Modern Wireless Communication

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Chapter 7
Wireless Architectures

Contents

7.1 Introduction

7.2 Comparison of Multiple-Access Strategies

- Four multiple-access strategies
  - FDMA
    - Users share spectrum by dividing it into different frequency channel
  - TDMA
    - Users time-share the spectrum
  - CDMA
    - All users use the same spectrum simultaneously but the number of users is limited by their multiple-access interference.
  - SDMA
    - Users share the spectrum in angular direction with the use of smart antennas.

- Practical systems are usually a hybrid of tow or more of the multiple-access strategies
  - Provide a reasonable growth strategy
  - Reduce the complexity of the overall system
  - Backwardly compatible with existing system

TABLE 7.1 Comparison of Different Multiple-Access Strategies.

	FDMA	TDMA	CDMA	SDMA
Modulation	- relies on bandwidth-efficient modulation	- relies on bandwidth-efficient modulation	- simple modulation	- transparent
Forward error correction	- increases power efficiency at expense of bandwidth efficiency	- increases power efficiency at expense of bandwidth efficiency	- can be implemented without affecting bandwidth efficiency	- transparent
Source coding	- improves efficiency	- improves efficiency	- improves efficiency - voice activation advantage	- transparent
Diversity	- requires multiple transmitters or receivers	- requires multiple transmitters or receivers - can be frequency-hopped	- includes frequency diversity when implemented with a RAKE receiver	- single antenna reduces space diversity - orthogonal coding improves diversity with multiple transmit antennas
User terminal complexity	- simple	- medium complexity	- more complex	- requires smart antennas
Handover	- hard	- hard	- soft	- potentially soft
System complexity	- large number of simple components	- reduced number of channel units	- large number of complex interacting components	- additional complexity related to antennas
Multiple-access interference	- limited by system planning	- limited by system planning	- dynamic power control	- limited by resolution of antennas
Fading	- flat-fading - no diversity - simple to track	- may be frequency-selective - may need equalizer	- frequency-selective diversity via RAKE receiver	- reduced multipath
Bandwidth efficiency	- hard limits - based on modulation and channel spacing	- hard limits - based on modulation and channel spacing	- soft limits	- depends on antenna resolution
Synchronization	- low resolution	- mid-resolution	- high resolution	- requires terminal location
Flexibility	- fixed data rate	- data rate variable in discrete steps	- can provide a variety of data rates without affecting signal in space	- transparent
Voice and data integration	- possible, but may require revisions to system	- straightforward using multiple slots	- multicode transmission, which may decrease efficiency of mobile terminal	- transparent
Evolution	- bandwidth to fit application	- requires medium initial bandwidth	- requires large initial bandwidth	- flexible, can be added as needed - does not affect mobile

7.3 OSI Reference Model

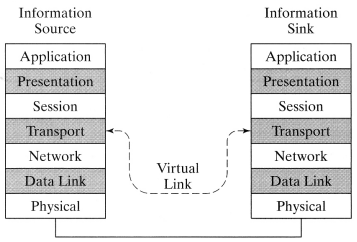

FIGURE 7.1 Seven layers of OSI model of communications.

1. Physical Layer
   1. Provides a physical mechanism for transmitting bits between any pair of nodes.
2. Data Link Layer
   1. Performs error correction or detection in order to provide a reliable error-free link to higher layers.
   2. Responsible for ordering of packets.
   3. *Medium access control (MAC)* sublayer for multiaccess communications.
3. Network Layer
   1. Determine the *routing* of packet.
   2. Determine the *quality of service*.
   3. *Flow control*.

4. Transport Layer
   1. Separates messages into packets
   2. Provides reliable end-to-end communications by retransmitting incomplete or erroneous messages.
   3. Restarts transmissions after connection failure.
   4. Provides a multiplexing function.
5. Session Layer
   1. Find the right delivery service.
   2. Determines access right.
6. Presentation Layer
   1. Data encryption, data compression and code conversion.
7. Application layer
   1. Provides interface to user.

- For some implementations, the following may occur:
  1. The session, transport and network layers are treated as single entity.
  2. The error correction is performed in the modem as part of the physical layer.
  3. The presentation and application layers are combined into single application.

