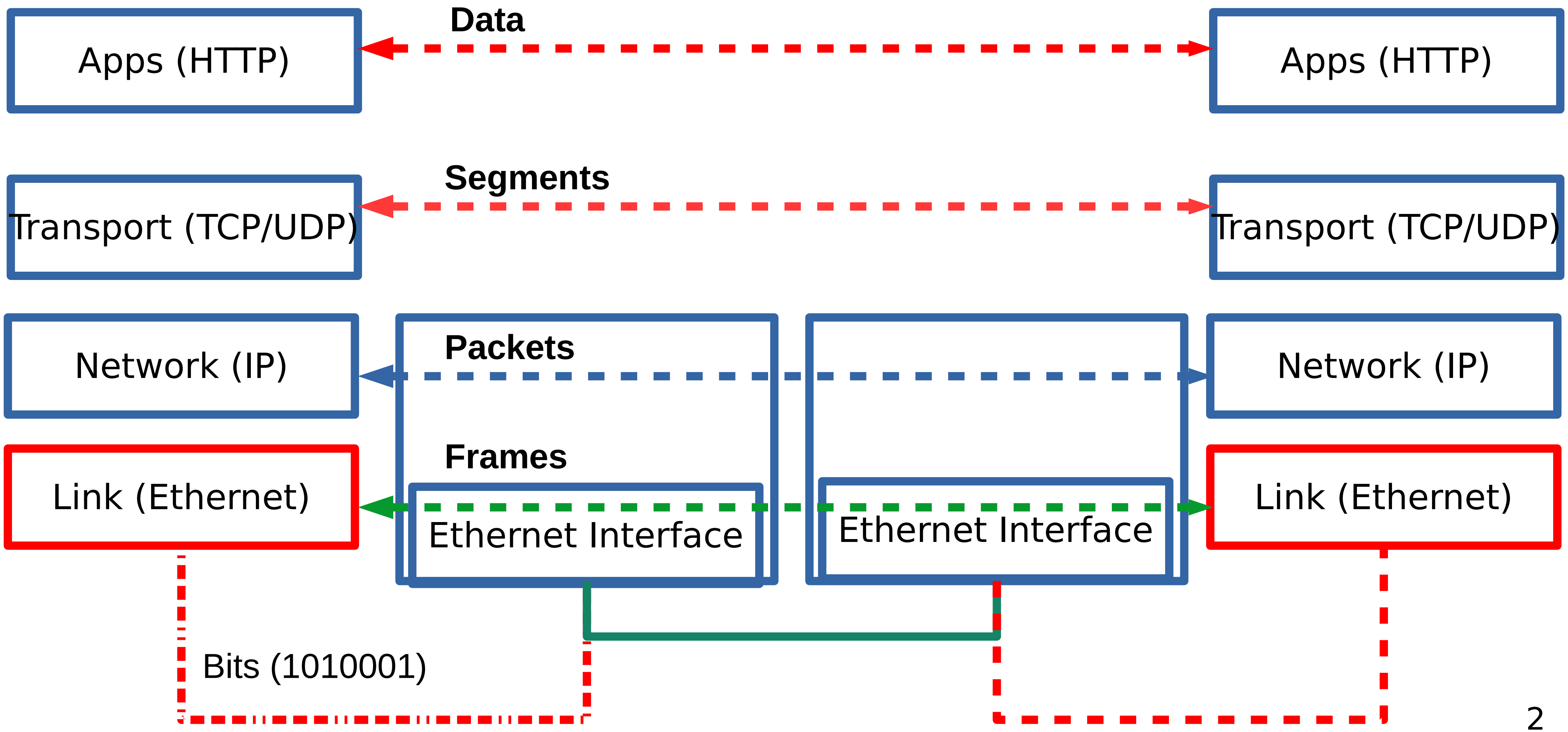
CSC4200/5200 – COMPUTER NETWORKING

PHYSICAL AND LINK LAYER RECAP

Instructor: Susmit Shannigrahi
sshannigrahi@tntech.edu

Recap – All this for a cat picture!!



Apps (HTTP)

Data

Apps (HTTP)

Transport (TCP/UDP)

Segments

Transport (TCP/UDP)

Network (IP)

Packets

Network (IP)

Link (Ethernet)

Frames

Ethernet Interface

Ethernet Interface

Link (Ethernet)

Bits (1010001)

Links, Nodes, Network, Internet

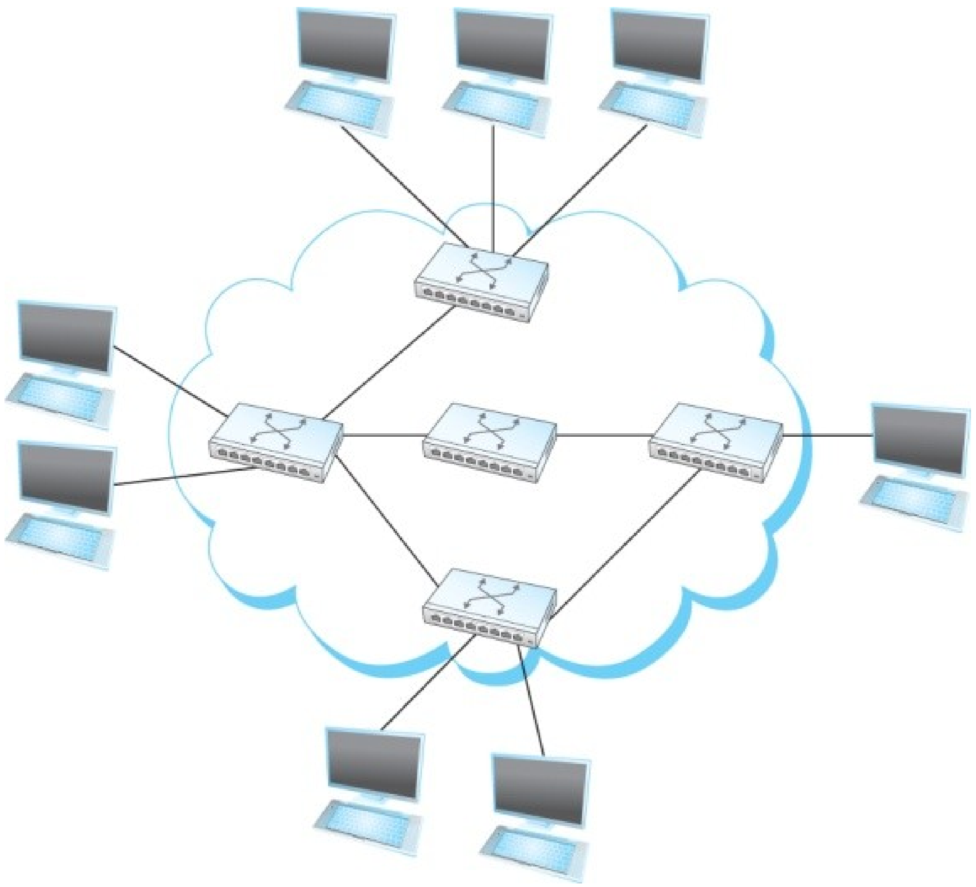
- You can view the network as a graph

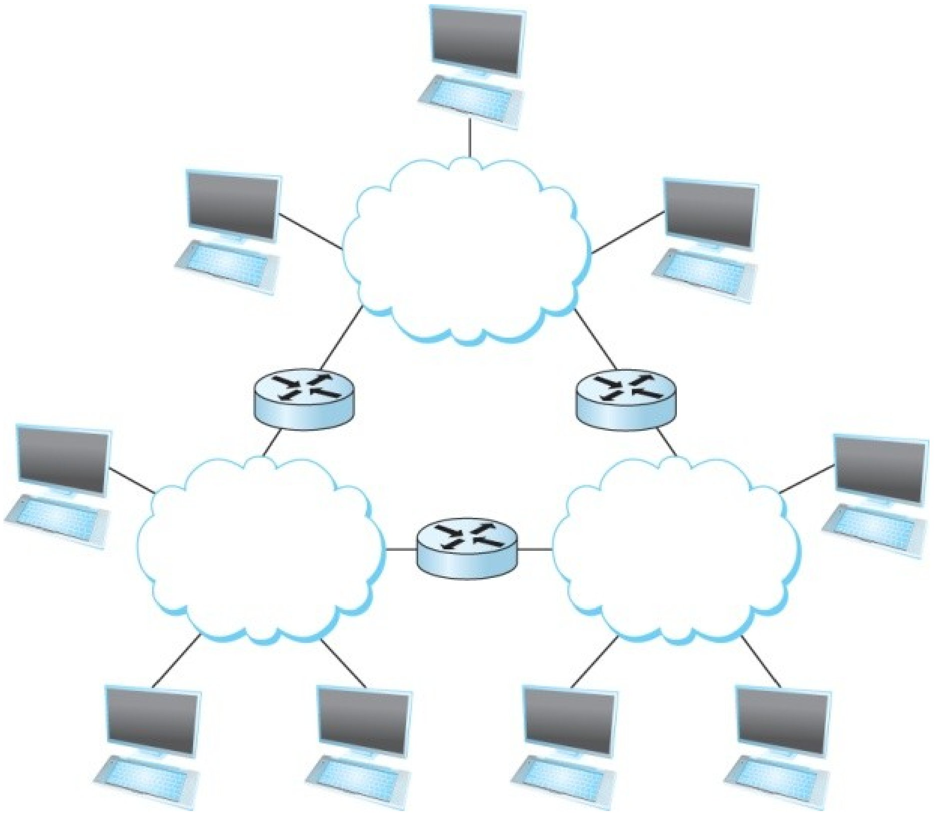
- Each device (a phone, a computer) is a node

- Each connection is a link
  - Wires = real links
  - Bluetooth, Radio, Infrared = virtual links

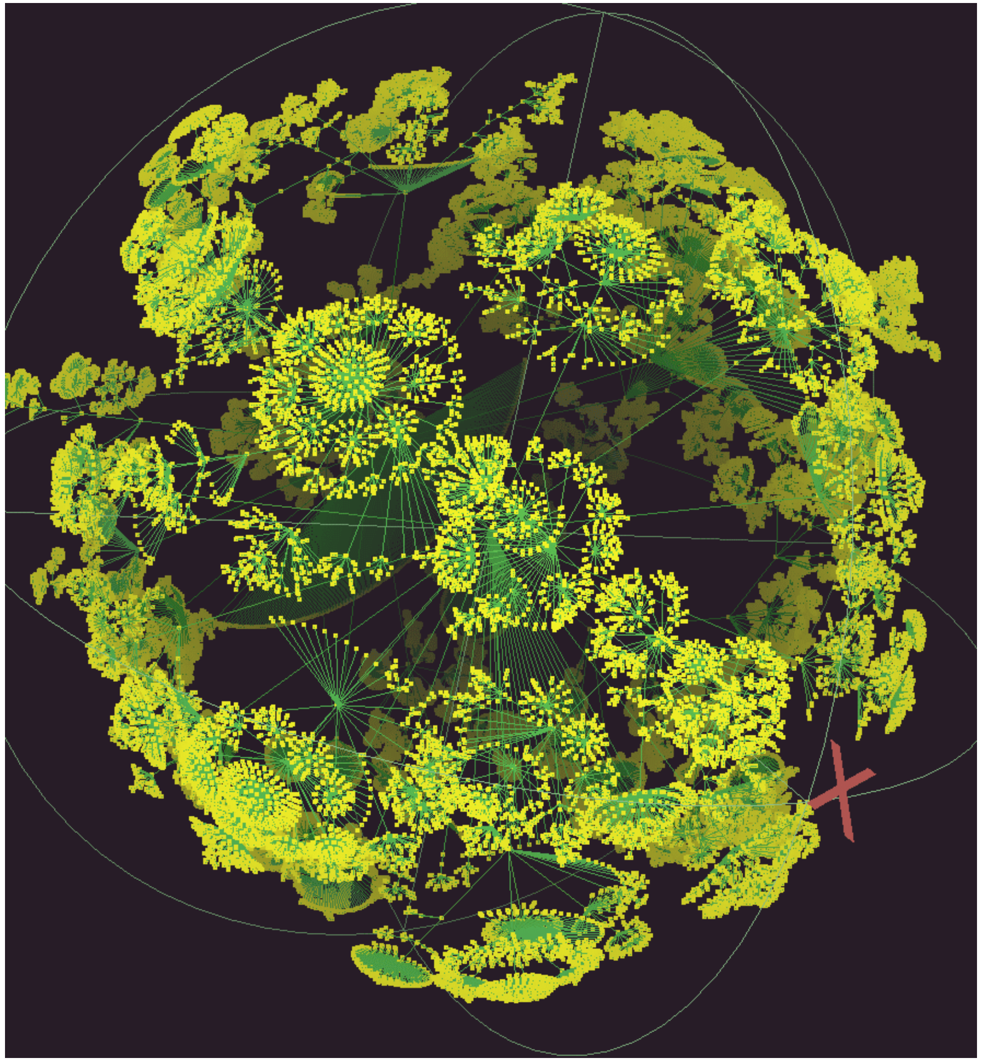
- Nodes + links = a network
  - Many connected networks = Internet

