TELE303 Mobile Systems

Lecture 6 – Medium Access Control

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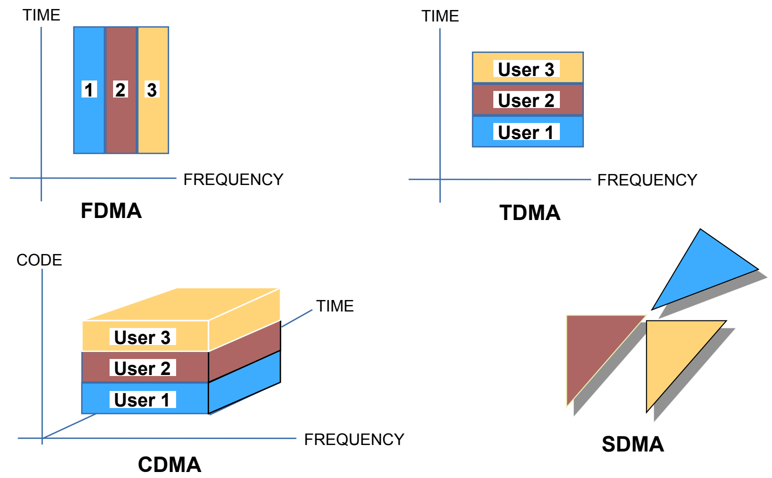
Multiple Access Techniques



PN Sequences

- PN generator produces periodic sequence that appears to be random
- PN Sequences
  - Generated by an algorithm using initial seed
  - Sequence isn't truly random but will pass many test of randomness
  - Sequences referred to as pseudorandom numbers or pseudonoise sequences
  - Unless algorithm and seed are known, the sequence is impractical to predict

Definitions

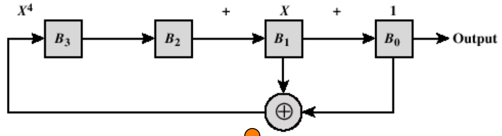
- Correlation of two arrays: $Corr(A,B) = \frac{1}{N}\sum_{i=1}^{N} A_i B_i$
  - Measures the similarity between the two
  - Range between –1 and 1
    - 1: the two are a perfect match
    - 0: they are orthogonal
    - -1: they are mirror images
- **Autocorrelation**: comparison between a sequence and its shifted copy
- **Cross correlation**: the comparison between two sequences from different sources

Important PN Properties – cont.

- *Autocorrelation*: when a period of sequence compared with any cycle shift of itself, difference between number of same numbers and number of different numbers is at most 1.
- Cross correlation
  - o Cross correlation between a PN sequence and noise should be low.
  - o Cross correlation between two different PN sequences should be low.

Linear Feedback Shift Register

- PN generator can be implemented as a circuit consisting of XOR gates and a shift register (LFSR).



(a) Shift-register implementation

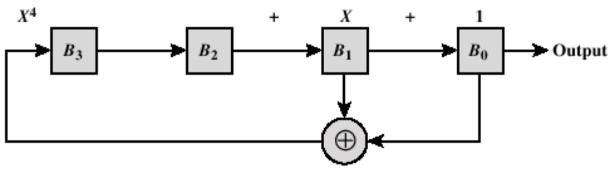
- A simple example:
  $B_3 = B_0 \oplus B_1$
- LFSR contains n bits.
- LFSR output is periodic with a maximum period of $N = 2^n - 1$.

Example with initial state of '1000'

State	B_3	B_2	B_1	B_0	$B_0 \oplus B_1$	Output
Init.=0	1	0	0	0	0	0
1	0	1	0	0	0	0
2	0	0	1	0	1	0
3	1	0	0	1	1	1
4	1	0	0	0	0	0
......						
13	0	0	1	1	0	1
14	0	0	0	1	1	1
15	1	0	0	0	0	0

M-Sequences

- Feedback configuration can be found for PN codes generated by LFSR to have the maximal period of N.
- The resulting sequences are called Maximal-length sequences, or *M-sequences*.
- Important in enabling synchronisation by the receiver and in FHSS and DSSS use.



