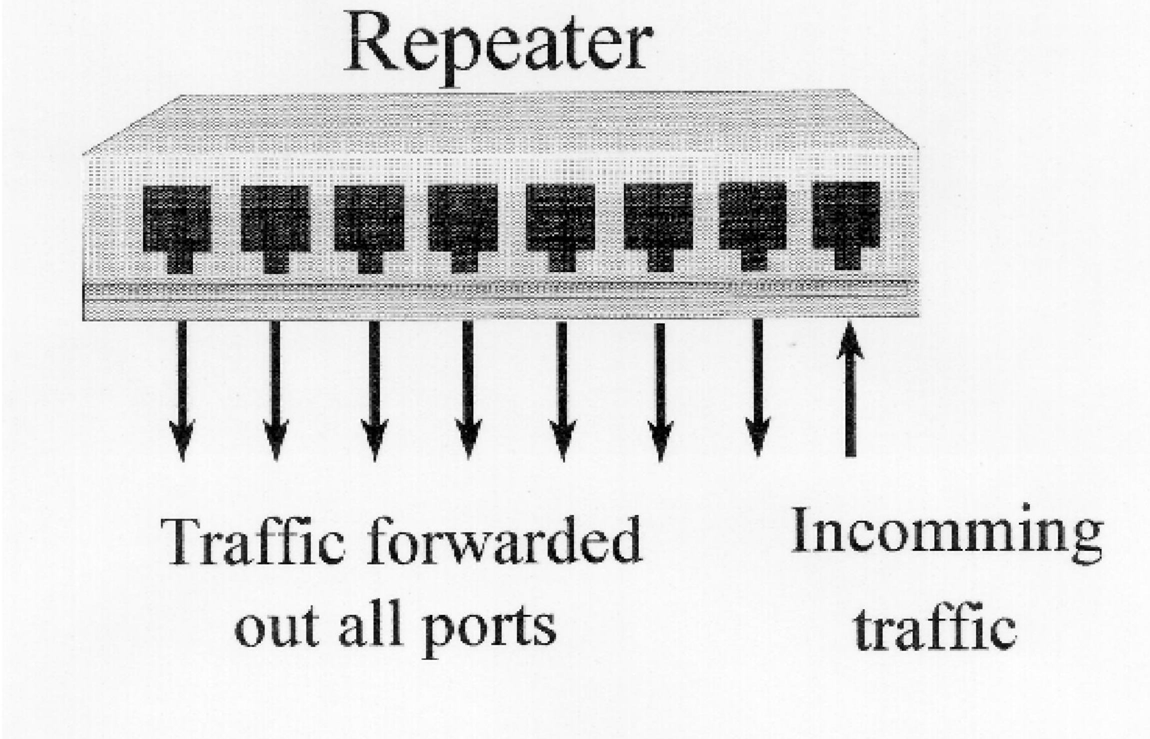
Hub or



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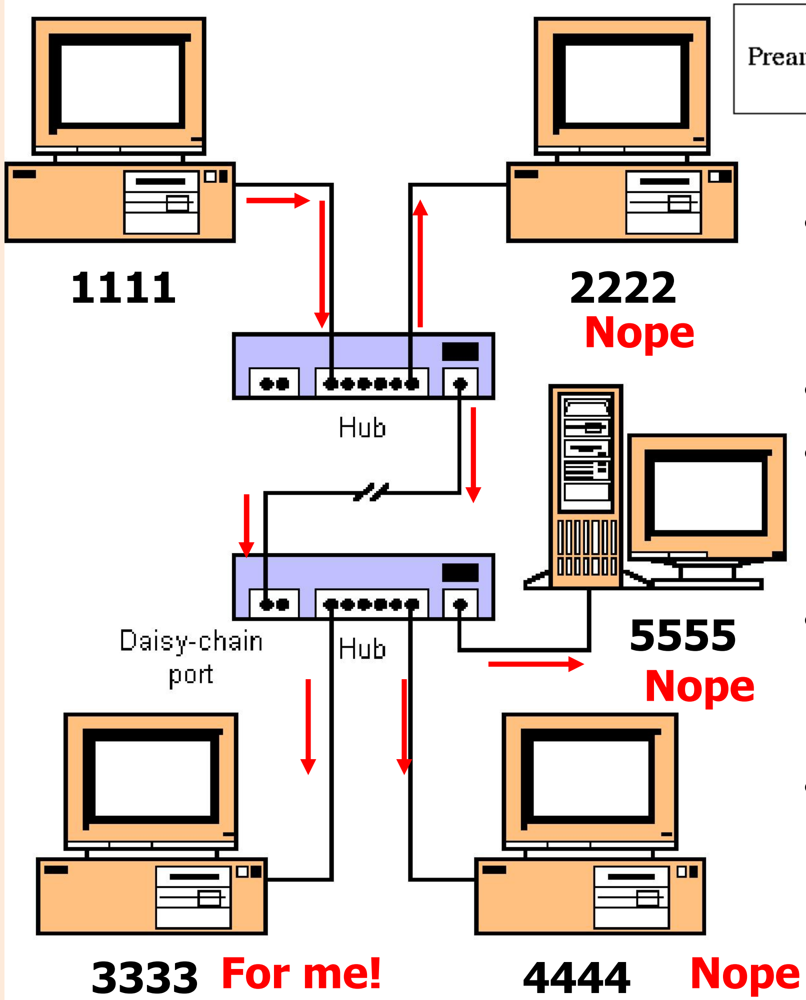

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC

3333 1111

- The hub will **flood** it out all ports except for the incoming port.
- Hub is a layer 1 device.
- A hub does NOT look at layer 2 addresses, so it is fast in transmitting data.
- Disadvantage with hubs: A hub or series of hubs is a single **collision domain**.
- A collision will occur if any two or more devices transmit at the same time within the collision domain.

