Chapter 14

Broadband Wireless Access Networks

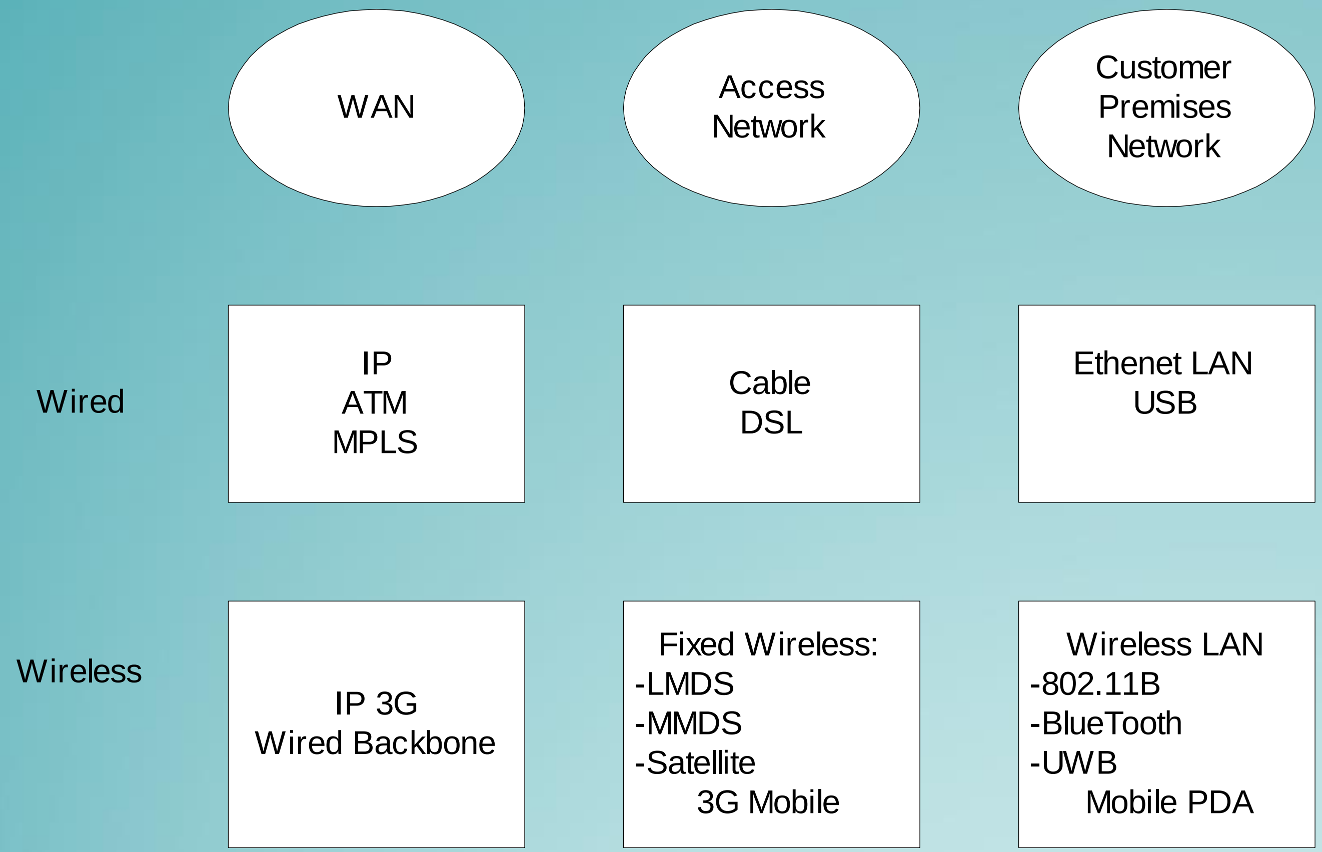
Objectives

- Broadband wireless access networks
  - Multichannel multipoint distribution service, MMDS
  - Local multipoint distribution service, LMDS
  - IEEE 802.16/WiMax networks
- Components of wireless access network
  - Base station (BS)
  - Subscriber station (SS)
  - Wireless medium
  - Wireless spectrum
- Basic principles of wireless communication
  - Free space propagation
  - Terrestrial propagation
  - Cellular mobile environment
  - Fading phenomena
- MMDS and LMDS
  - Deployment in rural areas
  - Line-of-sight (LOS) limitation
  - Operational spectrum and modes
  - Similarity with cable access network

Objectives (cont.)

- IEEE 802.16/WiMax networks
  - IEEE 802.16 spectrum 10 to 66 GHz
  - WiMax spectrum windows in the 2 to 11 GHz
  - WiMax mesh network eliminates LOS limitation
  - Management of BS and SS
  - Spectrum management
  - Service flow management
  - Management using wmanIfMib
- Mobile wireless network
  - 2.5, 3, and 4G technologies
  - TDM, TDMA, and CDMA protocol systems
  - Management issues
  - Use of mobile IP
  - Mobility management
  - Power and resource management
  - QoS management
  - Security management
- VSAT network and management

Wired & Wireless Broadband Networks



Analogous Wired and Wireless Broadband Network Segments

Wired/ Wireless technologies for :

1. WAN
2. Access Network
3. Customer premises network

Notes

- Wireless Mobile ATM (WmATM) is not shown in Wireless WAN as it does not appear to be in the current road map of technology.

Wireless Broadband Networks

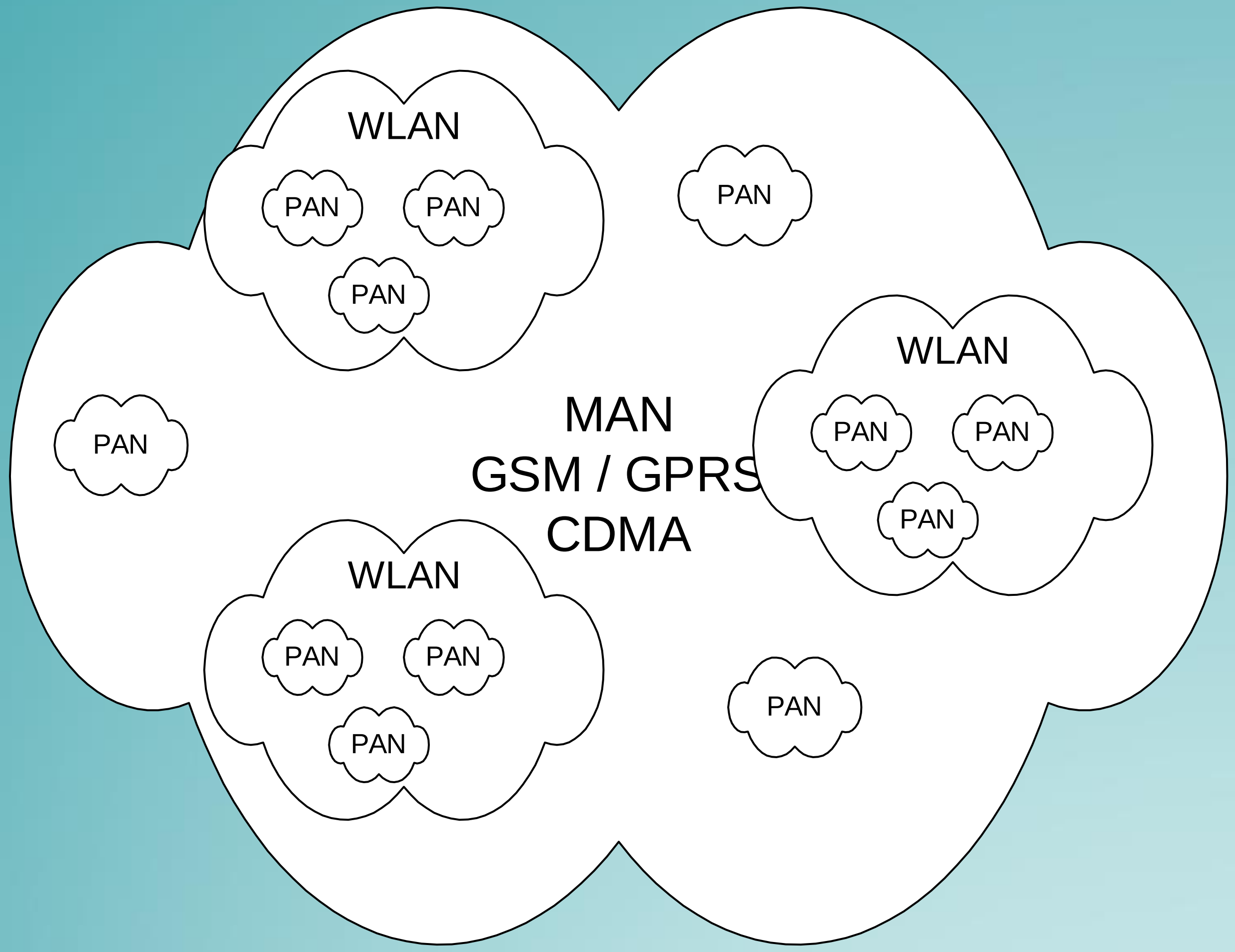


Figure 14.1 Wireless Networks

- Access Networks
  - MAN a.k.a. WiMax
- Wireless LAN (WLAN)
- Personal Area Network (PAN)

Notes

The application of wireless technologies can be grouped into three categories. They are personal area networks (PANs), wireless LANs (WLANs), and access networks—metropolitan area network (MAN), GPS/general packet radio service (GPRS), and code division multiple access (CDMA)—and are represented in Figure 14.1.

Basic Principles in wireless communication

Outdoor Propagation

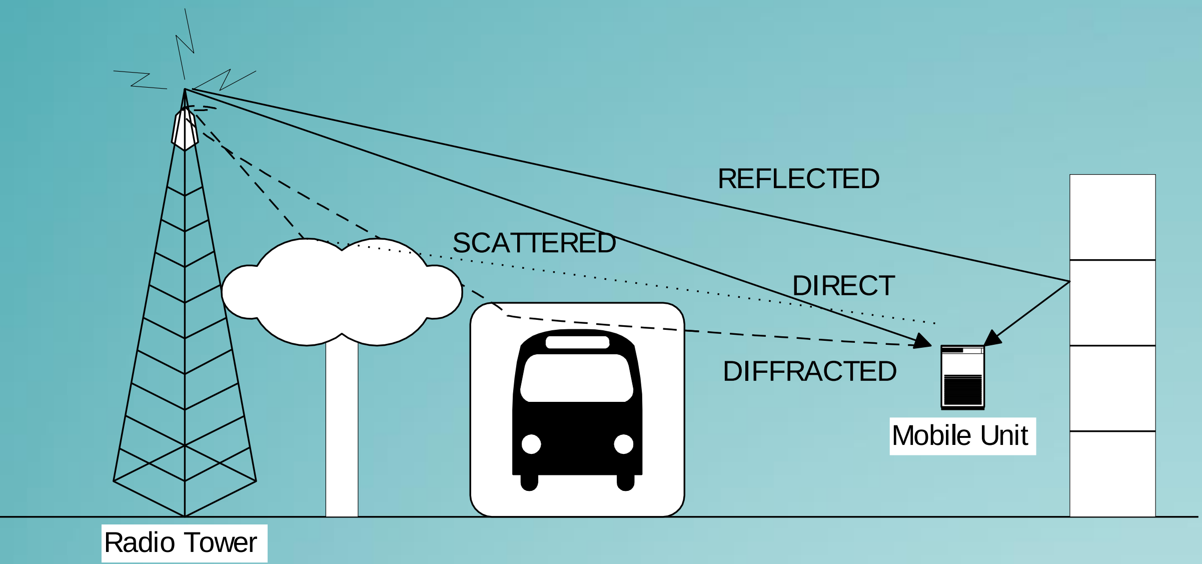


Figure 14.2 Wireless Outdoor Propagation

Notes

- Adverse Characteristics:
  - Attenuation
  - Dispersion: Frequency and Phase (independent of refractive index)
  - Dispersion due to refractive index
  - Decreasing signal strength due to beam pattern
  - Water absorption
  - Fading: short and long
  - Doppler effect

There are several physical mechanisms to consider in dealing with wireless propagation, which we do not have with propagation through wired networks.

For outdoor propagation, shown in Figure 14.2, the physical mechanisms that we need to consider are line-of-sight (LOS) path, reflection, and diffraction–from ground and other stationary and moving objects–and scattering such as from foliage and buildings.

http://missionscience.nasa.gov/ems/03_behaviors.html

http://www.dictionaryofengineering.com/

Let us compare wired media with wireless media. We can list the following three main characteristics of wired media that adversely affect broadband propagation. First is attenuation, which is based on conductivity in copper, or reflection and refraction losses in fiber. The next characteristic is frequency and phase dispersion that are dependent on the refractive index, which in turn is dependent on frequency. The third is time dispersion caused by the speed of transmission, which is dependent on the dispersive refractive index.

