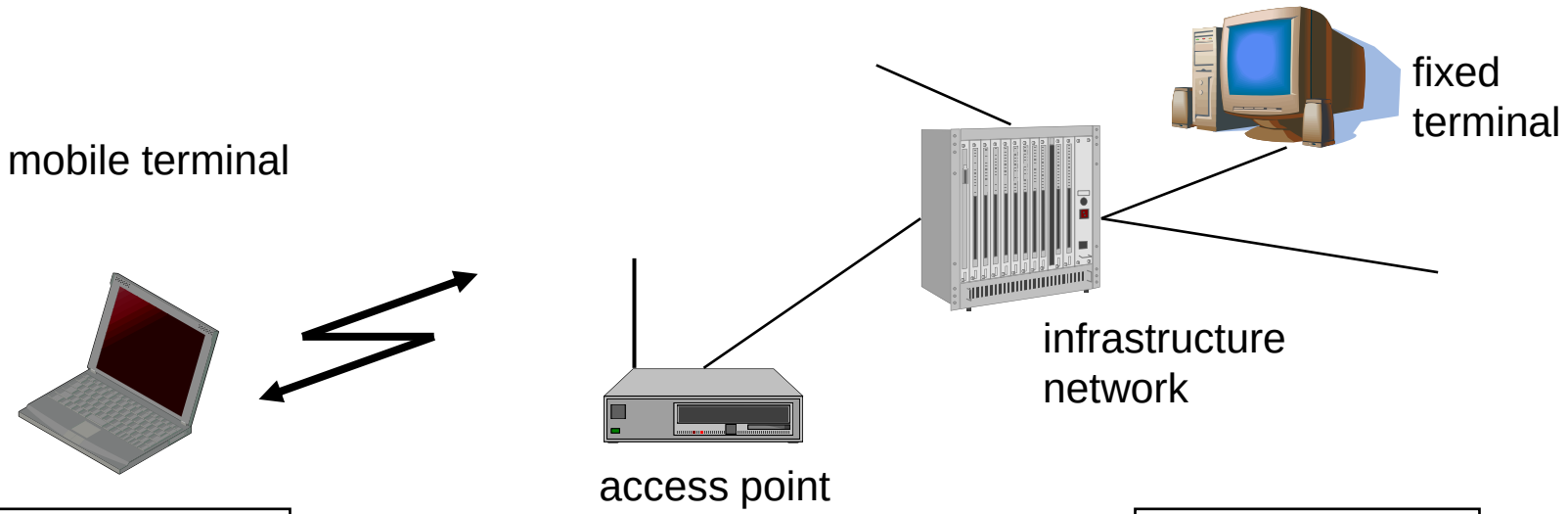
MAC Protocols

Beulah A.
AP/CSE

Purpose of MAC Protocols

- The MAC sublayer provides
  - Addressing
  - channel access when multiple stations contend for the medium.
- Size of MAC Address??
- Mobile device MAC Address size???

Purpose of MAC Protocols



application		application
TCP		TCP
IP		IP
LLC	LLC	LLC
802.11 MAC	802.11 MAC / 802.3 MAC	802.3 MAC
802.11 PHY	802.11 PHY / 802.3 PHY	802.3 PHY

Properties – MAC Protocols

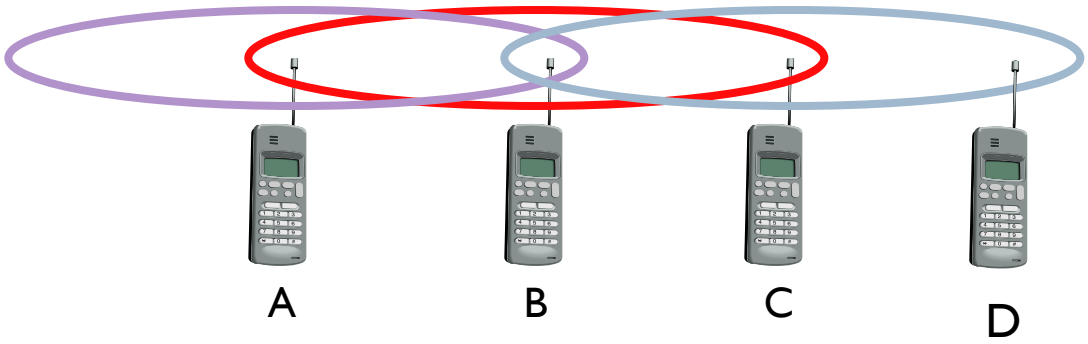
- Should implement some rules to enforce discipline when multiple nodes contend for a shared channel.
- Maximize the utilization of the channel.
- Fair Channel allocation
  - No discrimination for any node.
- Support different types of traffic with maximum and average bit rates.
- Robust incase of equipment failure and changing network conditions
- IEEE 802.11 (WLAN) – wifi hotspots.
- MANET- MACA

Issues

- Difficult to implement a collision detection scheme, as collisions are hard to detect by the nodes.
- The main issues need to be addressed while designing a MAC protocol for ad hoc networks:
  - **Hidden and exposed terminal problems**:
  - Distributed Nature/Lack of Central Coordination
  - Mobility of Nodes: Nodes are mobile most of the time.

