CSC4200/5200 – COMPUTER NETWORKING

ETHERNET AND WIFI

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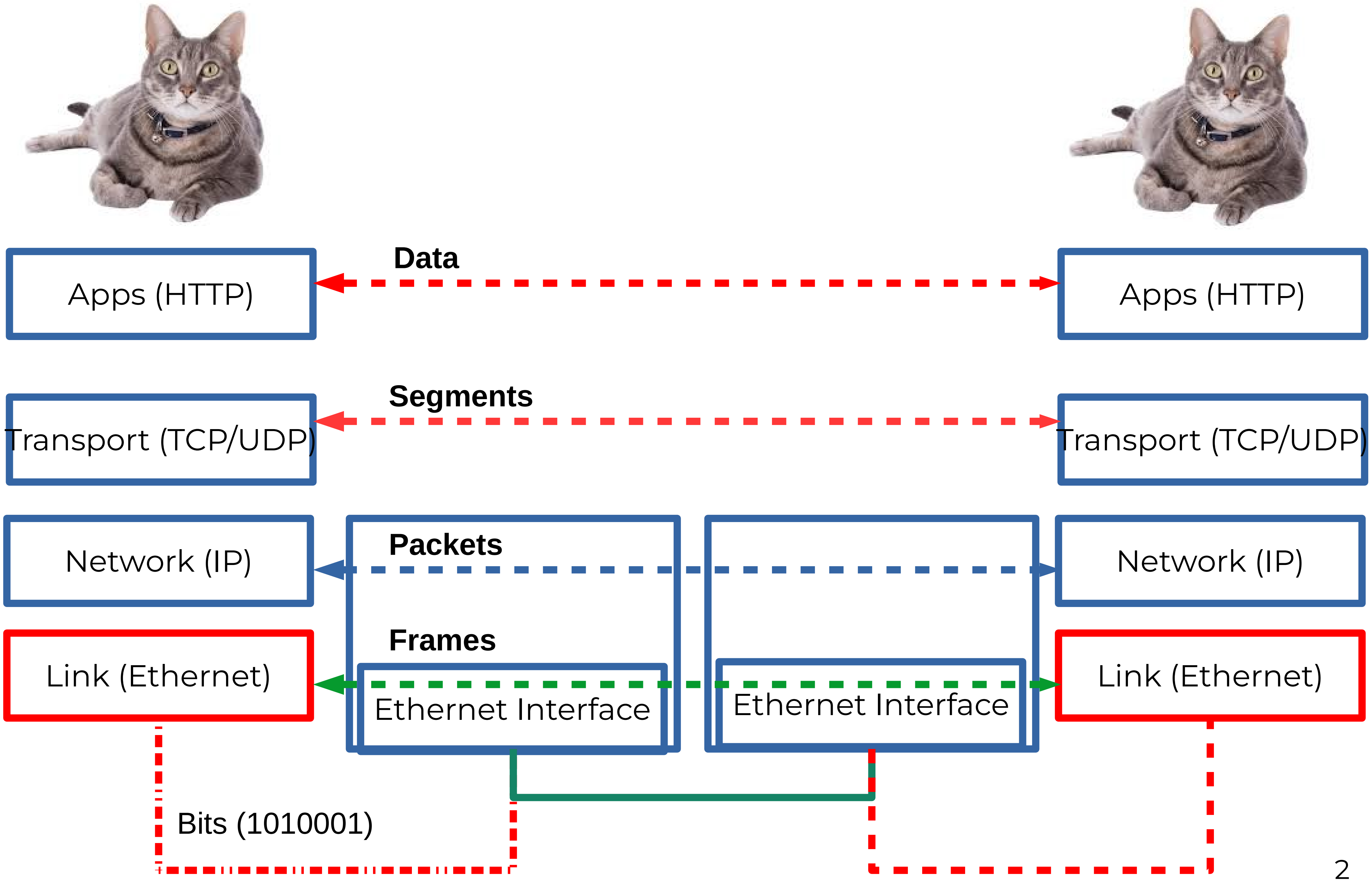
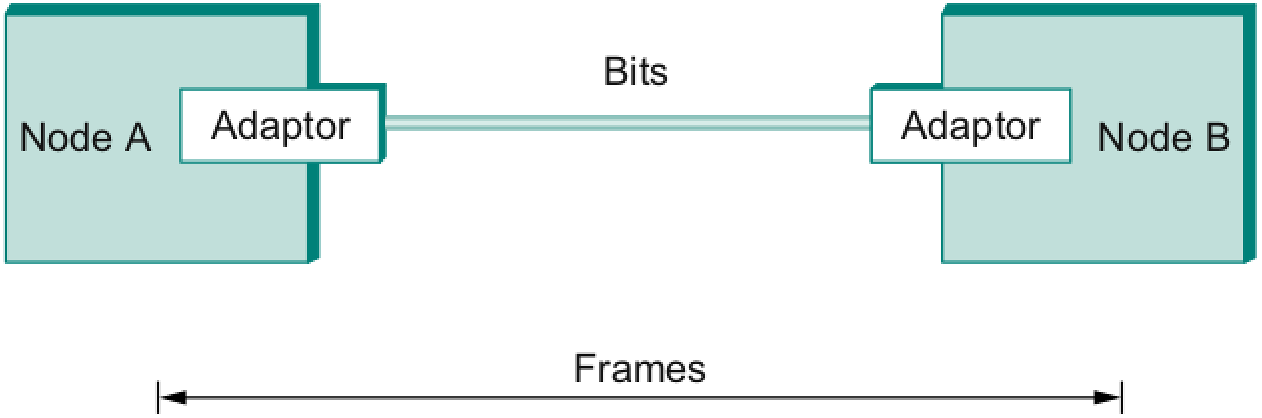
Tennessee TECH

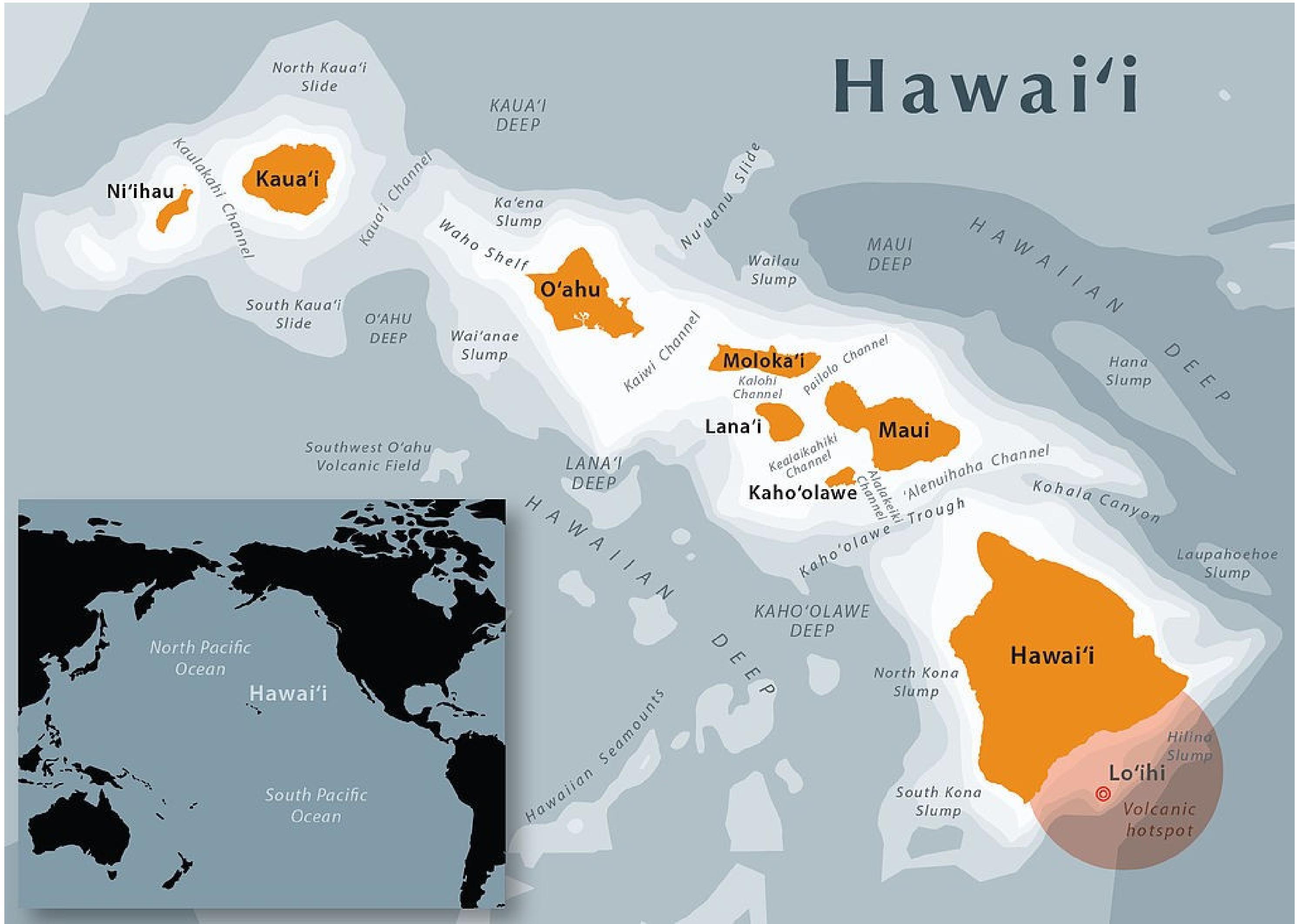

Data
Apps (HTTP)
Apps (HTTP)
Segments
Transport (TCP/UDP)
Transport (TCP/UDP)
Packets
Network (IP)
Network (IP)
Frames
Link (Ethernet)
Ethernet Interface
Ethernet Interface
Link (Ethernet)
Bits (1010001)

So far…



- 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?