Manifestations of the above adversely impacting characteristics of wired media are also present for wireless media. There is attenuation due to absorption by the media, such as water vapor or obstruction of the LOS between the source and the destination such as trees and buildings. There is also decreasing signal strength as we move away from the source antenna since open-space wave propagation is not guided but is divergent. The major cause of frequency, phase, and time dispersion can all be attributed to the signal from the source arriving as multiple signals at the receiver by the multipath. They arrive at the receiver at different times, with changes in frequency and phase, causing interference of short and long duration. If it is a rapid change, it resembles phase, frequency, and time dispersion. If it is gradual and the signal strength degrades, it is called fading. Fading can be slow or rapid temporally or could be spatially fluctuating. Frequency shift is due to Doppler effect when the source or the receiver moves fast with respect to each other.

- Doppler effect: A change in the observed frequency of a wave, as of sound or light, occurring when the source and observer are in motion relative to each other, with the frequency increasing when the source and observer approach each other and decreasing when they move apart.

Isotropic Propagation

14.1.1 Free-Space Propagation

Let us first consider the signal strength, which varies with distance from the source in free space. This is shown in Figure 14.3 for an isotropic antenna.

The power at distance *d* from the source is given by

isotropic : (of an object or substance) having a physical property that has the same value when measured in different directions

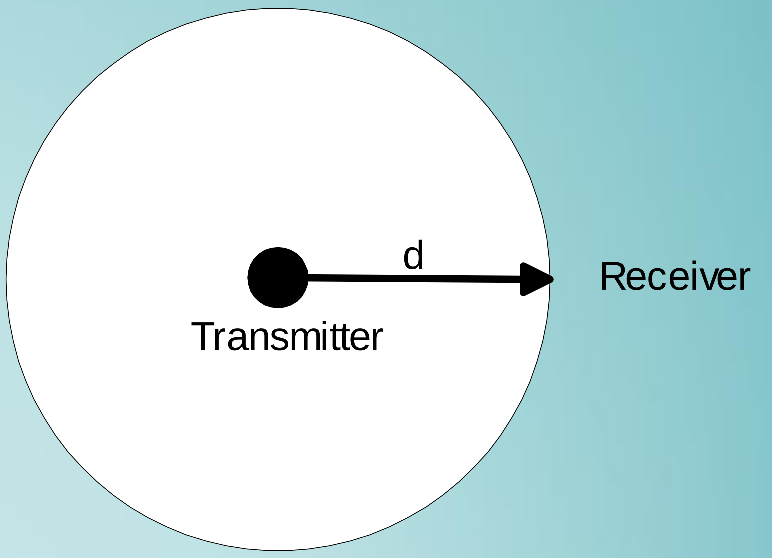


Figure 14.3 Isotropic Antenna Propagation

Notes

$$Pr = (PT / 4\pi d^2) \text{ watts } /m^2 \quad (14\text{-}1)$$

Pr = Received power per unit area and
PT = Total transmitted power.

Non-Isotropic Propagation

isotropic : (of an object or substance) having a physical property that has the same value when measured in different directions

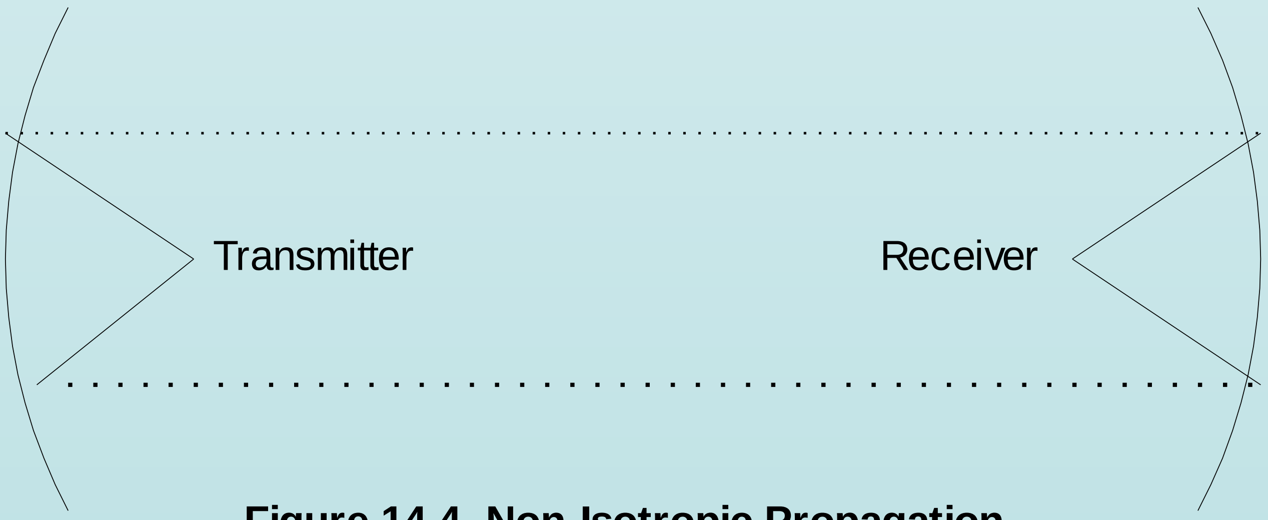


Figure 14.4 Non-Isotropic Propagation

Notes

$$P_R = P_T G_T G_R (\lambda / 4d)2 \qquad (14\text{-}5)$$

P_R = Received power
P_T = Transmitted power
G_T = Transmitter antenna gain
G_R = Receiver antenna gain
λ = Wavelength

Satellite Free Space Propagation

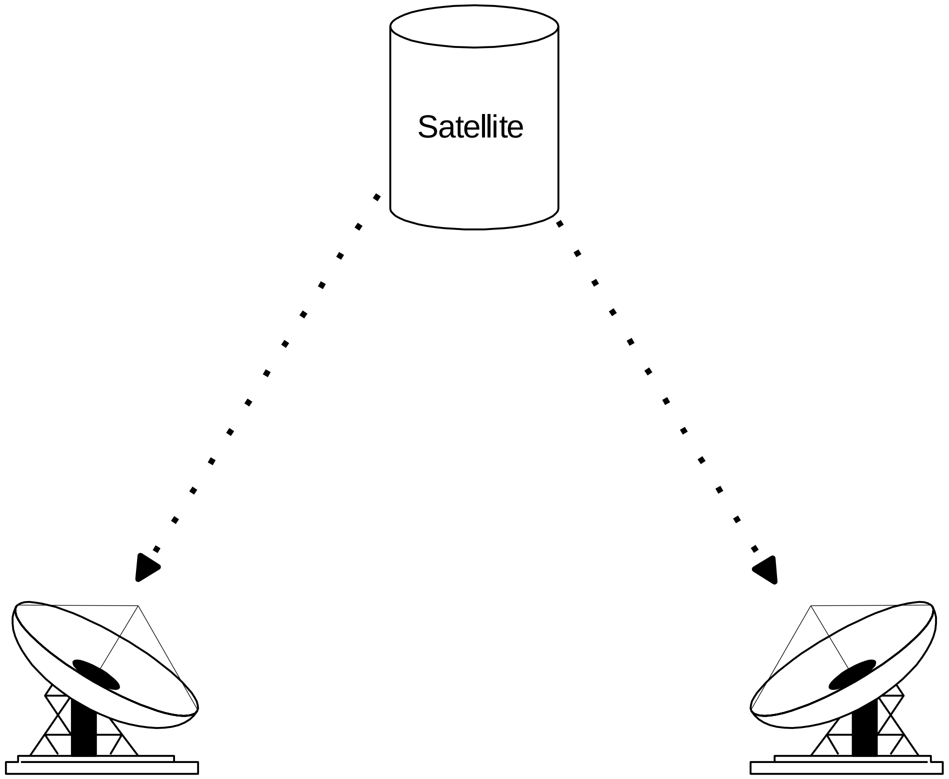


Figure 14.5 Satellite Transmission

Notes

This would be valid for the satellite transmission system shown in Figure 14.5

$$P_R = \left(\frac{1}{4\pi d}\right)^2 P_T G_T G_R \qquad (14\text{-}5)$$

Define P_0 = power received at the first meter (d = 1 m). Then

$$P_R = P_0 / d^2 = P_0\, g(d) \qquad (14\text{-}6)$$

where $g(d)$ is the path-loss distance dependence factor.

Terrestrial Propagation

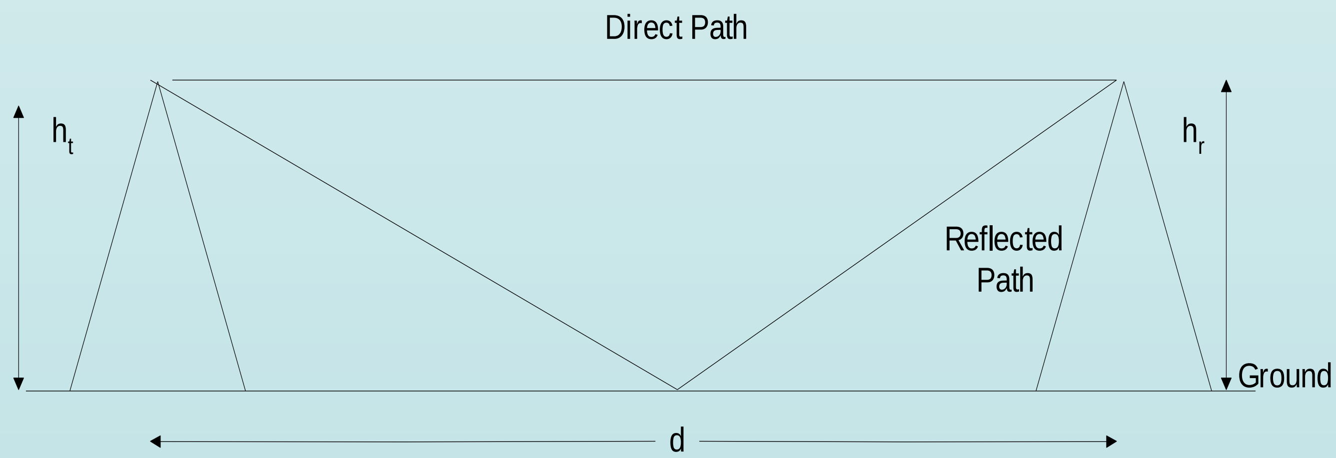


Figure 14.6 Terrestrial Two-Ray Propagation Model

Notes

14.1.2 Two-Ray Propagation

The free-space propagation model derived in Section 14.1.1 can be applied to satellite propagation. However, it does not apply to the terrestrial propagation model. Figure 14.6 shows a simple terrestrial propagation model. The signal travels from the transmitter to the receiver along two paths. The first is a direct path and the other an indirect path caused by ground reflection. If the height of the transmitter and receiver antennas is assumed to be h_t and h_r, it can be shown [Schwartz, 2005] that

$$P_R = P_T G_T G_R (h_t^2 h_r^2 / d^4) \quad (14\text{-}8)$$

where d is the horizontal distance between the transmitter and the receiver.

Path Loss Dependency

Now, the distance-dependent path-loss factor is 40 dB per decade or 12 dB per octave. Figure 14.7 shows the two cases. In the real world, distance dependency would transition between the two cases as either the distance is increased or the height of the antenna is varied.

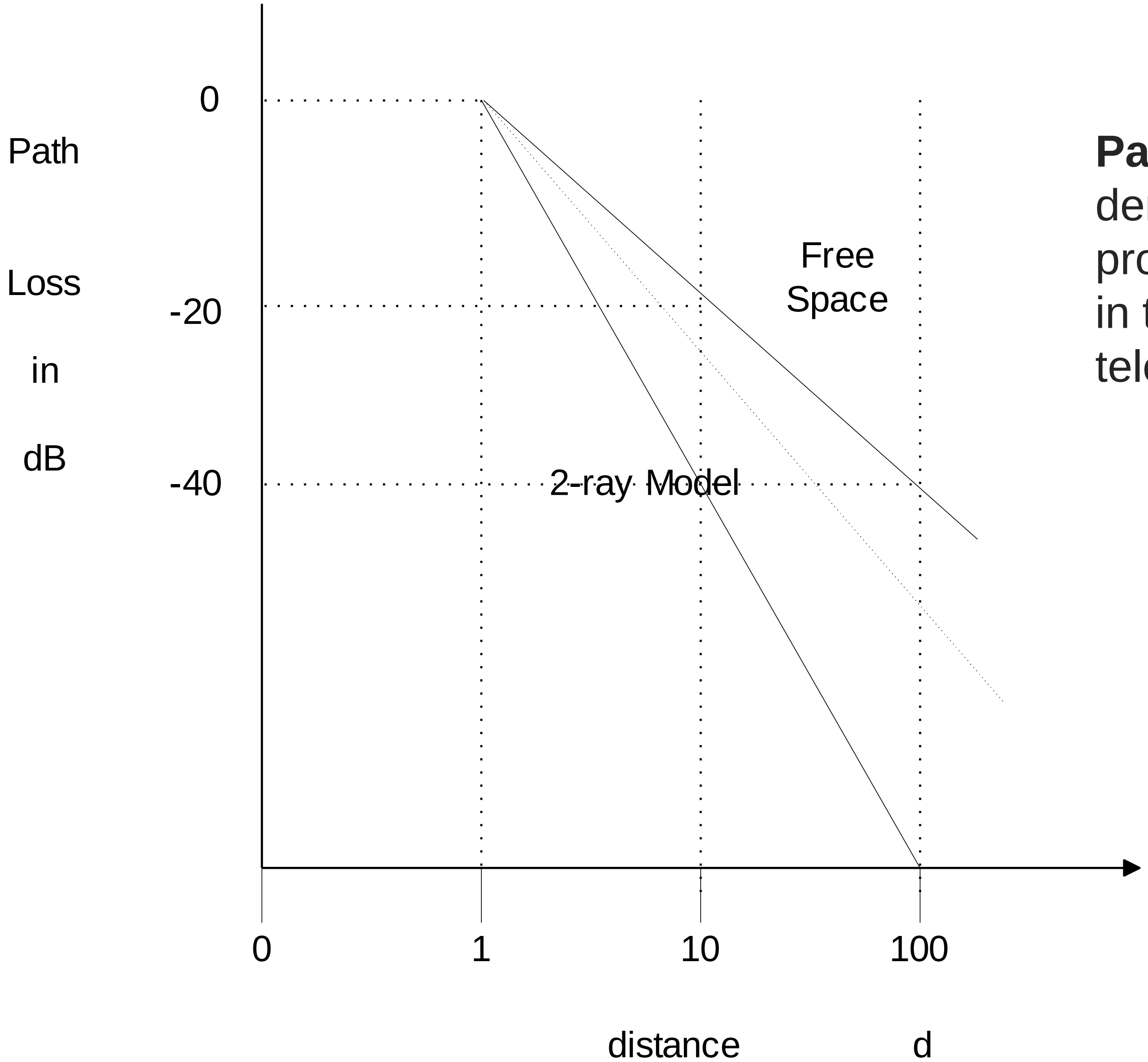


Figure 14.7 Path Loss Depending on Distance

Path loss (or **path attenuation**) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. Path loss is a major component in the analysis and design of the link budget of a telecommunication system.