7.4 The OSI Model and Wireless Communications

- Basic tenet of OSI model
  - Protocols and procedures of various levels should be independent with the other levels.
  - Only physical layer to be affected by the choice of transmission medium.
  - For wireless communications, it affects three layers
    - Physical layer
    - Data link layer
    - Network layer

- Key resource in wireless system
  - *Radio spectrum*
- At physical layer
  - Emphasis is on modulation, source coding, channel coding and detection techniques.
- At link layer
  - Emphasis is on how the spectrum is shared in time, frequency, area or angular direction.
- At network layer
  - Emphasis is on routing and quality of service.

7.5 MAC Sublayer Signaling and Protocols

- MAC sublayer
  - Important consideration in design of wireless systems.
  - Convention for cellular telephone system to assign different MAC functions to
    - Logical channels
      - connections between link layer entities.

- Four different types of logical channels

1. Synchronization and broadcast channel
   1. Assist the mobile terminal in gaining access to resources of mobile telephone network.
   2. Base station may transmit an unmodulated signal or some other reference signal for assisting and accelerate the above process.
   3. Broadcast channel can provides:
      1. System time.
      2. Base station ID.
      3. Information regarding frame timing.
      4. Information regarding channel to use for requesting telephone channels.
      5. Information regarding channel to use to listen for pages.

2. Paging and access channels
   1. Provide a short messaging service between base station and mobile terminal.
      1. *Log-on and log-off messages*
         1. Mobile terminal logs onto (or logs off) of base station and informs it that it is listening for calls.
      2. *Pages*
         1. Short messages from base station to mobile terminal to inform the user that there is an incoming telephone call.
         2. Contain information regarding which channel the call will be set up on.
      3. *Access*
         1. When the UT is to make a cell, it must first make an access request.

3. Control channels
   1. Provide communications link for control information that may need to be transferred between BA and UT.
   2. Two typical applications for control channels
      1. Power control
         - One end of the communication link requests the other end of the link to change the transmit power.
      2. Handover
         - Involve in changing the communications channel, transmit power and signaling channels.

4. Traffic channels
   1. Main resource of the network.
   2. Provide exchange of information between end users.
   3. Some traffic channels are shared and provide a packet data service among a number of UTs and BS.
   4. There are traffic channels in both downlink and uplink directions.

7.6 Power Control

- Solve near-far problem of communications.
  - Adjusting each transmitter's power so that received signal is at the minimum acceptable level.
  - Minimize interference with other users.
- Effective power control must be employed to maximize efficiency

7.6 Power Control

7.6.1 Open Loop

- Open-loop power control
  - Procedure whereby mobile terminal measures its received signal level and adjusts its transmit power.
- Advantage
  - Does not need to wait for round-trip delay
- Disadvantage
  - Limited correlation between received power levels on uplink and downlink.
- Not effective for fast Rayleigh fading.
- Can be applied in asymmetric fashion

7.6 Power Control

7.6.2 Closed Loop

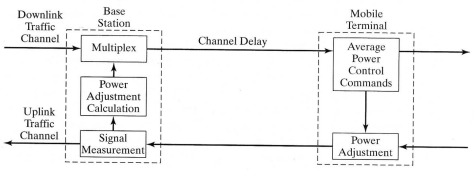

FIGURE 7.4 Illustration of closed-loop power control.

- BS measures received signal strength and sends adjustments to terminal.
- Delay between measurement and application is a critical parameter in closed-lop power control.
- Delay creeps into the process in a number of ways:
  1. Provide reasonably accurate measurement of received signal strength, the measurement must be averaged over several symbol periods.
  2. Power control adjustment must be multiplexed with outgoing transmission which implies a processing delay.
  3. Correction incurs transmission delay.
  4. At receiver, as the power-control adjustments are uncoded and less reliable, they should be averaged over several symbols, a process that incurs delay.

7.6 Power Control

7.6.3 Outer-Loop Power Control

- Fast closed-loop power control
  - Based on measurements of strength of signal at BS and comparisons with expected signal strength.
- Slower closed-loop power control
  - Ensure no systematic errors enter into comparison.
  - Based on frame error rate measurements.
- Cyclic redundancy check (CRC)
  - Included with frame and are used for error detection after error-correction decoding.
- Too high an error rate means user terminal is not getting the expected service.
- Too low an error rate means user terminal is generating more interference than is acceptable.

7.6 Power Control

7.6.4 Other Considerations

- With regard to intercell interference, power control limited total power emitted by terminals in adjacent cells.
- Integration of different power control strategies must be carefully considered
  - Different compensatory measure not counteract.
  - Power control be based on measured signal level, not signal-to-noise ratio.
- Transmit and receive diversity will be important components of 3G mobile cellular systems.

