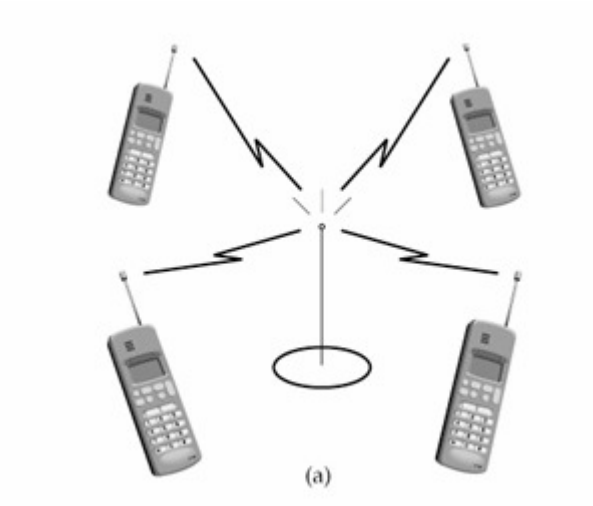
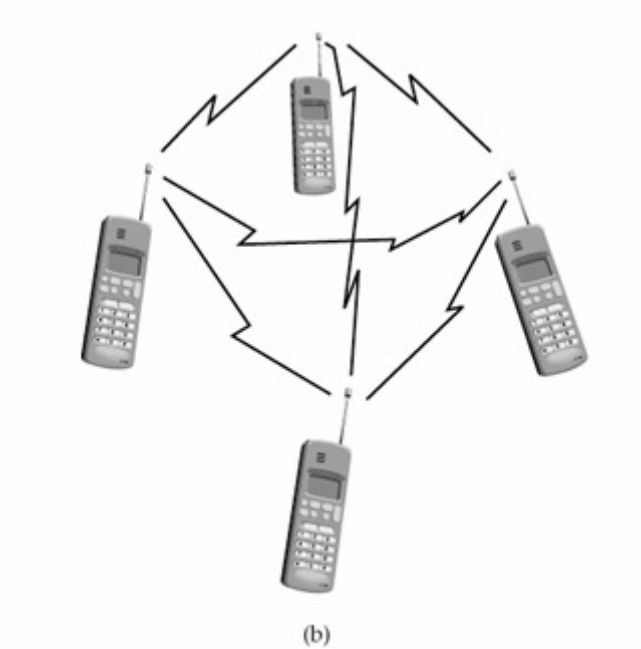
Lecture 4: Wireless MAC Overview

