Summary of MAC protocols

channel partitioning, by time, frequency or code

- Time Division, Frequency Division

random access (dynamic),

- ALOHA, S-ALOHA, CSMA, CSMA/CD
- carrier sensing: easy in some technologies (wire), hard in others (wireless)
- CSMA/CD used in Ethernet
- CSMA/CA used in 802.11

Wireless and Mobile Networks

Background:

wireless (mobile) phone subscribers now exceeds # wired phone subscribers!

wireless Internet-connected devices soon to exceed

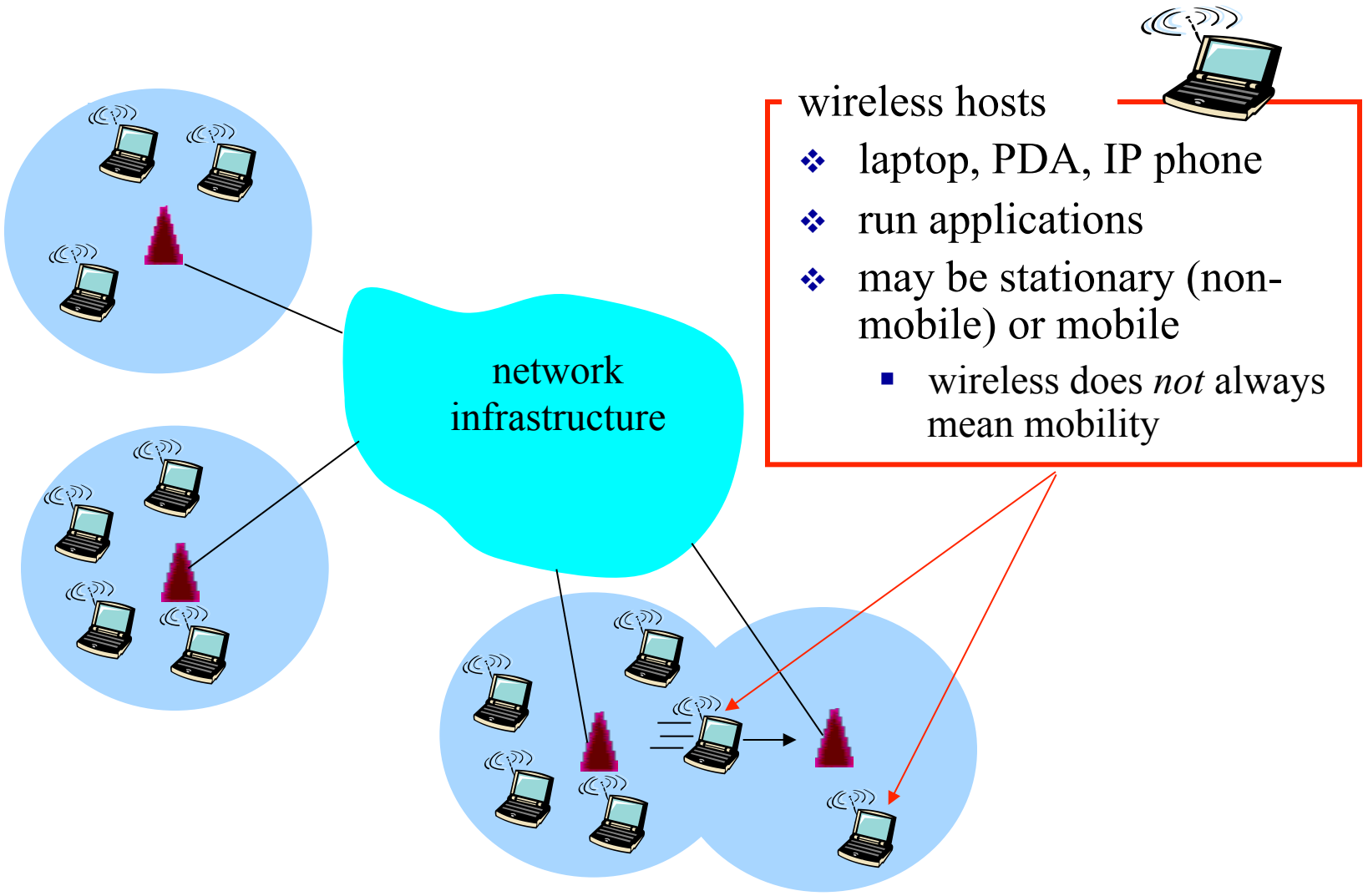
wireline Internet-connected devices

- laptops, Internet-enabled phones promise anytime untethered Internet access

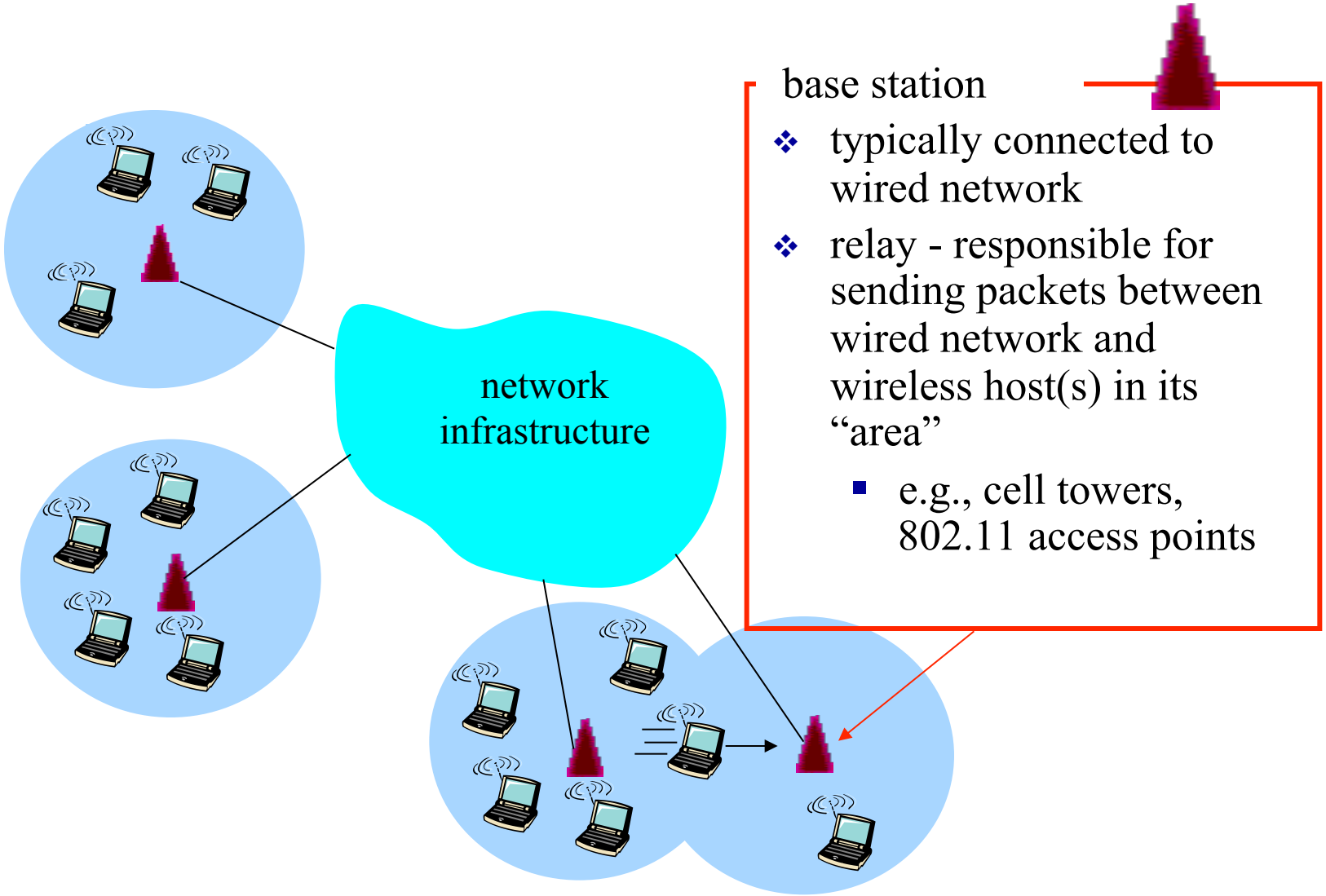
two important (but different) challenges