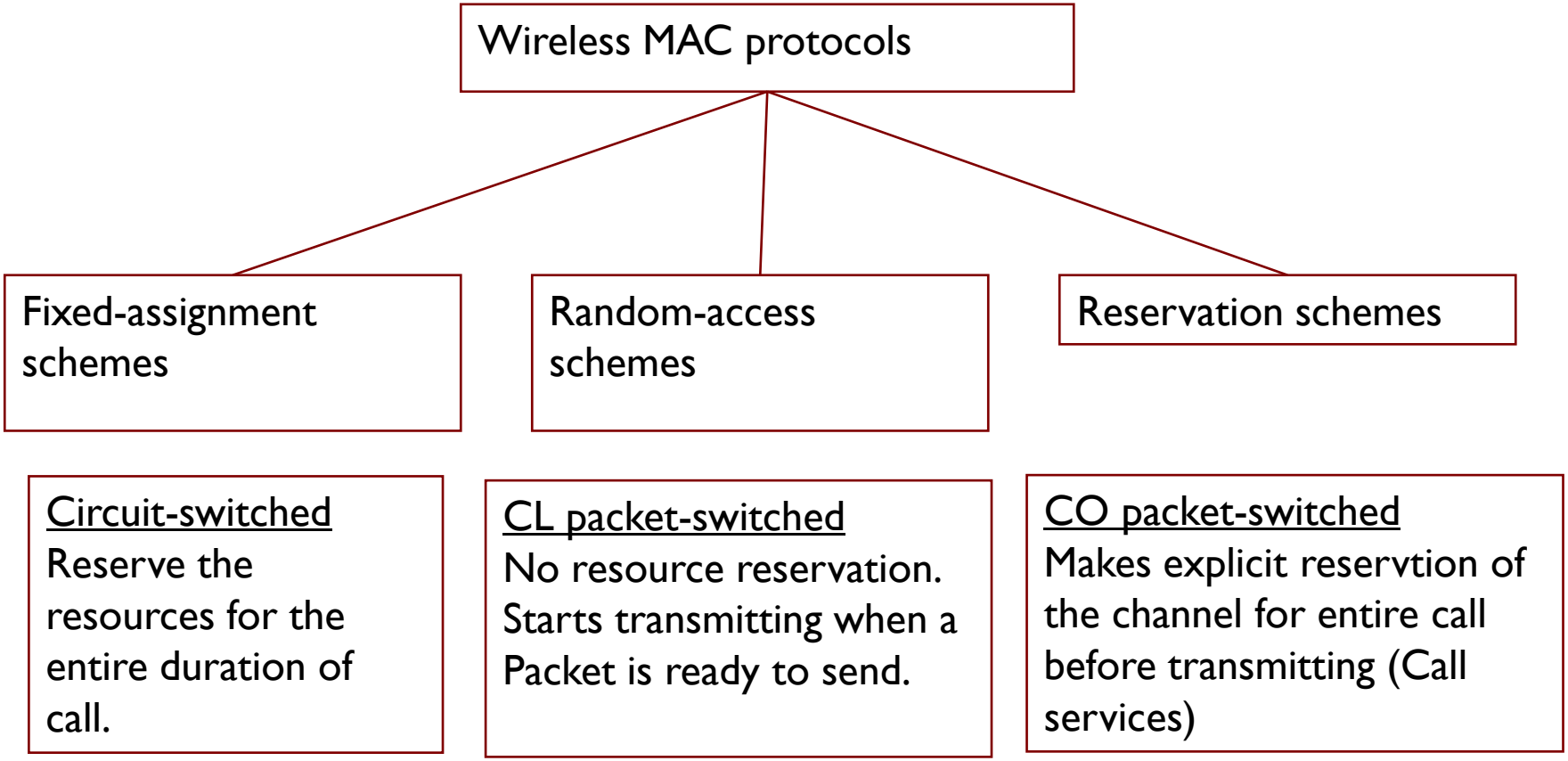
Hidden and exposed Terminal

- Hidden terminals
  - A sends to B, C cannot receive A
  - C wants to send to B, C senses a "free" medium
  - collision at B, A cannot receive the collision
  - A is "hidden" for C



- Exposed terminals
  - B sends to A, C wants to send to another terminal (not A or B)
  - C has to wait, C senses the medium in use
  - but A is outside the radio range of C, therefore waiting is not necessary
  - C is "exposed" to B

Taxonomy of MAC Protocols



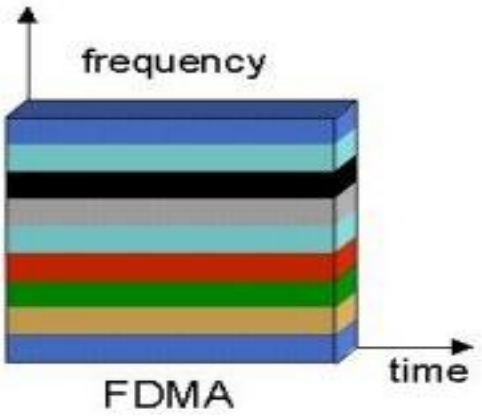
Fixed Assignment Schemes

- Frequency Division Multiple Access(FDMA)
- Time Division Multiple Access(TDMA)
- Code Division Multiple Access(CDMA)

- Ex. persons in public group(Channel) -Avoid cross talk
- Person take turn in speaking (TD)
- Speak at different pitches (FD)
- Speak in different language (CD). Same language understands each other.

FDMA

- Frequency division multiple access (FDMA) comprises all algorithms allocating frequencies to transmission channels according to the frequency division multiplexing (FDM)
- The existing bandwidth is divided into sub bands / channels



FDMA

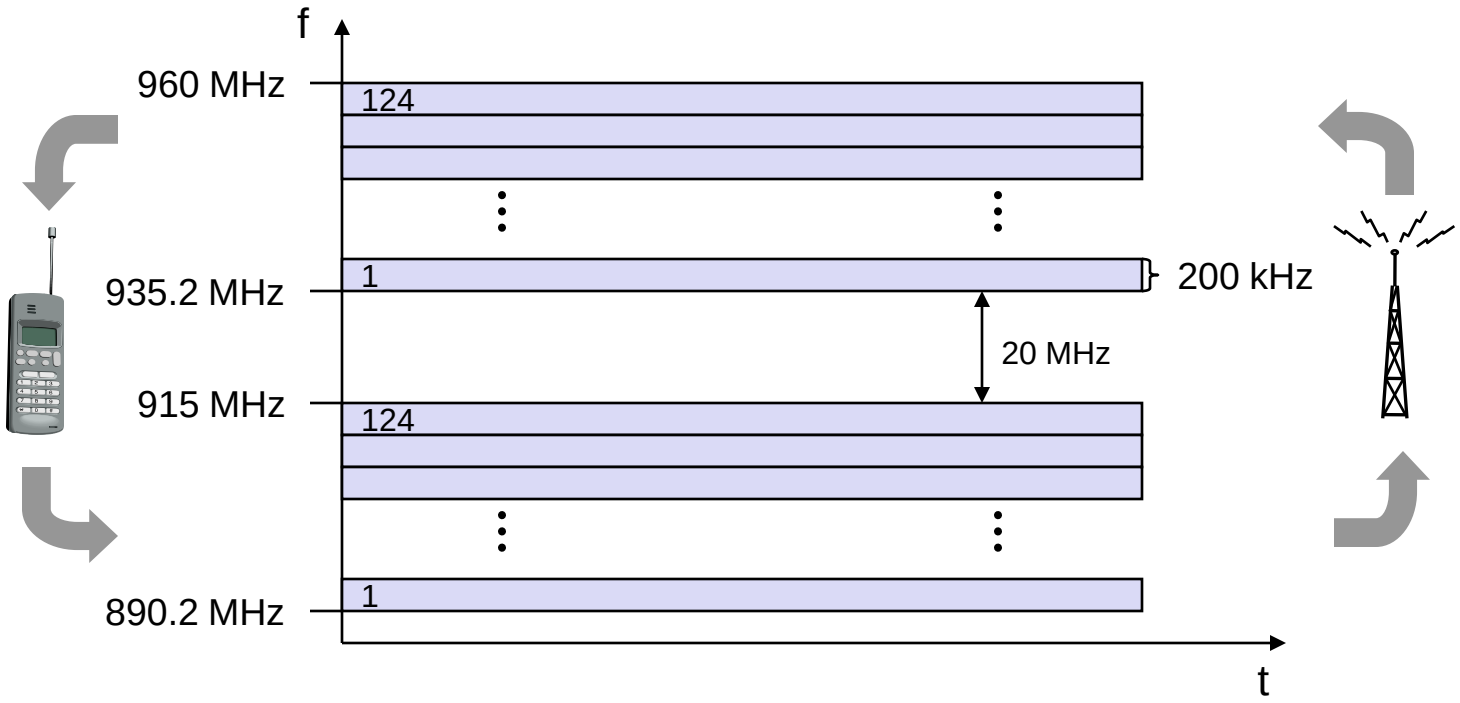
- Pure FDMA
  - Channels can be assigned to the same frequency at all times
- FDMA combined with TDMA
  - Channels can change frequencies according to a certain pattern
- For full duplex communication each user is allocated 2 unique frequency for transmitting and receiving signals during the call
  - Forward Link (Mobile to BS)
  - Reverse Channel (BS to Mobile)
- No other user can be allocated with same frequency to make a call.