Hung-Yu Wei
National Taiwan University

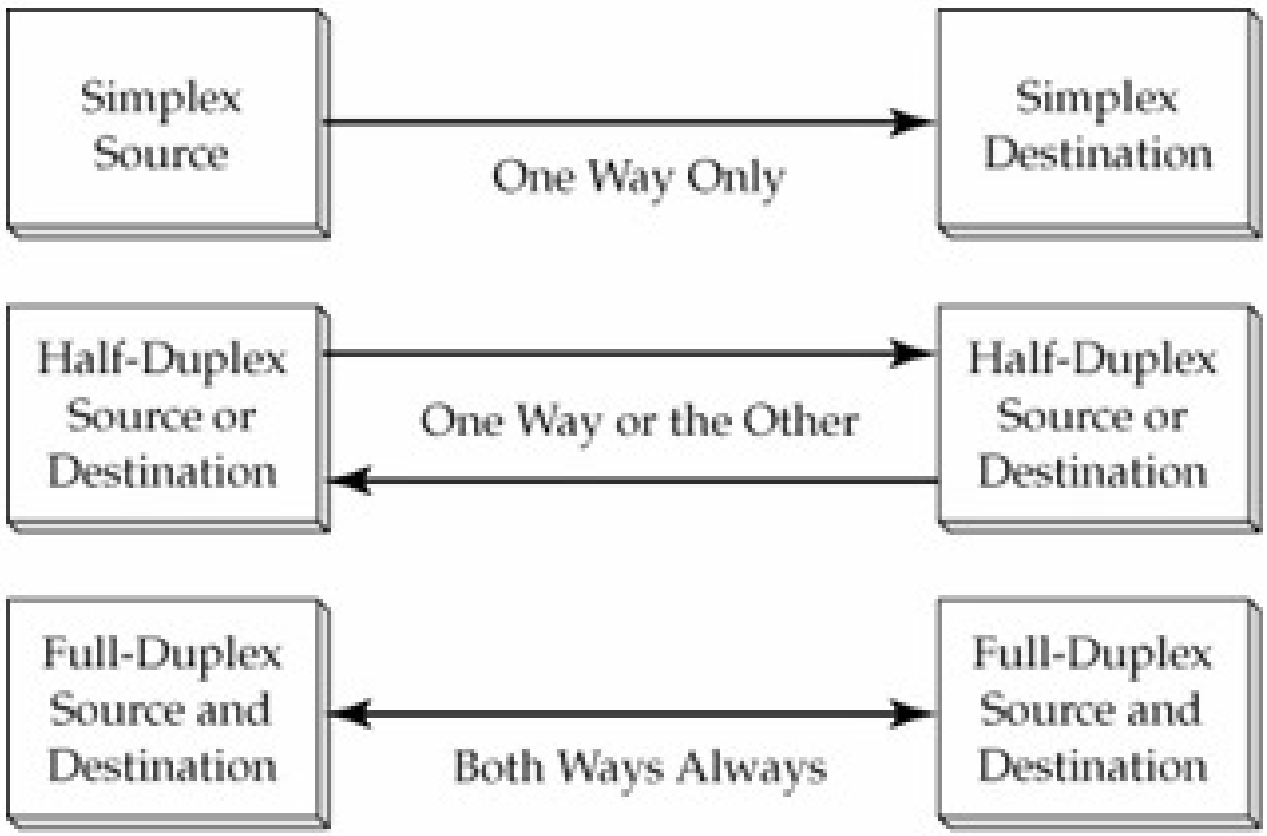
Medium Access Control

Topology





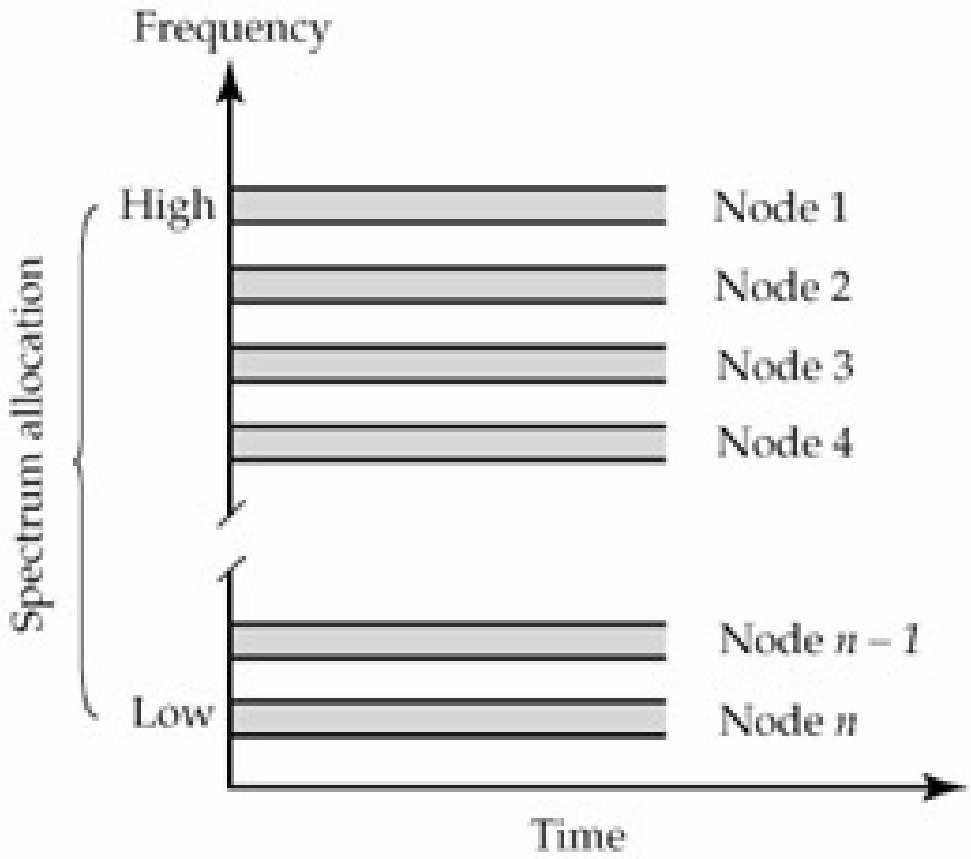
Simplex and Duplex



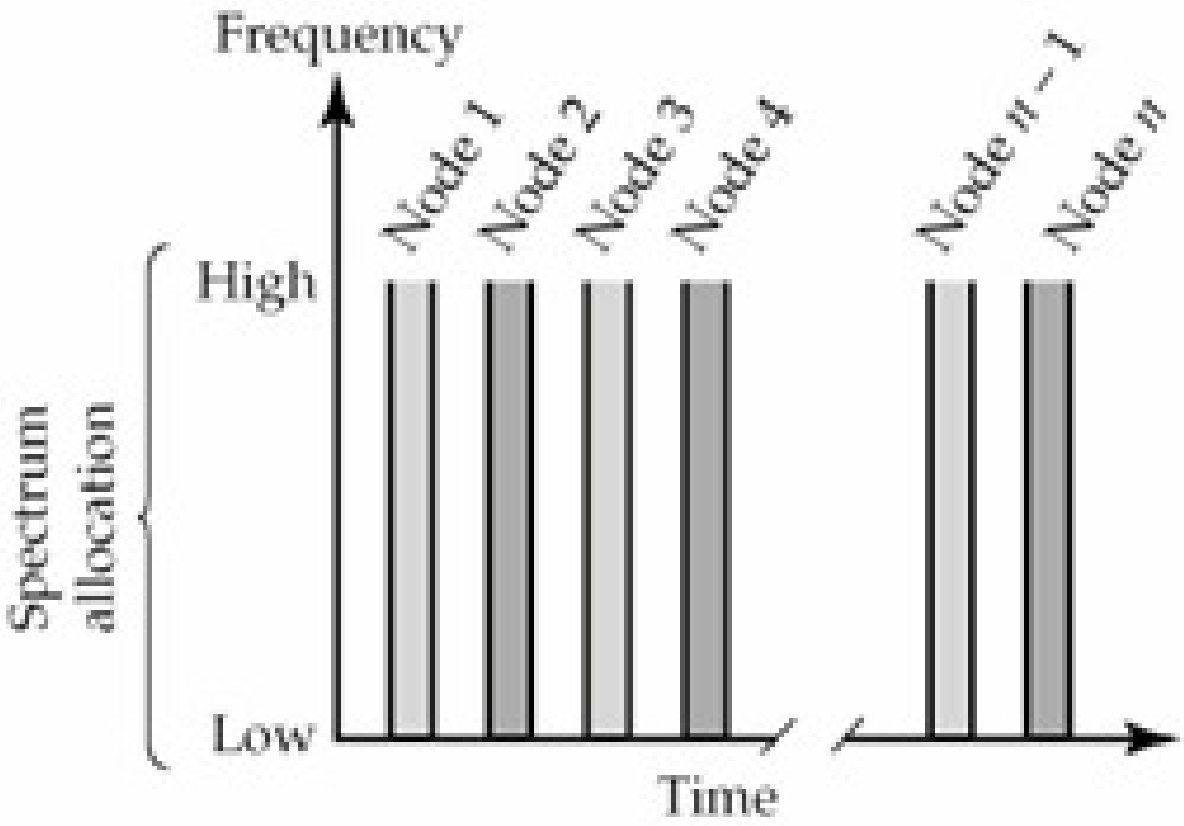
Multiple Access Methods

- FDMA
- TDMA
- CDMA
  - DSSS
  - FHSS
- Notice: CDMA and spread spectrum are related but differnt

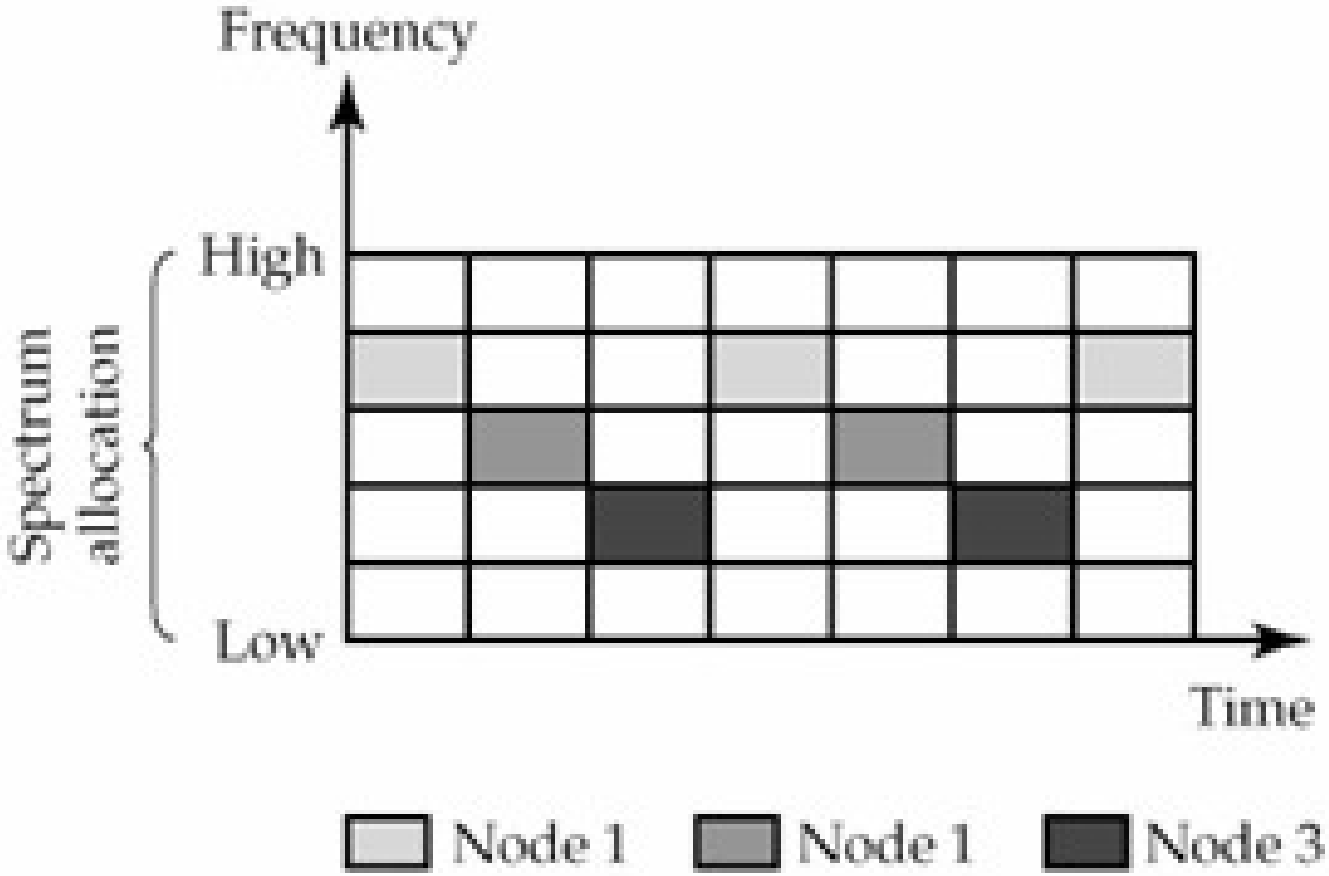
FDMA


Frequency
High
Low
Spectrum allocation
Node 1
Node 2
Node 3
Node 4
Node n – 1
Node n
Time

