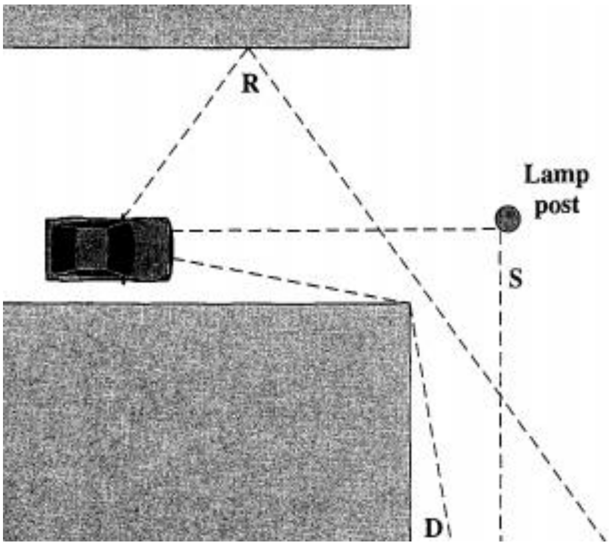
Techniques: antennas and propagation, signal encoding, spread spectrum, coding and error control.

Specifications	Wired network	Wireless network
Speed of operation	Higher	Lower, except advanced wireless technologies
System Bandwidth	High	Low
Cost	Less as cables are not expensive	More as stations, routers, AP and adapters are expensive
Installation	cumbersome and requires more time	easy and requires less time
Mobility	Limited	Not limited
Transmission medium	copper wires, optical fiber cables, Ethernet	EM waves or radio waves or infrared
Network coverage extension	requires hubs and switches	More area is covered by wireless base stations
Applications	LAN (Ethernet), MAN	WLAN, Infrared, Cellular WPAN (ZigBee, Bluetooth),
Channel Interference	Less	Higher
QoS (Quality of Service)	Better	Poor due to high value of jitter and delay in connection setup
Reliability	High	Reasonably high



Licensed band is for specific authorization, registration, needed to purchase licenses.

Factors: signal power, carrier frequency, propagation distance, interference.

outdoor : urban diffraction and scattering

indoor: reflection: multipath

free space loss: $\frac{P_t}{P_r} = \frac{(4\pi)^2(d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$

free space: $P_{r_{dBm}} = P_{t_{dBm}} + 10\lg(G_r G_t \lambda^2) - 20\lg(4\pi d)$

$$L_{dB} = 20\log(\lambda) + 20\log(d) - 10\log(A_t A_r) = -20\log(f) + 20\log(d) - 10\log(A_t A_r) + 169.54\text{ dB}$$

two-ray: $P_{r_{dBm}} = P_{t_{dBm}} + 10\lg(G h_t^2 h_r^2) - 40\lg(d)$

Path loss : $PL = P_{t_{dBm}} - P_{r_{dBm}} = 40\log_{10}(d) - 10\log_{10}(G h_t^2 h_r^2)$

Slow fading: Over longer distances, change in the average received power level about which the rapid fluctuations occur.

Fade margin = Receive power – Receive sensitivity. In dBm.(link budget)

Macrocell COST 231 WI: $L_{LOS}[\text{dB}] = 42.6 + 26\log_{10} d[\text{km}] + 20\log_{10} f[\text{MHz}]$

$L_{NLOS}[\text{dB}] = L_{FS} + L_{rts}(w_r, f, \Delta h_{Mobile}, \Phi) + L_{MSD}(\Delta h_{Base}, h_{Base}, d, f, b_S)$

$L_{rts} = -8.8 + 10\log_{10}(f[\text{MHz}]) + 20\log_{10}(\Delta h_{Mobile}[\text{m}]) - 10\log_{10}(w[\text{m}]) + L_{ori}$

$L_{MSD} = L_{bsh} + k_a + k_d\log_{10}(d[\text{km}]) + k_f\log_{10}(f[\text{MHz}]) - 9\log_{10}(b)$

$$L_{ORI} = \begin{cases} -10 + 0.35\Phi & 0 \le \Phi < 35^\circ \\ 2.5 + 0.075(\Phi - 35) & 35^\circ \le \Phi < 55^\circ \end{cases}$$

$$L_{bsh} = \begin{cases} -18\log_{10}(1 + \Delta h_{Base}) & h_{Base} > h_{Roof} \\ 0 & h_{Base} \le h_{Roof} \end{cases}$$

