Wireless Communication

Lecture 10

Cordless Systems and Wireless Local Loop

Cordless System Operating Environments

- Residential – a single base station can provide in-house voice and data support
- Office
  - A single base station can support a small office
  - Multiple base stations in a cellular configuration can support a larger office
- Telepoint – a base station set up in a public place, such as an airport

Design Considerations for Cordless Standards

- Modest range of handset from base station, so low-power designs are used
- Inexpensive handset and base station, dictating simple technical approaches
- Frequency flexibility is limited, so the system needs to be able to seek a low-interference channel whenever used

Time Division Duplex (TDD)

- TDD also known as time-compression multiplexing (TCM)
- Data transmitted in one direction at a time, with transmission between the two directions
  - Simple TDD
  - TDMA TDD

Simple TDD

- Bit stream is divided into equal segments, compressed in time to a higher transmission rate, and transmitted in bursts
- Effective bits transmitted per second:

$$R = B/2(T_p + T_b + T_g)$$

  - R = effective data rate
  - B = size of block in bits
  - T_p = propagation delay
  - T_b = burst transmission time
  - T_g = guard time

Simple TDD

- Actual data rate, *A*:

$$A = B / T_b$$

- Combined with previous equation:

$$A = 2R\left(1 + \frac{T_p + T_g}{T_b}\right)$$

- The actual data rate is more than double the effective data rate seen by the two sides

TDMA TDD

- Wireless TDD typically used with TDMA
  - A number of users receive forward channel signals in turn and then transmit reverse channel signals in turn, all on same carrier frequency
- Advantages of TDMA/TDD:
  - Improved ability to cope with fast fading
  - Improved capacity allocation

DECT Frame Format

- Preamble (16 bits) – alert receiver
- Sync (16 bits) – enable receiver to synchronize on beginning of time slot
- A field (64 bits) – used for network control
- B field (320 bits) – contains user data
- X field (4 bits) – parity check bits
- Guard (60 bits) – guard time, T_g

A Field Logical Control Channels

- Q channel – used to broadcast general system information from base station to all terminals
- P channel – provides paging from the base station to terminals
- M channel – used by terminal to exchange medium access control messages with base station
- N channel – provides handshaking protocol
- C channel – provides call management for active connections

B Field

- B field transmits data in two modes
  - Unprotected mode - used to transmit digitized voice
  - Protected mode - transmits nonvoice data traffic