https://en.wikipedia.org/wiki/Path_loss

Shadow Fading

14.1.3 Fading

Various factors contributing to fading phenomena in outdoor wireless propagation were presented in Figure 14.2. All of them impact the instantaneous value of the received signal that is varying temporally and spatially. The magnitude of the received power fluctuation is caused primarily either by path loss due to absorption and scattering, or due to multipath fading caused by the interference of direct wave with reflected, diffracted, or scattered waves.

The fading phenomenon has both spatial and temporal dependencies. We can classify them into large-scale fading and small-scale fading.

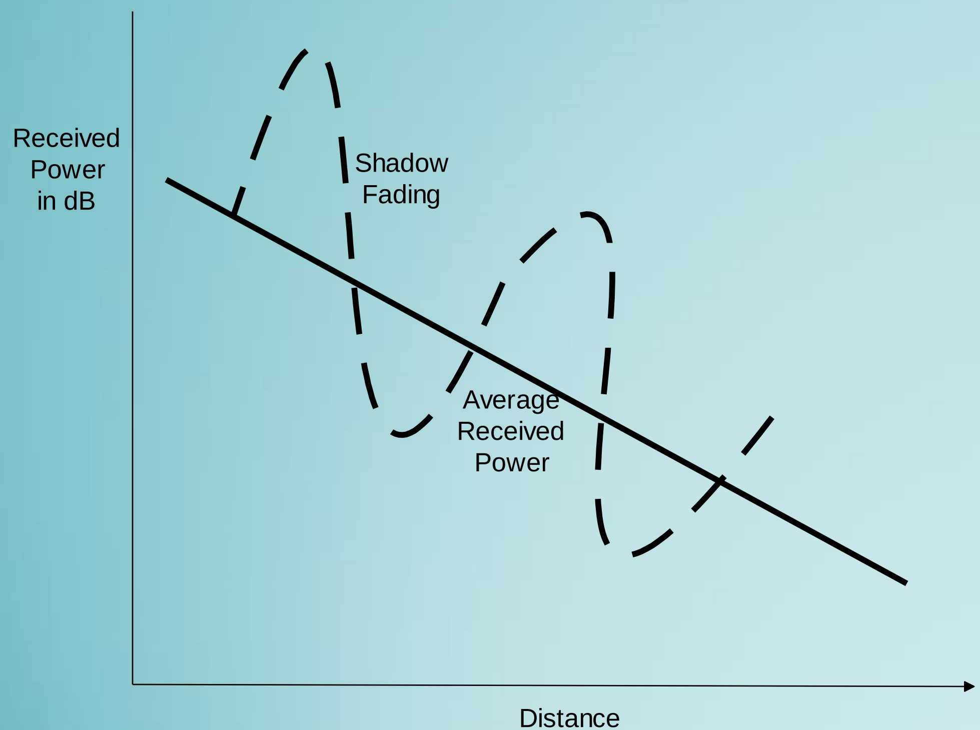


Figure 14.8 Shadow Fading over Average Path Loss

Notes

- Large-scale fading or Shadow fading
  - Slow spatial rate compared to wavelength
  - Slow rate of change
- Small-scale fading
  - Spatial dimension comparable to wavelength
  - Rapid rate of change

Shadow Fading

The fading phenomenon has both spatial and temporal dependencies. We can classify them into large-scale fading and small-scale fading. The former occurs at a slow spatial rate compared to the wavelength and is generally slow in temporal variation. The latter, namely small-scale fading, occurs at spatial dimension comparable to the wavelength and generally occurs at a more spatially rapid rate compared to large-scale fading. In addition to the above two classifications, there is fading due to Doppler effect in fast-moving mobile units.

Shadow Fading. Large-scale fading, which occurs at relatively long distances compared to wavelength, is also called shadow fading. It is caused due to reflection, scattering, diffraction, meteorological change such as absorption, etc. The fading follows a log-normal (Gaussian) distribution with a standard deviation of 6–10 dB around average power, as shown in Figure 14.8.

Small-Scale Fading. As we stated earlier, small-scale fading is caused by multipath fading, which is constructive or destructive interference of signals arriving at the receiver traversing different paths and hence at different phases. Moving the receiver by a distance comparable to the wavelength, the signal strength could vary significantly. For example, for the IEEE 802.11b WiFi signal, the data rate could go down from a strong several megabits per second (max. data rate is 11 Mbps) to less than 1 Kbps for displacement in the order of centimeters. Even for a wireless receiver in a stationary state, small-scale fading could occur as the environment fluctuates.

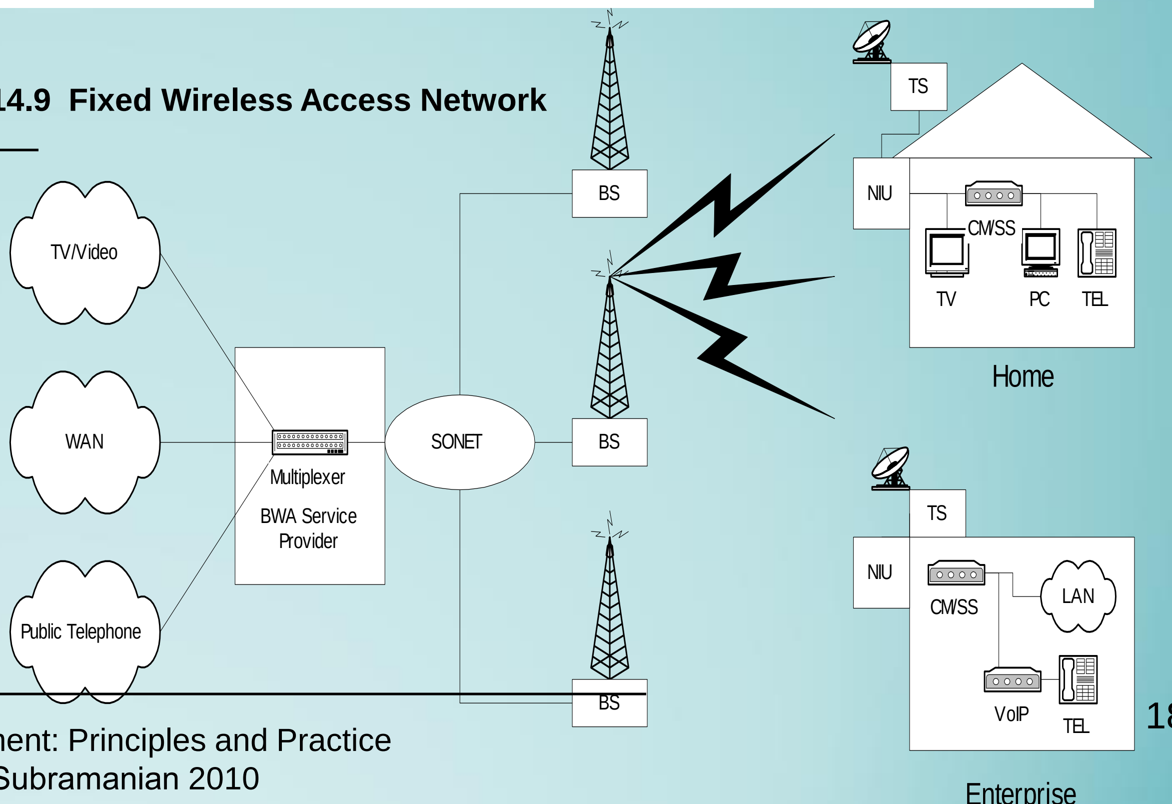
Fixed Wireless Networks

Base station

Fixed Wireless Network

A fixed BWA network is used to reach subscribers by wireless medium for the last mile and is shown in Figure 14.9. It is a point-to-multipoint network architecture. Broadband information comprising voice, video, and data is multiplexed at the BWA service provider head end and is carried over wired WAN or MAN to the BS from where it is transmitted to subscriber premises. Typical residence and Small Office Home Office (SOHO) subscribers are represented in Figure 14.9. The signal at the subscriber premises is up- and down-converted by transreceiver TR to the baseband signal. The network interface unit (NIU) serves the same function as the NIU in the cable modem system and is the demarcation point between the access network and the subscriber distribution network. At CPE, the network comprises of analog TV and digital network components. The NIU interfaces with either a subscriber station (SS) or a wireless modem (WM), both of which output Ethernet protocol to the CPE distribution network. The former is used with the IEEE 802.16 standard protocol access network. The latter uses a wireless modem termination system (WMTS) at the head end. In this case, the only difference between the fixed wireless system and the cable modem system is the transmission medium of the access network.

Figure 14.9 Fixed Wireless Access Network



Notes

- Fixed wireless access
  - a.k.a wireless local loop
- Point-to-multipoint network architecture
- Benefits:
  - Less capital investment
  - Quick and cheap to install and operate

Each BS in Figure 14.9 serves several hundred subscribers distributed over multiple sectors. The BS has generally multiple antennas serving multiple sectors. Three or four sectors are common configurations. BSs are spaced depending on the spatial coverage and density of subscribers, as well as the technology used for the access network. We will discuss the various technologies in the next several subsections.

MMDS Network

Multichannel Multipoint Distribution Service

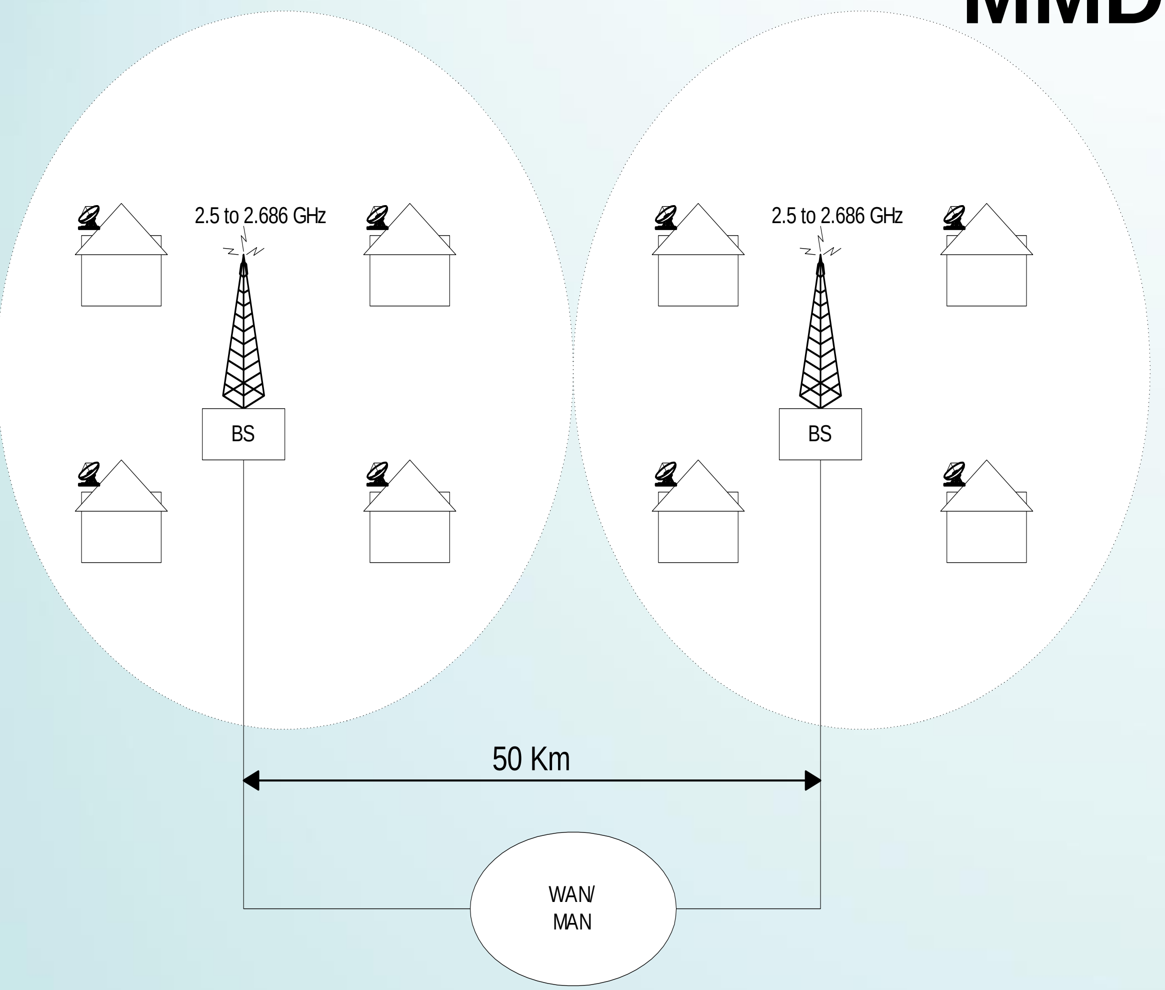


Figure 14.10 Multichannel Multipoint Distribution Service

Notes

- Point-to-multipoint architecture
- Range between BSs is 50 km
- Operates over 2.5 to 2.686 GHz band
- Could operate on multichannels and hence capable of providing 2-way high-speed communication
- An implementation using cable modem equipment at both ends

