Evolution of Mobile Radio Communication

- Wireless Communication is enjoying its fastest growth period in history due to enabling technologies which permit wide spread deployment.
- Wireless Communication was made available to the entire population when Bell laboratories conceived the Cellular concept in the 1960s and 1970s.
- With the development of highly reliable, miniature, solid state radio frequency hardware in the 1970s, the wireless communications era was born.
- Figure given illustrates how mobile telephony has penetrated our daily lives compared with other popular inventions of the 20th century.
- With the boom in CB radio and cordless appliances , number of users of mobile and portable radio in 1995 was about 100 million or 37% of the U.S. population.
- The number of cellular telephone users grew from 25000 in 1984 to about 16 million in 1994 and since then wireless services have experienced customer growth rates well in excess of 50% per year.

Paging Systems

- Paging systems are communication systems that send brief messages to a subscriber. Depending on the type of service the message may be a numeric, alphanumeric or voice message.
- Paging systems are used typically to notify a subscriber the need to call a particular telephone number or travel to known location to receive further instructions.
- In modern paging systems, news headlines, stock quotations and faxes maybe sent.
- A message is sent to a paging subscriber via the paging system access number with telephone keypad or modem. The issued message is called a page. The paging system then transmits the page throughout the service area using base stations which broadcast the page on a radio carrier.

- **Paging systems vary widely in their complexity and coverage area.**
- **Simple paging systems cover a limited range of 2 km to 5 km. They are confined to within individual buildings.**
- **Wide area paging system can provide worldwide coverage. They consist of a network of telephone lines, many base station transmitters and large radio towers that simultaneously broadcast a page from each base station which is called simulcasting. Simulcast transmitters maybe located within the same service area or in different countries or cities.**
- **Paging systems require a large transmitter power and low data rates for maximum coverage from each base station.**
- **The diagram of a wide area paging system is as shown.**

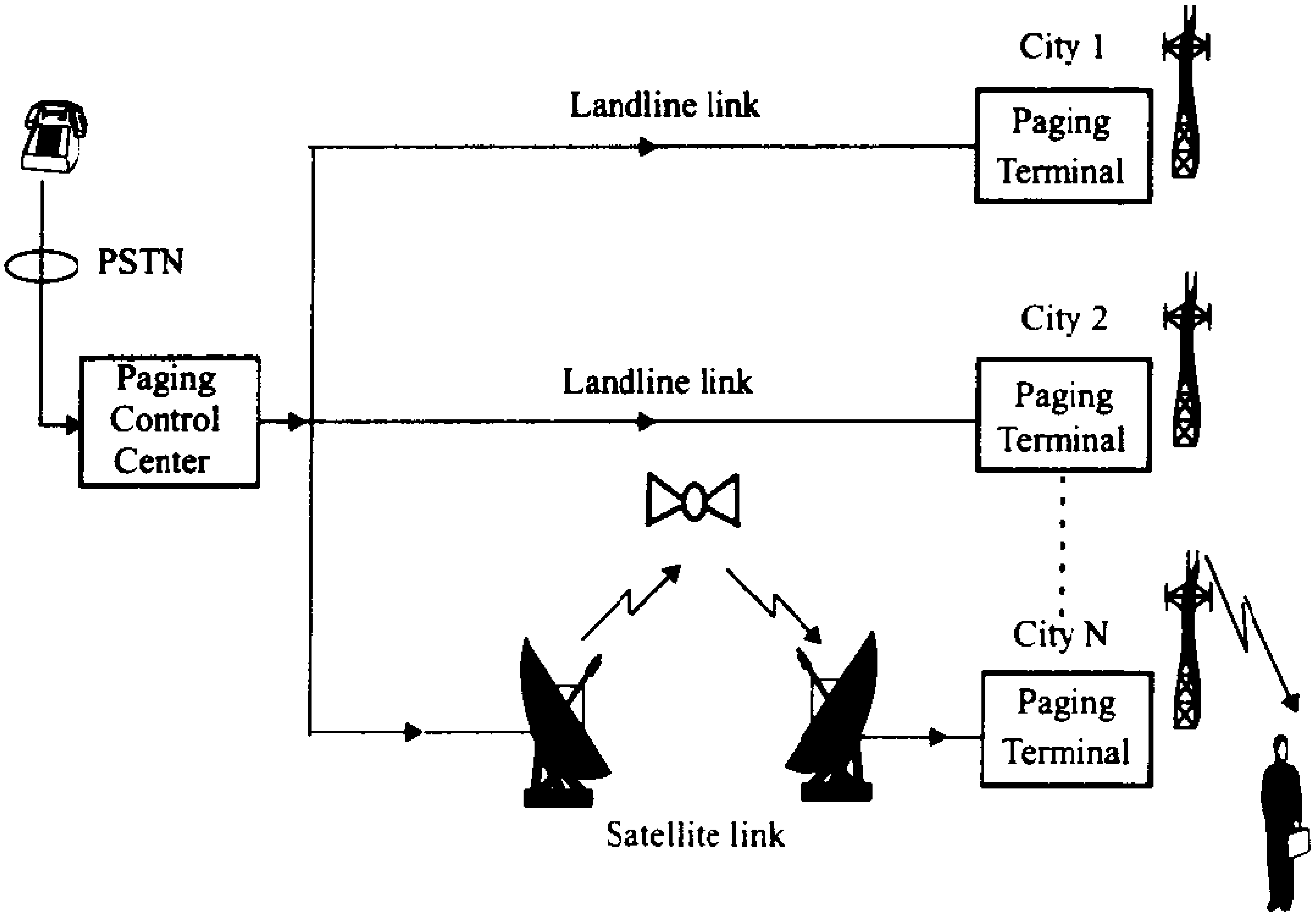


Figure 1.3
Diagram of a wide area paging system. The paging control center dispatches pages received from the PSTN throughout several cities at the same time.