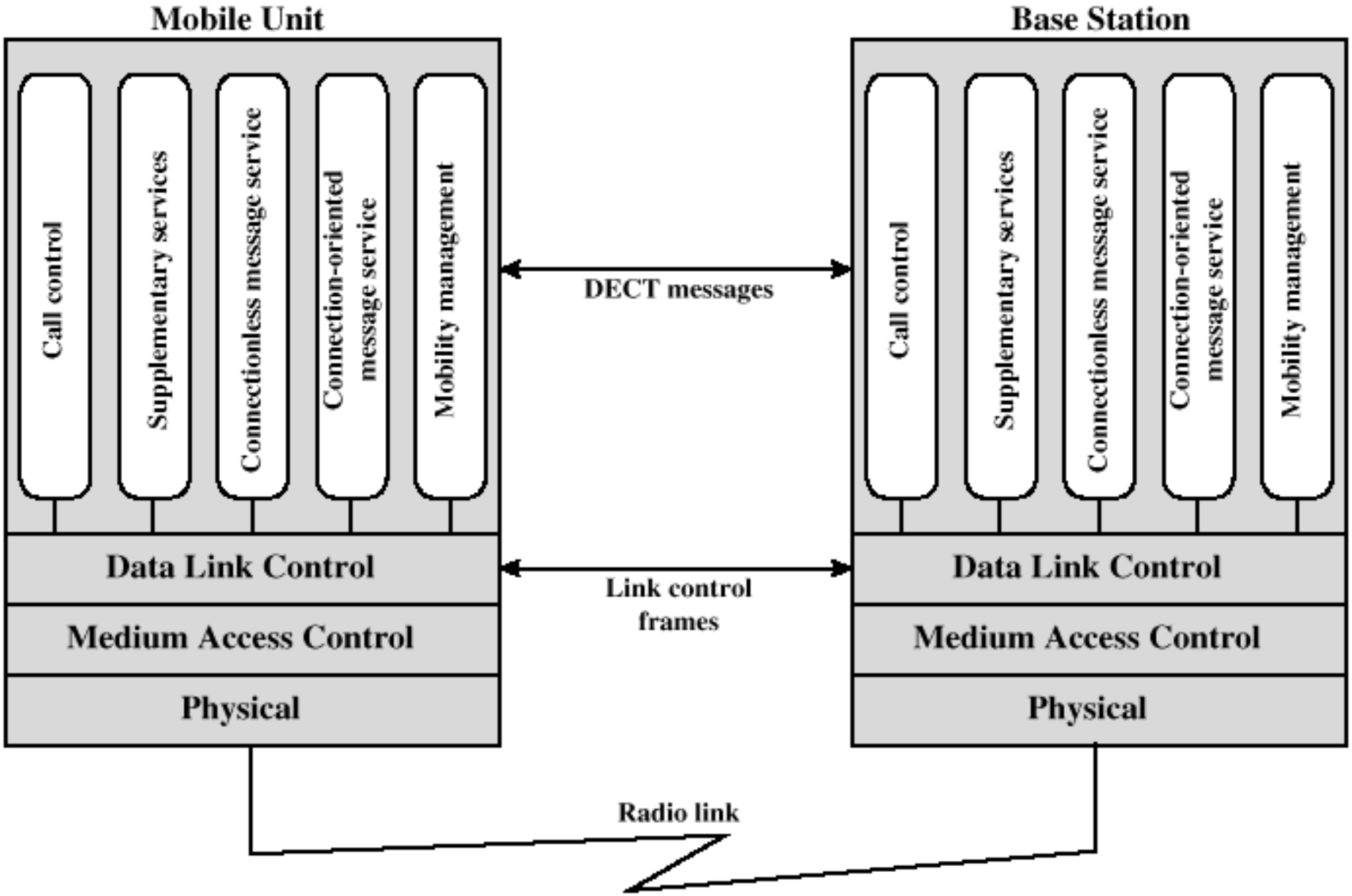


Figure 11.3 DECT Protocol Architecture

DECT Protocol Architecture

- Physical layer – data transmitted in TDMA-TDD frames over one of 10 RF carriers
- Medium access control (MAC) layer – selects/ establishes/releases connections on physical channels; supports three services:
  - Broadcast
  - Connection oriented
  - Connectionless
- Data link control layer – provides for the reliable transmission of messages using traditional data link control procedures

Differential Quantization

- Speech signals tend not to change much between two samples
  - Transmitted PCM values contain considerable redundancy
- Transmit difference value between adjacent samples rather than actual value
- If difference value between two samples exceeds transmitted bits, receiver output will drift from the true value
  - Encoder could replicate receiver output and additionally transmit that difference

