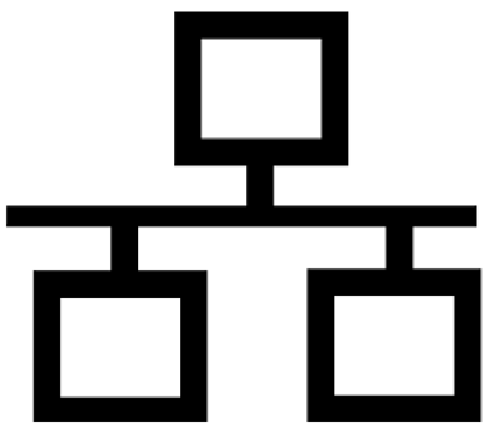
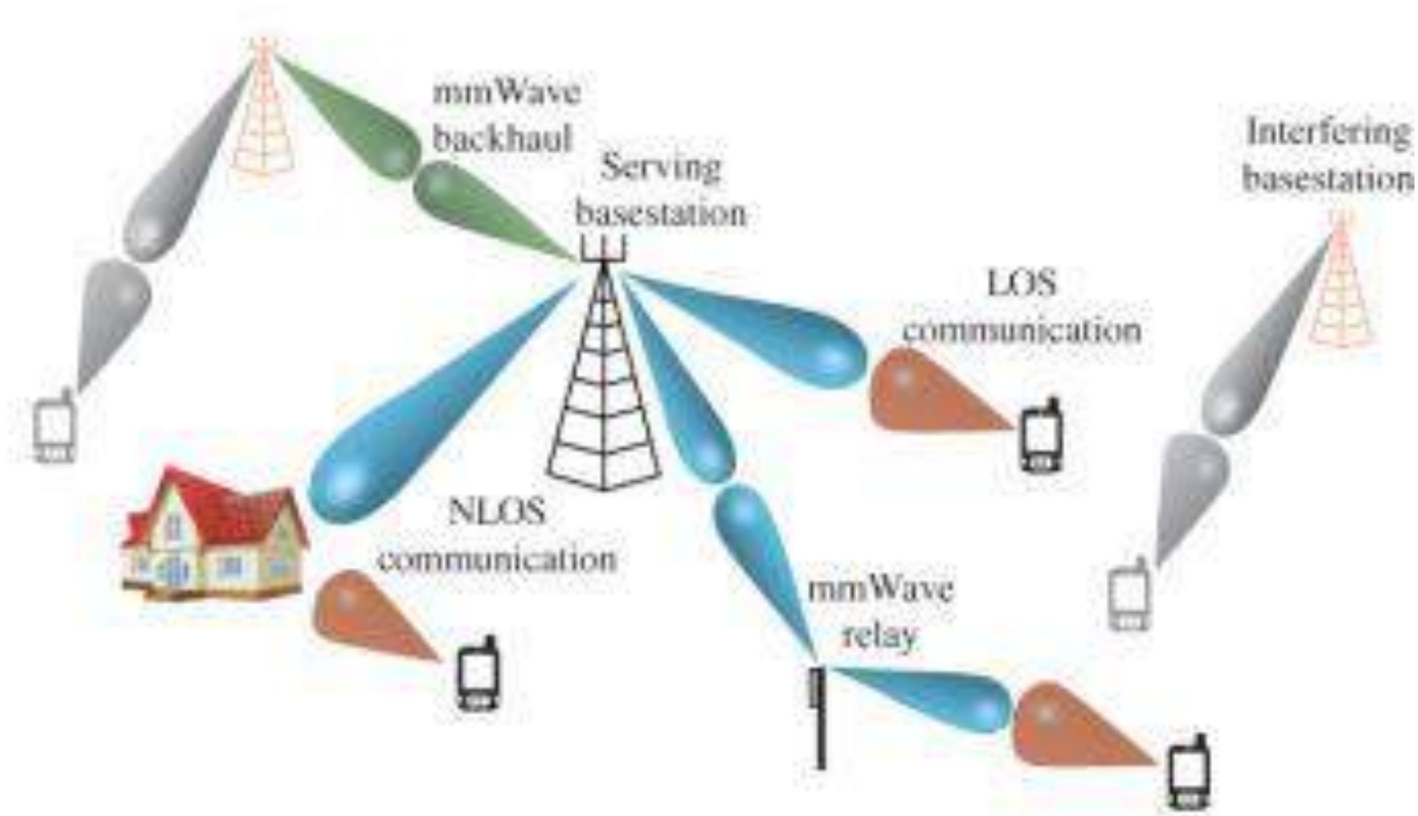
CS 118: Local Area Networks, Ethernet and 802.11

George Varghese

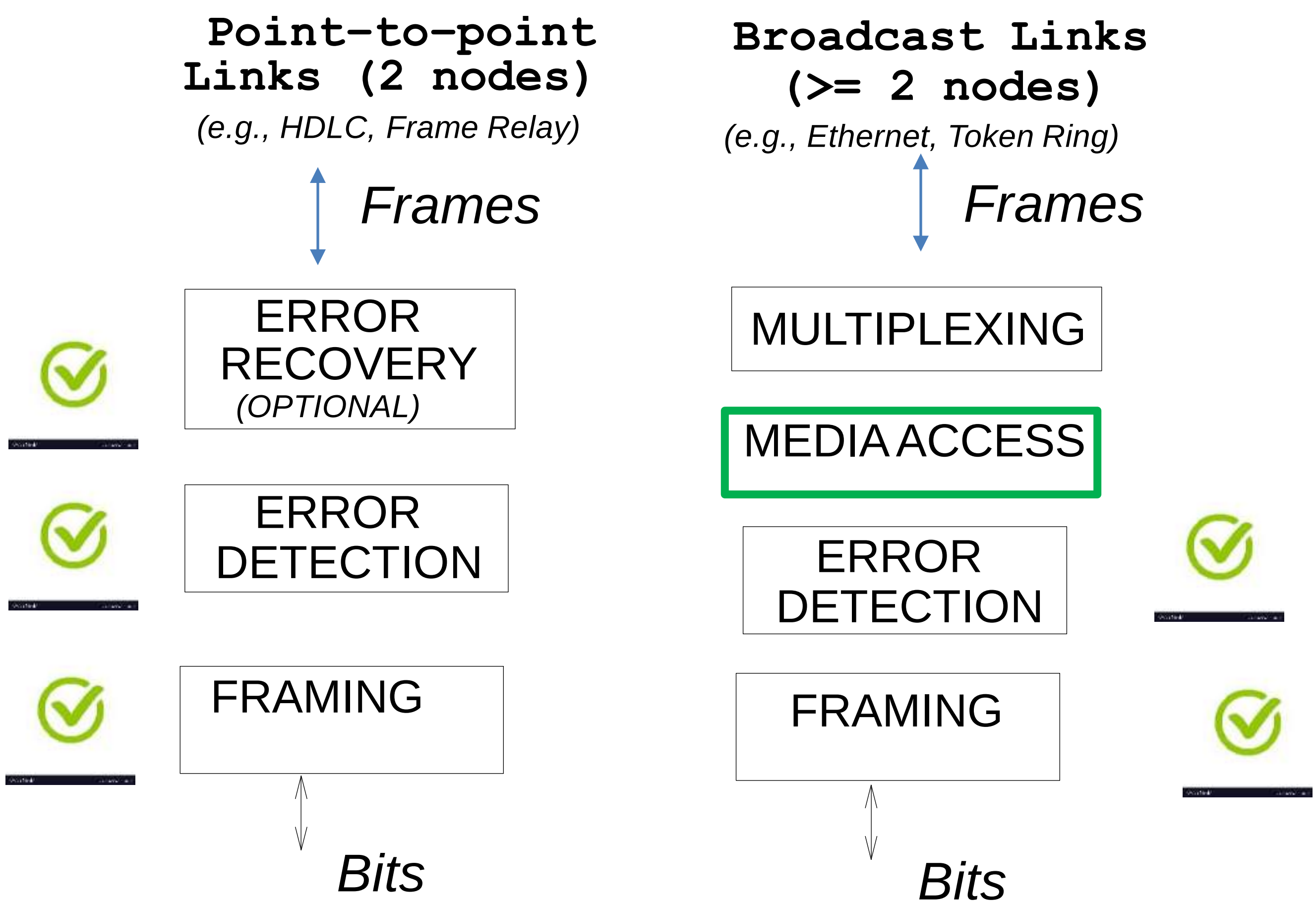
October 28th, 2021





Imagine you work for Qualcomm on their new mm wave local area network and you feel the design team is ignoring lessons from Ethernet collision detection. So its worth understanding not just how but why . . .

Data Link Sublayers

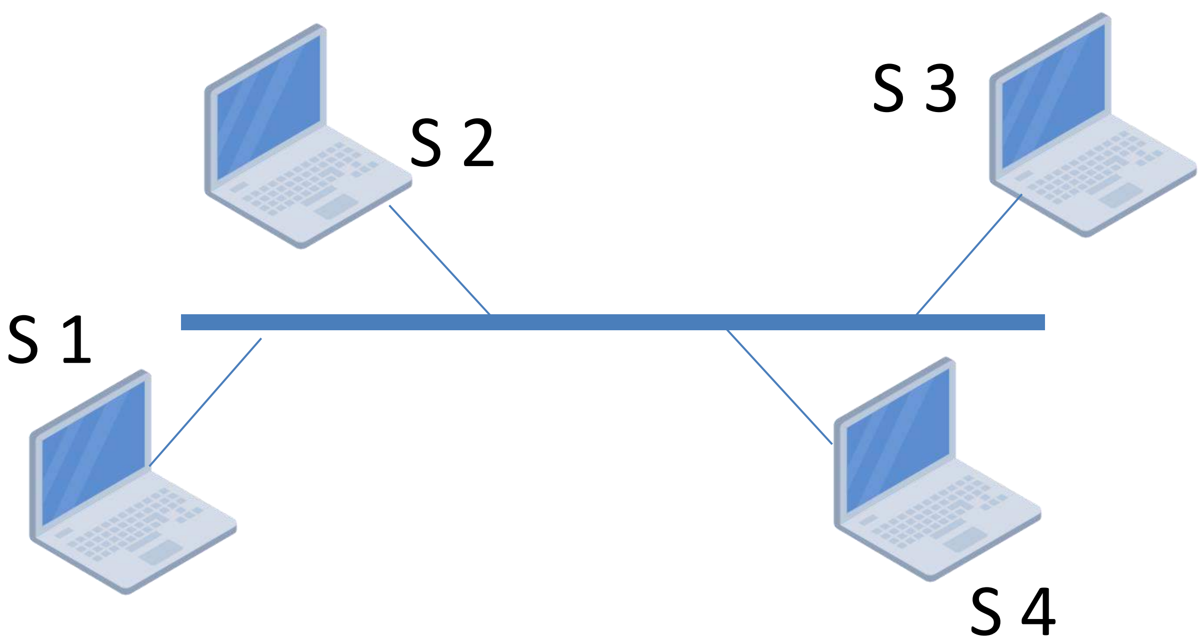


MOVING ON TO MEDIA ACCESS, MANY SENDERS AND RECEIVERS ON SAME LINK: e.g., Ethernet, 802.11

Big Transition this class

From 1 sender, 1 receiver (e.g., fiber) to . .