(a) Shift-register implementation

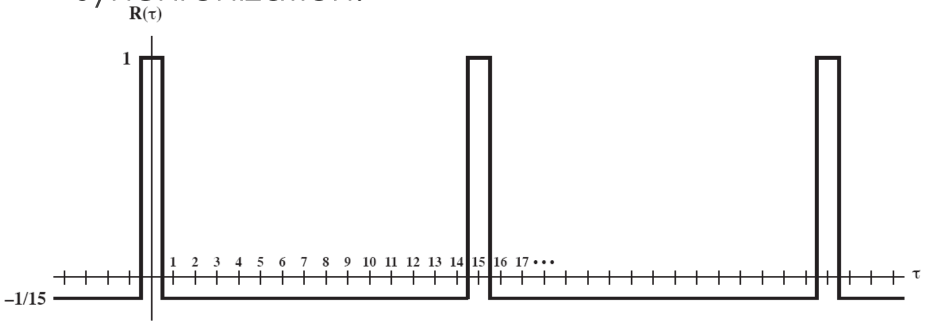
Cross Correlation in M-Sequences

☺ The cross correlation between an m-sequence and noise is low
  - o Useful to the receiver in filtering out noise

☺ The cross correlation between two different m-sequences is low
  - o Useful for CDMA applications
  - o Enables a receiver to discriminate among spread spectrum signals generated by different m-sequences

Auto-correlation

- M-Sequences have good auto-correlation properties that allow for easy synchronization.



(b) Sequence length = 15

Figure 7.15 PN Autocorrelation Function

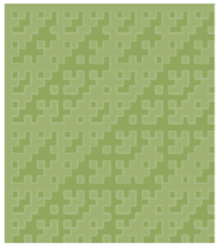
Orthogonal Codes

- Orthogonal codes
  - All pairwise cross correlations are zero
  - Fixed- and variable-length codes used in CDMA systems
  - For CDMA application, each mobile user uses one sequence in the set as a spreading code
    - Provides zero cross correlation among all users
- Types
  - Walsh codes
  - Variable-Length Orthogonal codes

Walsh Codes

- Set of Walsh codes of length *n* consists of *n* rows of a Walsh-Hadamard matrix.
- Take bipolar values (1 and –1).
- Every row is orthogonal to every other row and to the logical NOT of every other row

☹ Requires tight synchronization
  - Correlation between different shifts of the Walsh sequences is **not** zero.



FDMA

- Frequency-division multiple access
- Originally proposed for point-to-point systems, each pair operating on a specific channel
- Sometimes a different channel is assigned for each direction of transmission.
- Each user signal must be confined to the assigned channel to reduce interference.

FDMA: Pros and Cons

Pros

- Capacity can scale (lower bit rate and efficient speech encoding scheme)
- Device implementation simple