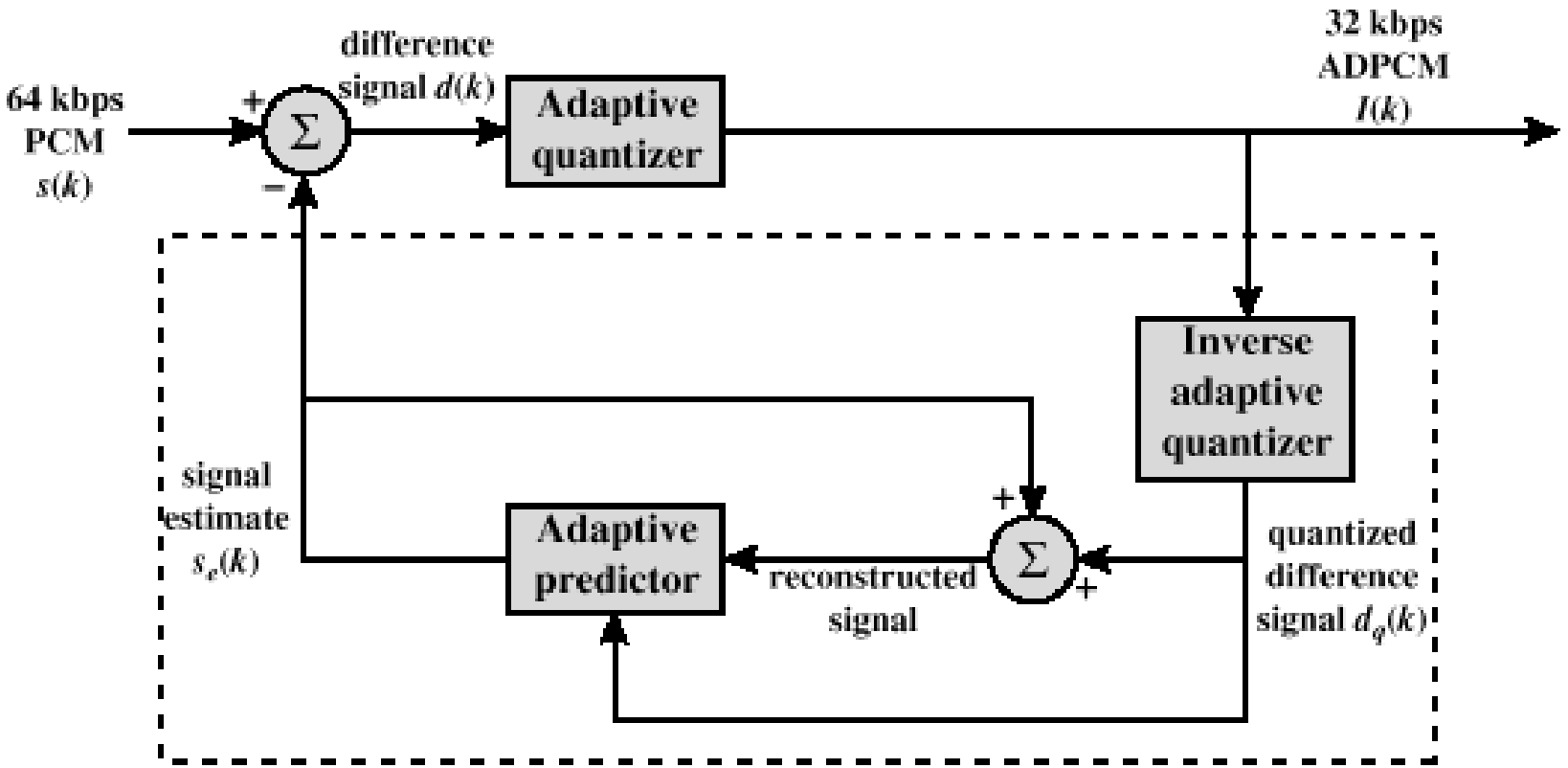
Differential PCM (DPCM)

- Since voice signals change relatively slowly, value of *k*th sample can be estimated by preceding samples
- Transmit difference between sample and estimated sample
  - Difference value should be less than difference between successive samples
- At the receiver, incoming difference value is added to the estimate of the current sample
  - Same estimation function is used

Adaptive Differential PCM (ADPCM)

