Last Lecture: Data Link Layer

1. *Design goals and issues*
2. *(More on) Error Control and Detection*
3. *Multiple Access Control (MAC)*
4. *Ethernet, LAN Addresses and ARP*
5. *Hubs, Bridges, Switches* ✔
6. *Wireless LANs*
7. WLAN Security
8. Mobile Networking

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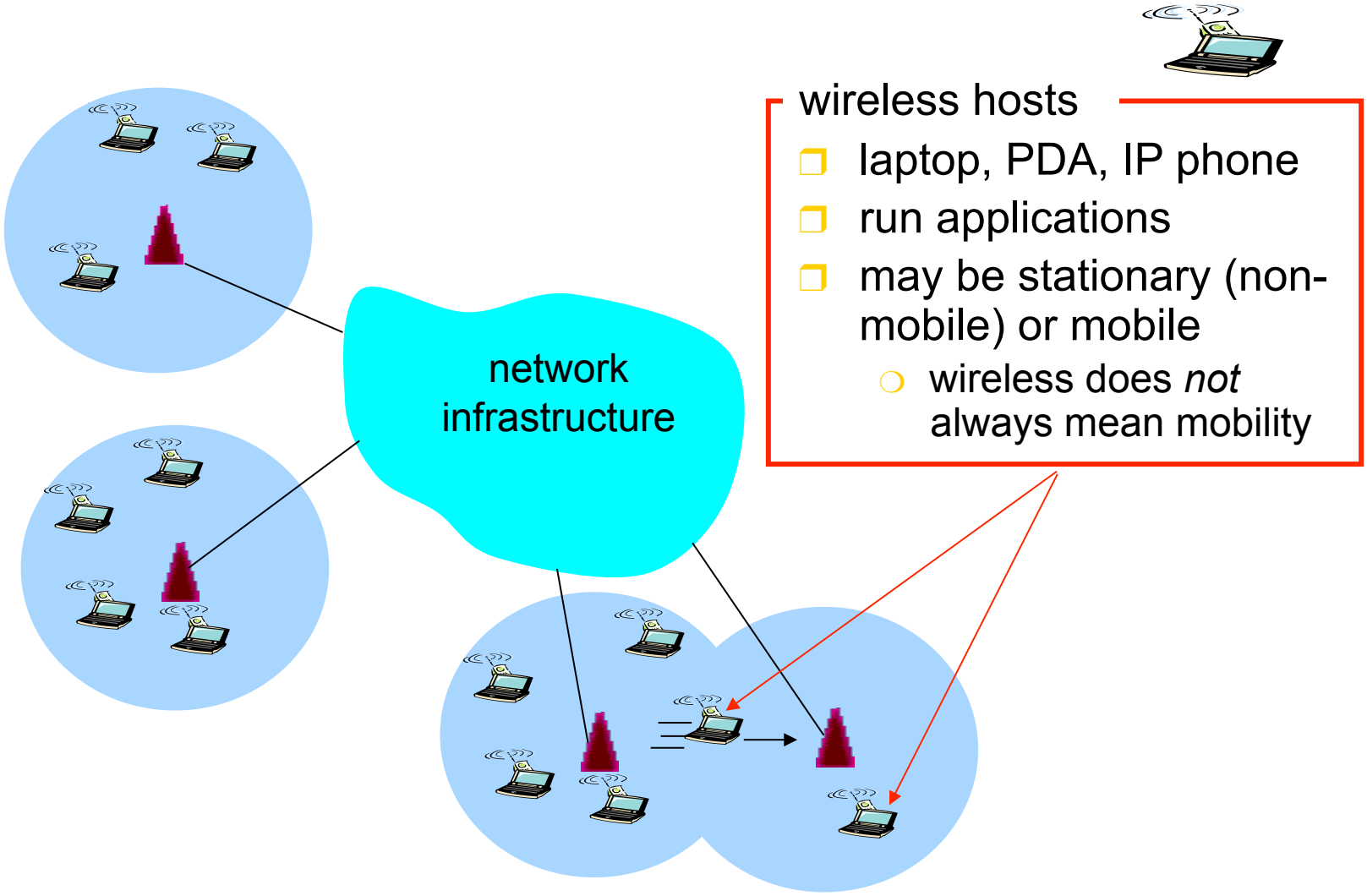
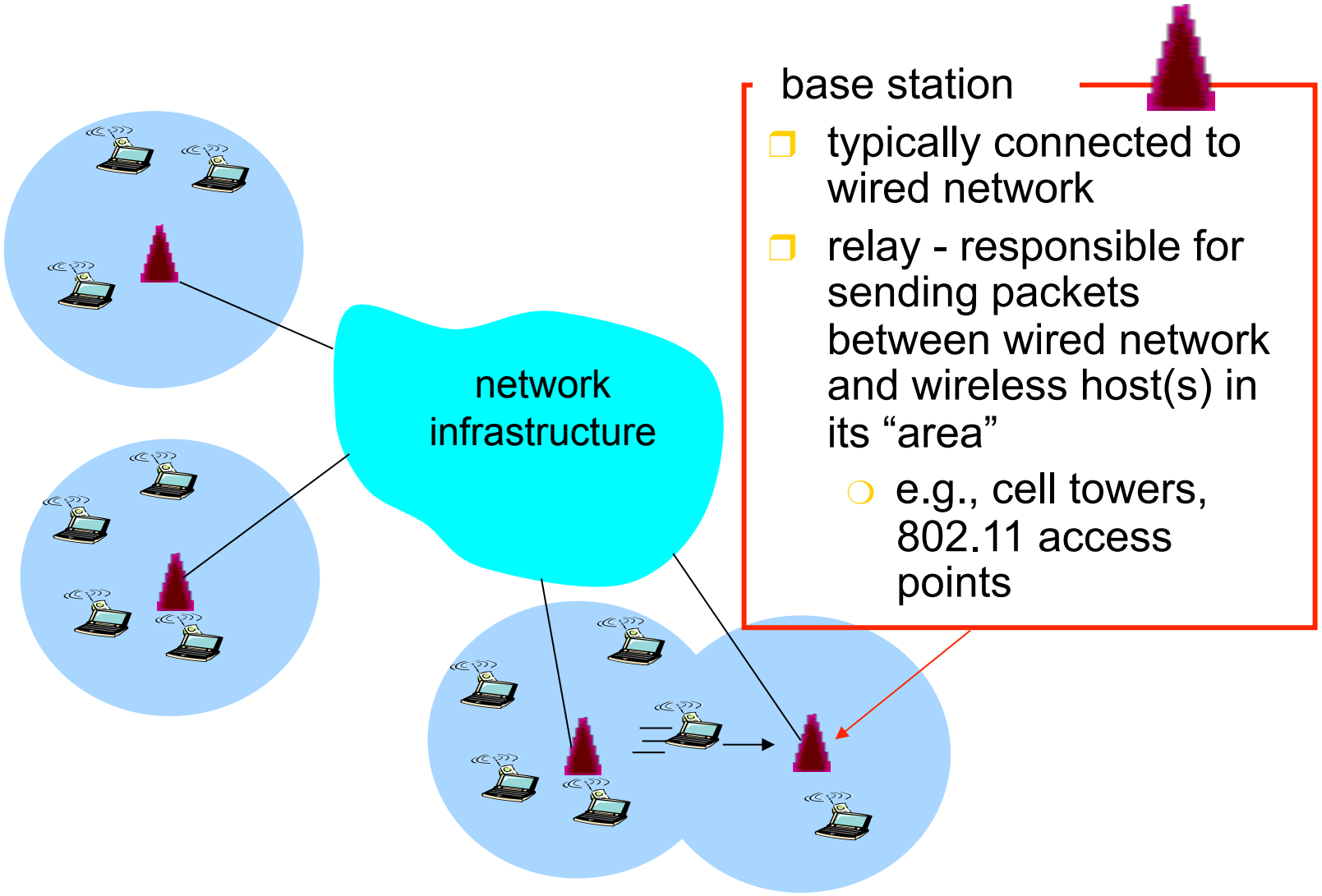
Brief Introduction to Wireless Networks