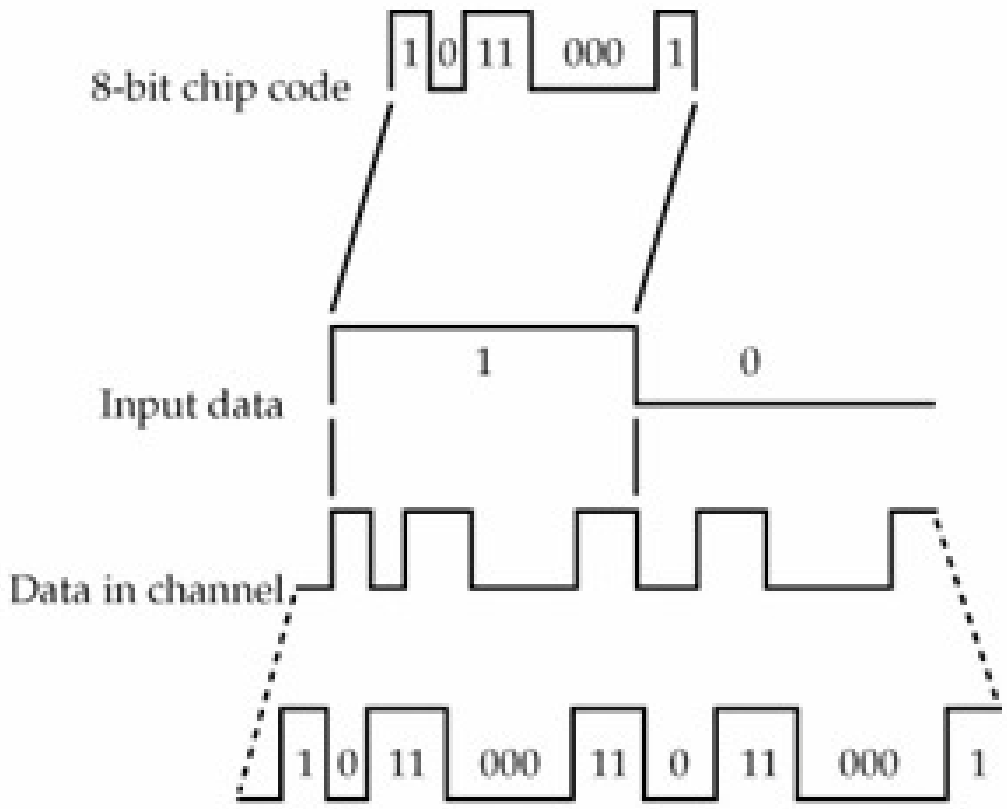
TDMA


Frequency
Node 1
Node 2
Node 3
Node 4
Node n − 1
Node n
High
Low
Spectrum allocation
Time