A Network and the Internet

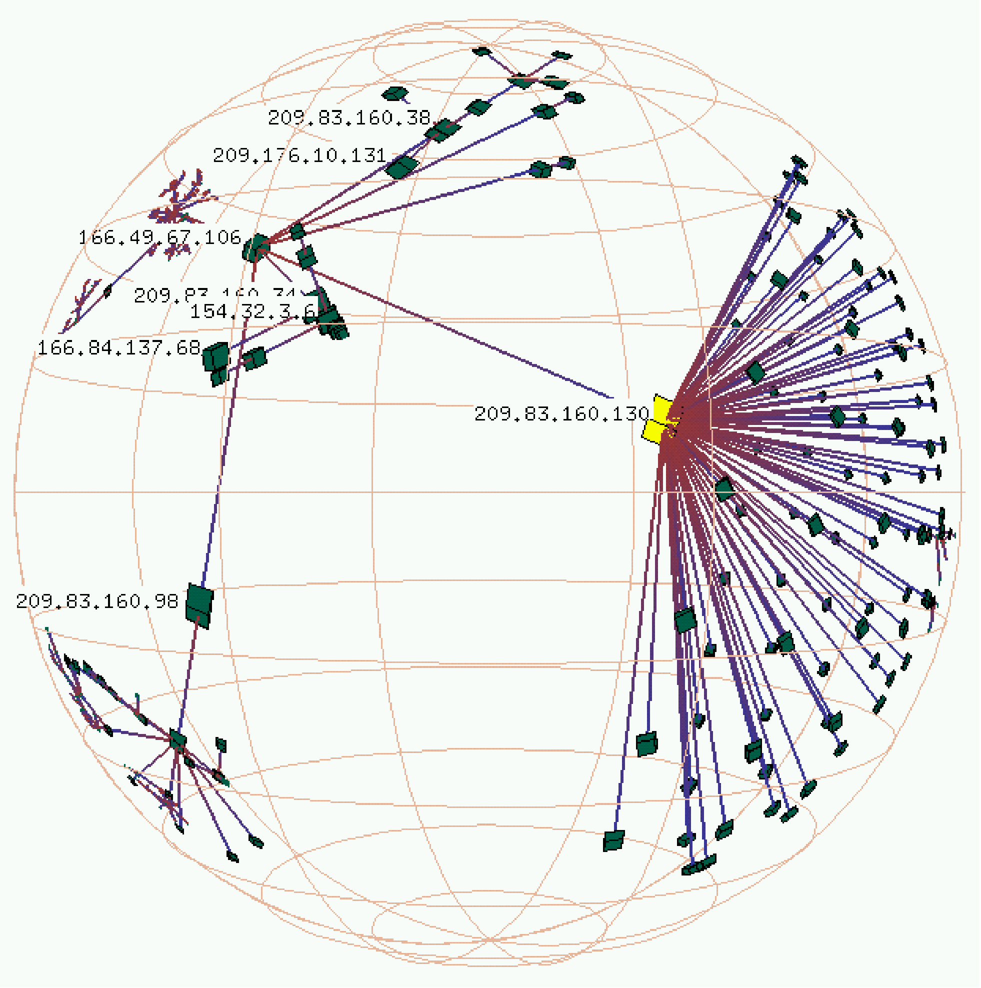




Links, Nodes, Network, Internet

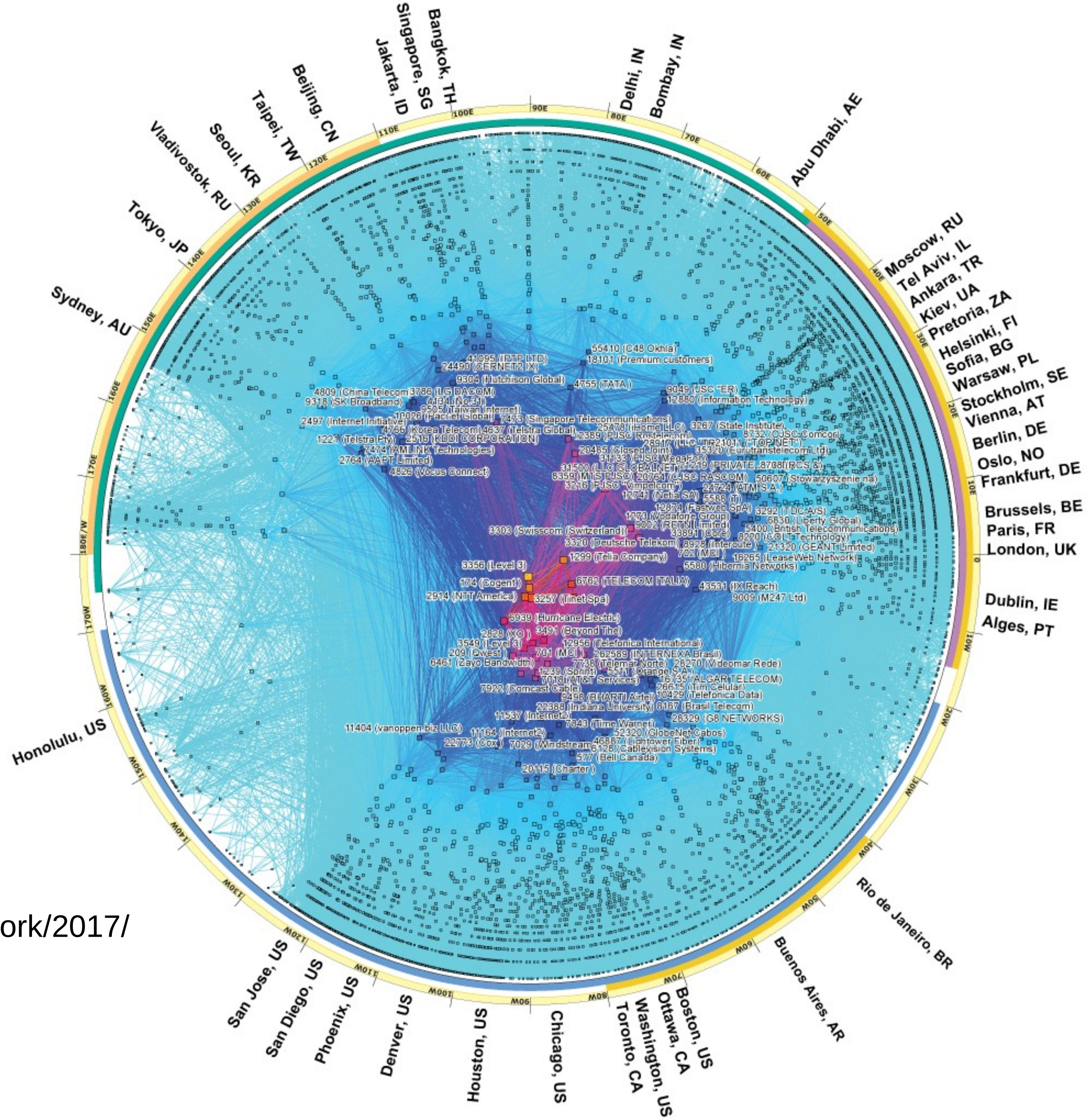


Not Actual data



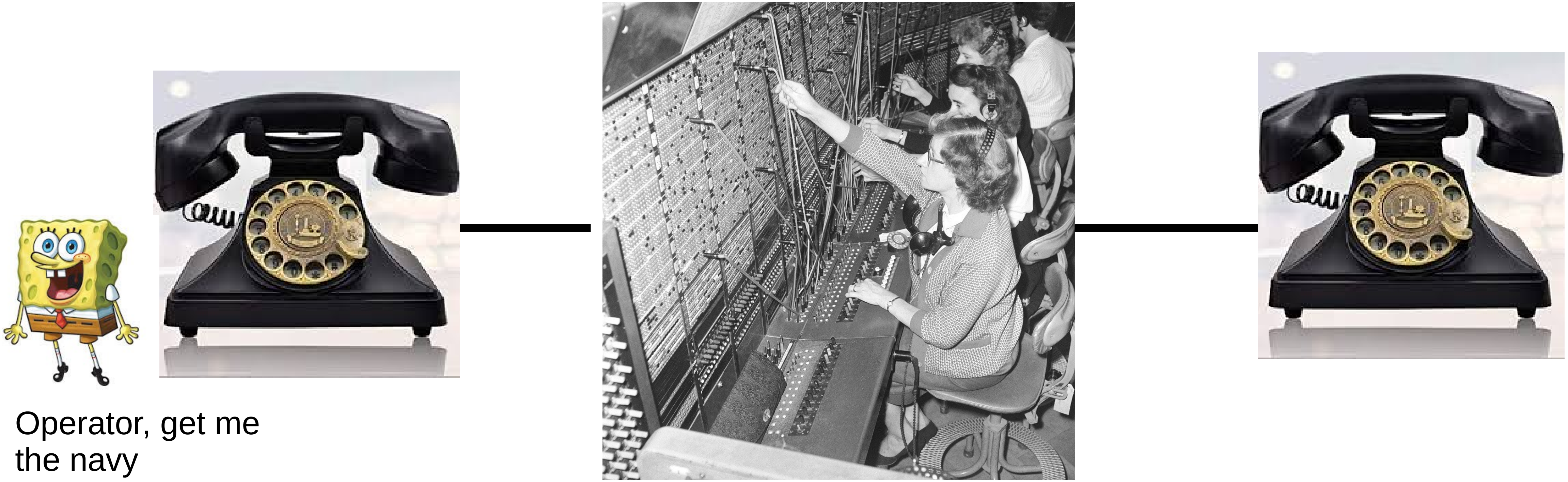
https://www.caida.org/tools/visualization/walrus/gallery1/lhr-old.png