FDMA

Frequency division duplex (FDD)

- The two directions, mobile station to base station and vice versa are separated using different frequencies.
- This scheme is called as frequency division duplex (FDD)
- Again, both partners have to know the frequencies in advance ; they cannot just listen into the medium.
- The two frequencies are also known as uplink and downlink

FDMA



FDMA

Uplink Frequency (For Transmission)

- From mobile station to base station or from ground control to satellite
- All uplinks use the band between 890.2 and 915

Downlink Frequency (Receiving information)

- From base station to mobile station or from satellite to ground control
- All downlinks use 935.2 to 960 MHz

FDMA

Allocation of uplink and downlink Frequency

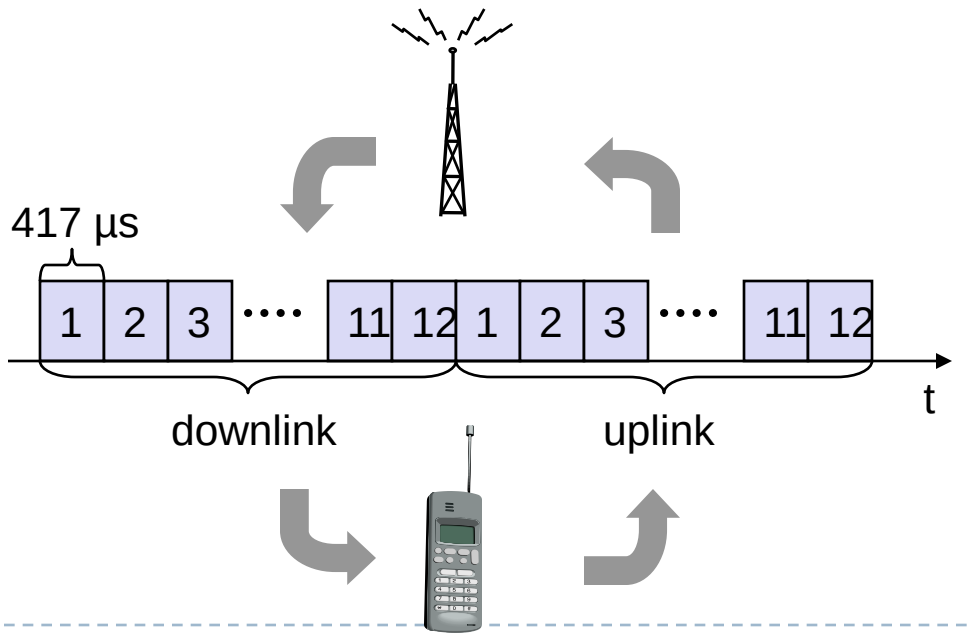
- According to FDMA, the base station, allocates a certain frequency for up and downlink to establish a with a mobile phone
- Up and downlink have a fixed relation
- If the uplink frequency is fu= 890 MHz + n·0.2 MHz, the downlink frequency is fd= fu+ 45 MHz, i.e., fd= 935 MHz + n·0.2 MHz for a certain channel n.
- The base station selects the channel. Each channel (uplink and downlink) has a bandwidth of 200 kHz
- This illustrates the use of FDM for multiple access (124 channels per direction are available at 900 MHz) and duplex according to a predetermined scheme.

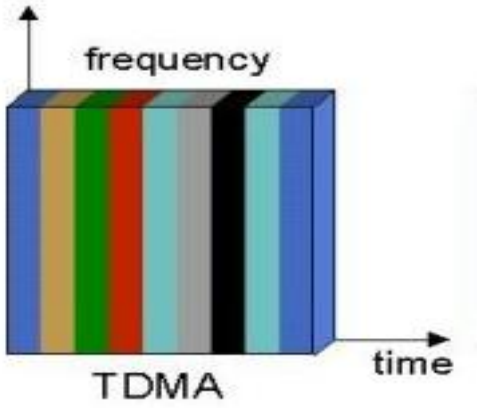
FDMA

- Drawback
  - When allocated user paused between transmission –unused transmission
  - No user is allocated, the band goes idle.
  - Does not achieve high channel utilization

TDMA

- Time division multiple access (TDMA) allocate certain time slots for communication, i.e., controlling TDM.
- The timeline is divided into fixed time slots.
- Time slots are allocated in round robin manner.

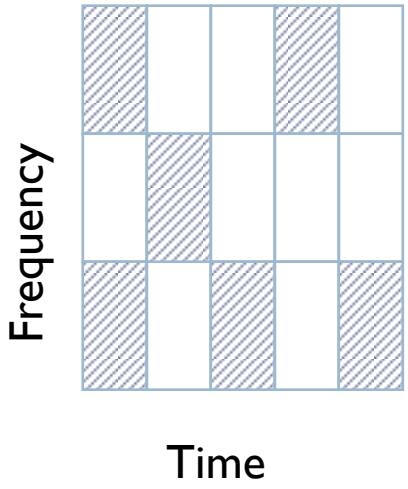




TDMA

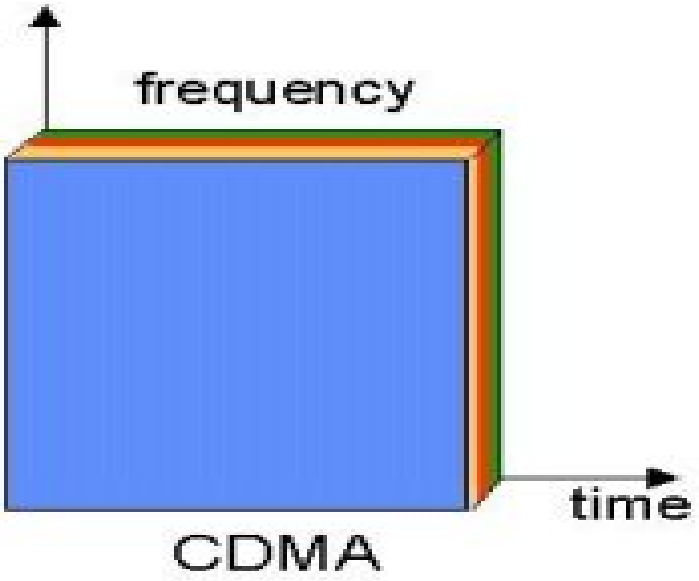
- Only one frequency is used.
- Each partner must be able to access the medium for a time slot at the right moment.
- The base station uses 12 slots for downlink and the mobile uses other 12 slots for uplink.
- Up to 12 different mobile stations can use the same frequency.
- Every 10ms = 417μs*24 a mobile station can access the medium.
- Very inefficient for bursty data
- Unused Time slots go idle , leading to low channel Utilization