Cordless Telephone Systems

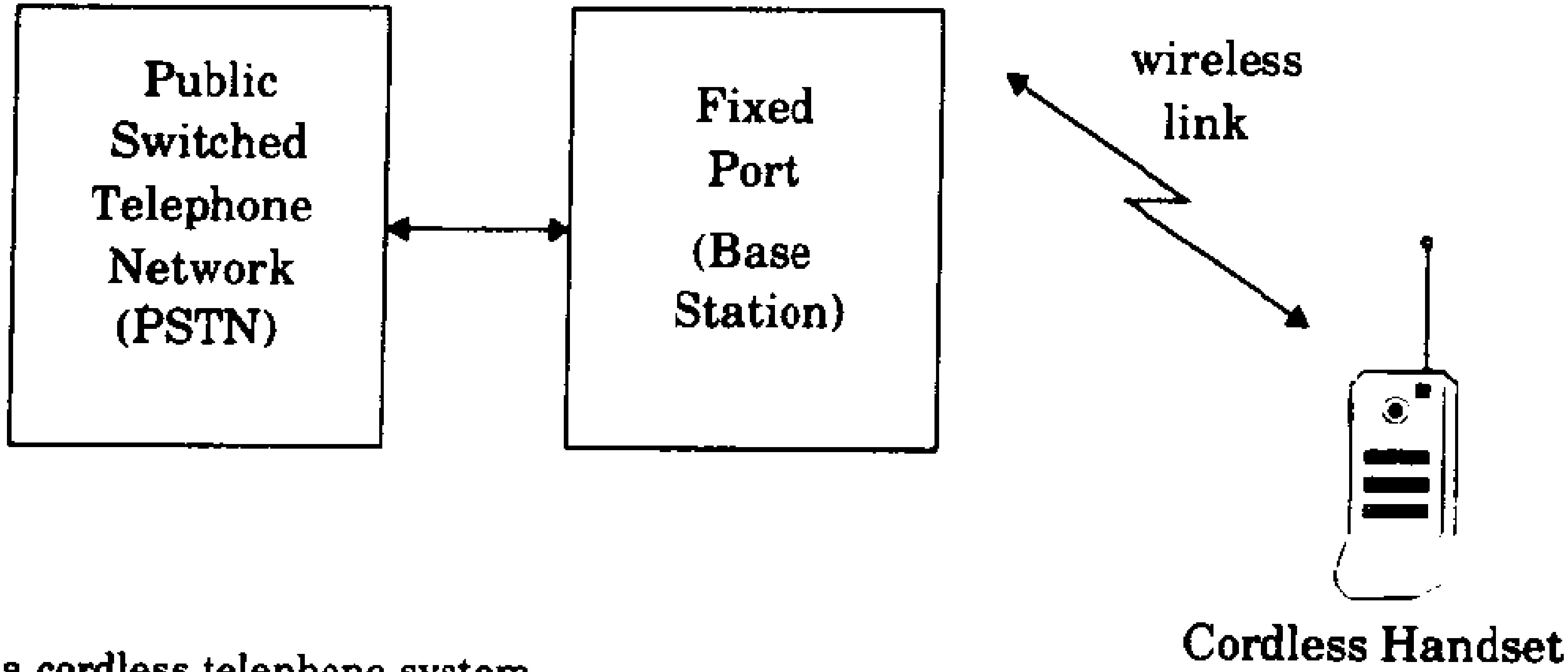


Figure 1.4
Diagram of a cordless telephone system.

- Cordless telephone systems are full duplex communication systems that use radio to connect a portable handset to a dedicated base station, which is then connected to a dedicated telephone line with a specific telephone number on the public switched telephone network.
- First generation cordless telephone systems in the 1980s had the portable unit communicating only to the dedicated base unit and only over distances of a few tens of meters. Early cordless telephones operated solely as extension telephones to a transceiver connected to a subscriber line on the PSTN and were primarily for in-home use.

Second generation cordless telephones allow subscribers to use their handsets at outdoor locations within urban centers.

- Modern cordless telephones are sometimes combined with paging receivers so that a subscriber may first be paged and then respond to the page using the cordless telephone.
- Cordless telephone systems provide the user with limited range and mobility as it is usually not possible to maintain a call if the user travels outside the range of the base station.
- Typical second generation base stations provide a coverage of up to a few hundreds of meters.

Comparison of common mobile radio systems

Table 1.5 Comparison of Mobile Communication Systems — Mobile Station

Service	Coverage Range	Required Infra-structure	Complexity	Hardware Cost	Carrier Frequency	Functionality
TV Remote Control	Low	Low	Low	Low	Infra-red	Transmitter
Garage Door Opener	Low	Low	Low	Low	< 100 MHz	Transmitter
Paging System	High	High	Low	Low	< 1 GHz	Receiver
Cordless Phone	Low	Low	Moderate	Low	< 100 MHz	Transceiver
Cellular Phone	High	High	High	Moderate	< 1 GHz	Transceiver