Links, Nodes, Network, Interne



https://www.caida.org/research/topology/as_core_network/2017/

Circuit Switching – Old telephone networks

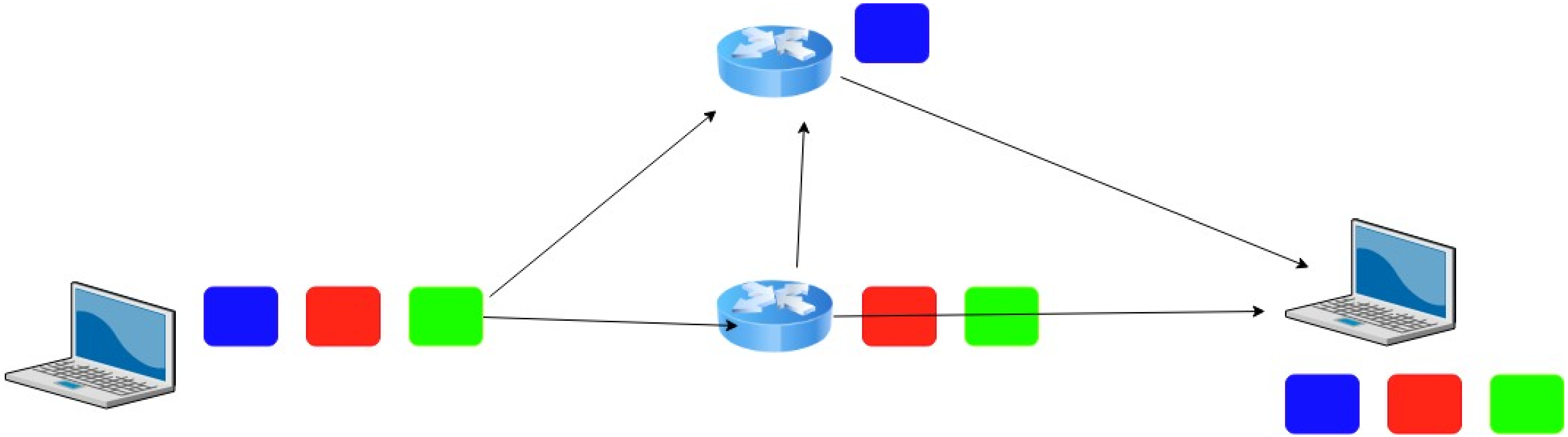


Operator, get me the navy

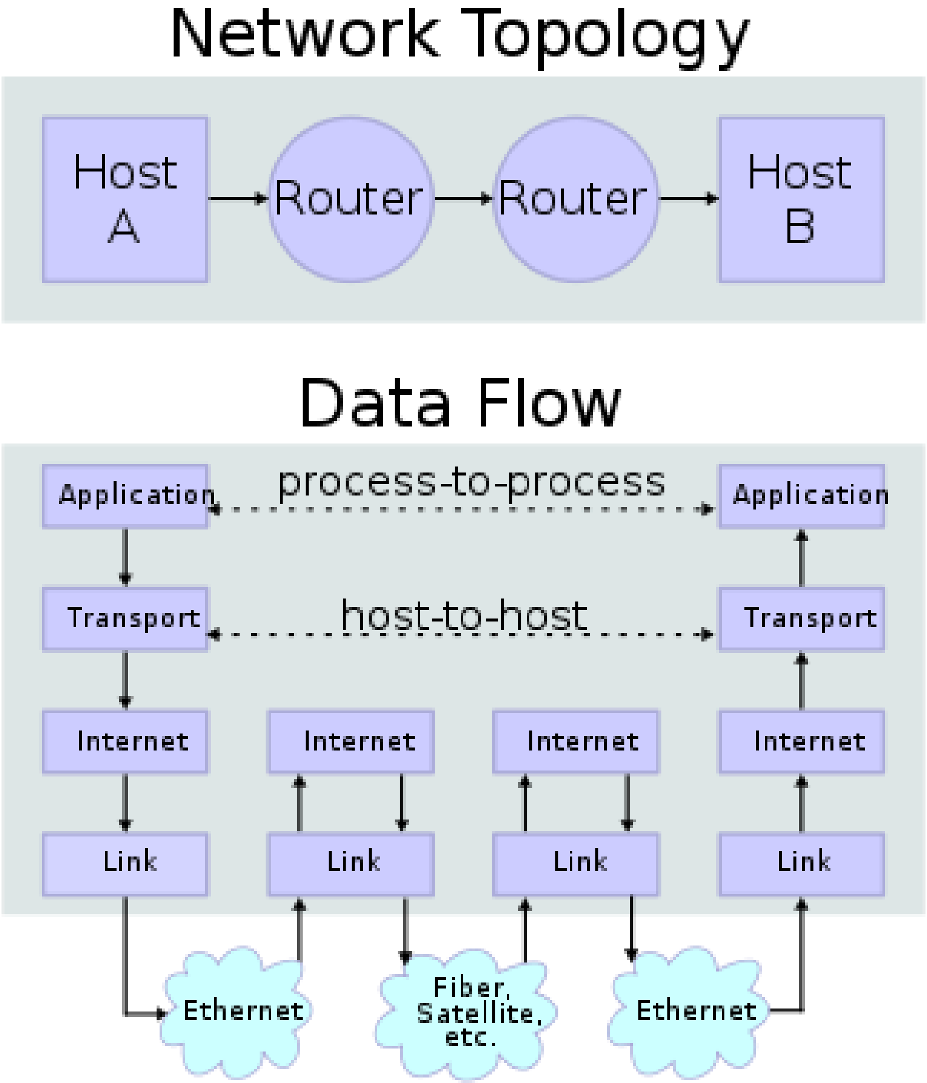
- Build physical wire:
  - Guaranteed resources
  - Great for voice

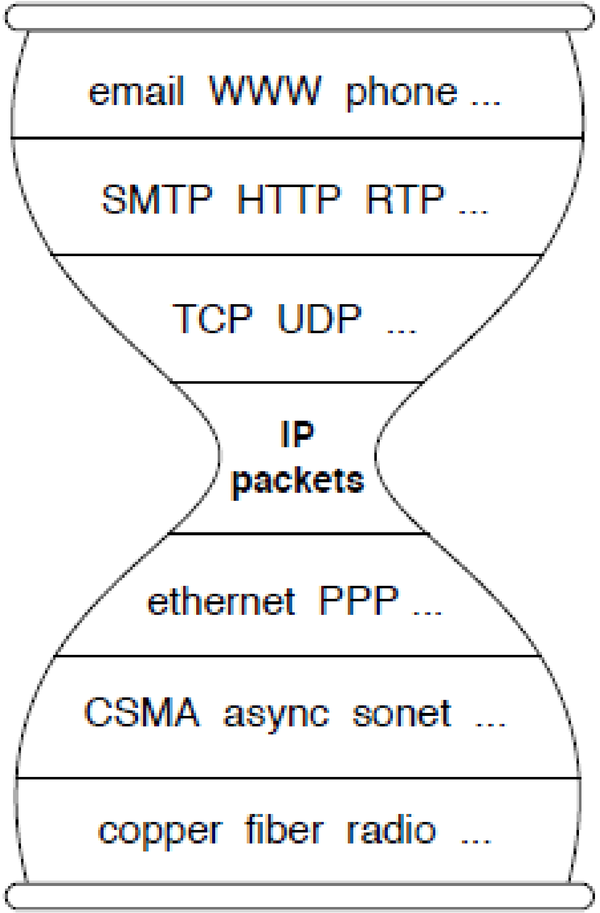
Why change?

Packet Switching



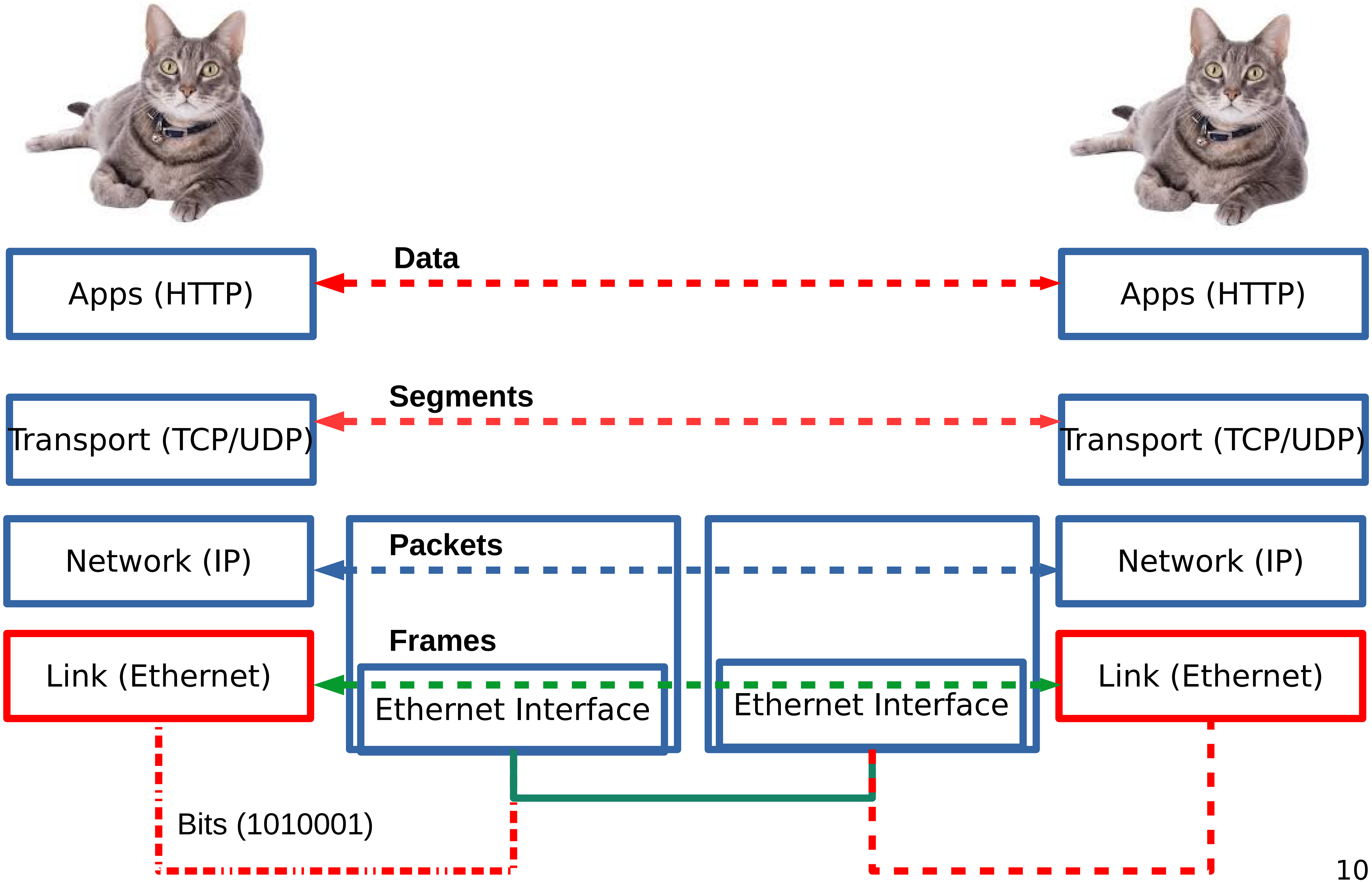
IP Suite





wikipedia

We reject kings, presidents, and voting. We believe in rough consensus and running code. (David Clark, IETF, July 1992)