An MMDS broadband system shown in Figure 14.10 comprises a head end, which is the BS, antennas at the head end and at the SS, transreceivers that convert the baseband signal to the microwave signal, and the cable modem at the subscriber end that converts DOCSIS+ protocol to Ethernet protocol for a CPE distribution network. The range of a BS is about 25 kilometers, and hence BSs are separated by about 50 kilometers. The broadband signal is brought to the BSs via WAN or MAN. The range can be extended by having repeater stations, which enables low-powered systems to be used at the SS.

Downstream propagation is TDM broadcast mode and upstream is TDMA transmission. Downstream modulation is QAM and upstream is QPSK. The system is ideal for rural areas. When it is used in the metropolitan area, the LOS is not always good and OFDM modulation is used to mitigate the problem.

LMDS

Local Multipoint distribution service

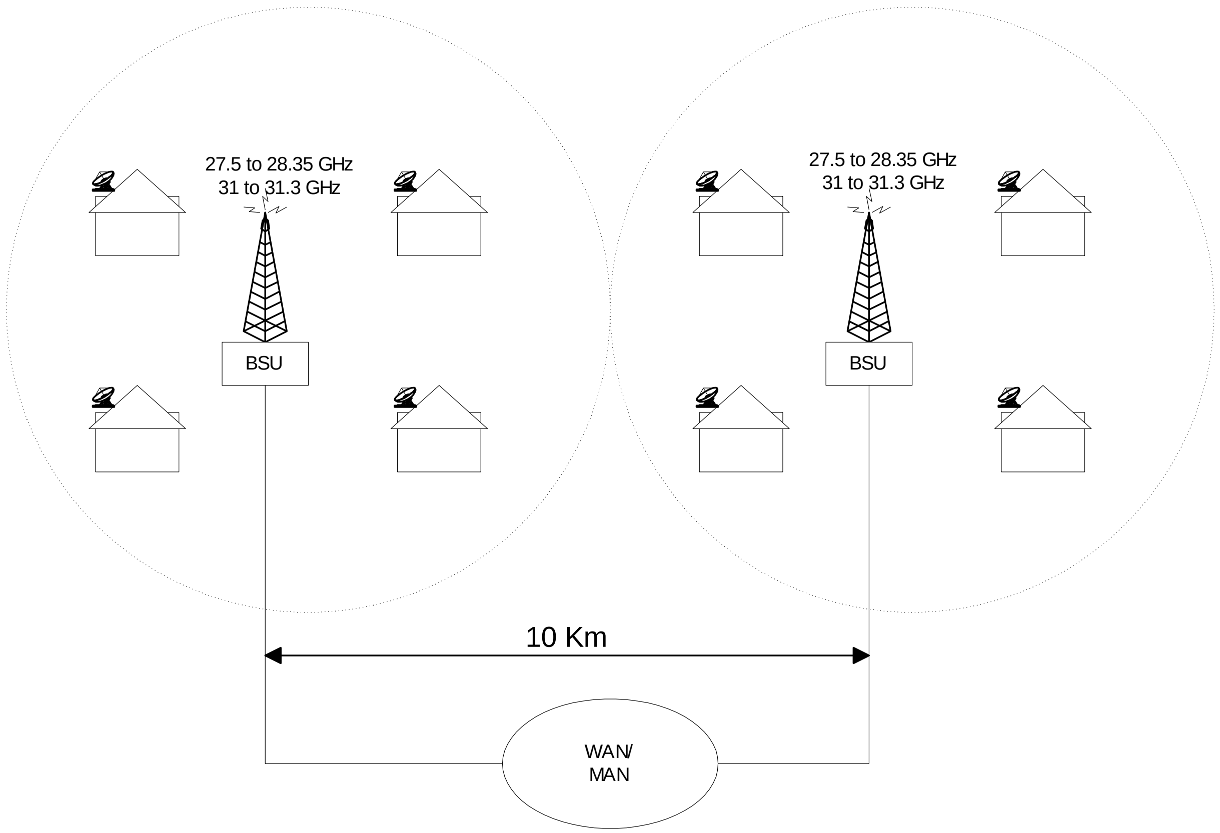


Figure 14.11 Local Multipoint Distribution Service

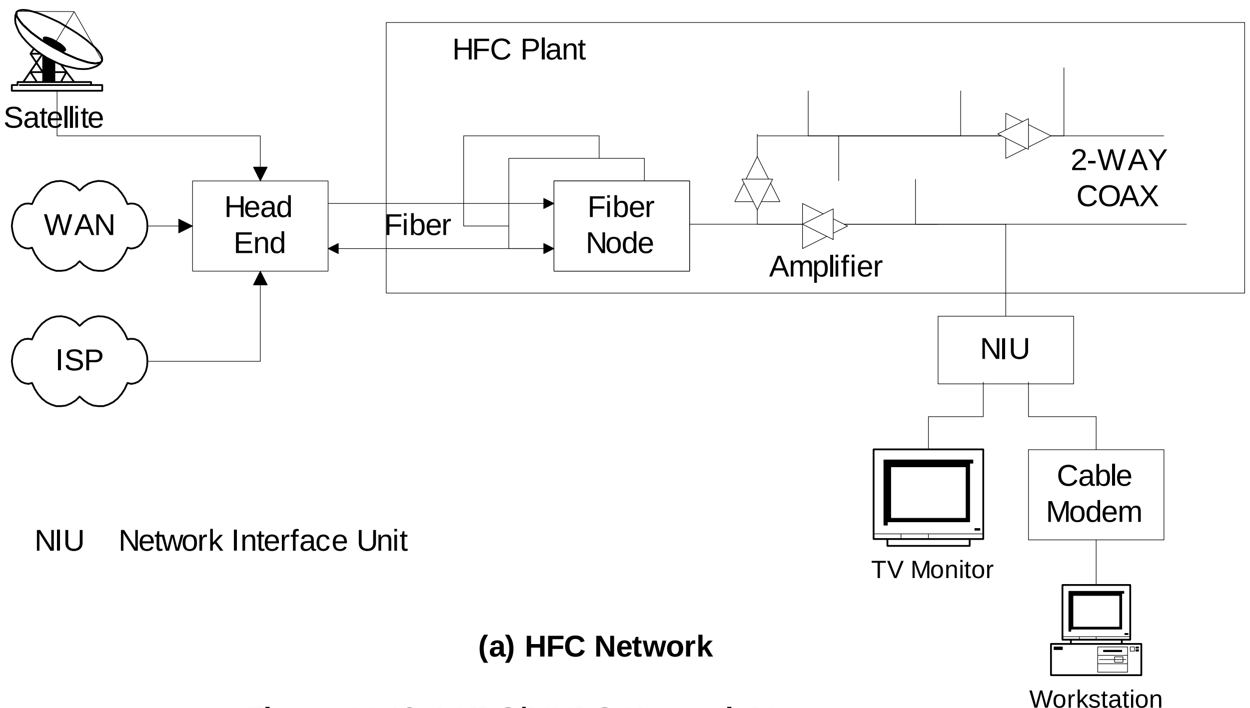
Notes

- Point-to-multipoint architecture
- Covers 5 km radius; BSUs spaced 10 km apart
- Operates over 27-28.35 and 31-31.3 GHz bands
- Sensitive to rain attenuation
- Deploys cable modem equipment at both ends

Local multipoint distribution service (LMDS) is a last-mile broadband access network that operates in the K band spectrum, primarily in the 20–40 GHz band. There is no uniformity in the spectral allocation across the world. FCC has allocated the 27.5–29.5 GHz band in the US to LMDS. The architecture of LMDS is the same as MMDS. Its range is shorter than MMDS, about 5 kilometers and hence BSs are separated by about 10 kilometers, as shown in Figure 14.11. One reason for the range limitation is due to the absorption of millimeter waves in the LMDS spectrum by precipitation.

MMDS / LMDS Network Management

LMDS (except in exceptional cases mentioned in the previous section) and MMDS have adapted the DOCSIS standards from the cable modem world. As mentioned earlier, the version of DOCSIS modified for wireless broadband is known as DOCSIS+. The management of MMDS and LMDS in these cases can be pictured as the wireless medium replacing the HFC medium, as shown in Figure 14.12. At the head end, CMTS is replaced with a WMTS and the CM is replaced with a WM.



(a) HFC Network

Figure 14.12 LMDS/MMDS Network Management

Notes

- Head end:
  - Signals from multiple sources multiplexed
  - Frequency conversion for local signal
- NIU demarcation point between customer and service provider networks
- Cable modem: RF-to-Ethernet conversion

Cable Modem Termination System
Wireless Modem Termination System

MMDS / LMDS Network Management

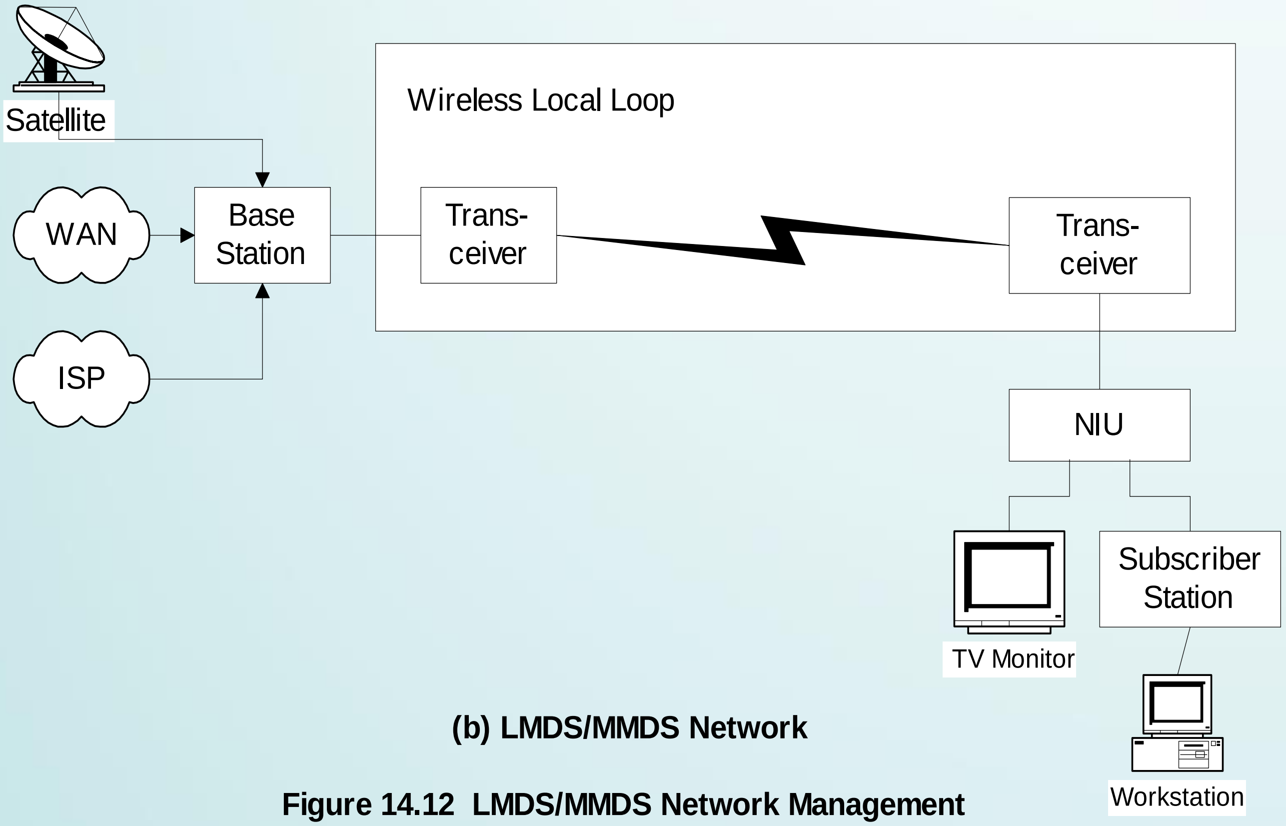


Figure 14.12 LMDS/MMDS Network Management

Notes

- Head end is replaced by base station
- Cable modem replaced by transceiver and subscriber station
- HFC plant replaced by wireless

MMDS and LMDS will in the future migrate to 802.16 or WiMax standard, which we will consider next.