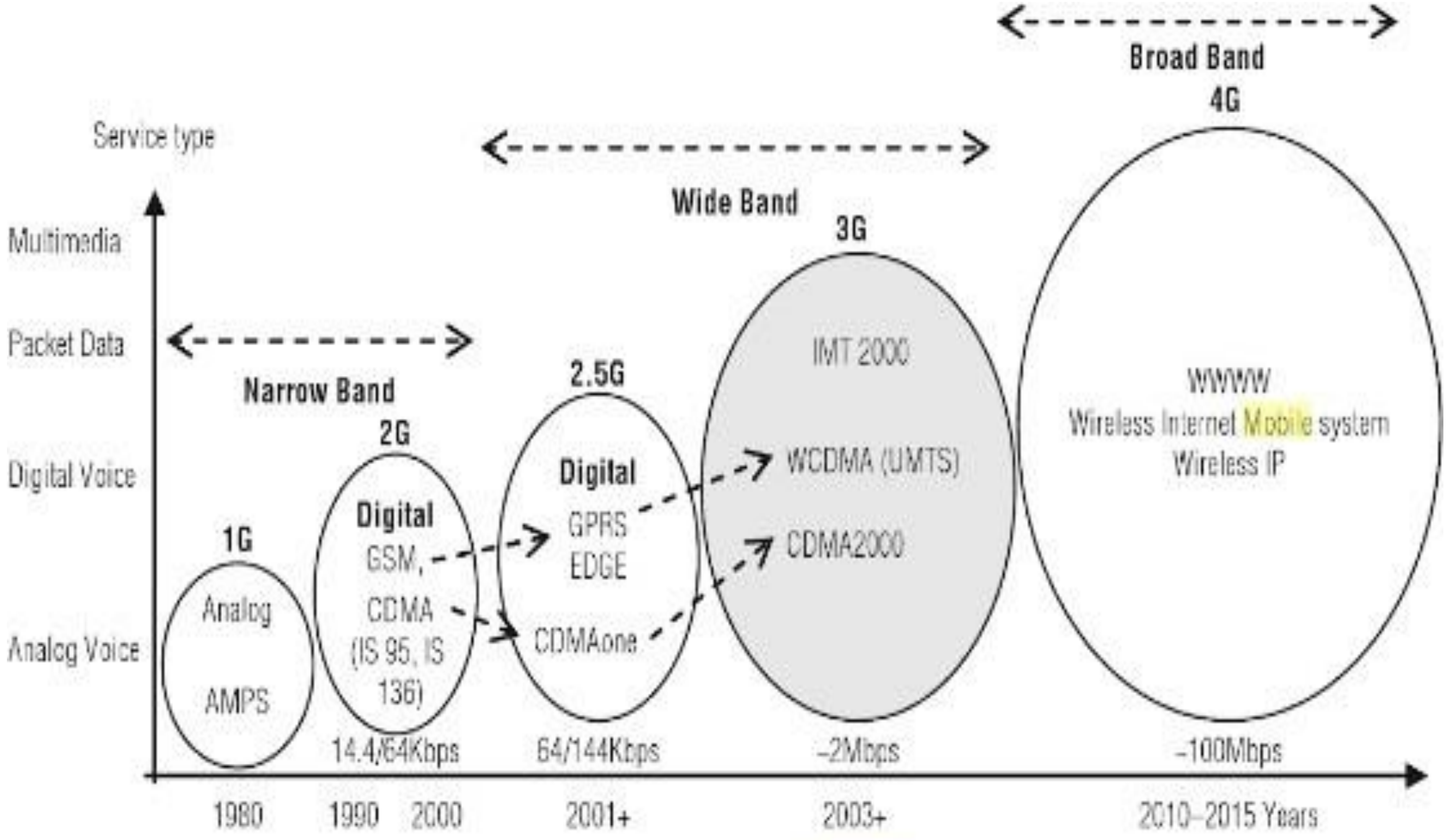
Comparison of common mobile radio systems

Table 1.6 Comparison of Mobile Communication Systems — Base Station

Service	Coverage Range	Required Infra-structure	Complexity	Hardware Cost	Carrier Frequency	Functionality
TV Remote Control	Low	Low	Low	Low	Infra-red	Receiver
Garage Door Opener	Low	Low	Low	Low	< 100 MHz	Receiver
Paging System	High	High	High	High	< 1 GHz	Transmitter
Cordless Phone	Low	Low	Low	Moderate	< 100 MHz	Transceiver
Cellular Phone	High	High	High	High	< 1 GHz	Transceiver

Introduction to cellular telephone systems

- Cellular telephone began as a relatively simple concept. However, the increased demand for cellular services has caused cellular telephone systems to evolve into complicated networks and internetworks comprised of several types of cellular communications systems.
- Cellular telephone began as a relatively simple two-way analog communications system using frequency modulation (FM) for voice and frequency-shift keying (FSK) for transporting control and signaling information.
- The most recent cellular telephone systems use higher-level digital modulation schemes for conveying both voice and control information. In addition, the Federal Communications Commission has recently assigned new frequency bands for cellular telephone.