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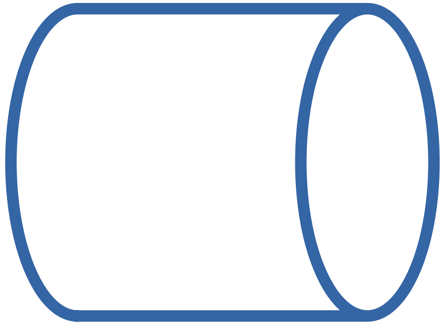
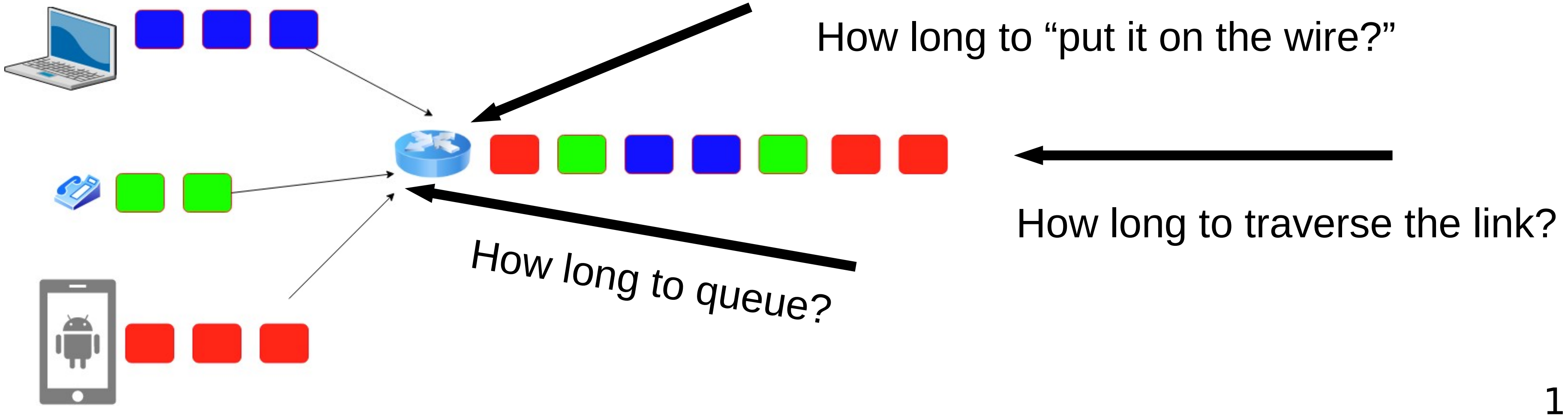
Performance - Bandwidth and Latency



- **Bandwidth = Size of the network pipe**
- **Latency = Delay in sending packets**
- **Throughput = How fast your can send data, function of both bandwidth and latency (and other things)**

Performance - Latency

- Latency = Propagation Delay + Transmission Delay + Queuing Delay
- Propagation = Distance/Speed Of Light (in Copper or Fiber)
- Transmit = Size/Bandwidth

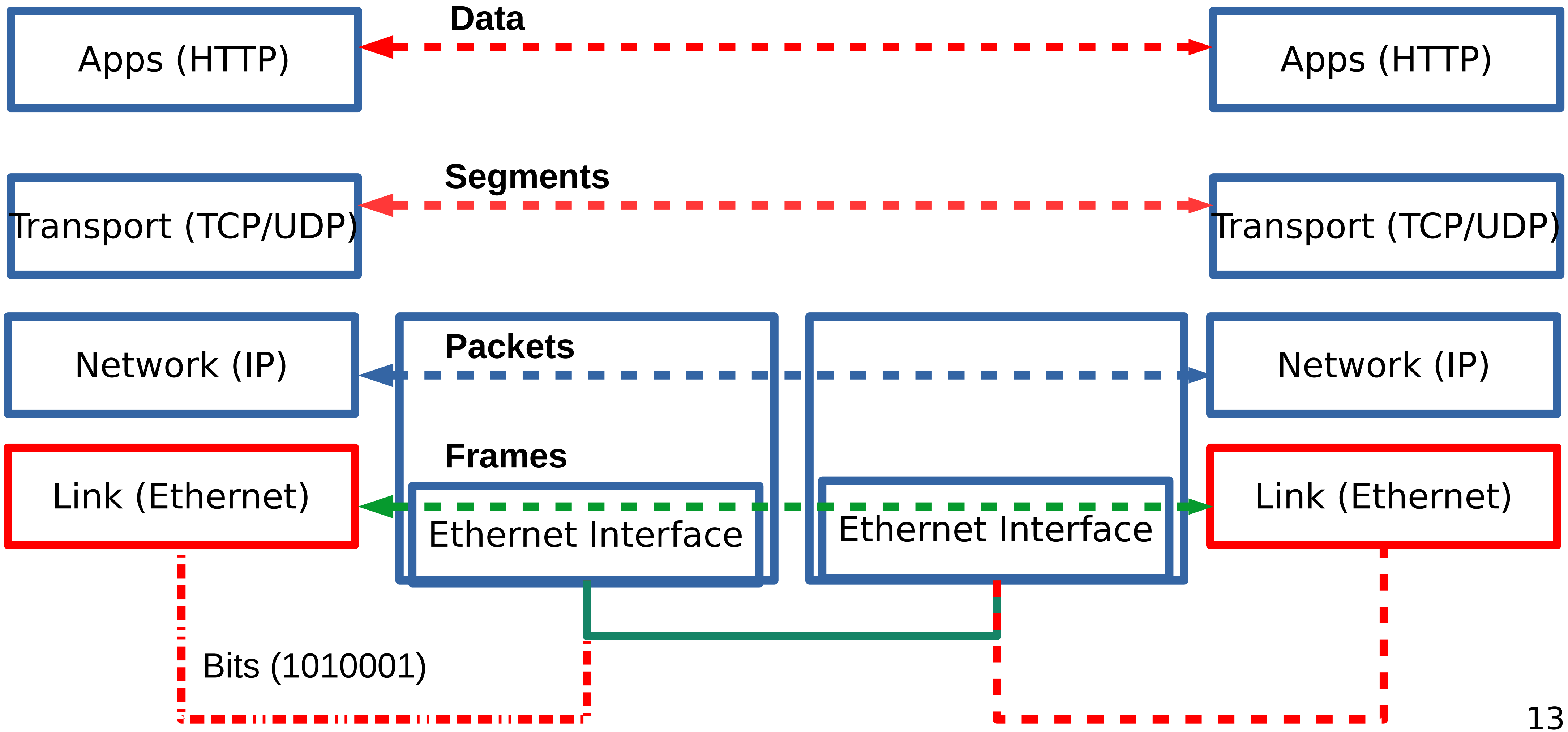


How long to “put it on the wire?”

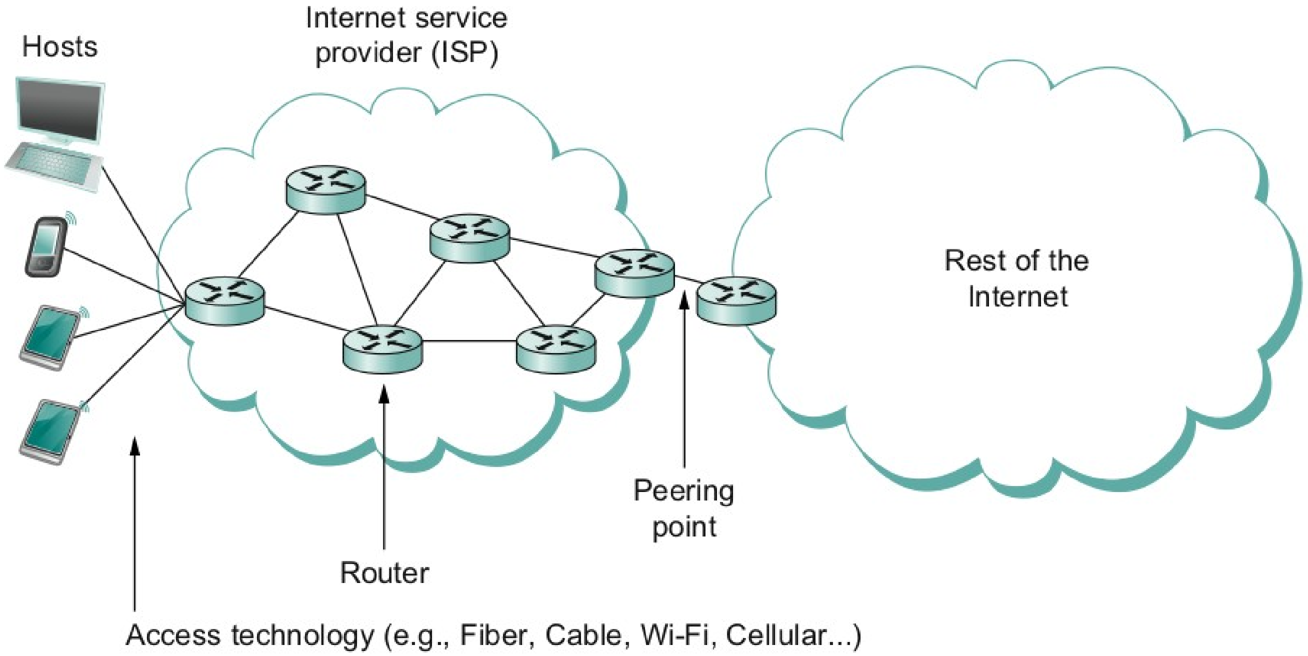
How long to traverse the link?

How long to queue?

Link Layer Recap – How much work for a cat picture?



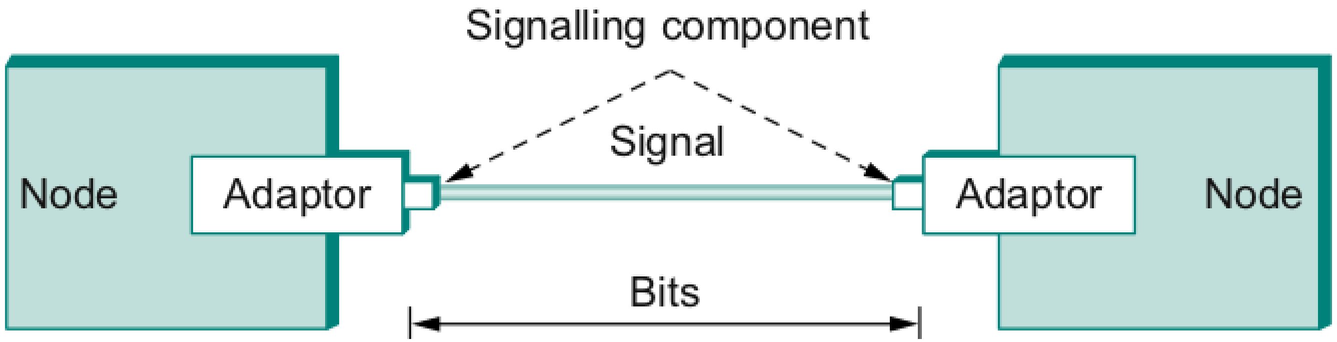
What does it take to create a link?

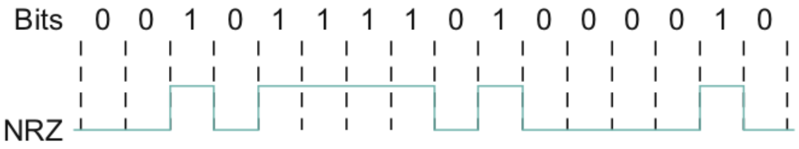

Hosts
Internet service provider (ISP)
Rest of the Internet
Peering point
Router
Access technology (e.g., Fiber, Cable, Wi-Fi, Cellular...)

- Common abstractions
  - Why?

