



## Unit 1 Mobile computing

Cellular and Mobile Communications (Jawaharlal Nehru Technological University,  
Kakinada)



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# Mobile Computing

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## Unit -1

### Introduction to Wireless Networks

What is wireless network introduction?

Wireless networking is a method by which homes, telecommunications networks and business installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations.

A **wireless network** is a computer network that uses wireless data connections between nodes.

Wireless networking is a method by which homes, telecommunications networks and business installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations.

Telecommunications networks are generally implemented and administered using radio communication.

This implementation takes place at the physical level (layer) of the OSI model network structure.

Examples of wireless networks include cell phone networks, wireless local area networks (WLANs), wireless sensor networks, satellite communication networks, and terrestrial microwave networks.

### History

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#### Wireless networks

The first professional wireless network was developed under the brand [ALOHAnet](#) in 1969 at the University of Hawaii and became operational in June 1971.

The first commercial wireless network was the [WaveLAN](#) product family, developed by [NCR](#) in 1986.

- 1973 – Ethernet 802.3
- 1991 – [2G](#) cell phone network
- June 1997 – [802.11](#) "[Wi-Fi](#)" protocol first release
- 1999 – [803.11](#) [VoIP](#) integration
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## Underlying technology

Advances in [MOSFET](#) (MOS transistor) wireless technology enabled the development of digital [wireless networks](#).

The wide adoption of [RF CMOS](#) (radio frequency CMOS), [power MOSFET](#) and [LDMOS](#) (lateral diffused MOS) devices led to the development and proliferation of digital wireless networks by the 1990s, with further advances in MOSFET technology leading to increasing [bandwidth](#) in the 2000s ([Edholm's law](#)).

Most of the essential elements of wireless networks are built from MOSFETs, including the mobile [transceivers](#), [base station](#) modules, [routers](#), [RF power amplifiers](#), [telecommunication circuits](#),<sup>[8]</sup> [RF circuits](#), and [radio transceivers](#) in networks such as [2G](#), [3G](#), and [4G](#).

## Wireless links

Computers are very often connected to networks using wireless links, e.g. WLANs

- *Terrestrial microwave* – Terrestrial microwave communication uses Earth-based transmitters and receivers resembling satellite dishes. Terrestrial microwaves are in the low gigahertz range, which limits all communications to line-of-sight. Relay stations are spaced approximately 48 km (30 mi) apart.
- *Communications satellites* – Satellites communicate via microwave radio waves, which are not deflected by the Earth's [atmosphere](#).
- The satellites are stationed in space, typically in [geosynchronous orbit](#) 35,400 km (22,000 mi) above the equator. These Earth-orbiting systems are capable of receiving and relaying voice, data, and TV signals.
- *Cellular and PCS systems* use several radio communications technologies.
- The systems divide the region covered into multiple geographic areas.
- Each area has a low-power transmitter or radio relay antenna device to relay calls from one area to the next area.
- *Radio and [spread spectrum](#) technologies* – Wireless local area networks use a high-frequency radio technology similar to digital cellular and a low-frequency radio technology.
- Wireless LANs use spread spectrum technology to enable communication between multiple devices in a limited area.
- [IEEE 802.11](#) defines a common flavor of open-standards wireless radio-wave technology known as [Wi-Fi](#).

- *Free-space optical communication* uses visible or invisible light for communications. In most cases, [line-of-sight propagation](#) is used, which limits the physical positioning of communicating devices.

