Computer Networks

-Mobile systems and wireless networks-

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W11 short test (1)

- Why would network designers use the telephone network or cable TV network instead just installing new fiber cables?
  - Network designers rely on existing telecommunication facilities, because engineering the existing physical infrastructure to increase transmission speeds is less expensive than using new fiber cables.
- What are the three major components in the PSTN?
  - local loops, trunks, switching offices
- Why splitters needed for the ADSL equipment configuration?
  - Because the telephone service band (the voice portion of the signal) needs to be separated from the data.
- What is the main idea behind HFC?
  - A system with fiber for the long-hauls and coaxial cable to the houses is a Hybrid Fiber Coax, where a single fiber node can feed multiple coaxial cables.

W11 short test (2)

- True or False? IPsec is algorithm independent.
  - True
- True or False? IPsec is connectionless.
  - False
- What are the two main modes of IPsec?
  - Transport mode and tunnel mode.
- What is a VPN?
  - Virtual Private Networks are overlay networks on top of public networks with most of the properties of private networks. The most popular approach is to build a VPN over the Internet.

W11 recap (1)

- The physical layer defines the electrical, timing, and other interfaces by which bits are sent as signals over channels
- Full-duplex vs. half-duplex vs. simplex links
- Transmission media that rely on a physical cable/wire are often called guided transmission media
  - each type has its own set of trade-offs: frequency, bandwidth, delay, cost, maintenance
- Twisted pair has a low cost, and bandwidth depends on the thickness of the wire and the distance traveled
  - Cat 5e, Cat 7e, etc.
- Coaxial cable has better shielding and greater bandwidth than UTP
- Electrical power lines are a common kind of wiring: deliver electrical power to houses, and within houses distributed power to outlets

W11 recap (2)

- Fiber optics has a huge bandwidth, and used for long-haul transmission in network backbones, high-speed LANs, and high-speed Internet access
  - three key components: light source, transmission medium, detector
  - multimode vs single-mode fiber, with two kinds of light sources
  - connectors, splicing, fusing
  - can handle much higher bandwidths than copper, and not affected by as many environmental issues
  - thin and lightweight, but can be damaged easily
  - unidirectional and the interfaces cost more than electrical
- For all kinds of wireless transmissions: when an antenna is attached to an electrical circuit, the waves can be broadcast and received by a receiver
- The amount of information a signal such as an electromagnetic wave can carry depends on the received power and is proportional to its bandwidth
  - different bands in the electromagnetic spectrum

W11 recap (3)

- The process of converting between bits and signals that represent them is called digital modulation
- In baseband transmission, the signal occupies frequencies from zero up to a maximum that depends on the signaling rate
- Schemes which regulate the amplitude, phase, or frequency of a carrier signal to convey bits are called passband transmission schemes
- When channels are shared by multiple signals it is called multiplexing