Map of Hawaii



wikipedia

AlohaNET

- Connect University of Hawaiʻi's computers using wireless radio to main campus in Oahu

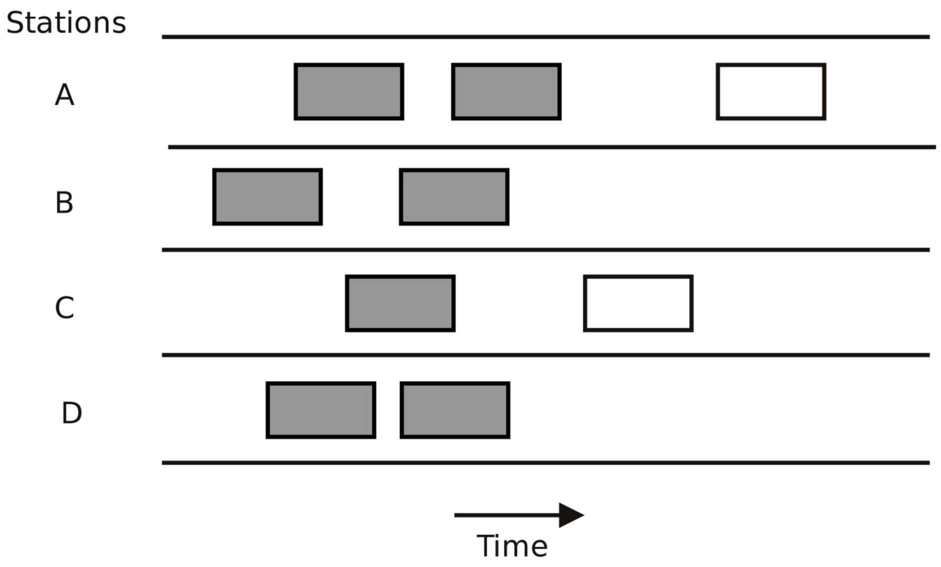
- Random access to radio channel
  - If you have data, send
  - If you hear someone else, collision! Resend "later"

- Fixed frequency channels
  - Shared medium

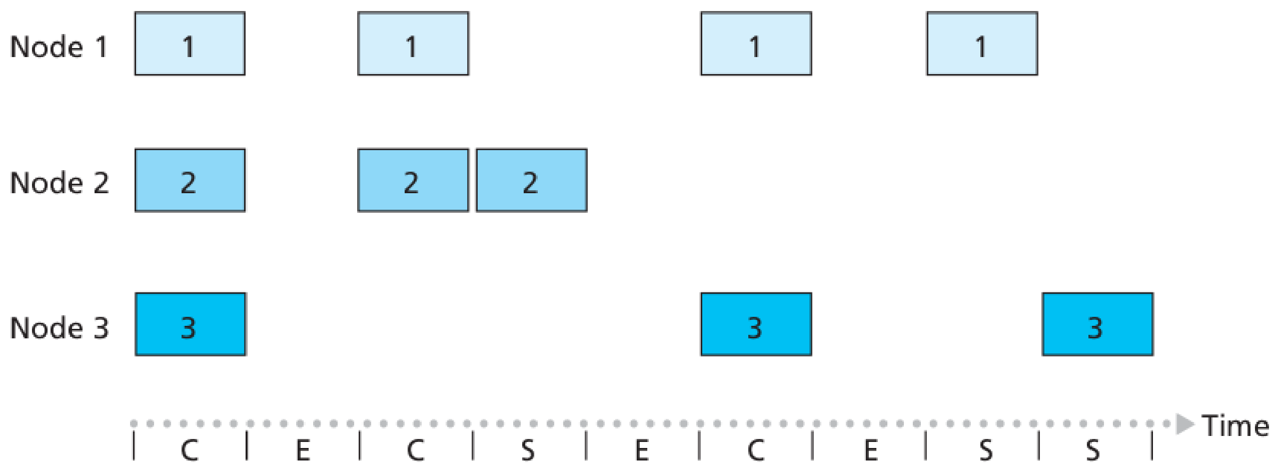
Abramson, Norman. "Development of the ALOHANET." IEEE transactions on Information Theory 31.2 (1985): 119-123.
https://www.eng.hawaii.edu/about/history/alohanet/

Pure Aloha

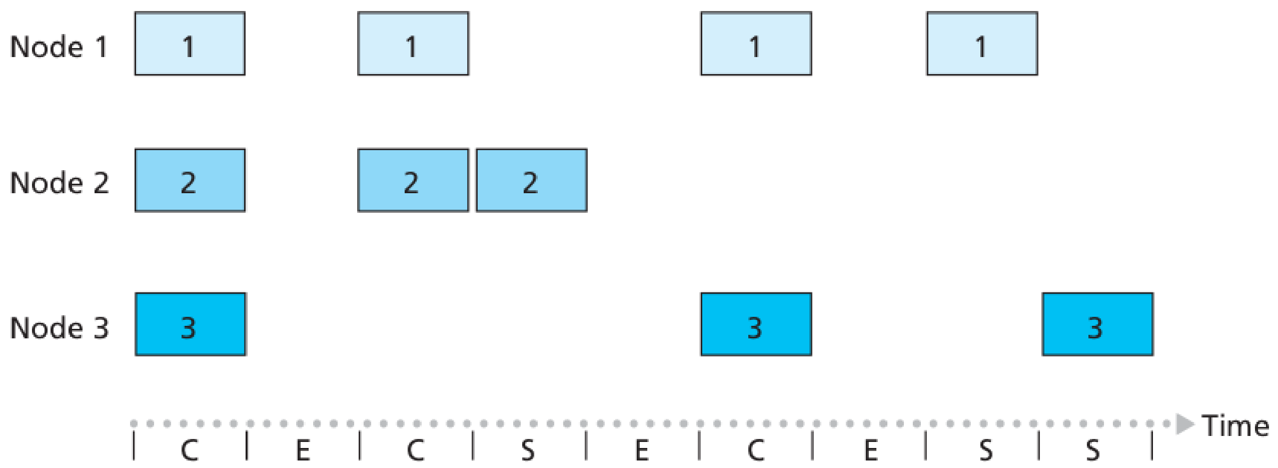
- If you have data to send, send it.
- While transmitting, if you hear from anyone else, collision!
  - Try retransmitting later.



Slotted ALOHA

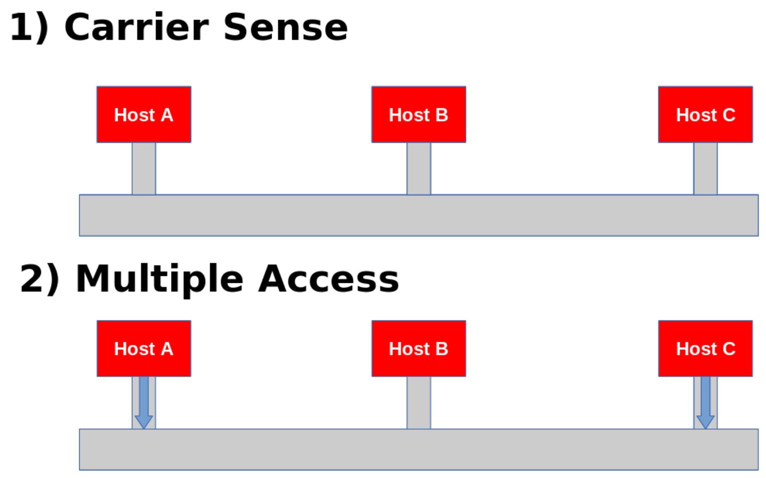


Slotted ALOHA - Problems



- Wasted slots
- Idle slots
- Need to sync
- Low efficiency

CSMA – Improvement over Aloha

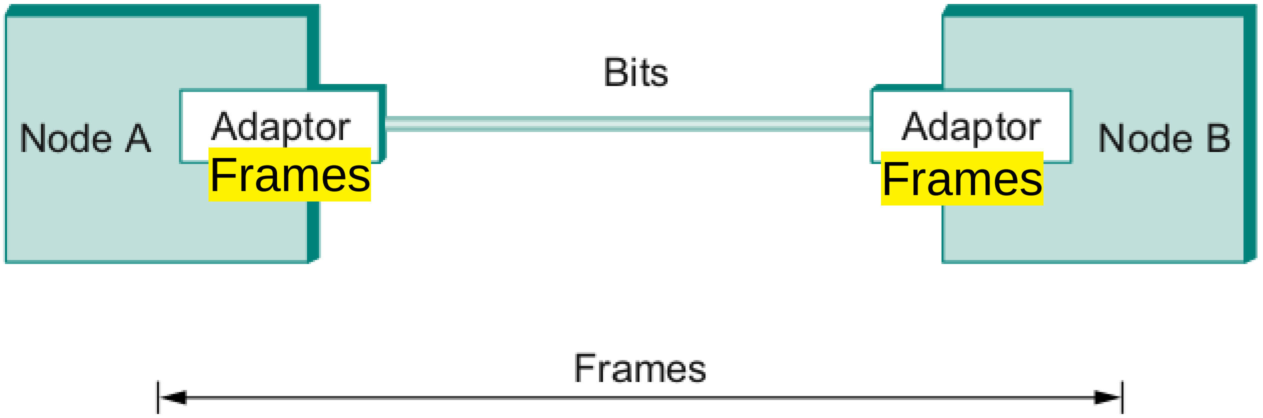


- Listen first -
  - If chennel is idle, send
  - If channel is busy, wait and send later
- Propagation delay
  - You may not hear others before it's too late!