## Types of wireless networks

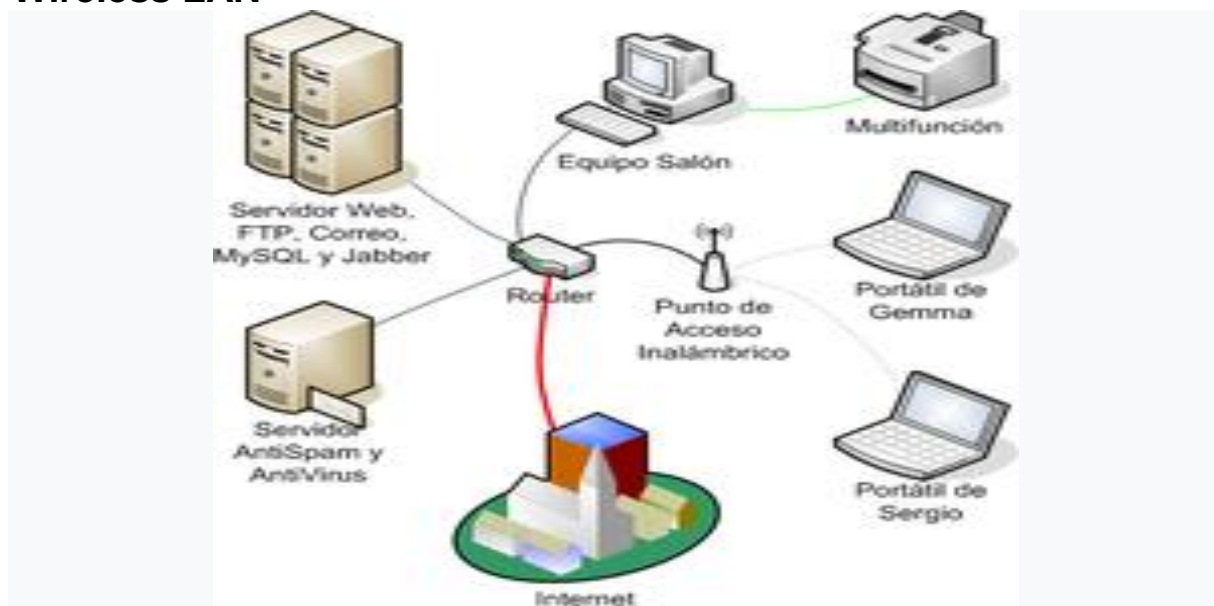
### Wireless PAN

Wireless [personal area networks](#) (WPANs) connect devices within a relatively small area, that is generally within a person's reach.<sup>[9]</sup> For example, both [Bluetooth](#) radio and invisible [infrared](#) light provides a WPAN for interconnecting a headset to a laptop.

[Zigbee](#) also supports WPAN applications.<sup>[10]</sup> Wi-Fi PANs are becoming commonplace (2010) as equipment designers start to integrate Wi-Fi into a variety of consumer electronic devices.

[Intel](#) "My WiFi" and [Windows 7](#) "[virtual](#) Wi-Fi" capabilities have made Wi-Fi PANs simpler and easier to set up and configure.<sup>[11]</sup>

### **Wireless LAN**



Wireless LANs are often used for connecting to local resources and to the Internet

A [wireless local area network](#) (WLAN) links two or more devices over a short distance using a wireless distribution method, usually providing a connection through an access point for internet access.

The use of [spread-spectrum](#) or [OFDM](#) technologies may allow users to move around within a local coverage area, and still remain connected to the network.

Products using the [IEEE 802.11](#) WLAN standards are marketed under the [Wi-Fi](#) brand name. [Fixed wireless](#) technology implements [point-to-point](#) links between computers or networks at two distant locations, often using dedicated [microwave](#) or modulated [laser light](#) beams over [line of sight](#) paths.

It is often used in cities to connect networks in two or more buildings without installing a wired link.

To connect to [Wi-Fi](#) using a mobile device, one can use a device like a [wireless router](#) or the [private hotspot](#) capability of another mobile device.

### **Wireless ad hoc networks**

A wireless ad hoc network, also known as a [wireless mesh network](#) or [mobile ad hoc network](#) (MANET), is a wireless network made up of radio nodes organized in a mesh topology.

Each node forwards messages on behalf of the other nodes and each node performs routing.

Adhoc networks can "self-heal", automatically re-routing around a node that has lost power.

Various network layer protocols are needed to realize ad hoc mobile networks, such as Distance Sequenced Distance Vector routing, [Associativity-Based Routing](#), Ad hoc on-demand [Distance Vector routing](#), and [Dynamic source routing](#).

### **Wireless MAN[edit]**

Wireless [metropolitan area networks](#) are a type of wireless network that connects several wireless LANs.

- [WiMAX](#) is a type of Wireless MAN and is described by the [IEEE 802.16](#) standard.<sup>[13]</sup>

### **Wireless WAN**

[Wireless wide area networks](#) are wireless networks that typically cover large areas, such as between neighboring towns and cities, or city and suburb.