Elements of a wireless network



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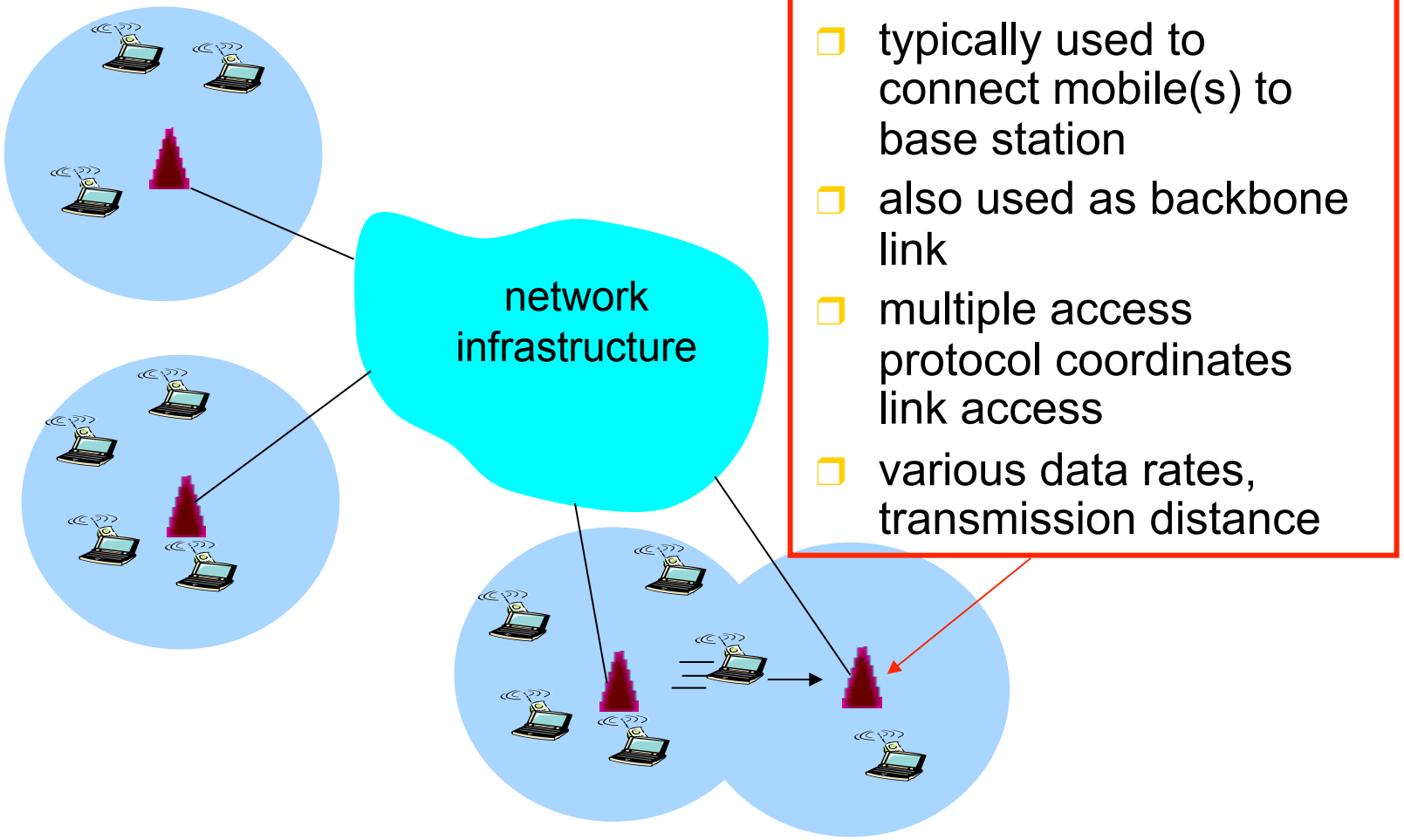
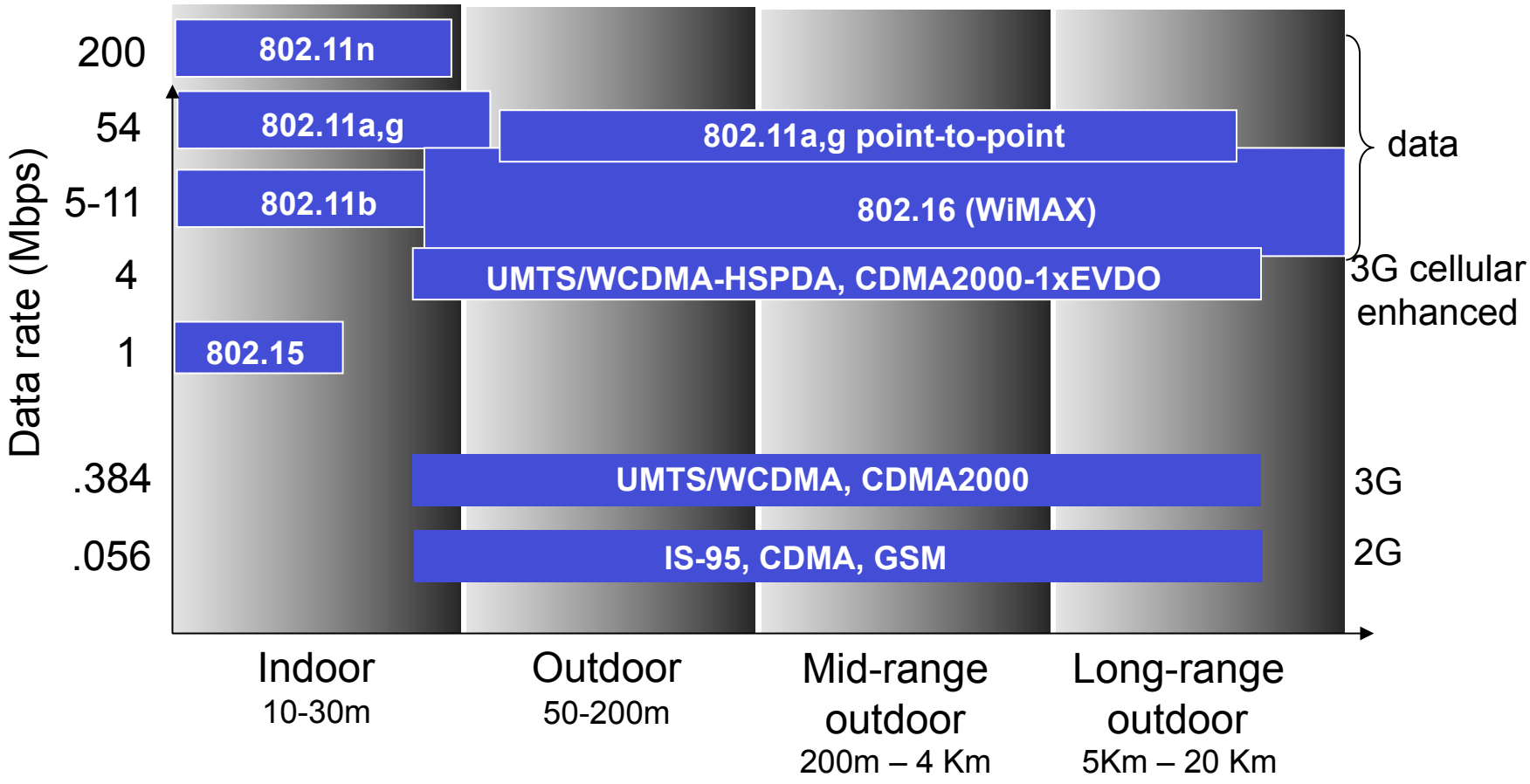


Characteristics of selected wireless link standards



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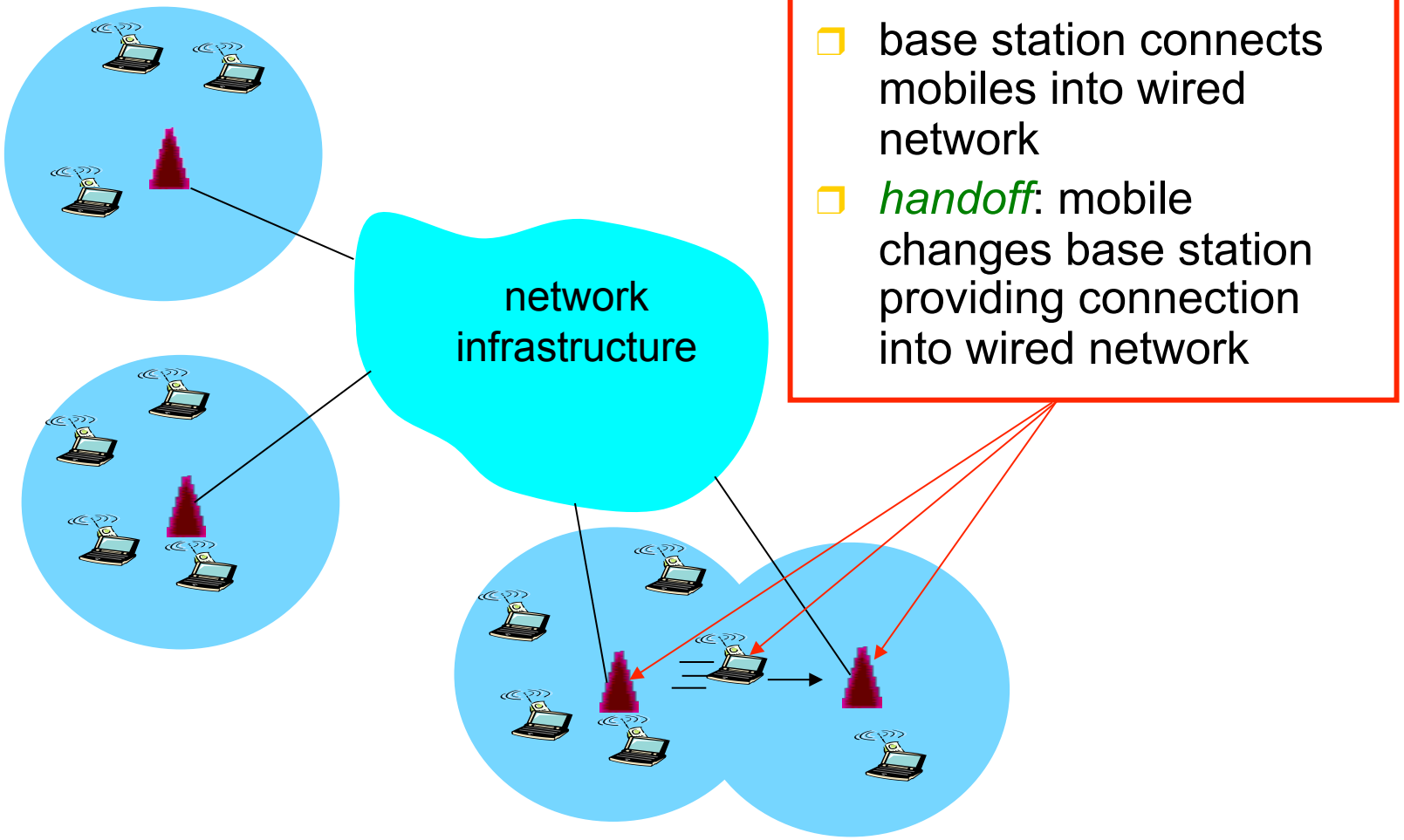