- *wireless:* communication over wireless link
- *mobility:* handling the mobile user who changes point of attachment to network

Elements of a wireless network



Elements of a wireless network



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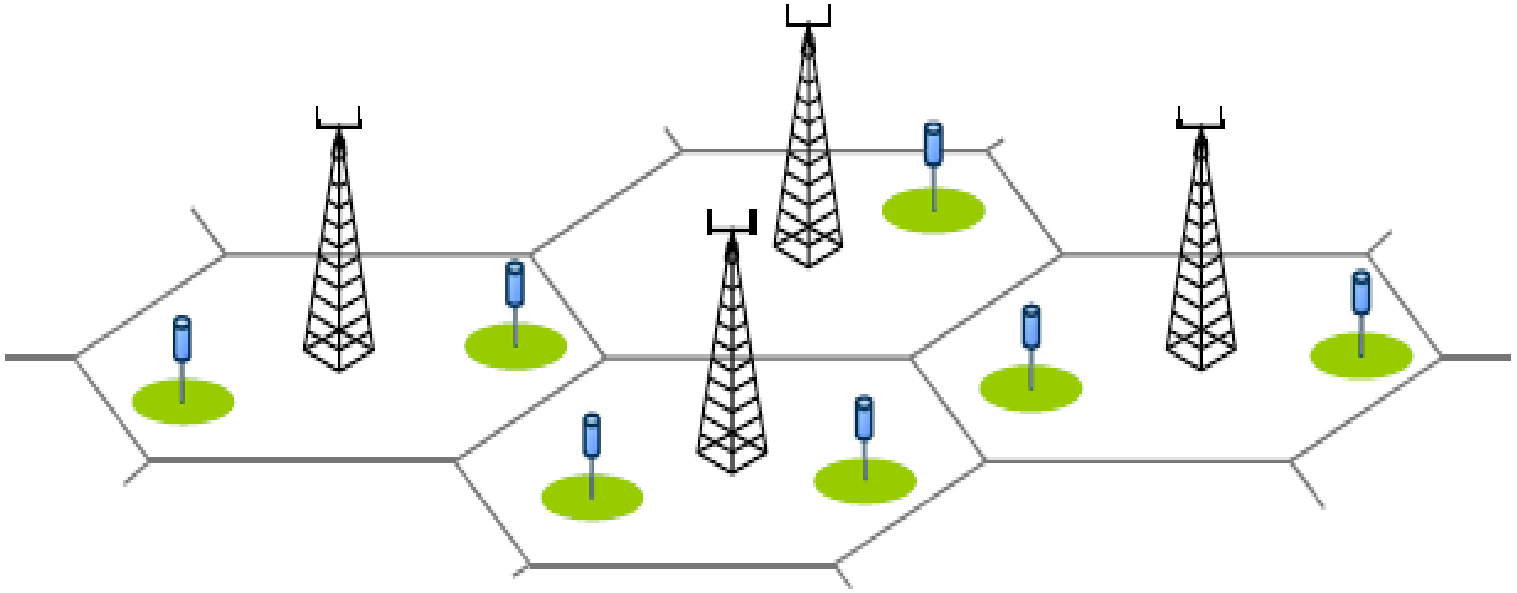