Hybrid FDMA/TDMA



CDMA

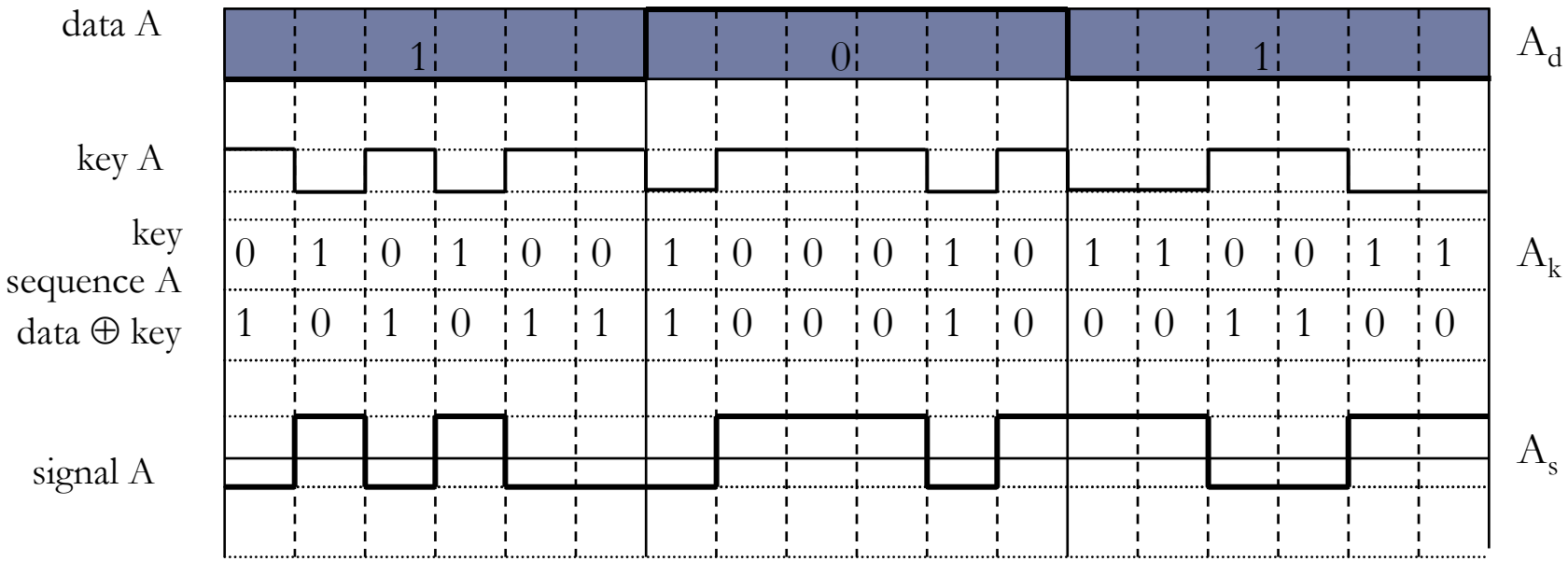
- All terminals send on the same frequency probably at the same time and can use the whole bandwidth of the transmission channel
- Each sender has a unique random number, the sender XORs the signal with this random number
- The receiver can "tune" into this signal if it knows the pseudo random number, tuning is done via a correlation function



CDMA

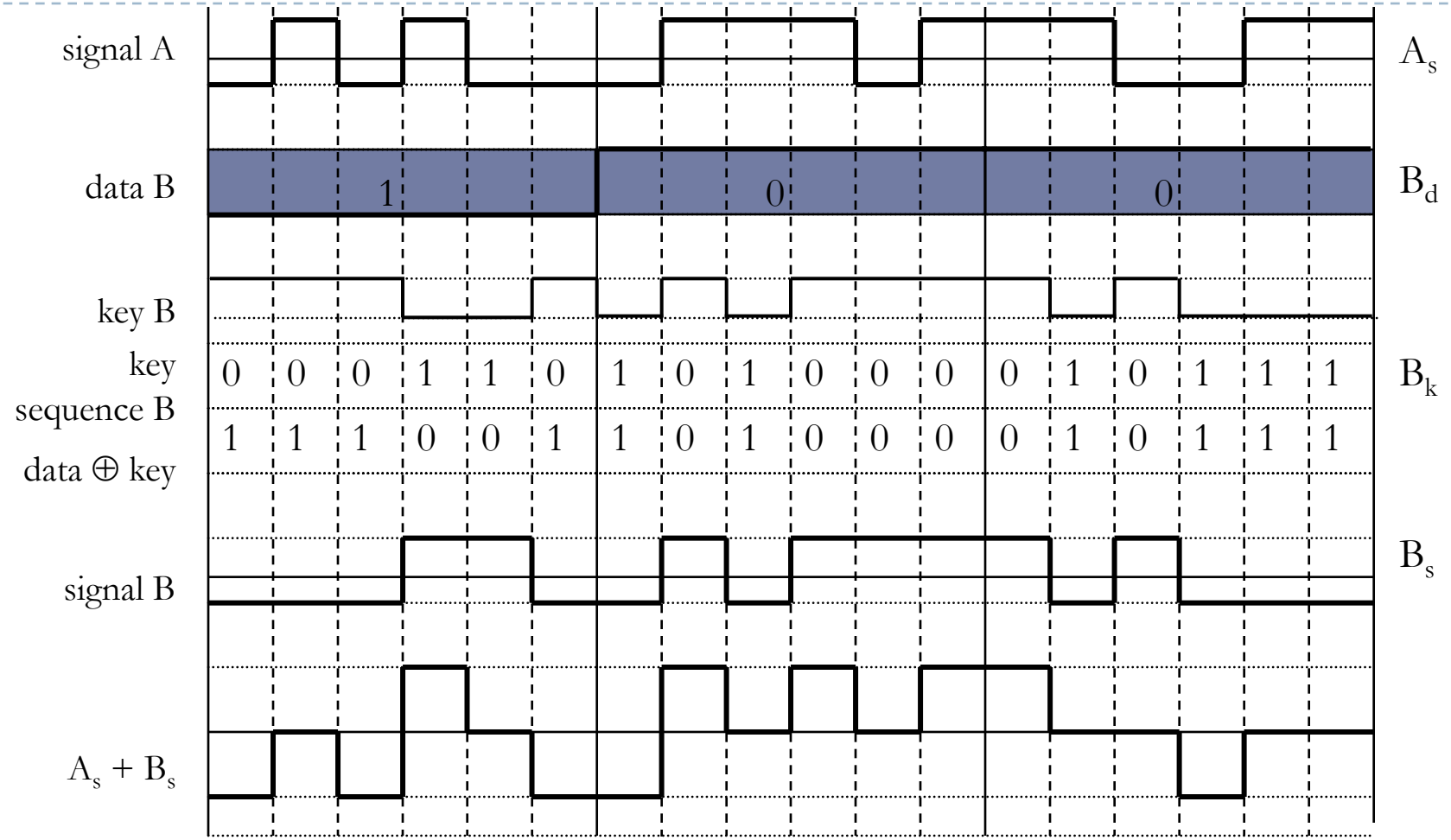
- Sender A
  - sends $A_d = 1$, key $A_k = 010011$ (assign: "0"= -1, "1"= +1)
  - sending signal $A_s = A_d * A_k = (-1, +1, -1, -1, +1, +1)$
- Sender B
  - sends $B_d = 0$, key $B_k = 110101$ (assign: "0"= -1, "1"= +1)
  - sending signal $B_s = B_d * B_k = (-1, -1, +1, -1, +1, -1)$
- Both signals superimpose in space
  - interference neglected (noise etc.)
  - $A_s + B_s = (-2, 0, 0, -2, +2, 0)$
- Receiver wants to receive signal from sender A
  - apply key A_k bitwise (inner product)
    - $A_e = (-2, 0, 0, -2, +2, 0) \bullet A_k = 2 + 0 + 0 + 2 + 2 + 0 = 6$
    - result greater than 0, therefore, original bit was "1"
  - receiving B
    - $B_e = (-2, 0, 0, -2, +2, 0) \bullet B_k = -2 + 0 + 0 - 2 - 2 + 0 = -6$, i.e. "0"