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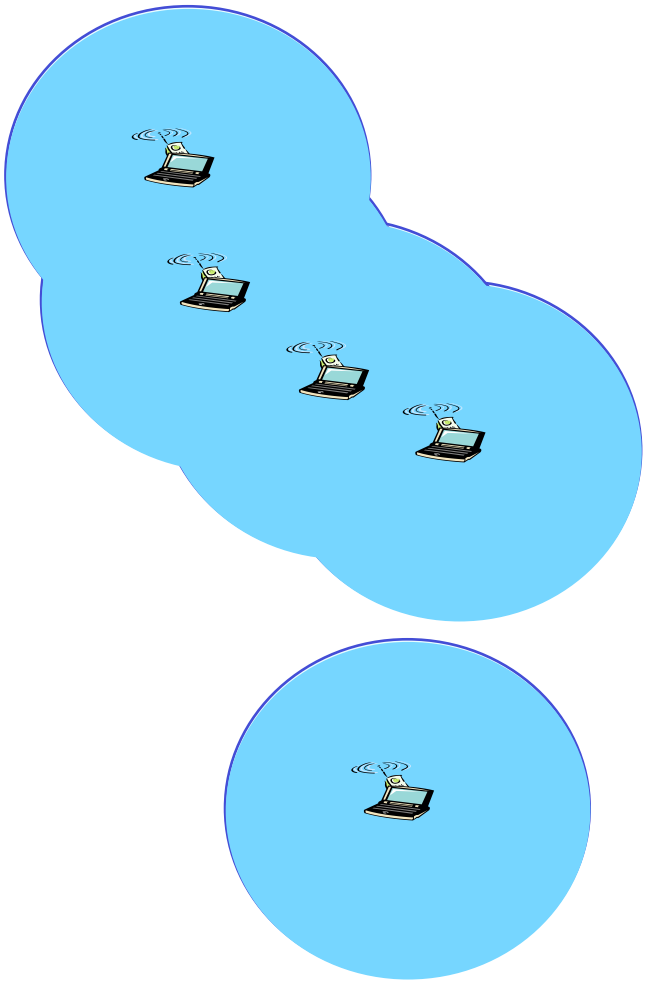


ad hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

Wireless Networks Taxonomy

	Infrastructure-based	Infrastructure-less
Single hop	Base station connected to larger wired network (e.g., WiFi wireless LAN, and cellular telephony networks)	No wired network; one node coordinates the transmissions of the others (e.g., Bluetooth, and ad hoc 802.11)
Multi-hop	Base station exists, but some nodes must relay through other nodes (e.g., wireless sensor networks, and wireless mesh networks)	No base station exists, and some nodes must relay through others (e.g., mobile ad hoc networks, like vehicular ad hoc networks)

Going Wireless: Widespread Deployment

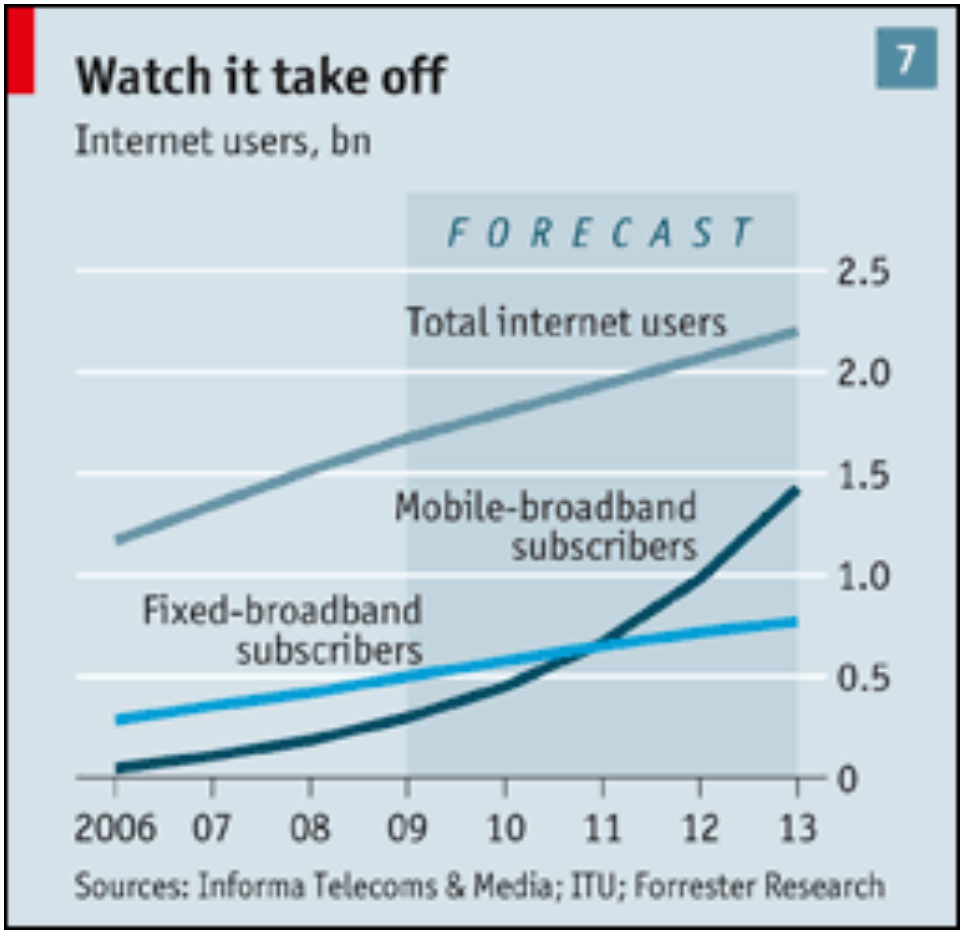
- Worldwide cellular subscribers
  - 1993: 34 million
  - 2005: more than 2 billion
  - *2009: more than 4 billion*
  - More than landline subscribers

- Wireless LANs
  - Wireless adapters built in to most laptops, and even PDAs
  - > 286,000 known WiFi locations in > 134 countries
  - Probably many, many more (e.g., home networks, corporate networks, …)

