Topic 6: Multiple Access Techniques for Wireless Communications

Content:

1) Random Access Techniques

- Slotted ALOHA Scheme
- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) Scheme

2) Collision-free Access Techniques

- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)
- Spectral Efficiency of FDMA, TDMA and CDMA Systems

Topic 6 Learning Outcomes

At the end of this Topic, you will be able to:

- Distinguish among the different multiple access techniques for wireless communication systems
- Analyze the capacity and spectral efficiency of multiple access techniques used in wireless communication systems

Multiple Access in Wireless Communications

Definition of Multiple Access Protocols:

- Rules for efficient sharing of the radio resources among the mobile stations or rules for controlling access of mobile stations to the base station

- The two extremes of multiple access protocols are:
  1) random access protocols
  2) collision-free (or fixed) access protocols

Random Access Protocols: Slotted ALOHA

Operation: (Assume the shared channel is error-free, feedback path is also error-free)

Preamble: Channel time is slotted: one slot = packet transmission time (channel slotting provides a 100% improvement in max throughput compared to pure ALOHA)

1. MS's are constrained to start transmission only at the beginning of slot boundaries
2. All packets transmitted in the network have the same size: packets are forced to collide completely or not at all.
3. Transmission is successful if only one packet is transmitted at a slot boundary.
4. Transmission is unsuccessful if more than one packet are transmitted at a slot boundary (collision event)
5. Colliding MS's retransmit after a random, independently selected backoff intervals.

- Theoretical throughput performance of Slotted ALOHA is 36%

Random Access Protocols: Carrier Sense Multiple Access (CSMA)

Operation:

Listen before transmitting (or Carrier Sensing)

- a station with a packet to transmit first listens to the channel
- if the channel is sensed to be idle, the station transmits
- Otherwise, the station takes one of the following actions:
  - the station waits until the channel becomes idle and then tries again: 1-persistent mode
  - defers transmission and tries again after a random delay: non-persistent mode

- Networks that use the listen before transmitting process are called Carrier Sense Multiple Access Networks

Listen before transmitting reduces the number of collisions compared to that experienced with slotted ALOHA (Note that collisions can still occur in CSMA due to nonzero propagation delay and lack of coordination among the stations)

Random Access Protocols: CSMA with Collision Avoidance (CSMA/CA)

CSMA/CA protocol:

- medium access control protocol for IEEE802.11 (and variants) wireless local area networks (WLANs)
- applicable to “Distributed Coordination Function” mode of operation
- Techniques for collision avoidance:

  1) Exchange of short-duration control frames: Ready-to-Send (RTS) and Clear-to-Send (CTS) packets prior to the transfer of actual data frames

  2) Introduce a set of delays prior to transmission by a station that senses the channel idle

Collision-free Multiple Access Techniques

- A base station allocates a dedicated resource to an MS during a call connection setup request

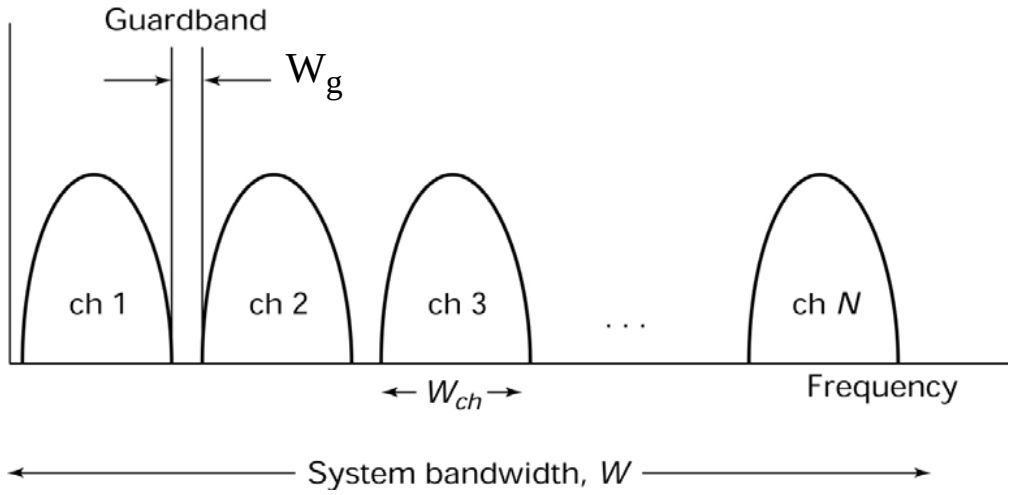
  (following the initial access performed via the access channel, using a random access technique)