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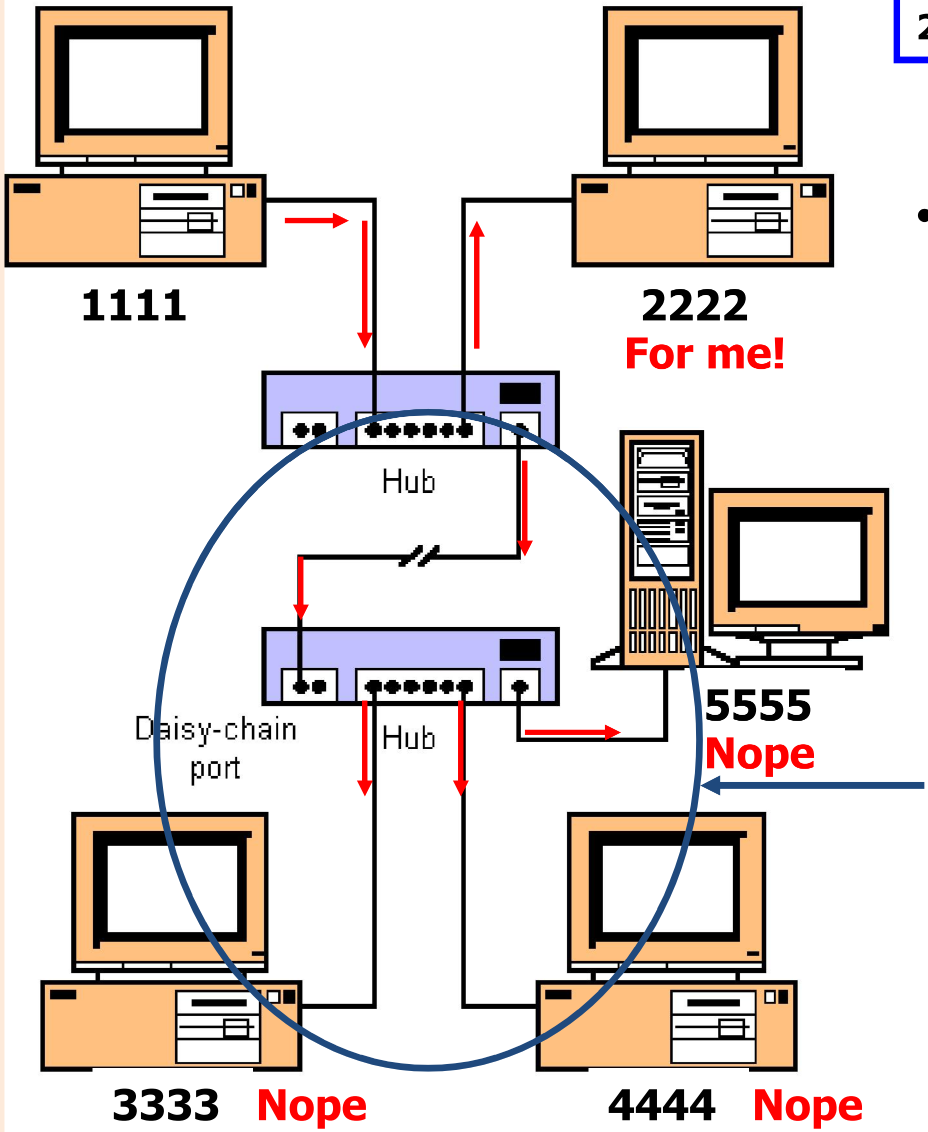
Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	2222	1111				



- Another disadvantage with hubs is that is take up unnecessary bandwidth on other links.

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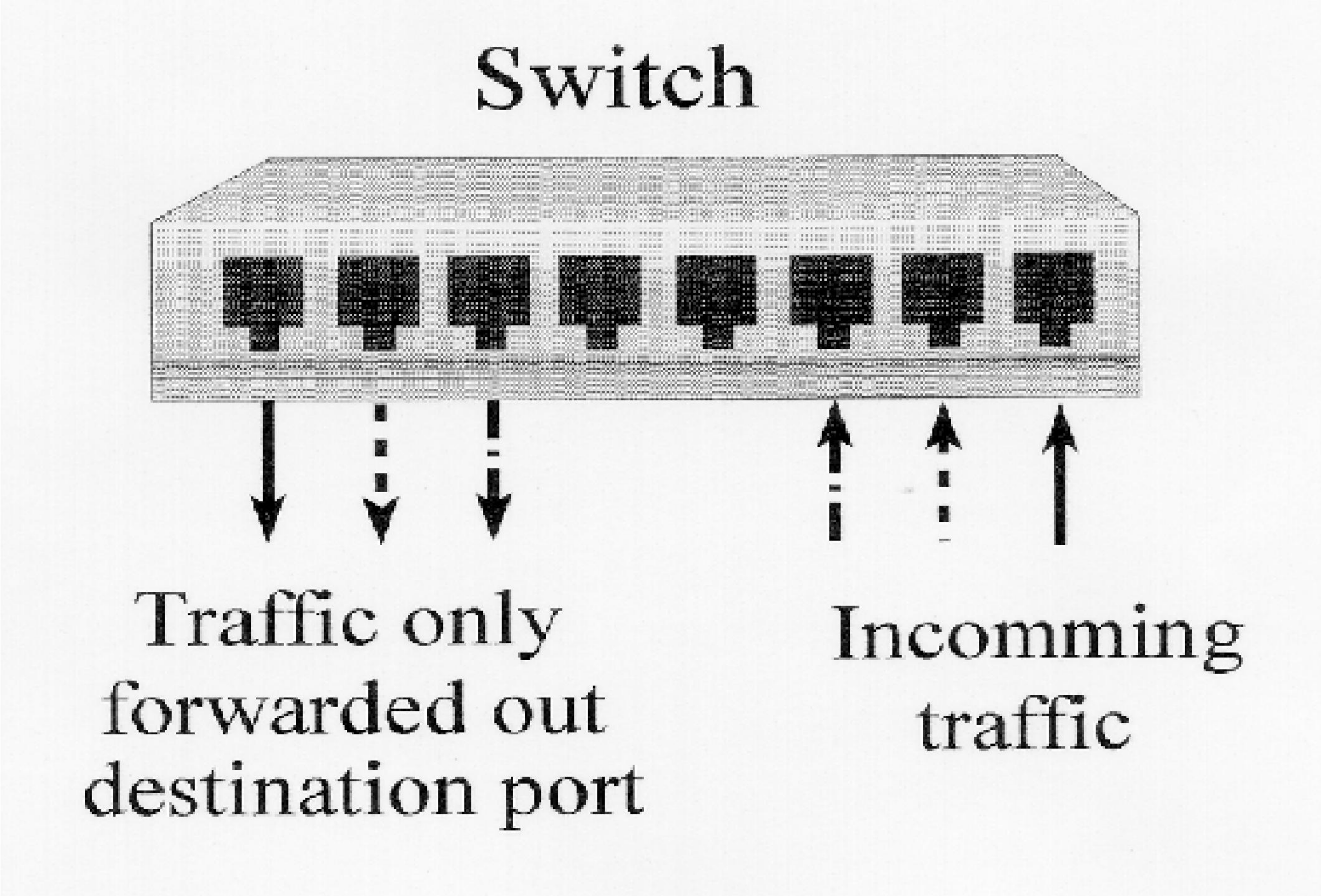

4.2. Switched Fabric

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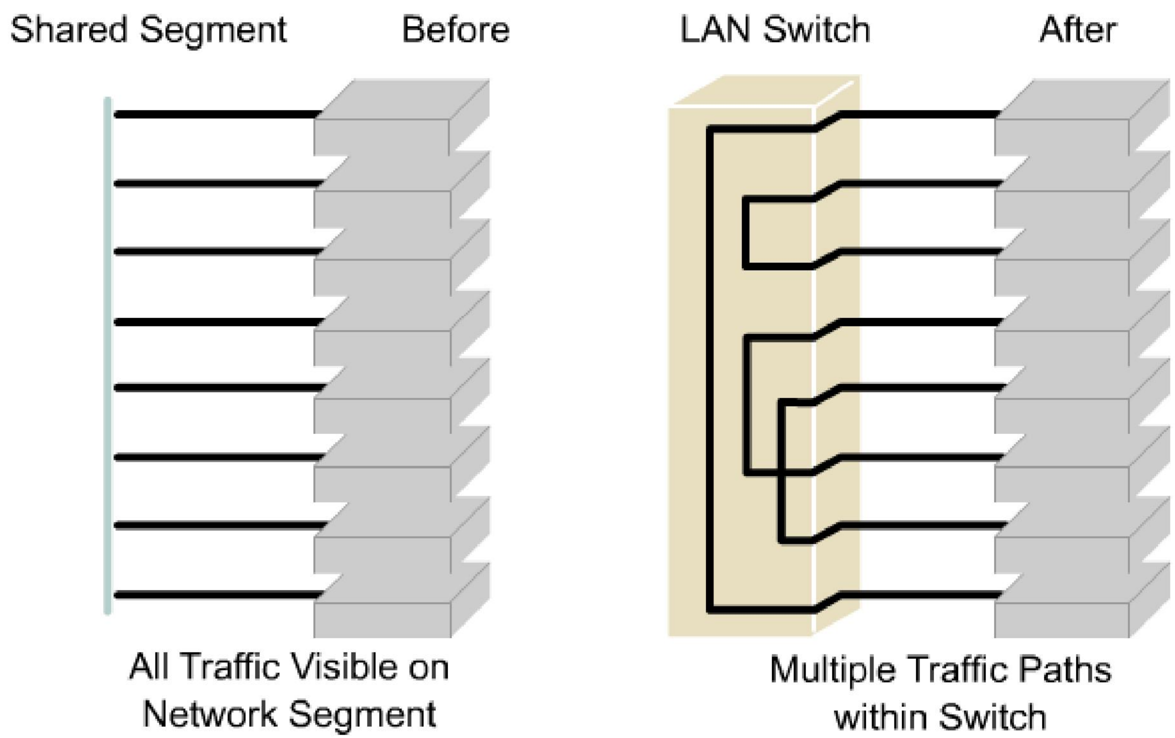