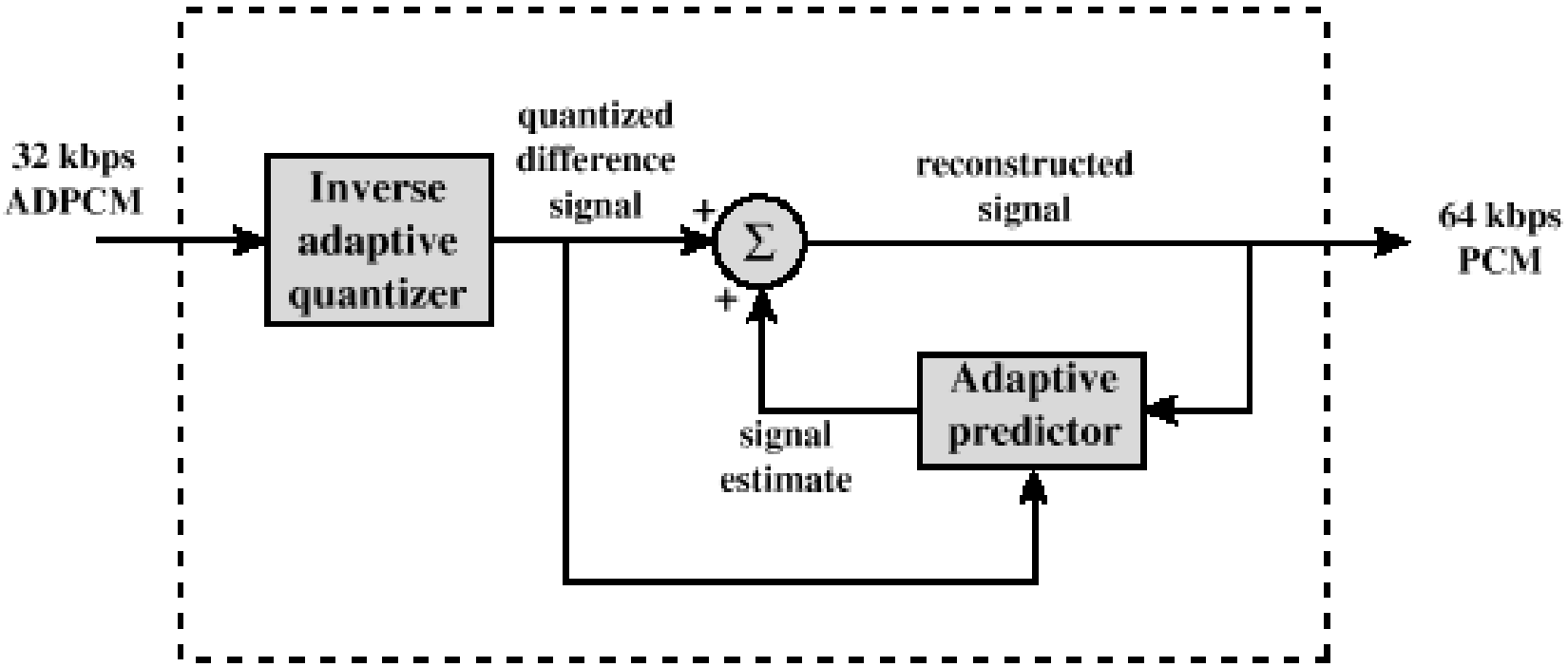
- Improve DPCM performance using adaptive prediction and quantization
  - Predictor and difference quantizer adapt to the changing characteristics of the speech
- Modules
  - Adaptive quantizer
  - Inverse adaptive quantizer
  - Adaptive predictor

ADPCM Encoder



(a) ADPCM encoder

ADPCM Decoder



(b) ADPCM decoder

Subject Measurement of Coder Performance

- Subjective measurements of quality are more relevant than objective measures
- Mean opinion score (MOS) – group of subjects listen to a sample of coded speech; classify output on a 5-point scale
- MOS scale is used in a number of specifications as a standard for quality

Wireless Local Loop

- Wired technologies responding to need for reliable, high-speed access by residential, business, and government subscribers
  - ISDN, xDSL, cable modems
- Increasing interest shown in competing wireless technologies for subscriber access
- Wireless local loop (WLL)
  - Narrowband – offers a replacement for existing telephony services
  - Broadband – provides high-speed two-way voice and data service