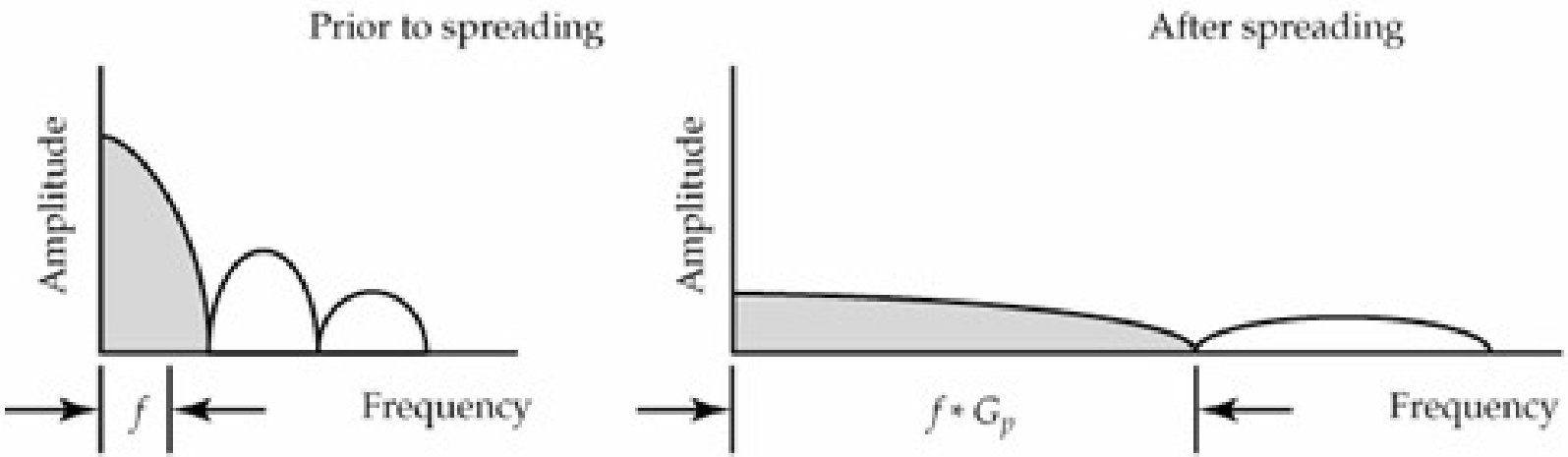
Hybrid FDM/TDMA



DSSS and chip

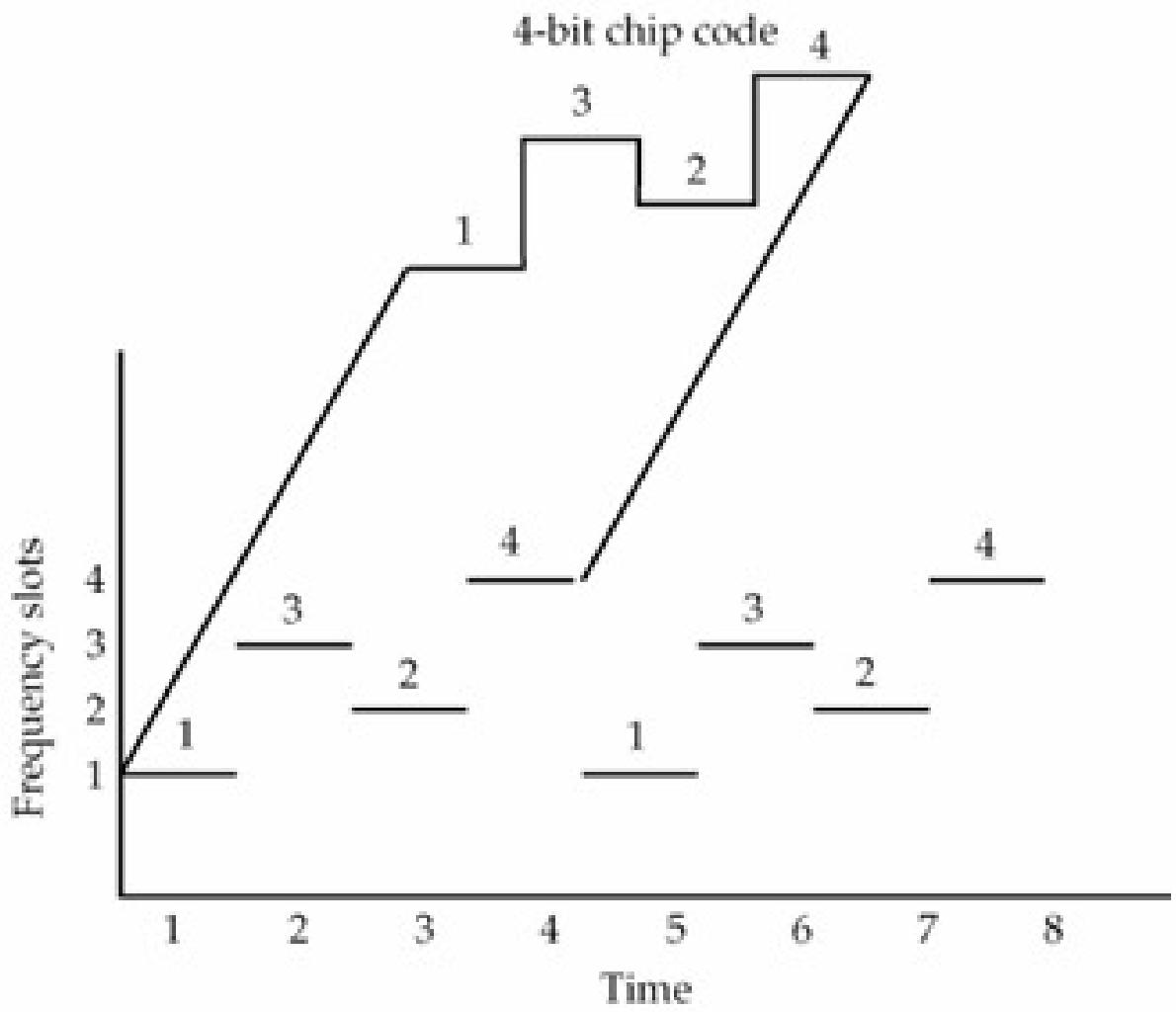


Spreading with DSSS

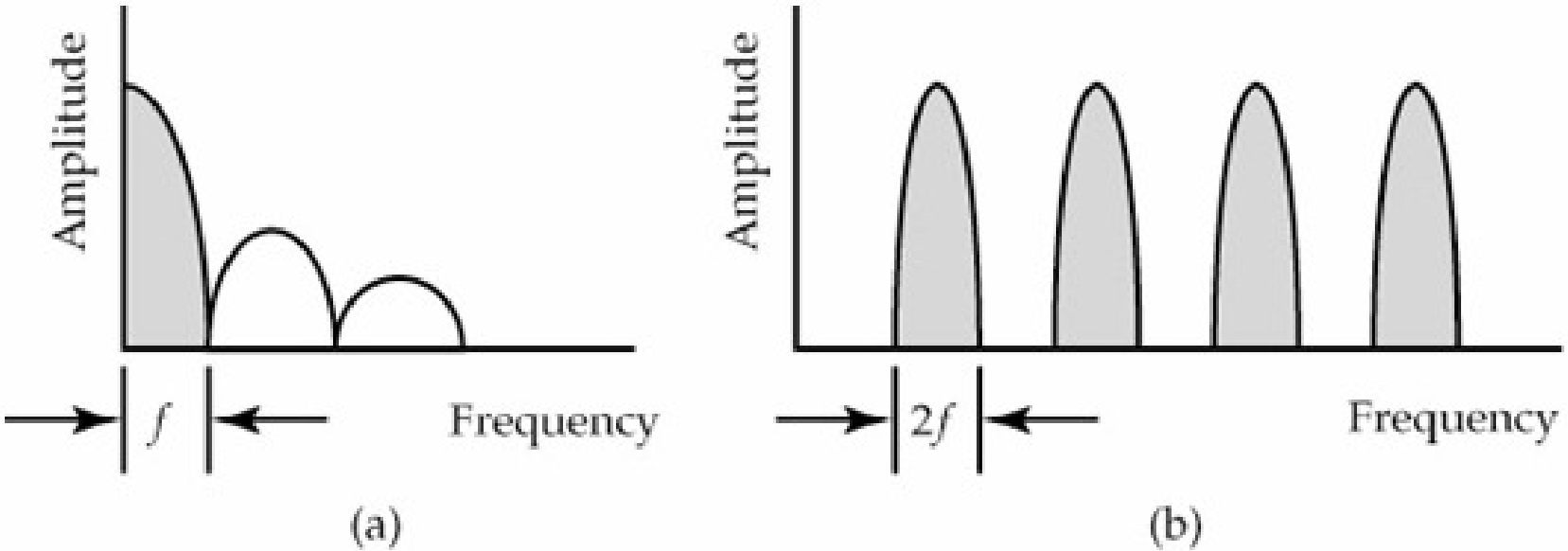


The shaded area is the same, but the signal after spreading is at very low peak powers.

FHSS code



Spreading with FHSS



Wireless MAC

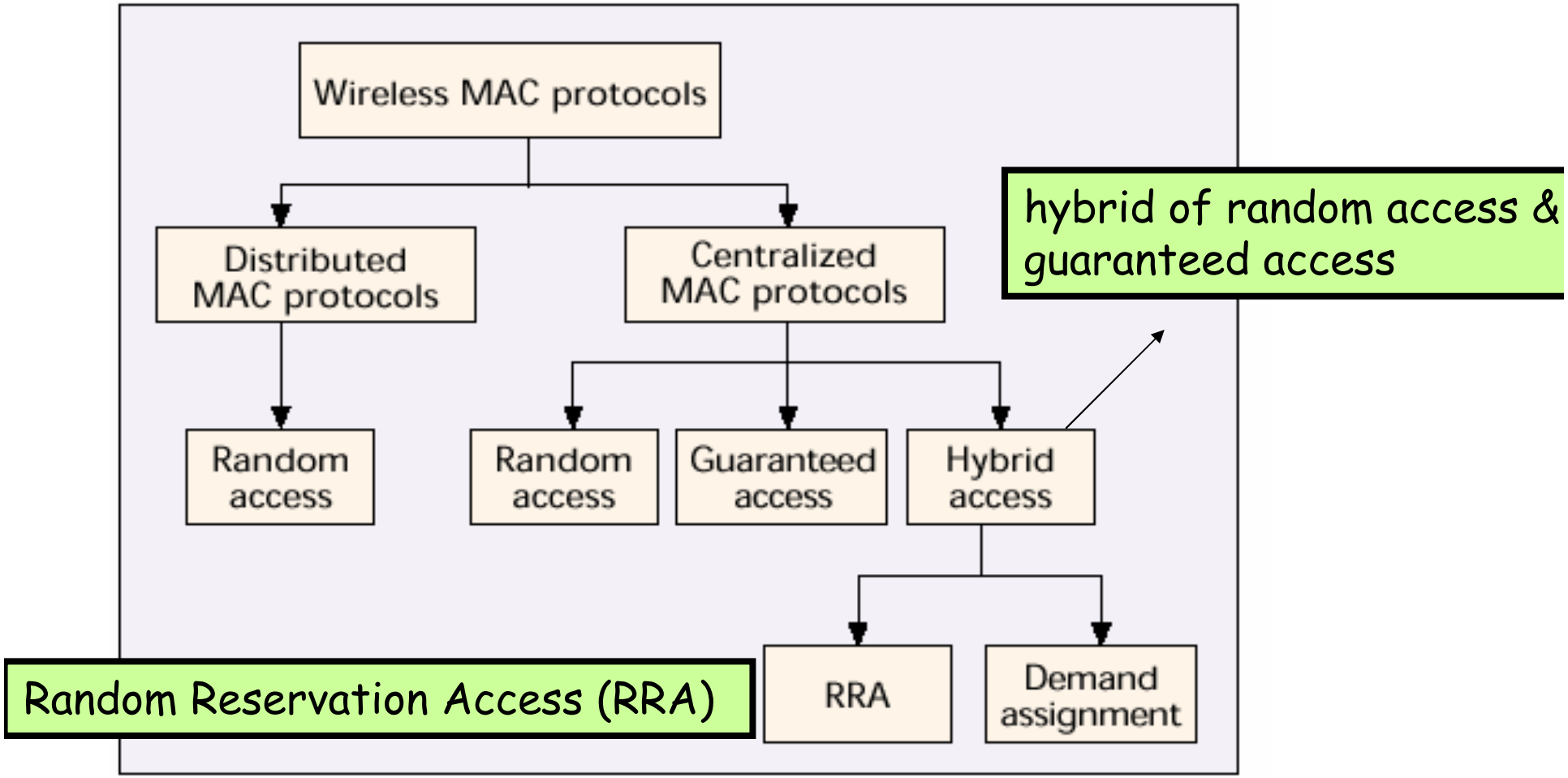
What's MAC

- Medium Access Control
  - Sharing the wireless medium
- The MAC protocol defines
  - a set of rules for the orderly access of a shared media wireless channel by multiple mobile devices
  - a set of services that support real-time voice and video, and reliable delivery of data
  - plays a crucial role in the efficient and fair sharing of scarce wireless bandwidth