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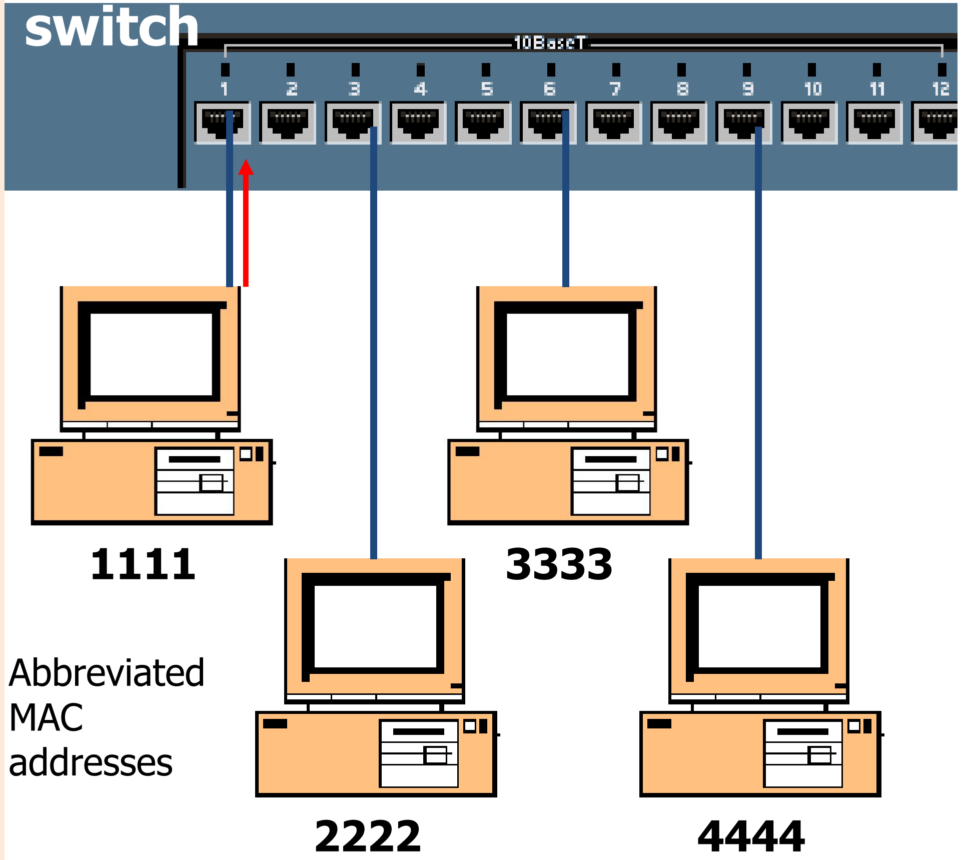
4.3. Sending and receiving Ethernet frames via a switch

Source Address Table

Port	Source MAC Add.	Port	Source MAC Add.

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				



Abbreviated MAC addresses

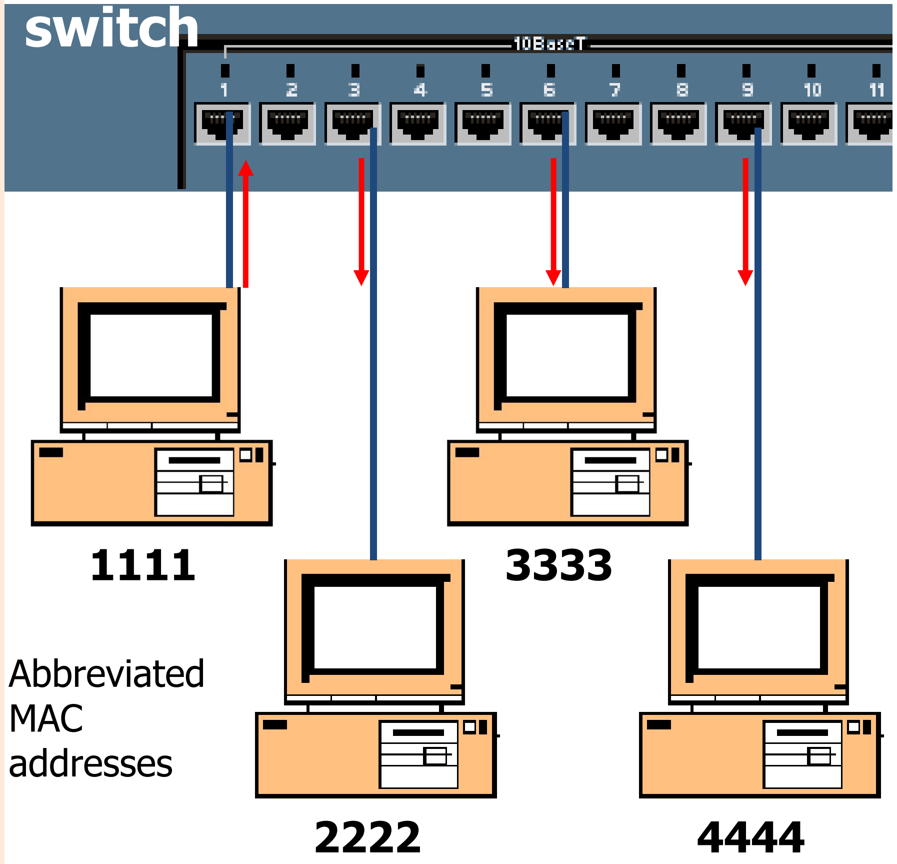
- Switches are also known as **learning bridges** or **learning switches**.
- A switch has a source address table in cache (RAM) where it stores source MAC address after it learns about them.
- A switch receives an Ethernet frame it searches the source address table for the Destination MAC address.
- If it finds a match, it **filters** the frame by only sending it out that port.
- If there is not a match if **floods** it out all ports.

No Destination Address in table, Flood

Source Address Table

Port	Source MAC Add.	Port	Source MAC Add.
1	1111		

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				



- How does it learn source MAC addresses?
- First, the switch will see if the SA (1111) is in it's table.
- If it is, it resets the timer (more in a moment).
- If it is NOT in the table it adds it, with the port number.
- Next, in our scenario, the switch will **flood** the frame out all other ports, because the DA is not in the source address table.