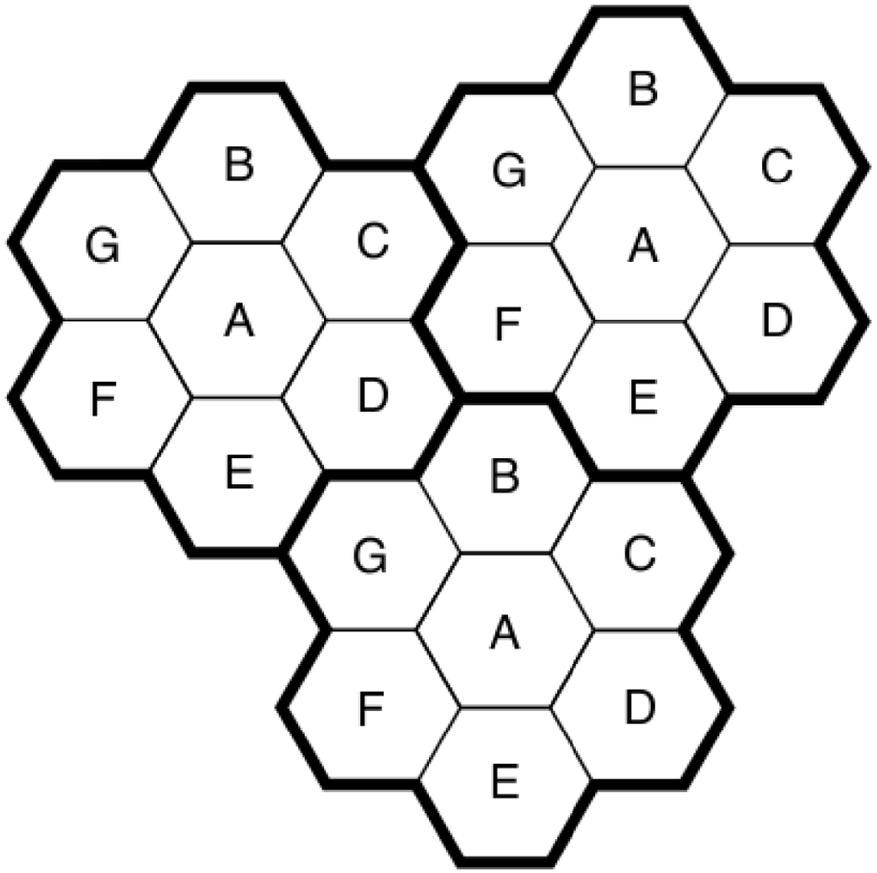
Agenda

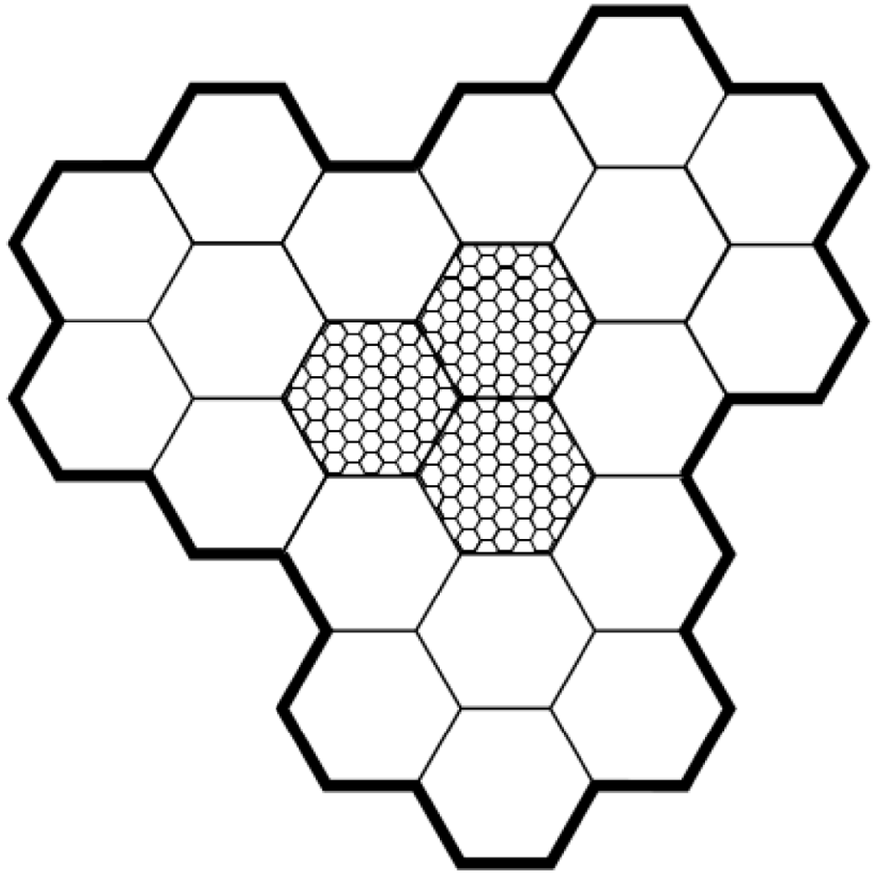
- Cellular/Mobile networks
- Wireless LANs
- MAC Sublayer protocol for the 802.11
- Services and Security
- Summary

Cellular networks basics (1)

- People nowadays expect to to use their phones in places where there is no cable connection
- The mobile phone system is used for wide area voice and data communication
  - five generations: 1G, 2G, 3G, 4G, 5G
- In mobile phone systems, a geographic region is divided up into **cells**
  - each cell uses some set of frequencies not used by any of its neighbors
  - use relatively small cells, and reuse transmission frequencies in nearby (but not adjacent) cells
  - with small cells, system capacity is increased and less power is needed
  - if cell is overloaded, split it into microcells

Cells and microcells





Cellular networks basics (2)

- At the center of each cell is a **base station** to which all the telephones in the cell transmit
  - computer + transmitter-receiver with antenna
  - the base stations are connected to an **MSC** (Mobile Switcher Center)
- **Handoff** is about transferring the ownership: when a mobile phone physically leaves a cell, the base station asks the surrounding base station how much signal they are getting from it, then the phone switches channels
- Four type of **channels**
  - base to mobile, managing the system: control channels
  - base to mobile, alert users to calls: paging channels
  - bidirectional for call setup and channel assignment: access channels
  - bidirectional for carrying voice, fax, data: data channels