wikipedia

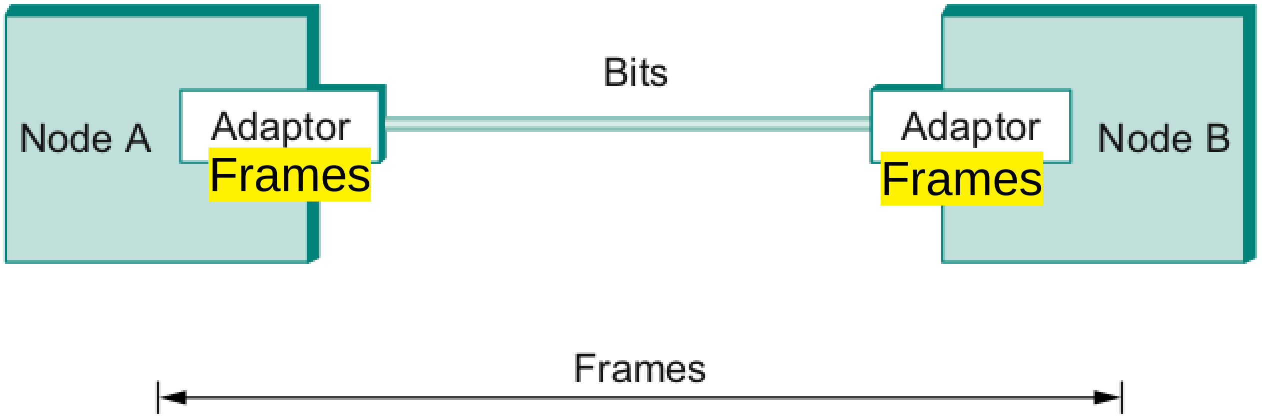
Ethernet – Wire as Shared Medium

- Most successful local area networking technology of last 20 years.
- Developed in the mid-1970s by researchers at the Xerox Palo Alto Research Centers (PARC).
- For alohanet the medium was the atmosphere, for ethernet, coax cables

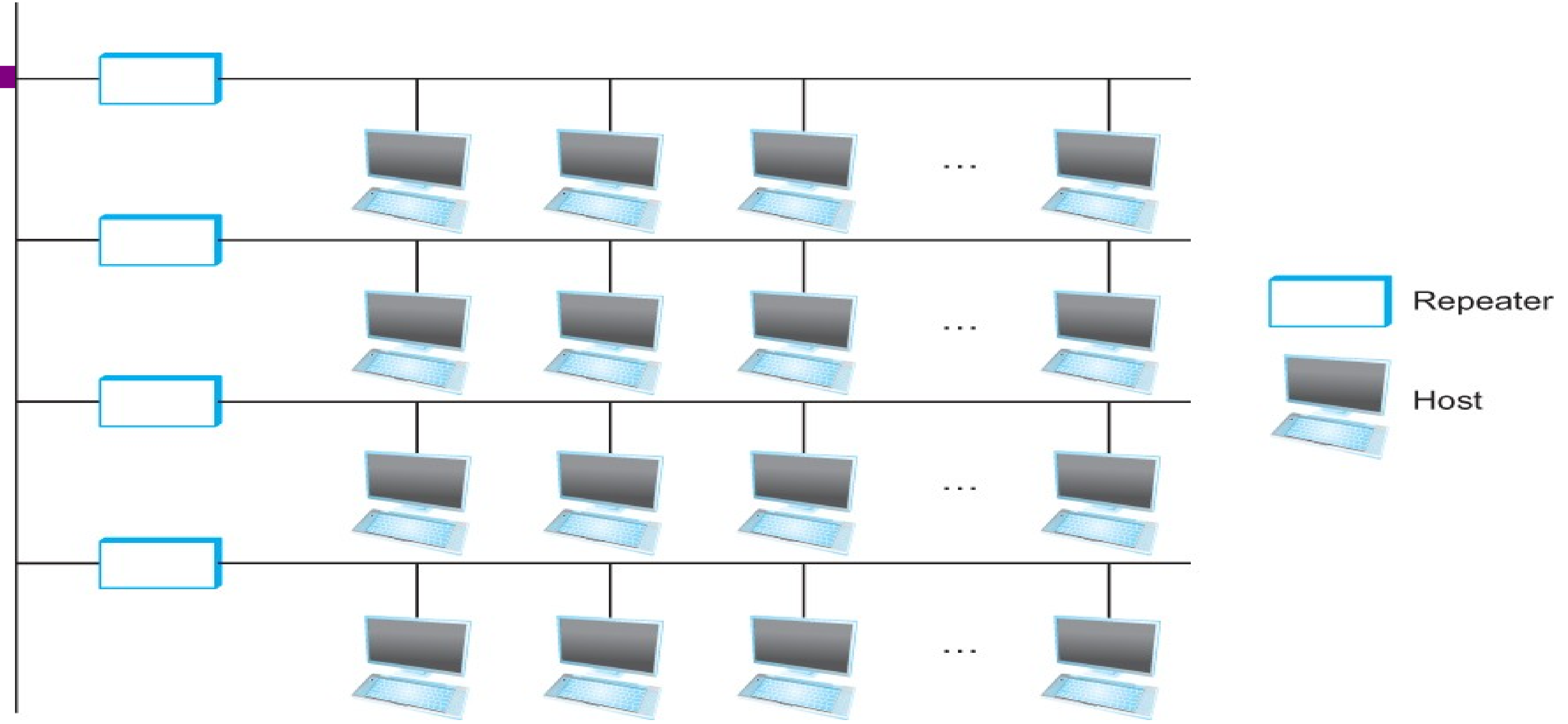


Ethernet – IEEE Standard 802.3

- How to allow many adaptors to send frames over the wire?
  - Access protocol



Ethernet



Ethernet repeater

Ethernet – Random Access

- How to allow many adaptors to send frames over the wire?
  - **Random access**

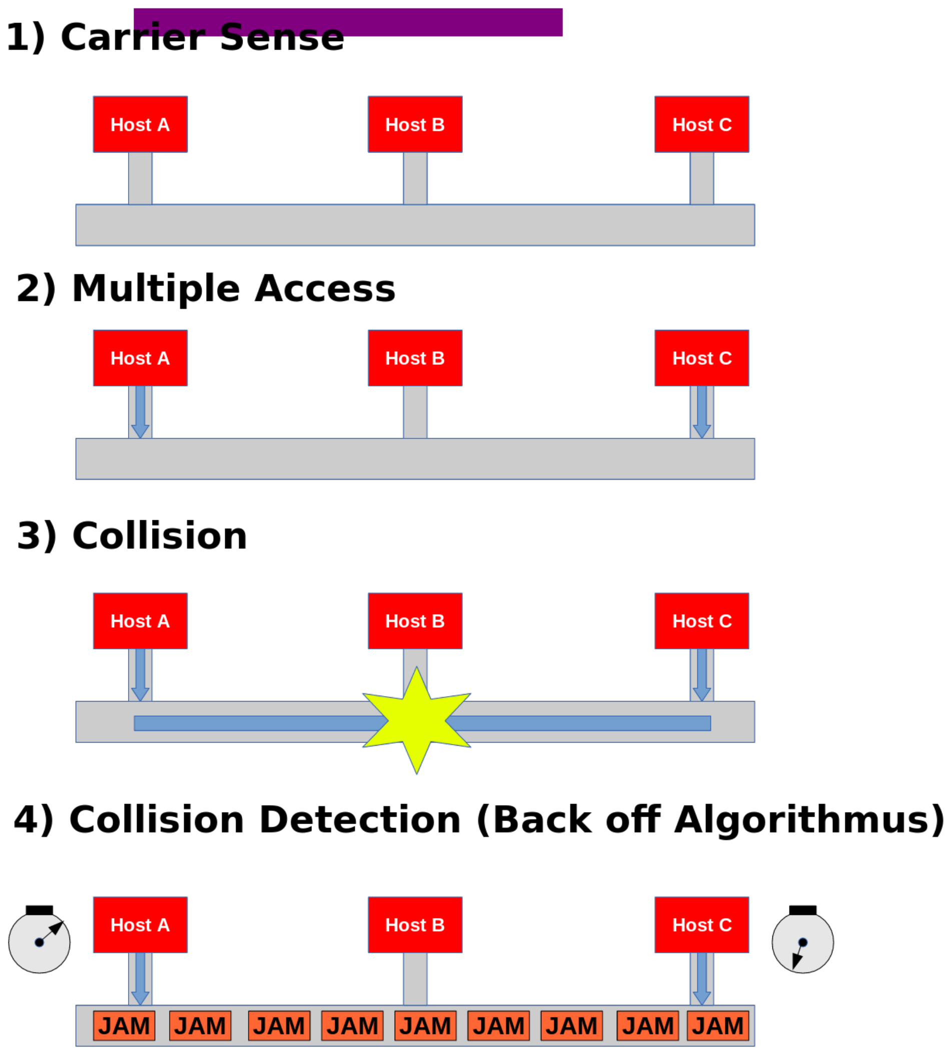
  - When you have data – send at Full channel rate!
  - No coordination needed.

- If collision happens
  - Detect
  - Recover
  - Retransmit

CSMA/CD – Listen first, talk later!