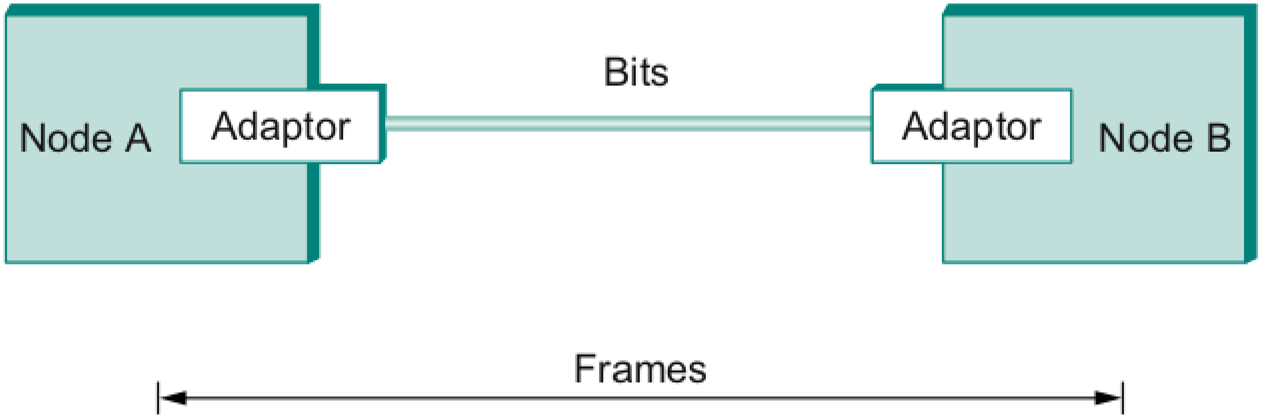
Packet to Low level Signals

- Bit pattern - 0101001
  - Must encode it into electrical signals and then decode it on the other end!





Frames – bag of bits



- Sending side – encapsulation, add error check bits, flow control
- Receiving side – extract frames, check for error, flow control

Error Detection

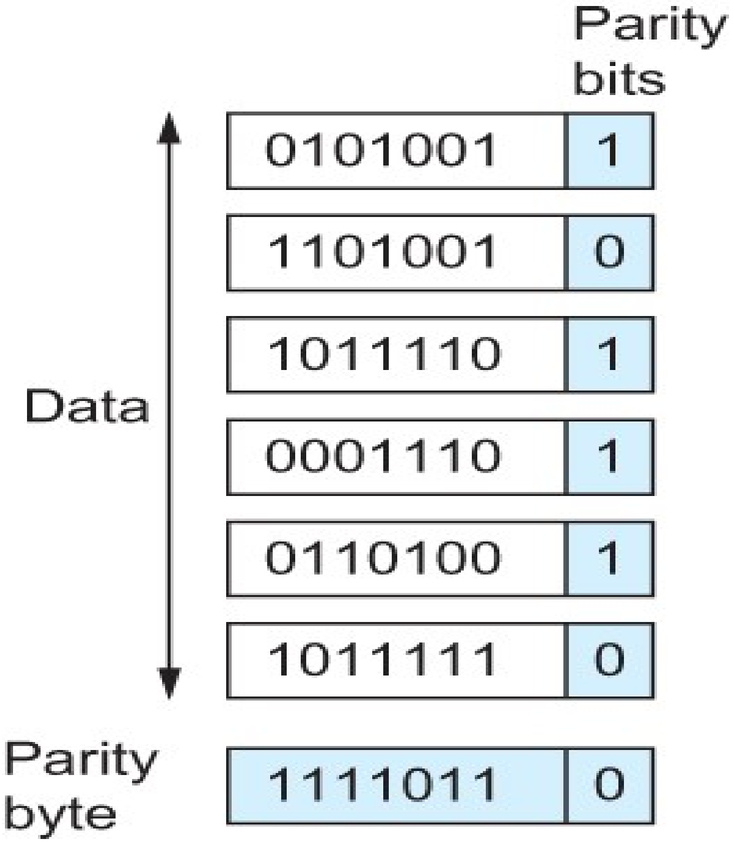
- Bit errors are introduced into frames
  - Because of electrical interference and thermal noises
- Detecting Error
- Correction Error
- Two approaches when the recipient detects an error
  - Notify the sender that the message was corrupted, so the sender can send again.
    - If the error is rare, then the retransmitted message will be error-free
  - Using some error correct detection and correction algorithm, the receiver reconstructs the message

One an Two-dimensional parity

0	1	0	1	0	**0**

0	1	0	1	1	**1**

Number of 1s
- Odd 1s = Parity bit 0
- Even 1s = Parity bit 1



0101001	1
1101001	0
1011110	1
0001110	1
0110100	1
1011111	0
1111011	0

Two Dimensional Parity

Internet Checksum Algorithm (RFC 1071)

-

- A =
- B =

A+B =

- C =

–

Reliable Delivery – Correct FRAMEs!!!

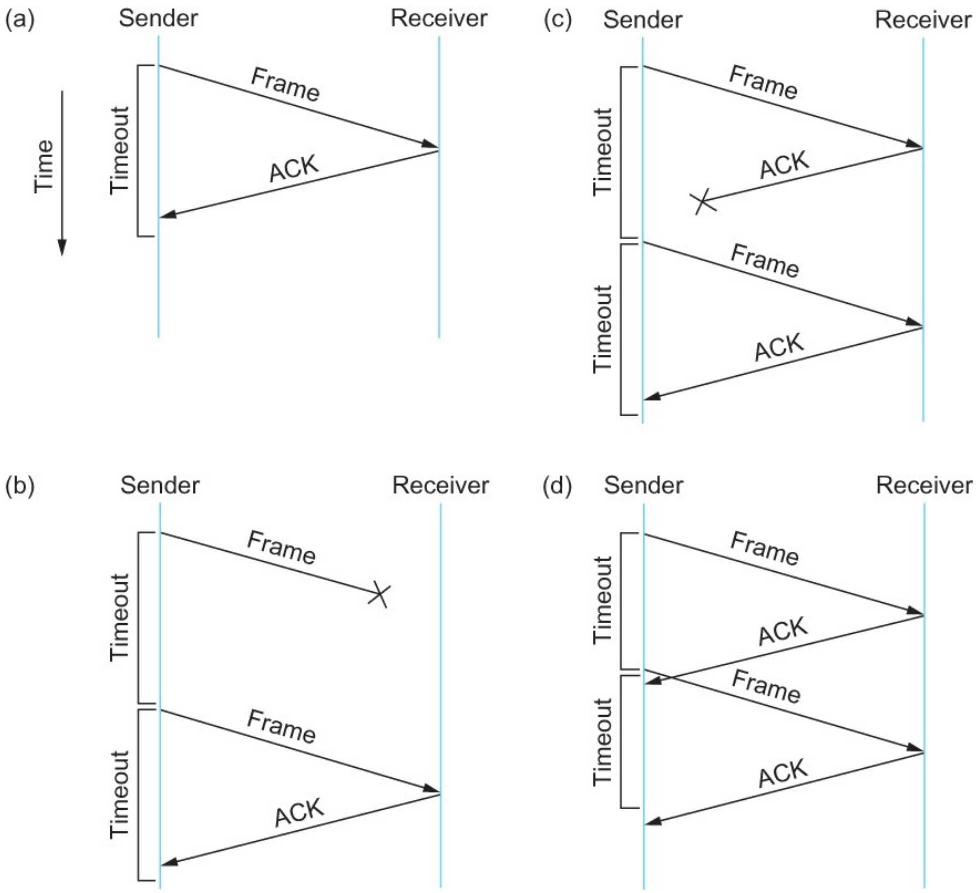
- Frames might get lost
  - Too many bits lost
  - Clock did not sync properly
  - Error detected but the report got lost

- Can we build links that does not have errors?
  - Not possible

- How about all those error correction stuff we learned?
  - Can we add them to frames?
  - We could, but think of the overhead
  - What happens when the entire frame is lost?

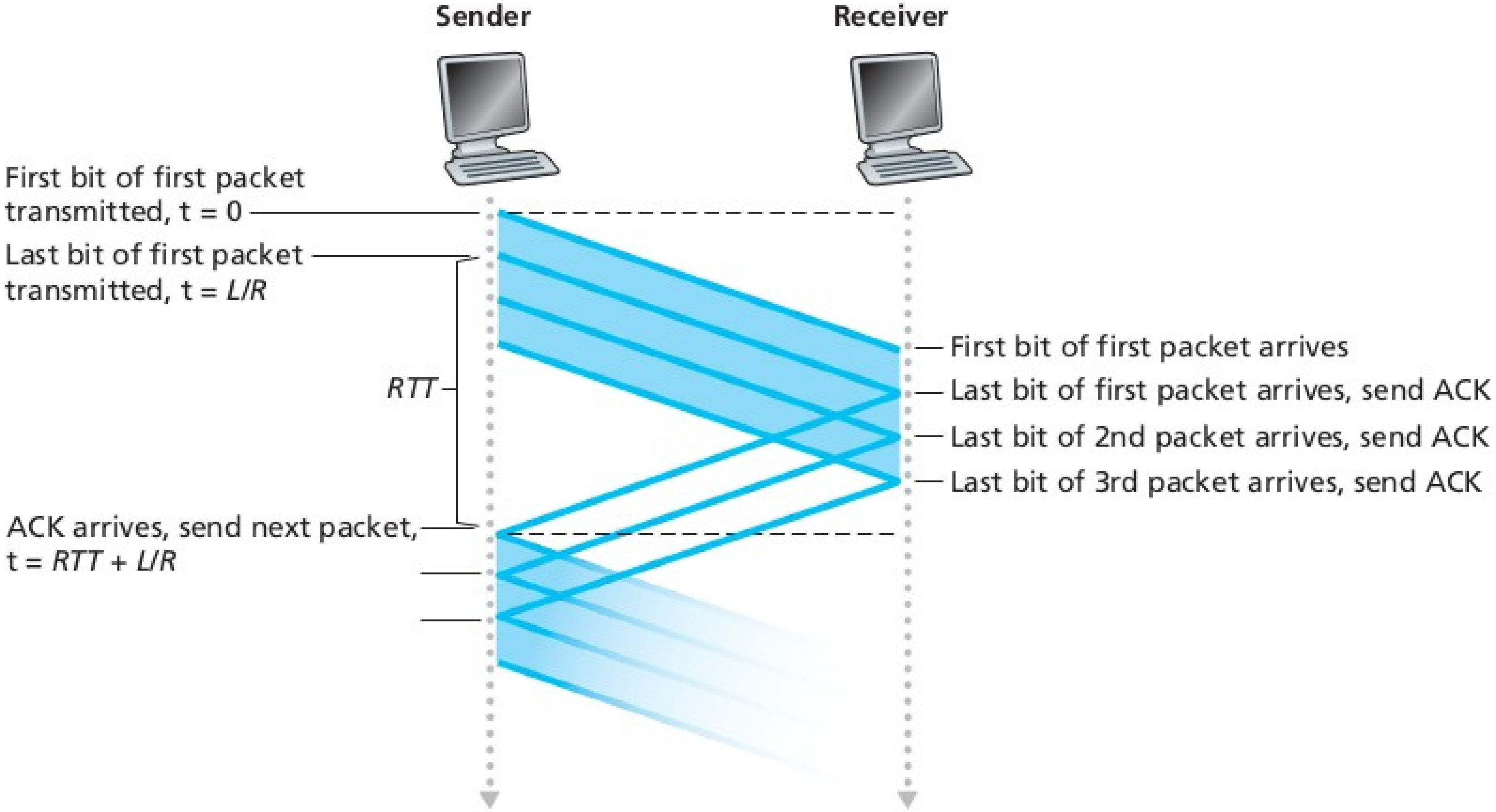
Stop and Wait

- Sender sends a frame, sets a timeout (e.g., 1 sec)
- Receiver receives the frame, sends an ACK
- Sender
  - sends the next frame on ACK
  - retransmits the same frame if timeout happens
- **Spot the bugs in the protocol**