Cons

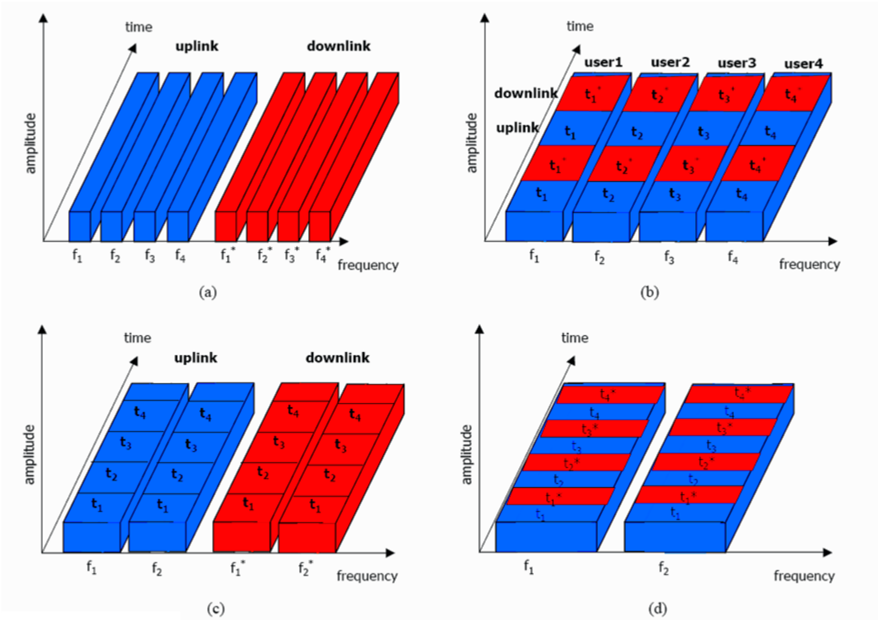
- Capacity scaling depends on lower SNR
- Fixed bit rate
- Inefficient use of spectrum: idle band means waste; guard bands needed
- Crosstalk between channels possible

TDMA

- Time-division multiple access
- Originally designed for point-to-multipoint systems
- Modern digital systems later appeared with more complex and efficient sharing strategies
- Suited for data application

TDMA: Pros and Cons

- Pros
  - Permits flexible bit rate
  - Enables frame-by-frame monitoring (error control; handoffs)
  - More efficient spectrum utilization and no need for guard bands
- Cons
  - Requires substantial amount of DSP
  - Guard time between time slots need to be sufficiently long to cope with delay variance
  - More power consumption
  - Strong synchronization requirements



(a) FDMA/FDD (b) FDMA/TDD (c) TDMA/FDD with multiple carriers (d) TDMA/TDD with multiple carriers

CDMA

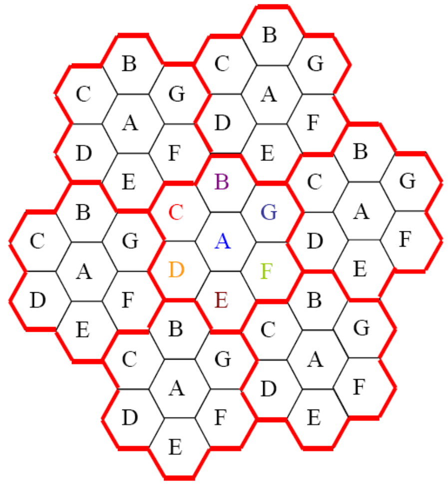
- Code-division multiple access
- Spread spectrum techniques (Frequency Hopping and Direct Sequence) are developed to improve the reuse of channel frequencies.

☹ Receiver complexity; power control necessary.

- Cellular system gives another good example.
  - Cells use/reuse channels allocated on a hexagonal pattern.
  - Within a cell, FDMA or TDMA can be used.
  - User Terminals can roam between cells.

Example of A Cellular System

- Hexagonal cellular architecture with a cluster size of 7.
- Clusters have the same frequency reuse pattern.
- Co-channel cells are two cells apart.

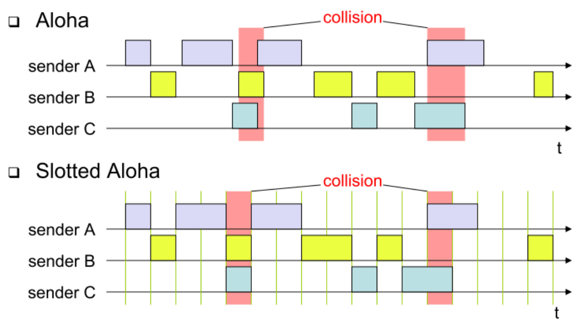


Other Medium Access Techniques

- i.e., **without** channel partitioning
- Useful especially in LAN environments
- Take-turns
  - e.g., polling, token passing
- Random Access
  - ALOHA
  - Slotted ALOHA
  - CSMA/CD