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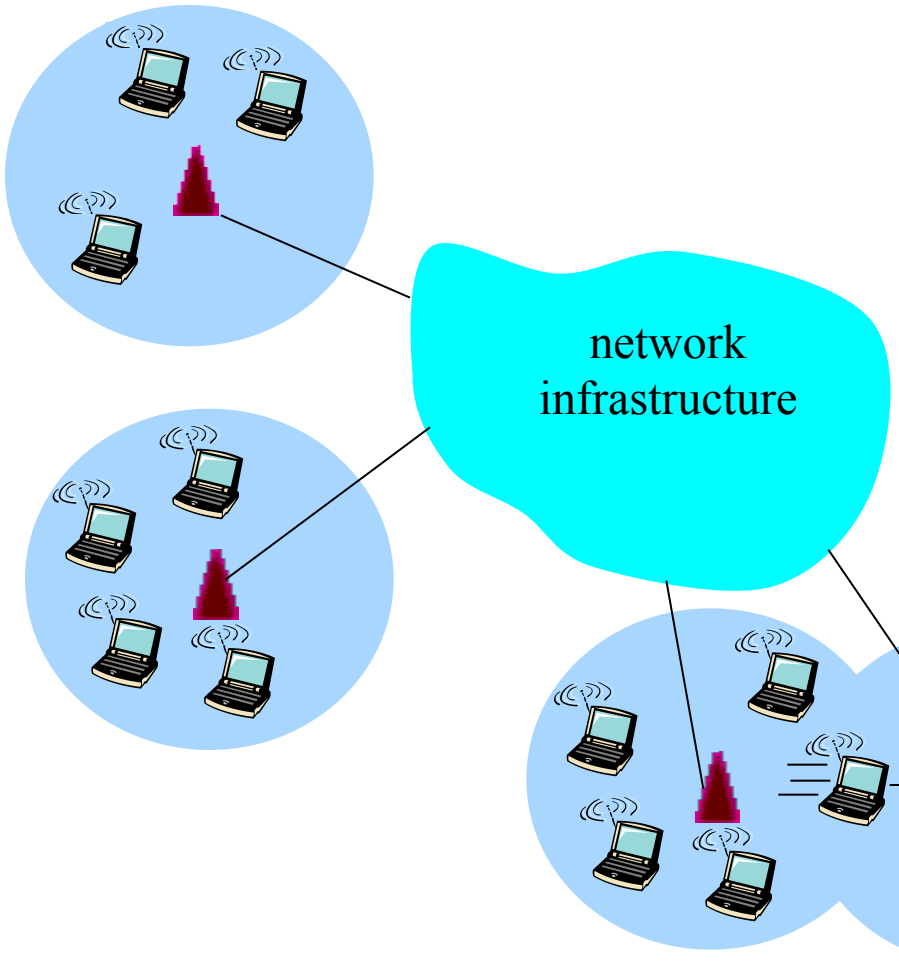
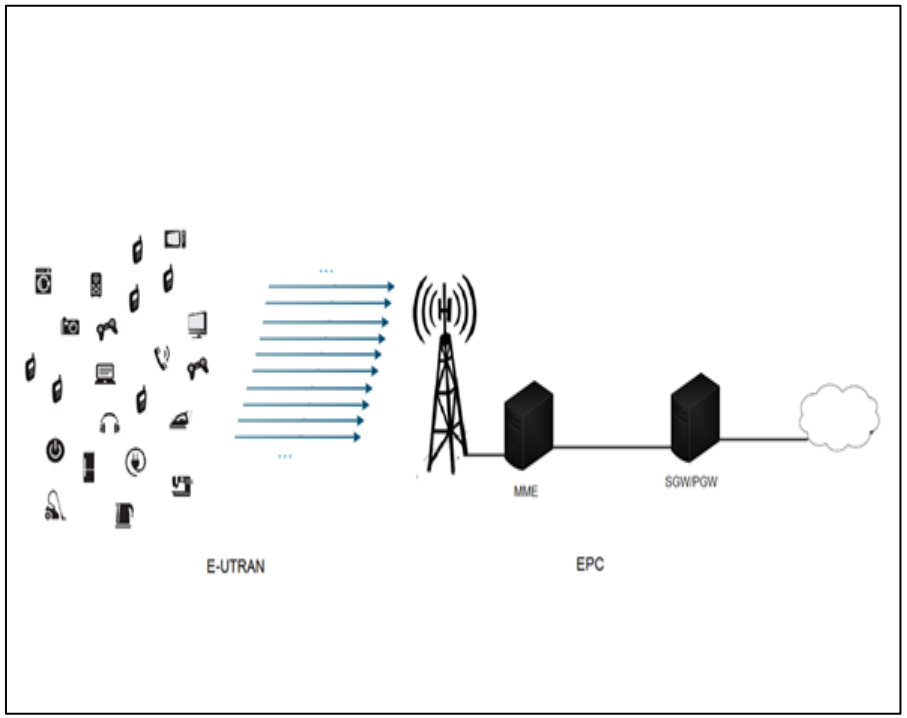


wireless link

- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

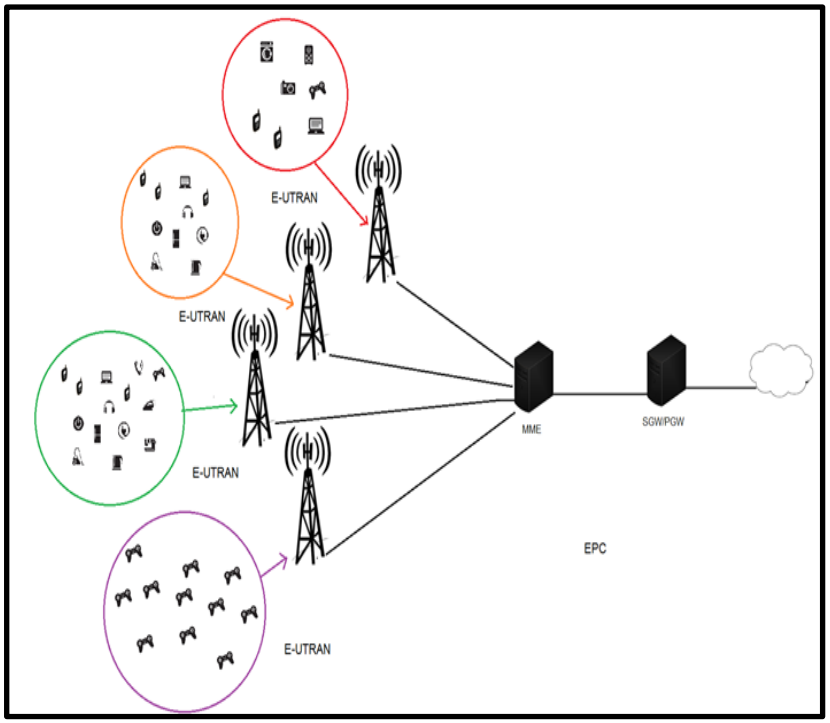
Elements of a wireless network

Radio Access Network (RAN)