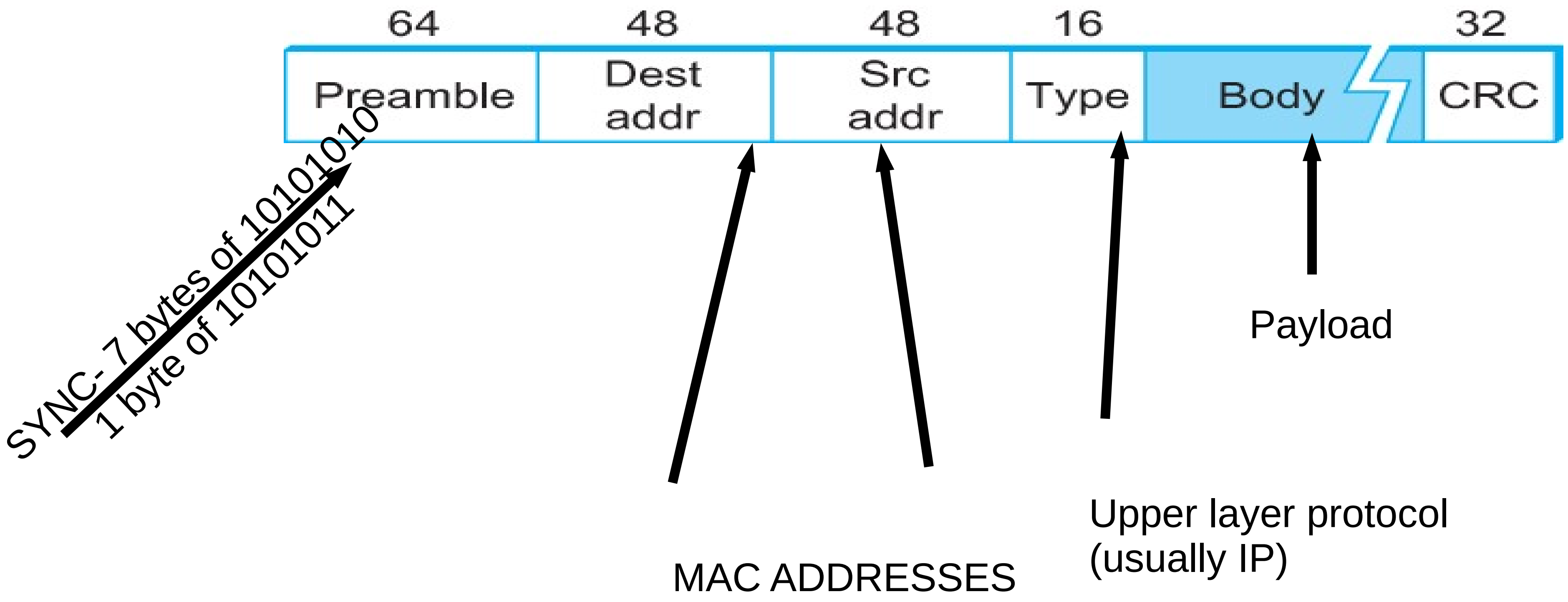
- CSMA – Carrier sense Multiple access
  - Listen if anyone is transmitting
  - Wait until carrier is free, do not interrupt others
  - **What is the carrier here?**
- CD – Collision Detection
  - If you hear anyone while talking, **collision, stop!**
  - Monitor signal strength at the adapter
  - Higher than normal = collision
- Random wait before retransmitting
  - **Why?**

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 m^{th} collision, $t = random(0, 2^{m-1})$,
  - Wait t*512 bit times before retry

Ethernet Frame



Access Protocol for Ethernet

- The algorithm is commonly called Ethernet’s Media Access Control (MAC).
  - It is implemented in Hardware on the network adaptor.
- Frame format
  - Preamble (64bit): allows the receiver to synchronize with the signal (sequence of alternating 0s and 1s).
  - Host and Destination Address (48bit each).
    - Hardcoded
  - Packet type (16bit): acts as demux key to identify the higher level protocol.
  - Data (up to 1500 bytes)
    - Minimally a frame must contain at least 46 bytes of data.
    - Frame must be long enough to detect collision.
  - CRC (32bit)

Ethernet Transmitter Algorithm

- Once an adaptor has detected a collision, and stopped its transmission, it waits a certain amount of time and tries again.
- Each time the adaptor tries to transmit but fails, it doubles the amount of time it waits before trying again.
- This strategy of doubling the delay interval between each retransmission attempt is known as *Exponential Backoff*.

Ethernet Transmitter Algorithm

- The adaptor first delays either 0 or 51.2 μs, selected at random
- If this effort fails, it then waits 0, 51.2, 102.4, 153.6 μs (selected randomly) before trying again;
  - This is k * 51.2 for k = 0, 1, 2, 3
- After the third collision, it waits k * 51.2 for $k = 0 \ldots 2^3 - 1$ (again selected at random).
- In general, the algorithm randomly selects a k between 0 and $2^n - 1$ and waits for k * 51.2 μs, where n is the number of collisions experienced so far.

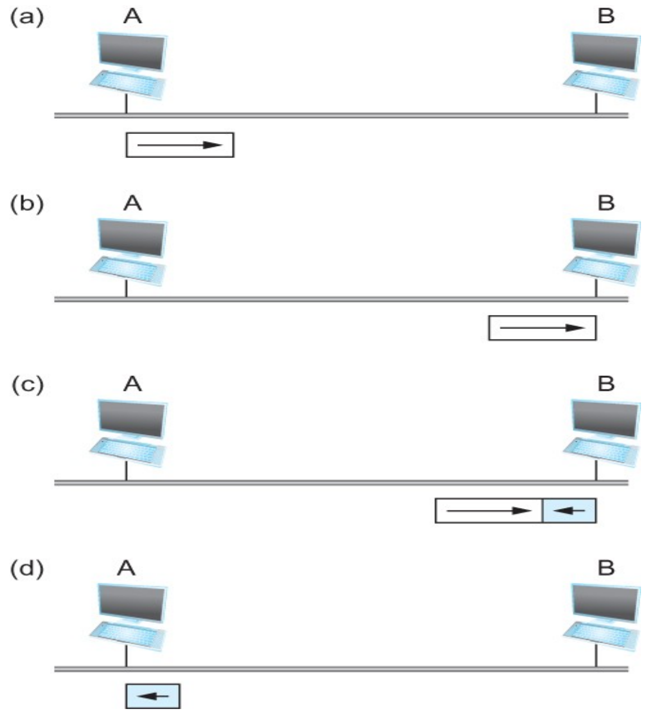
Ethernet Transmitter Algorithm

- An adaptor may begin transmitting at/near the same time
  - Either because both found the line to be idle,
  - Or, both had been waiting for a busy line to become idle.
- Simultaneously transmitted frames collide

- Each sender can detect collisions (CDMA/CS)
  - **Detection MUST happen during transmission**
  - Each transmits a 32-bit jamming sequence
  - Will minimally send **96** bits (*runt* frame)
    - 64-bit preamble + 32-bit jamming sequence
    - Works if hosts are close to each other

  - Worst case: transmitter may need to send up to **512** bits
    - Every Ethernet frame must be at least 512 bits (64 bytes) long.
    - 14 bytes of header + 46 bytes of data + 4 bytes of CRC

Ethernet Transmitter Algorithm



Worst-case scenario:

(a) A sends a frame at time *t;*

(b) A's frame arrives at B at time *t + d;*

(c) B begins transmitting at time t + d,
collides with A's frame;

(d) B's runt (32-bit) frame arrives at A at time *t + 2d.*

(e) A is no longer transmitting – so, it does nothing!

Ethernet Minimum Frame Size

- Ethernet max length = 2500 meters
- RTT in worst case is 51.2 μs, which corresponds to the transmission time of 512 bits
- Each ethernet frame MUST be at least 512 bits

Experience with Ethernet

- Ethernets work best under lightly loaded conditions.
  - Under heavy loads, too much of the network's capacity is wasted by collisions.
- Most Ethernets are far shorter than 2500m with a round-trip delay of closer to 5 μs than 51.2 μs.
- Ethernets are easy to administer and maintain.
  - There are no switches that can fail and no routing and configuration tables that have to be kept up-to-date.
  - Cable is cheap, and only other cost is the network adaptor on each host.

Wireless

- Wireless links transmit electromagnetic signals
  - Radio, microwave, infrared
- Wireless links all share the same “wire” (so to speak)
  - The challenge is to share it efficiently without unduly interfering with each other
  - Most of this sharing is accomplished by dividing the “wire” along the dimensions of frequency and space
- Exclusive use of a particular frequency in a particular geographic area may be allocated to an individual entity such as a corporation

Wireless Links

- Wireless technologies differ in a variety of dimensions
  - How much bandwidth they provide
  - How far apart the communication nodes can be

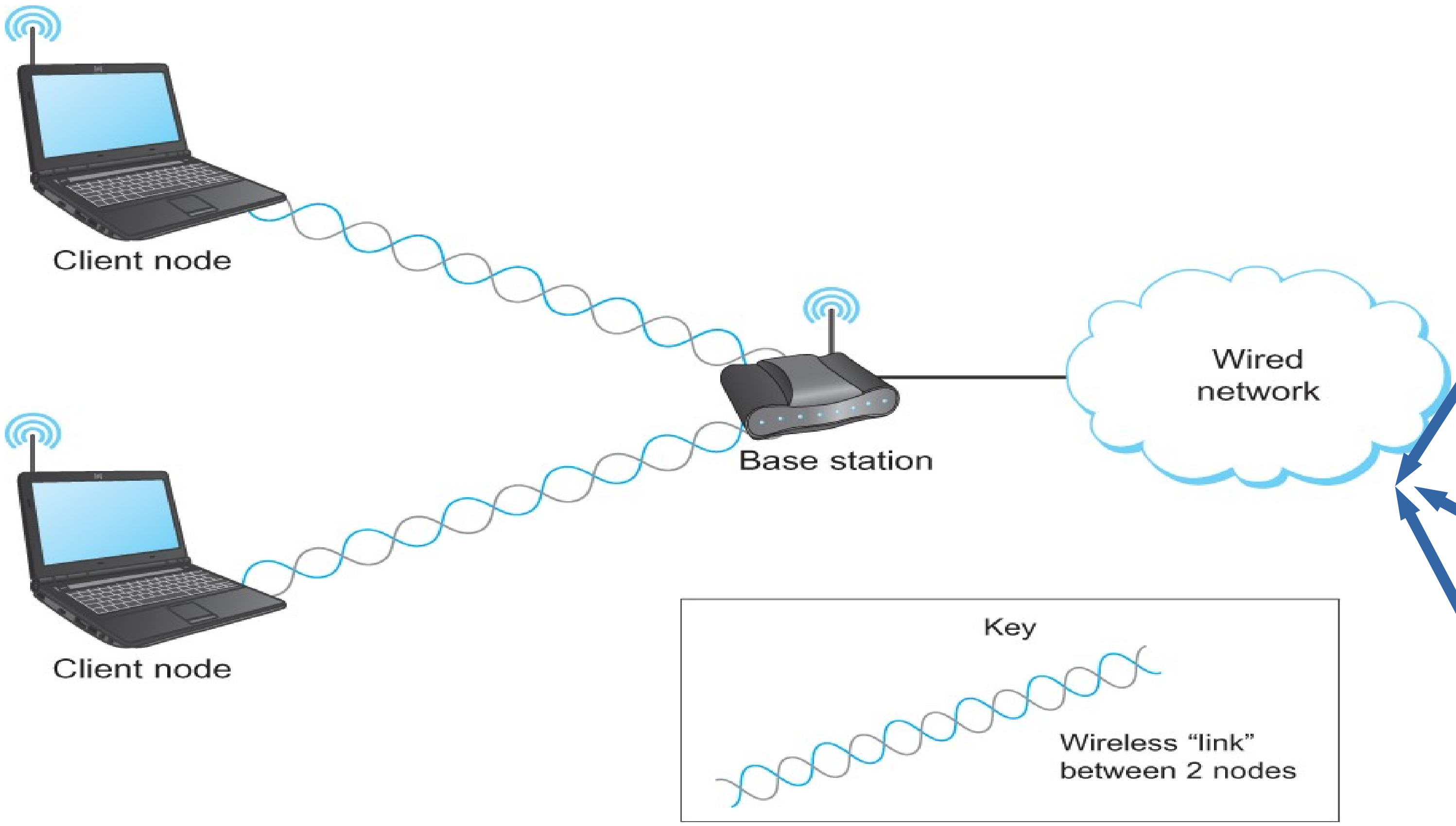
- Four prominent wireless technologies
  - Bluetooth
  - Wi-Fi (more formally known as 802.11)
  - WiMAX (802.16)
  - Cellular wireless (3/4/5G) – 6G anyone?