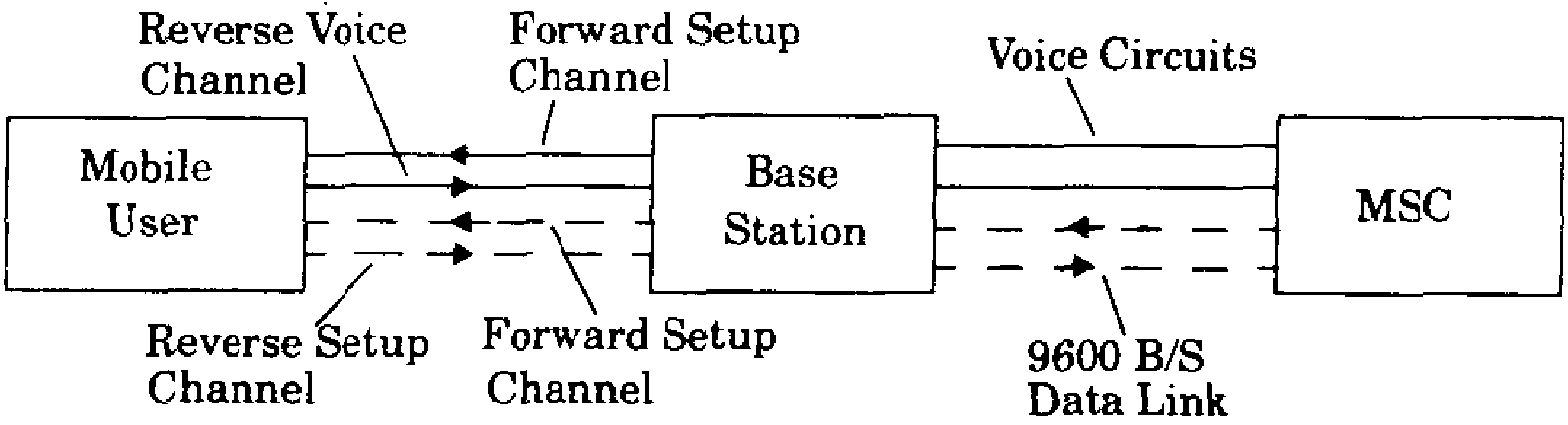


Evolution of cellular systems

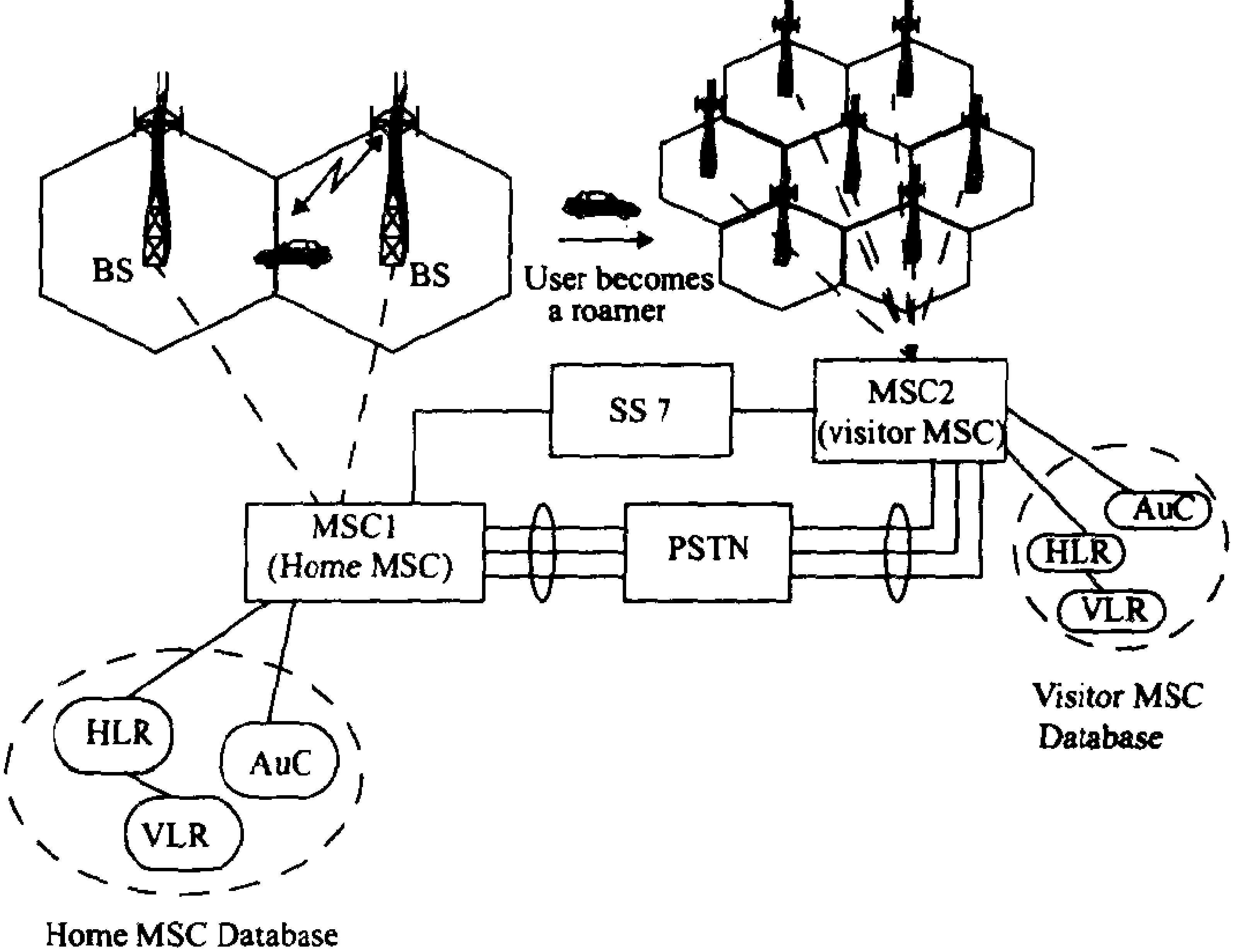
First-generation analog cellular telephone

- First generation cellular and cordless telephone networks are based on analog circuit switching technology. The first 1G mobile phone was introduced in the USA in 1980. FDMA was the multiple access technique used and worked mainly in the 800-900 MHz frequency bands. The 1G mobile phone had only voice facility.
- Examples of 1G systems are AMPS (Advanced mobile phone service) and TACS (total access communication systems)
- The limitations of 1G are:
- Supports Speech only
- Low traffic capacity
- Unreliable handover
- Long call setup time
- Frequent call drops
- Inefficient bandwidth usage
- Poor battery life
- Poor voice quality
- Large size of handset
- Allowed users to make voice calls within a country only

- A typical example of a cellular telephone system is the Advance Mobile Phone Services (AMPS) system used in the United States. In 1971, Bell Telephone Laboratories in Murry Hill, New Jersey, proposed the cellular telephone concept as the Advanced Mobile Telephone System (AMPS). AMPS is a standard cellular telephone service (CTS) initially placed into operation on October 13, 1983, by Illinois Bell that incorporated several large cell areas to cover approximately 2100 square miles in the Chicago area.
- Basically all first generation systems use the transport architecture shown in the figure



Block diagram of a first-generation analog cellular telephone network



HLR: Home Location Register
VLR: Visitor Location Register
AuC: Authentication Center

- **The block diagram of a first generation cellular telephone network is shown in the figure .**
- **The system control for each market resides in the MSC which maintains all mobile related information and controls each mobile handoff. The MSC also performs the functions of network management, call handling and processing, billing and fraud detection within the market.**
- **The MSC is interconnected with the PSTN via the landline trunked lines and a tandem switch. MSCs are connected with other MSCs via dedicated signaling channels for exchange of location, validation and call signaling information.**
- **First generation wireless systems provide analog speech and inefficient low-rate data transmission between the base station and the mobile user. The speech signals are usually digitized using a standard TDM format for transmission between the base station and the MSC and are always digitized for distribution from the MSC to the PSTN.**

Second-generation wireless telephone networks

- First-generation cellular telephone systems were designed primarily for a limited customer base, such as business customers and a limited number of affluent residential customers. The problems inherent with these cellular telephones were poor battery performance and channel unavailability. Improved batteries were also needed to reduce the size and cost of mobile units, especially those that were designed to be handheld. Weak signal strengths resulted in poor performance and a high rate of falsely initiated handoffs (false handoffs).
- It was determined that improved battery performance and higher signal quality were possible only by employing digital technologies.
- In the United States, the shortcomings of the first-generation cellular systems led to the development of several second-generation cellular telephone systems, such as narrowband AMPS (N-AMPS) and systems employing the IS-54, IS-136, and IS-95 standards.
- A second-generation standard, known as Global System for Mobile Communications (GSM), emerged in Europe. The U.S Standards of TDMA and CDMA also belong to this generation.
- Other second generation wireless standard include the British Cordless telephone standard CT2, Personal access Communication System (PACS) and the European standard for cordless and office telephony Digital European Cordless telephone(DECT).
- 2 G technology supports data, speech, fax, sms and WAP services.