Destination Address in table, Filter

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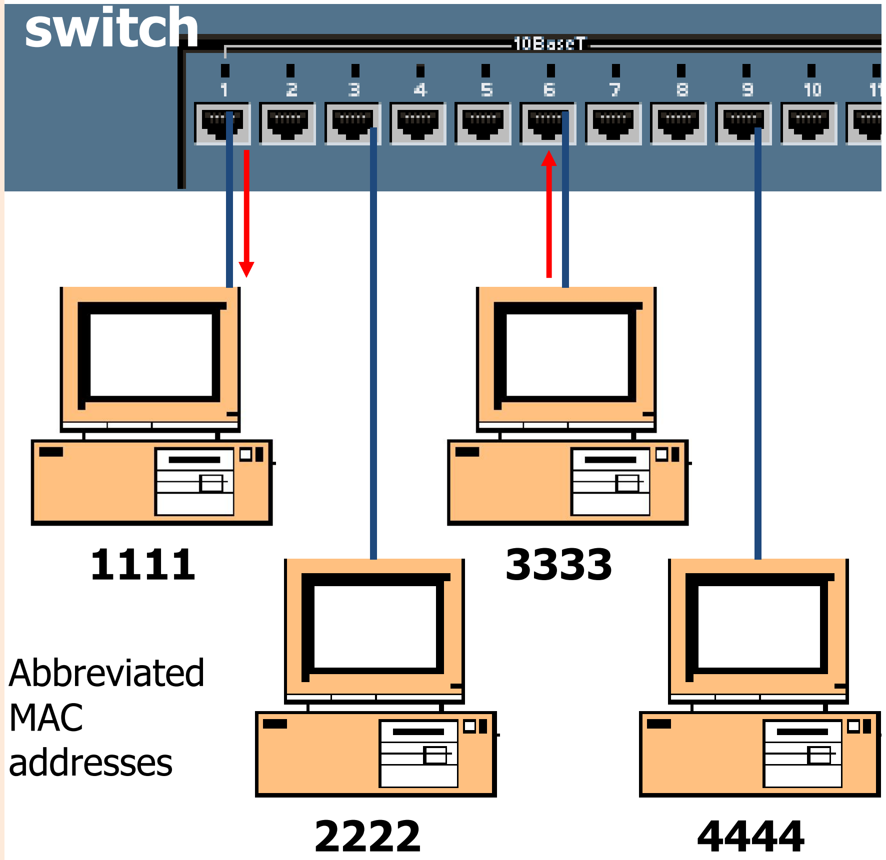
Source Address Table

Port	Source MAC Add.	Port	Source MAC Add.
1	1111	6	3333

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	1111	3333				



- Most communications involve some sort of client-server relationship or exchange of information. (You will understand this more as you learn about TCP/IP.)
- Now 3333 sends data back to 1111.
- The switch sees if it has the SA stored.
- It does NOT so it adds it. (This will help next time 1111 sends to 3333.)
- Next, it checks the DA and in our case it can **filter** the frame, by sending it only out port 1.

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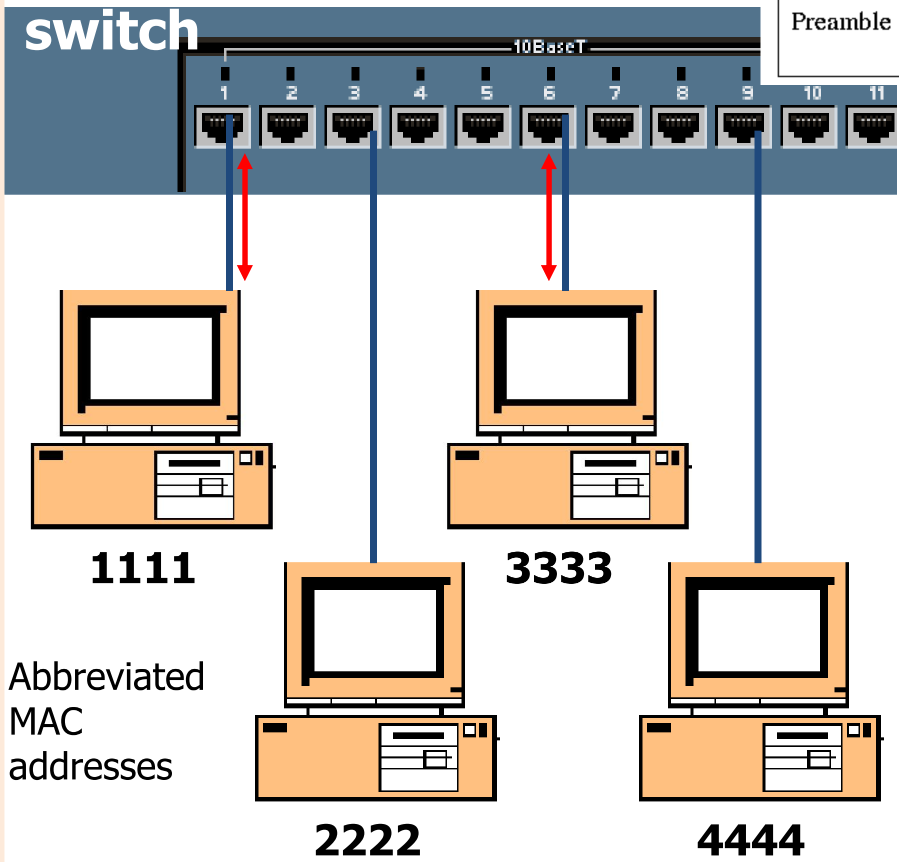
Destination Address in table, Filter

Source Address Table

Port	Source MAC Add.	Port	Source MAC Add.
1	**1111**	**6**	**3333**

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	**1111**				

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	1111	**3333**				



- Now, because both MAC addresses are in the switch's table, any information exchanged between 1111 and 3333 can be sent (filtered) out the appropriate port.
- **What happens when two devices send to same destination?**
- **What if this was a hub?**
- **Where is (are) the collision domain(s) in this example?**