Microcell Two-ray model $\frac{1}{L} = \left(\frac{\lambda}{4\pi}\right)^2 \left|\frac{e^{-jkr_1}}{r_1} + R\frac{e^{-jkr_2}}{r_2}\right|^2$ R = Fresnel reflection coefficient

Multipath: 1) different phases add destructively, the signal level relative to noise declines, making signal detection at the receiver more difficult. **2)** ISI

Doppler effect: $f_d = 2 \cdot cos\theta \cdot V_{MS} \cdot \frac{f_c}{c}$

Rayleigh fading: none distinct dominant path. ($\alpha = 0$)

Rician fading: with a dominant path.

$$f_{ric}(r) = \frac{r}{\sigma^2}exp\left(\frac{-(r^2+\alpha^2)}{2\sigma^2}\right)I_0\left(\frac{\alpha r}{\sigma^2}\right), r \ge 0, \alpha \ge 0$$

Level crossing rate $\text{LCR} = \sqrt{2\pi} f_d \rho e^{-\rho^2}$ f_d Doppler shift. $\rho = R_{thresh} / R_{rms}$ **average fade duratio** $\text{AFD} = (e^{\rho^2} - 1)/(\rho f_d \sqrt{2\pi})$

$\frac{S}{I} = \frac{r^{-\alpha}}{\sum_{i=1}^{N_i} D_i^{-\alpha}}$ $\frac{D}{R} = \sqrt{3N}$ $C = KM$

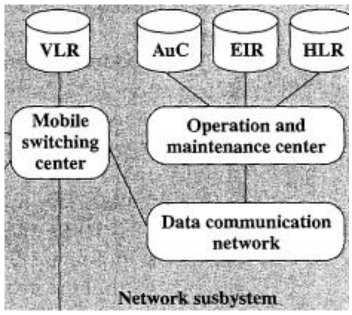
BS: fixed-location transceiver which provides network coverage. **Uplink:** from a phone to the RBS. **Downlink:** the other way. **Cells:** an area of land. **Location area:** limited number of cells.

Mobile switching centers: MSC, the primary service delivery node for GSM/CDMA.

Visitor Location Register (VLR) is a database of the subscribers who have roamed into the jurisdiction of the MSC (Mobile Switching Center) which it serves.

Home location register (HLR) is a central database that contains details of each mobile phone subscriber that is authorized to use the GSM core network.

Handoff: Handoff is the procedure for changing the assignment of a mobile unit from one BS to another as the mobile unit moves from one cell to another.



Location management: deals with location registration and tracking of mobile terminals.

2G VS 3G: cost: 3G>2G; **data transmission:** 3G>>2G; **function:** 2G info via voice signals, 3G data via video conferencing, MMS; **feature:** 3G has mobile TV, video transfers, GPS systems, etc; **frequencies:** 2G broad range for both upper and lower bands; **implication:** 3G high security; **making calls:** no noticeable difference except 3G has video call; **speed:** 2G 236k, 3G 21M/5.7M.

TDMA: Transmission is in the form of a repetitive sequence of frames, each of which is divided into a number of time slots. Each slot position across the sequence of frames forms a separate logical channel.

CDMA: CDMA is a multiplexing technique used with spread spectrum and a special coding scheme(each transmitter assigned a code), where several transmitters can send information simultaneously over a single communication channel.

GGSN is responsible for the internetworking between the GPRS network and external packet switched networks.

SGSN is responsible for the delivery of data packets from and to the mobile stations within its geographical service area.

MSC is responsible for routing voice calls, SMS and other services (such as conference calls, FAX and circuit switched data).

GMSC is a special kind of MSC that is used to route calls outside the mobile network.

Standards: IMT 2000, WCDMA, Wimax, TD-SCDMA, CDMA2000 **3G:** 2Mbps, bandwidth 2GHz, carrier frequency 5MHz

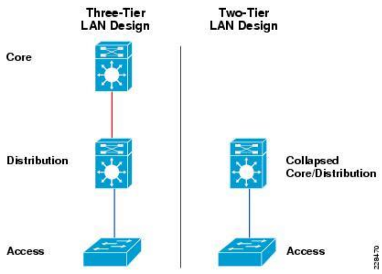
Key Features: high data rate transmission; high service flexibility; both FDD and TDD; support future enhancing techs…

all-IP wireless networks: ISB, is based on a combination of DiffServ andIntServ models appropriate for low-bandwidth 3G cellular networks with significant resource management capabilities. **DSB** purely based on the DiffServ model targetedfor high-bandwidth wireless LANs with little resource management capabilities. **AIP,** combines ISB and DSB architectures to facilitate the integration of wireless LAN and3G cellular networks towards a uniform architecture for all-IP wireless networks.