Multiple senders, receivers (e.g., Ethernet)



New problem: how to share a link (MAC)

A Rose by any other Name

Inherently sequential. Link shared among multiple senders. Also Known as:

- *Multiaccess links* because there are multiple nodes that may simultaneously access link.
- *Broadcast links* because every transmission can be heard by all other stations.
- *Local Area Networks* or LANs because the geographical area serviced by a LAN is local and small – from 1-10 Kms, covering an office, a building, or at most a campus.

WHY LANS

- Cost: Connect up all computers in a building, office, campus. 200-1000 users. Saves wiring costs to share one wire (or the air waves, no dedicated air waves).
- Bandwidth: Provides high bandwidth and low error rates for local group of users. Worth it because most high-bandwidth distributed computing (e.g., file servers etc.) has acess locality.
- Statistical Multiplexing: Time division multiplexing not a good idea when user traffic is bursty as data is. Bursty = high peak/average ratio. Each user gets access to entire LAN bandwidth when other users are idle. As more users are added, they share the bandwidth

How might you share a Xerox Machine?

By time slots? No collisions, but wasteful!

John: 10 – 11.00 am

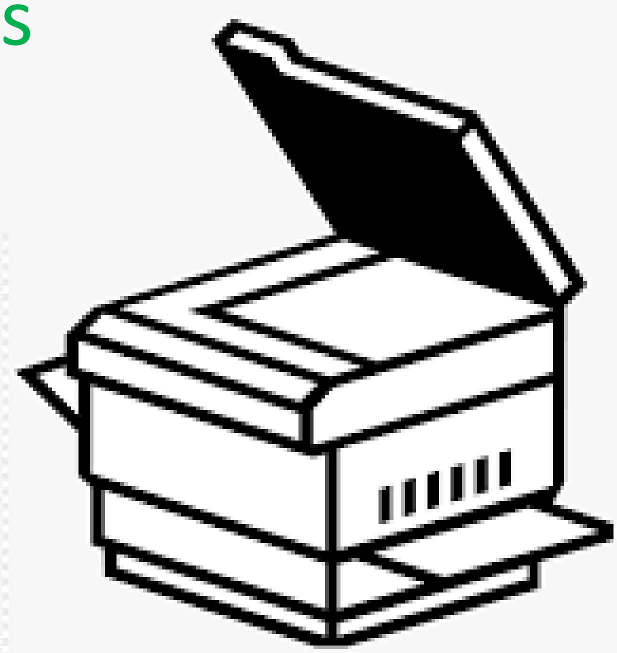
Bob: 12 – 1.00 am

Ron: 11 – 12.00 am

Meg: 12 – 1.00 ar

How would you share a Xerox Machine?

Just show up but
sort out collisions



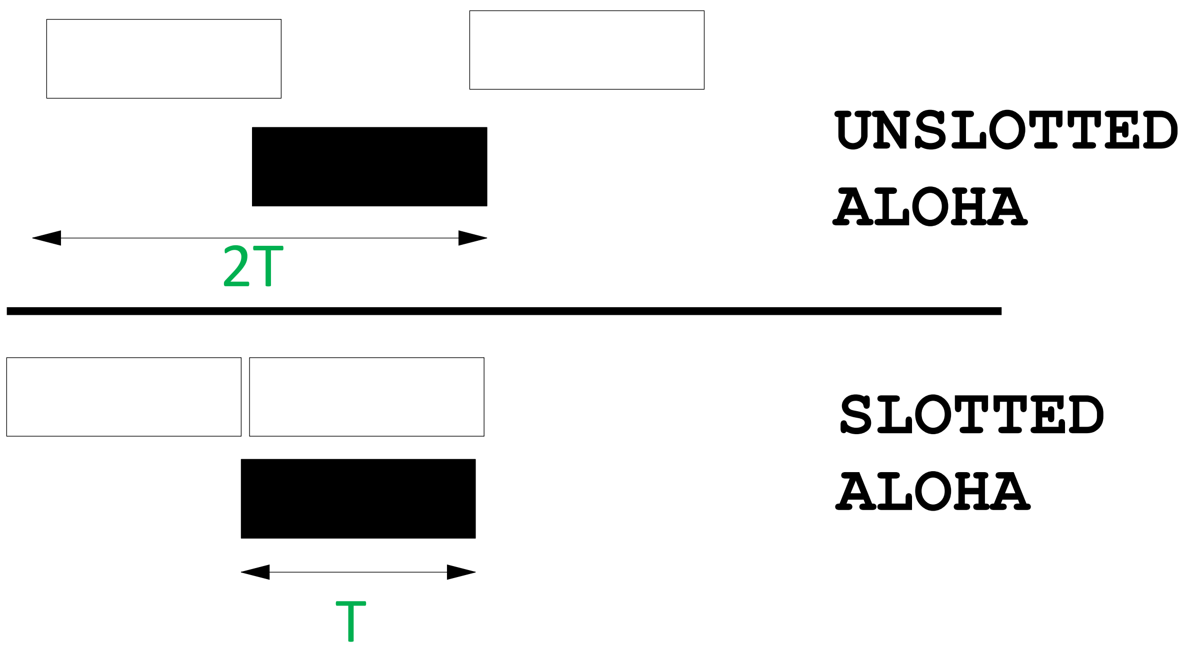
Ron: waits for John

We call this <u>statistical multiplexing,</u> better latency & throughput in common case: what Ethernet does

Statistical versus Strict Multiplexing

- Strict multiplexing: TDM or FDM where a user is given a fixed allocation ***regardless*** of whether the user has data to send or not.
- Bursty: traffic has a high peak/average ratio.
- Analysis: gives each user B/N , where N is the number of possible sources; stat multiplexing attempts to give each user, B/x, where x is the number of busy users. N large (100 -1000) while x is small (1-10).
- Example: Suppose 100 users each transfer a 125 kbyte file every 2 hours. At 10 Mbps, a 125 kbyte file takes 0.1 seconds to transmit. At 0.1 Mbps, file takes 10 seconds to transfer.

ALOHA



- Ethernet Predecessor: Multiple ground stations in various parts of Hawai.
- Problem: Couldn't detect collisions or sense when channel was busy. Similar problems in 802.11
- Slotted Aloha: reduces vulnerable period by half but requires a common clock

In transmission collision detection and semi-reliability

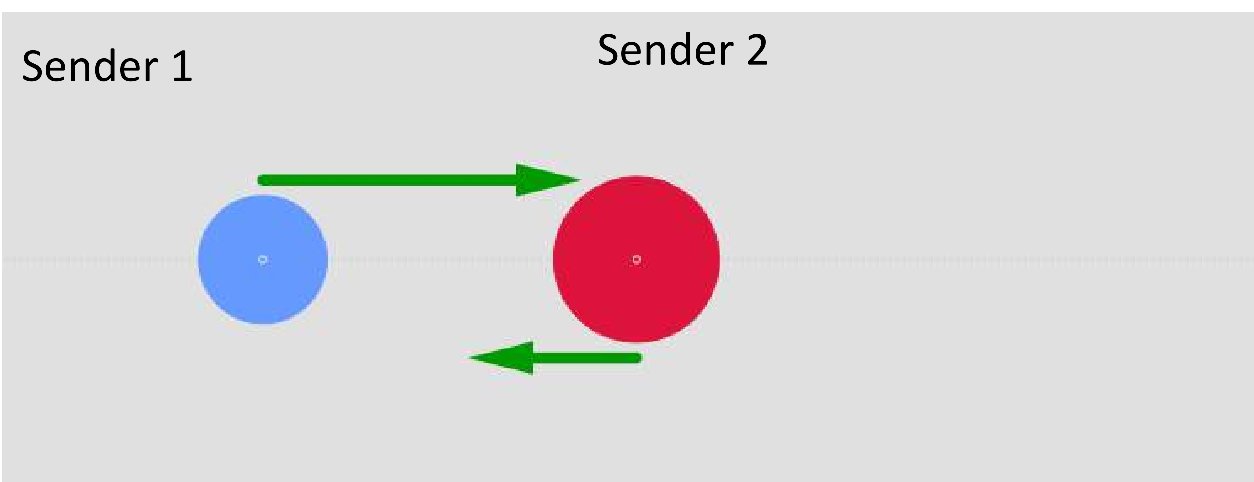
- Metcalfe knew about Aloha. He knew he could do better because of the smaller distance.

- 1500 byte frame involved in a collision. Ethernet *aborts* transmission after 64 bytes. Aloha will send the entire 1500 bytes and detect when ack is not received. Better for large frames, and large frame sizes allow efficiency.
- No recovery from frame corruption. (1 in million). However, collisions are frequent. Semi-reliable: detect collisions and retransmit in hardware.

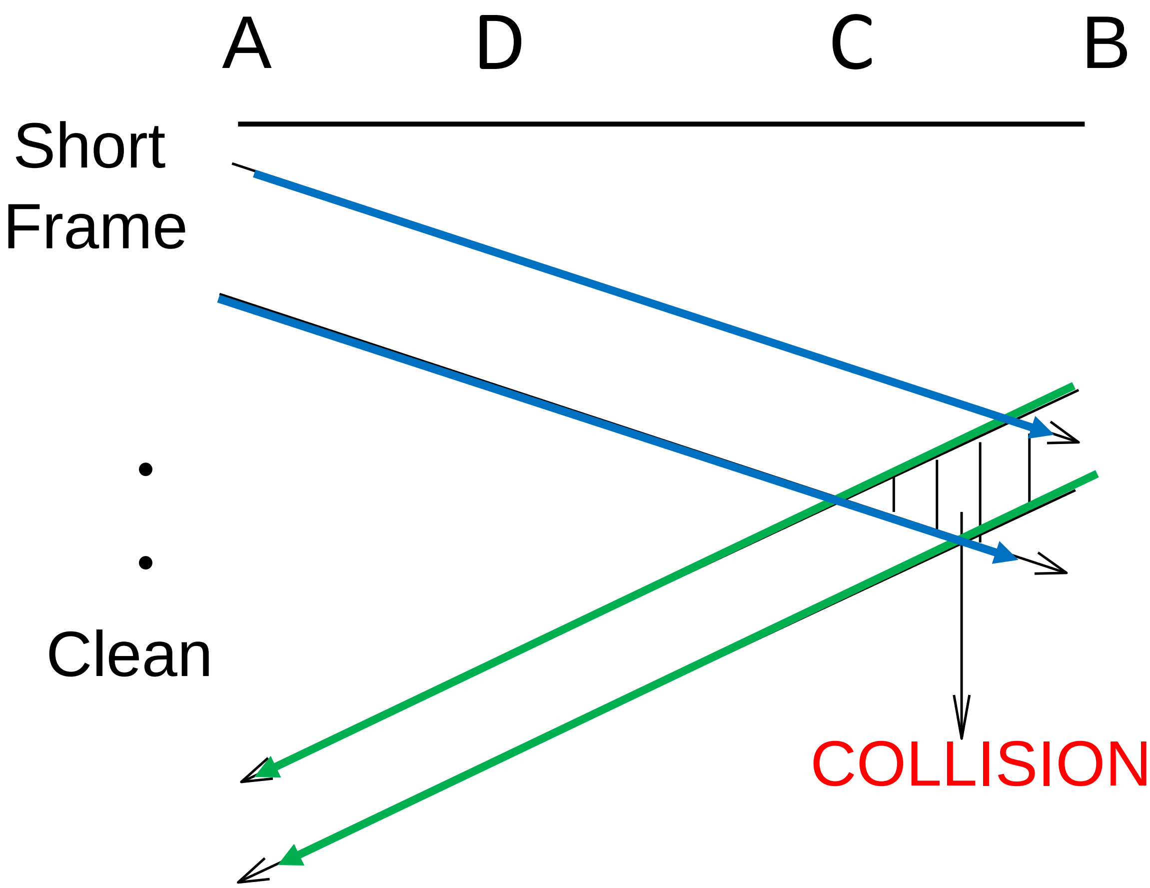
What is a collision?