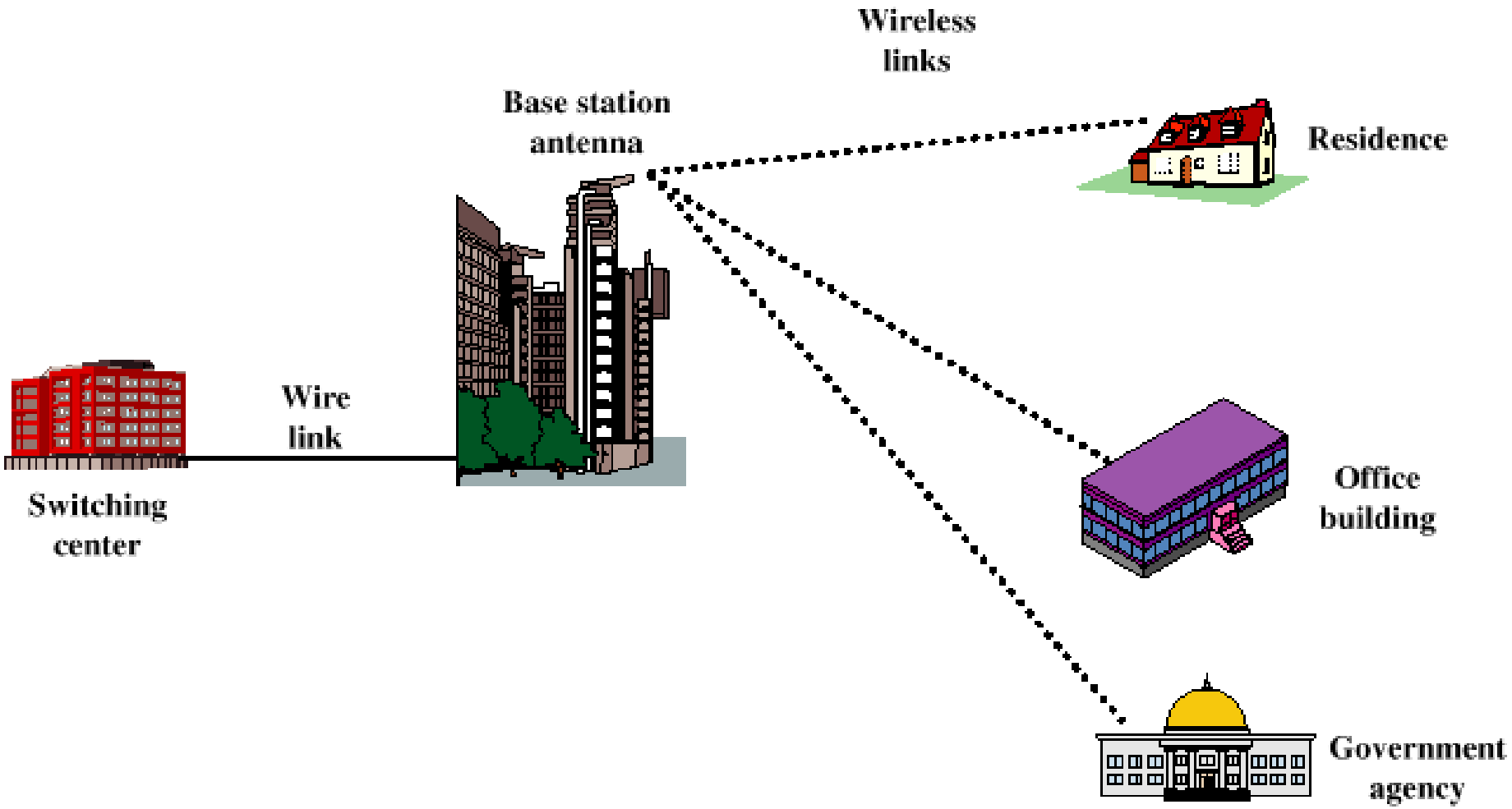


Figure 11.9 WLL Configuration

Advantages of WLL over Wired Approach

- Cost – wireless systems are less expensive due to cost of cable installation that's avoided
- Installation time – WLL systems can be installed in a small fraction of the time required for a new wired system
- Selective installation – radio units installed for subscribers who want service at a given time
  - With a wired system, cable is laid out in anticipation of serving every subscriber in a given area

Propagation Considerations for WLL

- Most high-speed WLL schemes use millimeter wave frequencies (10 GHz to about 300 GHz)
  - There are wide unused frequency bands available above 25 GHz
  - At these high frequencies, wide channel bandwidths can be used, providing high data rates
  - Small size transceivers and adaptive antenna arrays can be used

Propagation Considerations for WLL

- Millimeter wave systems have some undesirable propagation characteristics
  - Free space loss increases with the square of the frequency; losses are much higher in millimeter wave range
  - Above 10 GHz, attenuation effects due to rainfall and atmospheric or gaseous absorption are large
  - Multipath losses can be quite high

Fresnel Zone

- How much space around direct path between transmitter and receiver should be clear of obstacles?
  - Objects within a series of concentric circles around the line of sight between transceivers have constructive/destructive effects on communication
- For point along the direct path, radius of first Fresnel zone:

$$R = \sqrt{\frac{\lambda SD}{S + D}}$$

  - S = distance from transmitter
  - D = distance from receiver

Atmospheric Absorption

- Radio waves at frequencies above 10 GHz are subject to molecular absorption
  - Peak of water vapor absorption at 22 GHz
  - Peak of oxygen absorption near 60 GHz
- Favorable windows for communication:
  - From 28 GHz to 42 GHz
  - From 75 GHz to 95 GHz