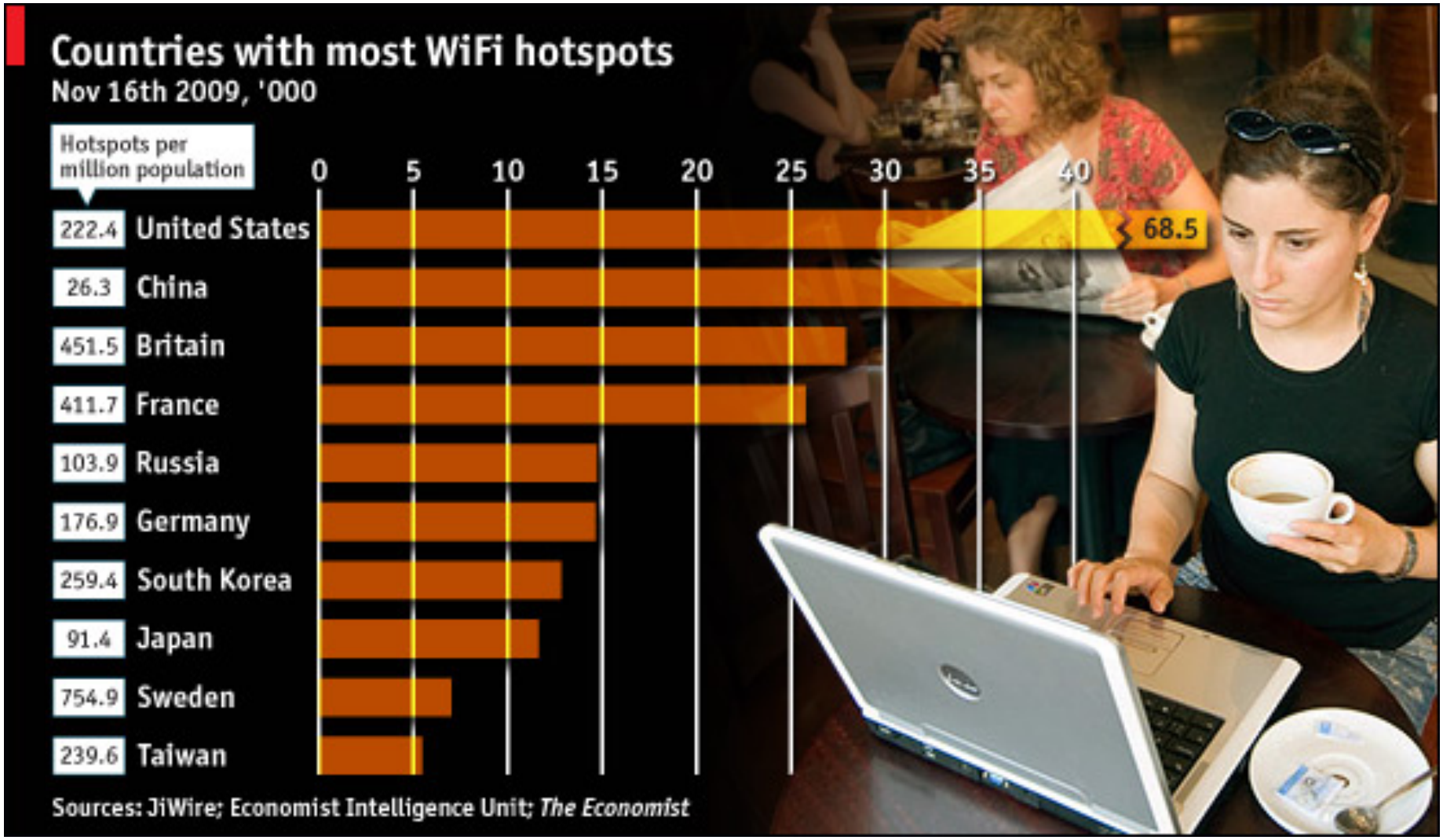
http://www.economist.com/daily/chartgallery/displaystory.cfm?story_id=14896700

Everyone on earth has a cell phone?

- In 10 years or so
  - http://www.economist.com/specialreports/displaystory.cfm?story_id=14483856



Wifi Hotspots Everywhere



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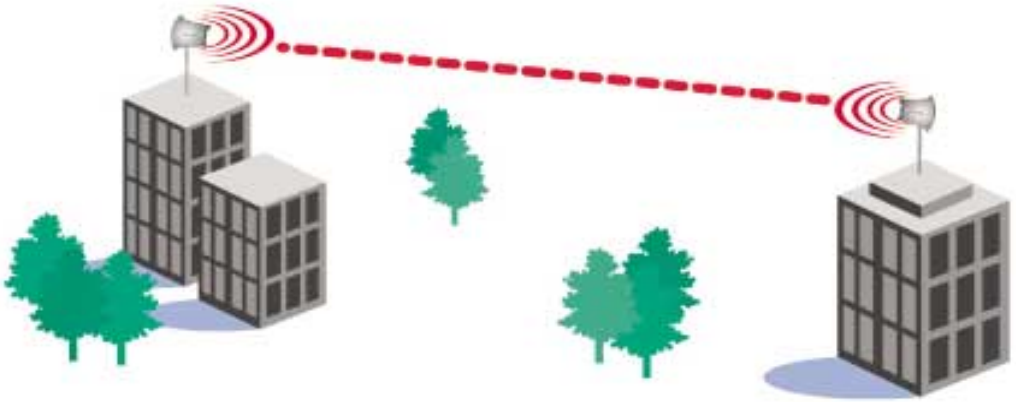
Wireless Networking: Challenges

- *Wireless links*: unique link characteristics
  - High, time-varying bit-error rate
  - Broadcast where some nodes can't hear each other
- *Mobility*: addressing and routing challenges
  - Keeping track of the host's changing attachment point
  - Maintaining a data transfer as the host moves
- We only have time for one specific example:
  - Wireless: 802.11 wireless LAN (aka "WiFi")

Wireless Links: High Bit Error Rate (BER)

- Decreasing signal strength
  - Disperses as it travels greater distance
  - Attenuates as it passes through matter

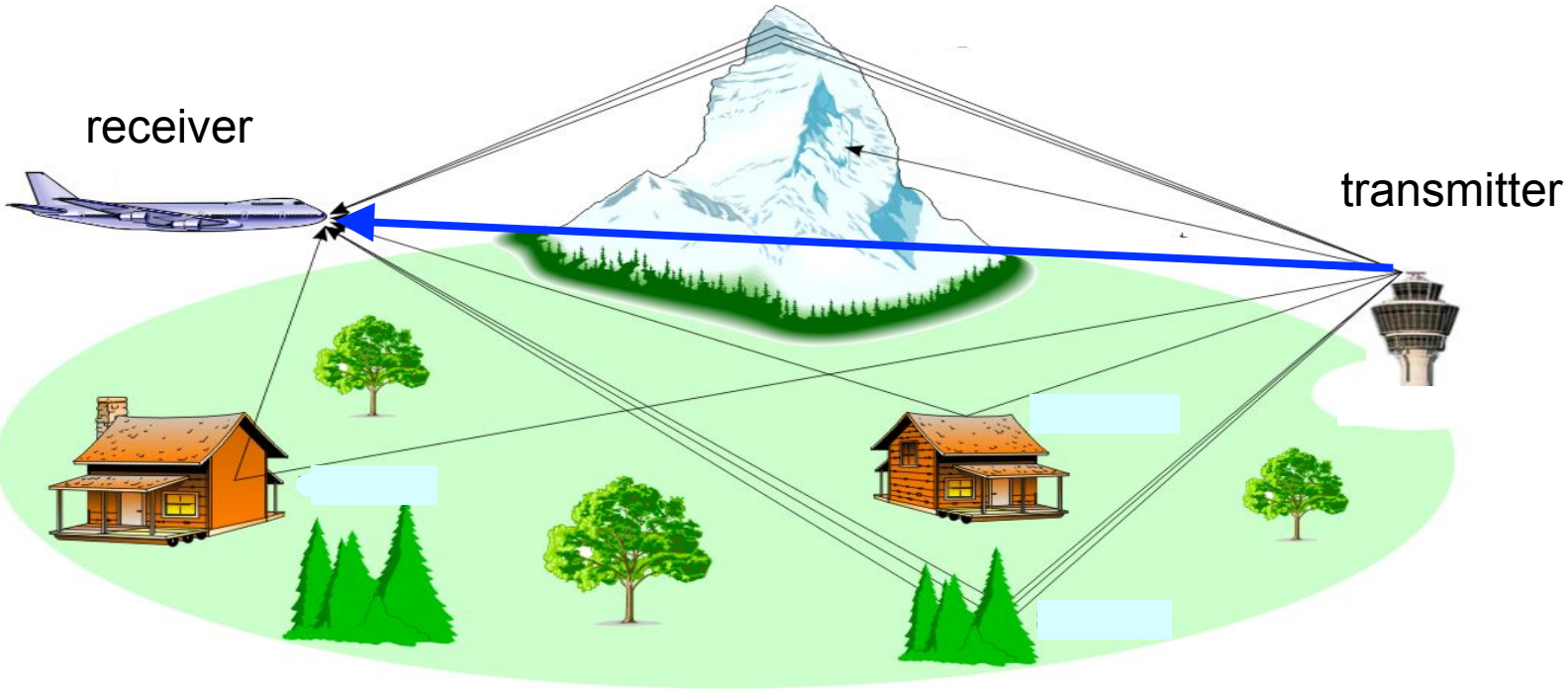


Wireless Links: High Bit Error Rate

- *Interference from other sources*
  - Radio sources in same frequency band
  - E.g., 2.4 GHz wireless phone interferes with 802.11b wireless LAN
  - Electromagnetic noise (e.g., microwave oven)

Wireless Links: High Bit Error Rate

- *Multi-path propagation*
  - Electromagnetic waves reflect off objects
  - Taking many paths of different lengths
  - Causing blurring of signal at the receiver