1G technology: analog voice

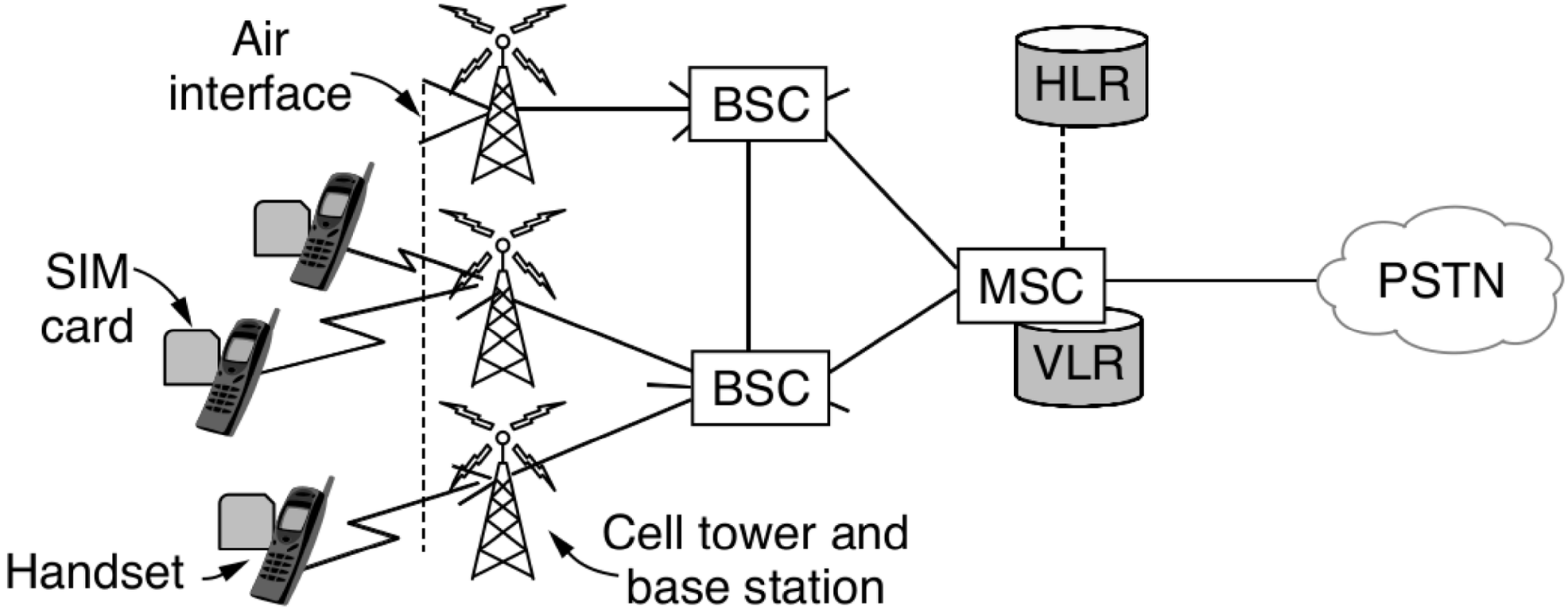
- First generation: using an analog mobile phone system called AMPS (Advanced Mobile Phone System)
  - each mobile has a 32-bit serial number and a 10-digit telephone number
  - when the phone is switched on, it chooses the most powerful signal (using the control channels), then sends its serial and telephone number
  - the base stations tells the information to the MSC
- Making a call: transmit the number to be called and own identity to the access channel, then the MSC looks for an idle channel and the number is sent back on the control channel (then the phone switches to that channel)
- Incoming calls: the idle phones listen to the paging channel to detect messages for them

2G technology: digital voice

- Switching to digital increases capacity by allowing digitization and compression
- Improves security by allowing voice and control signals to be encrypted
- No worldwide standard, several systems: D-AMPS (Digital Advanced Mobile Phone System), **GSM** (Global System for Mobile communications), etc.
  - GSM started as an effort to standardize 2G in Europe
  - the mobile is divided into the handset and a removable chip with subscriber and account information: **SIM** (Subscriber Identity Module)

GSM network architecture

- Where are the mobile phones currently? VLR (Visitor Location Register)
- What is the last known location of the mobile phones? HLR (Home Location Register)