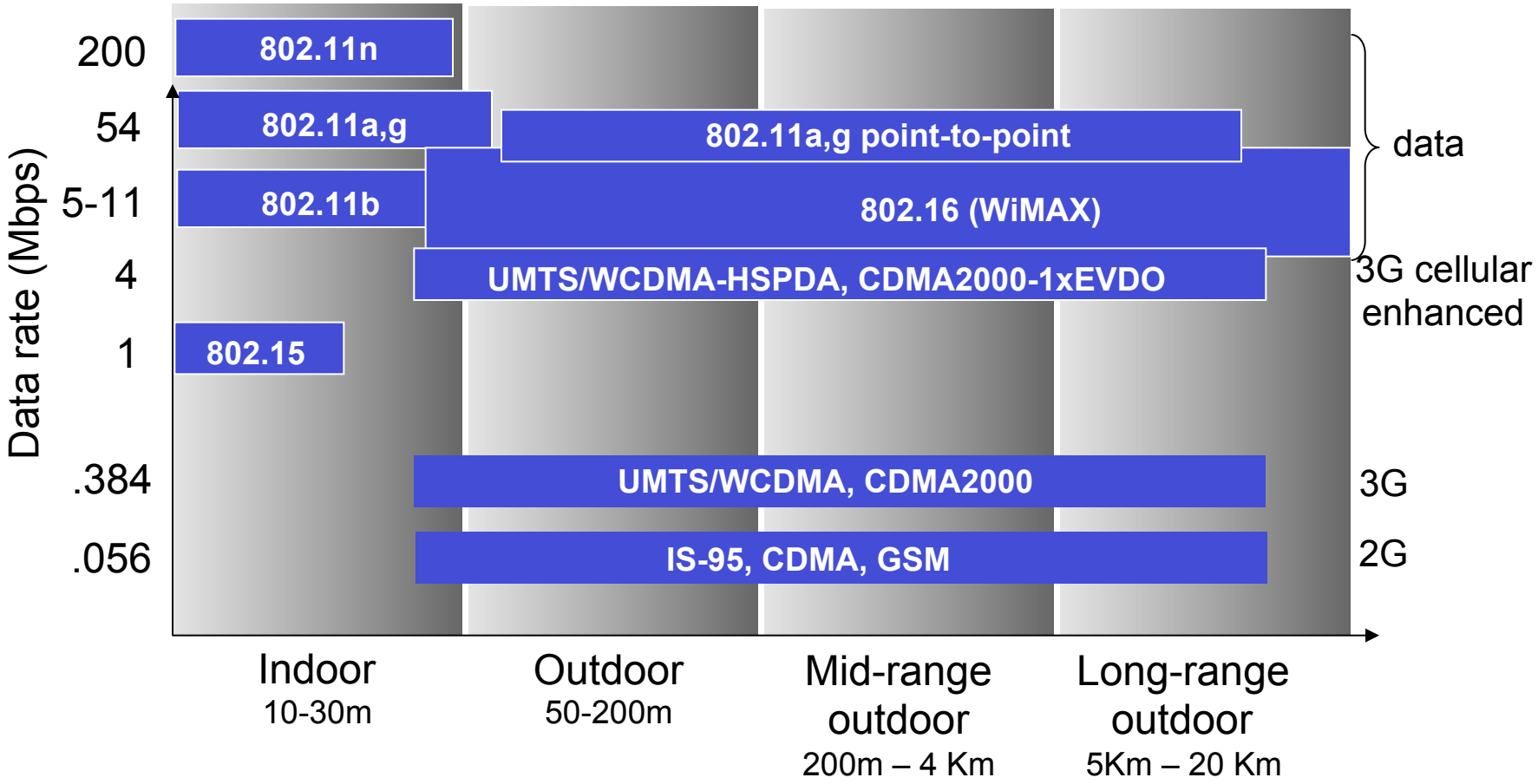
RAN - Congestion

Core Network (CN)