- **The architecture employed in second generation networks have reduced the computational burden on the MSC.**
- **GSM for example uses a base station controller (BSC) which allowed the data interface between the BSC and MSC to be standardized. This allows carriers to use different manufacturers for MSC and BSC components.**
- **All Second generation systems use digital voice coding and digital modulation. The systems employ dedicated control channels within the air interface for simultaneously exchanging voice and control information between the subscriber, the base station and the MSC while the call is in progress.**
- **Second generation networks also provide dedicated voice and signaling trunks between MSCs and between each MSC and the PSTN.**
- **The first generation systems were designed primarily for voice whereas the second generation systems are specifically designed to provide paging, Fax and high data rate internet access.**
- **The network controlling structure is more distributed in second generation networks since mobile stations assume greater control functions.**
- **The handoff process is more mobile controlled and is known as Mobile assisted handoff (MAHO). The mobile units perform additional functions of received power reporting, adjacent base station scanning, data encoding and encryption.**

- DECT (Digital European Cordless telephone) is an example of a second generation cordless standard. It allows each cordless phone to communicate with any number of base stations. The base station with the greatest signal level is selected. The base stations have greater control in terms of switching, signaling and controlling handoffs.
- In general, second generation systems have been designed to reduce the computational and switching burden at the base station or MSC. They also provide more flexibility in the channel allocation scheme so that systems may be deployed rapidly and in a less coordinated manner.
- The limitations of 2G are
- Low data rates ranging from 9.6 kbps to 28.8 kbps
- Circuit switched network
- End systems are dedicated for the entire call duration
- Inefficient usage of bandwidth and resources

Interim 2.5 G -generation wireless telephone networks

- The need for increased throughput data rates in data transfer such as web browsing and email led to the evolution of 2.5 G which is between 2g and 3G.
- The mobile technology using GPRS (General Packet Radio Service) has been termed as 2.5 G.
- The 2.5 G was started in 1998 with added GPRS and enhanced data rates for GSM evolution (EDGE). In addition to the Hypertext transfer protocol (HTTP) it supports the Wireless Access Protocol (WAP) through which web pages can be viewd on the small screen of a mobile phone or a handheld device which led to the development of mobile commerce (m-commerce).
- 2.5 G is packet switched and can use some of the existing infrastructures of GSM and CDMA (Code division multiple access) networks.

Third-generation wireless telephone networks

- The aim of third generation wireless networks is to provide a single set of standards that can meet a wide range of wireless applications and provide universal access throughout the world.
- In 3 G networks the distinctions between cordless telephones and cellular telephones disappear and a universal personal communicator or personal handset provides access to a variety of voice, data and video communication services.
- 3rd generation systems use the Broadband ISDN to provide access to information networks such as the internet and other private and public databases.
- 3 G networks carry all types of information like voice, data and video.
- They operate in densely populated and sparsely populated areas.
- They serve both stationary users and vehicular users travelling at high speeds.
- Packet radio communication is used in the 3 G networks
- Personal communication System (PCS) ,International Mobile Telecommunication (IMT-2000) and Universal Mobile telecommunication System(UMTS) are examples of 3G wireless networks. UMTS is also known as W-CDMA(Wideband CDMA)

- 3G technology has added multimedia facilities to 2.5 G phones.
- 3 G operates in the 1710-2170 MHz band
- In short 3G is the next generation of wireless network technology that provides high speed bandwidth (high data transfer rates) to handheld devices. The high data transfer rates will allow 3G networks to offer multimedia services combining voice and data.
- Main characteristics of 3 G networks include
- Always-on connectivity. 3G networks use IP connectivity, which is packet based.
- Multi-media services with streaming audio and video.
- Email with full-fledged attachments such as PowerPoint files.
- Instant messaging with video/audio clips.
- Fast downloads of large files such as faxes and PowerPoint files.
- Access to corporate applications.
- Applications include Mobile TV, Video on demand, Video conferencing, Telemedicine, Location based services.

Fourth-generation wireless telephone networks

- 4th-generation networks emerged as a data-optimized technology with the promise of speed improvements up to 10-fold over existing 3G technologies.
- It is basically the extension in the 3G technology with more bandwidth and services offers in the 3G.
- The expectation for the 4G technology is basically the high quality audio/video streaming over end to end Internet Protocol. The transmission rates of 4G will be upto 20Mbps higher than that of 3G.
- The first two commercially available technologies billed as 4G were the WiMAX standard and the LTE standard. LTE – Advanced is the newest version of LTE.
- One of the main ways in which 4G differed technologically from 3G was in its elimination of circuit switching, instead employing an all-IP network. 4G utilizes packet switching over internet, LAN or WAN networks via VoIP.
- 4G technology is meant to provide what is known as "ultra-broadband" access for mobile devices. It is set to deliver 100 Mbps to a roaming mobile device and up to 1 Gbps to a stationary device.
- 4G will bring the perfect real world wireless inter networking called WWWW: World Wide Wireless Web.

- **4 G allows for video conferencing, streaming picture perfect video for telemetric applications**
- **OFDMA multi-carrier transmission methods ,frequency-domain equalization (FDE) methods, MIMO (Multiple Input Multiple Output) and Turbo Code techniques are used in 4 G networks.**
- **Peak data rates for 4G networks must be close to 100 megabit per second for a user on a highly mobile network and 1gigabit per second for a user with local wireless access or a nomadic connection.**
- **True 4G must also be able to offer smooth handovers across differing networks without data loss and provide high quality of service for next-gen media.**
- **One of the most important aspects of 4G technology is the elimination of parallel circuit-switched and packet-switched network nodes using Internet Protocol version 6 (IPv6). The currently used standard, IPv4, has a finite limitation on the number of IP addresses that can be assigned to devices,**

Comparison of the different generations

- A short history of the evolution from 1G to 4G is shown below.
- 4G is not a single defined standard but rather a collection of technologies and protocols aimed at creating fully packet-switched networks optimized for data.