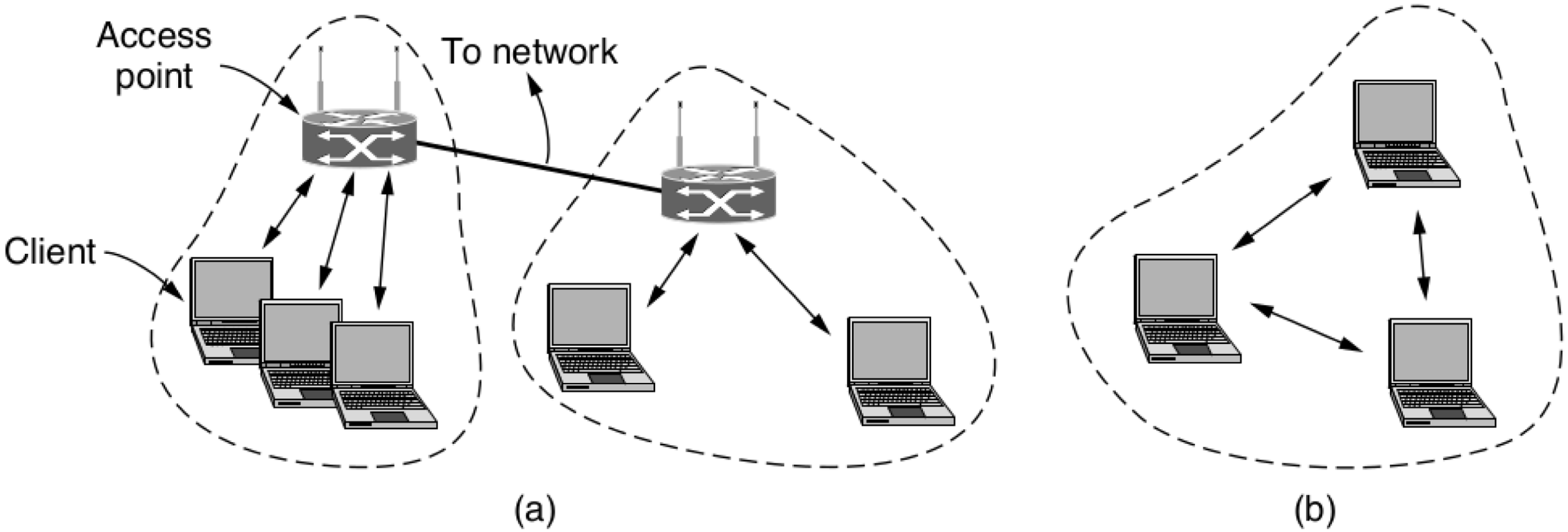
3G, 4G, and 5G technologies

- Data traffic began to exceed voice traffic on the fixed network
- 3G: digital voice and data
  - smartphones, video services, etc.
  - transition started with 2.5G networks
- 4G is a packet-switched network technology (no circuit switching)
  - LTE (Long Term Evolution) and "4G LTE" are the predecessors
  - carries both voice and data in IP packets: a type of VoIP network
- Higher data rates and lower latency for 5G
  - improves the *area capacity* (amount of data that the network can serve per unit area) of 4G significantly

The 802.11 architecture (1)

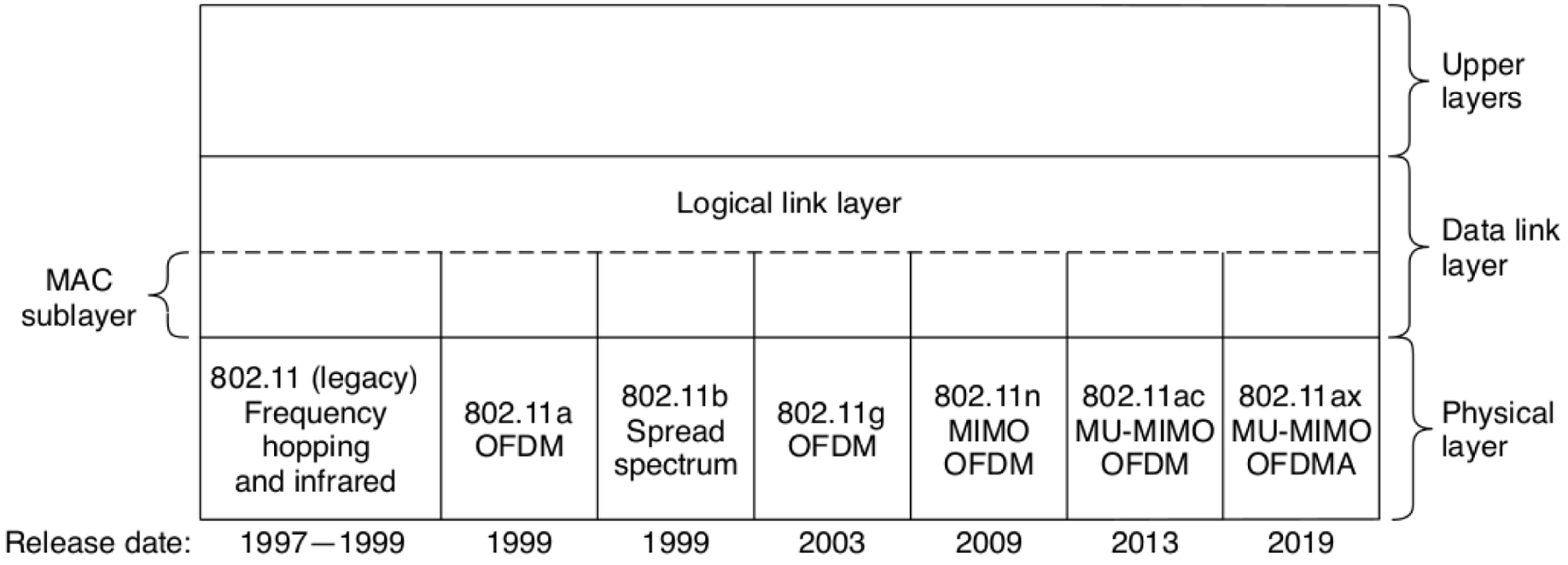
- The main wireless LAN standard for over two decades has been the 802.11
- Infrastructure mode: the usual way is connect clients (e.g., laptops, smartphones, etc.) to another network (e.g., company intranet or the Internet)
  - the client sends and receives its packets via the AP (Access Point)
- In an **ad hoc network**, there is no AP, just a collection of computers that are associated so that they can send directly frames to each other