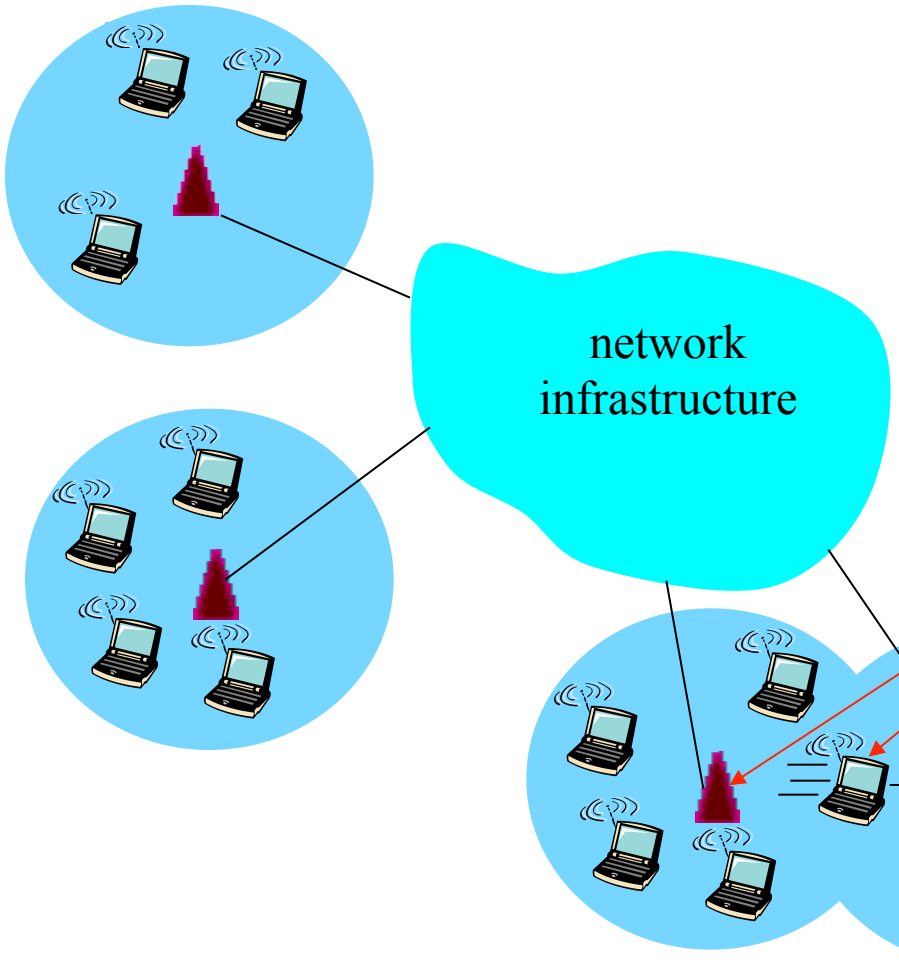


EPC - Congestion

Characteristics of selected wireless link standards



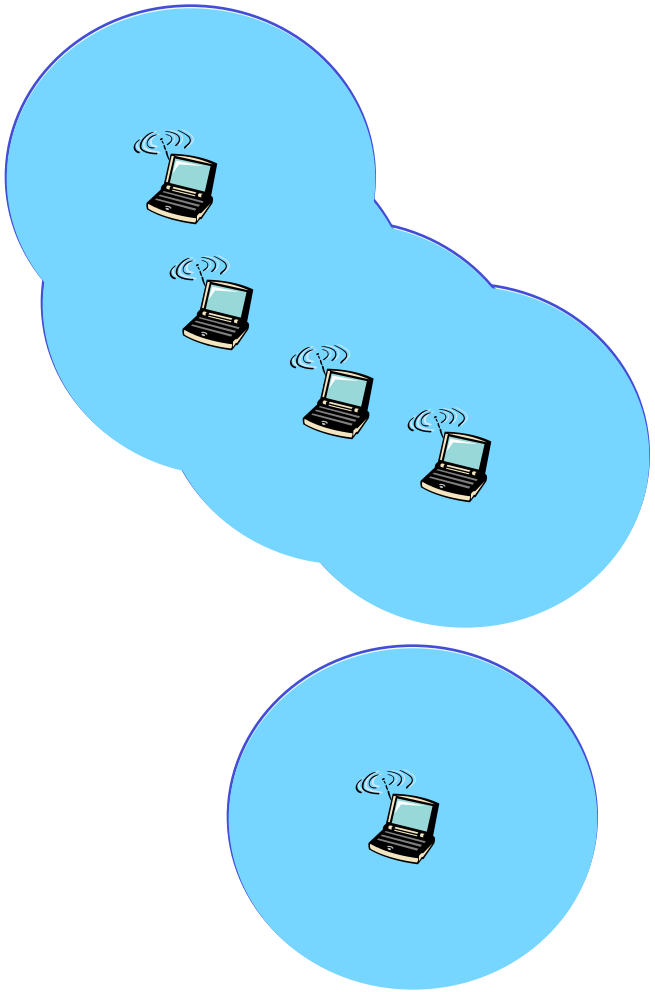
Elements of a wireless network



infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

Elements of a wireless network



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 network taxonomy

	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, WiMAX, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
no infrastructure	no base station, no connection to larger Internet (Bluetooth, ad hoc nets)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

Wireless Link Characteristics (1)

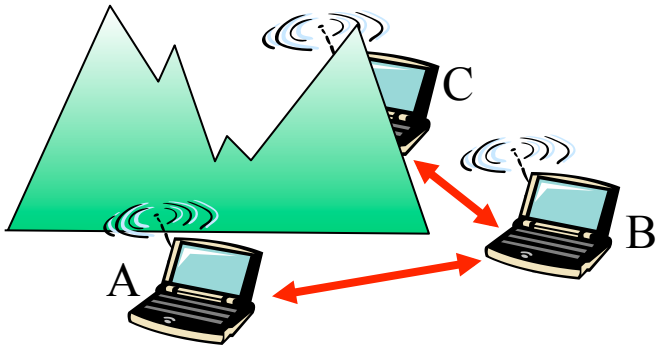
Differences from wired link ….

- decreased signal strength: radio signal attenuates as it propagates through matter (path loss)
- interference from other sources: standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
- multipath propagation: radio signal reflects off objects ground, arriving ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more “difficult”

Wireless network characteristics

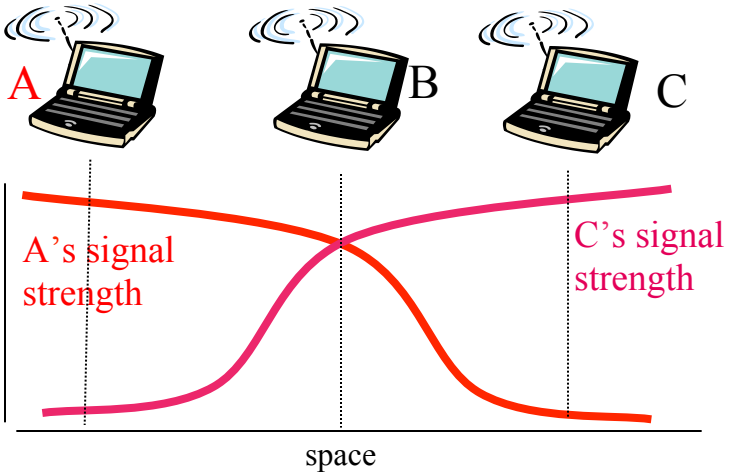
Multiple wireless senders and receivers create additional problems (beyond multiple access):



Hidden terminal problem

- B, A hear each other
- B, C hear each other
- A, C can not hear each other

means A, C unaware of their interference at B



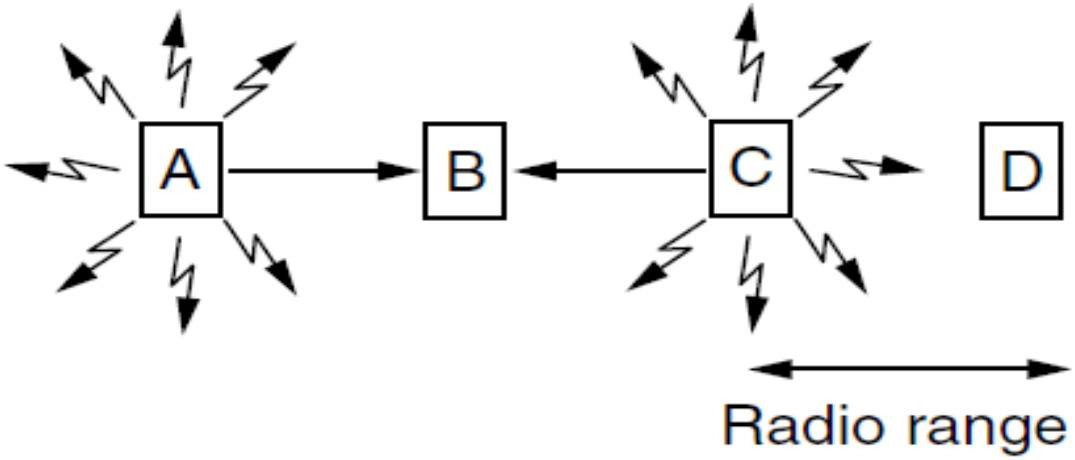
Signal attenuation:

- B, A hear each other
- B, C hear each other
- A, C can not hear each other interfering at B

Wireless LANs (2) – Hidden terminals

Hidden terminals are senders that cannot sense each other but nonetheless collide at intended receiver

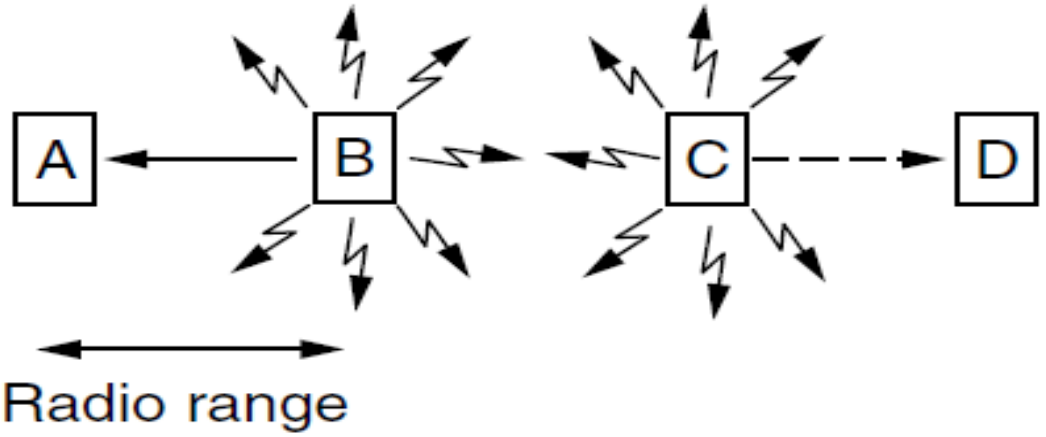
- Want to prevent; loss of efficiency
- A and C are hidden terminals when sending to B