History of 1G, 2G, 3G, and 4G technologies

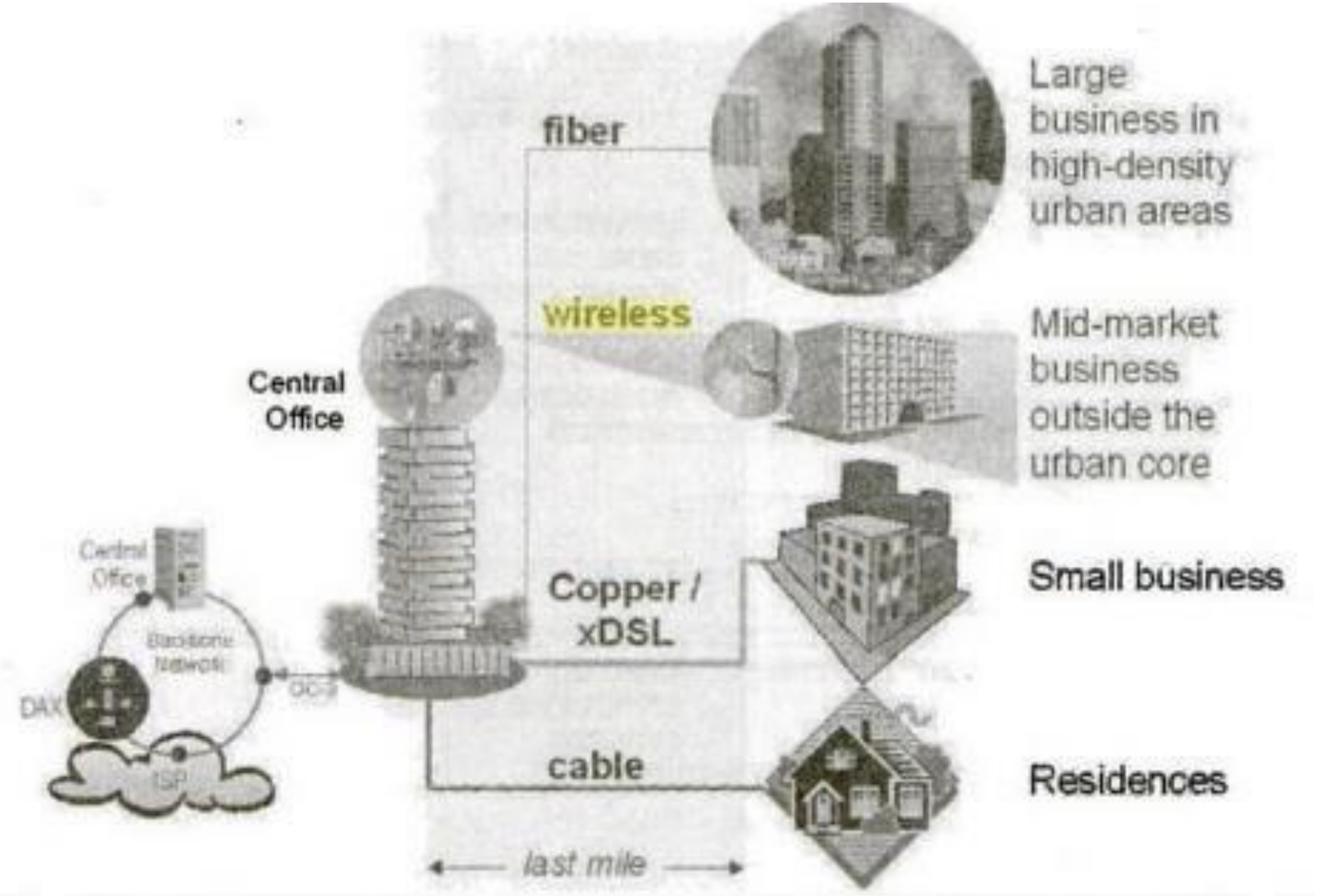
Technology	Various generations				
	1G	2G	2.5G	3G	4G
Design began	1970	1980	1985	1990	2000
Implementation	1984	1991	1999	2002	2012–2015
Service	Analogue voice	Digital voice	High-capacity packets, MMS	High-capacity broadband data	Higher capacity, completely IP, Multimedia
Multiple access	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	OFDMA
Standards	AMPS, TACS, NMT	CDMA, GSM, PDC	GPRS, EDGE	WCDMA, CDMA2000	Single standard
Bandwidth	1.9 kbps	14.4 kbps	384 kbps	2 Mbps	200 Mbps
Core network	PSTN	PSTN	PSTN, Packet network	Packet network	Internet

- Some examples of mobile communication systems currently in use in addition to the cellular radio networks are
- Wireless Local Loop (WLL)
- Wireless Local area networks (WLAN)
- Personal Area Networks(PAN)
- Bluetooth
- Worldwide Interoperability for Microwave Access (WiMAX)

Wireless local Loop (WLL)

- WLL is a cellular –like phone without mobility. These are designed for fixed communications where it is easier, cheaper or more advantageous than wire line connections and are often based on cellular or cordless technologies.
- WLL employs a cellular-like technology where the subscriber unit is fixed like a wire line telephone. Thus the local loop between the exchange and the subscribers home is replaced with a wireless link. The same basic architecture and principles of radio communication are used.
- Fixed wireless equipment is extremely well suited for rapidly deploying a broadband connection in homes and offices. These fixed wireless systems are able to take advantage of the very well-defined, time-invariant nature of the propagation channel between the fixed transmitter and fixed receiver.
- They are assigned microwave or millimeter frequencies in the 28 GHz band and hence the wavelengths are extremely small. Thus very high gain directional antennas are required. These high gain antennas reject multipath signals and in turn supports the transmission of very wide bandwidth signals.