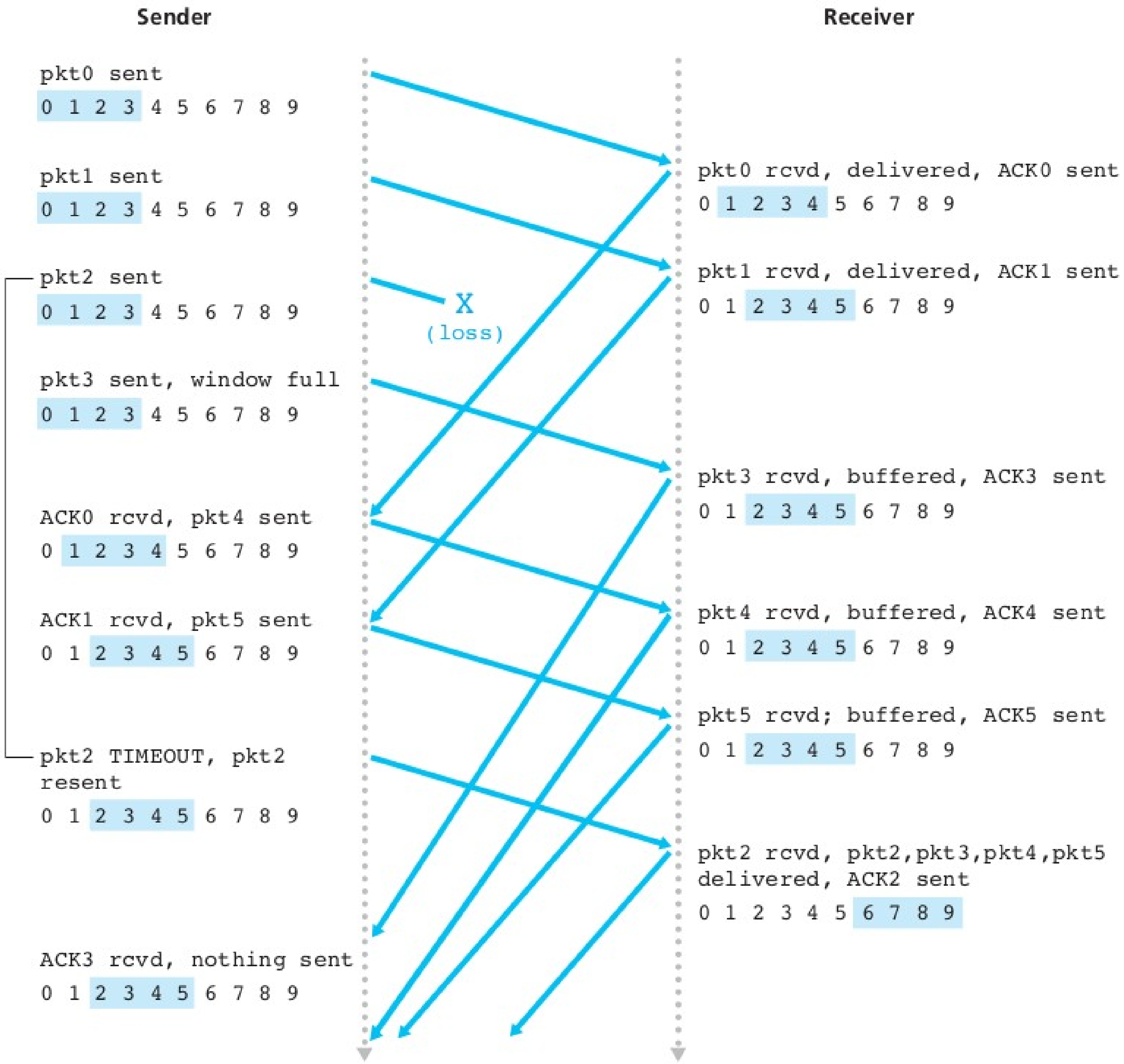


Sliding window to the rescue!

Utilization = 0.008*3/30.008 = 0.00079 (3 times increase)


Sender
Receiver
First bit of first packet transmitted, t = 0
Last bit of first packet transmitted, t = L/R
RTT
ACK arrives, send next packet, t = RTT + L/R
First bit of first packet arrives
Last bit of first packet arrives, send ACK
Last bit of 2nd packet arrives, send ACK
Last bit of 3rd packet arrives, send ACK

b. Pipelined operation



Sender

Receiver

pkt0 sent
0 1 2 3 4 5 6 7 8 9

pkt1 sent
0 1 2 3 4 5 6 7 8 9

pkt2 sent
0 1 2 3 4 5 6 7 8 9

pkt3 sent, window full
0 1 2 3 4 5 6 7 8 9

ACK0 rcvd, pkt4 sent
0 1 2 3 4 5 6 7 8 9

ACK1 rcvd, pkt5 sent
0 1 2 3 4 5 6 7 8 9

pkt2 TIMEOUT, pkt2 resent
0 1 2 3 4 5 6 7 8 9

ACK3 rcvd, nothing sent
0 1 2 3 4 5 6 7 8 9

pkt0 rcvd, delivered, ACK0 sent
0 1 2 3 4 5 6 7 8 9

pkt1 rcvd, delivered, ACK1 sent
0 1 2 3 4 5 6 7 8 9

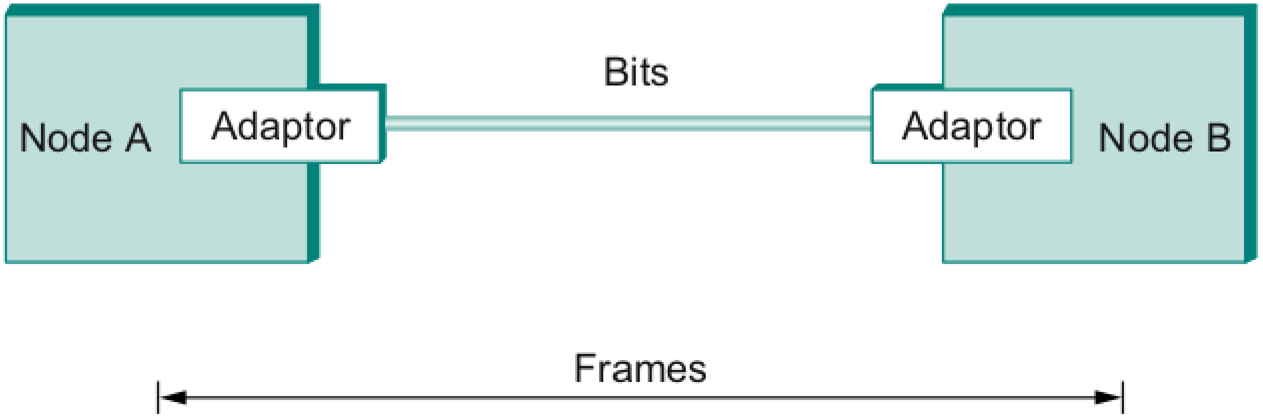
pkt3 rcvd, buffered, ACK3 sent
0 1 2 3 4 5 6 7 8 9

pkt4 rcvd, buffered, ACK4 sent
0 1 2 3 4 5 6 7 8 9

pkt5 rcvd; buffered, ACK5 sent
0 1 2 3 4 5 6 7 8 9

pkt2 rcvd, pkt2,pkt3,pkt4,pkt5 delivered, ACK2 sent
0 1 2 3 4 5 6 7 8 9

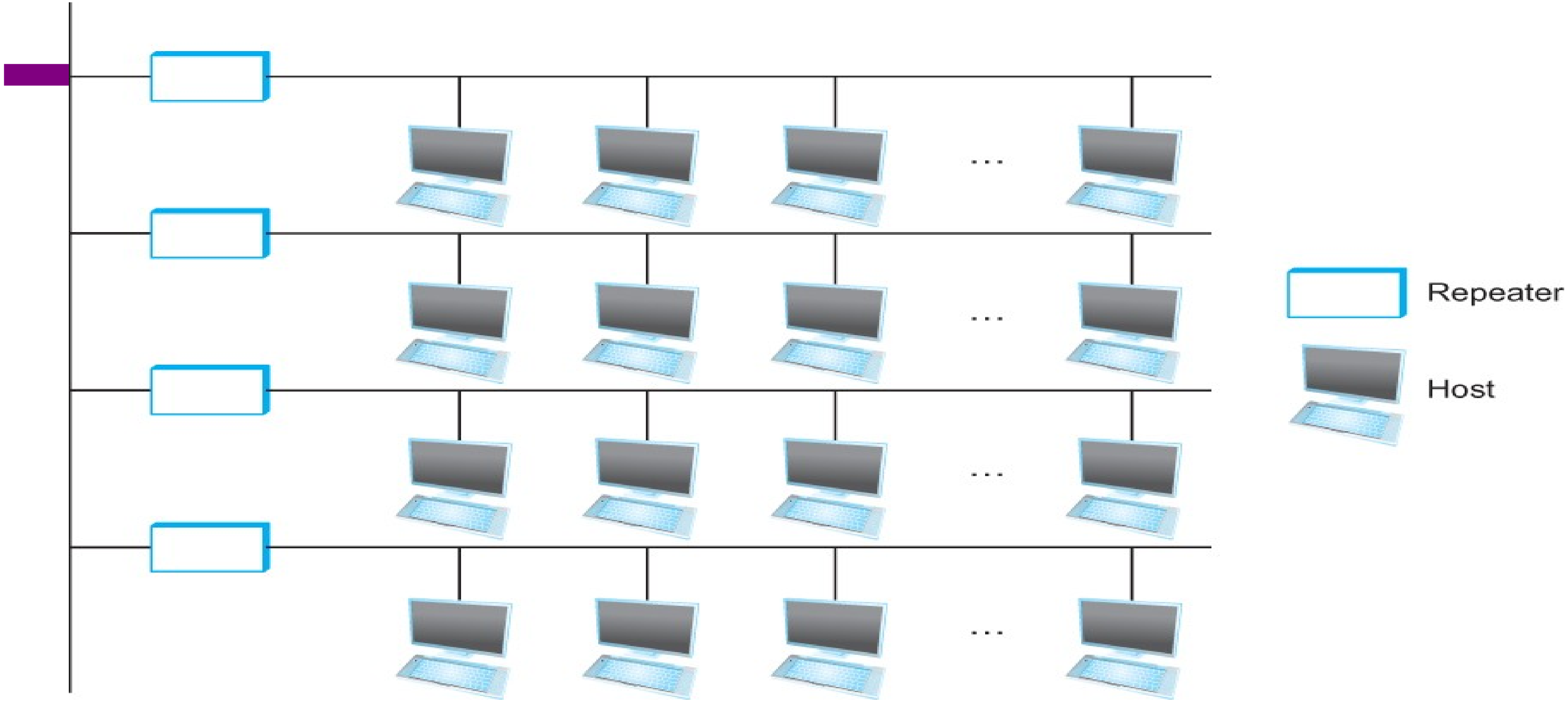
So far we connected two machines – how about more than two?