The notion of a collision is nuanced

- Definition: A station A detects a collision if two or more signals from different senders coexist at A
- Like relativity: Different stations detect collisions at *different* times. Worse, without care some stations may detect collisions and some may not
- Need mechanisms: Want to convert relativity to universality, so that if receiver detects a collision so does sender, so sender can retransmit. One big mechanism is forcing a **minimum packet size**
- Waves not balls: On Ethernet and 802.11 Frames are sent as waves that pass through each other, and **don't collide and rebound** like balls!

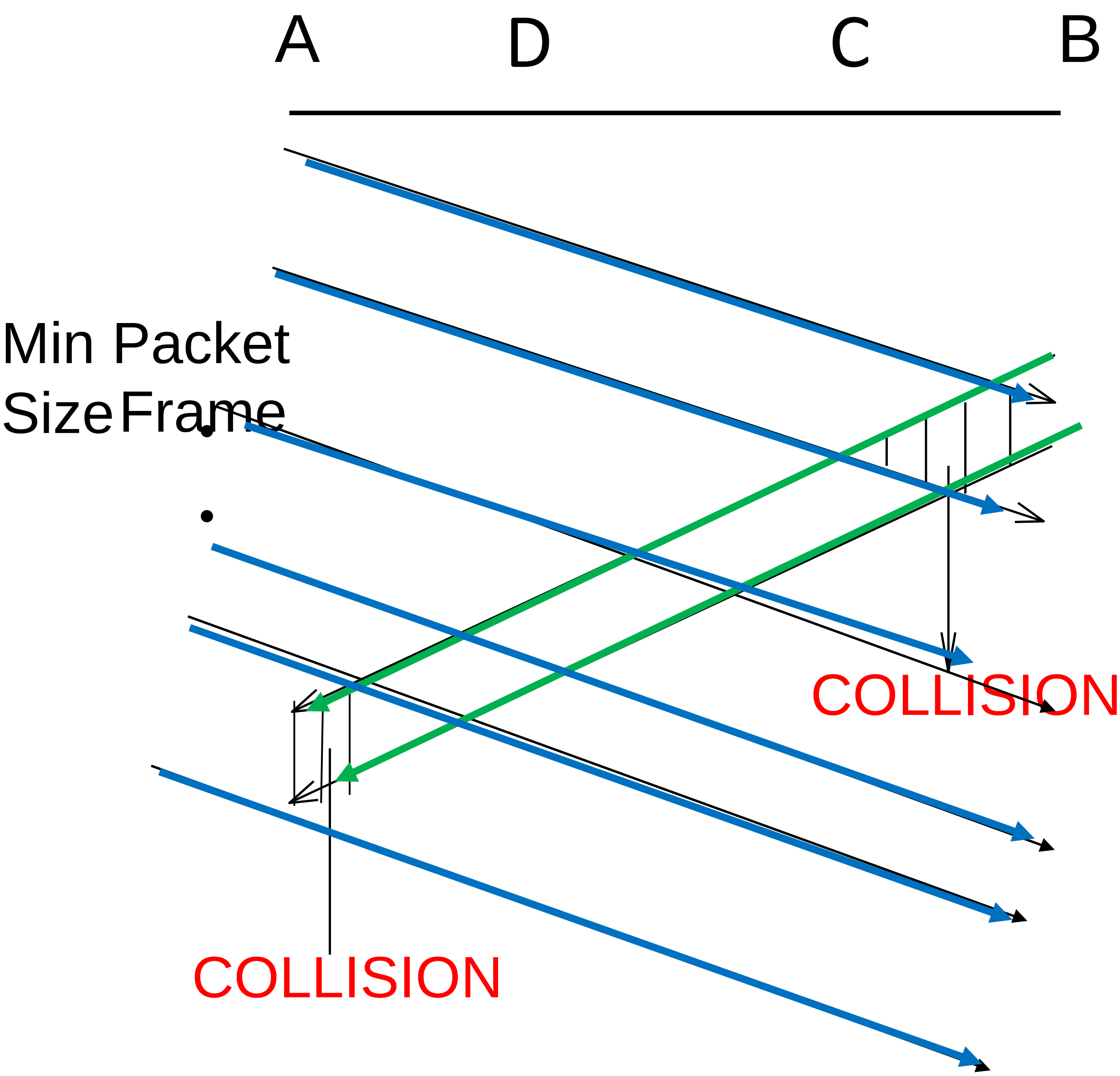


Without Min Packet Size



A transmits to C and B transmits to D, if A sends a short frame *C will detect a collision and A will not.* So A won't retransmit

With Min Packet Size



A transmits to C and B transmits to D, if A sends a "long enough" frame, *C will detect a collision and A will too.* So A will retransmit

Question 1 for breakout: If the transmission speed is 10 Mbit/sec and the max propagation delay is 25.6 usec what should the min Packet size be?

It’s subtler than you might think

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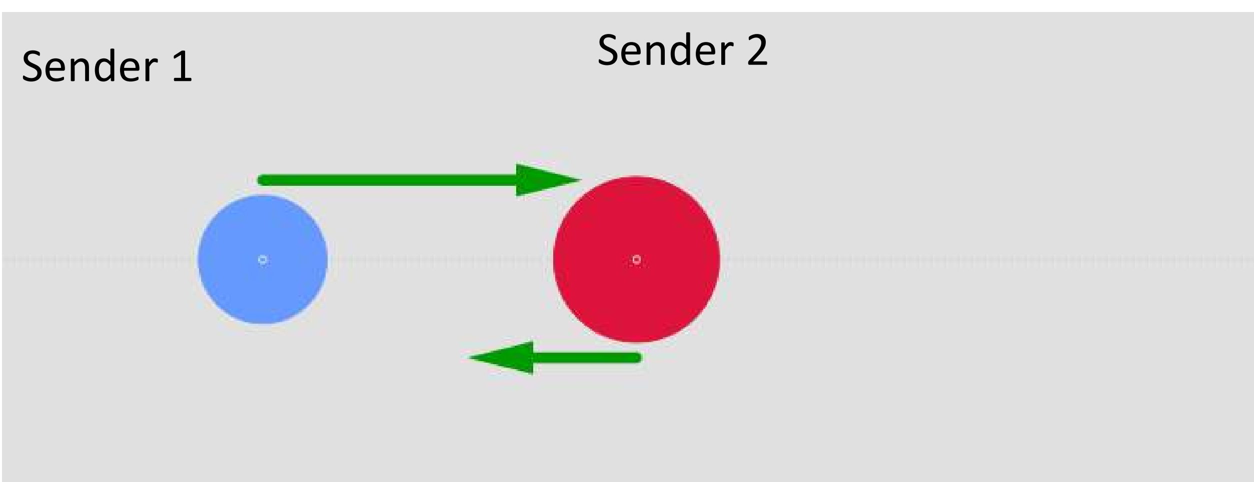
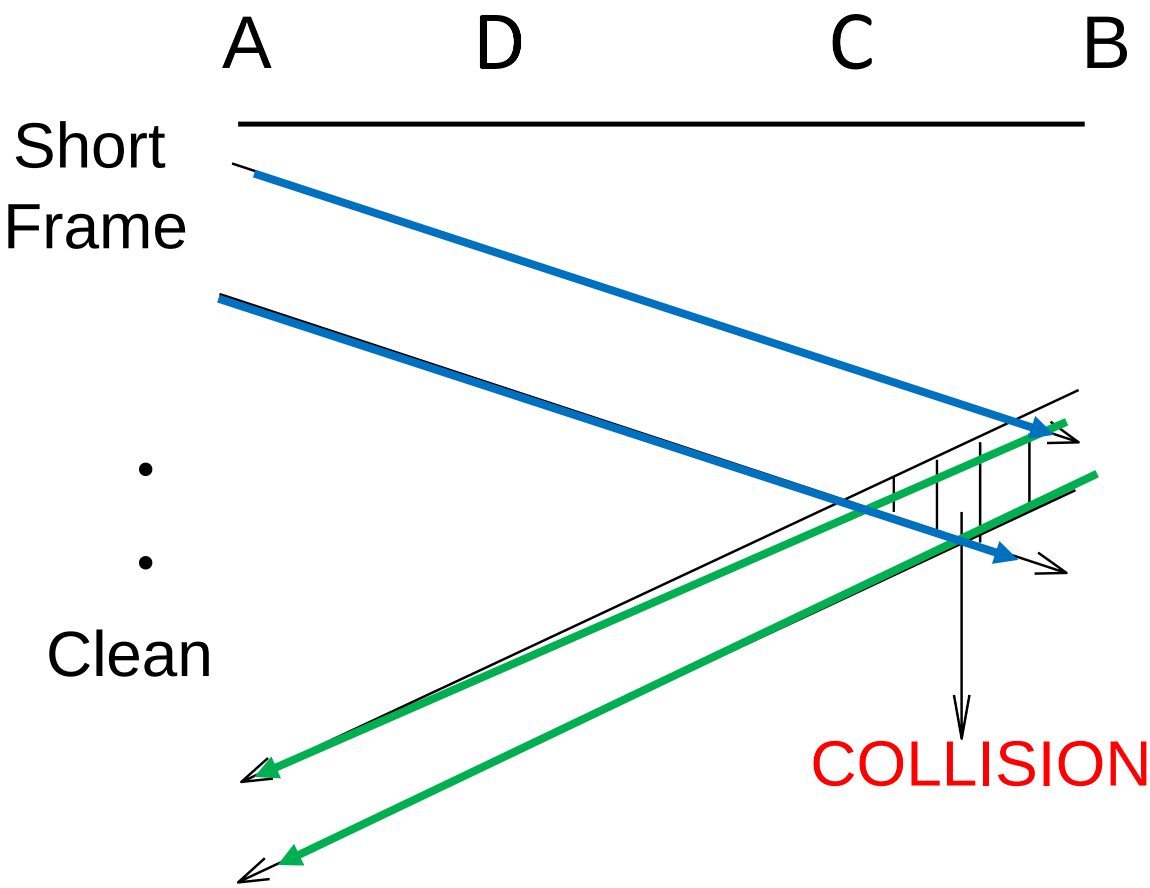
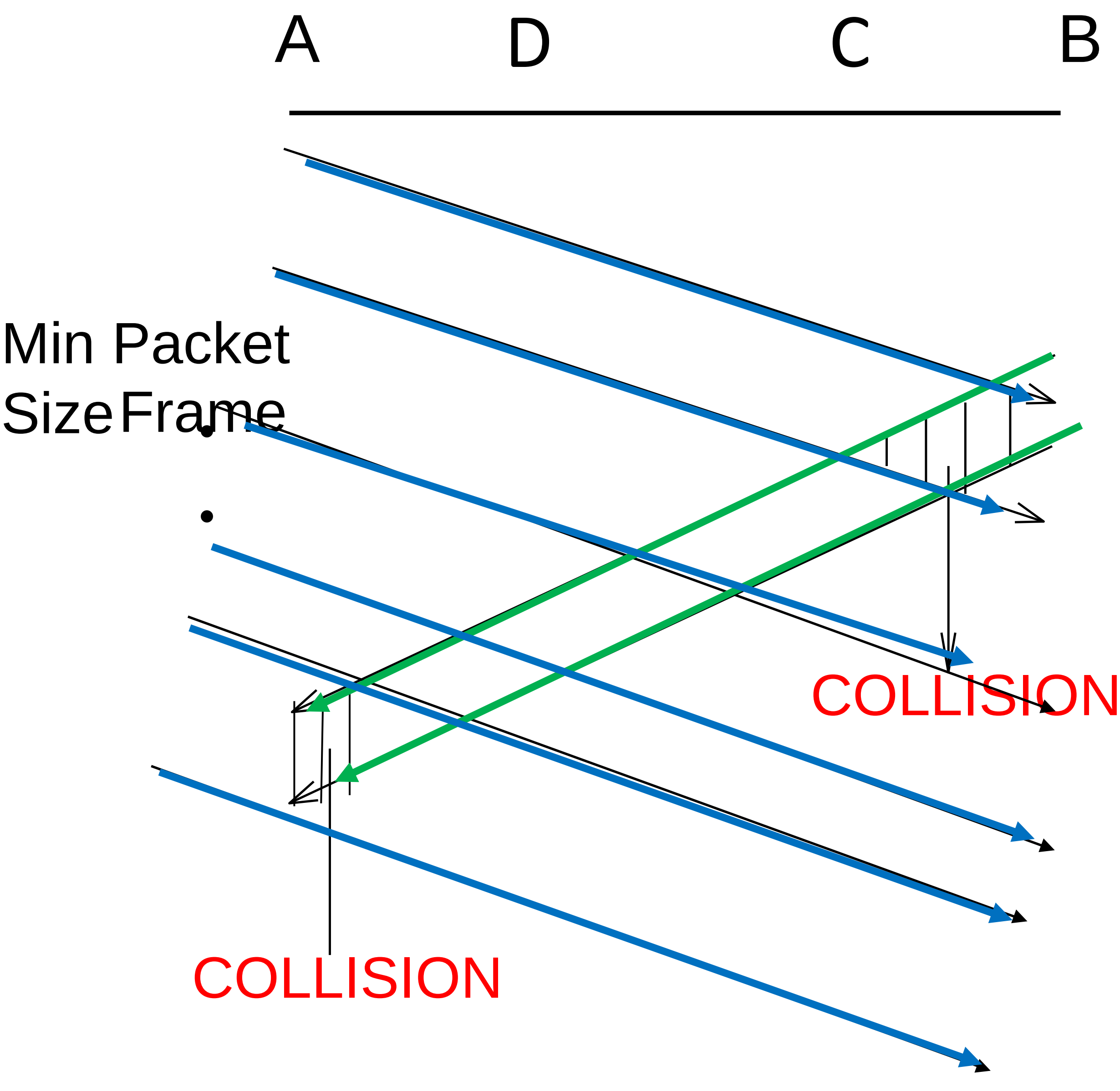