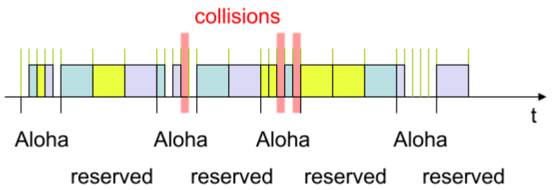
ALOHA/Slotted ALOHA

- Random, distributed time-division multiplexing
- Slotted Aloha additionally uses time-slots, sending must always start at slot boundaries
- Channel efficiency reaches only 0.36 for slotted ALOHA



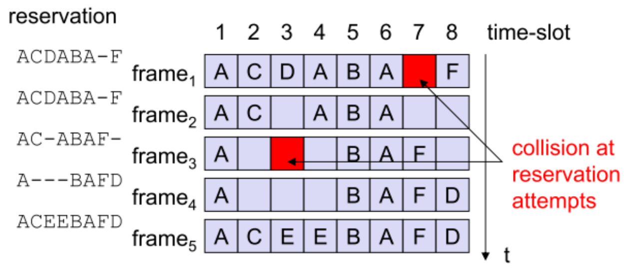
Reserved ALOHA

- Explicit reservation
- Competition for small reservation slots
  - Collisions possible
- Reserved mode for data transmission within successful reserved slots (no collisions possible)
- All stations keep the reservation list consistent
- All stations must synchronize from time to time



PRMA

- Packet Reservation MA (implicit reservation)
- Stations compete for empty slots according to the slotted ALOHA principle
- Once a station reserves a slot successfully, this slot is automatically assigned to this station in all following frames as long as the station has data to send
- Competition for this slots starts again as soon as the slot was empty in the last frame



CSMA-CD

- Carrier Sense Multiple Access with Collision Detection
- Procedure
  - Listen to medium and wait until it is free
  - Then start talking, but listen to see if someone else starts talking too
  - If a collision occurs, stop and then start talking after a random back-off time
- This scheme is used for hub-based Ethernet

➢ Requires ability to detect collisions

Physical Carrier Sense Mechanisms

- Energy detection threshold
  - Monitors channel during "idle" times between packets to measure the noise floor
  - Energy levels above the this noise floor by a threshold trigger carrier sense
- DSSS correlation threshold
  - Monitors the channel for Direct Sequence Spread Spectrum (DSSS) coded signal
  - Triggers carrier sense if the correlation peak is above a threshold
  - More sensitive than energy detection

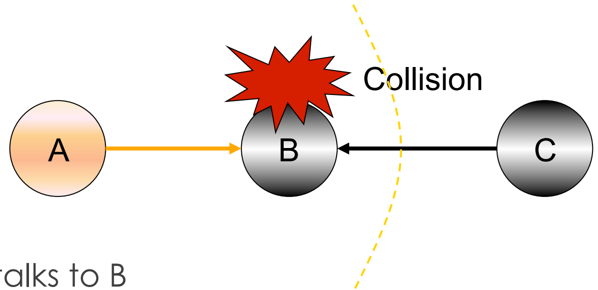
MACA

- Multiple Access with collision avoidance: use short signaling packets
  - Request (or ready) to send RTS: a sender requests the right to send from a receiver with a short RTS packet before it sends a data packet
  - Clear to send CTS: the receiver grants the right to send as soon as it is ready to receive
- Signaling packets contain
  - sender address
  - receiver address
  - packet size
- Example: Wireless LAN (802.11)