802.16 Fixed Wireless System (WiMax)

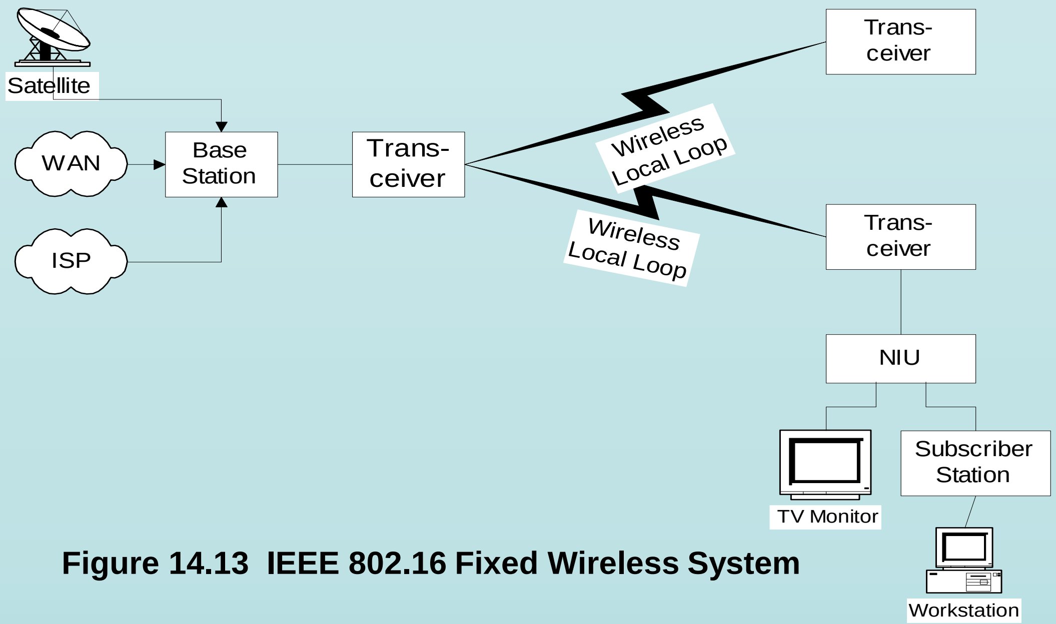


Figure 14.13 IEEE 802.16 Fixed Wireless System

Notes

- IEEE 802.16.1 specifications for 11 GHz to 66 GHz
- Encompasses multiple end configurations and transmission modes
- Point-to-multipoint architecture
- Early implementation based on cable network
- HFC medium replaced with wireless carrier
- Transceivers perform up-conversion and down-conversion
- Subscriber station a more complex modem than CM
- Base station functions as enhanced CMTS
- **TDMA (Time Division Multiple Access) downstream transmission**
- **DAMA (Demand Assigned Multiple Access) – TDMA upstream transmission**

An IEEE 802.16-based fixed wireless system is shown in Figure 14.13. The original IEEE 802.16 standard covered 10–66 GHz spectral band. IEEE 802.16a extends the spectral range coverage from 2 to 11 GHz. It is generally deployed as point-to-multipoint architecture, although specifications can be adopted to configure as mesh architecture, as shown in Figure 14.14. Head end transmission is sectionalized with multiple antennas. Transceivers TS convert the RF signal to the baseband as receivers and vice versa as transmitters at both ends. WMTS is at the BS and performs a similar function as CMTS in the cable system. All SSs in a cell terminate at the head end or the BS. The head end allocates bandwidth requested by SS to meet QoS.

- A cable modem termination system or CMTS is a piece of equipment, typically located in a cable company's headend or hubsite, which is used to provide high speed data services, such as cable Internet or Voice over Internet Protocol, to cable subscribers.
- OFDM: **OFDM** (Orthogonal frequency-division multiplexing)is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method.

- Orthogonal Frequency-Division Multiple Access (OFDMA) is a multi-user version of the popular orthogonal frequency-division multiplexing (OFDM) digital modulation scheme. Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users as shown in the illustration below.

- DAMA: Demand Assigned Multiple Access (DAMA) is **a technology used to assign a channel to clients** that don't need to use it constantly. DAMA systems assign communication channels based on requests issued from user terminals to a network control system. When the circuit is no longer in use, the channels are then returned to the central pool for reassignment to other users.

802.16 Base Station

- 802.16 uses sector technology for base station antenna (HFC uses tree topology)
- Point-to-multipoint transmission
- All SSs in a cell terminated at the head end
- Downstream in broadcast mode
- Upstream transmission by DAMA-TDMA
- Allocates bandwidth requested by SS to meet QoS
- Gateway to the external (core) network
- Multiplexes and demultiplexes signals
- Frequency converts upstream to downstream signals in FDD (Frequency Division Duplex)
- Can be designed either as a bridge or router

Notes

802.16 Subscriber Station

- Highly directional antenna
- Downstream in broadcast mode
- Upstream transmission by CM/SS coordinated by head end

Notes

IEEE 802.16 Extensions

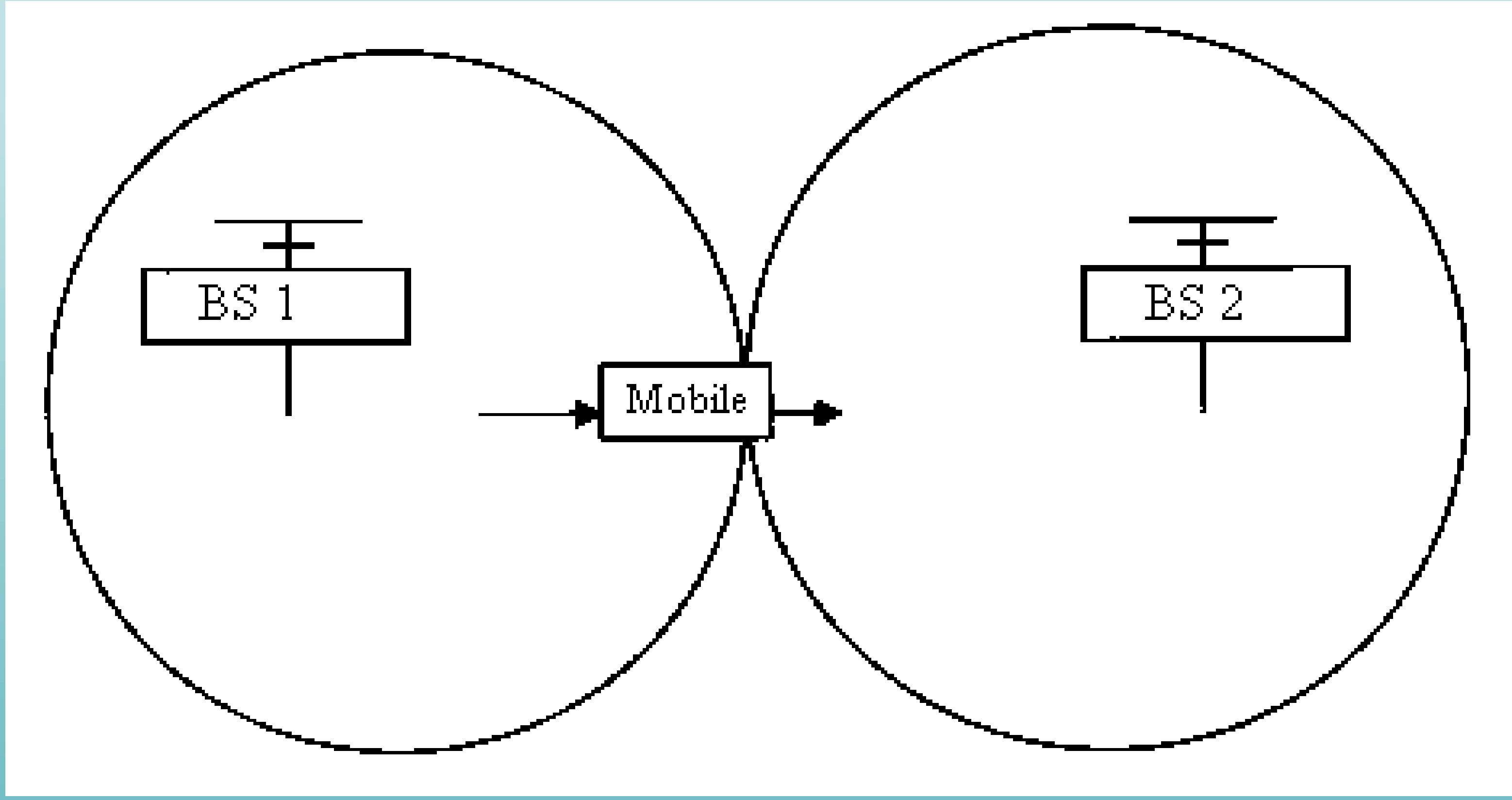
- **IEEE 802.16a**
  - 2 to 11 GHz; Supports mesh deployment
- **IEEE 802.16b**
  - 5 TO 6 GHz; Real-time DiffServ service
- **IEEE 802.16c**
  - 10 to 66 GHz
- **IEEE 802.16d**
  - Improvement over 802.16a
- **IEEE 802.16e** (future)
  - Standard networking between carrier base stations
  - High-speed handoff with moving vehicles

Differentiated services or DiffServ is a computer networking architecture that specifies a simple, scalable and coarse-grained mechanism for classifying and managing network traffic and providing Quality of Service (QoS) on modern IP networks.

Notes

handoff

When a mobile user travels from one area of coverage or cell to another cell within a call's duration the call should be transferred to the new cell's base station. Otherwise, the call will be dropped because the link with the current base station becomes too weak as the mobile recedes. Indeed**, this ability for transference is a design matter in mobile cellular system design and is called handoff**.



802.16d WiMax- Worldwide Interoperability for Microwave Access

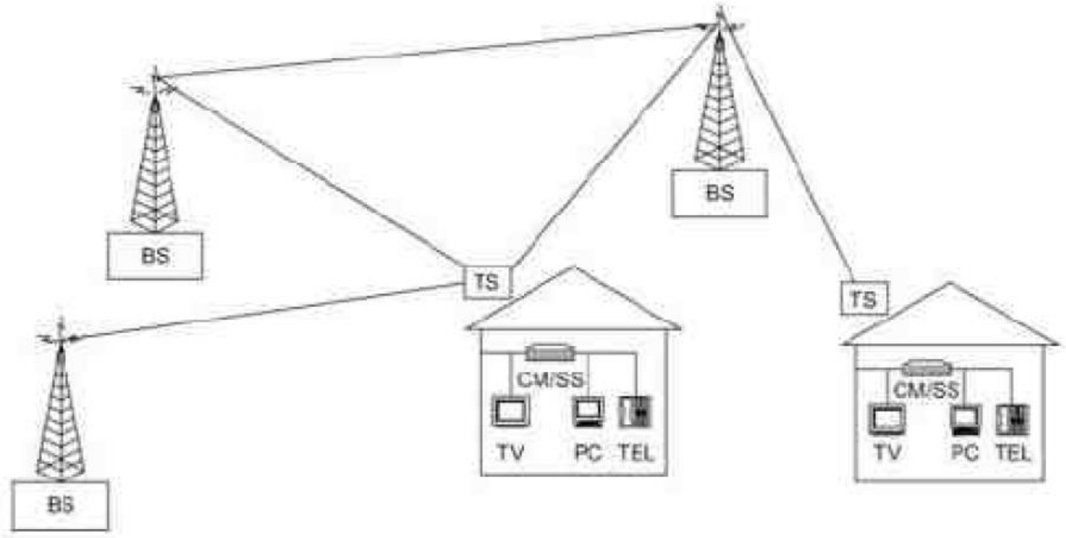


Figure 14.14 WiMax Mesh Network

Notes

- WMAN … Wireless Metropolitan Network
- 802.16a **can support no-line-of-sight access** (unlike 802.16)
- 802.16a operated in the frequency range of 2–11 GHz and thus supports both licensed and unlicensed spectrum
- Modulation scheme is OFDM as in 802.11a and 802.11g
- **Support for mesh architecture**.