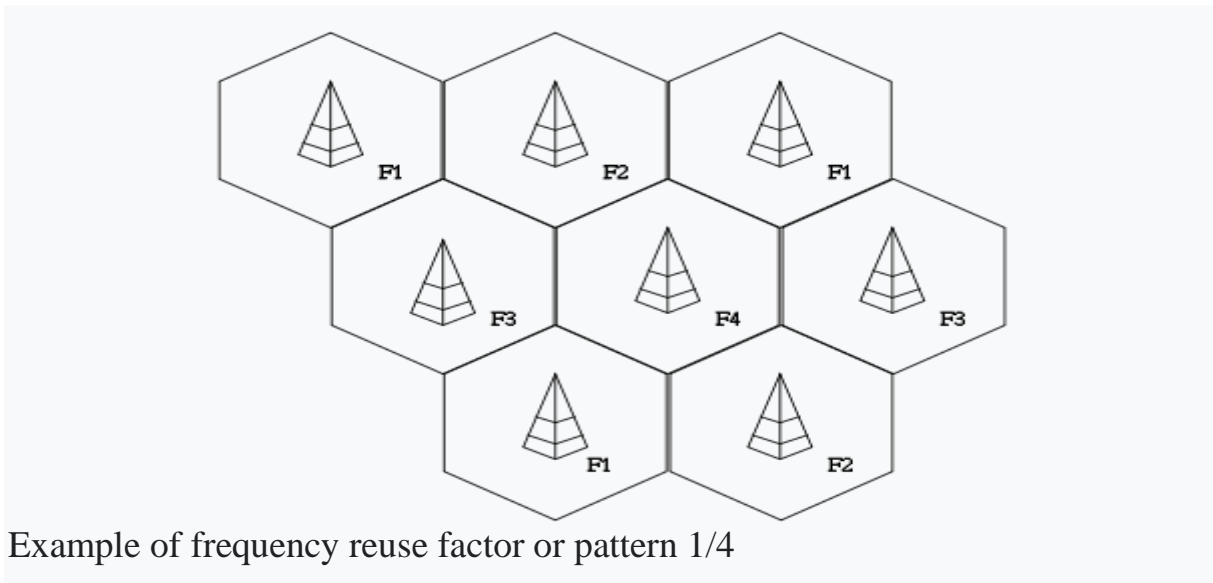
These networks can be used to connect branch offices of business or as a public Internet access system.

The wireless connections between access points are usually [point to point microwave links](#) using [parabolic dishes](#) on the 2.4 GHz and 5.8 GHz band, rather than [omnidirectional antennas](#) used with smaller networks.

A typical system contains base station gateways, access points and wireless bridging relays. Other configurations are mesh systems where each access point acts as a relay also.

When combined with renewable energy systems such as photovoltaic solar panels or wind systems they can be stand alone systems.

## Cellular network



A **cellular network** or **mobile network** is a radio network distributed over land areas called cells, each served by at least one fixed-location **transceiver**, known as a **cell site** or **base station**.

In a cellular network, each cell characteristically uses a different set of radio frequencies from all their immediate neighboring cells to avoid any interference.

When joined these cells provide radio coverage over a wide geographic area.

This enables a large number of portable transceivers (e.g., mobile phones, **paggers**, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

Although originally intended for cell phones, with the development of **smart phones**, **cellular telephone networks** routinely carry data in addition to telephone conversations:

- **Global System for Mobile Communications (GSM)**: The GSM network is divided into three major systems: the switching system, the base station system, and the operation and support system.
- The cell phone connects to the base system station which then connects to the operation and support station;
- it then connects to the switching station where the call is transferred to where it needs to go. GSM is the most common standard and is used for a majority of cell phones.<sup>[14]</sup>

- [Personal Communications Service \(PCS\)](#): PCS is a radio band that can be used by mobile phones in North America and South Asia.
- Sprint happened to be the first service to set up a PCS.
- [D-AMPS](#): Digital Advanced Mobile Phone Service, an upgraded version of AMPS, is being phased out due to advancement in technology.
- The newer GSM networks are replacing the older system.

### ***Private LTE/5G networks***

Private LTE/5G networks use licensed, shared or unlicensed wireless spectrum thanks to LTE or 5G cellular network base stations, small cells and other radio access network (RAN) infrastructure to transmit voice and data to edge devices (smart phones, embedded modules, routers and gateways).

3GPP defines 5G private networks as non-public networks that typically employ a smaller-scale deployment to meet an organization's needs for reliability, accessibility, and maintainability.