Effect of Rain

- Attenuation due to rain
  - Presence of raindrops can severely degrade the reliability and performance of communication links
  - The effect of rain depends on drop shape, drop size, rain rate, and frequency
- Estimated attenuation due to rain:

$$A = aR^b$$

  - A = attenuation (dB/km)
  - R = rain rate (mm/hr)
  - a and b depend on drop sizes and frequency

Effects of Vegetation

- Trees near subscriber sites can lead to multipath fading
- Multipath effects from the tree canopy are diffraction and scattering
- Measurements in orchards found considerable attenuation values when the foliage is within 60% of the first Fresnel zone
- Multipath effects highly variable due to wind

Multipoint Distribution Service (MDS)

- Multichannel multipoint distribution service (MMDS)
  - Also referred to as wireless cable
  - Used mainly by residential subscribers and small businesses
- Local multipoint distribution service (LMDS)
  - Appeals to larger companies with greater bandwidth demands

Advantages of MMDS

- MMDS signals have larger wavelengths and can travel farther without losing significant power
- Equipment at lower frequencies is less expensive
- MMDS signals don't get blocked as easily by objects and are less susceptible to rain absorption

Advantages of LMDS

- Relatively high data rates
- Capable of providing video, telephony, and data
- Relatively low cost in comparison with cable alternatives