Wireless Links

	Bluetooth (802.15.1)	Wi-Fi (802.11)	3G Cellular
Typical link length	10 m	100 m	Tens of kilometers
Typical data rate	2 Mbps (shared)	54 Mbps (shared)	Hundreds of kbps (per connection)
Typical use	Link a peripheral to a computer	Link a computer to a wired base	Link a mobile phone to a wired tower
Wired technology analogy	USB	Ethernet	DSL

Overview of leading wireless technologies

Wireless Links - Infrastructure



A wireless network using a base stat

Typically connects to Base stations

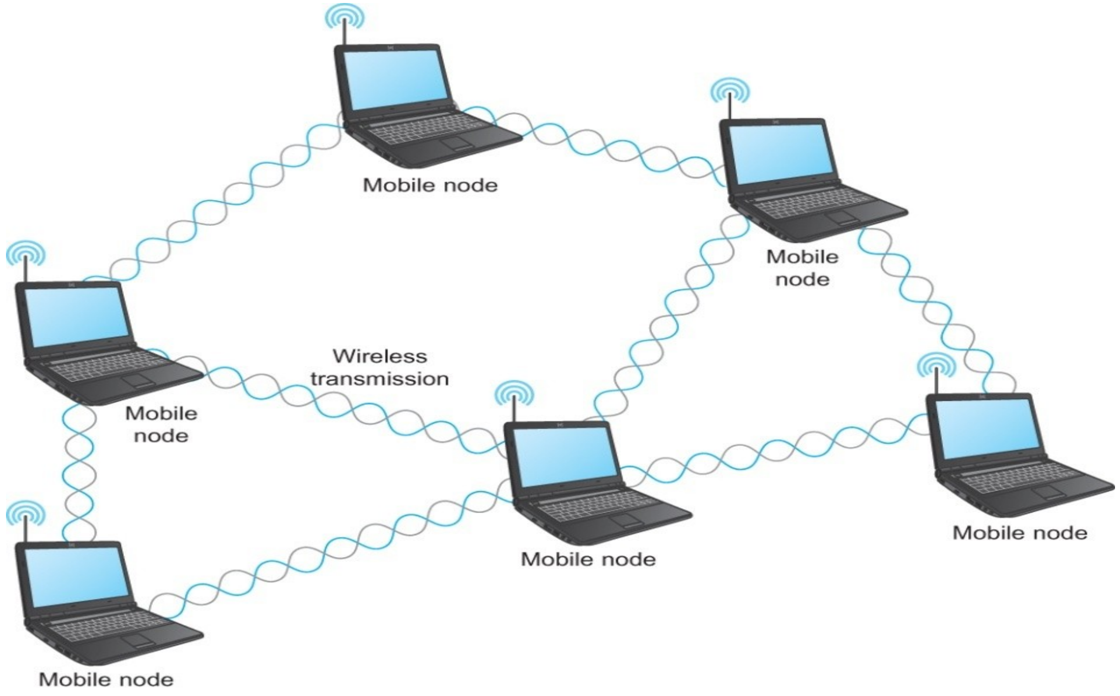
Multiple access

Handoff protocols

Wireless != Mobile

Wireless Links – Ad hoc

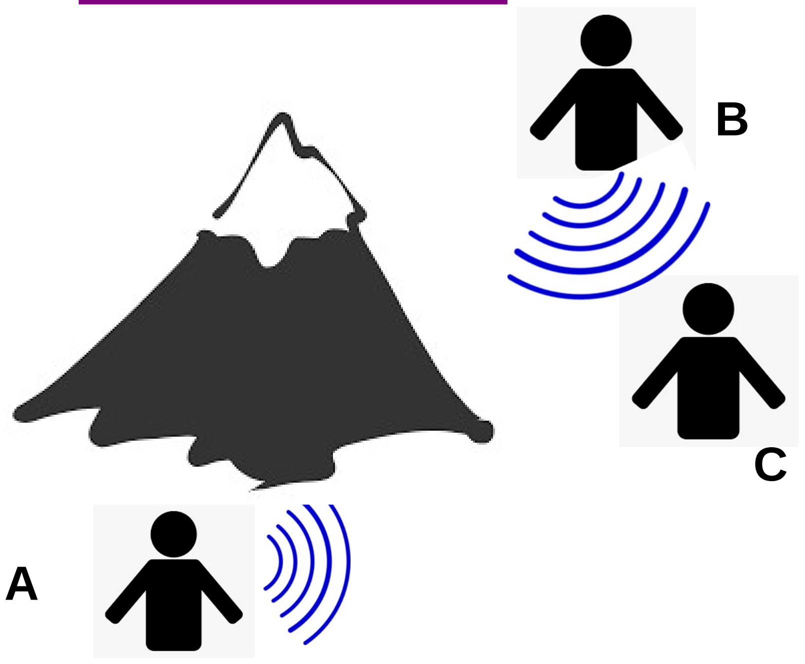
- Mesh or Ad-hoc network
  - Nodes are peers
  - Messages may be forwarded via a chain of peer nodes



Wireless Links – Characteristics

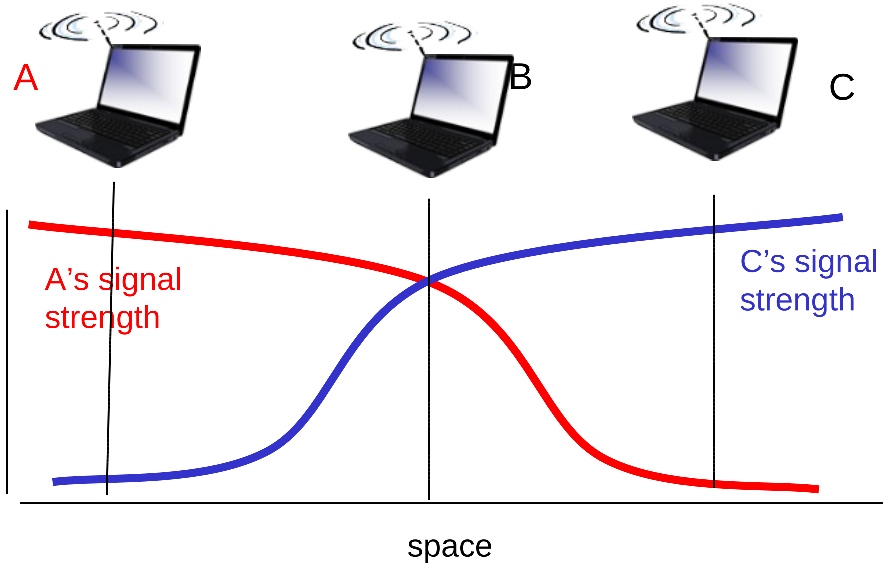
- Difference from wired?
  - Decreased signal strength (radio signals travel through the atmosphere)
  - Interference (Other signals interfere, microwave, phones, each other)
  - Multipath and noise
    - Reflects of objects

Wireless Links – other problems



Hidden terminal

Signal Fading



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

WiFi – 802.11 Wireless Lan

802.11 b
- 2.4-5 GHZ unlicensed spectrum
- Divided into 11 (or 13) channels
- Widely deployed
- Uses base stations, 11Mbps

802.11 G

54Mbps

802.11 N

450Mbps

802.11 A/C

1.3 Gbps

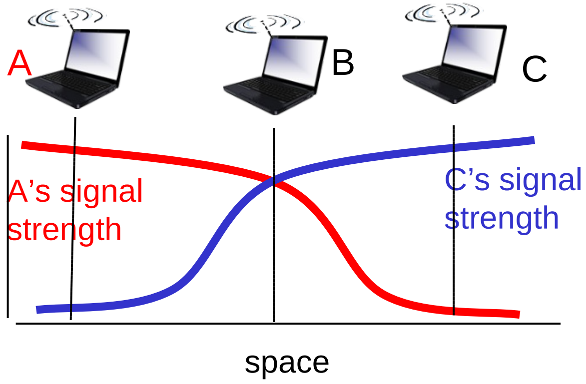
All use base station or ac-hoc versions

All use CSMA/CA for multiple access

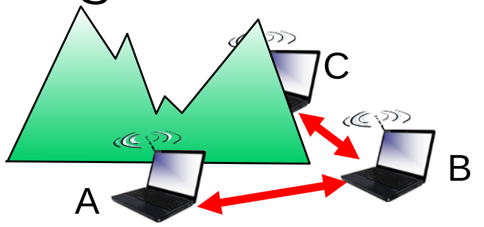
802.11 – CSMA/Collision Avoidance (CA)

- **802.11: no collision detection! Why?**
  - It won't work anyway, hidden node, signal fading
- **Avoid Collisions**
- **CSMA - sense before transmitting**

IEEE 802.11: Multiple Access



- Avoid collisions: 2+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/C(ollision)A(voidance)