- We have connected two machines using point to point wires
  - Encoded bits
  - Sent bits as Frames
  - Caught and corrected errors
  - Tuned efficiency and reliability using sliding window

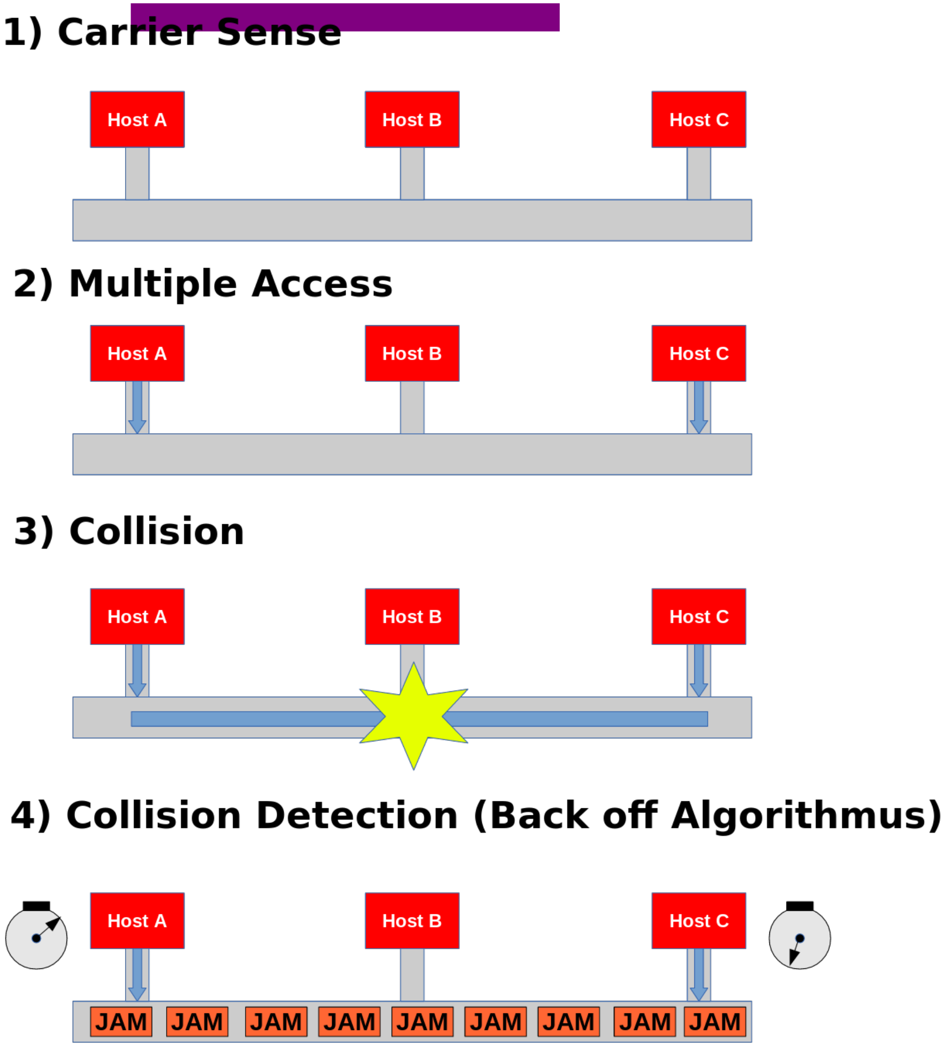
- What happens when there are more than two machines?

Ethernet



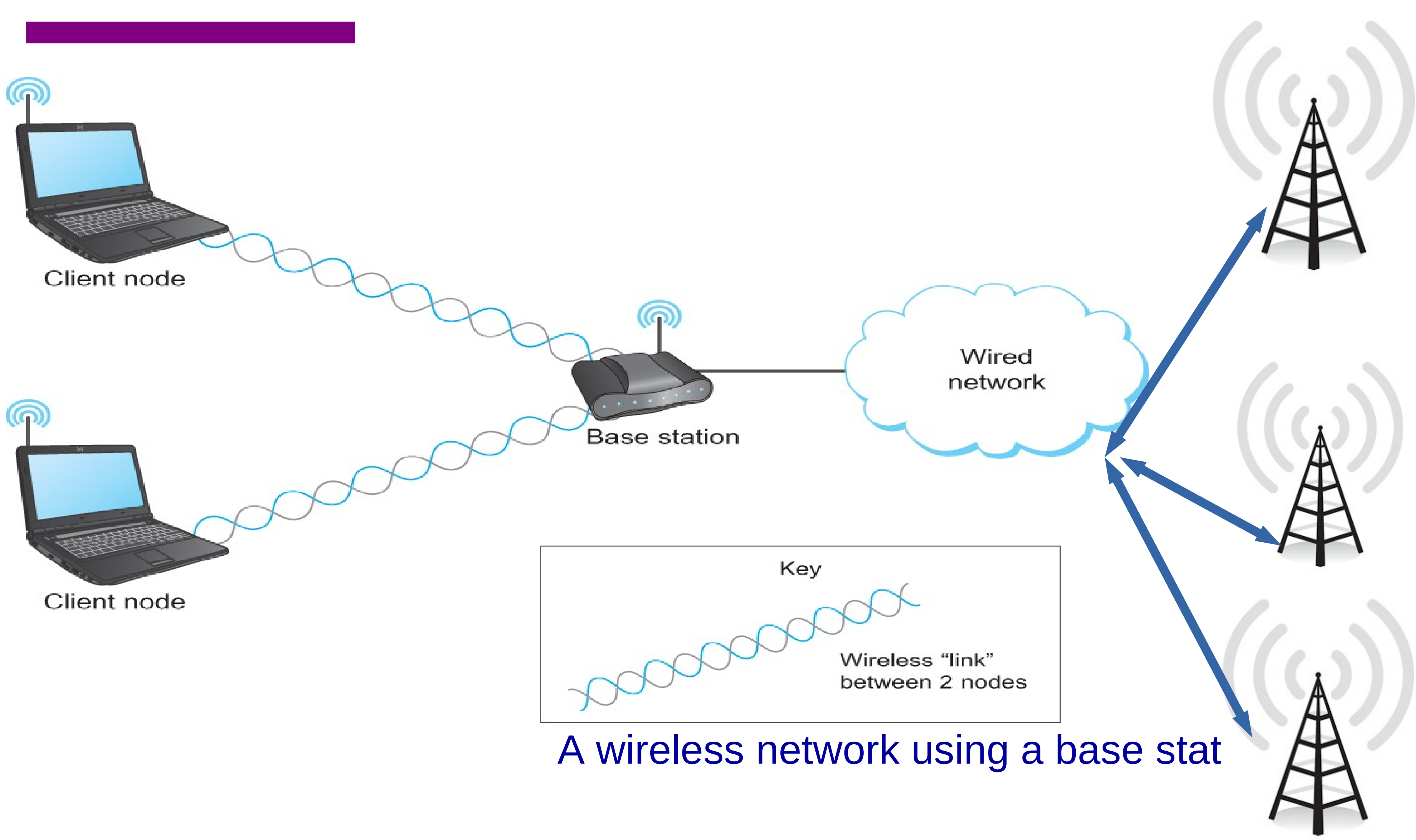
Ethernet repeater

CSMA/CD – Ethernet



- CS – wait until idle
  - Channel idle – trasmit
  - Channel busy – wait
- CD – listen while transmitting
  - No collision: transmission successful
  - Collission: abort, send jam signal (32bit special sequence)
- Wait random time
  - Try again
  - After mth collision, t = random(0,2^{m-} 1),
  - Wait t*512 bit times before retry

Wireless Links - Infrastructure



A wireless network using a base stat

Typically connects to
Base stations

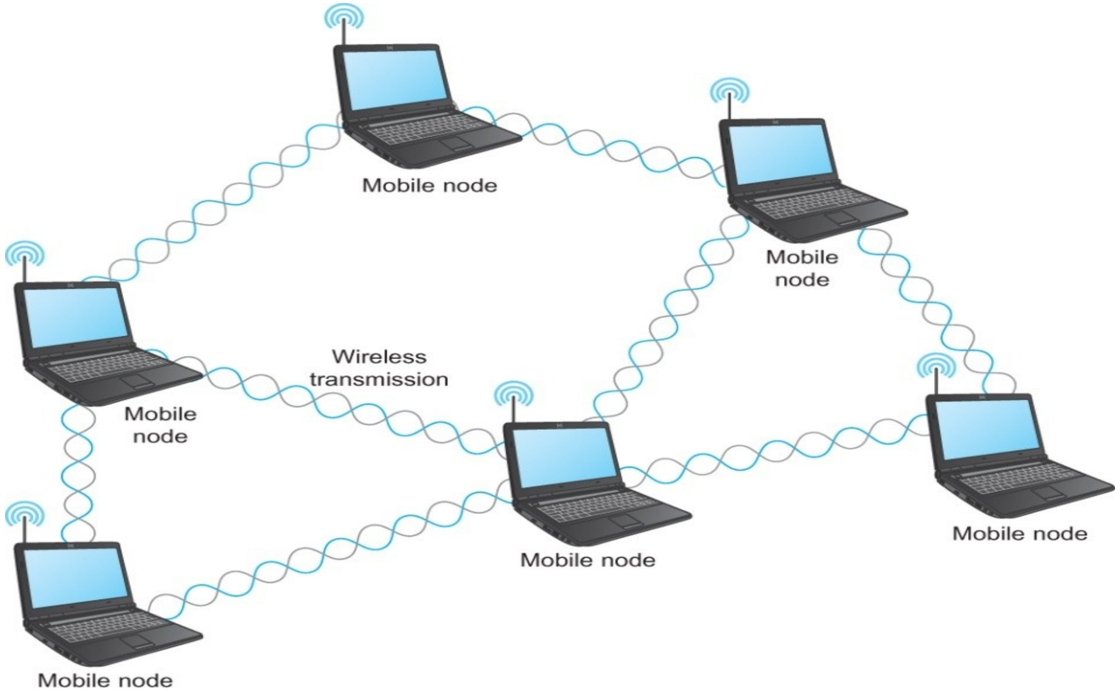
Multiple access

Handoff protocols

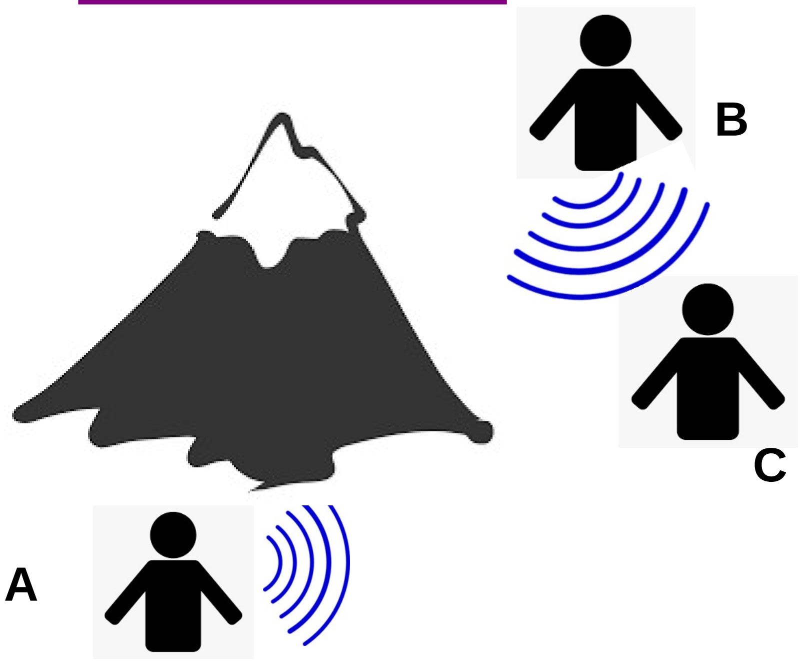
Wireless != Mobile

Wireless Links – Ad hoc

- Mesh or Ad-hoc network
  - Nodes are peers
  - Messages may be forwarded via a chain of peer nodes