Wireless LANs (3) – Exposed terminals

Exposed terminals are senders who can sense each other but still transmit safely (to different receivers)

- Desirably concurrency; improves performance
- B → A and C → D are exposed terminals



IEEE 802.11: multiple access

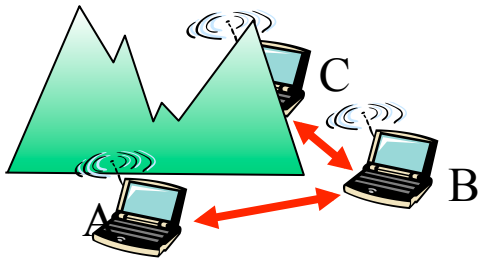
avoid collisions: 2^+ nodes transmitting at same time

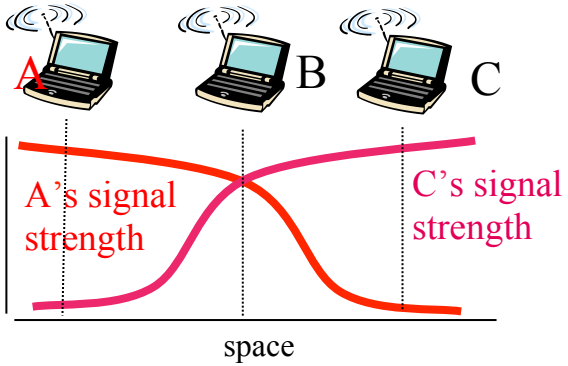
802.11: CSMA - sense before transmitting

- 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

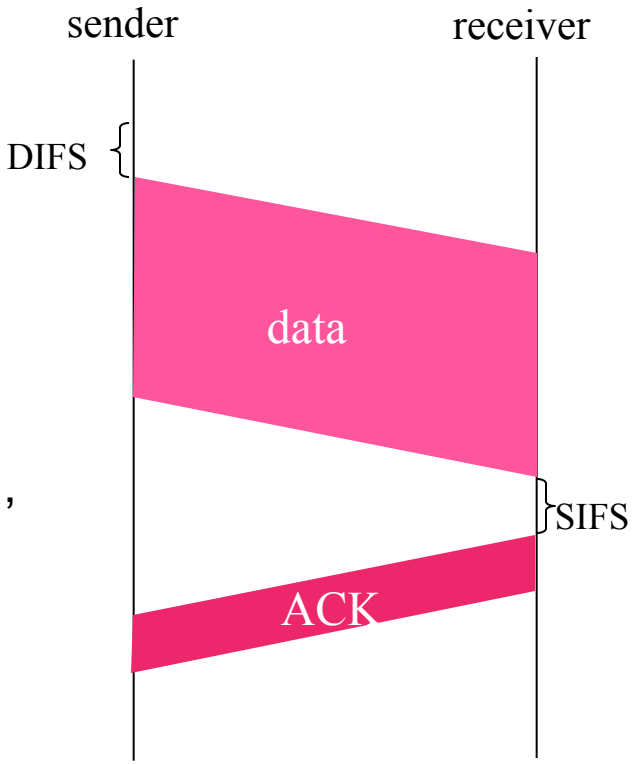
2 if sense channel busy then

I. start random backoff time

II. timer counts down while channel idle

III. transmit when timer expires

IV. 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 (Distributed Inter-frame Spacing)

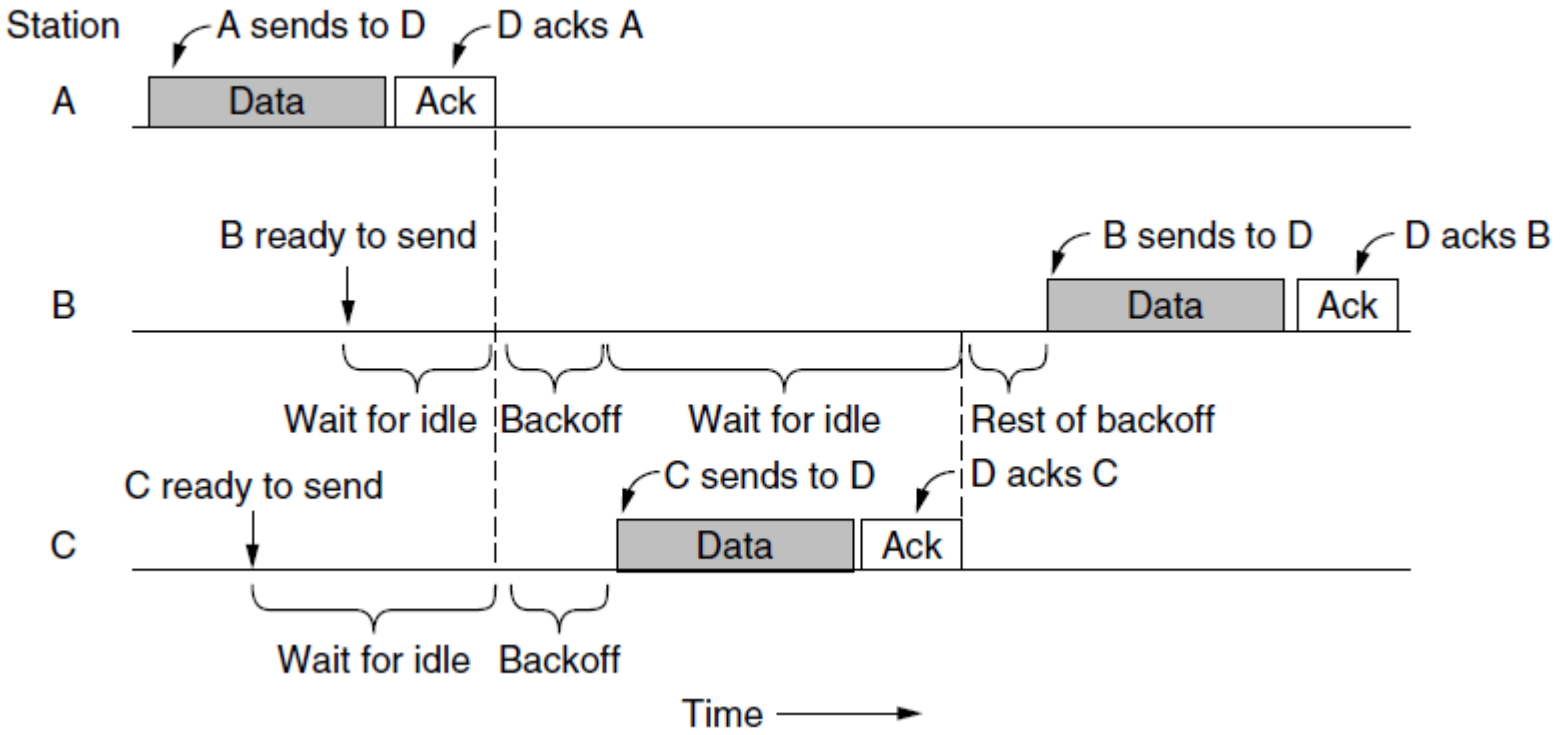
SIFS (Short Inter-frame Spacing)