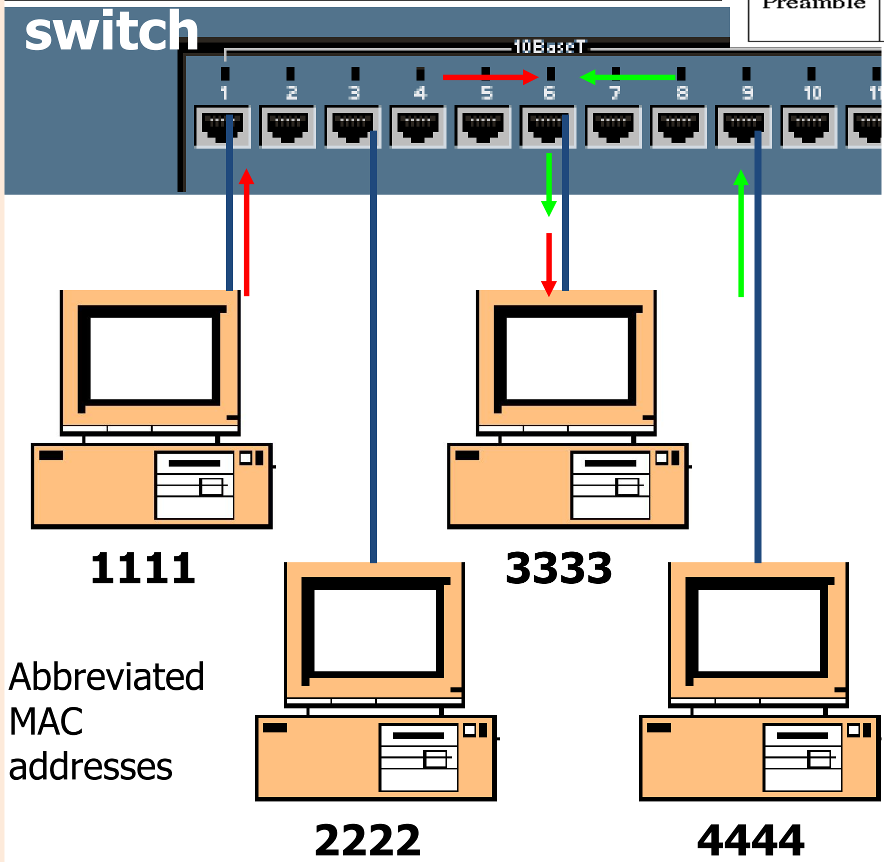
4.4. No Collisions in Switch, Buffering

Source Address Table

Port	Source MAC Add.	Port	Source MAC Add.
1	1111	6	3333
9	4444		

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	4444				



- Unlike a hub, a collision does NOT occur, which would cause the two PCs to have to retransmit the frames.
- Instead the switch buffers the frames and sends them out port #6 one at a time.
- The sending PCs have no idea that their was another PC wanting to send to the same destination.

4.4. No Collisions in Switch, Buffering

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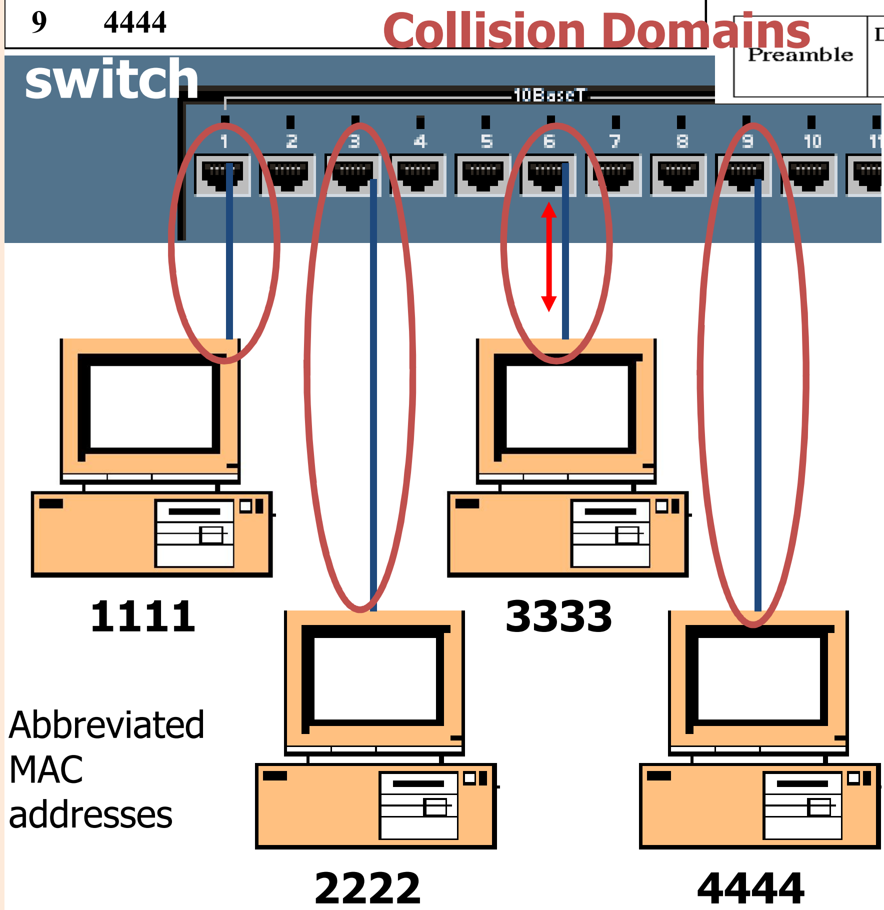
Source Address Table

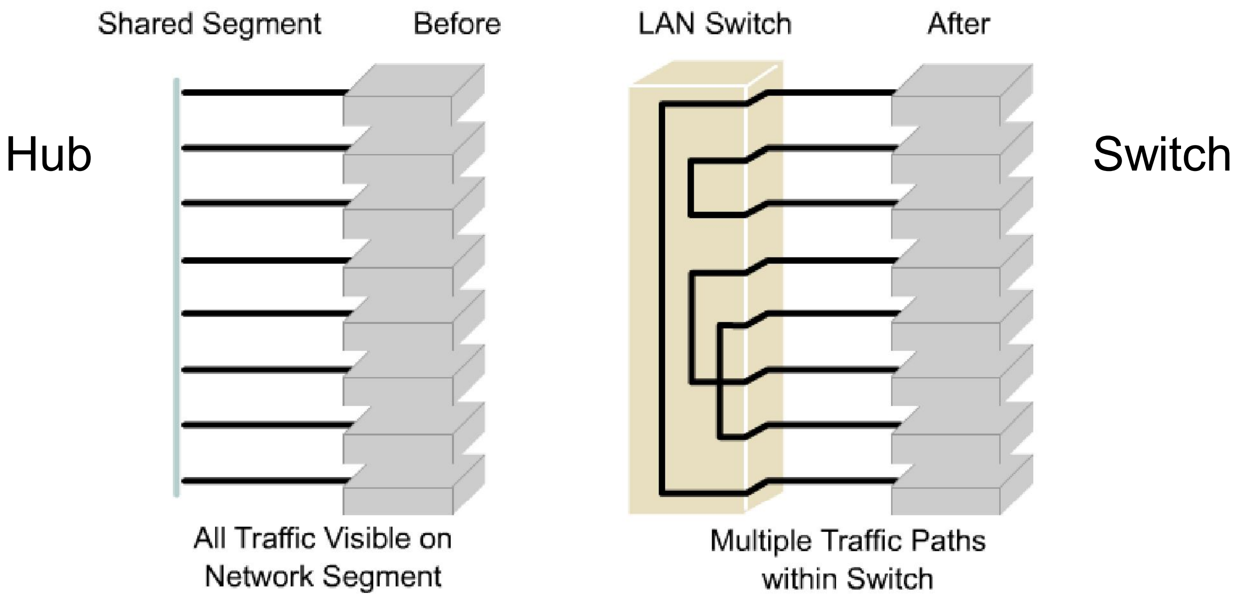
Port	Source MAC Add.	Port	Source MAC Add.
1	1111	6	3333
9	4444		

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	1111				

Preamble	Destination Address	Source Address	Type	Data	Pad	CRC
	3333	4444				



- In half duplex mode and when there is only one device on a switch port, the collision domain is only between the PC and the switch.
- With a **full-duplex** PC and switch port, there will be no collision, since the devices and the medium can send and receive at the same time.