Phase I (Path extension): It simply extends the connection from the old AP (the anchor switch) to the new AP (the target switch) to maintain the call connectivity. **Phase II (Path optimization):** It may be invoked to setup an optimal path in certainsituations. It involves determining the location of the crossover switch, replacing the old branch connection with the new branch, and updating the connection server about the status of the new existing route.

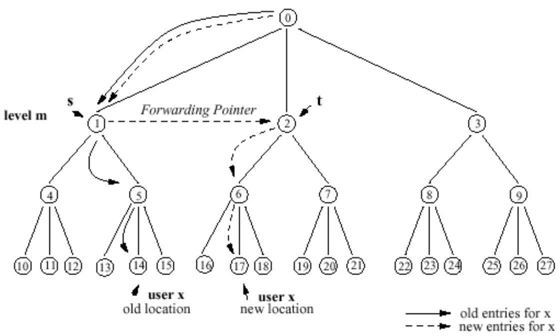
MCHO The MS continuously monitors the signals of the surrounding BSs and initiates the handoff process when some handoff criteria are met. **NCHO** The surrounding BSs measure the signal from the MS, and the network initiates the handoff process when some handoff criteria are met. **MAHO** The network asks the MS to measure the signal from the surrounding BSs. The network makes the handoff decision based on reports from the MS.

hard hand-off, a mobile station communicates with only one base station. **soft hand-off**, a mobile station communicates with two base stations at the same time. the soft-handoff link-transfer procedure may not be faster than that for hard handoff. However, soft handoff is not time critical as compared with hard handoff.



straight-line model: Once a movement direction is chosen, the node moves in a straight line until the direction changes. **Fluid flow:** If the Gauss-Markov Model has strong memory, the velocity of mobile node at time slot t is same as its previous velocity. In the nomenclature of vehicular traffic theory, this model is called as fluid flow model.

time-based: not dependant on Location Areas; lower paging cost; only internal clock easy to manage; value of T could be set different for each user; **pros:** useless cost the user is stationary; location uncertainty cannot be bounded. **movement-based: pros:** when user travels around the boundary, unnecessary updates occur; **distance-based:** paging cost is low when move less and move within specific distance; **pros:** unnecessary location updates if the user crosses the boundary very frequently.

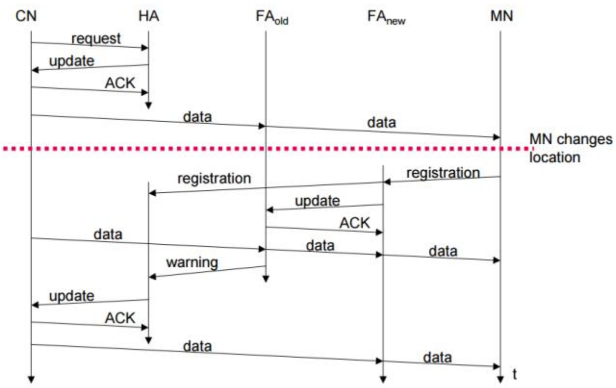


When x moves from i to j, instead of updating all databases on the path from j through LCA(j, i) to i, only the databases up to a level m are updated. A **forwarding pointer** is set from node s to node t, where s is the ancestor of i at level m, and t is the ancestor of j at level m.

Permanent: Host your own File or FTP server; Host your own website or domain name server; Use other servers or equipment; faster.

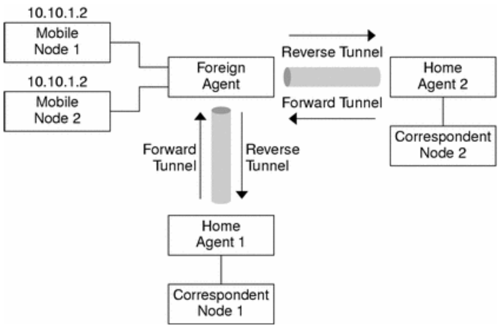
Mobile Node (MN) System (node) that can change the point of connection to the network without changing its IP address; Typically a mobile end-system. **Home Agent (HA)** System in the home network of the MN, typically a router; Registers the location of the MN, tunnels IP datagrams to the COA. **Foreign Agent**

(FA) System in the current foreign network of the MN, typically a router; Forwards the tunneled datagrams to the MN, typically also the default router for the MN, provides the COA. **Care-of Address (COA)** Address of the current tunnel end-point for the MN; Actual location of the MN from an IP point of view.