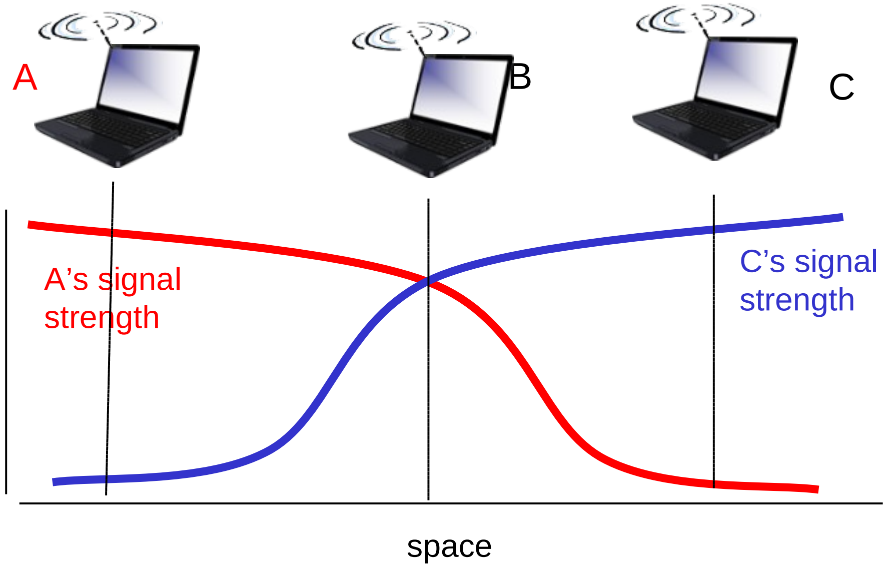
Wireless Links – problems



A and C can talk
B and C can talk
A and B can not!!!
Interference at B

Hidden terminal

Signal Fading



IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

1 if sense channel idle for **DIFS** then

transmit entire frame (no CD)

2 if sense channel busy then

start random backoff time

timer counts down while channel idle

transmit when timer expires

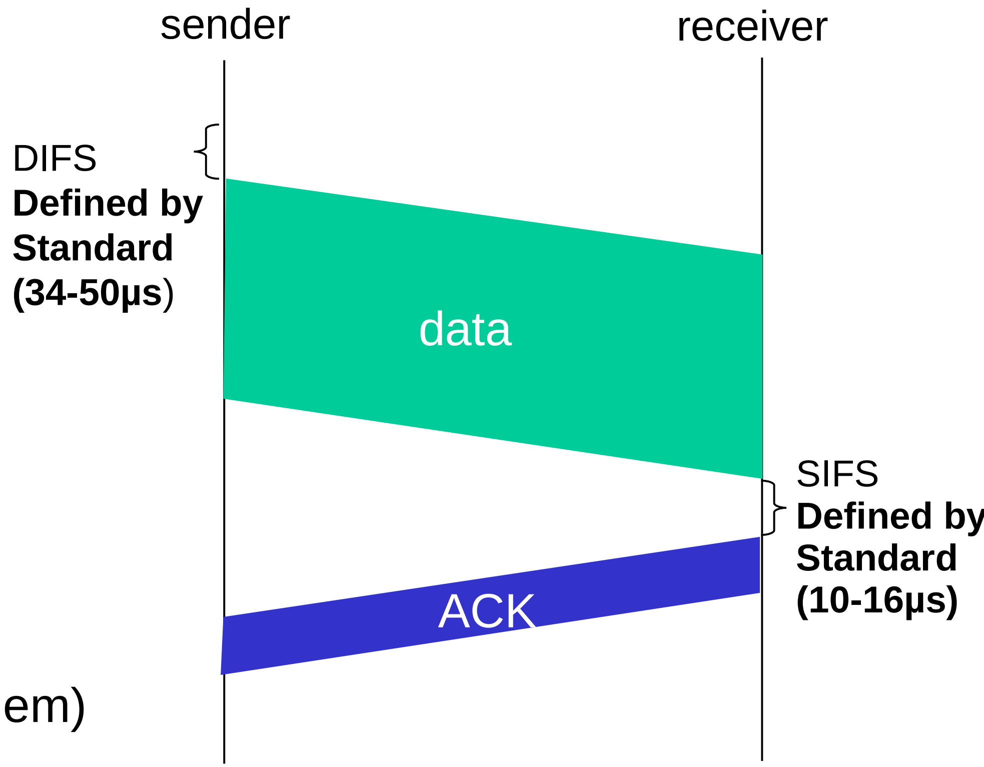
if no ACK, increase random backoff interval, repeat 2

802.11 receiver

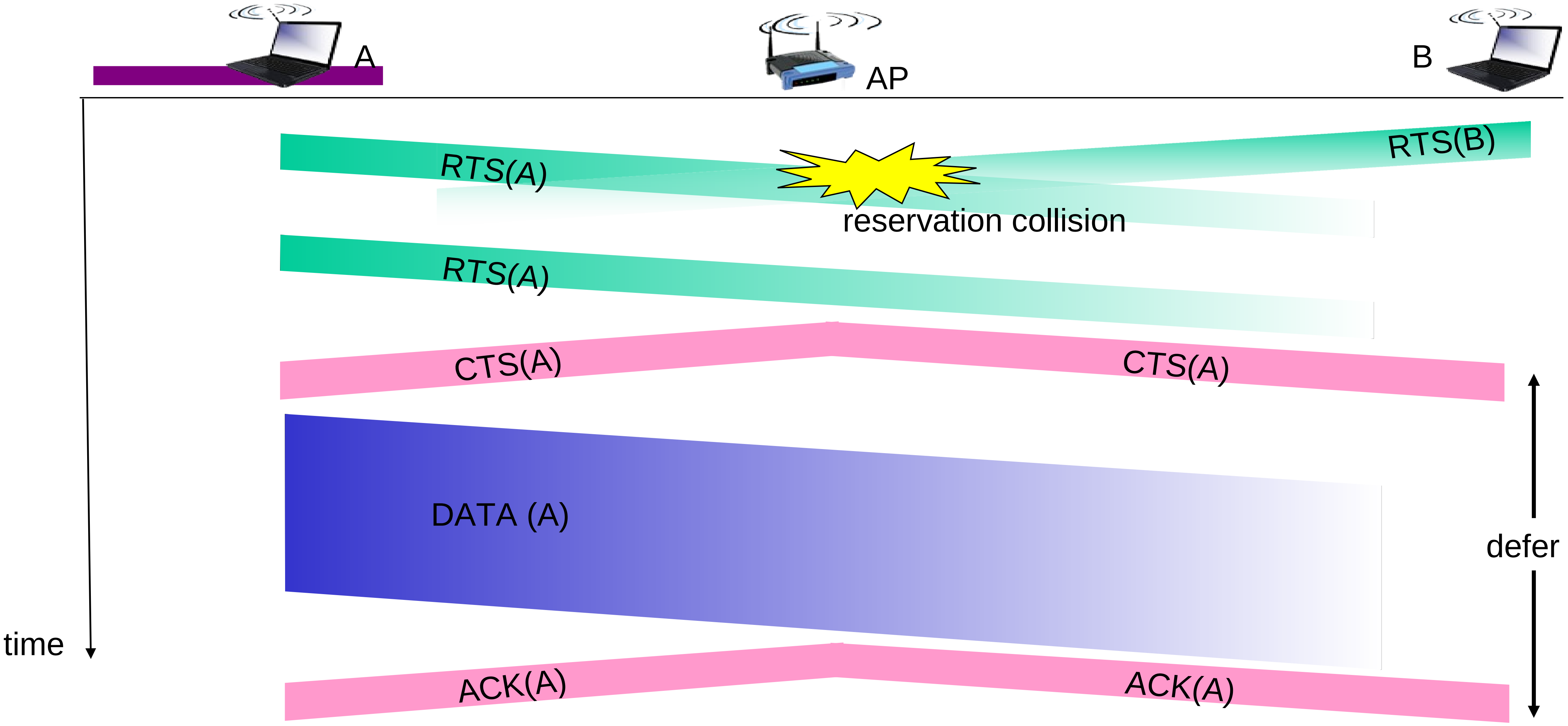
- if frame received OK

return ACK after **SIFS** (ACK needed due to hidden terminal problem)

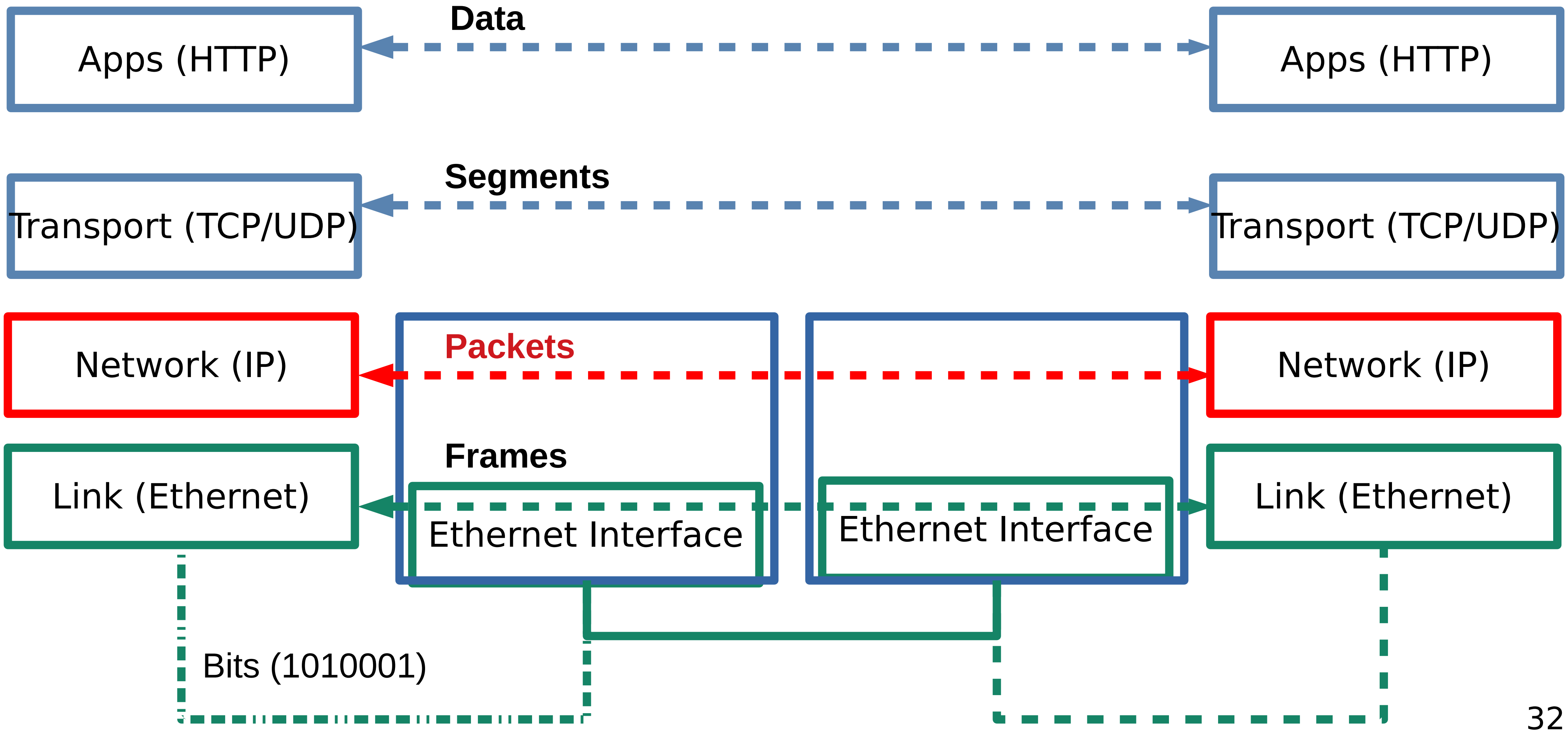
DIFS = SIFS + (2 * Slot time)



Collision Avoidance: RTS-CTS exchange



Next Step – Cat in bits
To Cat in packets!!!!



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