- First is to isolate traffic between segments.
- The second reason is to achieve more bandwidth per user by creating smaller collision domains.

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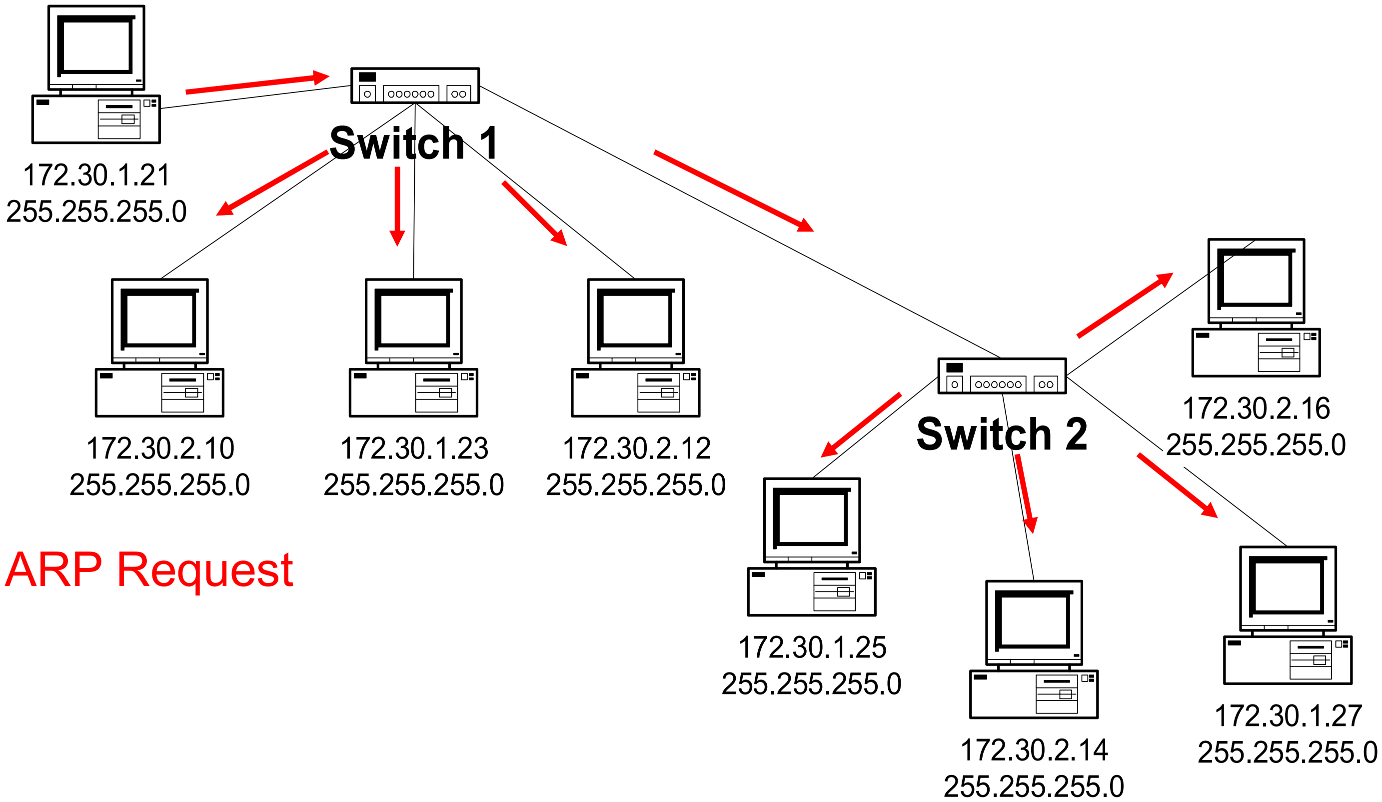
- A switch employs "microsegmentation" to reduce the collision domain on a LAN.
- The switch does this by creating dedicated network segments, or point-to-point connections.