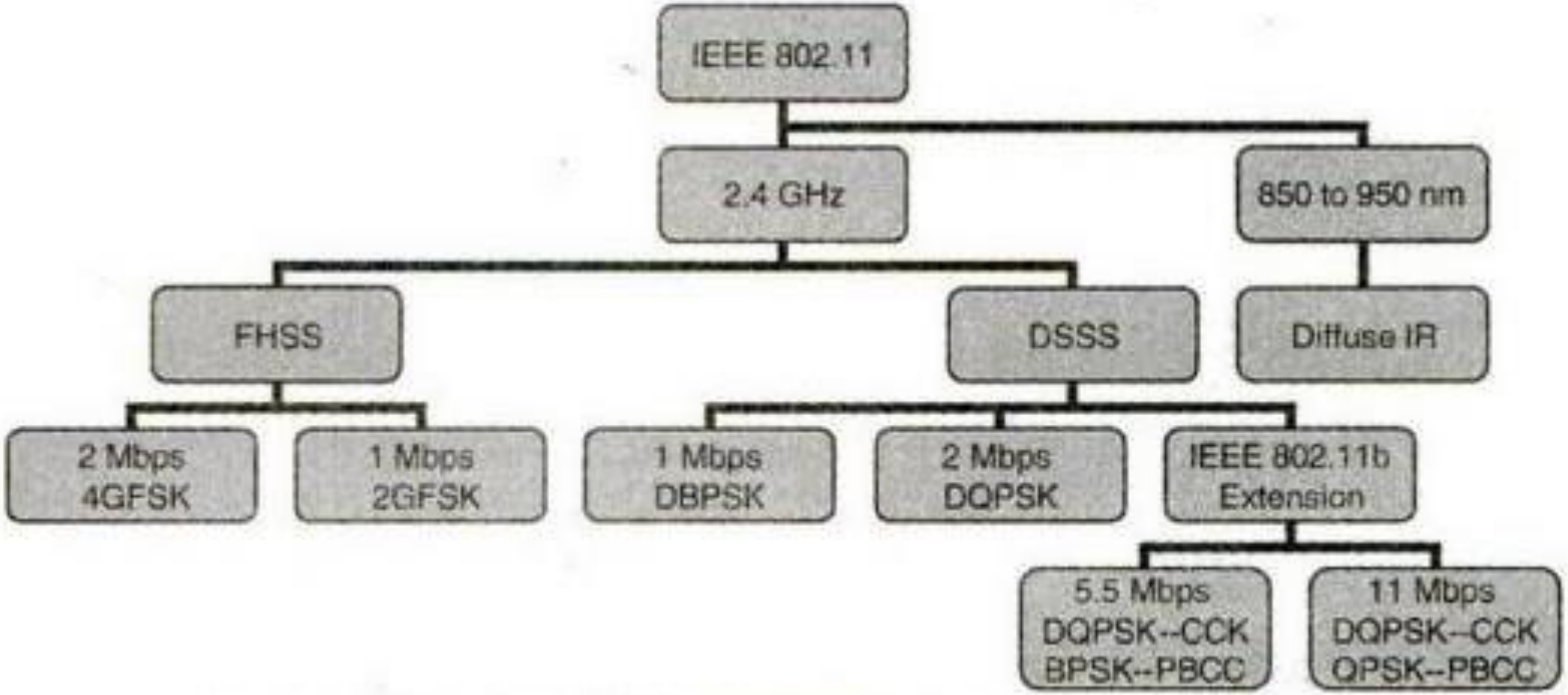
- A WLL can be created as shown in the figure. The local loop is the last mile connection between the Central Office and individual homes and offices. Copper or fibre optic cables are installed to these destinations and can be leased from a service provider on a monthly basis.
- An advanced service that has been proposed to make efficient use of the WLL technology is the Local Multipoint Distribution Service (LMDS) which provides broadband telecommunications access in the local exchange. The U.S LMDS band is in the 27-31 GHz range.



- A wireless local area network (WLAN) is a wireless distribution method for two or more devices that use high-frequency radio waves or spread spectrum and often include an access point to the Internet. A WLAN allows users to move around the coverage area, often a home or small office, while maintaining a network connection.
- The FCC has allocated 300 MHz of unlicensed spectrum in the ISM bands of 5.1 GHz and 5.8 GHz range for supporting private computer connections by WLAN. The IEEE 802.11 WLAN standard is the popular standard for the use of internet and wireless communication.
- Types of WLAN
  - Peer to peer – allows wireless devices to directly communicate with each other.
  - Bridge-an Ethernet bridge acts as the connection point to the wireless LAN

Wireless Local Area Network (WLAN)

- **Figure illustrates the evolution of the IEEE 802.11 WLAN standards**



Overview of the IEEE 802.11 Wireless LAN standard.

- Both frequency hopping spread spectrum (FHSS) and direct sequence spread spectrum (DS-SS) were used in the early IEEE 802.11 standard with 2MBps throughput.
- Later only DS-SS was standardized for high rate 11 Mbps user data rates by the IEEE 802.11b standard. This DS-SS IEEE 802.11b has been named Wi-fi.
- The High performance Radio Local Area Network (HiPERLAN) was developed to provide similar capability to IEEE 802.11.This was intended to provide individual wireless LANs for computer communications and used the 5.2 GHz and 17.1GHz frequency bands.

Personal Area Network (PAN)

- PAN represents the interconnection of information technology devices within the range of an individual person typically within 10m,
- This like a person while travelling with a laptop, Personal Digital Assistant (PDA) and a portable printer could interconnect them without having to plug in anything or by using some form of wireless technology.
- This kind of PAN also could be interconnected without wires to the Internet.
- The basic difference between PAN and WAN is that PAN is centered around one person while the latter serves multiple users.
- The PANs can be constructed with cables or wireless USB
- Firewire technology links together a wired PAN
- Wireless PAN uses Bluetooth or Infrared connections. Bluetooth PANs are also called piconets.
- A piconet schematic is shown in the figure.

- Piconet is formed by a composition of upto 8 devices in a master-slave relationship. The first Bluetooth device is called the master and all the others are slaves.These slaves communicate with the master within a range of 10m.Bluetooth is wireless PAN which uses the IEEE 802.15 standard.