In reverse tunneling, MN delivers the packets to FA using source address as its home address [3]. FA encapsulates the datagrams and sends them to HA using reverse tunneling. HA delivers the packets to CN after decapsulating them.

Registration Phase: In this phase MN registers it's current CoA with HA by sending the registration request message to HA, either via FA or directly using mobile node's CCoA. In response to this registration request message, HA sends a registration reply message to MN again either via FA or directly to CCoA. This registration must be authenticated for the successful delivery of packets to and from the MN as it moves around. The MN must register its current location before registration time expires. After the authenticated registration of MN, HA and FA update their binding caches and visitor list entry respectively.



distributed coordination function (DCF): A class of coordination function where the same coordination function logic is active in every station (STA) in the basic service set (BSS) whenever the network is in operation.

point coordination function (PCF): A class of possible coordination functions in which the coordination function logic is active in only one station (STA) in a basic service set (BSS) at any given time that the network is in operation.

IFS: The time interval between frames is called the IFS. A STA shall determine that the medium is idle through the use of the CS function for the interval specified. Ten different IFSs are defined to provide priority levels for access to the wireless medium. Figure 10-4 shows some of these relationships. All timings are referenced from occurrence of the PHY interface primitives PHY-TXEND.confirm, PHY-TXSTART.confirm, PHYRXSTART.indication, and PHY-RXEND.indication.

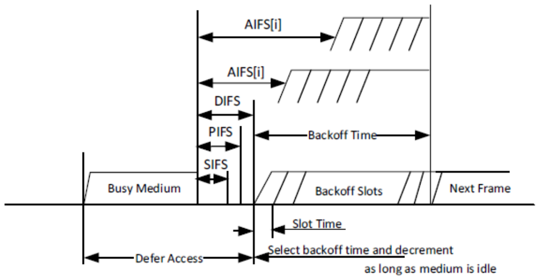
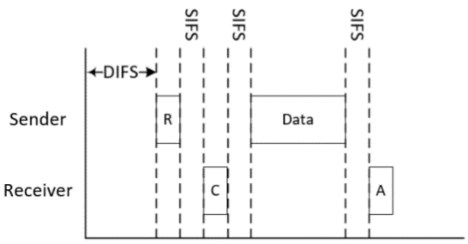


Figure 10-4—Some IFS relationships



SIFS The SIFS is the time from the end of the last symbol, or signal extension if present, of the previous frame to the beginning of the first symbol of the preamble of the subsequent frame as seen on the WM. **PIFS** The PIFS is used to gain priority access to the medium. **DIFS** The DIFS shall be used by STAs operating under the DCF to transmit Data frames (MPDUs) and Management frames (MMPDUs).

IEEE 802.11e-2005 or 802.11e is an approved amendment to the IEEE 802.11 standard that defines a set of quality of service (QoS) enhancements for wireless LAN applications through modifications to the Media Access Control (MAC) layer.

enhanced distributed channel access (EDCA): The prioritized carrier sense multiple access with collision avoidance (CSMA/CA) access mechanism used by quality-of-service (QoS) stations (STAs) in a QoS basic service set (BSS) and STAs operating outside the context of a BSS. This access mechanism is also used by the QoS access point (AP) and operates concurrently with hybrid coordination function (HCF) controlled channel access (HCCA).

hybrid coordination function (HCF): A coordination function that combines and enhances aspects of the contention based and contention free access methods to provide quality-of-service (QoS) stations (STAs) with prioritized and parameterized QoS access to the wireless medium (WM), while continuing to support non-QoS STAs for best-effort transfer.

infrastructure mode: Devices on the network all communicate through a single access point, which is generally the wireless router. For example, let’s say you have two laptops sitting next to each other, each connected to the same wireless network. Even when sitting right next to each other, they’re not communicating directly. Instead, they’re communicating indirectly through the wireless access point. They send packets to the access point — probably a wireless router — and it sends the packets back to the other laptop. Infrastructure mode requires a central access point that all devices connect to.

Ad-hoc mode: is also known as “peer-to-peer” mode. Ad-hoc networks don’t require a centralized access point. Instead, devices on the wireless network connect directly to each other. If you set up the two laptops in ad-hoc wireless mode, they’d connect directly to each other without the need for a centralized access point. An Ad-hoc network allows each device to communicate directly with each other. There is no central Access Point controlling device communication.

AP: STA **MAC :** data link layer; **PHY :** physical layer

The Logical Link Control (LLC) (IEEE-802.2) sublayer acts as an interface between the media access control (MAC) sublayer and the network layer. The LLC sublayer is primarily concerned with multiplexing protocols transmitted over the MAC layer (when transmitting) and decoding them (when receiving). In 802.11, flow control and error management is part of the CSMA/CA MAC protocol, and not part of the LLC layer.