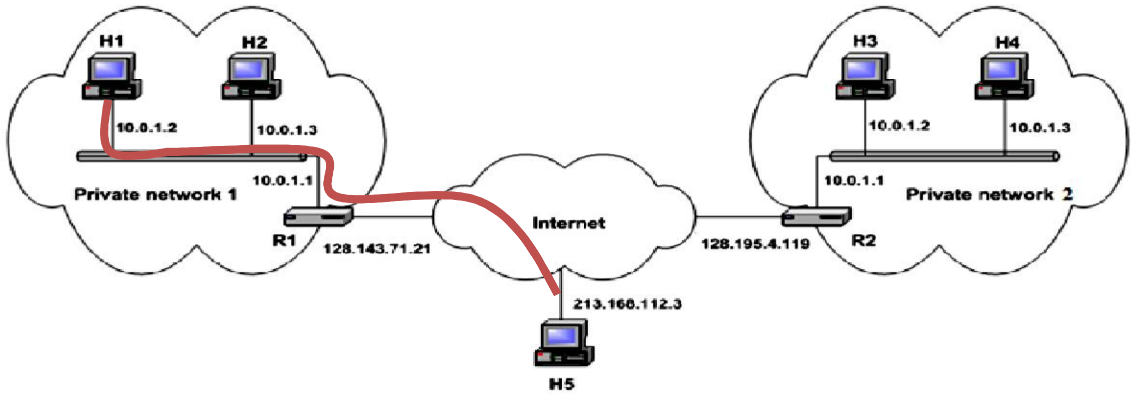


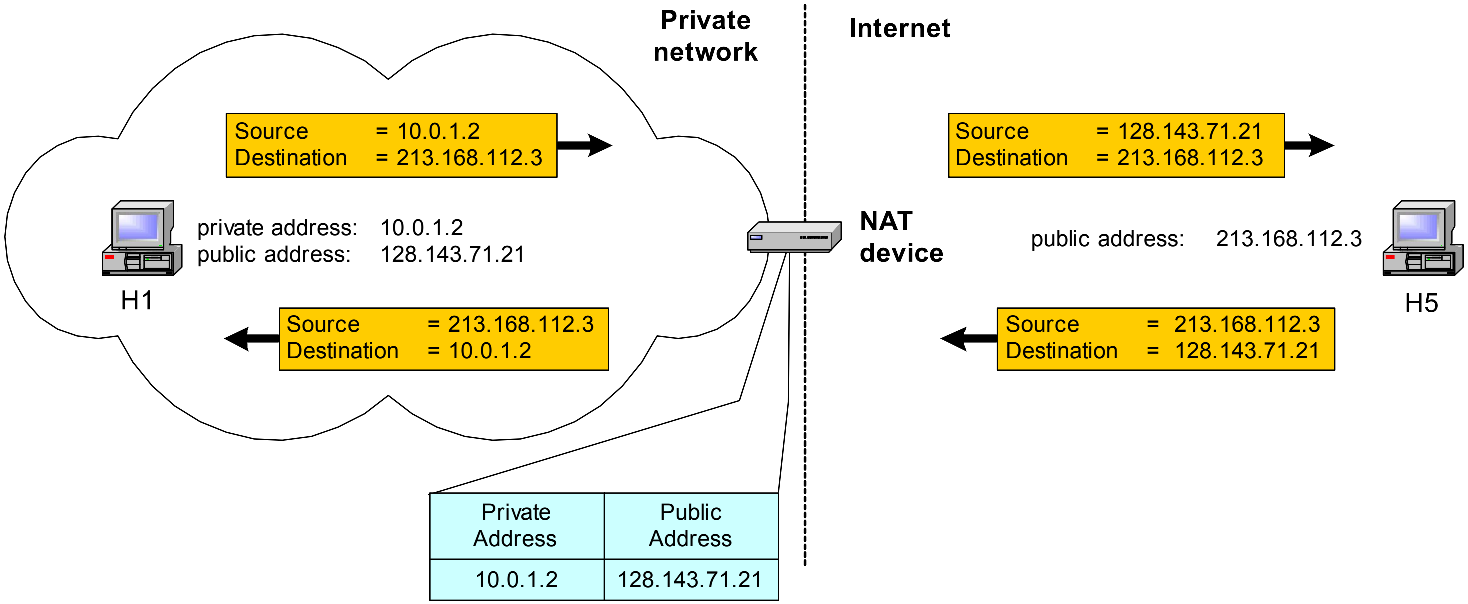
- ARP Request

- Even though the LAN switch reduces the size of collision domains, all hosts connected to the switch are still in the same broadcast domain.
- Therefore, a broadcast from one node will still be seen by all the other nodes connected through the LAN switch.

Outlines

Reminder: NAT - Network Address Translation



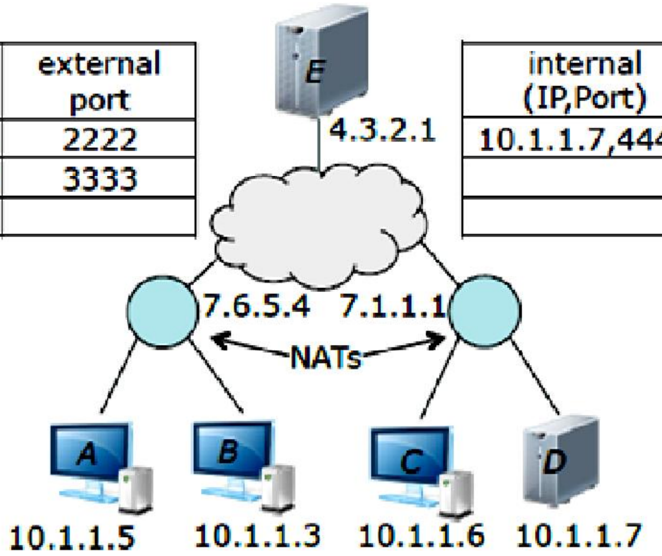


Exercise:

The figure below shows two residential networks with routers that implement NAT. Suppose host *A is* connected to the web server at host *E.*

In the left-hand NAT table, add an entry that would allow *A to communicate with E. You may choose any port numbers you* like, but the internal port numbers should be different from the external port numbers.

Show the values of the address and port fields in the diagram below, for a typical packet sent by host *A*.



internal (IP,Port)	external port
10.1.1.5,1111	2222
10.1.1.3,7777	3333

internal (IP,Port)	external port
10.1.1.7,4444	5555

src adr	dest adr	src port	dest port

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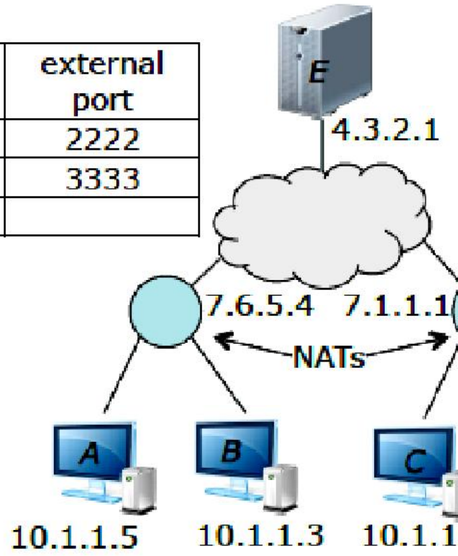
internal (IP,Port)	external port
10.1.1.5,1111	2222
10.1.1.3,7777	3333



internal (IP,Port)	external port
10.1.1.7,4444	5555

src adr	dest adr	src port	dest port
10.1.1.5	4.3.2.1	1111	80

Outlines

- Introduction
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- Fast and Gigabit Ethernet
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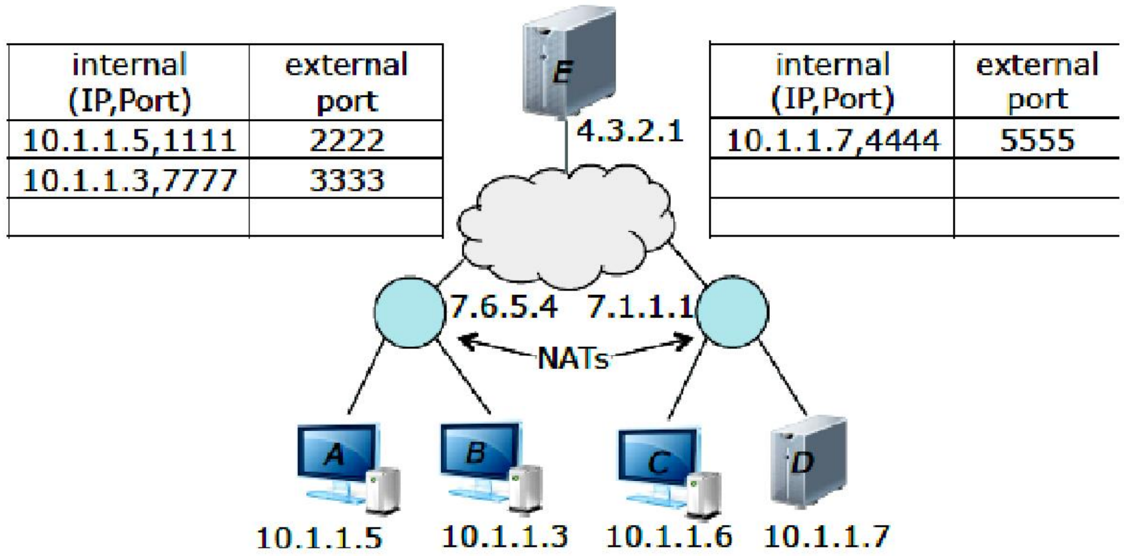
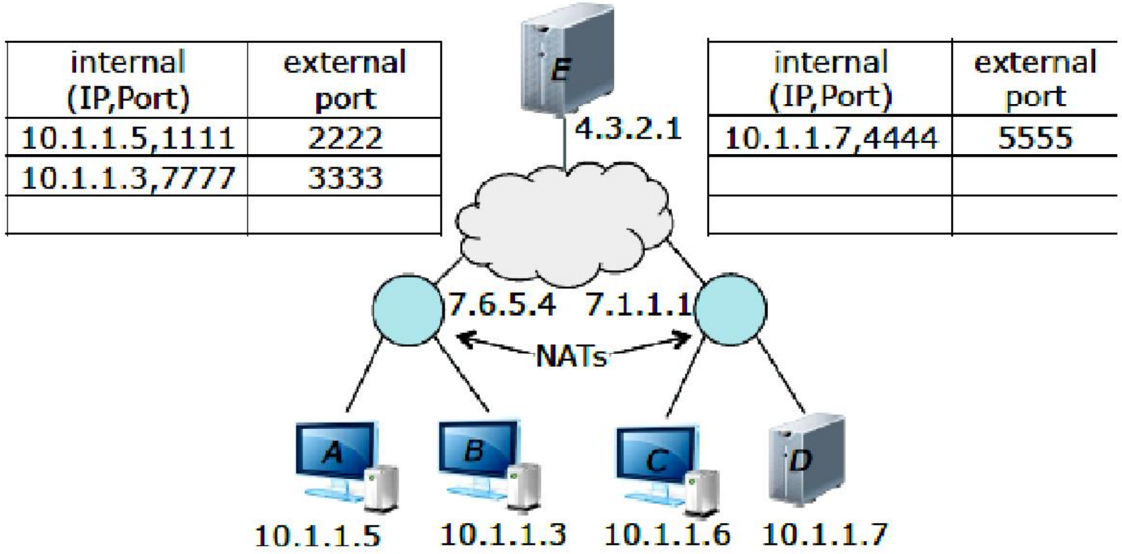
- Why did Ethernet Win?