Issues in MAC

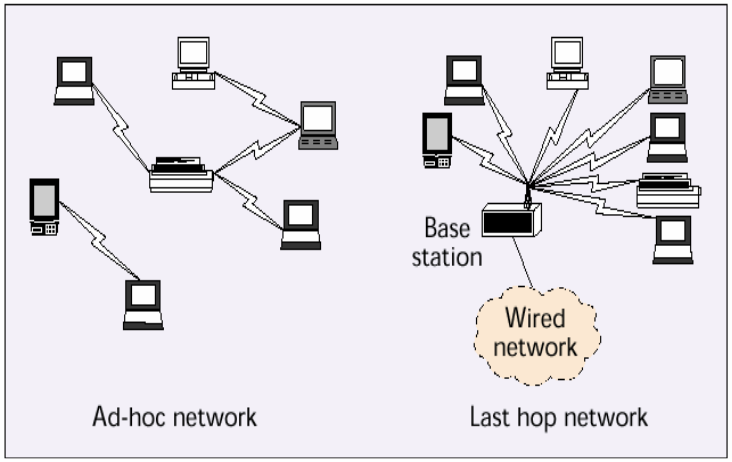
- Multiple devices need to share the "channel" efficiently
  - Problems: "interfere", contention, access control, channel quality varies over space and time
- Different service requirements
  - Voice (real-time, reservation-based)
  - Data (best effort, reliable deliver)
- Different approaches and trade-offs
  - "Centralized vs. Distributed"
- Other challenges
  - Mobility, power conservation, security considerations
- It's a difficult problem
  - Near-far, hidden terminals, time-varying channel, burst errors, etc.

Classify Wireless MACs



Centralized vs. Distributed Control

- **Distributed wireless networks** such as packet radio or ad hoc networks have no central controller. Usually single shared frequency
- **Centralized wireless networks**, infrastructure mode in WLANS, cellular MAC, broadcast on the down link and the AP or BS can control the uplink access according to QOS. Various approaches exist.
- **Slotted systems,** requires network wide synchronization for use of discrete time slots. Easy to achieve in centralized networks, much more challenging in ad hoc or packet radio networks.



Similar (but confusing) terms

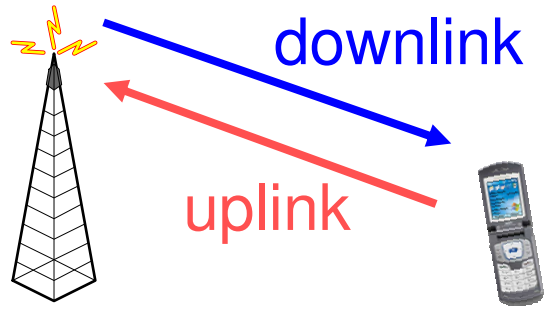
- MAC (medium access control) protocol
  - A protocol that control which user should access the medium at a given moment
- Multiple Access
  - Multiple users access network simultaneously
- Multiplexing
  - Combine multiple signals/transmissions into 1 transmission

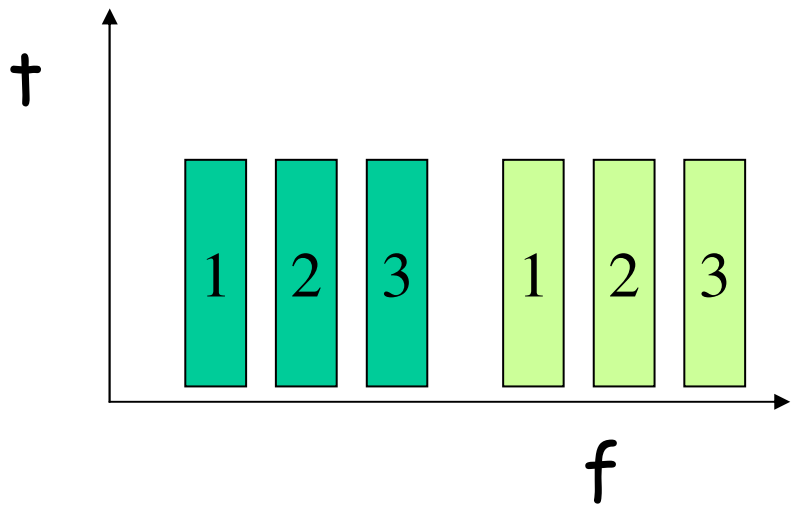
Similar (but confusing) terms

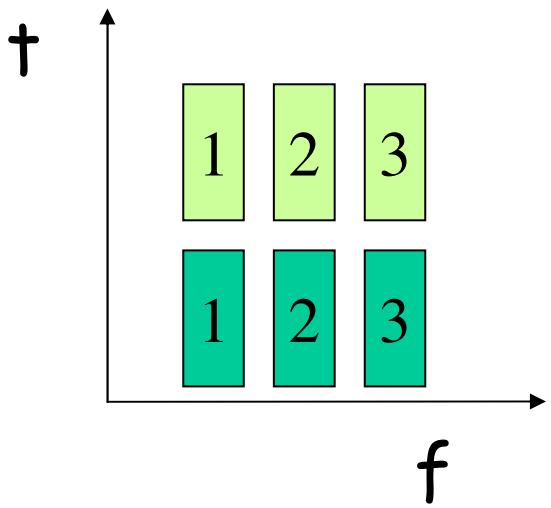
- Duplex
  - TDD (time division duplex)
  - FDD (frequency division duplex)
- Multiple access
  - TDMA (time division multiple access)
  - FDMA (frequency division multiple access)
- Multiplexing
  - TDM (time division multiplexing)
  - FDM (frequency division multiplexing)