802.16d: MAC Layer

- Supports mesh network
- Two sublayers
  - Convergence-specific: transport-specific
  - Common: independent of transport mechanism

Notes

Fixed BWA (Broadband Wireless Access) Management

- Components to be managed:
  - CM/SS management
  - BS management
  - Wireless link management
  - RF spectrum management

- 802.16 Recommendation OSI standards

- FCAPS functions managed

Notes

FCAPS = fault, configuration, administration, performamnce, security

BWA NM Reference Model

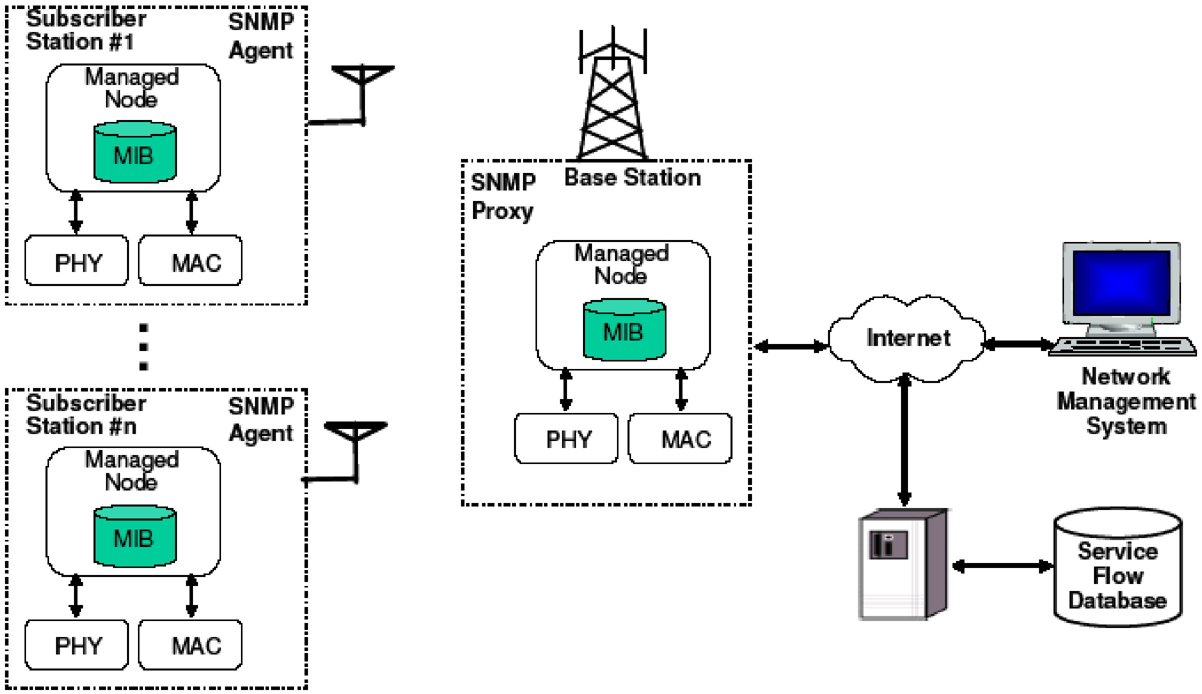


Figure 1 - BWA Network Management Reference Model

Figure 14.15 BWA Network Management Reference Model

Notes

- Reference:
  "MAC and PHY MIB for WirelessMAN and WirelessHUMAN BS and SS,"
  IEEE C802.16mgt-04/04r1,
  http://ieee802.org/16

Figure 14.15 shows the management reference model of BWA networks [Chou *et al*., 2004; Dudzinski and Bozier, 2004]. It consists of a network management system (NMS), managed nodes BS and SSs, and a service flow database. The service flow database contains service flow and associated QoS information that have to be populated in BS and SS when service is provisioned, or a mobile SS roams into BS coverage. SSs can be managed directly by NMS, or indirectly through BS, acting as the SNMP proxy. Management information between SS and BS will be carried over second management connection ID (CID) for managed SS. If the second management CID does not exist, SNMP messages will go through another interface in the customer premises. The SNMP agent in the SS can be managed directly or via an SNMP proxy in the BS.

Class of Service and QoS

- 802.16 supports classes of service with various QoS for bearer services

- Bandwidth negotiation for connectionless service
- State information maintainable for connection- oriented service

- classes of services:
  - –in IEEE802.16d (UGS, rtPS, nrtPS, and BE)
  - –in IEEE802.16e (ertPS)

- IETF Traffic categories: (Integrated services RFC 1633 and differentiated services RFC 2475)
  - Elastic:
    - Interactive bursts (Telnet)
    - Interactive bulk (FTP)
    - Asynchronous bulk (email)
  - Real-time
    - Guaranteed service (audio and video conferencing)
    - Predictive service (video playback)

WMAN IF MIB

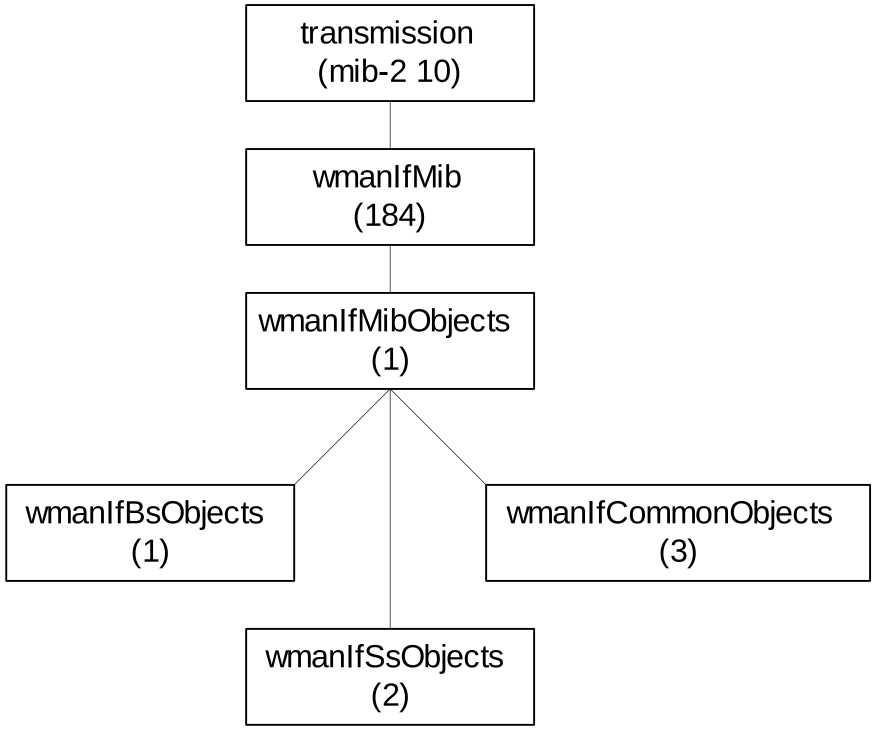


Figure 14.16 WMAN IF MIB

Notes

Usage of ifTable Objects for Base Station

Table 14.1 Usage of ifTable Objects for the Base Station

ifTable	*ifIndex*	*ifType (IANA)*	*ifSpeed*	*ifPhysAddress*	*ifAdminStatus*	*ifOperStatus*
BS Sector 1	An ifEntry per BS sector (1)	propBWAp2Mp	Null	MAC address of BS sector	Administration Status	Operational Status
BS Sector 2	An ifEntry per BS sector (2)	propBWAp2Mp	Null	MAC address of BS sector	Administration Status	Operational Status
BS Sector 3	An ifEntry per BS sector (3)	propBWAp2Mp	Null	MAC address of BS sector	Administration Status	Operational Status
Ethernet			Null	MAC address	Administration Status	Operational Status

Notes

- SNMP agent in a common base station controller: Each BS sector will have an entry in the ifTable
- SNMP agent in the sector controller: One entry for the BS sector in the ifTable

Usage of ifTable Objects for Subscriber Station

Table 14.2 Usage of ifTable Objects for the Subscriber Station

ifTable	*ifIndex*	*ifType (IANA)*	*ifSpeed*	*ifPhysAddress*	*ifAdminStatus*	*ifOperStatus*
SS	An ifEntry for SS	propBWAp2Mp	Null	MAC address of SS	Administration Status	Operational Status
Ethernet			Null	MAC address	Administration Status	Operational Status

Notes

Mobile Wireless Networks

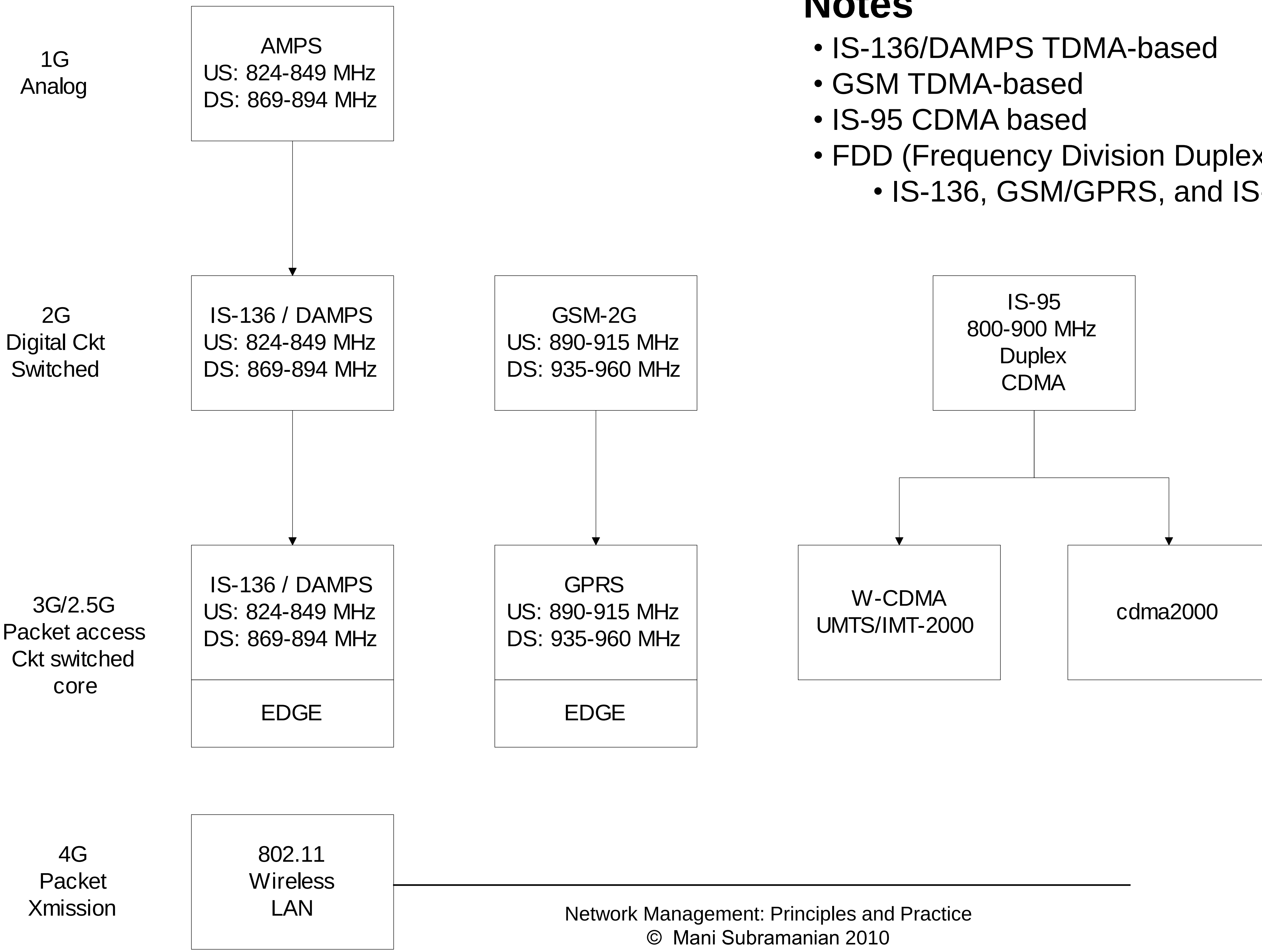
Mobile and Wireless

- Mobile Network
  - A network with ability to perform computing anytime/anywhere
  - May or may not use wireless transmission medium
  - Types of mobility
    - Cellular: Always-on
    - Nomadic: Session not active while in motion
- Wireless Network
  - A network with wireless interface to computing devices and/or wired network
  - Deployed for networking both fixed and mobile users
- Mobile and Wireless Broadband Network Management
  - Management of integrated wired/wireless and fixed/mobile broadband – voice, video, and data networks

Mobile Wireless Evolution

Notes

- IS-136/DAMPS TDMA-based
- GSM TDMA-based
- IS-95 CDMA based
- FDD (Frequency Division Duplex)
    - IS-136, GSM/GPRS, and IS-95