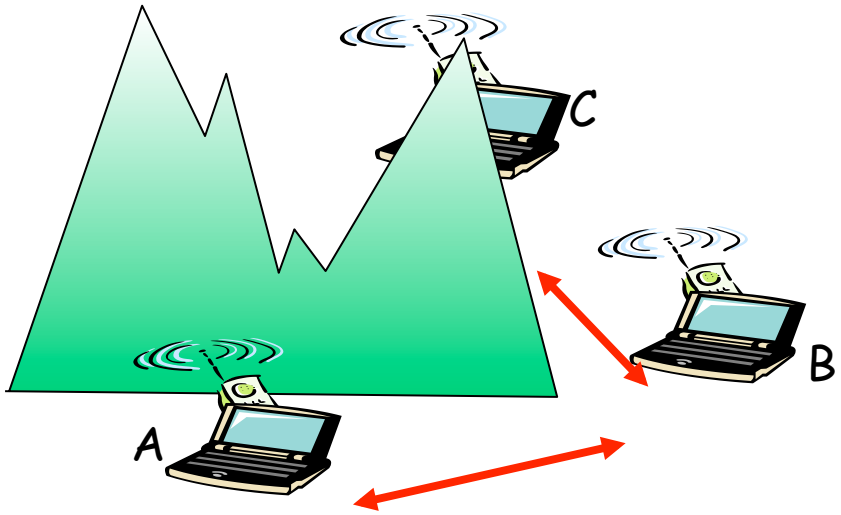


Dealing With Bit Errors

- Wireless vs. wired links
  - Wired: most loss is due to congestion
  - Wireless: *higher*, time-varying bit-error rate
- Dealing with high bit-error rates
  - Sender could increase transmission power
    - Requires more energy (bad for battery-powered hosts)
    - Creates more interference with other senders
  - Stronger error detection and recovery
    - More powerful error detection codes
    - Link-layer retransmission of corrupted frames

Wireless Links: Broadcast Limitations

- Wired broadcast links
  - E.g., Ethernet bridging, in wired LANs
  - All nodes receive transmissions from all other nodes
- Wireless broadcast: *hidden terminal problem*



- A and B hear each other
- B and C hear each other
- But, A and C do not

So, A and C are unaware of their interference at B.

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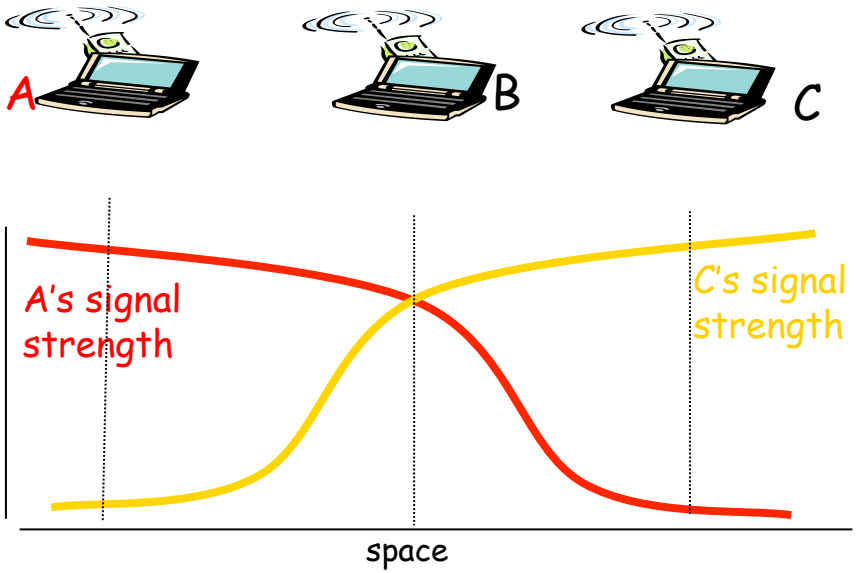

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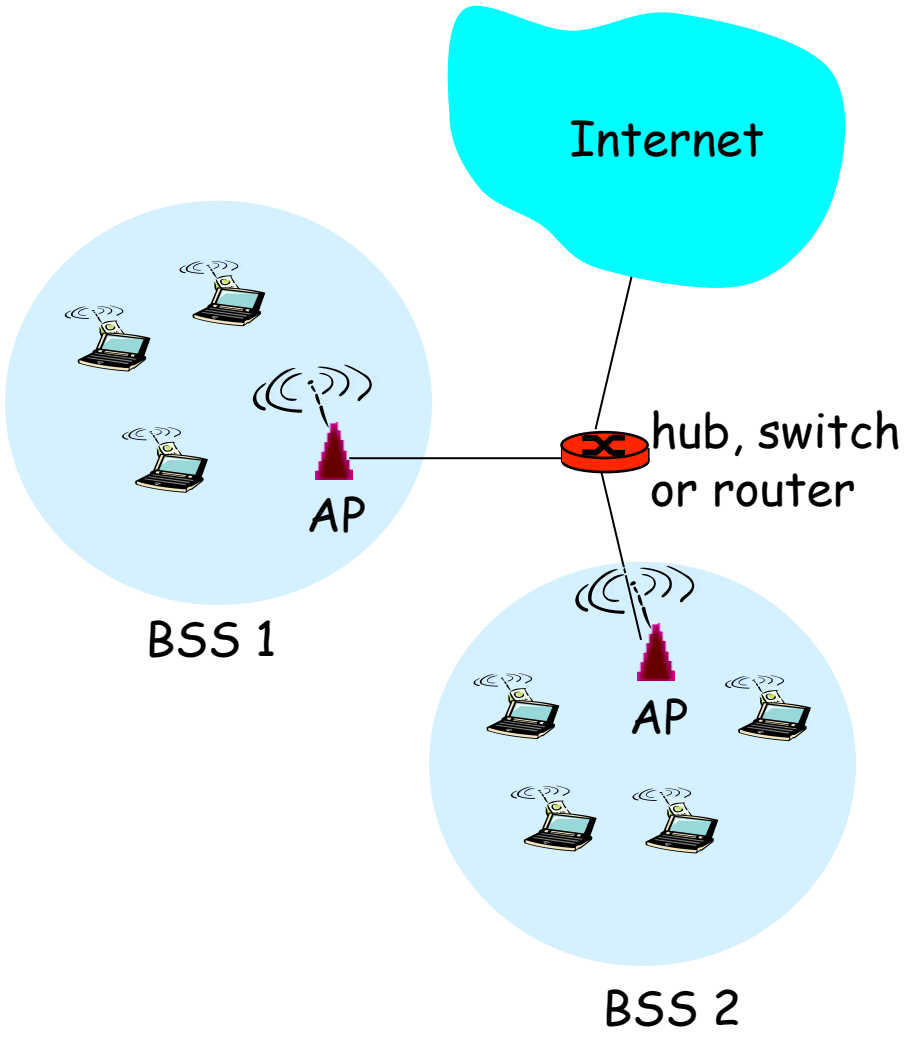
IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-5 GHz unlicensed spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code
- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps
- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps
- 802.11n: multiple antennae
  - 2.4-5 GHz range
  - up to 200 Mbps

- all use CSMA/CA for multiple access
- all have base-station and ad-hoc network versions

802.11 WLAN Architecture

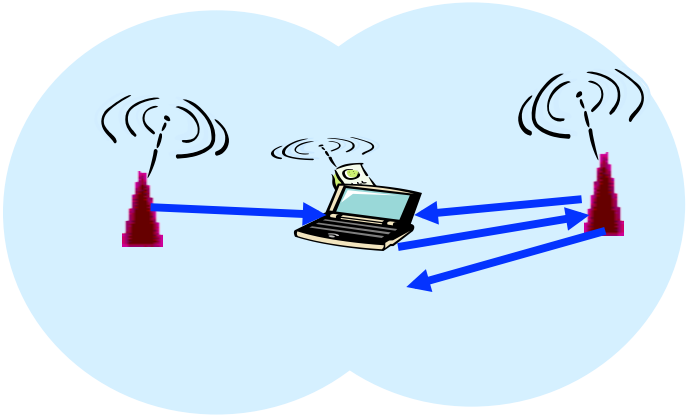


- Access Point (AP)
  - Base station that communicates with the wireless hosts
- Basic Service Set (BSS)
  - Coverage of one AP
  - AP acts as the master
  - Identified by a "network name" known as an SSID