Without Min Packet Size



A transmits to C and B transmits to D, if A sends a short frame *C will detect a collision and A will not.* So A won’t retransmit

With Min Packet Size



A transmits to C and B transmits to D, if A sends a “long enough” frame, *C will detect a collision and A will too.* So A will retransmit

Question: If the transmission speed is 10 Mbit/sec and the max propagation delay is 25.6 usec what should the min Packet size be?

Question 2

- **Case 1:** Consider 2 colliders. One should wait 1 slot and the other 0. Can approximate by tossing a coin.
- **Case 2:** Consider 16 colliders. Ordinary coin-tossing does not work. Pick random numbers from 1 to 16.
- But stations don't know in advance which Case (or others) will happen!
- Can you think of a clever way to work around this. Hint: think of how much you wait after a collision as a dynamic variable not a static one..

Answers

- **Question 1**: The **min packet size** is the "pipe"size. Round trip delay * Transmission Speed = 10 Mbs * 51,2 = 512 bits = 64 bytes.
- **Question 2**: Ethernet does **Binary exponential backoff**. After attempt I, each station randomly picks a random number of of slots between 0 and $2^I - 1$. A slot is 51.2 usec. So after one collision pick 0 or 1 slot, after 2: 0, 1, 2., or 3 slots, After 3 collisions: 0., 1., 2, 3, 4, 5, 6, or 7 slots
- Both ideas are now classical

ETHERNET

Three main mechanisms: :

- Carrier sense and deference: No point transmitting when someone else is speaking
- Collision Detection: Stop frame (< 1500 bytes) when before 64 bytes you detect a collision.
- Exponential Backoff: Collisions very frequent, so must retransmit. Random backoff avoids synchronized collisions. Dynamically adjust to number of colliders.

ETHERNET CONTINUED

Smaller mechanism to make main ideas work:

- Slot time: = 2T, T is 1-way propagation delay limited to 51.2 usec = 64 bit times at 10 Mbps: maximum delay to detect a collision.
- Minimum packet size: 64 bytes to avoid finishing transmission before collision is detected. Add pad if needed.
- Jam: transmit small number of bits after you detect a collision to ensure that other transmitters also detect collision.
- Collision detection: One way is to use Manchester with average DC level per bit. Collision detection by detecting increased voltage level. Better ways today.

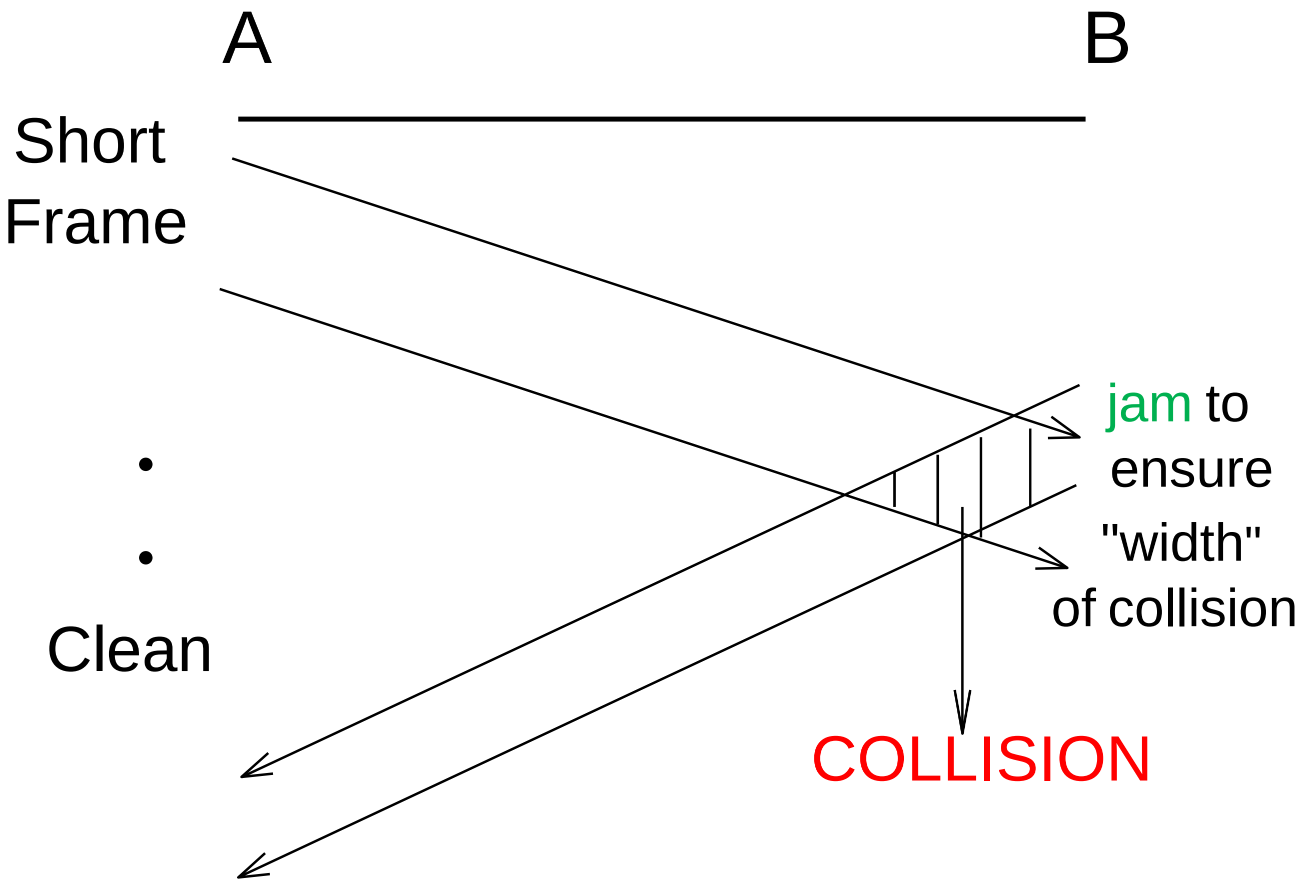
Ethernet Header

01010111 preamble	Dest (6)	Source (6)	Length (2)	Data	Pad	CRC

LLC sublayer

Total Frame length
64<=L<=1500

Why Jam?


A
B
Short
Frame
Clean
jam to
ensure
"width"
of collision
COLLISION

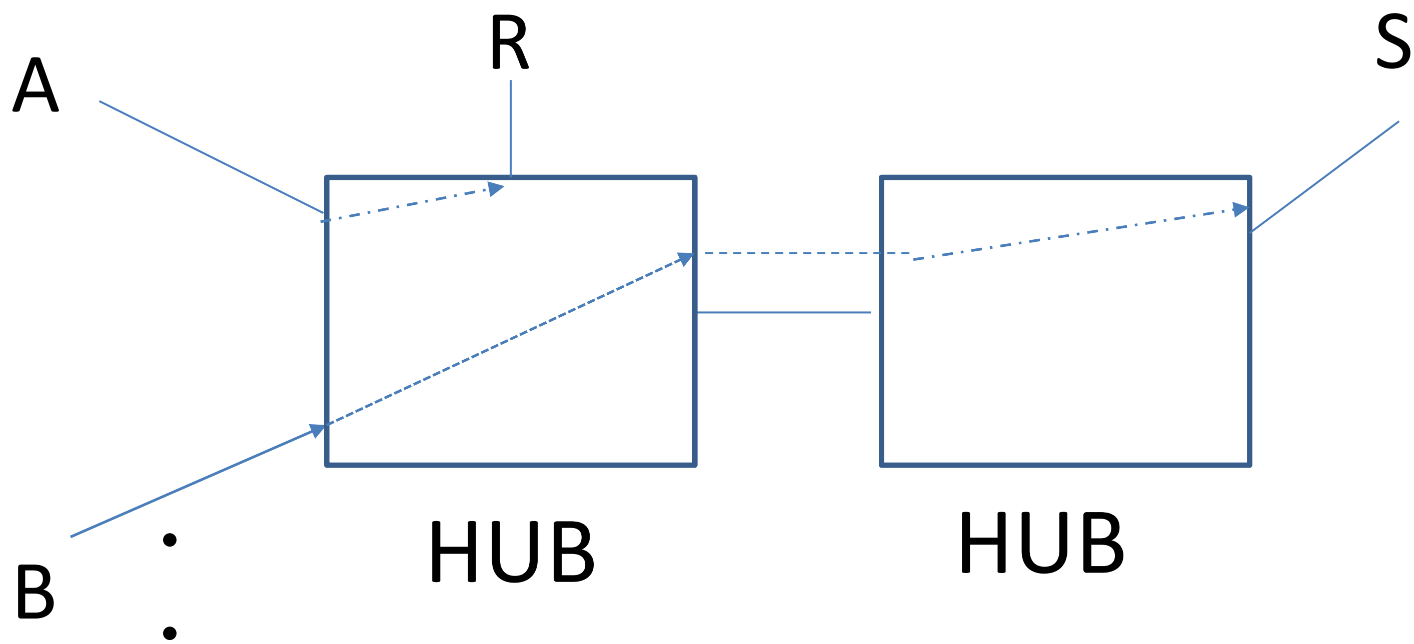
Ethernet Implementation Details

- Limited distance (2.5 km). 500 m wires. 4 repeaters.
- Thin wire, Thick wire
- Repeaters/Hubs: important device, reads in a bit and writes out a bit on other side, boosting signal strength.
- Physical Topology is a star or tree.