- A dedicated resource can be expressed in terms of time, frequency, code and any combinations of {time, frequency, code}

- In wireless cellular systems, collision-free multiple access techniques include:

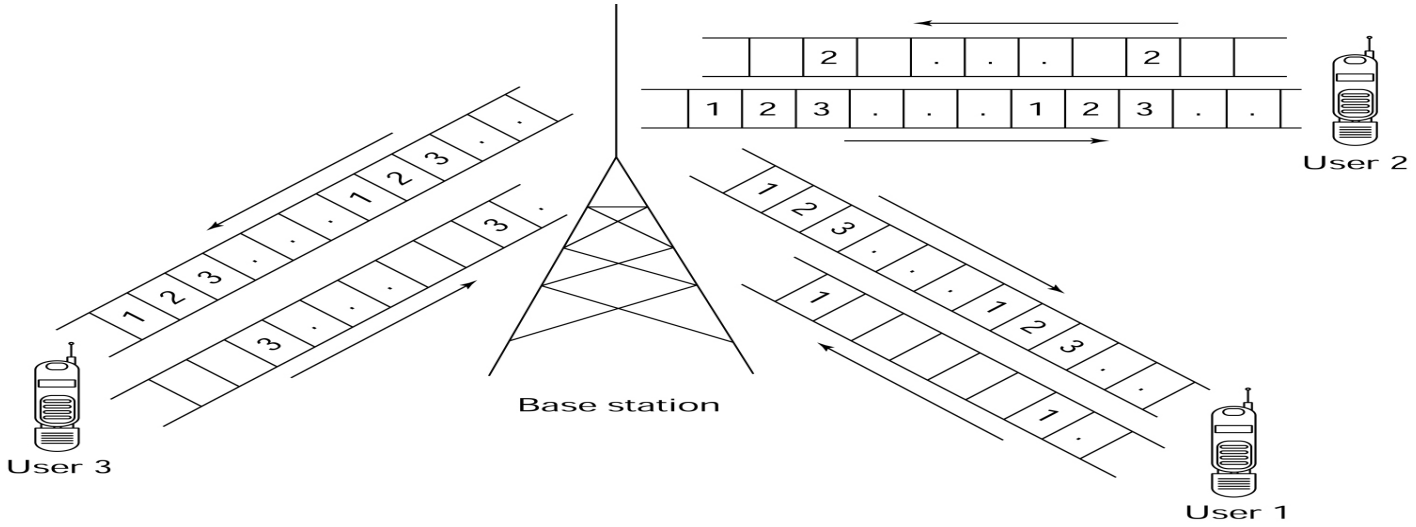
1. Frequency Division Multiple Access (FDMA): 1G Cellular Systems
2. Time Division Multiple Access (TDMA): 2G Cellular Systems
3. Code Division Multiple Access (CDMA): 2G and 3G Cellular Systems
4. Hybrids of the above: e.g. FDMA/TDMA - GSM; TDMA/CDMA: 1xEV-DO, UMTS
5. Orthogonal Frequency Division Multiple Access (OFDMA): e.g. LTE, LTE-A

Principle of Frequency Division Multiple Access Technique



- Total bandwidth *W* is divided into *N* non-overlapping bands each of width W_{ch}
- A guardband is introduced to reduce the effects of adjacent channel interference
- Each user is assigned a channel from one of the free (i.e. unallocated) channels and hangs on to it throughout the call
- FDMA supports narrowband transmissions

Principles of Time Division Multiple Access Technique



- The channel time is divided into frames, a TDMA frame is further partitioned into time slots
- During a call connection, a user is assigned a slot, the slot assignment can be fixed or dynamic
- If the assigned slot is fixed from frame to frame for the call duration, the users have to synchronize to their assigned slots. (This mode is referred to as synchronous TDMA or STDMA)
- If slots are dynamically assigned from frame to frame, this mode is referred as asynchronous TDMA or ATDMA

Direct Sequence Code Division Multiple Access Technique

Characteristics:

- Each user is assigned a “spreading code” also known as a pseudonoise (PN) code
- All users occupy the entire bandwidth *W* simultaneously
- At the transmitter, the user’s data is multiplied by the user’s spreading signal
- At the receiver, the received signal is multiplied by the spreading signal to recover the transmitted data

  Note: multiplication of the user data signal by the spreading signal is the same as modulo-2 addition of user data with spreading sequence
- DS-CDMA has applications in commercial CDMA systems (IS95, CDMA2000, WCDMA)