SSID: Service Set Identifier

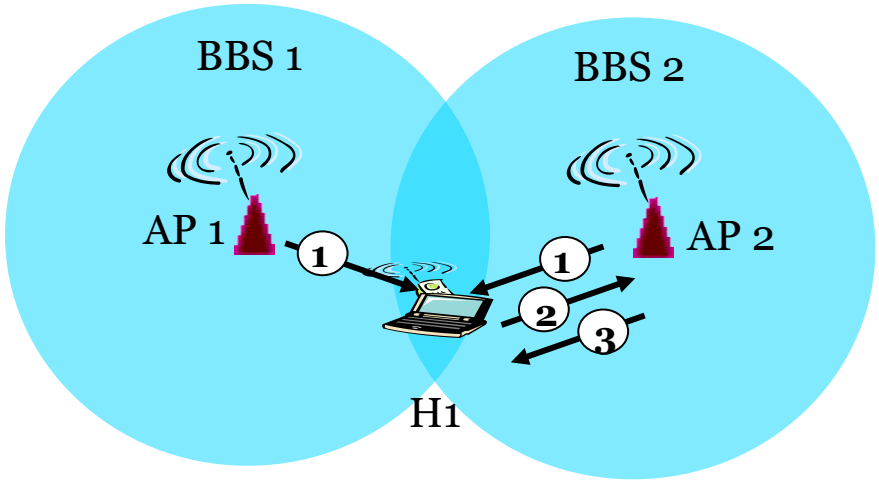
Channels and Association

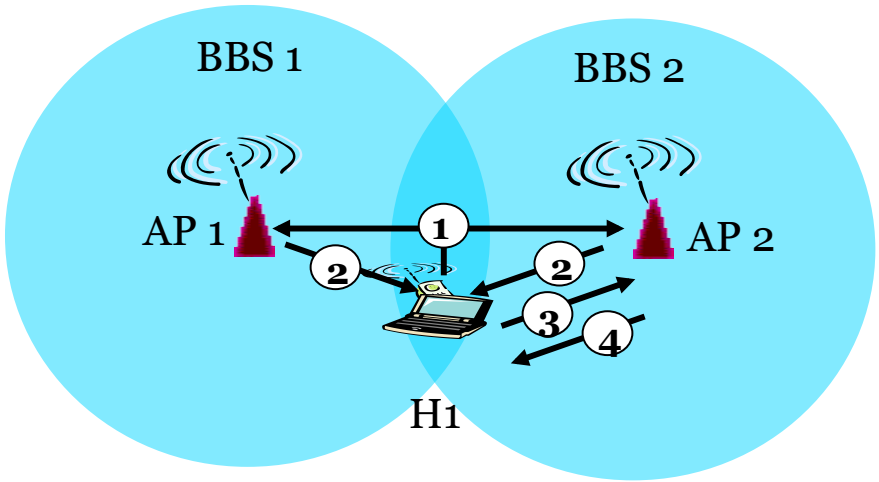
- *802.11b*: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - Network administrator chooses frequency for AP
  - Interference if channel is same as neighboring AP
- Access points send *periodic beacon frames*
  - Containing AP's name (SSID) and MAC address
  - Host scans channels, listening for beacon frames
  - Host selects an access point to *associate* with



- Beacon frames from APs
- Associate request from host
- Association response from AP

802.11: Passive/Active scanning





Passive Scanning:

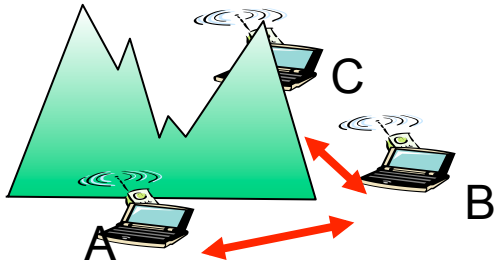
(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent: H1 to selected AP

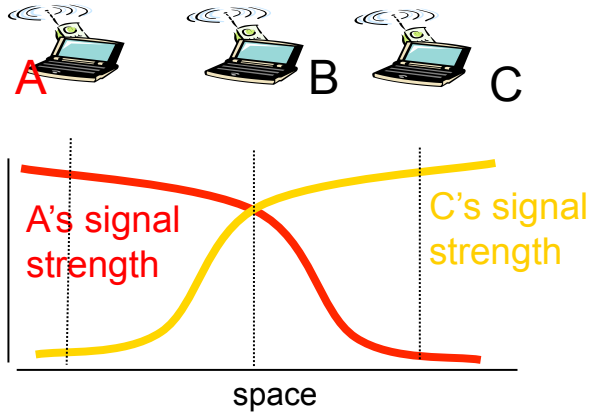
Active Scanning:

(1) Probe Request frame broadcast from H1
(2) Probes response frame sent from APs
(3) Association Request frame sent: H1 to selected AP
(4) Association Response frame sent: H1 to selected AP

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

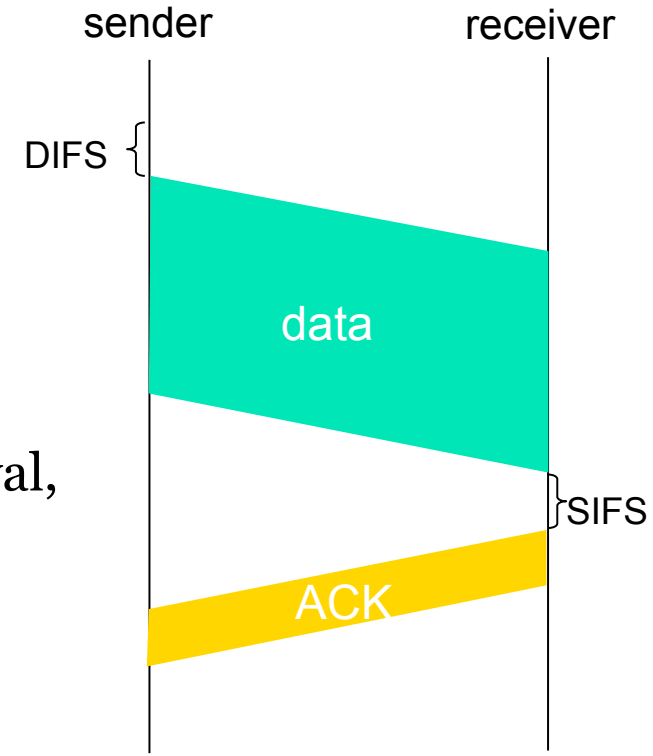
transmit when timer expires

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)



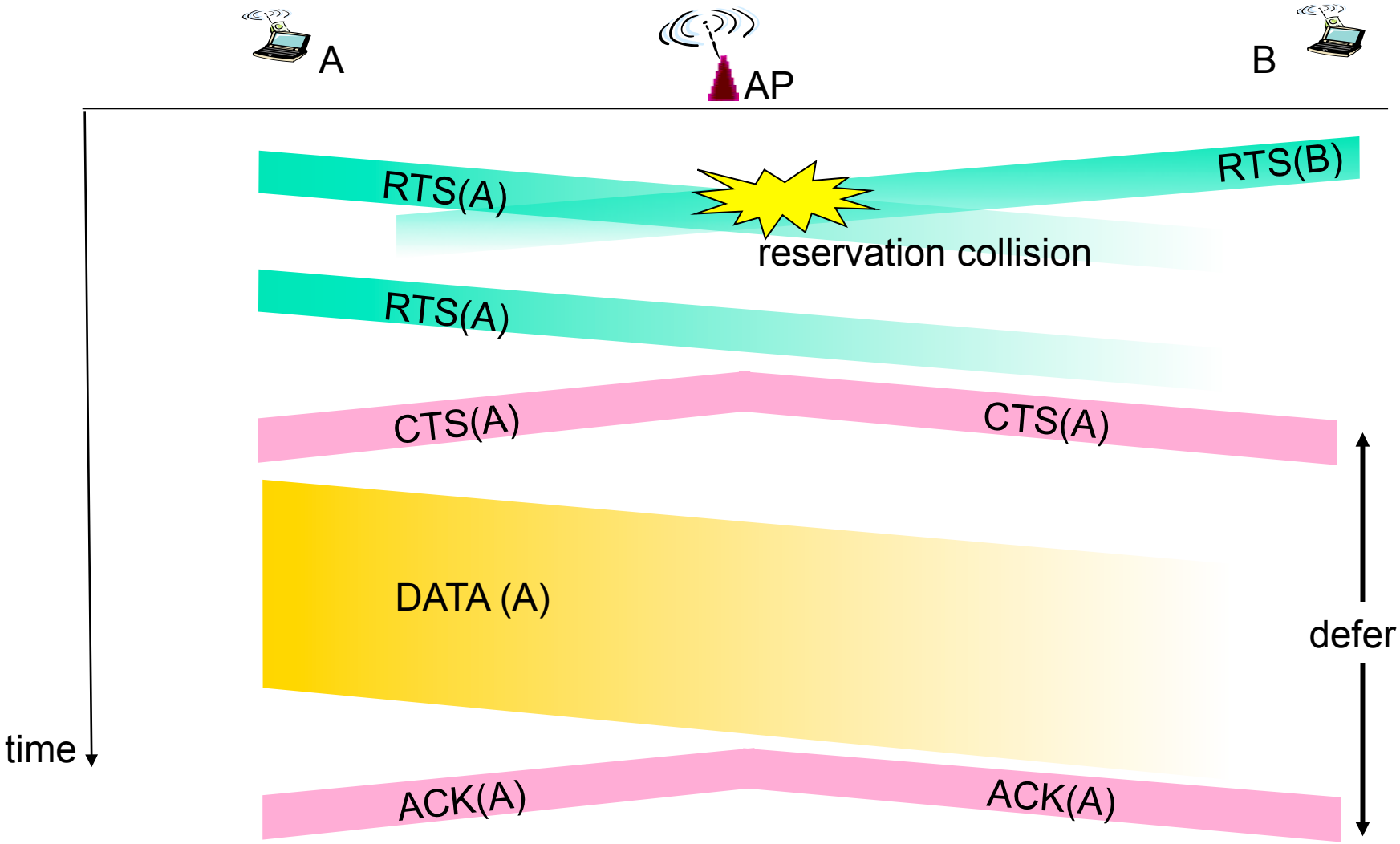
Avoiding collisions (more)

idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

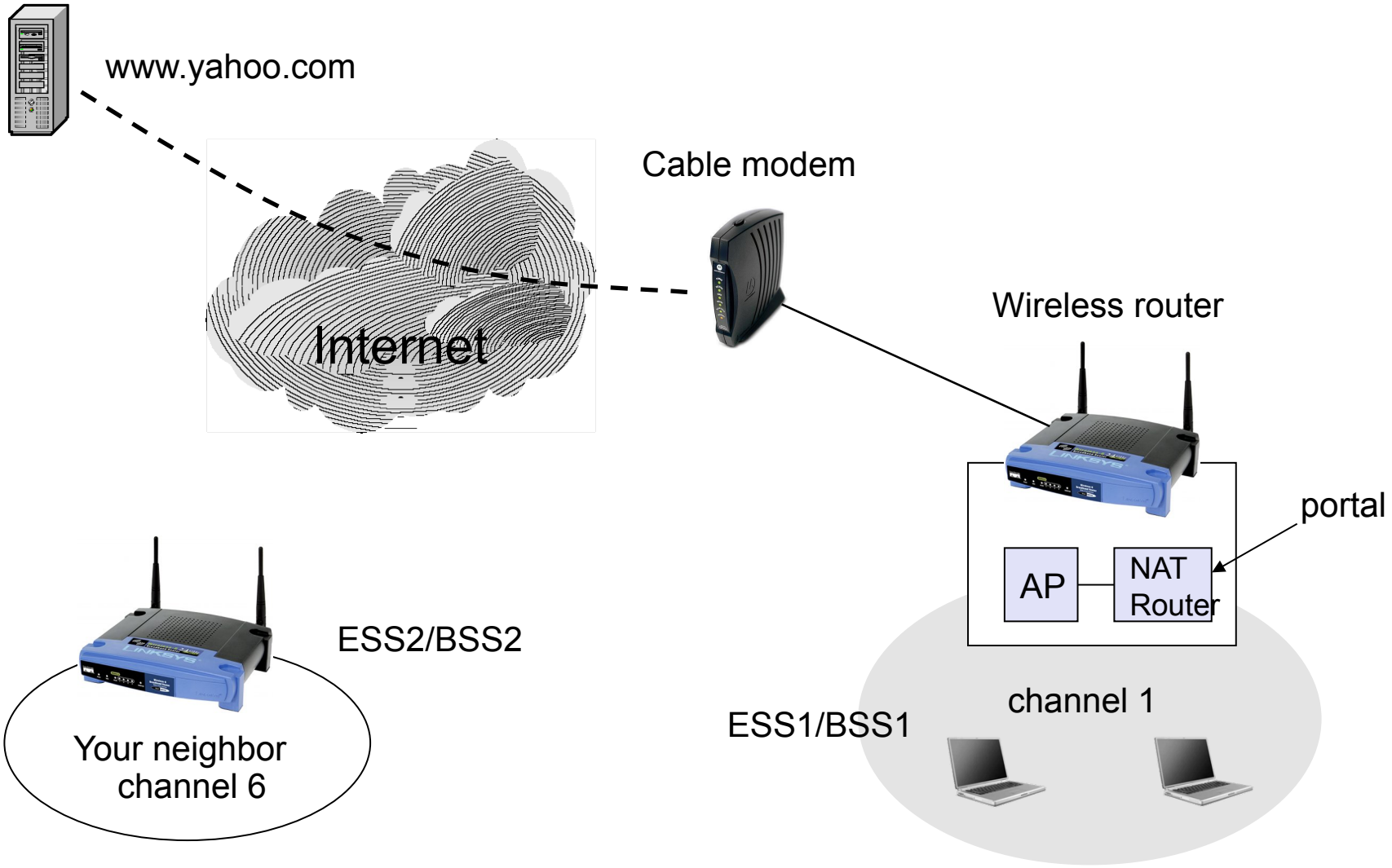
- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

avoid data frame collisions completely
using small reservation packets!