7.7 Handover

- The procedure to transfer the call to base station of new cell.
- Dropped call
  - handover does not occur and the call is lost
- Call may be dropped for a number of reasons:
  - Received signal drops below an acceptable level before the handover is completed.
  - Too much processing burden at mobile switching center.
  - No free channels available in new cell to transfer the call to .

7.7 Handover

7.7.1 Handover Algorithms

- Define threshold T at a set level above minimum acceptable signal level

$$T(dBm) = Minimum\ acceptable\ power\ level\ (dBm) + \delta_{th}(dB) \quad (7.3)$$

- Trade-off of this algorithm:
  1. The additive term δ_{th} cannot be too small, or else it will result in too many dropped calls.
  2. Nor can δ_{th} be too large, or else there will be too many handovers, putting a processing burden on mobile switching center (MSC)
  3. Averaging of received signal level must be performed.

- Second handover algorithm
  - A handover is initiated when the power of neighboring cell base station exceeds current base station by specified amount or for certain period.
  - Similar design trade-offs related to selection of power difference or waiting time.
- Number of handovers occur depends on size of cell and velocity of terminals.

7.7 Handover

7.7.2 Multiple-Access Considerations

1. With FDMA and TDMA/FDMA combination system, the mobile terminal must change their frequencies of both its traffic and signaling channels, and synchronize to new base station.
2. With CDMA, there may be a soft-handover capability
   - Since the same frequencies are used in each cell, there is no need to change channels in order to change base stations.
3. With SDMA, if antenna beams are fixed
   - handover will be necessary whenever a mobile terminal crosses a beam boundary.

7.8 Network Layer

- Reasons that wireless physical layer may affect layers above the data link layer:
  1. Reliability of wireless link and the error-control measures taken by data link layer may be less than higher layers.
  2. In applications, there are real-time requirements that affect all of the layers.
  3. If the terminals are mobile, they can move between cells or be activated in areas far from their home location.

7.8 Network Layer

7.8.1 Cellular Networks

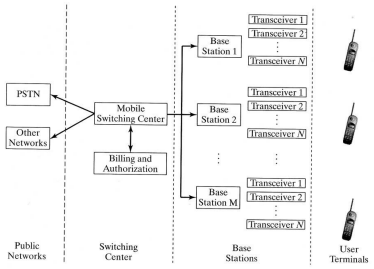

FIGURE 7.5 General interface to PSTN for a mobile telephone network.

- Roles of mobile switching center (MSC):
  1. Performs network layer function
     1. Act as interface between cellular radio system and public switched telephone network
  2. Performs MAC sublayer function
     1. Provide overall supervision and control of mobile communication
  3. MSC authorizes the use of system if user has a valid account.
     1. Also performs a *billing* function and must keep track of system utilization by users.
  4. MSC finds the *home location* of user terminal if it is activated away from its usual service area.

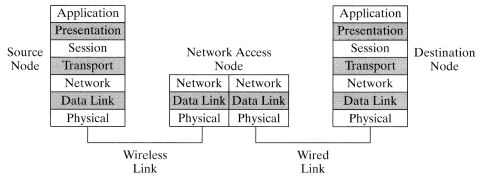

FIGURE 7.6 Protocol stacks for combined wireless/wired connection.

7.8 Network Layer

7.8.2 Indoor LANs

- Different between indoor and outdoor terminology:
  - Cells are referred to as *service sets*, with the distinction that service sets may physically overlap or even coincide.
  - User terminals are referred to as *stations (STAs)*.
  - All terminals are stations, but each service set has one station that acts as a base station, referred to *access point (AP)*.

- Features of Indoor LANs that are not usually exhibited by cellular data networks:
  - Indoor LANs are often formed without preplanning.
  - LANs of same type can be overlapped.
- Features of LANs that are common to many data networks
  1. *Fragmentation*
     - Long packets received from network layer are split into smaller units for transmission over wireless channel.
  2. All traffic intended for a single destination requires immediate acknowledgment.
  3. User terminals often have a power save mode.

4. Reassociation
   1. Each UT must *associate* itself with an access point before communication between higher layers can occur.
   2. If a terminal moves, it may change its association
5. IEEE 802.11 MAC layer protocol uses a technique known as *virtual carrier* sense for scheduling interference-free transmissions.
6. Virtual carrier sense is a form of distributed control.
7. IEEE 802.11 provides the ability to encrypt the contents of messages.
8. Higher layer connections are maintained, although the terminal may be reassociated with another AP.