802.11 Physical (PHY) layer is divided into two sublayers

1. PLCP (Physical Layer Convergence Procedure) sublayer. The PLCP prepare the frame for transmission by taking the frame from the MAC sublayer & creating PLCP Protocol Data Unit (PPDU).

2. PMD (Physical Medium Dependent) sublayer. PMD sublayer then modulates and transmits the data as bits.

However, in IEEE 802.11-2016 the PHY sublayer is never divided into two parts.

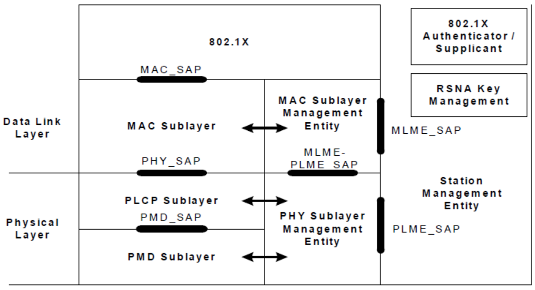
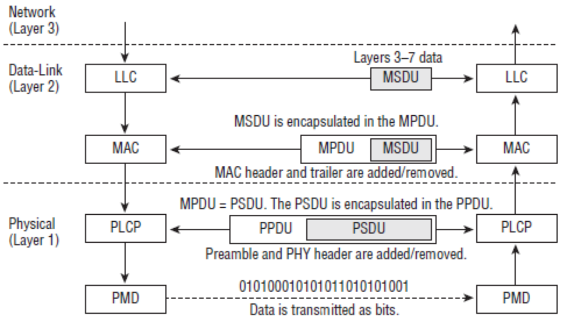


Figure 4-14—Portion of the ISO/IEC basic reference model covered in this standard

The IR PHY uses near-visible light in the 850 nm to 950 nm range for signaling. Radio wireless networks use radio waves on a particular frequency for data transmission from device to device. **IR:** pro: cheap; con: range is limited, in an environment that has few or no reflecting surfaces, and where there is no line-of-sight, an IR PHY system may suffer reduced range. **RF:** pro: range; Con: expensive **802.11 a/b/g/n/ac/ae/aa/ad/af/ai**



Priority: based on the priority part of the MSDU

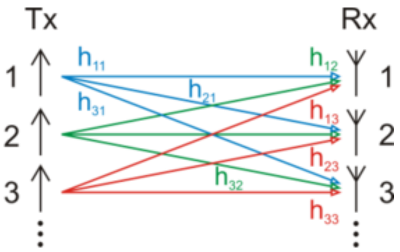
three access methods: for MAC address, it has 1~6 addresses, 3 access is mainly for data. See my address PPT.

synchronization: many kinds, for OFDM symbol syn, carrier syn,

Software-defined networking (SDN) is an approach to computer networking that allows network administrators to programmatically initialize, control, change, and manage network behavior dynamically via open interfaces[1] and abstraction of lower-level functionality.

characterizations of WiMAX OFDM-based Physical Layer; Very High Peak Data Rates; Scalable Bandwidth and Data Rate Support; Adaptive Modulation and Coding (AMC); Link-layer Retransmissions; Support for TDD and FDD; WiMAX Uses OFDM; Flexible and Dynamic per User Resource Allocation; Support for Advanced Antenna Techniques; Quality-of-service Support; Robust Security; Support for Mobility; IP-based Architecture.

PHY: 10–66 GHz **Frames duration:** 0.5, 1, or 2ms; **The frame :** divided in PHY slots (PS) for the purpose of bandwidth allocation and identification of PHY transitions; One PHY slot is defined to be 4 QAM symbols; **TDD-PHY:** UL sub-frame follows the DL sub-frame on the same carrier frequency. **FDD-PHY:** UL and DL sub-frames are coincident in time but are carried on separate frequencies.



MIMO diff: SISO system only one antenna MIMO case multiple antennas are used. MIMO system achieves better Bit Error rate at the same SNR; MIMO system delivers higher data rate; MIMO with SM and beamforming can be employed to obtain enhancement to both the coverage and data rate requirement in a wireless system; SISO is used in radio, satellite, GSM and CDMA systems while MIMO is used in next generation wireless technologies.

Space diversity is achieved by observing the data from different paths in the space. **Space multiplexing** is used for high throughput.

Bitcoin: CryptoCurrency Security Standard covers a list of 10 security aspects of an information system that stores, transacts with, accepts.