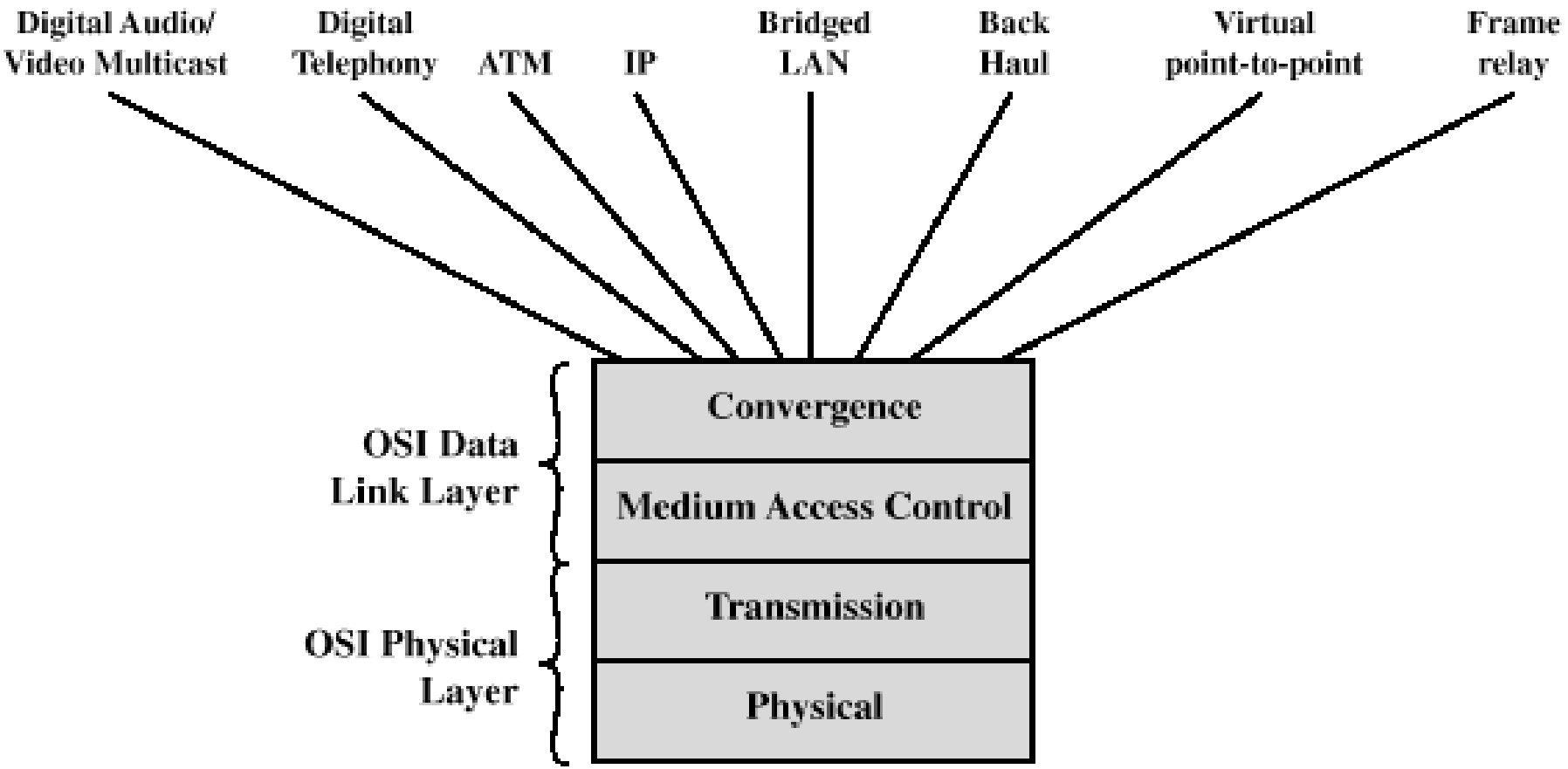
802.16 Standards Development

- Use wireless links with microwave or millimeter wave radios
- Use licensed spectrum
- Are metropolitan in scale
- Provide public network service to fee-paying customers
- Use point-to-multipoint architecture with stationary rooftop or tower-mounted antennas

802.16 Standards Development

- Provide efficient transport of heterogeneous traffic supporting quality of service (QoS)
- Use wireless links with microwave or millimeter wave radios
- Are capable of broadband transmissions (>2 Mbps)

IEEE 802.16 Protocol Architecture



Protocol Architecture

- Physical and transmission layer functions:
  - Encoding/decoding of signals
  - Preamble generation/removal
  - Bit transmission/reception
- Medium access control layer functions:
  - On transmission, assemble data into a frame with address and error detection fields
  - On reception, disassemble frame, and perform address recognition and error detection
  - Govern access to the wireless transmission medium

Protocol Architecture

- Convergence layer functions:
  - Encapsulate PDU framing of upper layers into native 802.16 MAC/PHY frames
  - Map upper layer's addresses into 802.16 addresses
  - Translate upper layer QoS parameters into native 802.16 MAC format
  - Adapt time dependencies of upper layer traffic into equivalent MAC service

IEEE 802.16.1 Services

- Digital audio/video multicast
- Digital telephony
- ATM
- Internet protocol
- Bridged LAN
- Back-haul
- Frame relay

IEEE 802.16.3 Services

- Voice transport
- Data transport
- Bridged LAN

IEEE 802.16.1 Frame Format

IEEE 802.16.1 Frame Format

- Header - protocol control information
  - Downlink header – used by the base station
  - Uplink header – used by the subscriber to convey bandwidth management needs to base station
  - Bandwidth request header – used by subscriber to request additional bandwidth
- Payload – either higher-level data or a MAC control message
- CRC – error-detecting code

MAC Management Messages

- Uplink and downlink channel descriptor
- Uplink and downlink access definition
- Ranging request and response
- Registration request, response and acknowledge
- Privacy key management request and response
- Dynamic service addition request, response and acknowledge

MAC Management Messages

- Dynamic service change request, response, and acknowledge
- Dynamic service deletion request and response
- Multicast polling assignment request and response
- Downlink data grant type request
- ARQ acknowledgment

Physical Layer – Upstream Transmission

- Uses a DAMA-TDMA technique
- Error correction uses Reed-Solomon code
- Modulation scheme based on QPSK

Physical Layer – Downstream Transmission

- Continuous downstream mode
  - For continuous transmission stream (audio, video)
  - Simple TDM scheme is used for channel access
  - Duplexing technique is frequency division duplex (FDD)
- Burst downstream mode
  - Targets burst transmission stream (IP-based traffic)
  - DAMA-TDMA scheme is used for channel access
  - Duplexing techniques are FDD with adaptive modulation, frequency shift division duplexing (FSDD), time division duplexing (TDD)