### **Space network**

Space networks are networks used for communication between spacecraft, usually in the vicinity of the Earth. The example of this is NASA's [Space Network](#).

### **Uses**

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Some examples of usage include cellular phones which are part of everyday wireless networks, allowing easy personal communications.

Another example, Intercontinental network systems, use radio [satellites](#) to communicate across the world.

[Emergency services](#) such as the police utilize wireless networks to communicate effectively as well.

Individuals and businesses use wireless networks to send and share data rapidly, whether it be in a small office building or across the world.

### **How wireless networks work**

Wireless Local Area Network (WLAN) serves the same function as a wired one to connect a group of computers. Since “wireless” does not require expensive wiring, the primary advantage is that it is typically simpler, quicker, and cheaper to set up.

By contrast, it can be labor-intensive and costly to build a network by dragging wires over an office’s walls and ceilings. But a wireless network can be a cost-

effective way to extend or increase it, even though you have a wired network already in place.

Wireless networks operate using Radio Frequency (RF) technology, a frequency associated with radio wave propagation within the electromagnetic spectrum.

An electromagnetic field is generated when an RF current is supplied to an antenna that can then spread through space.

## Types of wireless networks

We now know how wireless network works; let's focus our attention to different types of wireless.



### 1. Wireless Local Area Networks (WLAN)

**WLAN** refers to the type of network connecting two or more computers via a wireless distribution method.

They have high-frequency radio waves and an AP (access points) to the internet.

They are advantageous to use as it allows users to move around the coverage area, not restricted to a single location. They are also known as *Local Area Wireless Network (LAWN)*.

### 2. Wireless Wide Area Networks (WWAN)

**WWAN** is also known as *wireless broadband*, it makes use of cell towers. These towers transmit radio signals spanning thousands of miles, in contrast to WLAN that spans a few hundred feet.

It comprises three major technologies, Global System for Mobile communications (GSM) and Code Division Multiple Access (CDMA), and the newer WiMAX.

These technologies are beyond the scope of this article, but you're free to look for more resources on the topic or [here](#).

A point to note is that Wide Area Networks do not connect to your individual computers but instead to several Local Area networks.

### 3. Wireless Metropolitan Area Networks (WMAN)

WMAN has a coverage range size approximately that of a city. It's smaller as compared to WWAN but larger than WLAN. It belongs to a single entity such as the government, Internet Service Provider, or cooperation.

WMAN restricts access to authorized users or subscriber devices only. An example of a form of WMAN would be \**WiMAX*.

#### Benefits of wireless networking

- It has contributed significantly to the Voice over Internet (VoIP) as calls can now be made easily over this protocol.
- It has enabled mobility, a more significant advantage to its users as servers can be accessed anywhere as long as Access Point access exists.
- They are relatively cheap when compared to wired networks, which involve a lot of expenses when purchasing cables.
- The network can be secure due to data encryption method and current technologies. This allows the sharing of sensitive information.
- What are wireless network and its types?
- There are four types of wireless networks -- **wireless local area networks, wireless metropolitan area networks, wireless personal area networks and wireless wide area networks** -- each with its own function.
- Below we discuss the different types of wireless networks and the various equipment and connections they require.  
Wireless networks offer the following productivity, convenience, and cost advantages over traditional wired networks:

- **Mobility:** provide mobile users with access to real-time information so that they can roam around in the network without getting disconnected from the network. This mobility supports productivity and service opportunities not possible with wired networks.
- **Installation speed and simplicity:** installing a wireless system can be fast and easy and can eliminate the need to pull cable through walls and ceilings.
- **Reach of the network:** the network can be extended to places which can not be wired
- **More Flexibility:** wireless networks offer more flexibility and adapt easily to changes in the configuration of the network.
- **Reduced cost of ownership:** while the initial investment required for wireless network hardware can be higher than the cost of wired network hardware, overall installation expenses and life-cycle costs can be significantly lower in dynamic environments.
- **Scalability:** wireless systems can be configured in a variety of topologies to meet the needs of specific applications and installations.
- Configurations can be easily changed and range from peer-to-peer networks suitable for a small number of users to large infrastructure networks that enable roaming over a broad area.

Bluetooth and 802.11b have the potential to dramatically alter how people use devices to connect and communicate in everyday life.