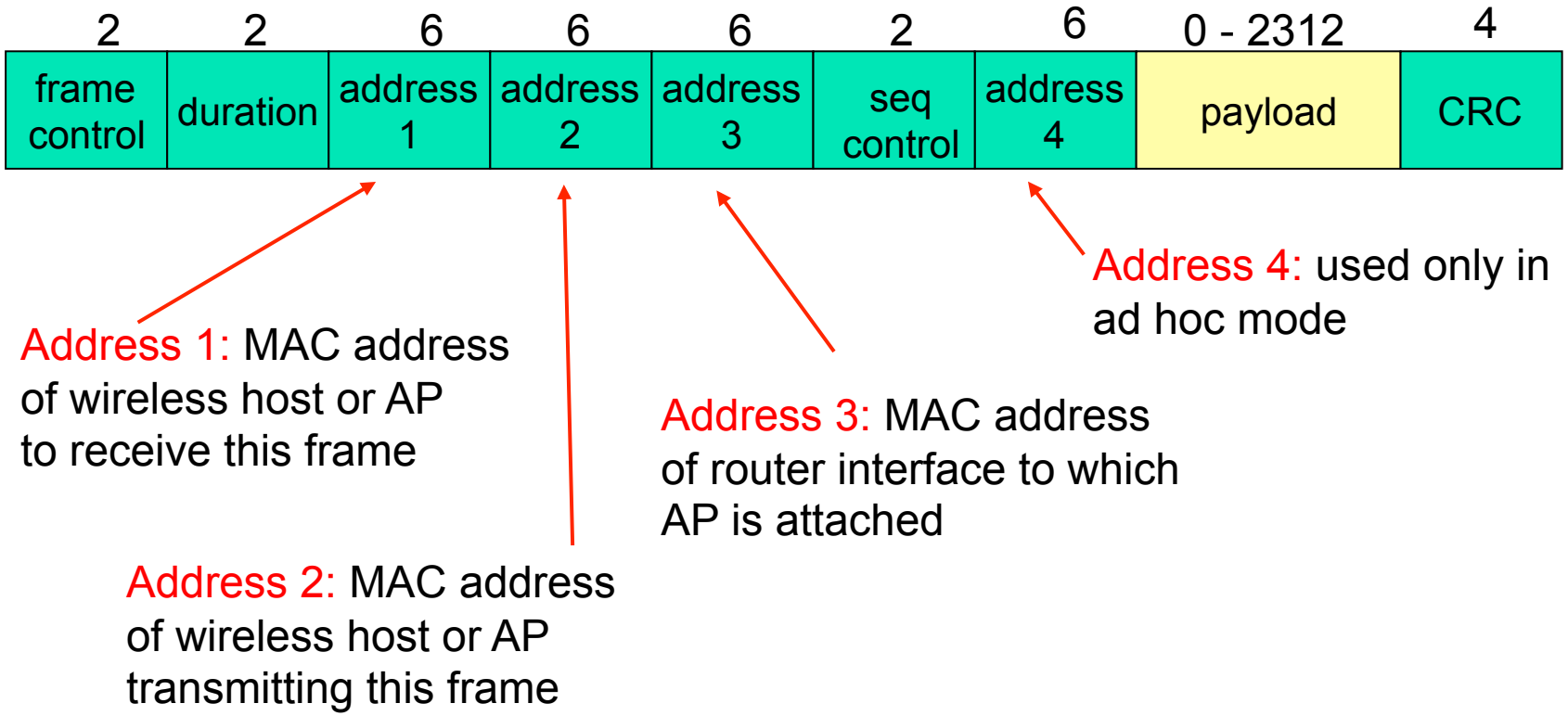
Collision Avoidance: RTS-CTS exchange



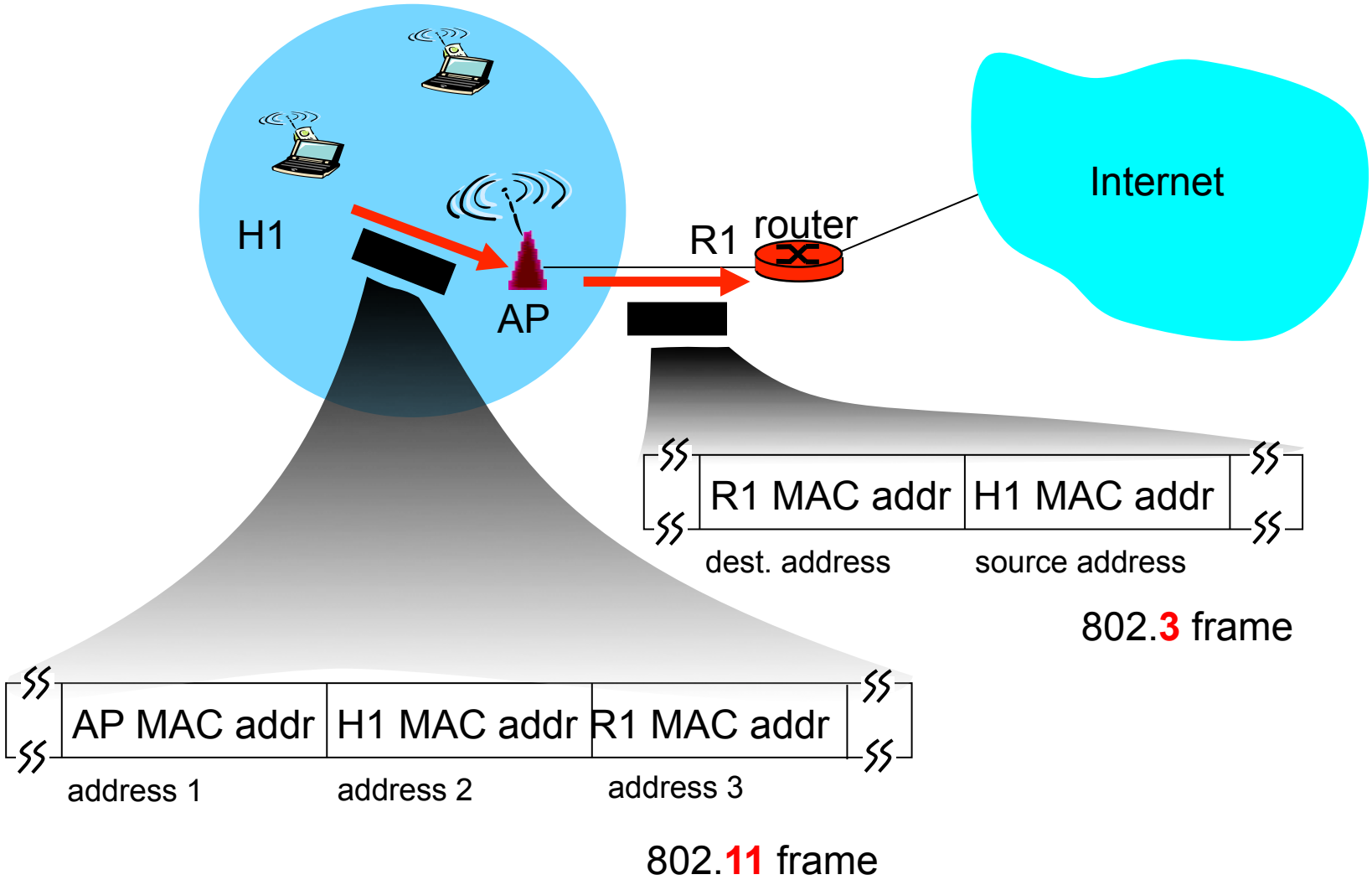
Wireless Router in Your Home



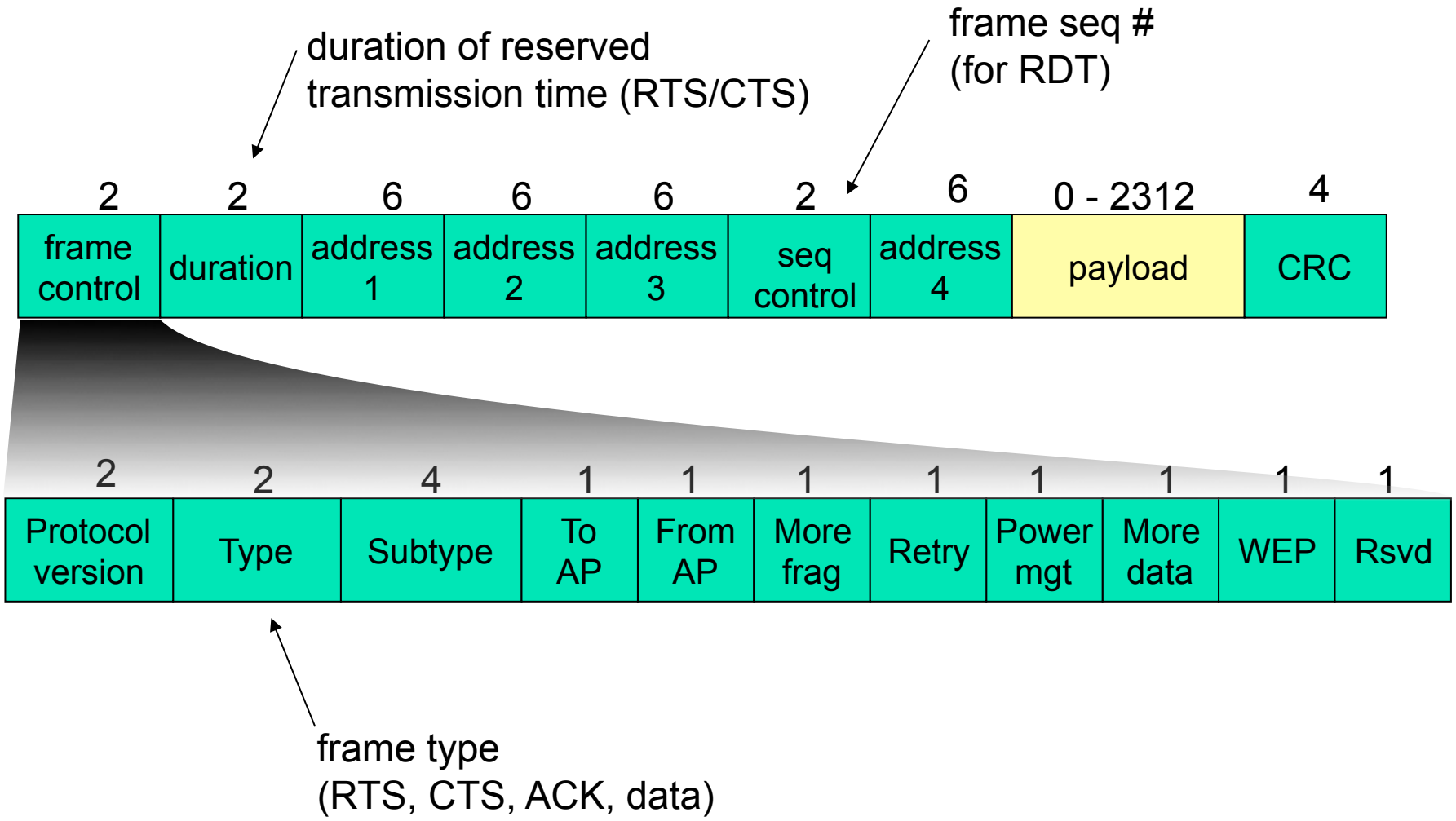
802.11 Frame: Addressing



802.11 frame: addressing

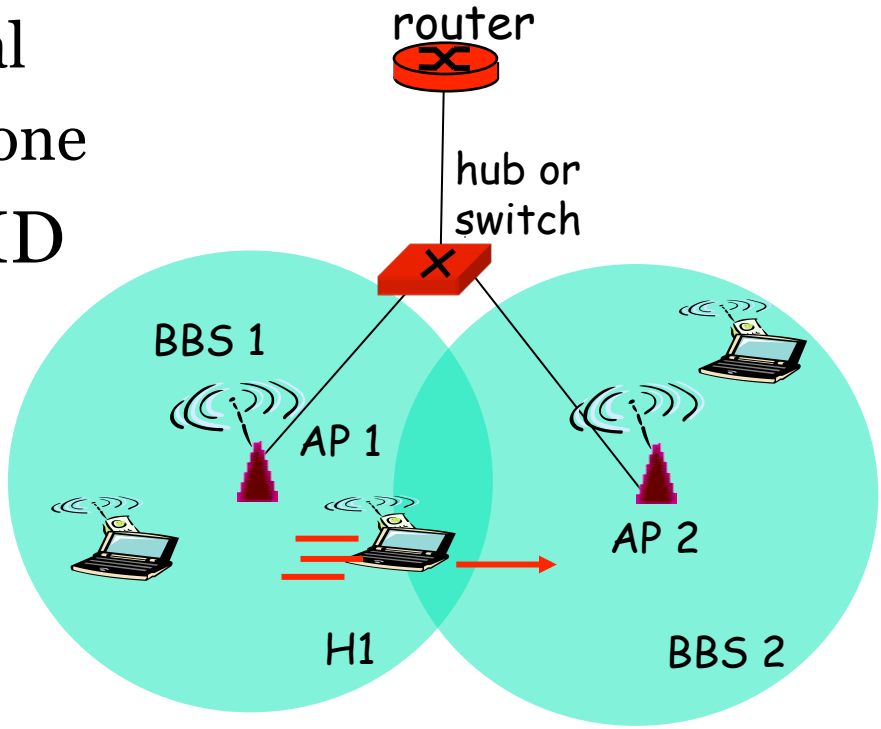


802.11 frame: more



Mobility Within the Same Subnet

- H1 remains in same IP subnet
  - IP address of the host can remain same
  - Ongoing data transfers can continue uninterrupted
- H1 recognizes the need to change
  - H1 detects a weakening signal
  - Starts scanning for stronger one
- Changes APs with same SSID
  - H1 disassociates from one
  - And associates with other
- Switch learns new location
  - Self-learning mechanism



Conclusions

- Wireless
  - Already a major way people connect to the Internet
  - Gradually becoming more than just an access network
- Mobility
  - Today's users tolerate disruptions as they move
  - … and applications try to hide the effects
  - Tomorrow's users expect seamless mobility
- Challenges the design of network protocols
  - Wireless breaks the abstraction of a link, and the assumption that packet loss implies congestion
  - Mobility breaks association of address and location
  - Higher-layer protocols don't perform as well