CDMA

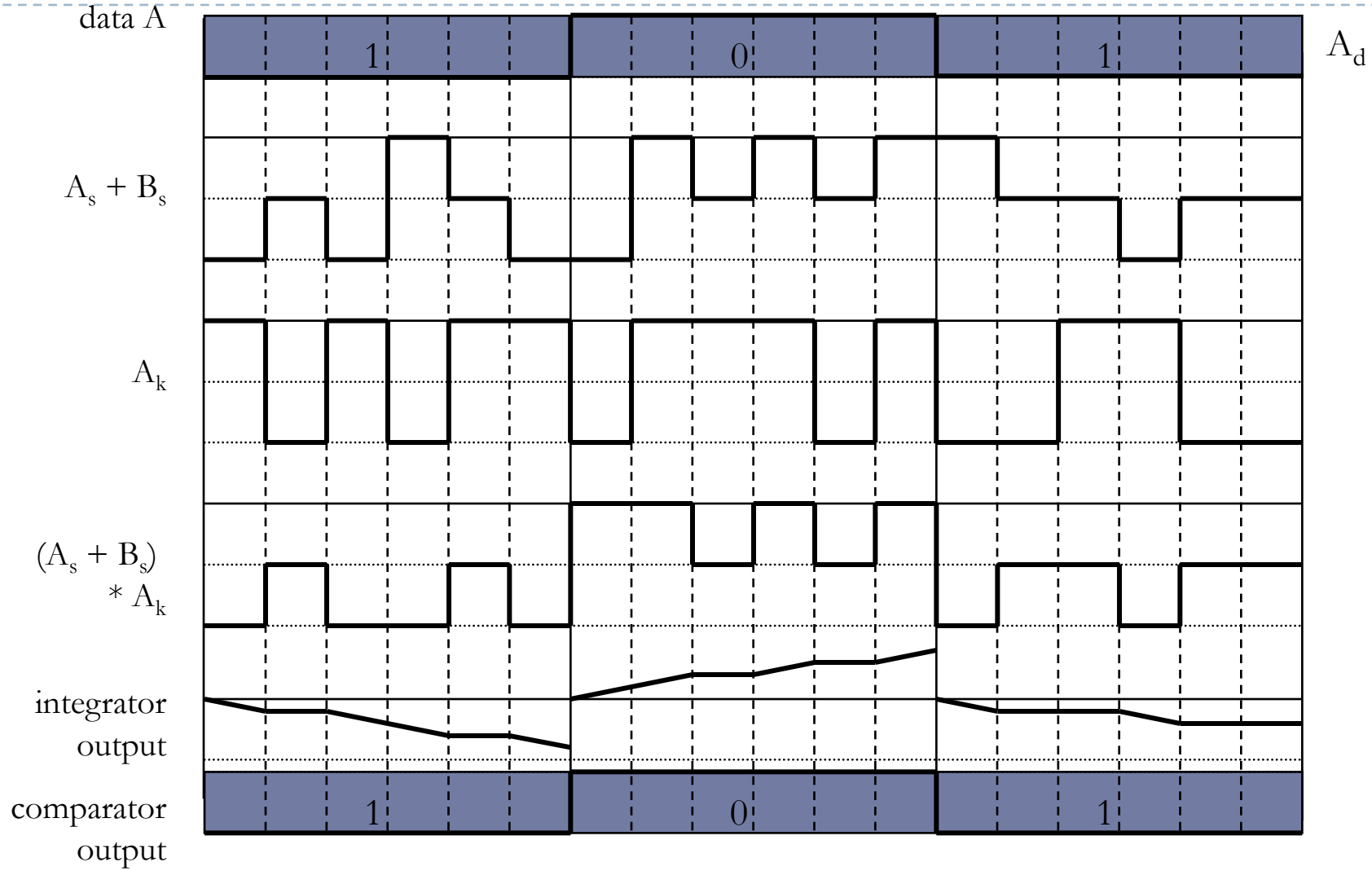


Real systems use much longer keys resulting in a larger distance between single code words in code space.

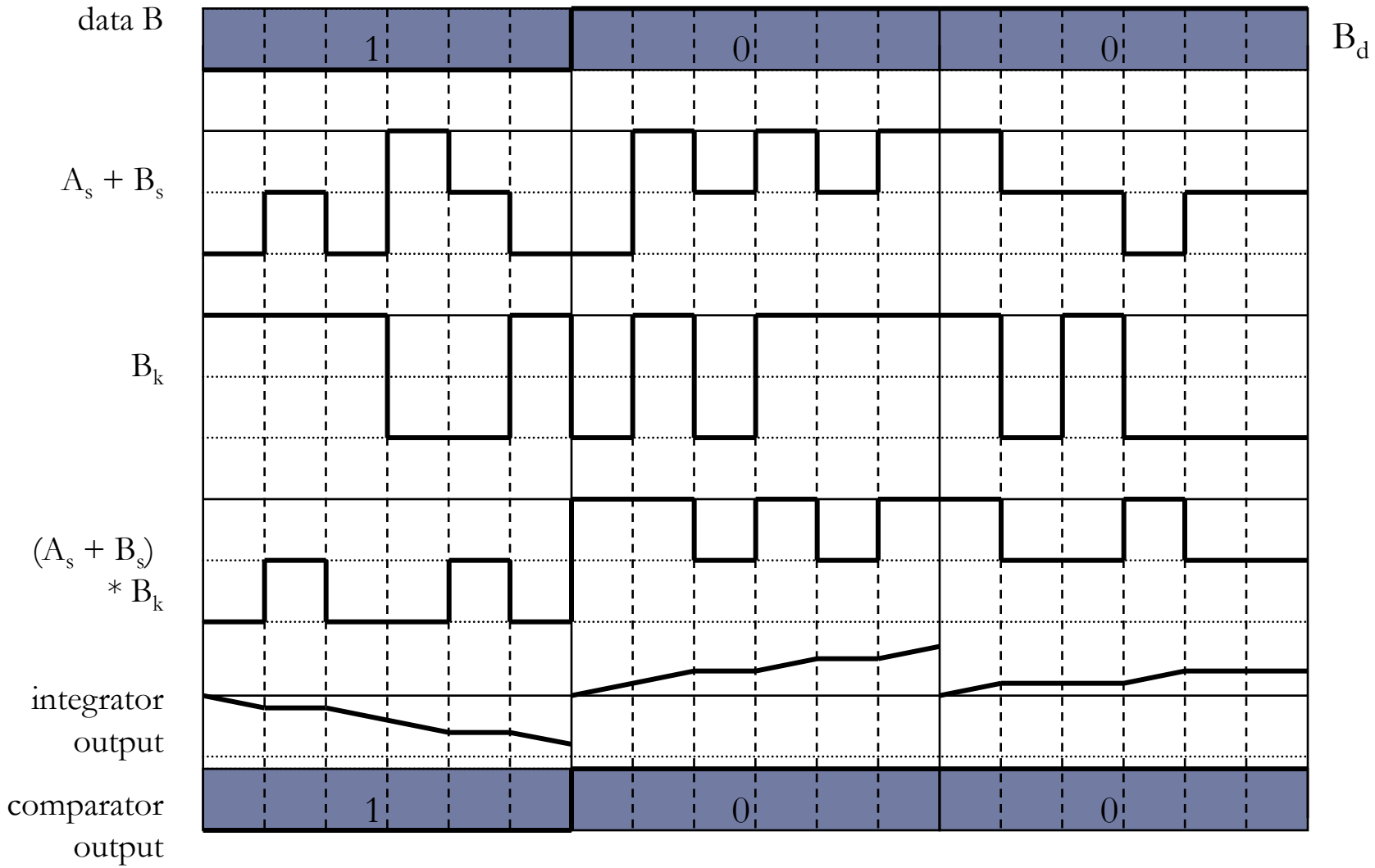
CDMA


signal A
A_s
data B
1
0
0
B_d
key B
key sequence B
0 0 0 1 1 0 1 0 1 0 0 0 0 1 0 1 1 1
B_k
1 1 1 0 0 1 1 0 1 0 0 0 0 1 0 1 1 1
data ⊕ key
B_s
signal B
$A_s + B_s$

CDMA


data A
1
0
1
A_d
$A_s + B_s$
A_k
$(A_s + B_s) * A_k$
integrator output
comparator output
1
0
1