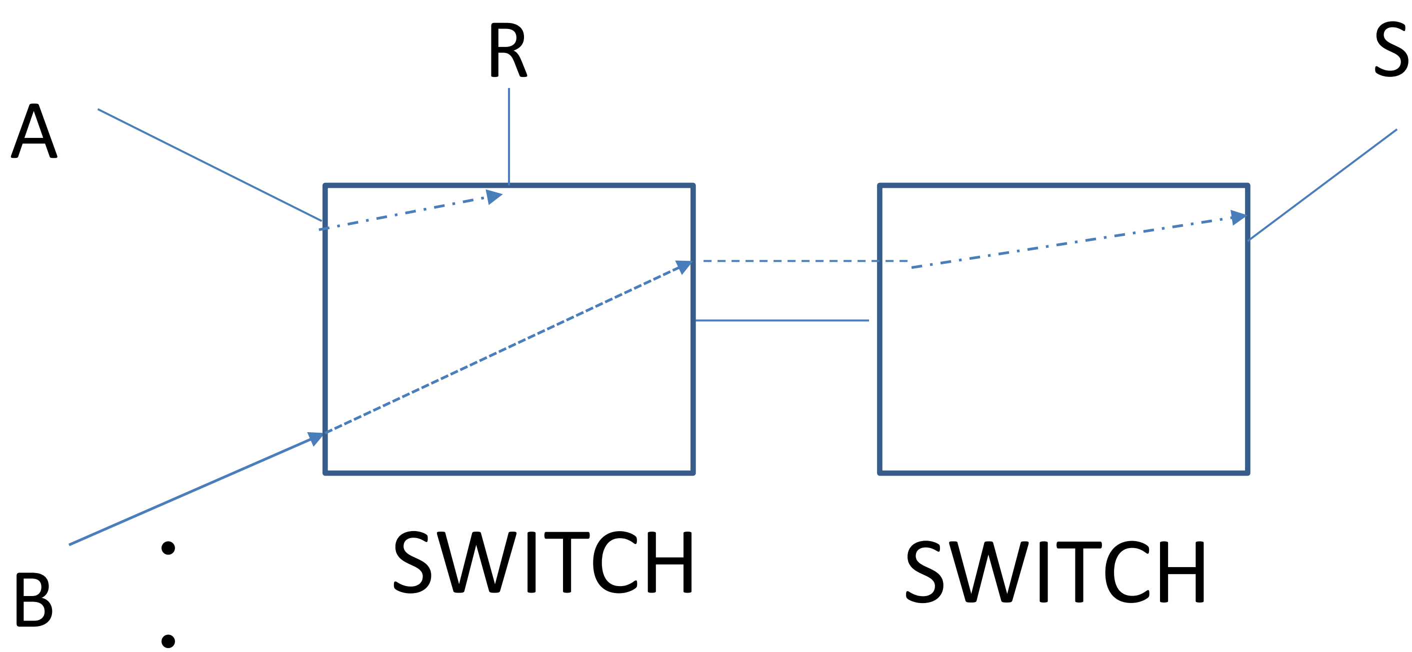
Cost of statistical muxing in Ethernet

- If distance goes up by a factor of 10 or speed, then what happens to min packet size? Why is it wasteful?
- 100 Mbps Ethernet proposal has only 200 m extent.
- Gigabit Ethernet? Span too small (2 m? What kind of LAN is that?) Instead, replace shared wire with point to point links and hubs with switches.
- The cost of statistical multiplexing is why Ethernet is limited to Local Area Networks!

From CSMA/CD to switching



If A talks to R at same time as B talks to S there is a collision. True for 10 and 100 M Ethernet.



A can talk to R at same time as B talks to S with no collision. Switch buffers and allows parallel connections. True for Gigabit Ethernet

So you are telling me that

- Gigabit Ethernet no longer uses CSMA/CD
- So why do we do study the stuff?
- Because similar Media Access protocols are used especially in wireless and 802.11 as we now describe

From a textbook by Richard Stallings

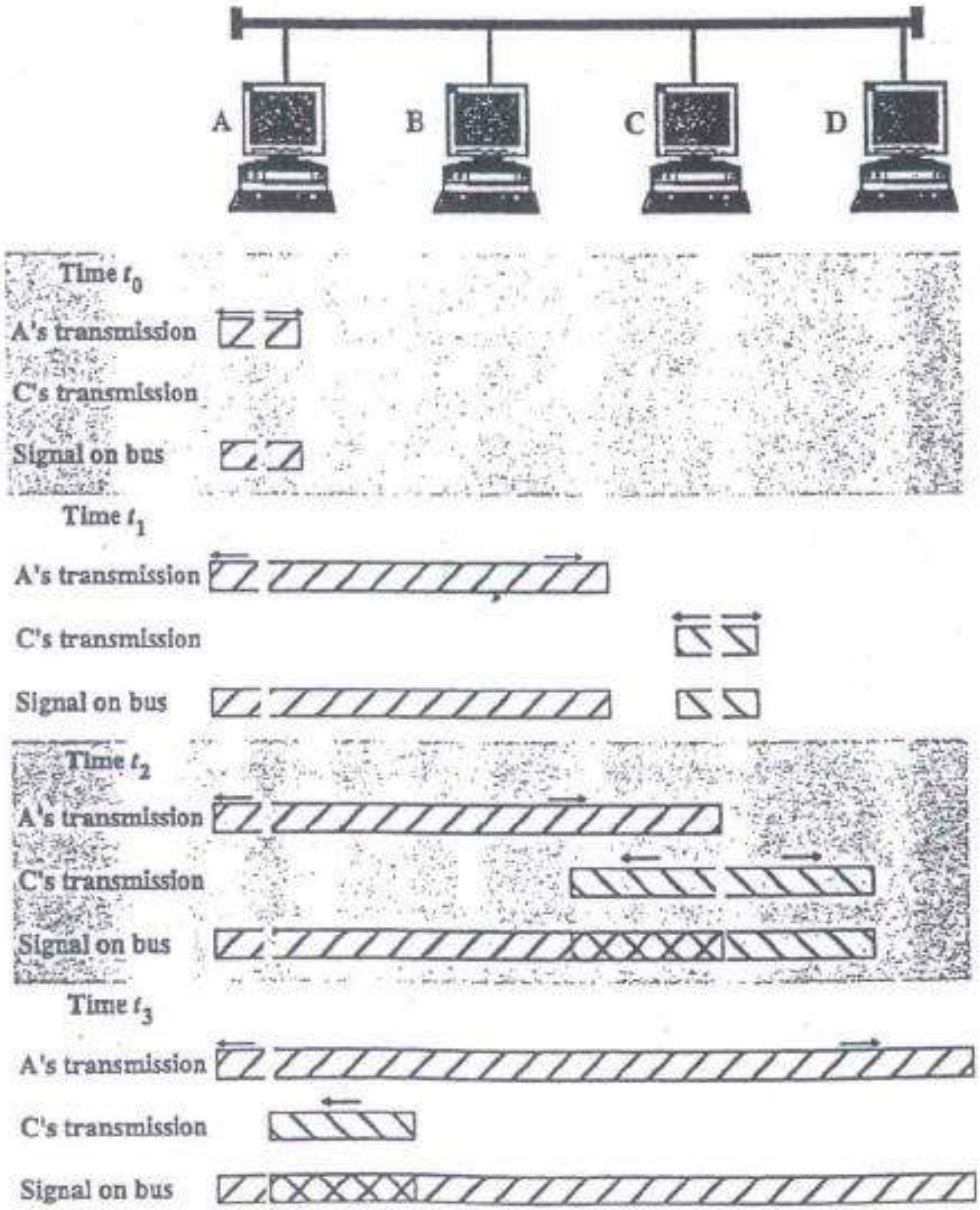
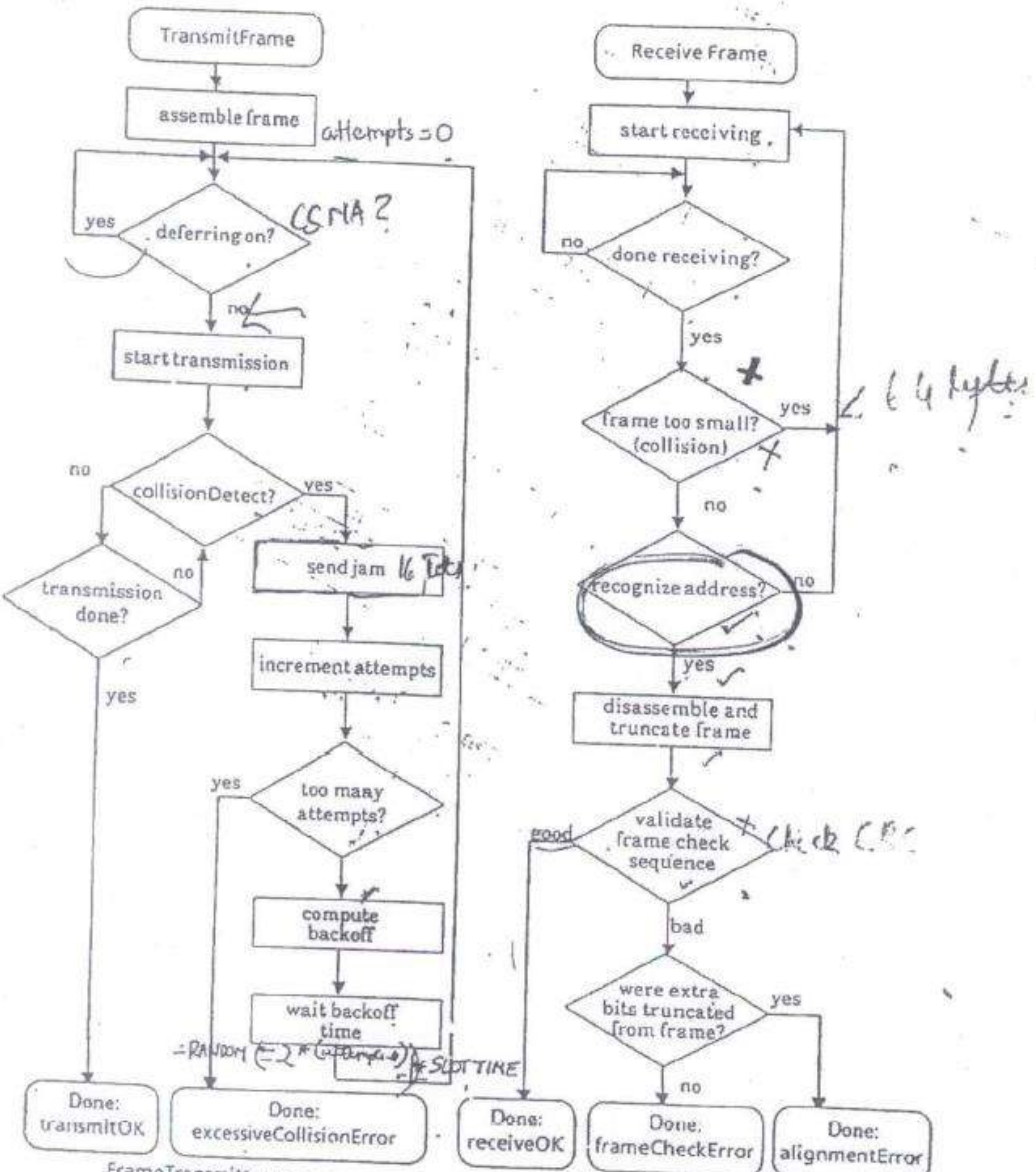