DCF (Distributed Coordination Function)

PCF (Point Coordination Function)

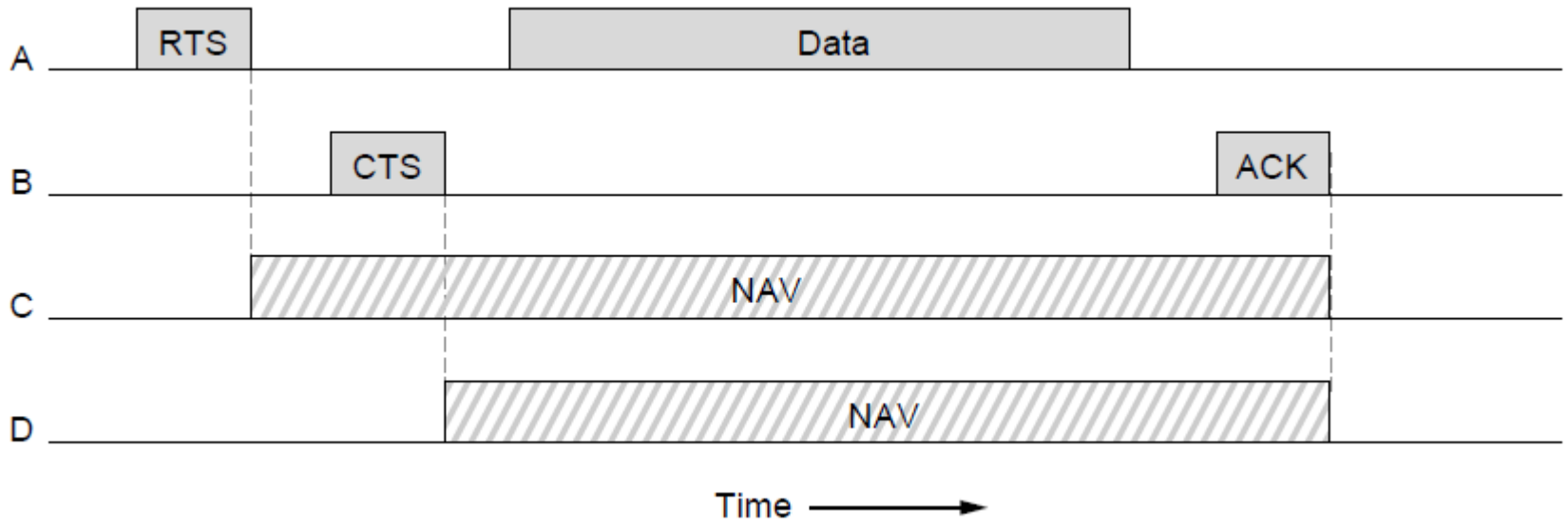
802.11 MAC (1)

- CSMA/CA inserts backoff slots to avoid collisions
- MAC uses ACKs/retransmissions for wireless errors



802.11 MAC (2)

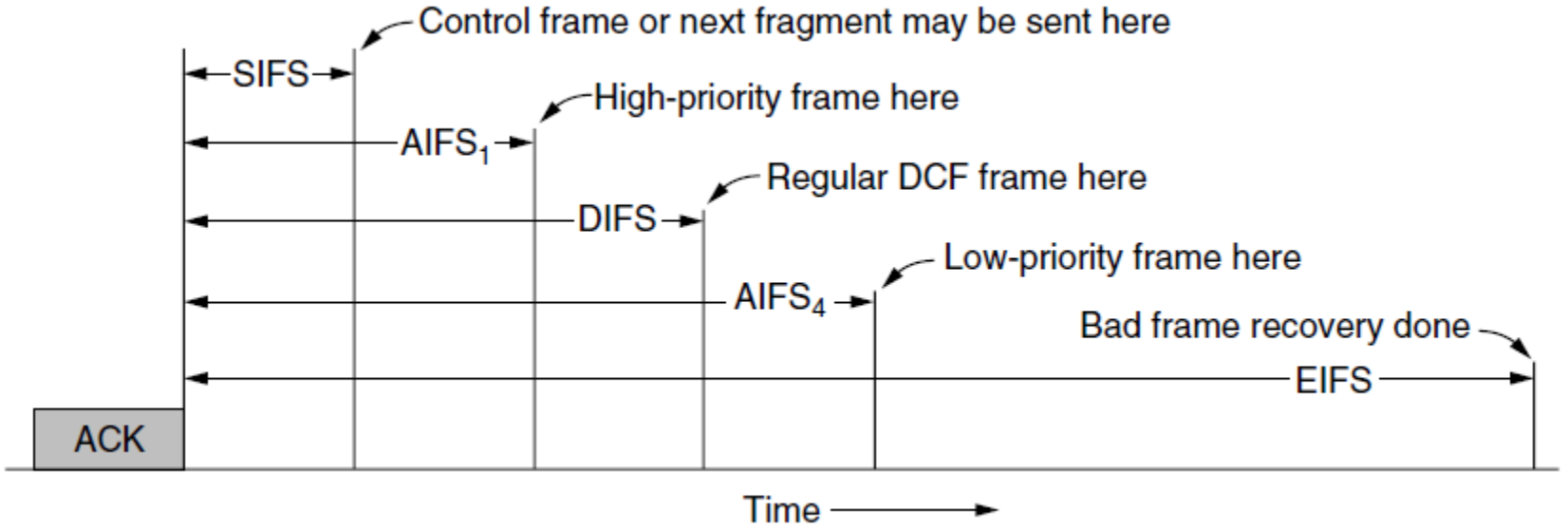
Virtual channel sensing with the NAV and optional RTS/ CTS (often not used) avoids hidden terminals