CSMA-CA

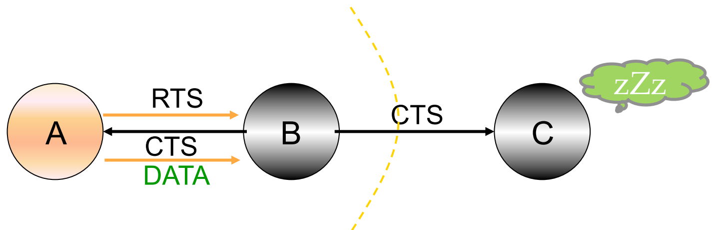
- Carrier Sense Multiple Access with Collision Avoidance
- Adopted in 802.11 WLAN
- Procedure
  - Similar to CSMA/CD
  - Four-frame exchange
    - RTS = request to send
    - CTS = clear to send
    - DATA = actual packet
    - ACK = acknowledgement

Hidden Terminal Problem



- A talks to B
- C does not hear A's transmission (out of range)
- C talks to B
- Signals from A and B collide

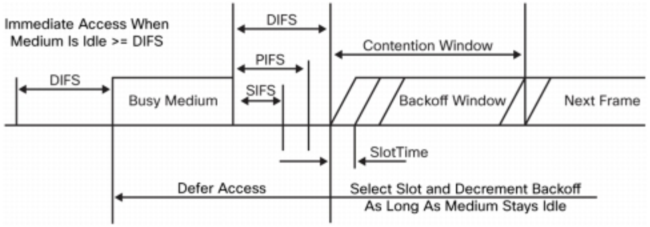
Hidden Terminal: A Solution



- Medium Access with Collision Avoidance (MACA)
  - A sends RTS (Request To Send)
  - B sends CTS (Clear To Send)
  - C overheads CTS
  - C inhibits its own transmitter
  - A successfully sends DATA to B
- Similar protocol adopted in IEEE 802.11 standards

MAC in IEEE 802.11

- Reliable data delivery based on 4-frame exchange
- Distributed Coordination Function (DCF)
  - Wait for IFS (interframe space) if channel idle (IFS can be DIFS, PIFS, or SIFS)
  - Transmit if still idle.
  - Otherwise wait for IFS; if idle now, exponential backoff then transmit.
  - Unsuccessful transmission indicated by lack of ACK

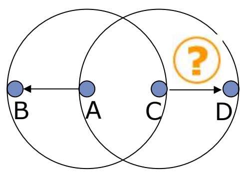


Virtual Carrier Sense

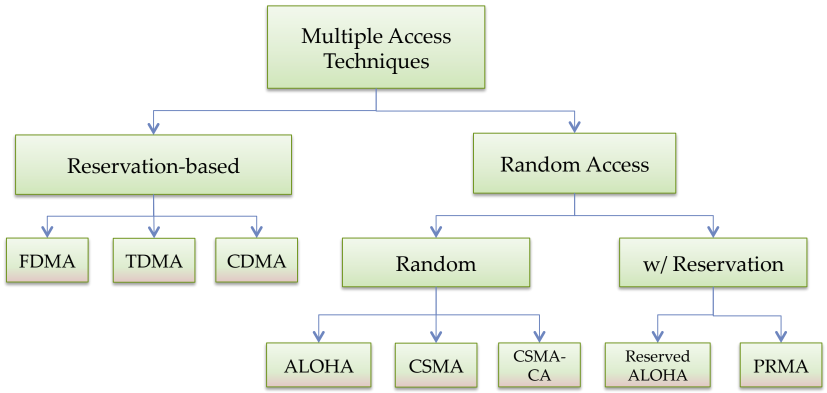
- Provided by RTS & CTS
- Designed to protect against hidden terminal collisions
- Small control frames lessen the cost of collisions (when data is large)
- FEC on control frames is beneficial
- More on 802.11 DCF (Distributed Coordination Function):
  - Wi-Fi Lecture; Stallings Chapter 14

Exposed Terminal Problem

- Hidden terminal is not the only challenge for a distributed wireless MAC protocol
- *A* sends to B. Can C send to D?
  - "RTS A" heard by B and C
  - B responds CTS
  - C unsure what to do



Recap



- Garg, Chap.6
- *Coming next*: mobile ad hoc networking