Bluetooth is a low-power, short-range technology for ad hoc cable replacement; it enables people to wirelessly combine devices wherever they bring them.

A communication device can thus exhibit one of the following characteristics:

- **Fixed and wired:** This configuration describes the typical desktop computer in an office.

Neither weight nor power consumption of the devices allow for mobile usage. The devices use fixed networks for performance reasons.

- **Mobile and wired:** Many of today's laptops fall into this category; users carry the laptop from one hotel to the next, reconnecting to the company's network via the telephone network and a modem.
- **Fixed and wireless:** This mode is used for installing networks, e.g., in historical buildings to avoid damage by installing wires, or at trade shows to ensure fast network setup.

Another example is bridging the last mile to a customer by a new operator that has no wired infrastructure and does not want to lease lines from a competitor.

- Mobile and wireless: This is the most interesting case. No cable restricts the user, who can roam between different wireless networks.

Most technologies discussed in this book deal with this type of device and the networks supporting them.

Today's most successful example for this category is GSM with more than 800 million users.

## **1 Applications**

Although many applications can benefit from wireless networks and mobile communications, particular application environments seem to be predestined for their use.

### **Vehicles**

Today's cars already comprise some, but tomorrow's cars will comprise many wireless communication systems and mobility aware applications.

Music, news, road conditions, weather reports, and other broadcast information are received via digital audio broadcasting (DAB) with 1.5 Mbit/s.

For personal communication, a universal mobile telecommunications system (UMTS) phone might be available offering voice and data connectivity with 384 kbit/s.

For remote areas, satellite communication can be used, while the current position of the car is determined via the global positioning system (GPS).

Cars driving in the same area build a local ad-hoc network for the fast exchange of information in emergency situations or to help each other keep a safe distance.

In case of an accident, not only will the airbag be triggered, but the police and ambulance service will be informed via an emergency call to a service provider. Cars with this technology are already available.

In the future, cars will also inform other cars about accidents via the ad-hoc network to help them slow down in time, even before a driver can recognize an accident.

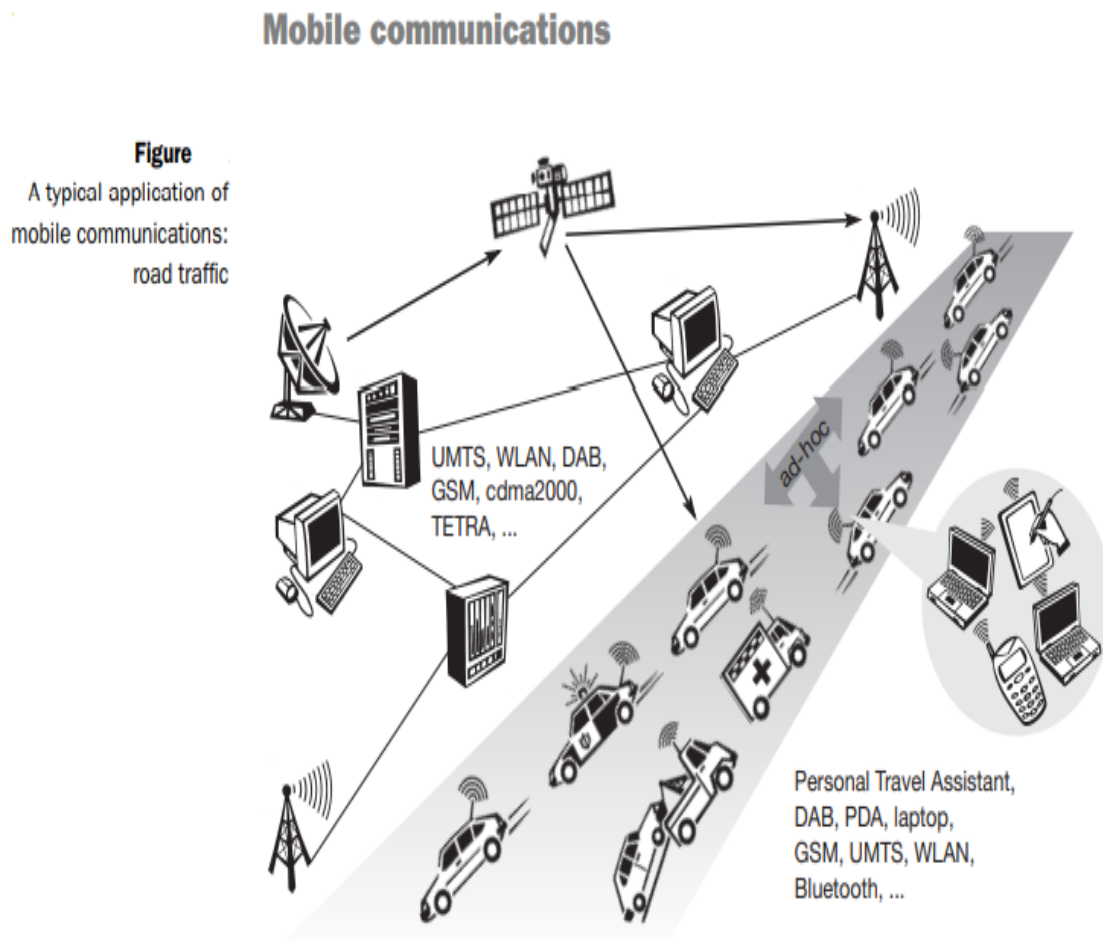
Buses, trucks, and trains are already transmitting maintenance and logistic information to their home base, which helps to improve organization (fleet management), and saves time and money