The 802.11 architecture (2)



Protocol stack for 802.11

- The data link layer is split into two or more sublayers
- The MAC sublayer determines how the channel is allocated
- The logical link control sublayer's job is to "hide" the differences between the different 802 variants and make them indistinguishable for the network layer
- Most modern mobile devices use the 802.11ac



Different bands and rates

- All of the 802.11 techniques use short-range radios to transmit signals in either the 2.4GHz or the 5GHz frequency bands
- Unlicensed bands, but freely available to any transmitter (e.g., also phones, microwaves, etc.)
- 5GHz has a shorter range, but the 2.4GHz band tends to be more crowded
- **Rate adaptation** to use different rates depending on the conditions: low rate to a weak signal, high rate to a clear signal

WiFi generations (1)

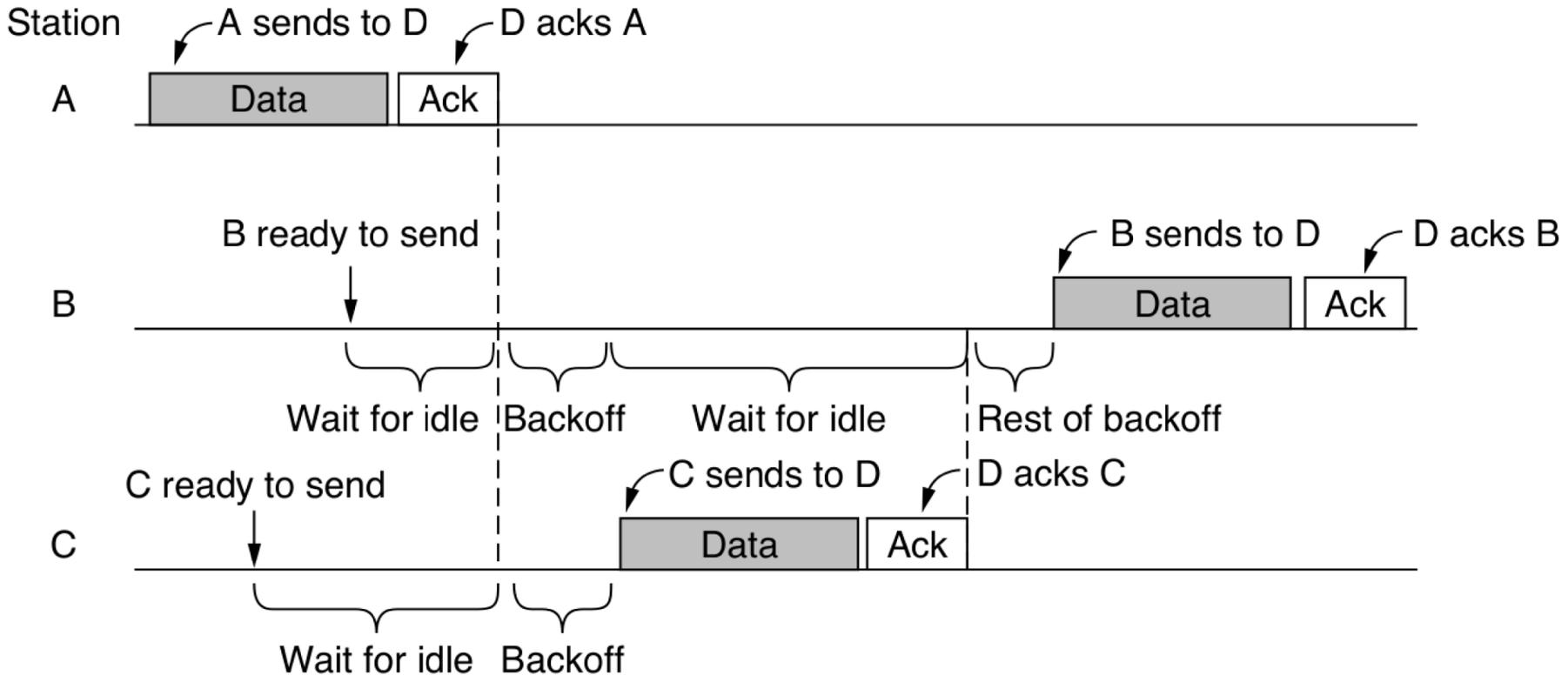
- 802.11b: spread-spectrum method, operating rate of 11 Mbps
- 802.11a: rates up to 54 Mbps in the 5GHz ISM band, using OFDM (Orthogonal Frequency Division Multiplexing) to use the spectrum efficiently and resist wireless signal degradation
- 802.11g: operates in the narrow 2.4GHz ISM band as the 802.11b, but due to the OFDM, same speed as 802.11a (+ compatible with 802.11b devices)
- 802.11n: higher speed and wider channels, and now a group of frames can be sent together
  - up to four antennas to transmit up to four streams of information
  - signals of the streams interfere at the receiver, so separate them using MIMO (Multiple Input Multiple Output) techniques