Examples

- FDMA/FDD
  - E.g. AMPS
- FDMA/TDD
  - E.g. CT-2







More about Wireless MAC

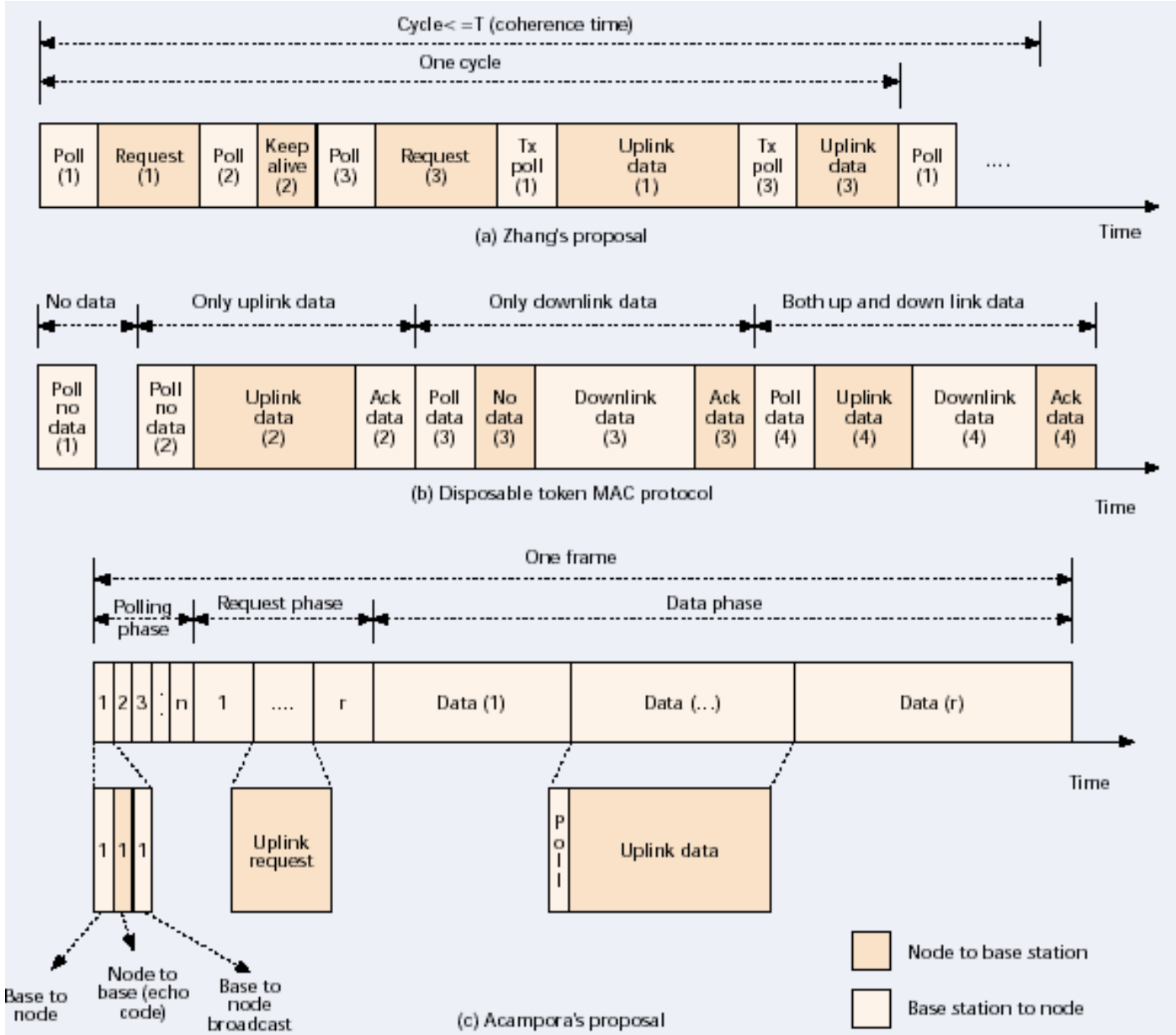
Types of wireless MAC

- (1) Centralized allocation
  - TDMA, CDMA, FDMA
    - Cellular downlink
    - Cellular uplink (dedicate allocation)
- (2) Request/Allocation
  - Polling
    - Cellular uplink
- (3) Random Access
  - CSMA, Aloha, 802.11

MAC: Polling

- MAC between TDMA and random access
- Master-slave architecture
  - E.g. BS (or AP) is the master
- BS sends a "poll" to MS
  - "Poll" frame indicates MS's MAC address
  - Uplink transmission is controlled by AP's polling
- 3 essential elements in polling
  - Request: MS request for uplink transmission
  - Poll: BS allocate bandwidth through polling
  - Data: Uplink data transmission

MAC: Polling

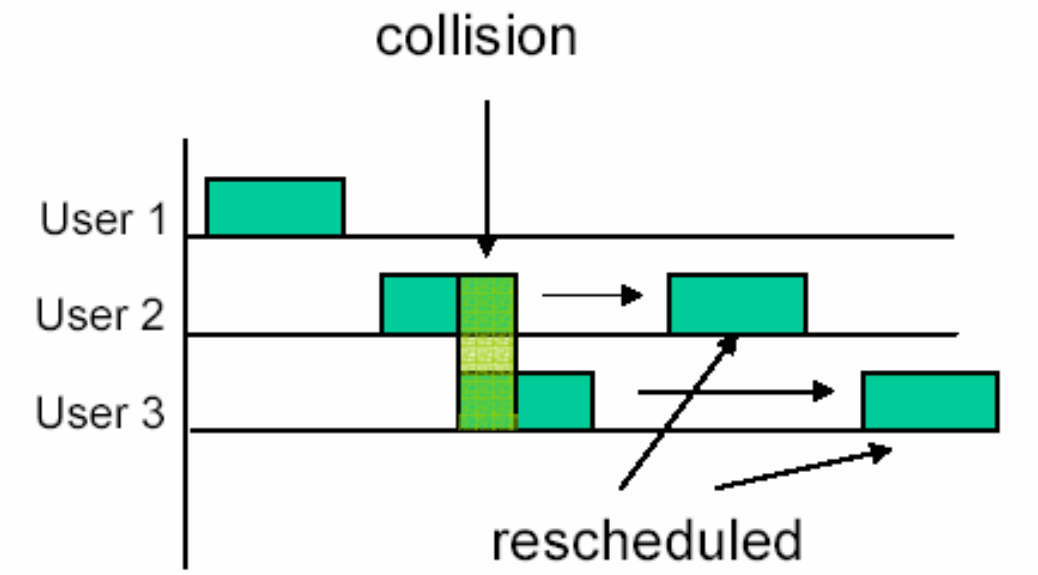

Cycle< =T (coherence time)
One cycle
Poll (1)
Request (1)
Poll (2)
Keep alive (2)
Poll (3)
Request (3)
Tx poll (1)
Uplink data (1)
Tx poll (3)
Uplink data (3)
Poll (1)
....
Time
(a) Zhang's proposal
No data
Only uplink data
Only downlink data
Both up and down link data
Poll no data (1)
Poll no data (2)
Uplink data (2)
Ack data (2)
Poll data (3)
No data (3)
Downlink data (3)
Ack data (3)
Poll data (4)
Uplink data (4)
Downlink data (4)
Ack data (4)
Time
(b) Disposable token MAC protocol
One frame
Polling phase
Request phase
Data phase
1 2 3 . . n 1 .... r
Data (1)
Data (...)
Data (r)
Time
1 1 1
Uplink request
P o l l
Uplink data
Base to node
Node to base (echo code)
Base to node broadcast
(c) Acampora's proposal
Node to base station
Base station to node

Random Access MAC

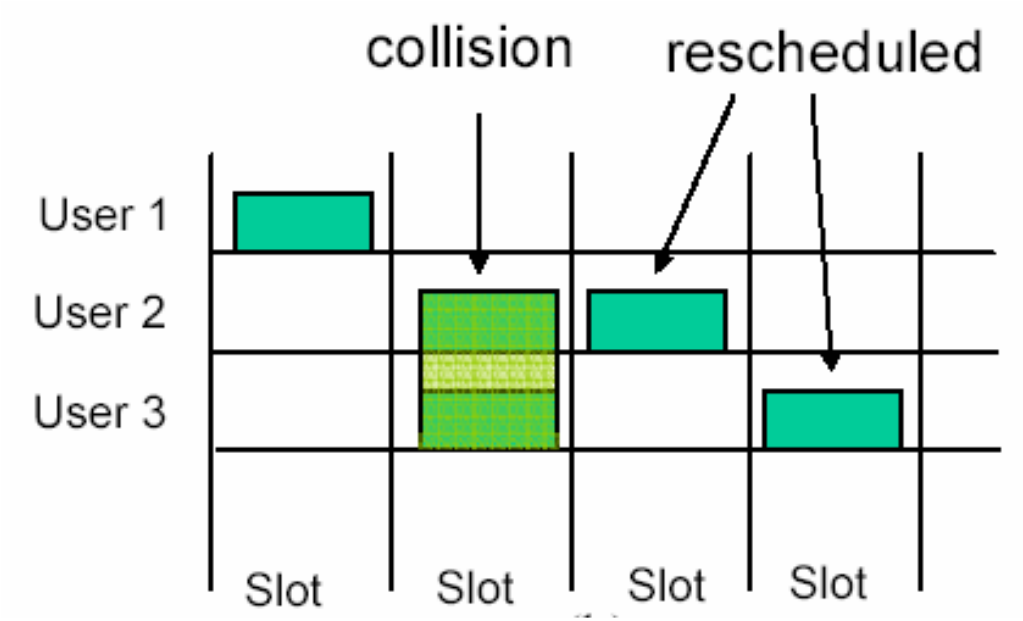
Aloha

- ALOHA network
  - University of Hawaii, 1970
- Aloha: random access MAC
  - A node has a packet to send, then the node sends it
  - If the packet collides, the node retries after some time
    - backoff
- Slotted-Aloha
  - Improved version of Aloha with discrete time slots
  - Wait to transmit until the beginning of the next time slot
    - Example: Slotted-Aloha is used in GSM initialization. MS first contacts BS through a random access channel.
      - Request Access Channel (RACH)