CDMA


data B
1
0
0
B_d
$A_s + B_s$
B_k
$(A_s + B_s) * B_k$
integrator output
comparator output
1
0
0

CDMA

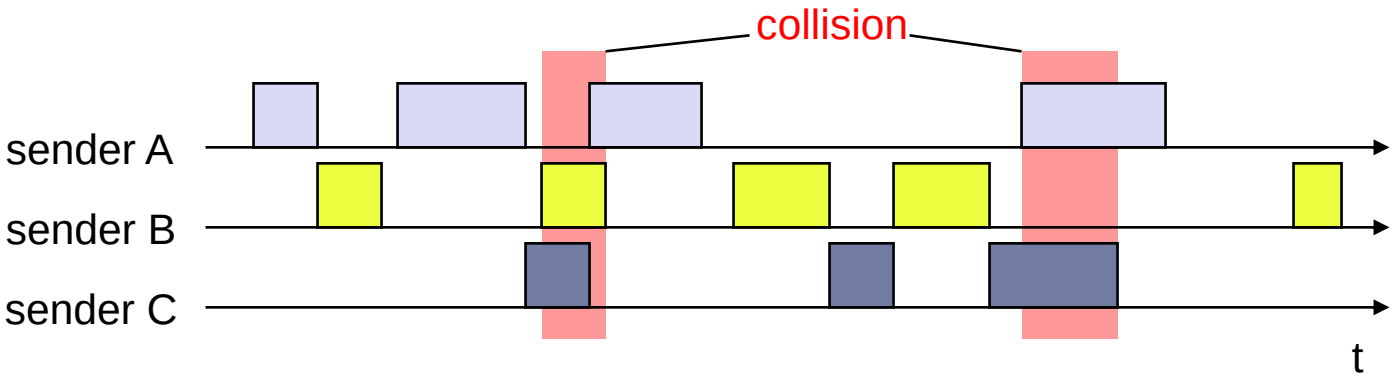
- Disadvantages:
  - Higher complexity of a receiver (receiver cannot just listen into the medium and start receiving if there is a signal)
  - All signals should have the same strength at a receiver
- Advantages:
  - All terminals can use the same frequency, no planning needed
  - Huge code space (e.g. 2^{32}) compared to frequency space
  - Interferences (e.g. white noise) is not coded
  - Forward error correction and encryption can be easily integrated

Random Assignment Schemes

- ALOHA
- Slotted ALOHA
- CSMA
- CSMA/CD
- CSMA/CA

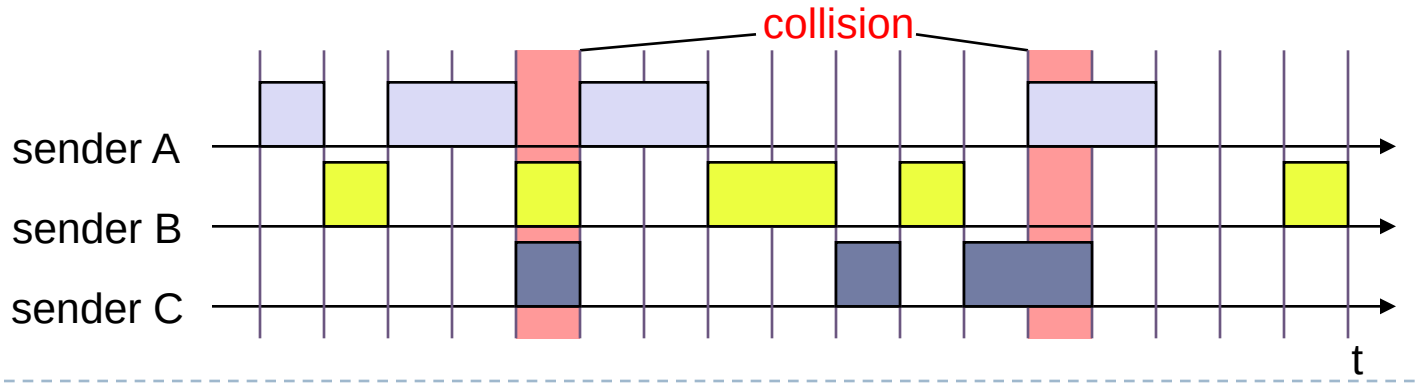
ALOHA

- Free for all
- Any station has a frame to transmit, it transmits.
- Collision occurs when more than one station transmits.



Slotted ALOHA

- Time is divided into slots
- Slot size is equal.
- Therefore fixed time for frame transmission.
- Beacon signal – to notify start of time slot
- If a station is ready with a frame, it waits until start of next transmission time.
- Collision occurs at time slots.



CSMA

- Carrier Sense Multiple Access.
- Before transmitting the data listens the medium
- If medium is idle then transmit else wait and try again.
- How to identify collision occurs?
- 2 stations senses and transmit at time t.
- No ack for some amount of time.
- Assume collision and retransmit.

CSMA/CD

- CSMA wastes bandwidth
- Some mechanism is needed to detect collision
- Listen the medium continuously when the medium is transmitting
  - If idle transmit
  - If collision stop transmission
    - Then transmit jamming signal.
  - Wait a random time and then try to transmit again. (exponential backoff algorithm)
- Improves performance by terminating transmission ie avoiding collision

Exponential Backoff Alg.

- The retransmission is delayed by an amount of time derived from the slot time and the number of attempts to retransmit.
- After *c* collisions, a random number of slot times between 0 and $2^c - 1$ is chosen.
- For the first collision, each sender will wait 0 or 1 slot times.
- After the second collision, the senders will wait anywhere from 0 to 3 slot times inclusive.

Exponential Backoff Alg.

- After the third collision, the senders will wait anywhere from 0 to 7 slot times (inclusive), and so forth.
- As the number of retransmission attempts increases, the number of possibilities for delay increases exponentially.
- The 'truncated' simply means that after a certain number of increases, the exponentiation stops; i.e. the retransmission timeout reaches a ceiling, and thereafter does not increase any further.
- For example, if the ceiling is set at i = 10 then the maximum delay is 1023 slot times.

CSMA/CD

- In wireless network CSMA/CD does not work well.
- Carrier sense → NAV (Network Allocation Vector)
  - Virtual carrier-sensing mechanism used with wireless network protocols such as IEEE 802.11
  - The MAC layer frame headers contain a *duration* field that specifies the transmission time required for the frame, in which time the medium will be busy.
  - The other stations listening on the wireless medium read the *Duration* field and set their NAV, which is an indicator for a station on how long it must defer from accessing the medium
  - The NAV may be thought of as a counter, which counts down to zero at a uniform rate
  - Counter → 0 → Medium is idle
  - Counter → non zero → Medium is busy

CSMA/CD

- Wired network → Collision Detection is simple.
  - No voltage → Medium idle
  - Current flows → some station is transmitting
  - Voltage for each bit → 18-20 mA
  - When collision each bit is > 24mA
- Wireless network → very difficult.
  - When the signal is weak, it can easily be masked by noise.
  - The destination notices this while performing checksum.
  - Leads to retransmission, wastage of bandwidth.
  - Therefore collision detection does not work well with wireless networks