WiFi generations (2)

- 802.11ac: higher speed and wider channels, up to eight streams
- 802.11ad and 802.11ay: very short radio waves (60GHz band), so only useful in a single room to transmit a lot of data fast
- 802.11ax or WiFi 6 or "high efficiency wireless": it can operate up to 7GHz and achieve data rate of 11 Gbps (only theoretically)

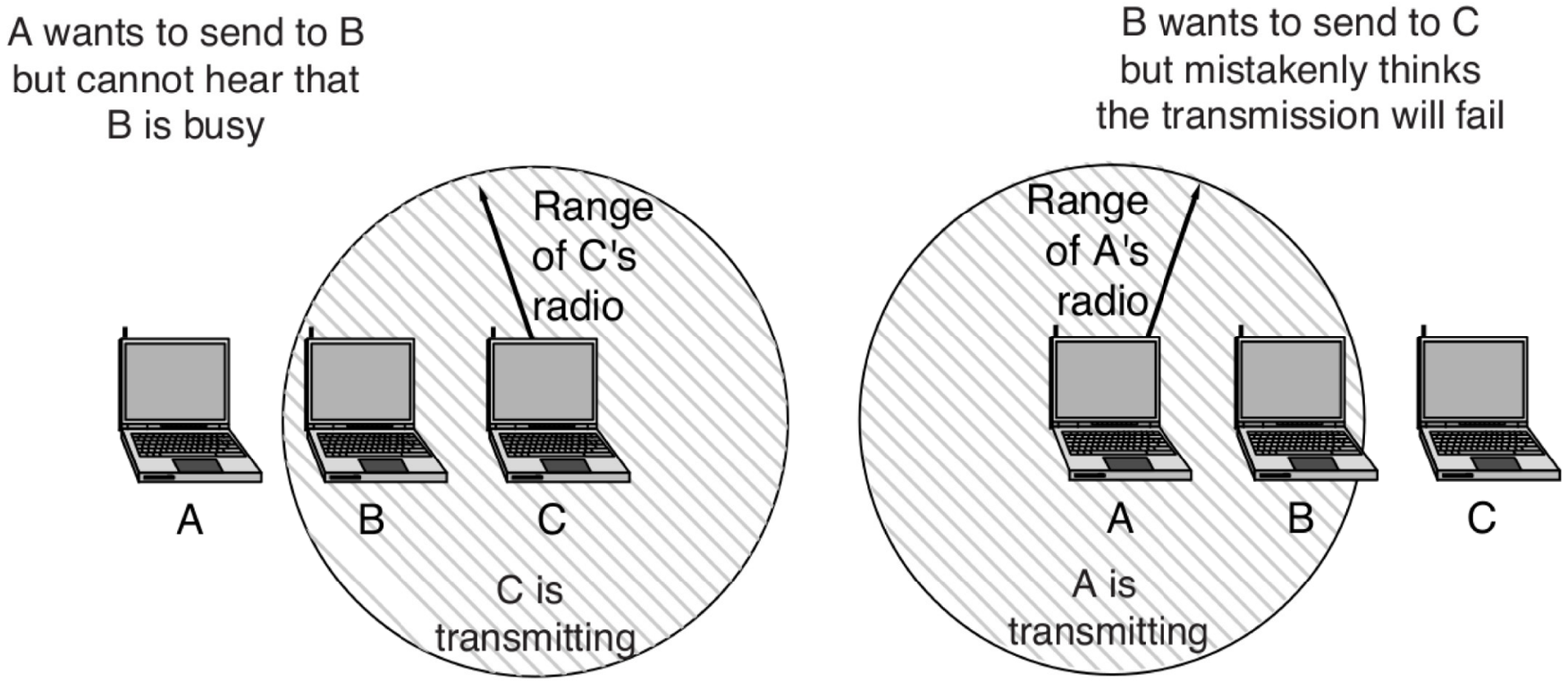
CSMA/CA