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

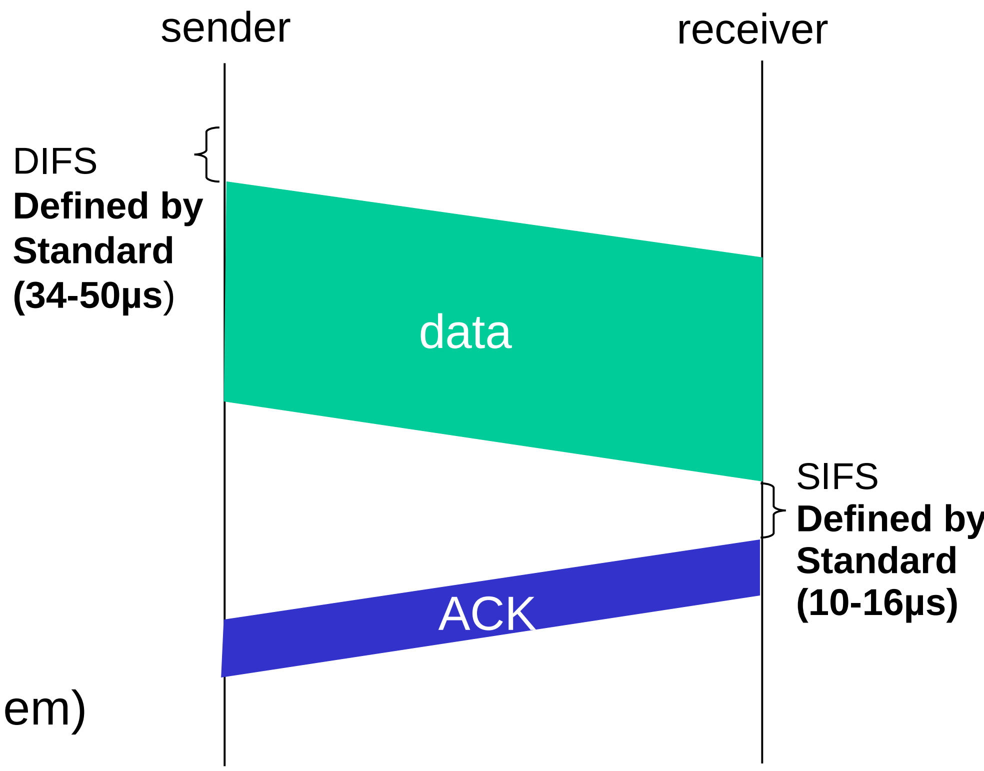
if no ACK, increase random backoff interval, repeat 2

802.11 receiver

- if frame received OK

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

DIFS = SIFS + (2 * Slot time)



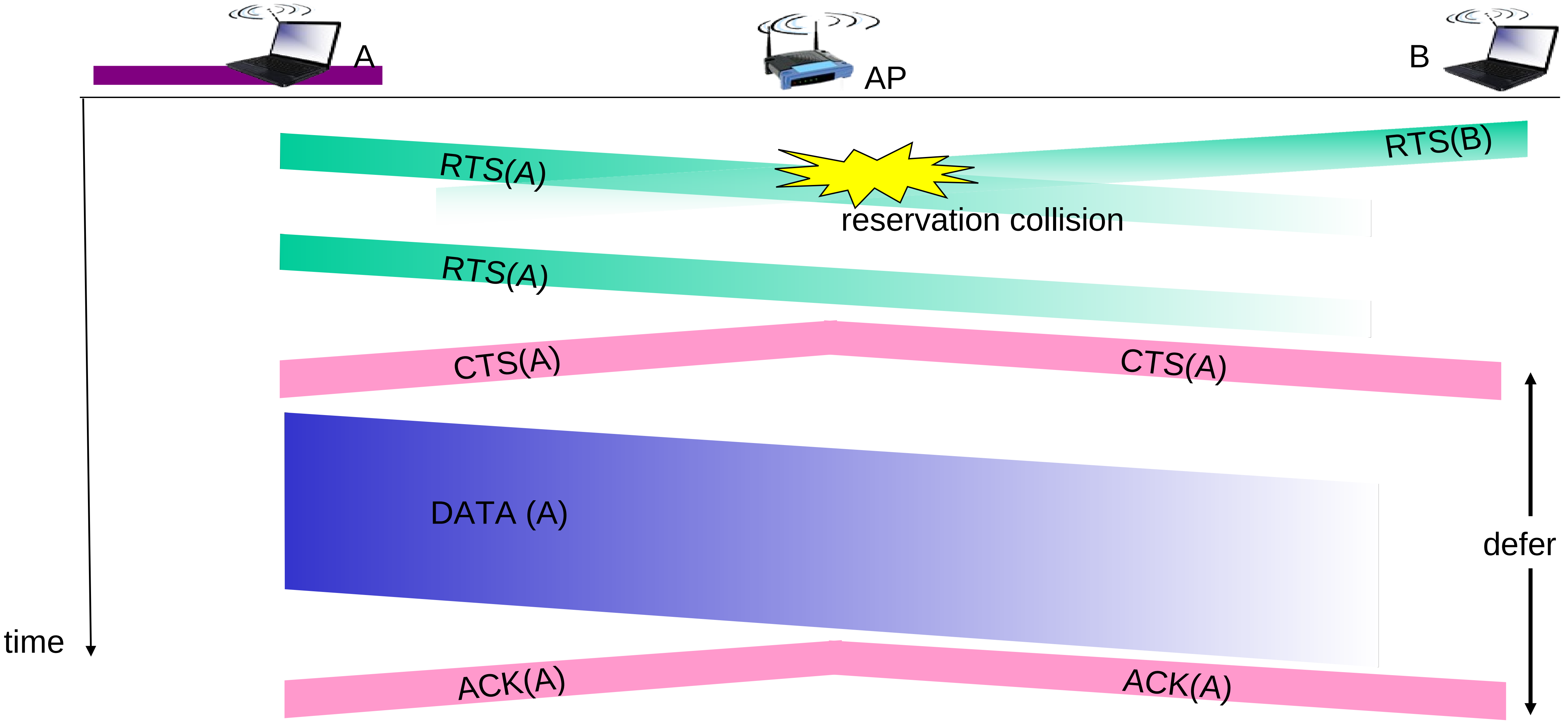
Avoiding collisions – Reserve before Send

idea: allow sender to "reserve" channel rather than random access

- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



802.11 frame: Addressing

2	2	6	6	6	2	6	0 - 2312	4
frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC

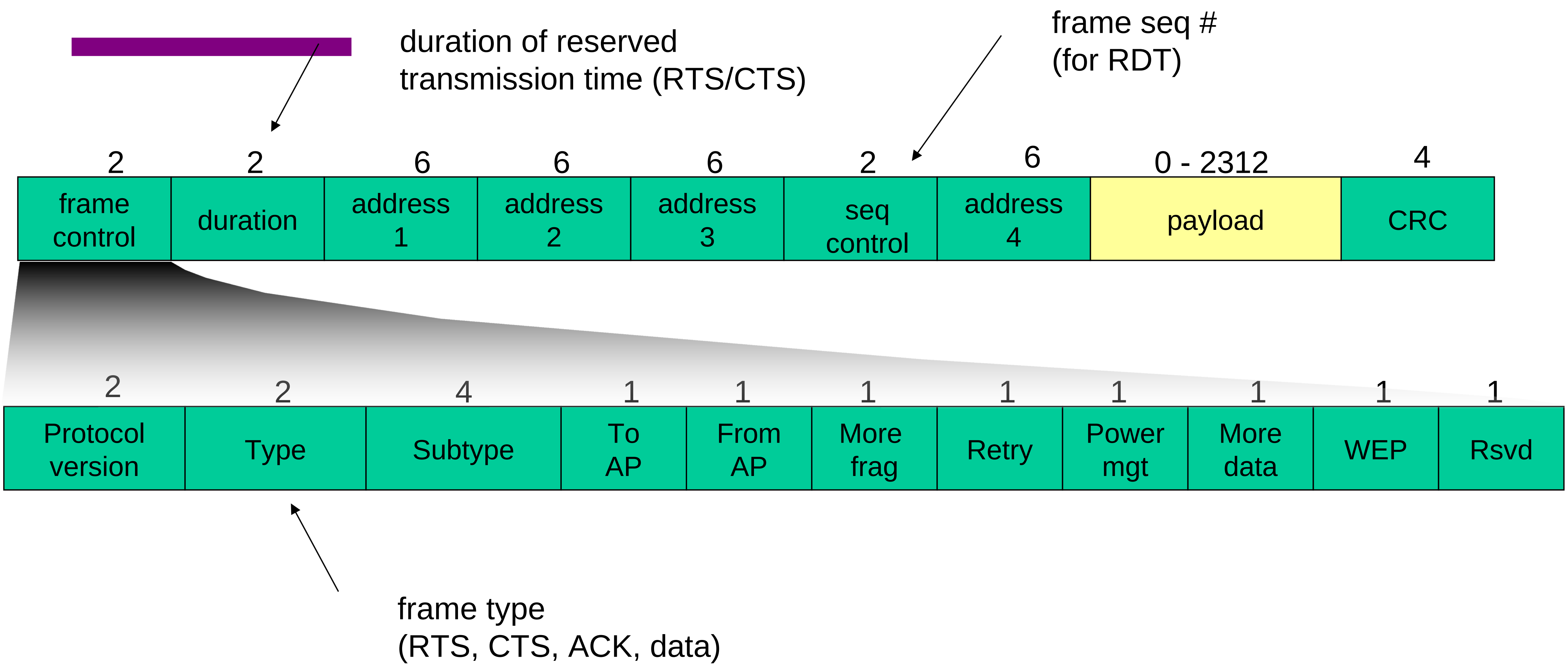
Address 4: used only in ad hoc mode

Address 1: MAC address of wireless host or AP to receive this frame

Address 3: MAC address of router interface to which AP is attached

Address 2: MAC address of wireless host or AP transmitting this frame

802.11 frame: More

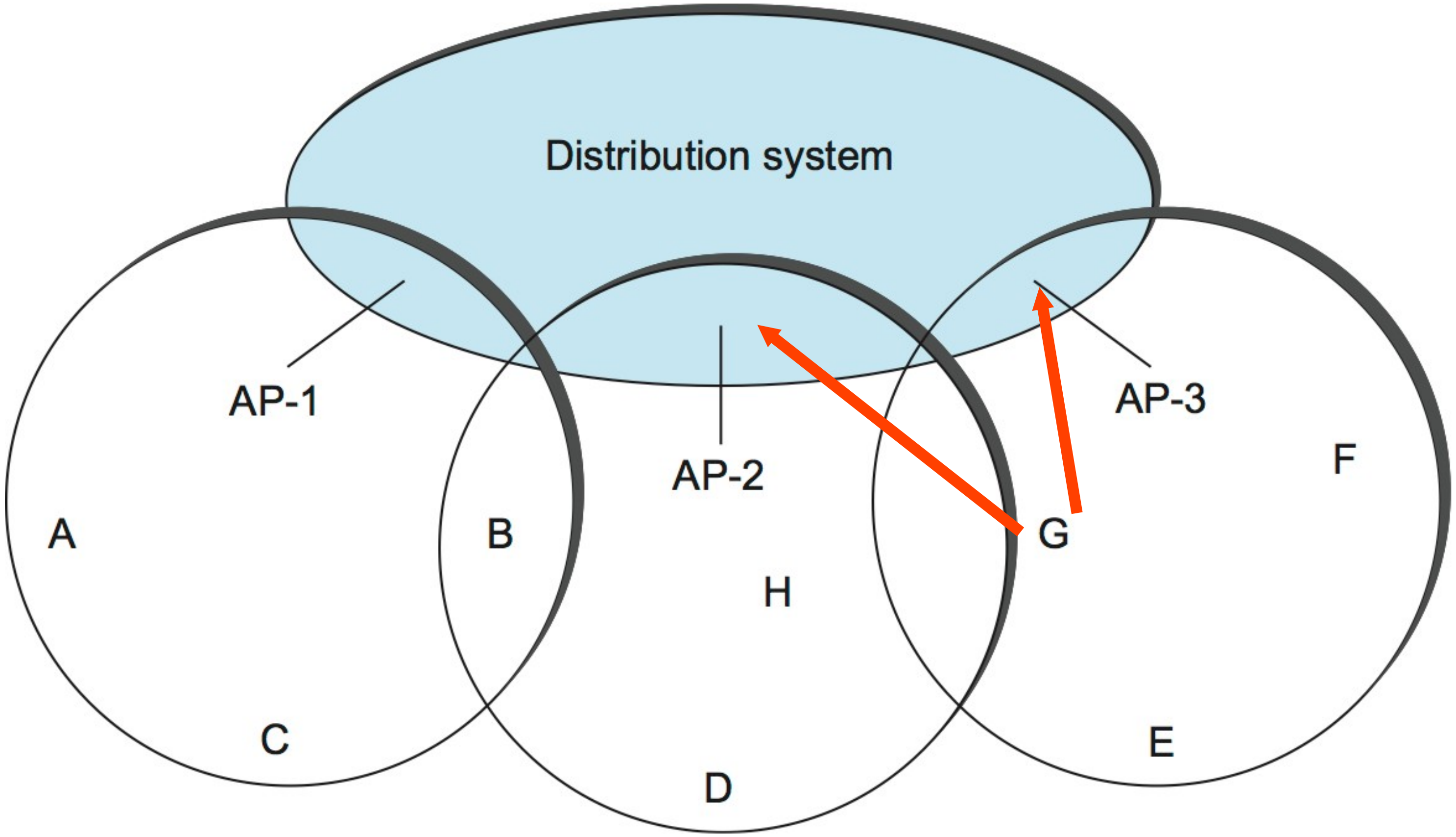


Wireless – How do nodes communicate?

Two modes:

- Infrastructure mode
- Ad-hoc mode

Wireless – Infrastructure Mode



A node (e.g., **G**) sends a Probe frame.

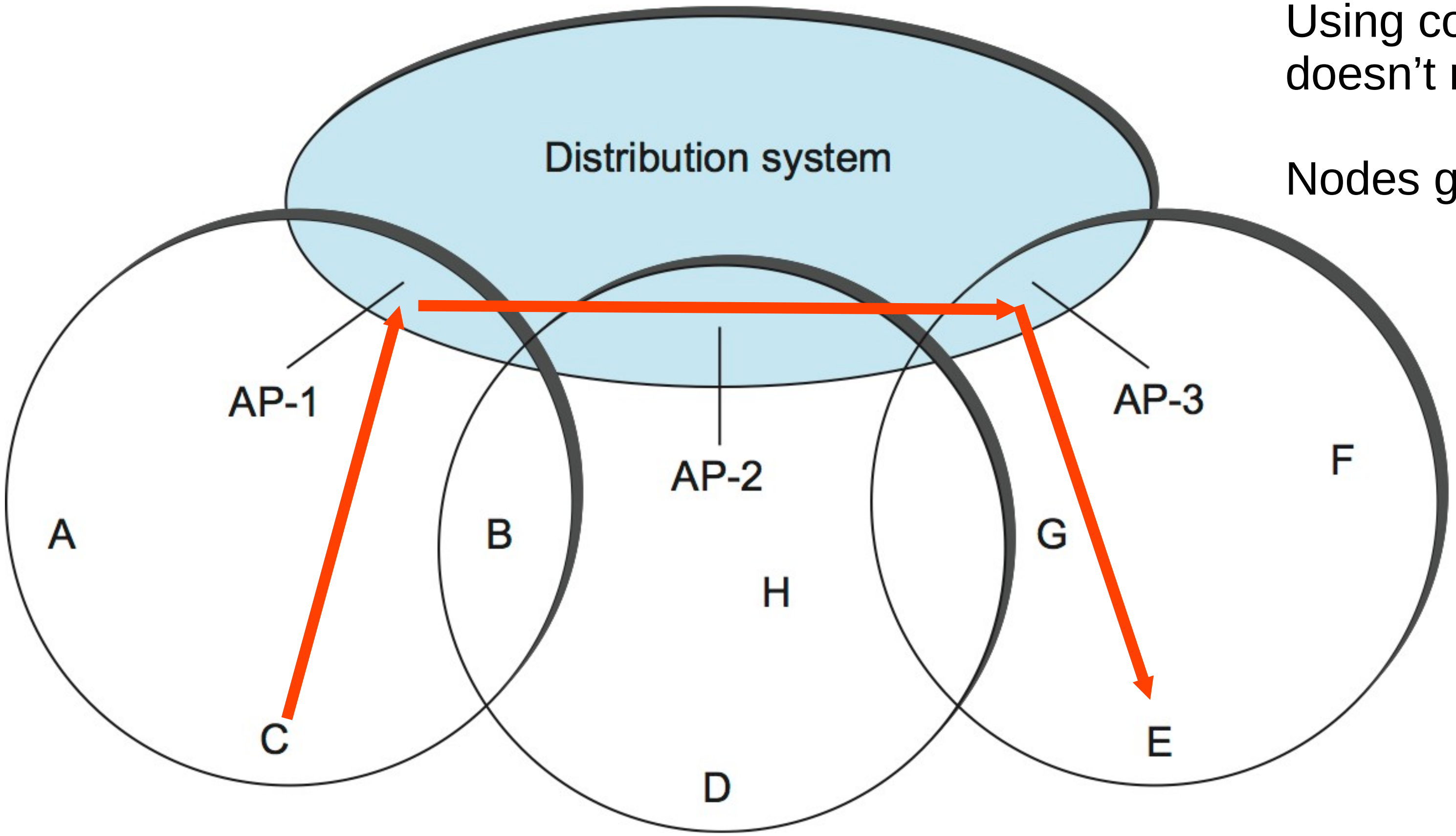
All APs within reach reply with a Probe Response frame.

The node selects one of the access points

The node sends that AP an Association Request frame.

The AP replies with an Association Response frame.