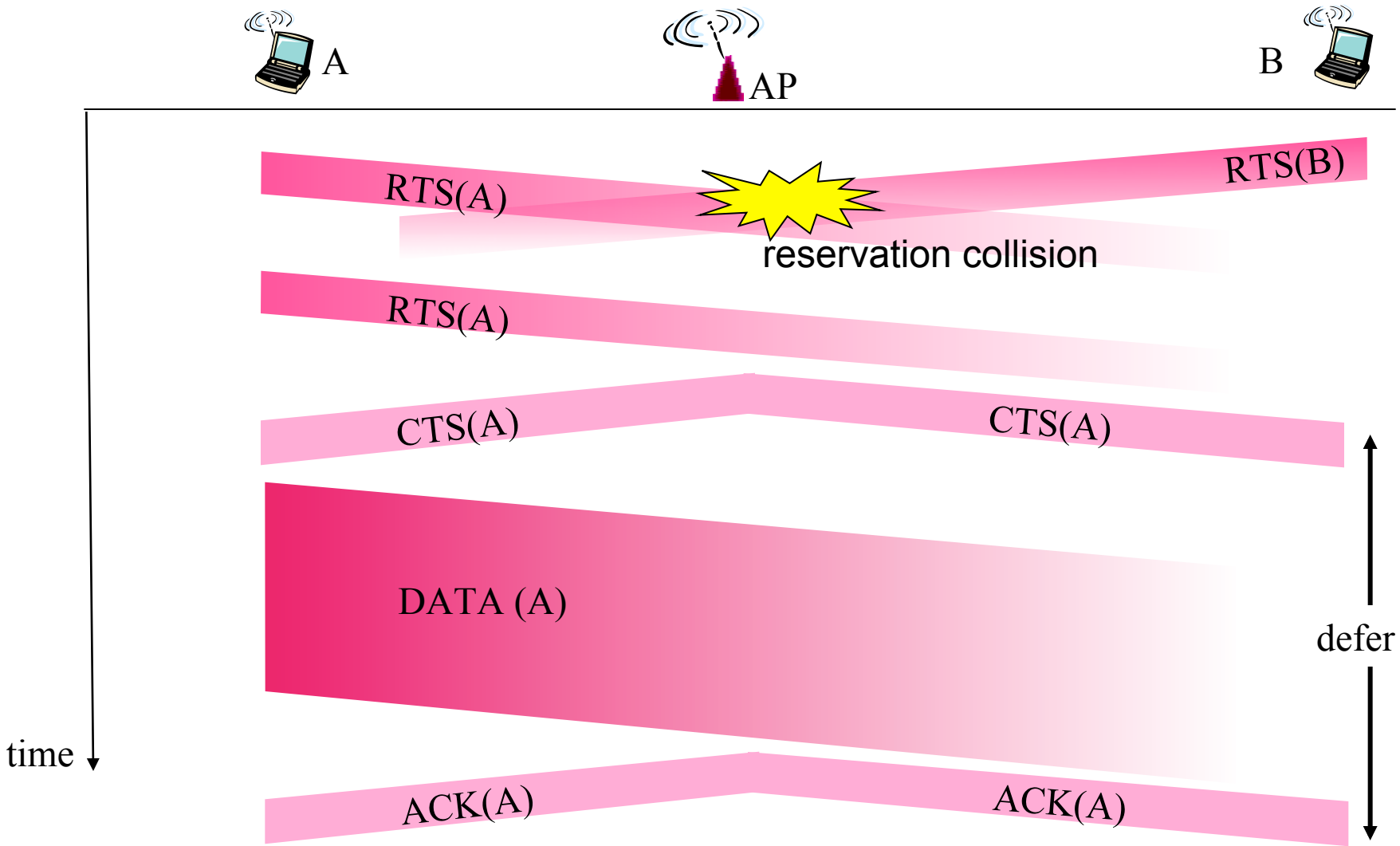
NAV = Network Allocation Vector to keep quiet for a certain period of time

802.11 MAC (3)

- Different backoff slot times add quality of service
  - Short intervals give preferred access, e.g., control, VoIP



Collision Avoidance: RTS-CTS exchange



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

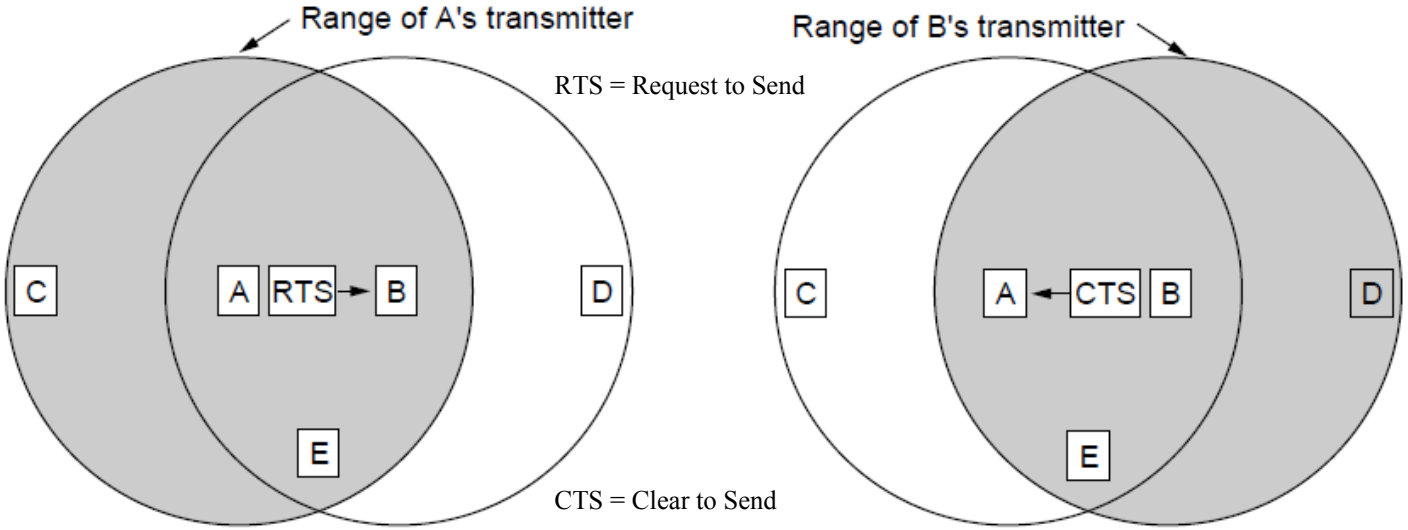
- sender transmits data frame
- other stations defer transmissions

avoid data frame collisions completely
using small reservation packets!

Wireless LANs (4) – MACA

MACA protocol grants access for A to send to B:

- A sends RTS to B [left]; B replies with CTS [right]
- A can send with exposed but no hidden terminals



A sends RTS to B; C and E hear and defer for CTS

B replies with CTS; D and E hear and defer for data