- First problem: radios are almost always half duplex: cannot transmit and listen for noise bursts at the same time on a single frequency
- 802.11 tries to avoid collisions with **CSMA/CA** (Carrier Sense Multiple Access with Collision Avoidance)



Hidden and exposed terminal problem

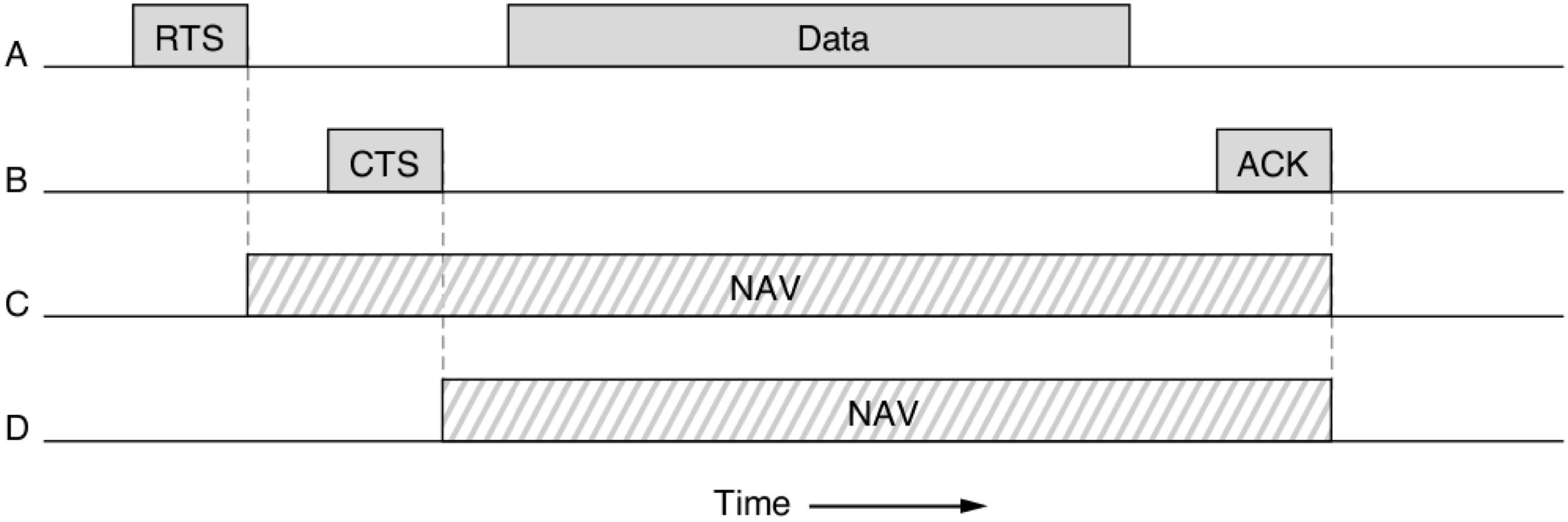
- Second problem: transmission ranges of different stations may be different
  - with a wire, all stations can hear each other, but with wireless, not all stations are within radio range of each other