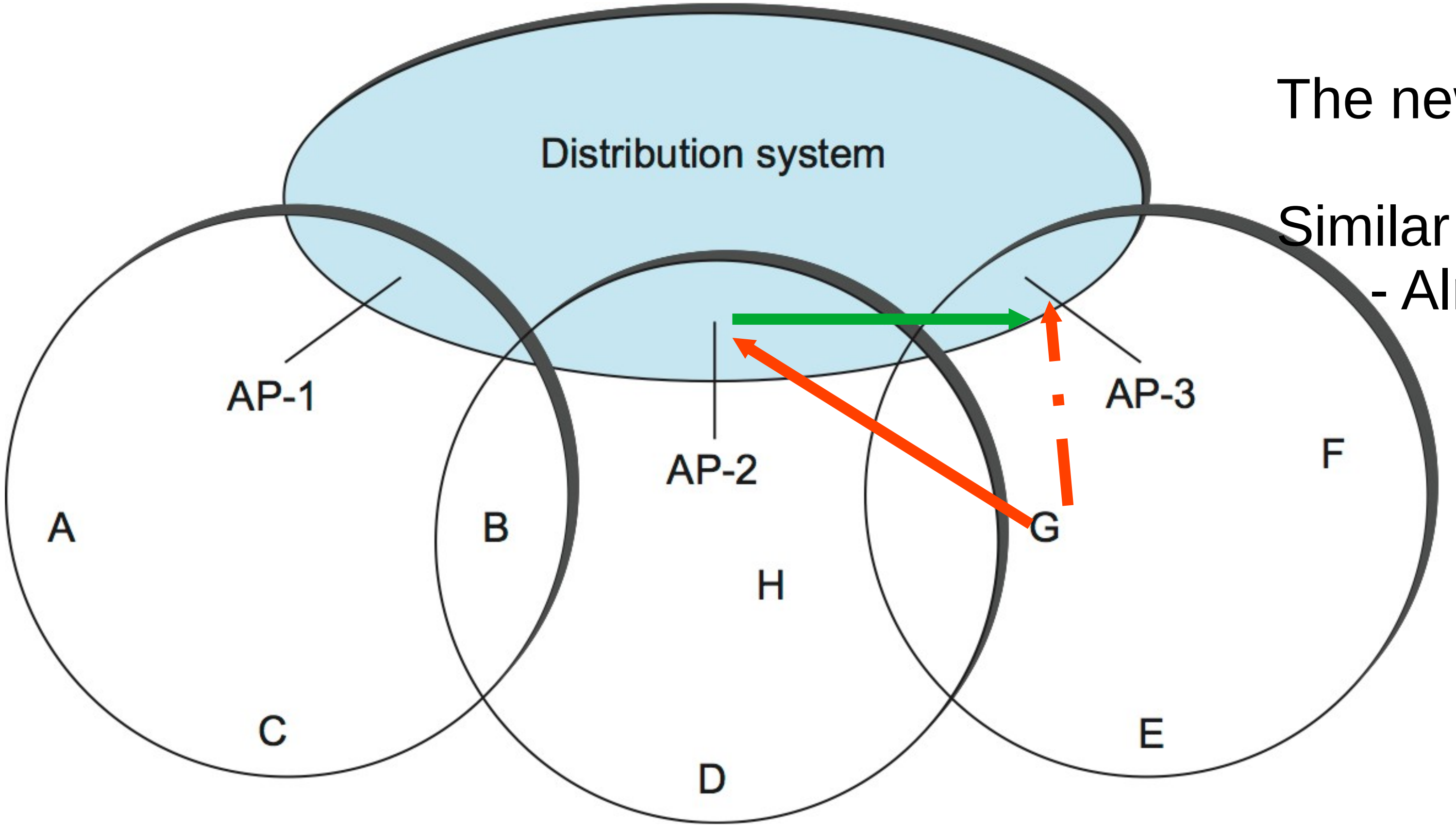
Wireless – Communication



Access points are connected
Using copper/fiber/wifi –
doesn’t matter

Nodes go through APs

Wireless – Handover

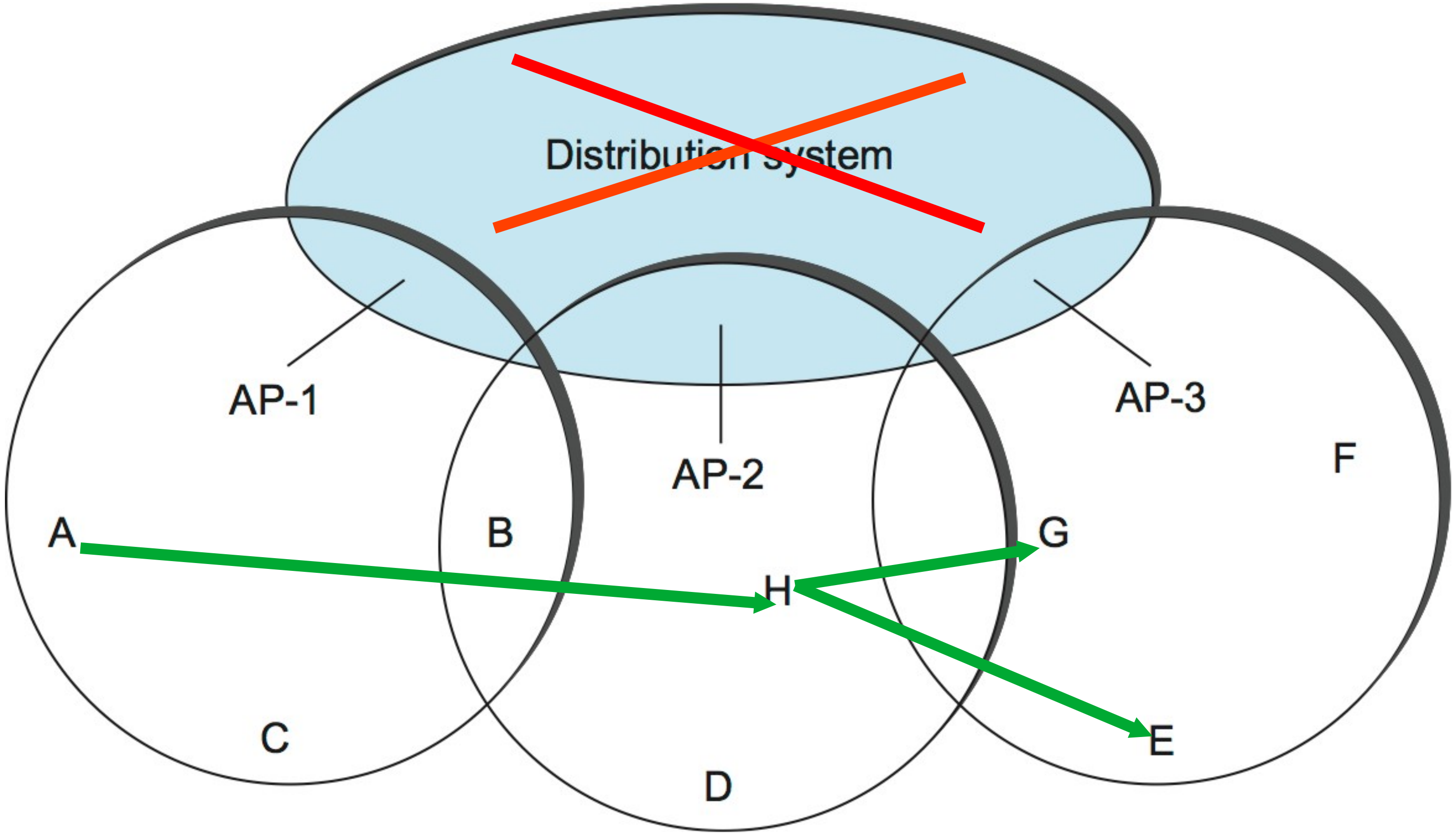


Node chooses a new AP

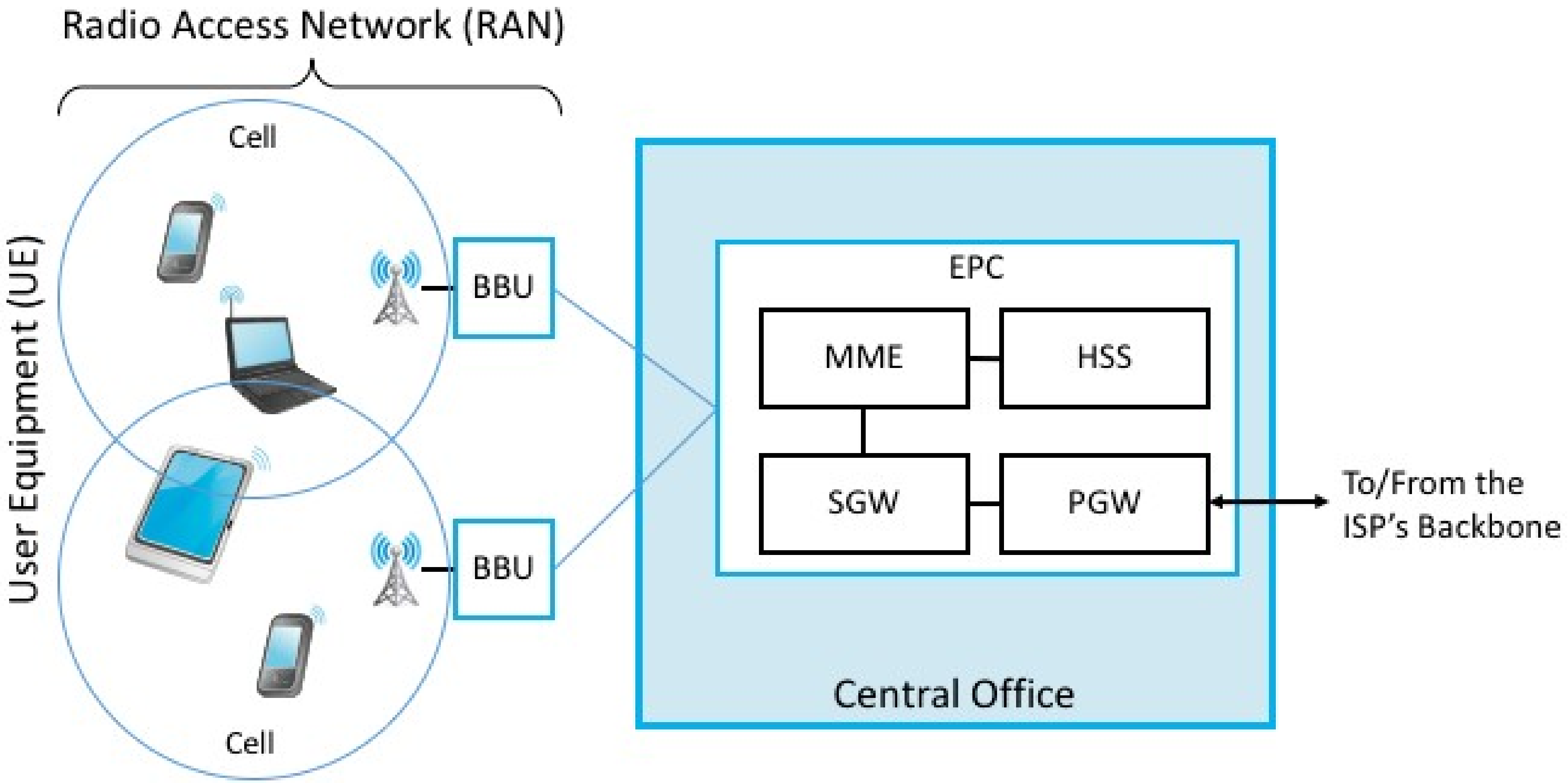
The new AP notifies old AP

Similar in mobile networks
- Almost similar

Ad-hoc Mode



Mobile Networks – 4G LTE



Reading Assignment

- Ethernet
  - Chapter 2.6
    - 30-40 minutes read

- Wireless:
  - Chapter 2.7.1

- Mobile/Access Network
  - https://book.systemsapproach.org/direct/access.html#cellular-network
  - Ignore PON
  - Read from “While cellular telephone technology had its roots” to “in the process of transitioning to 5G (with the promise of a tenfold increase in data rates).”

Link Layer Recap – All this for a cat picture