Figure 14.1 CSMA/CD Operation

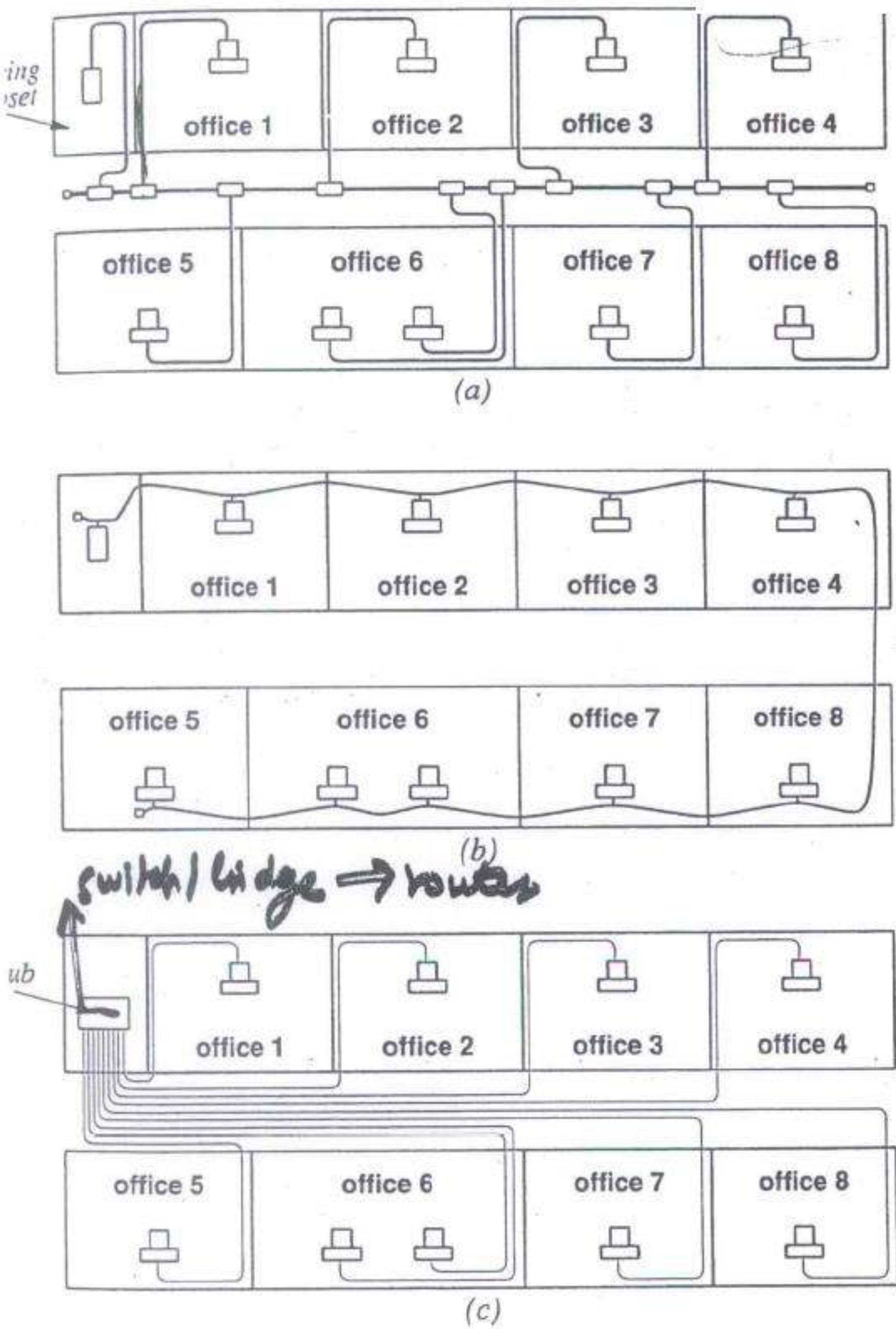
FROM EARLIEST DEC-XEROX-INTEL ETHERNET SPEC



FrameTransmitter process
(Invoking Data Link TransmitFrame operation)

FrameReceiver process
(Invoking Data Link ReceiveFrame operation)

HOW ETHERNET CAN BE WIRED (From STALLINGS)



10 base 5
THICKNET

ORIGINAL COAX WIRING

TWISTED PAIR, NO HUB

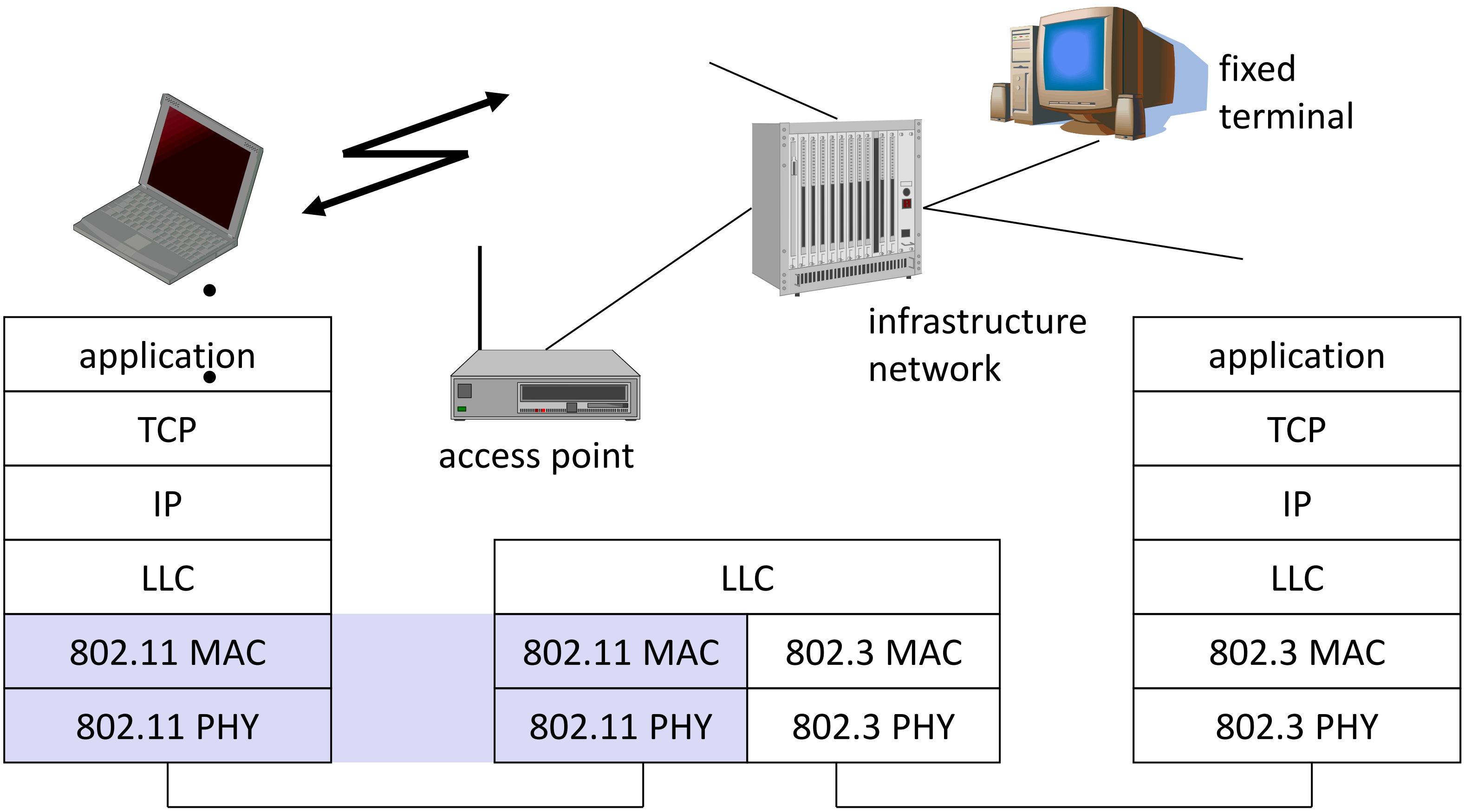
TWISTED PAIR, WITH A HUB

802.11

George Varghese

(slides from A. Snoeren, UCSD)