Aloha



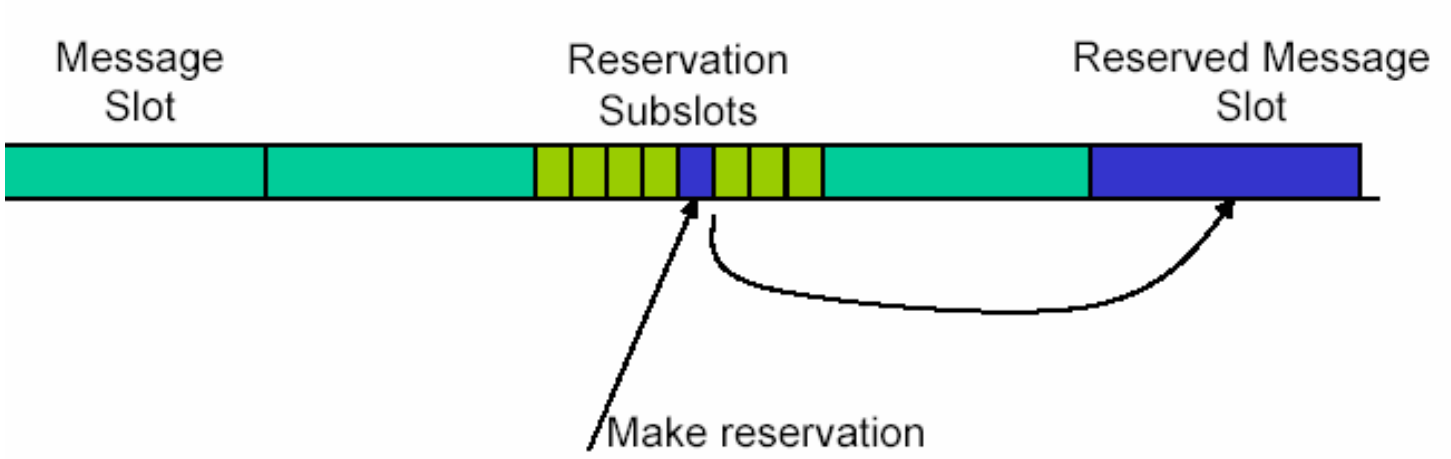
Aloha



Slotted Aloha

Making Reservation in Aloha

- Reservation Aloha
  - Combine Aloha with TDMA
  - A node wishing to transmit a packet tells its neighbors of its intention by transmitting a short reservation packet in the reservation phase of the protocol. Nodes contend for this reservation subslot in an aloha fashion.

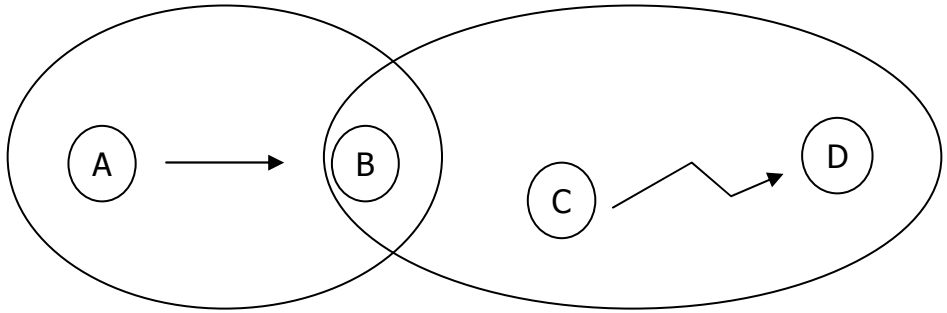


CSMA/CD

- Suitable for wired MAC
  - Ethernet
- Collision Detection
  - Detect the occurrence of collisions
    - Minimum frame length requirement in Ethernet (to guarantee collision detection)
  - Notify all stations about the collisions
    - Notification should be guaranteed to be delivered to all other stations
  - All stations back off for a random waiting time

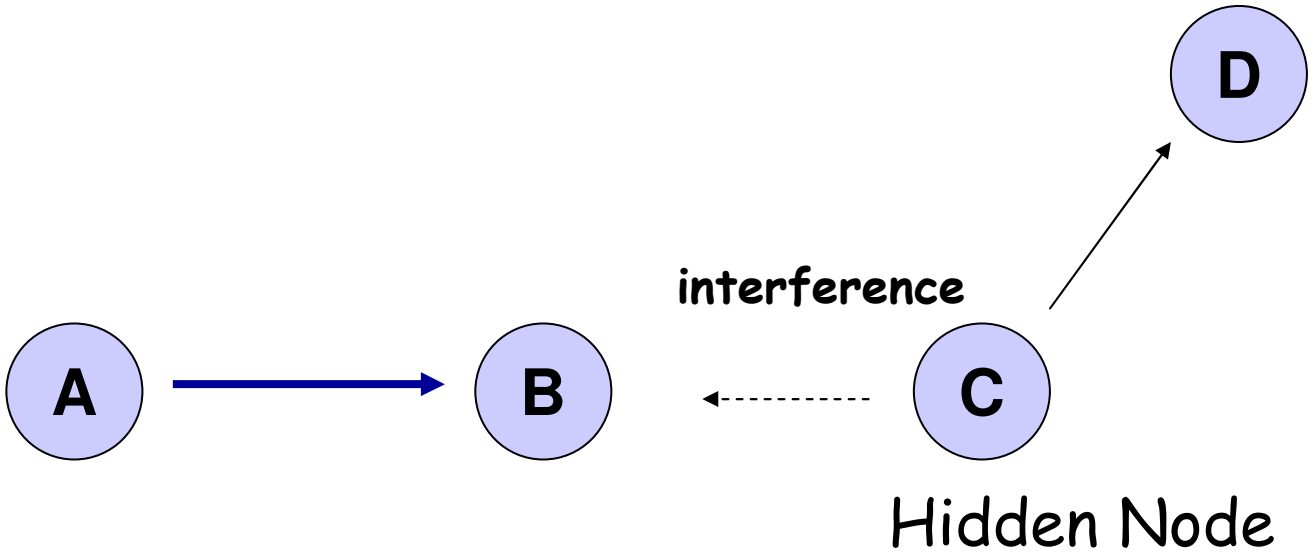
Many issue to solve in Packet Radio, Ad hoc, distributed wireless Networks

- CSMA/CD is problematic; radios are half-duplex and can't easily listen while transmitting like Ethernet. Therefore, collision avoidance (CA) techniques are needed rather than collision detection (CD).
- Other issues: burst errors, hidden terminal, capture/near-far, exposed terminals
- CSMA/CA, RTS-CTS techniques (IEEE 802.11) better suited