CSMA/CA

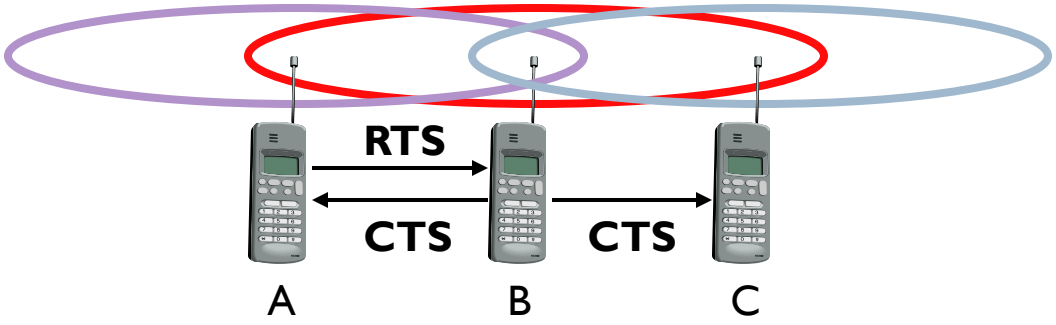
- A node wishing to transmit data has to first listen to the channel for a predetermined amount of time to determine whether or not another node is transmitting on the channel within the wireless range.
- If the channel is sensed "idle," then the node is permitted to begin the transmission process.
- If the channel is sensed as "busy," the node defers its transmission for a random period of time.
- Collision avoidance is used to improve CSMA performance by not allowing wireless transmission of a node if another node is transmitting, thus reducing the probability of collision due to the use of a random waiting time.

Reservation Based Schemes

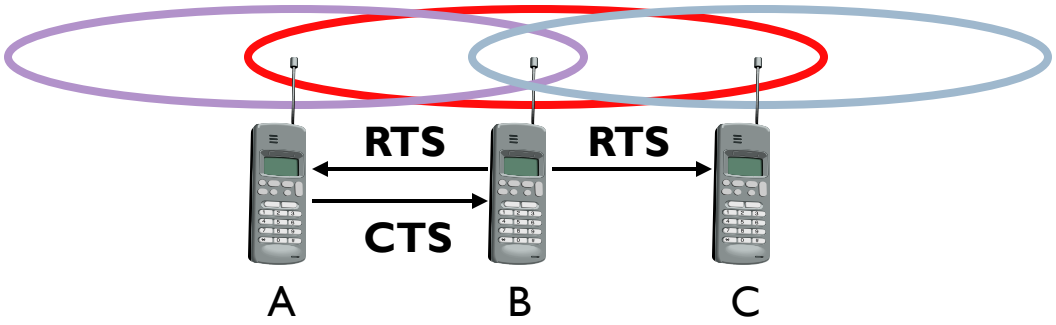
- This is done by RTS/CTS
- RTS (request to send):
  - A sender request the right to send from a receiver with a short RTS packet before it sends a data packet
- CTS (clear to send):
  - The receiver grants the right to send as soon as it is ready to receive

Multiple Access with Collision Avoidance

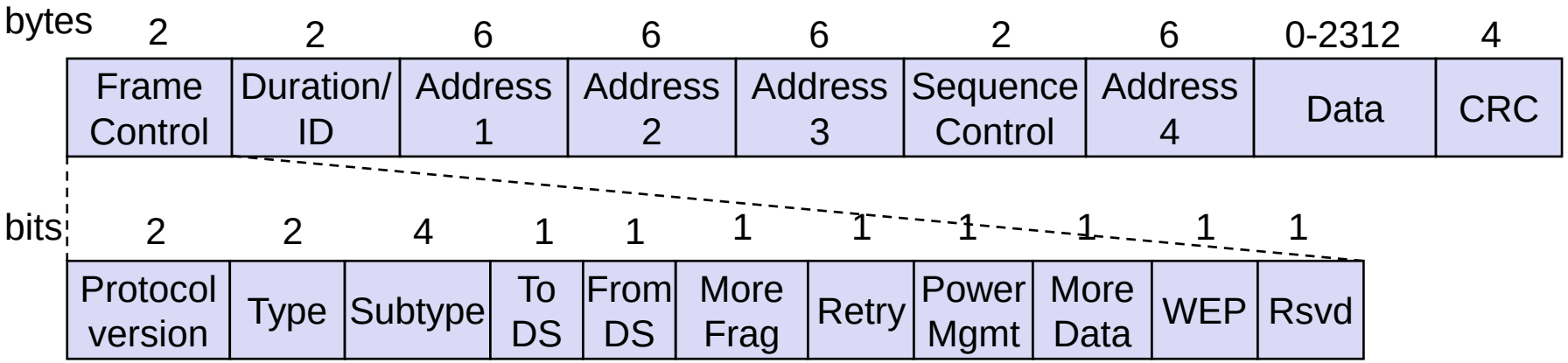
- MACA avoids the problem of hidden terminals
  - A and C want to send to B
  - A sends RTS first
  - C waits after receiving CTS from B



- MACA avoids the problem of exposed terminals
  - B wants to send to A, C to another terminal
  - now C does not have to wait for it cannot receive CTS from A



Frame format



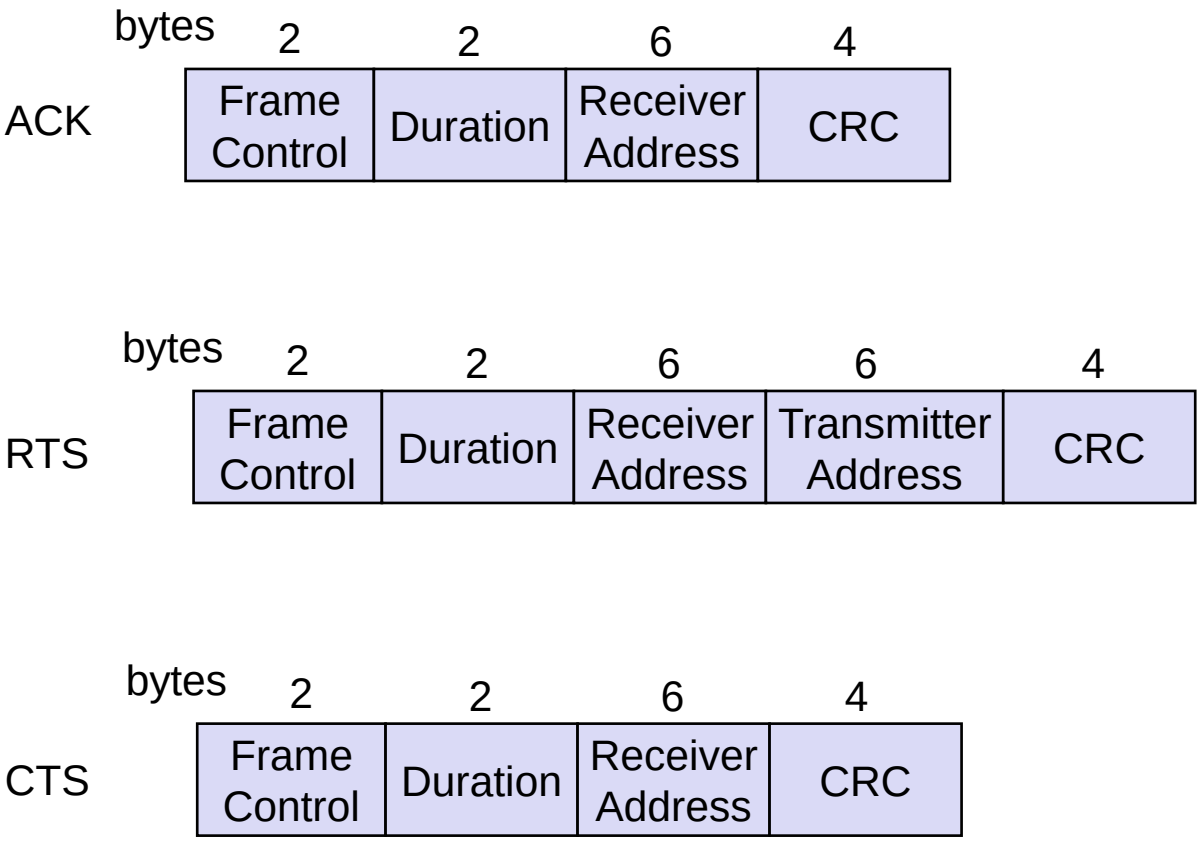
Frame format

Field	*Explanation*
Version	Current version is 0
Type	Type of information: management (00), control (01), or data (10)
Subtype	Subtype of each type (see Table 14.2)
To DS	Defined later
From DS	Defined later
More flag	When set to 1, means more fragments
Retry	When set to 1, means retransmitted frame
Pwr mgt	When set to 1, means station is in power management mode
More data	When set to 1, means station has more data to send
WEP	Wired equivalent privacy (encryption implemented)
Rsvd	Reserved