802.11 Layering



WLAN: IEEE 802.11b

Data rate
- 1, 2, 5.5, 11 Mbit/s
- User data rate max. approx. 6 Mbit/s

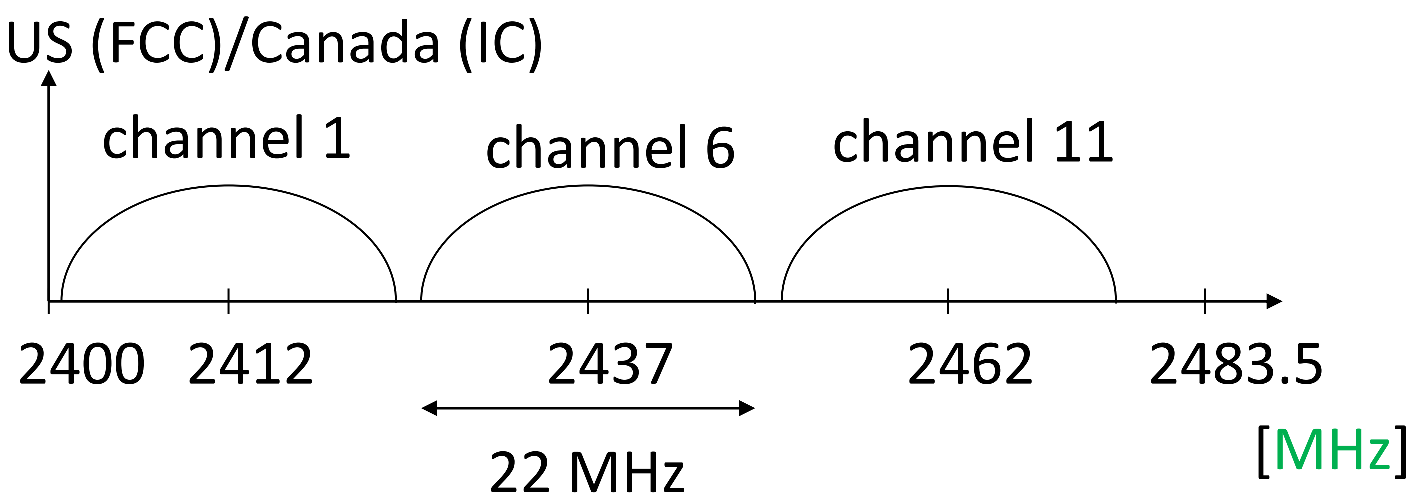
Transmission range
- 300m outdoor, 30m indoor
- Max. data rate ~10m indoor

Frequency
- Free 2.4 GHz ISM-band

Physical Channels

12 channels available for use in the US

- Each channel is 22 MHz wide
- Only 3 orthogonal channels
- Using any others causes interference



Carrier Sense Multiple Access

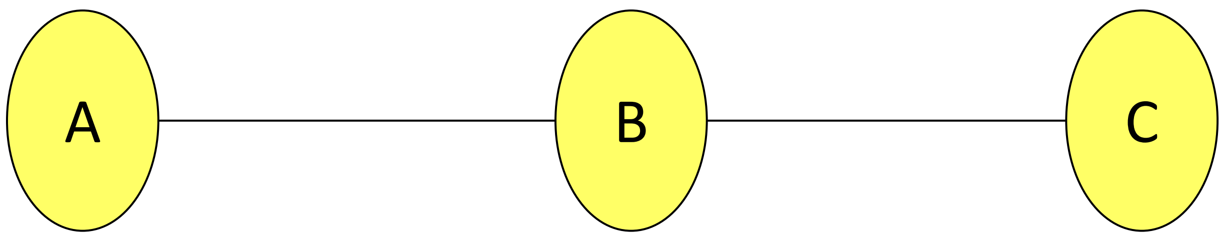
CSMA: listen before transmit:

If channel sensed idle: transmit entire pkt

If channel sensed busy, defer transmission

- Persistent CSMA: retry immediately with probability *p* when channel becomes idle (may cause instability)
- Non-persistent CSMA: retry after random interval

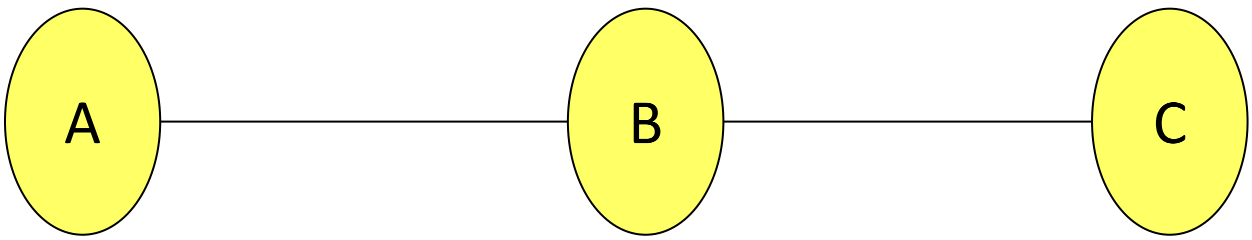
Hidden Terminal Problem



B can communicate with both A and C
A and C cannot hear each other – not a single shared channel
Problem
- When A transmits to B, C cannot detect the transmission using the carrier sense mechanism
- If C transmits, collision will occur at node B

Solution:
- Hidden sender C needs to *defer*

RTS/CTS (MACA)



When A wants to send a packet to B, A first sends a Request-to-Send (RTS) to B

On receiving RTS, B responds by sending Clear-to-Send (CTS), provided that A is able to receive the packet

When C overhears a CTS, it keeps quiet for the duration of the transfer

- Transfer duration is included in both RTS and CTS

Backoff Interval

Problem: With many contending nodes, RTS packets will frequently collide

Solution: When transmitting a packet, choose a backoff interval in the range [0, CW]

- CW is contention window

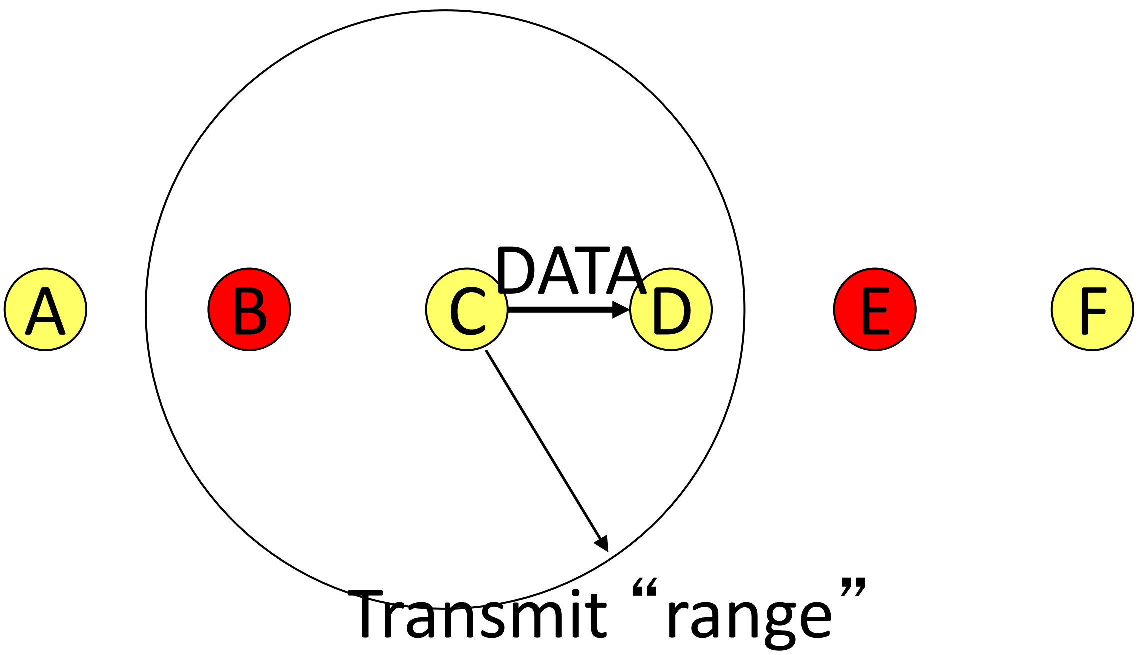
Wait the length of the interval when medium is idle

- Count-down is suspended if medium becomes busy
- Transmit when backoff interval reaches 0