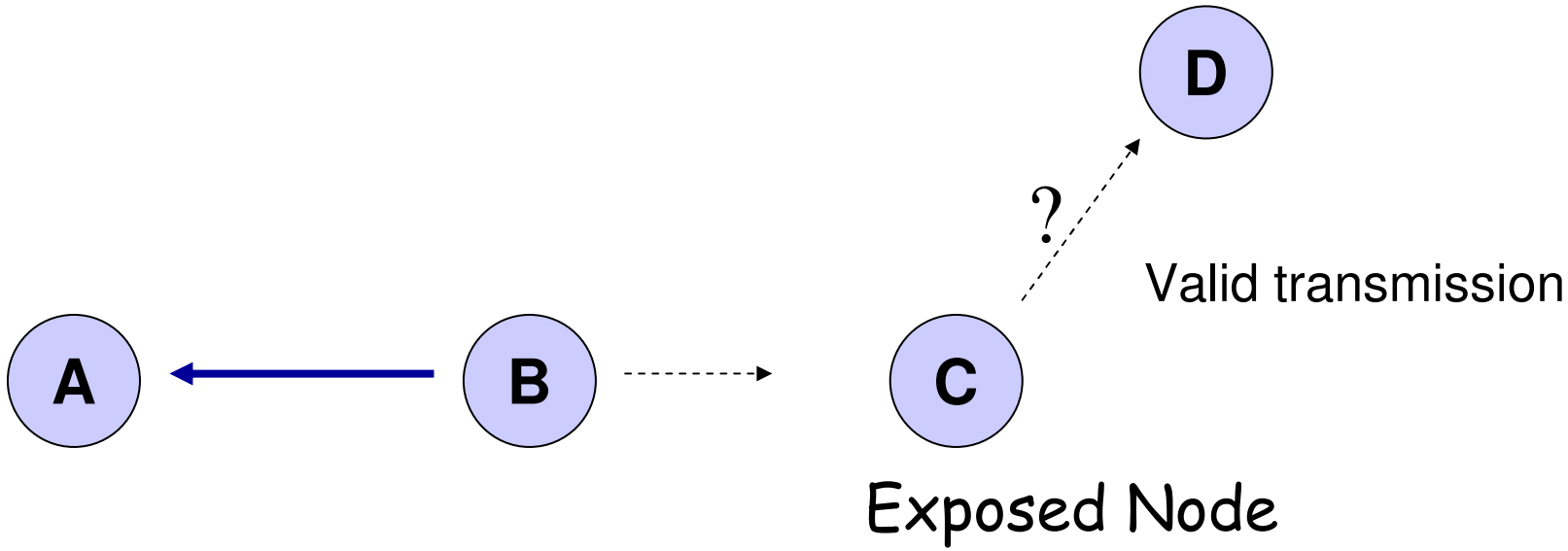


Cell: Coverage Range, range over which a node can transmit and receive data reliably.

Hidden Node

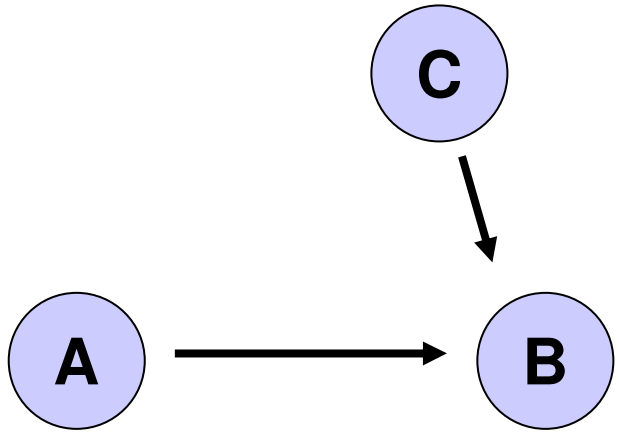


Exposed Node



Capture

- Capture occurs when a receiver can cleanly receive a transmission from one of two simultaneous transmissions.
  - Improve performance
  - But, result in unfairness

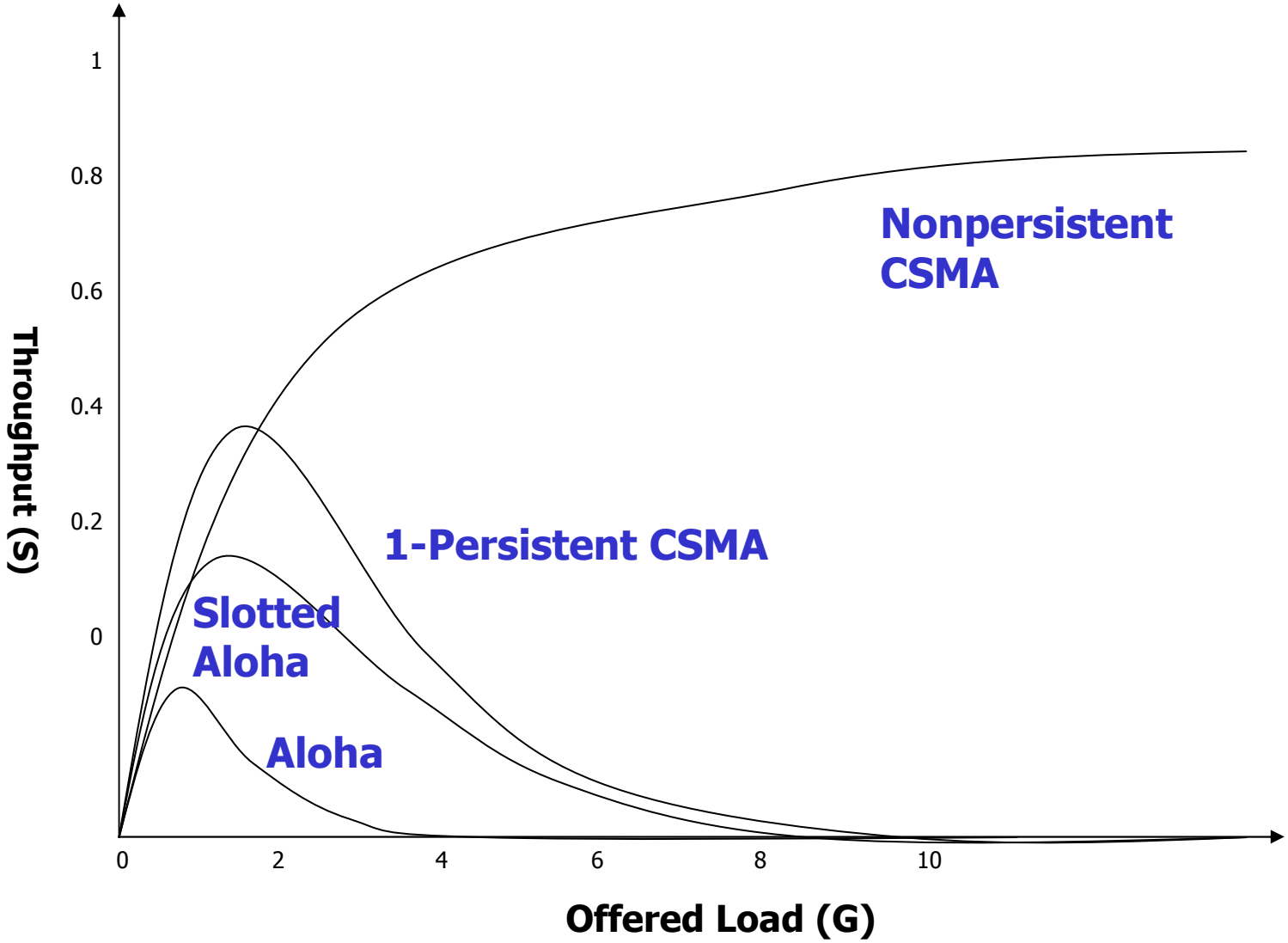


$P_{CB} >> P_{AB}$

CSMA

- Carrier Sense Multiple Access (CSMA)
- Carrier Sense
  - Listen (sense carrier) before transmission
  - Improvement over Aloha
    - Aloha doesn't consider what other users are doing
- Collision still occurs
  - Backoff when carrier is busy
  - Backoff when collision occurs
- CSMA/CD
  - Collision Detection (CD)
    - Listen for a collision with another node's transmission
    - Nodes are able to detect collision and stop transmissionl
  - IEEE 802.3 standard
    - Ethernet

Random MAC


1
0.8
0.6
0.4
0.2
0
Throughput (S)
Nonpersistent CSMA
1-Persistent CSMA
Slotted Aloha
Aloha
0
2
4
6
8
10
Offered Load (G)

Different types of backoff

- 1-persistence
  - After channel becomes idle, a node transmits its packet immediately
- p-persistence
  - After channel become idle, a node transmits its packet with probability p.
- Non-persistence
  - A node does not sense the channel until waiting for a random waiting period

Resolving Hidden Terminals

- Using RTS-CTS with CSMA
  - Request-to-Send
  - Clear-to-Send