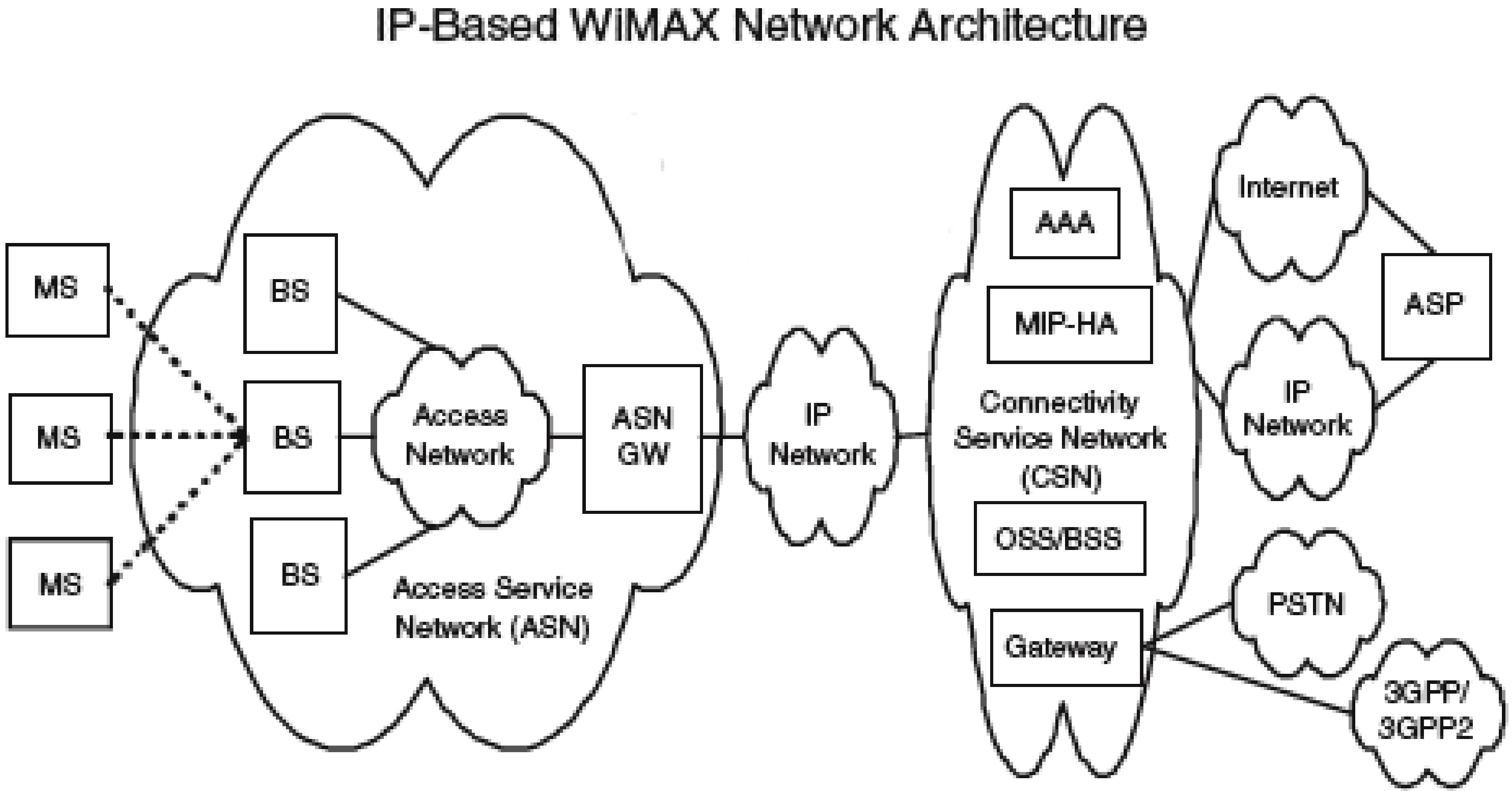
Bluetooth Technology

- Bluetooth is a short-range wireless communication technology that allows devices such as mobile phones, computers, and peripherals to transmit data or voice wirelessly over a short distance. The purpose of Bluetooth is to replace the cables that normally connect devices, while still keeping the communications between them secure. The devices can communicate within a nominal range of 10m.
- The "Bluetooth" name is taken from a 10th-century Danish king named Harald Bluetooth, who was said to unite disparate, warring regional factions. Like its namesake, Bluetooth technology brings together a broad range of devices across many different industries through a unifying communication standard.
- Bluetooth operates in the 2.4 GHz ISM band
- It uses the frequency hopping spread spectrum technique.
- The standard followed is IEEE 802.15.
- The modulation used is Gaussian FSK (GFSK).
- Data transfer rate of 1Mbps.
- Useful for data transfer between two devices that are near to each other in low bandwidth situations.
- Connection and exchange of information between mobile phones, laptops, PCs,GPS receivers, printers ,digital cameras, video game consoles etc is made possible.

WiMAX Technology

- WiMAX stands for Worldwide interoperability for Microwave Access.
- This technology enables universal delivery of wireless broadband service for fixed mobile users.
- The technology is based on the IEEE 802.16 standard and uses OFDMA.
- Also known as wireless metropolitan area networks (WMANs)
- This technology provides broadband wireless connectivity across a large geographical area such as a metro city.
- Mobile WiMAX is based on the IEEE 802.16e standard which provides mobility and roaming access. The IEEE 802.16e standard uses OFDMA interface and gives better performance in non-line-of-sight(NLOS) environments.
- WLANs and WPANs restrict the mobility of users to a few hundreds of metres from the source. LOS also has to be maintained.
- IEEE 802.16 and WiMAX are designed as complimentary technology to WiFi and Blutetooth. The original 802.16a standard specified transmissions in the range 10 - 66 GHz. Different bands are available for WiMAX applications in different parts of the world. The frequencies commonly used are 3.5 and 5.8 GHz for 802.16d and 2.3, 2.5 and 3.5 GHz for 802.16e.

- **WiMAX architecture**



- WiMAX architecture comprises of several components.
- The basic two components are Base Station (BS) and Mobile Station (MS).
- Mobile station is for the end user to access the mobile network. It is a portable station that is able to move to wide areas and perform data and voice communication. It has all the necessary user equipment such as transmitter, receiver, antenna, amplifier and all the required software for communication.
- The architecture is based on a packet-switched framework.
- The mobile station uses GSM,CDMA,W-CDMA,TDMA,FDMA devices.
- ASN is the access service network and creates radio access along with ASN gateways. The gateway controls the access in the network and coordinates between data and networking elements.
- CSN is the connectivity service network which provides IP connectivity to the internet or other public or corporate networks. It also applies per user policy management, address management, location management between the ASNs and ensures quality of service, roaming and security.ASP is the access service provider.
- Home Agent, HA: The Home Agent within the WiMAX network is located within the CSN., the Home Agent works in conjunction with the ASN Gateway, to provide an efficient end-to-end Mobile IP (MIP) solution.
- An Authentication, Authorisation and Accounting Server (AAA) is included within the CSN.