Cellular Network

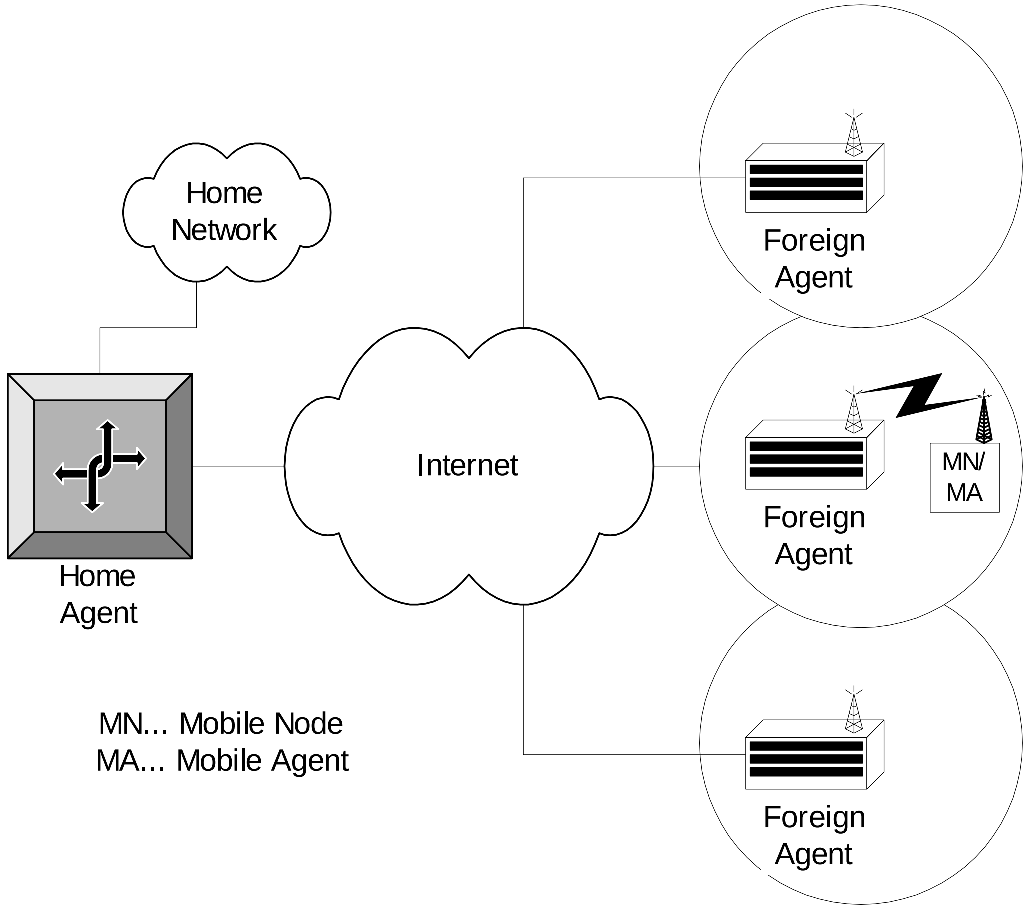


Table 14.17 Cellular Network

Notes

There are numerous ways to structure cells in cellular mobile networks. They are all based on the neighboring (adjacent) cells transmitting at different carrier frequencies. Figure 14.17 shows the architecture of a cellular network. Each mobile node (MN) is associated with a home network with a home agent (HA). It communicates with foreign nodes (FNs), each with its own foreign agent (FA), through the Internet (or WAN/MAN). The MN in turn communicates with the FN using its mobile agent (MA). As the MN transitions from one cell to the next, it is acquired by the FA of the new cell. The FA gets authorization from the MN's home node (HN) before information communication starts.

3G Management Issues

- Hierarchical LAN
- Joint management with wired network
- Mobile computing unit
  - Hardware limitations
  - Software limitations
- Mobility management
- Location tracking
- Resource management
- Wireless QoS management
- Power management
- Security management

Mobility Management

Packet Control Function
This is an entity in a radio access network that controls the transmission of packets between the BS (Base Station) and the PDSN (Packet Data Serving Node).

- Mobile IP
- Location tracking
  - Discovery of Foreign Agents by Mobile Units
  - Broadcasting/advertising to locate an MU
  - Solicitation by MU
- Handoff management
  - Packet control function (PCF) / Radio Network
  - Handoff of PCF to PCF within PDSN
  - Handoff of PCF between PDSNs

The Packet Data Serving Node, or PDSN, is a component of a CDMA2000 mobile network.[1] It acts as the connection point between the radio access and IP networks.

Mobile IP

- Mobile vs. nomadic
  - Mobile: activities not disrupted **when point of attachment is changed**
  - Nomadic: not active in motion; a.k.a. Portable computing
- Analogy with telephone: Subscriber assigned an ID in both – phone number vs. IP address
- **Mobile IP is analogous to call forwarding, except the forwarding address is mobile**

Mobile IP Functions - Roaming

- Mobile IP uses two addresses: a fixed home address and a care-of-address that changes the point of attachment
- Mobile IP functions:
  - Discovery of foreign agent (FA) and care-of-address
  - Registration of current location with FA and home agent (HA)
  - Tunneling of packets to and from the HA to FA care-of-address as mobile node roams

A mobile IP uses two addresses—a fixed home address and a care-of-address that changes with the point of attachment. There are three mobile IP functions performed by three mobile functional entities. They are mobile node, foreign node, and home node. MN is a host or router that changes point of attachment from one network or subnet to another. It has an embedded agent, MA, which does the discovery of an FA in the FN, which is the second entity. The FN is a router in the mobile network that provides services to the MN. The FA, after acquisition of the MA, registers the MN's location with the HA in the HN. The HN is a router on a mobile network that is the home network of the MN. The HA in the HN tunnels packets to and from the HA to the FA care-of-address as the MN roams.

Discovery and registration functions are presented in Figure 14.18. The MN discovers the FA and its care-of-address by the advertisement of the FA. The MN can also discover by its own solicitation. The MN registers the FA with the HA.

Discovery and Registration

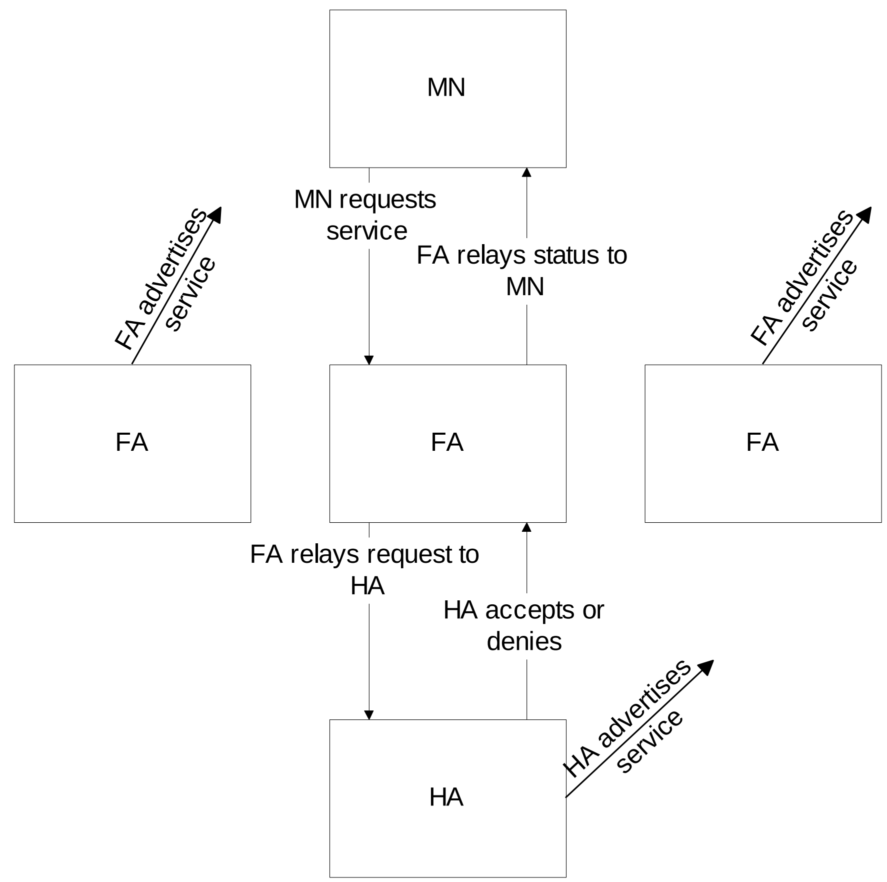


Table 14.18 Discovery and Registration in a Mobile System

Notes

- Mobile node discovers foreign agent (FA) and its care-of-address by advertisements of FA
- Mobile node can also discover by its solicitation
- Mobile node registers FA with HA

Tunneling

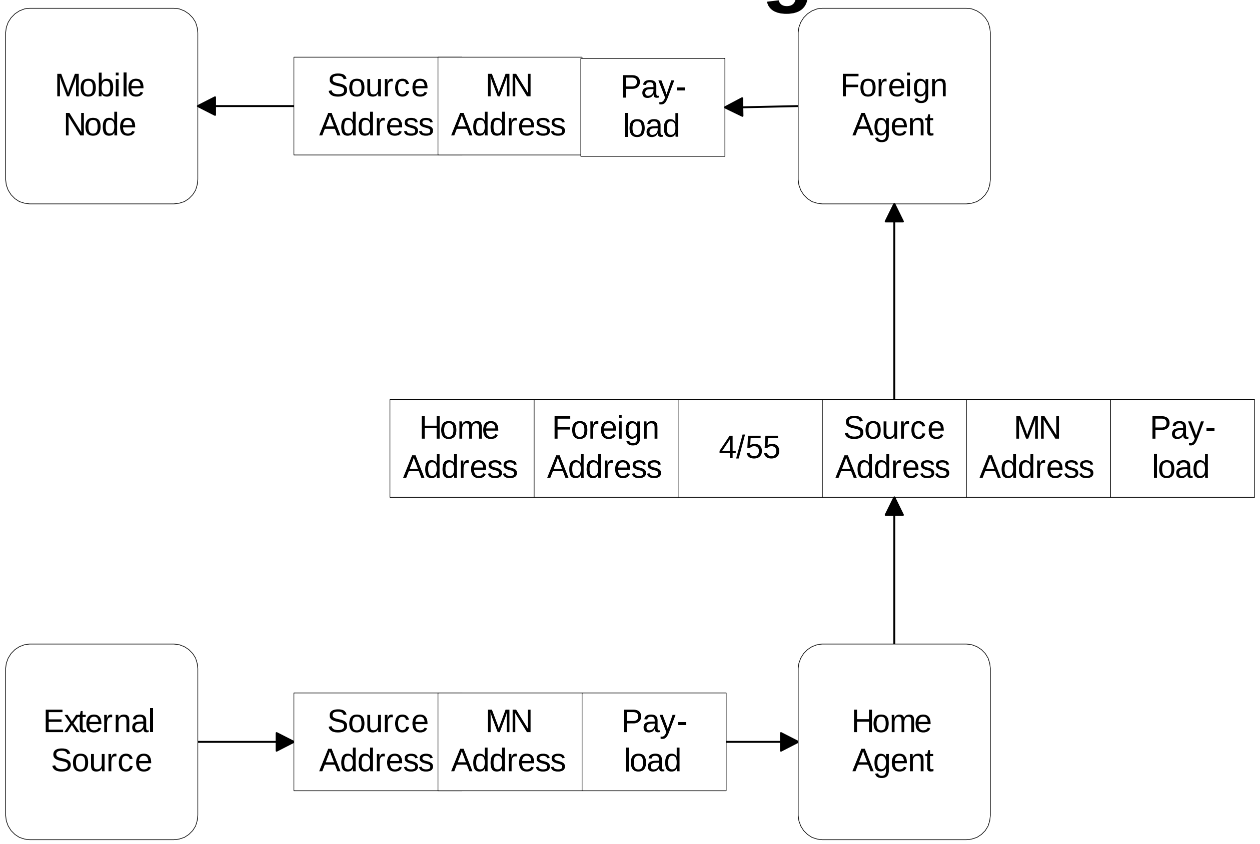


Table 14.19 Tunneling in a Mobile System

Notes

- Protocol number in the header:
  - 4 indicates to higher level that the next header is an IP header with full encapsulation
  - 55 indicates minimal encapsulation

SNMP Management of Mobile IP

- IETF Specifications using SMIv2 (RFC 1902) and MIB-II (RFC 1213)

- Functional entities in SNMP Management of Mobile IP:

  - Mobile Node: A host or router that changes point of attachment from one network or subnet to another

  - Home Agent: A router on a mobile node's home network, which tunnels packets to and from the mobile node via foreign agent

  - Foreign Agent: A router on a mobile node's visited network, which provides services to the mobile node

Notes

Mobile IP MIB Groups

Groups	Mobile Node	Foreign Agent	Home Agent
mipSystemGroup	X	X	X
mipSecAssociationGroup	X	X	X
mipSecViolationGroup	X	X	X
mnSystemGroup	X		
mnDiscoveryGroup	X		
mnRegistrationGroup	X		
maAdvertisementGroup		X	X
faSystemGroup		X	
faAdvertisementGroup		X	
faRegistrationGroup		X	
haRegistrationGroup			X
haRegNodeCountersGroup			x