Frame format

Subtype	*Meaning*
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)

Frame format

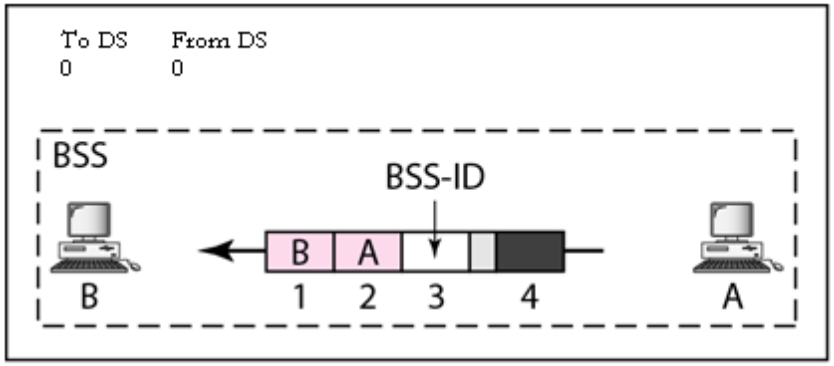


Frame format

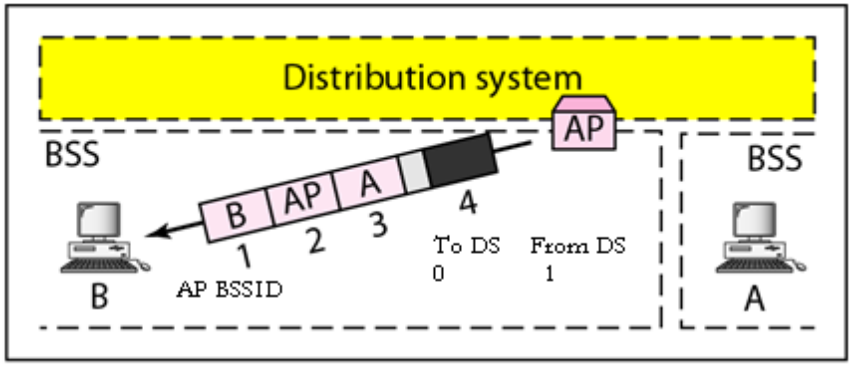
scenario	to DS	from DS	address 1	address 2	address 3	address 4
ad-hoc network	0	0	DA	SA	BSSID	-
infrastructure network, from AP	0	1	DA	BSSID	SA	-
infrastructure network, to AP	1	0	BSSID	SA	DA	-
infrastructure network, within DS	1	1	RA	TA	DA	SA

DS: Distribution System
AP: Access Point
DA: Destination Address
SA: Source Address
BSSID: Basic Service Set Identifier
RA: Receiver Address
TA: Transmitter Address

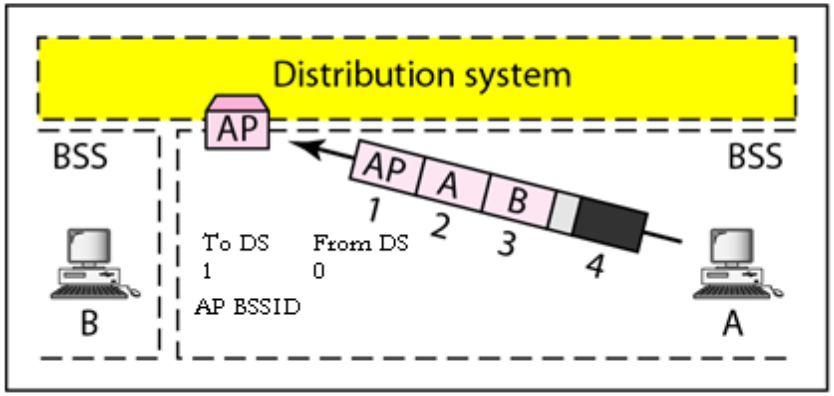
Frame format



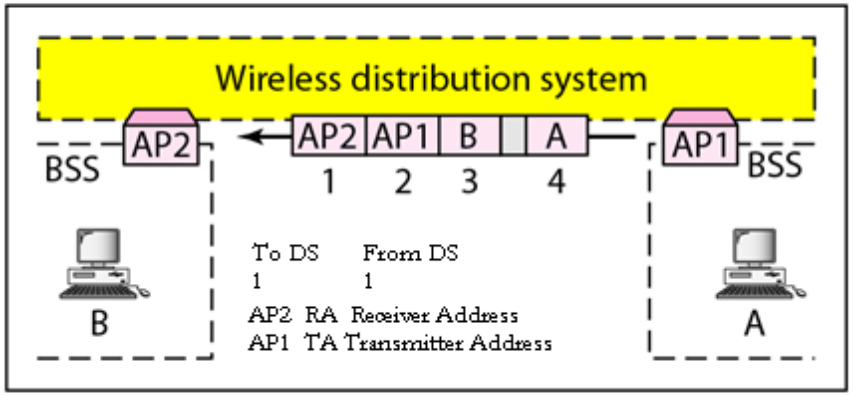
a. Case 1



b. Case 2



c. Case 3



d. Case 4

Summary

- MAC Protocols
  - Properties, Issues
  - Different Categories of MAC such as
    - Fixed Assignment Schemes (Wireless LAN)
    - Random Assignment Schemes (Wireless LAN)
    - Reservation Schemes (MANETs)
  - Detail Frame Format

Test your knowledge

- Switches are capable of reading the MAC address field from each frame that comes to them. So we can say they work on the _____ layer from the TCP/IP model.
  - Physical
  - Network
  - Data Link

- In IEEE 802.11, a ___ is made of stationary or mobile wireless stations and an optional central base station, known as the access point (AP)
  - ESS
  - BSS
  - CSS

Test your knowledge

- A BSS without an AP is called an _____.
  - an ad hoc architecture
  - an infrastructure network

- communication between two stations in two different BSSs usually occurs via two _____.
  - BSSs
  - ESSs
  - APs

Test your knowledge

- When a frame is going from one station to another in the same BSS without passing through the distribution system, the address flag is _____
  - 00
  - 01
  - 10
- When a frame is going from a station to an AP, the address flag is _____.
  - 01
  - 10
  - 11

References

- Prasant Kumar Pattnaik, Rajib Mall, "Fundamentals of Mobile Computing", PHI Learning Pvt. Ltd, New Delhi – 2012.
- Jochen H. Schller, "Mobile Communications", Second Edition, Pearson Education, New Delhi, 2007.
- Behrouz A. Forouzan, "Data communication and Networking", Fourth Edition,Tata McGraw – Hill, 2011.