NAV

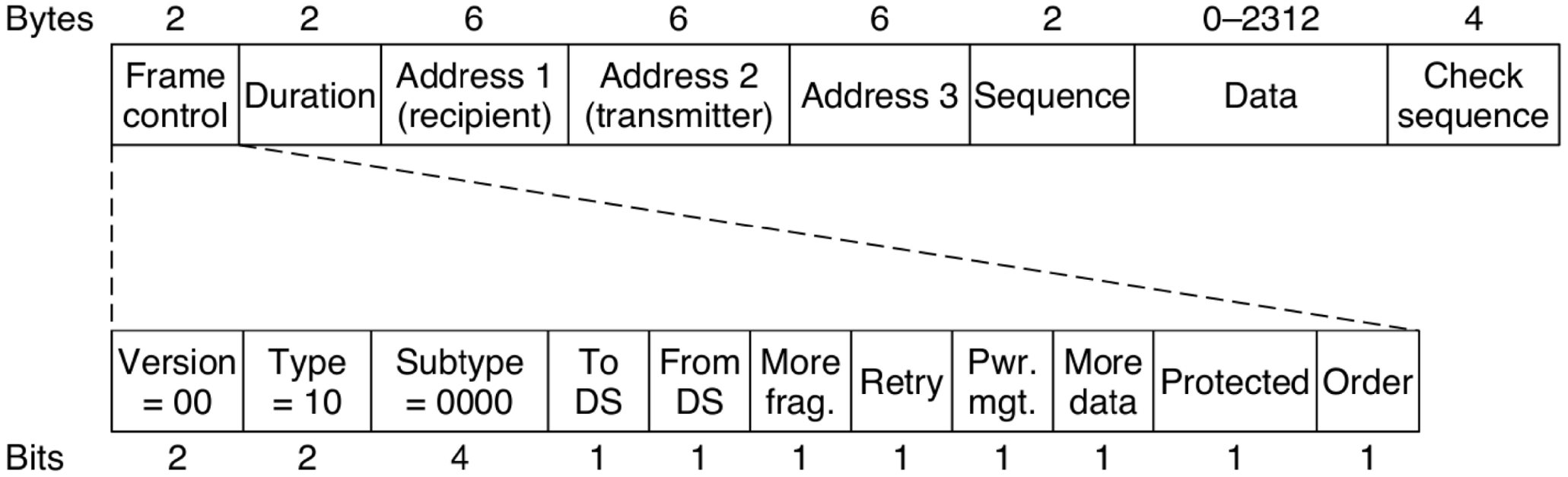
- To reduce ambiguities about which station is sending, 802.11 defines channel sensing to consist of both physical (checks the medium to see if there is a valid signal) and virtual sensing
- With virtual sensing, each station keeps a logical record of when the channel is in use by tracking the **NAV** (Network Allocation Vector)
  - each frame carries a NAV field that says how long the sequence of which this frame is part will take to complete
  - stations that overhear this frame know that the channel will be busy for the period indicated by the NAV (regardless of the physical signal)
- Battery life is always an issue with mobile wireless devices
  - clients should not waste power when they have neither information to send nor to receive (efficient power management and power-save modes)

Virtual sensing with RTS/CTS and NAV



802.11 frame structure

- Three different classes of frames: data, control, and management
  - each of these has a header with a variety of fields used within the MAC sublayer
- The data frame:



Services

- The **association service** is used by mobile stations to connect themselves to APs
  - after a station moves within radio range of the AP, it learns its identity and capabilities
  - broadcasting the AP's **SSID** (Service Set IDentifier) is optional
- Reassociation lets a station change its preferred AP (e.g., moving from one AP to another over the same extended 802.11 LAN)
- Once frames reach the AP, the **distribution service** determines how to route them
- **Data delivery service** lets stations transmit and receive data

Authentication

- Stations must also authenticate before they can send frames via the AP
  - **WPA2** (WiFi Protected Access 2), the AP can talk to an authentication server that has a username and password database to determine if the station is allowed to access the network
  - WPA2 uses a privacy service that manages the details of encryption and decryption (based on AES - Advanced Encryption Standard)
  - another approach is **port-based authentication**, common for enterprise networks
- WPA2 is already broken, moving towards WPA3

W12 summary (1)

- The mobile phone system is used for wide area voice and data communication
- In mobile phone systems, a geographic region is divided up into cells
- At the center of each cell is a base station to which all the telephones in the cell transmit
- 1G technology: analog voice, 2G technology: digital voice + GSM standard
- Data traffic began to exceed voice traffic on the fixed network
  - 3G: digital voice and data, 4G is a completely packet-switched network technology
  - even higher data rates and lower latency for 5G by improving the area capacity
- The main wireless LAN standard for over two decades has been the 802.11 (infrastructure and ad hoc modes)

W12 summary (2)

- For wireless, the data link layer is split into two or more sublayers
  - the MAC sublayer determines how the channel is allocated
  - the logical link control sublayer's job is to unify the different 802 variants for the network layer
- All of the 802.11 techniques use short-range radios to transmit signals in either the 2.4GHz or the 5GHz frequency bands
  - 5GHz has a shorter range, but the 2.4GHz band tends to be more crowded
  - different generations, but most modern mobile devices use the 802.11ac
- 802.11 tries to avoid collisions with CSMA/CA, and solve the hidden and exposed terminal problem using the NAV field in each frame

W12 summary (3)

- Clients should not waste power when they have neither information to send nor to receive: variety of power saving methods
- The association service is used by mobile stations to connect themselves to APs, and the data delivery service lets stations transmit and receive data
- Stations must also authenticate before they can send frames via the AP (nowadays mostly WPA2)