Figure, shows a typical scenario for mobile communications with many wireless devices.

Networks with a fixed infrastructure like cellular phones (GSM, UMTS) will be interconnected with trunked radio systems (TETRA) and wireless LANs (WLAN). Satellite communication links can also be used.

The networks between cars and inside each car will more likely work in an ad-hoc fashion.

Wireless pico networks inside a car can comprise personal digital assistants (PDA), laptops, or mobile phones, e.g., connected with each other using the Bluetooth technology.



## Emergencies

Just imagine the possibilities of an ambulance with a high-quality wireless connection to a hospital. Vital information about injured persons can be sent to the hospital from the scene of the accident.

All the necessary steps for this particular type of accident can be prepared and specialists can be consulted for an early diagnosis.

Wireless networks are the only means of communication in the case of natural disasters such as hurricanes or earthquakes.

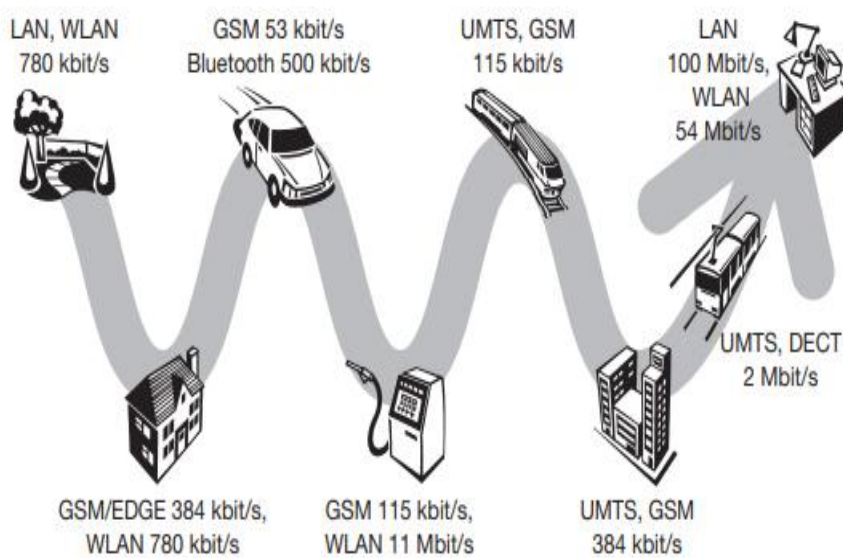
In the worst cases, only decentralized, wireless ad-hoc networks survive

### Business

A travelling salesman today needs instant access to the company's database: to ensure that files on his or her laptop reflect the current situation, to enable the company to keep track of all activities of their travelling employees, to keep databases consistent etc.

With wireless access, the laptop can be turned into a true mobile office, but efficient and powerful synchronization mechanisms are needed to ensure data consistency.

Figure 1.2 illustrates what may happen when employees try to communicate off base. At home, the laptop connects via a WLAN or LAN and DSL to the Internet



**Figure**  
Mobile and wireless services – always best connected

### Mobile and wireless devices

Even though many mobile and wireless devices are available, there will be many more in the future.