Mobile IP MIB

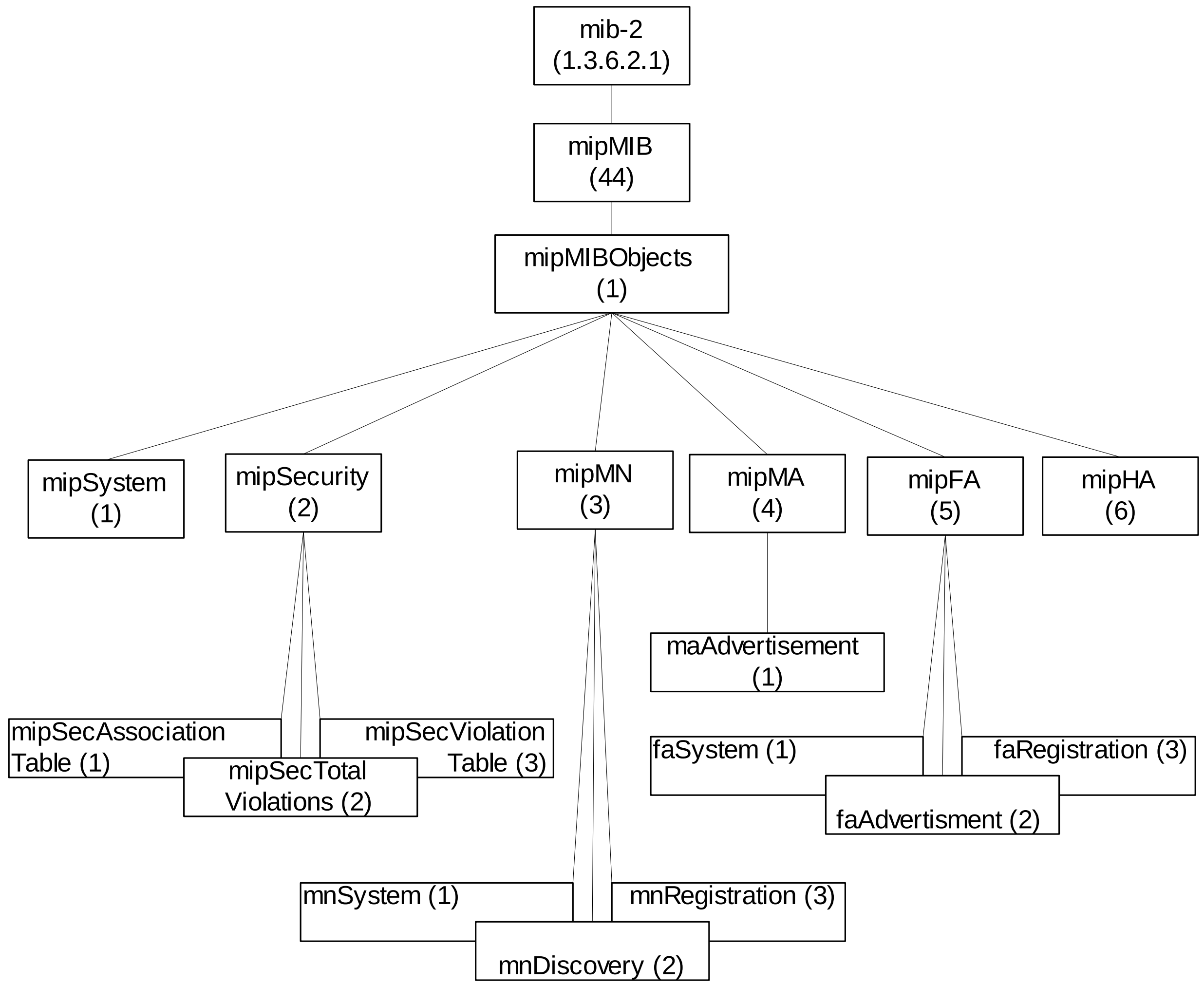


Figure 14.20 Mobile IP MIB

Notes

mipMIBObjects

Table 14.4 mipMIBObjects

Entity	OID	Description
mipMIBObjects	mipMIB 1	Objects under mipMIB
mipSystem	mipMIBObjects 1	Mobile IP system related parameters
mipSecurity	mipMIBObjects 2	Mobile IP security parameters
mipSecurity AssociationTable	mipSecurity 1	Security associations table
mipSecTotal Violations	mipSecurity 2	Total number of security violations in the entity
mipSecViolation Table	mipSecurity 3	Security violation information
mipMN	mipMIBObjects 3	Mobile node group
mnSystem	mipMN 1	Mobile node system information

Notes

mipMIBObjects

Table 14.4 mipMIBObjects (cont.)

Entity	OID	Description
mnDiscovery	mipMN 2	Mobile node discovery counter on solicitations, advertisements, and moves
mnRegistration	mipMN 3	Mobile node registration table
mipMA	mipMIBObjects 4	Mobile agent group
maAdvertisement	mipMA 1	Mobility agent advertisement configuration table present in both MN and FA
mipFA	mipMIBObjects 5	Foreign agent group
faSystem	mipFA 1	Foreign agent system information
faAdvertisement	mipFA 2	Foreign agent advertisement information plus MA advertisement group
faRegistration	mipFA 3	Foreign agent visitors list
mipHA	mipMIBObjects 6	Home agent registration group and mobility binding list

Resource Management

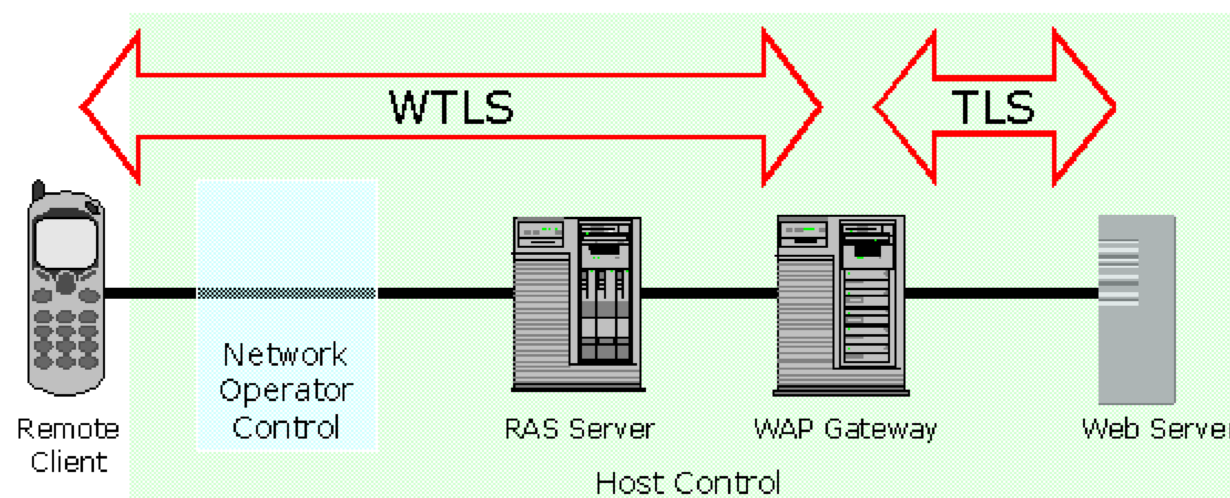
- Scheduling and call admission control
  - Reservation of guard channels for handoff - static
  - Dynamic control of call admission – complex to control multimedia service
  - Proposals for QoS-based handoffs
- Load balancing between access networks
- Power management

Security Management

Figure 14.21 shows WAP architecture [Howell]. The MN is connected to the WAP gateway through a network operator control and a remote access server. The security protocol used is wireless TLS (WTLS). The TLS protocol is used between the WAP gateway and remote server that the mobile subscriber is trying to access. Most security failures happen in the transition between the two. Robust security can be achieved by careful design and implementation of the WAP gateway using available security tools.

Notes

- WAP (Wireless Application Protocol) Security
  - WAP Wireless transport layer security (WTLS)
    - Based on transport layer security (TLS) or secured sockets shell (SSL)
    - "Walled garden" "vertical" integrated approach
- 3G network security
  - 3GPP (Third Generation Partnership Project) and 3GPP2 plan for IP to wireless device
  - Open standard SNMP based



QoS Management

Table 14.5 UMTS QoS Specifications

QoS Class	Transfer Delay	Transfer Delay Variation	Low BER	Guaranteed Bit Rate	Example
Conversation	Stringent	Stringent	No	Yes	VoIP, Video- and Audio-conferencing
Streaming	Constrained	Constrained	No	Yes	Broadcast service, news, sport
Interactive	Looser	No	Yes	No	Web browsing, interactive chat, games
Background	No	No	Yes	No	email, SMS, TFP transactions

Notes

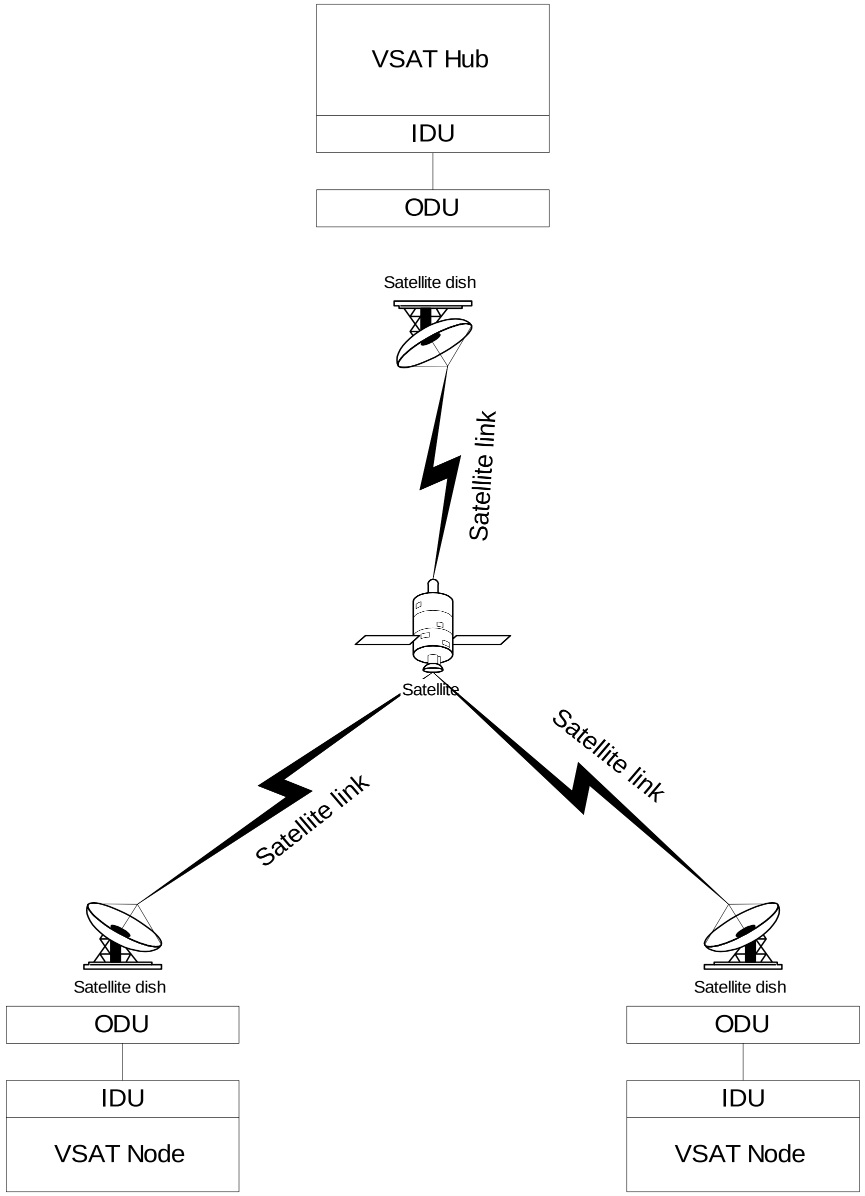
- QoS support for last leg between access point and mobile node
- Depends on mobility and resource management
- 3GPP/3GPP2 (3G Partnership Project) standards ensure interoperability
- 3GPP has defined four QoS classes (TS 23.107) shown above
- Telephony handled using SIP (session initiation protocol)
- Backbone based on DiffServ

14.4. Satellite Networks

14.4.1. VSAT Network

VSAT

Although satellite communication is currently not ideally suited for broadband communication, it is emerging as one in a limited manner. For example, VSAT (Figure 14.22) is a popular implementation of direct transmission to home (DTH) satellite access network. Some reasons for the revival of DTH are easy implementation, small and highly directional antenna, and video compression technique. It is used as a back-up link for communication by industrial organizations, as well as to set up communication to rural and inaccessible areas such as mountainous regions.



Notes

- KU Band and KA band
- 40 – 60 kbps uplink and 500 kbps downlink

http://searchmobilecomputing.techtarget.com/definition/VSAT

Figure 14.22 VSAT Broadband Links

VSAT Components

- ODU Outdoor unit
  - Power amplifier
  - Up-converter
  - Down-converter
- IDU Indoor unit
  - Modems
  - Frequency synthesizer
  - Encoder / decoder
- Proxy agent for management; Later models with SNMP agent

Notes