Show the fields in the packet as it might appear when it reaches *E.*

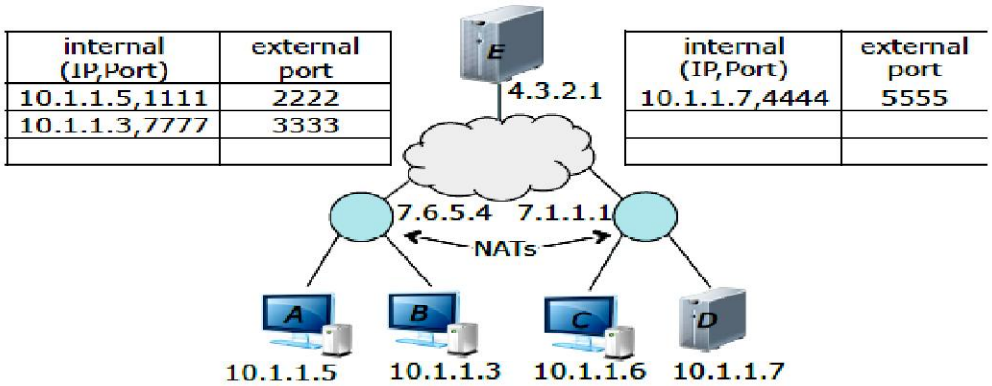
src adr	dest adr	src port	dest port

Outlines



Show the fields in the packet as it might appear when it reaches *E.*

src adr	dest adr	src port	dest port
7.6.5.4	4.3.2.1	2222	80



Suppose the user in the right-hand network runs a game server on host *D and invites her* friends to join her game sessions. Add an entry to the right-hand table that would allow remote connections to the game server. Again, you may pick your own port numbers, but the internal and external port numbers should be different. Assume host *B connects to the* game server at *D. Add an entry to the NAT table for this connection. Show the* address and port fields for a typical packet leaving host *B, the fields in the same packet as it* passes through the public internet, and the fields in the packet that is delivered to *D.*

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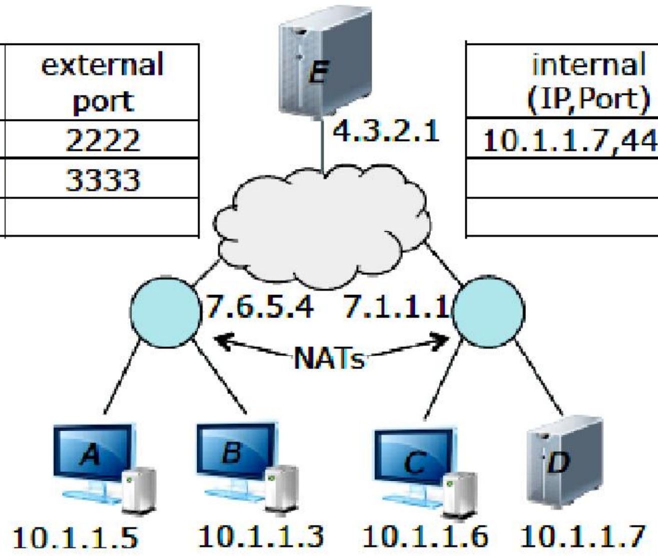
internal (IP,Port)	external port
10.1.1.5,1111	2222
10.1.1.3,7777	3333



internal (IP,Port)	external port
10.1.1.7,4444	5555

src adr	dest adr	src port	dest port

src adr	dest adr	src port	dest port

src adr	dest adr	src port	dest port

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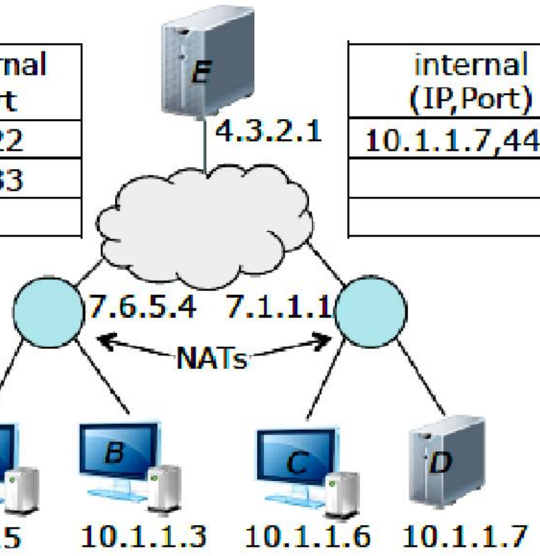
internal (IP,Port)	external port
10.1.1.5,1111	2222
10.1.1.3,7777	3333



internal (IP,Port)	external port
10.1.1.7,4444	5555

src adr	dest adr	src port	dest port
10.1.1.3	7.1.1.1	7777	5555

src adr	dest adr	src port	dest port
7.6.5.4	7.1.1.1	3333	5555

src adr	dest adr	src port	dest port
7.6.5.4	10.1.1.7	3333	4444

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5. Fast and Gigabit Ethernet

- Fast Ethernet (100Mbps) has technology very similar to 10Mbps Ethernet
  - Uses different physical layer encoding (4B5B)
  - Many NIC's are 10/100 capable
    - Can be used at either speed
- Gigabit Ethernet (1,000Mbps)
  - Compatible with lower speeds
  - Uses standard framing and CSMA/CD algorithm
  - Distances are severely limited
  - Typically used for backbones and inter-router connectivity
  - Becoming cost competitive
  - How much of this bandwidth is realizable?

6. Experiences with Ethernet

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- Ethernets work well under light loads
  - Utilization over 30% is considered heavy
    - Network capacity is wasted by collisions
- Most networks are limited to about 200 hosts
  - Specification allows for up to 1024
- Most networks are much shorter
  - 5 to 10 microsecond RTT
- Transport level flow control helps reduce load (number of back to back packets)
- Ethernet is inexpensive, fast and easy to administer!

Outlines

7. Ethernet Problems

- Ethernet's peak utilization is pretty low (like Aloha)
- Peak throughput worst with
  - More hosts
    - More collisions needed to identify single sender
  - Smaller packet sizes
    - More frequent arbitration
  - Longer links
    - Collisions take longer to be observed, more wasted bandwidth
  - Efficiency is improved by avoiding these conditions

8. Why did Ethernet Win?

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- There are LOTS of LAN protocols
- **Price**
- Performance
- Availability
- Ease of use
- Scalability