Need to adjust CW as contention varies

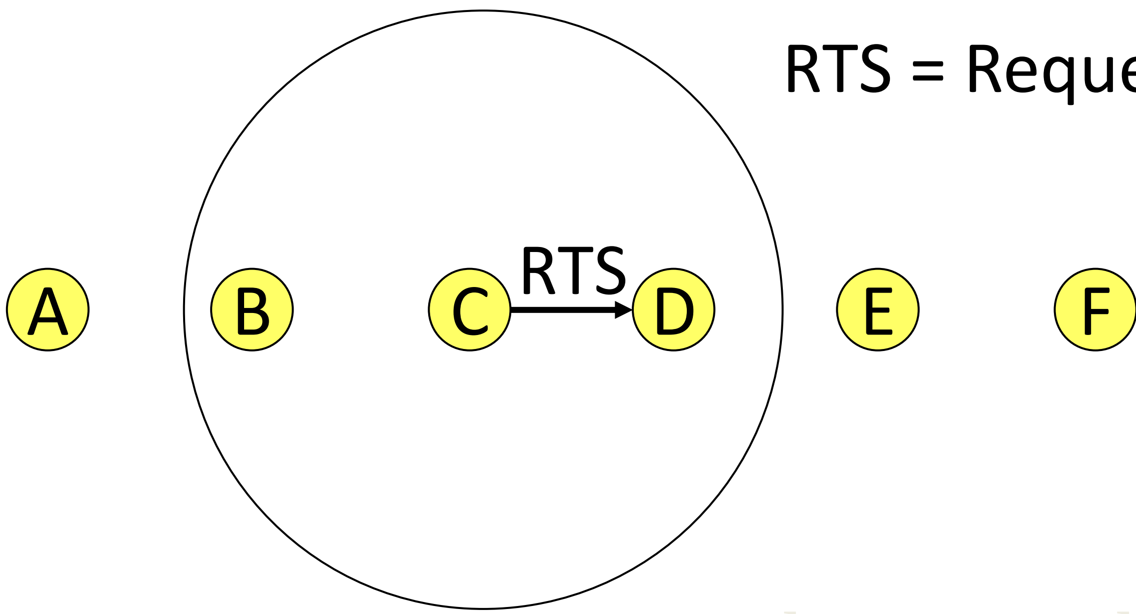
- Similar in spirit to Ethernet backoff

Non-symmetric ranges



802.11 COLLISION AVOIDANCE EXAMPLE

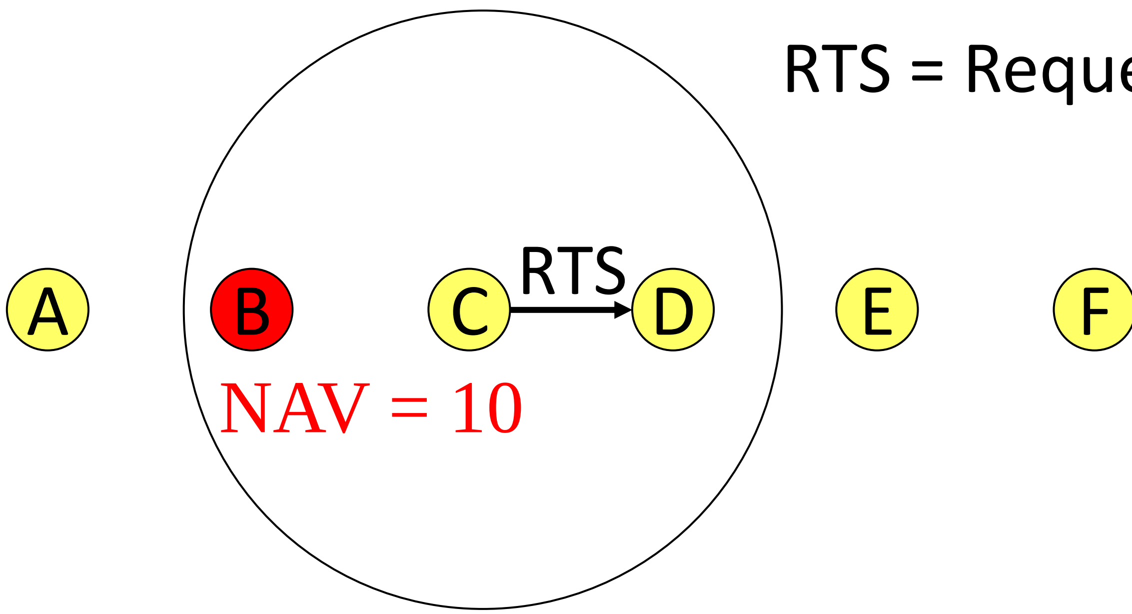
RTS = Request-to-Send



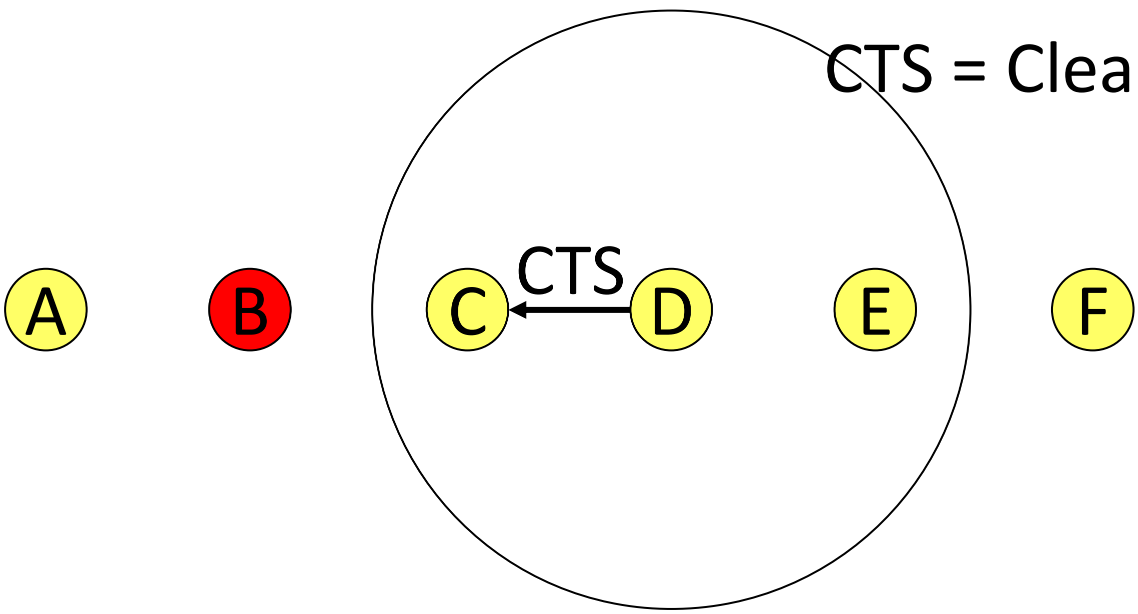
Pretending a circular range

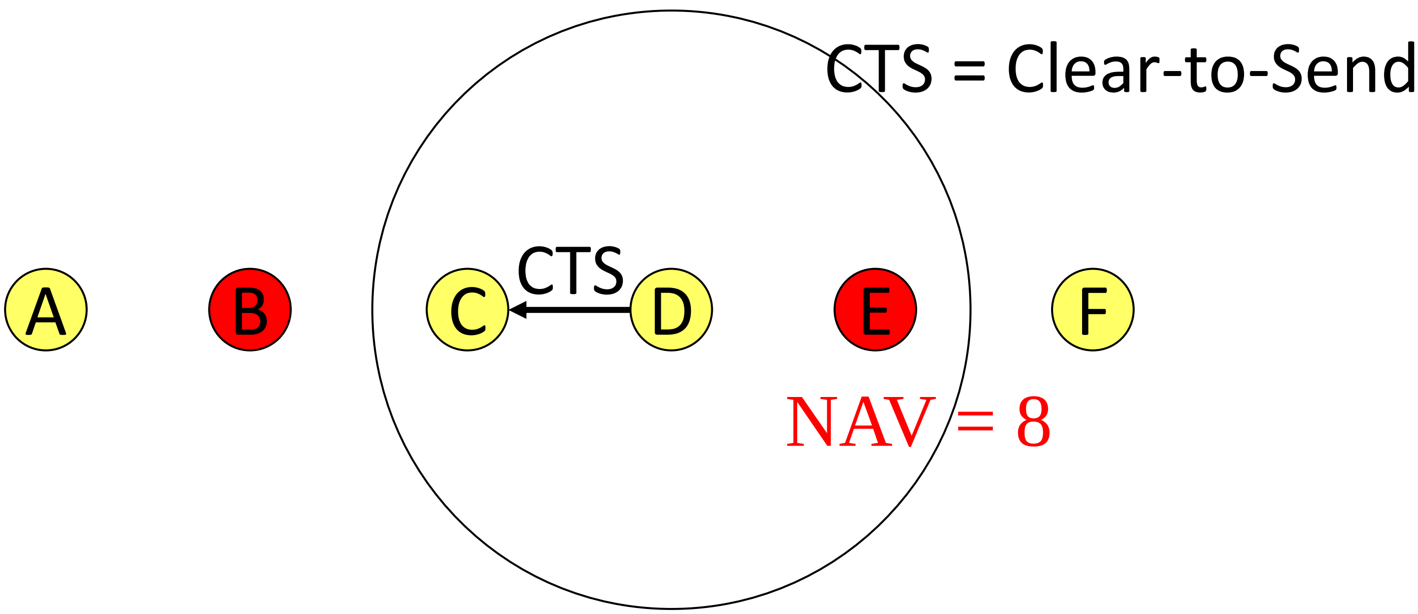
NAV = remaining duration to keep quiet

RTS = Request-to-Send

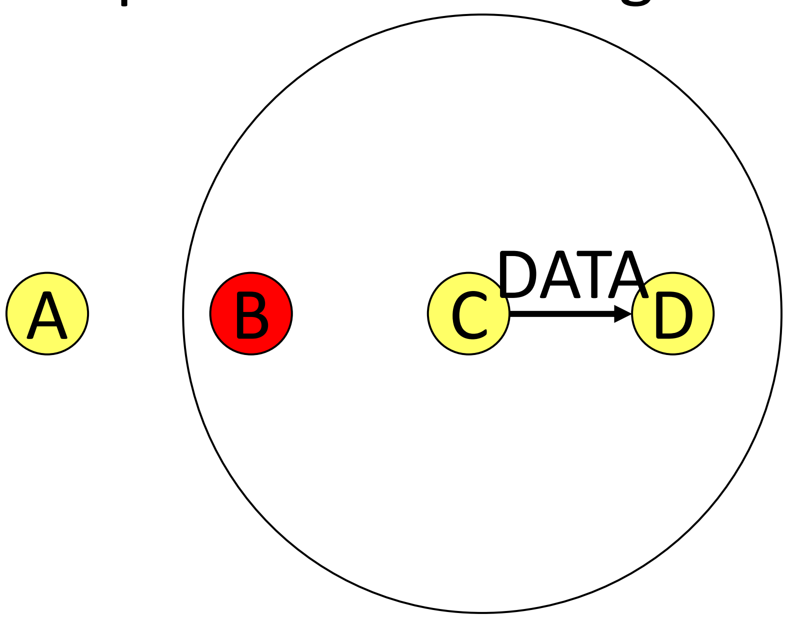


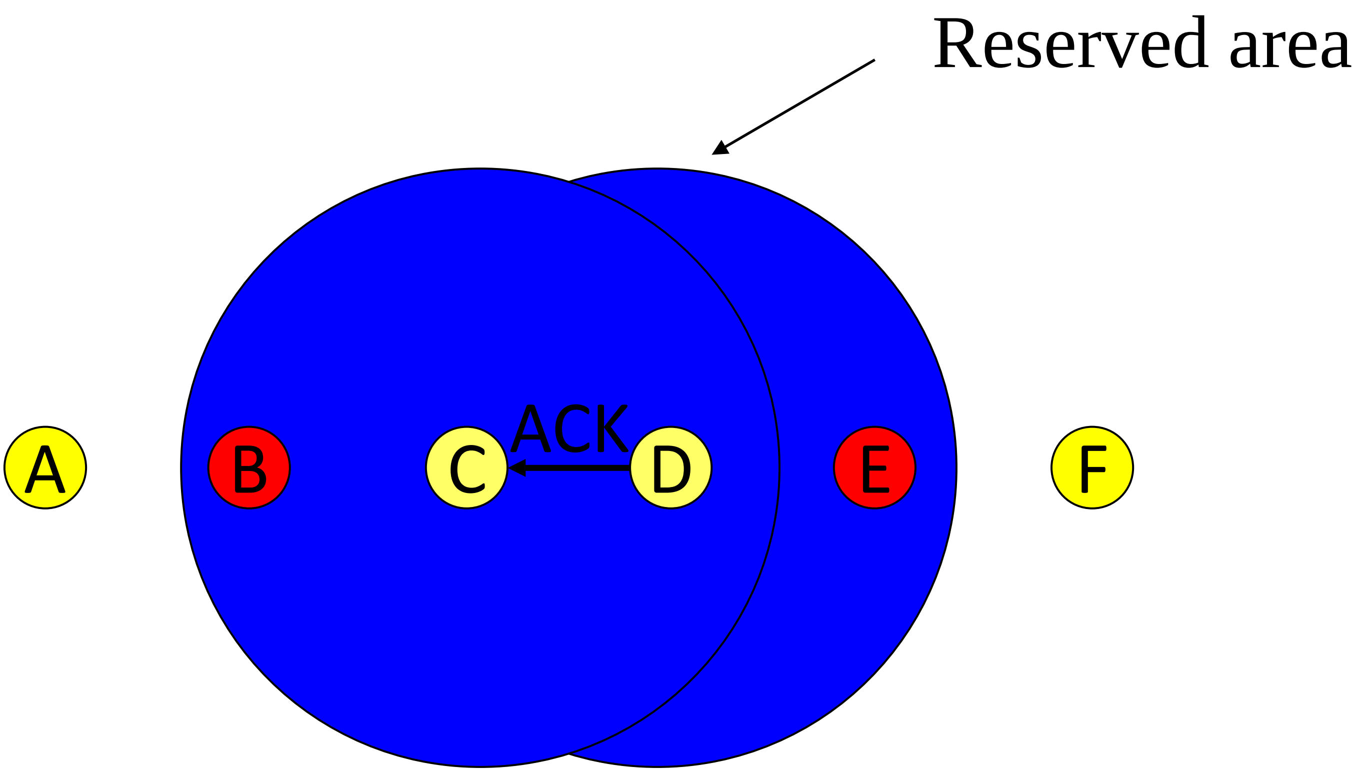
CTS = Clear-to-Send




CTS = Clear-to-Send
CTS
A
B
C
D
E
F
NAV = 8

- DATA packet follows CTS. Successful data reception acknowledged using ACK.




Reserved area
ACK
A
B
C
D
E
F

Concepts/Conclusions

- Statistical Multiplexing is a big idea
- Importance of Pipe-size or bandwidth delay product in determining efficiency.
- Logical versus physical topology. 10 M Ethernet is logically a bus but physically a star
- Ethernet ideas mostly gone in Gigabit Ethernet but some ideas like CSMA live on in 802.11. Also,10-100 Mbps Ethernet is still used