There is no precise classification of such devices, by size, shape, weight, or computing power. Currently, laptops are considered the upper end of the mobile device range.

The following list gives some examples of mobile and wireless devices graded by increasing performance (CPU, memory, display, input devices etc.).

However, there is no sharp line between the categories and companies tend to invent more and more new categories.

- **Sensor:** A very simple wireless device is represented by a sensor transmitting state information.

One example could be a switch sensing the office door. If the door is closed, the switch transmits this to the mobile phone inside the office which will not accept incoming calls.

Without user interaction, the semantics of a closed door is applied to phone calls.

- **Embedded controllers:** Many appliances already contain a simple or sometimes more complex controller.

Keyboards, mice, headsets, washing machines, coffee machines, hair dryers and TV sets are just some examples.

Why not have the hair dryer as a simple mobile and wireless device (from a communication point of view) that is able to communicate with the mobile phone?

Then the dryer would switch off as soon as the phone starts ringing – that would be a nice application!

- **Pager:** As a very simple receiver, a pager can only display short text messages, has a tiny display, and cannot send any messages.

Pagers can even be integrated into watches. The tremendous success of mobile phones has made the pager virtually redundant in many countries.

Short messages have replaced paging. T

Mobile phones: The traditional mobile phone only had a simple black and white text display and could send/receive voice or short messages.

Today, mobile phones migrate more and more toward PDAs. Mobile phones with full colour graphic display, touch screen, and Internet browser are easily available.

- Personal digital assistant: PDAs typically accompany a user and offer simple versions of office software (calendar, note-pad, mail).

The typical input device is a pen, with built-in character recognition translating handwriting into characters.

Web browsers and many other software packages are available for these devices.

- Pocket computer: The next steps toward full computers are pocket computers offering tiny keyboards, colour displays, and simple versions of programs found on desktop computers (text processing, spreadsheets etc.).

- Notebook/laptop: Finally, laptops offer more or less the same performance as standard desktop computers;

They use the same software – the only technical difference being size, weight, and the ability to run on a battery.

If operated mainly via a sensitive display (touch sensitive or electromagnetic), the devices are also known as notepads or tablet PCs.

### **A short history of wireless communication**

The use of light for wireless communications reaches back to ancient times. In former times, the light was either ‘modulated’ using mirrors to create a certain light on/light off pattern (‘amplitude modulation’) or, for example, flags were used to signal code words (‘amplitude and frequency modulation’)

The use of smoke signals for communication is mentioned by Polybius, Greece, as early as 150 BC.

It is also reported from the early (or western) Han dynasty in ancient China (206 BC–24 AD) that light was used for signalling messages along a line of signal towers towards the capitol Chang’an (Xi’an).

Using light and flags for wireless communication remained important for the navy until radio transmission was introduced,

Wired communication started with the first commercial telegraph line between Washington and Baltimore in 1843, and Alexander Graham Bell’s invention and marketing of the telephone in 1876 (others tried marketing before but did not succeed,

All optical transmission systems suffer from the high frequency of the carrier light.

As every little obstacle shadows the signal, rain and fog make communication almost impossible.

At that time it was not possible to focus light as efficiently as can be done today by means of a laser, wireless communication did not really take off until the discovery of electromagnetic waves and the development of the equipment to modulate them.

The new system aimed to:

- use a new spectrum at 900 MHz;
- allow roaming throughout Europe;
- be fully digital; and
- offer voice and data service. The 'Group Special Mobile' (GSM) was founded for this new development. In 1983 the US system advanced mobile phone system (AMPS) started (EIA, 1989).

AMPS is an analog mobile phone system working at 850 MHz. Telephones at home went wireless with the standard CT1 (cordless telephone) in 1984, (following its predecessor the CT0 from 1980).

As digital systems were not yet available, more analog standards followed, such as the German C-Netz at 450 MHz with analog voice transmission.

Hand-over between 'cells' was now possible, the signalling system was digital in accordance with the trends in fixed networks (SS7),

### **A simplified reference model**

The basic reference model used to structure communication systems (Tanenbaum, 2003).

Any readers who are unfamiliar with the basics of communication networks should look up the relevant sections in the recommended literature (Halsall, 1996), (Keshav, 1997), (Tanenbaum, 2003), (Kurose, 2003).

Figure shows a personal digital assistant (PDA) which provides an example for a wireless and portable device.

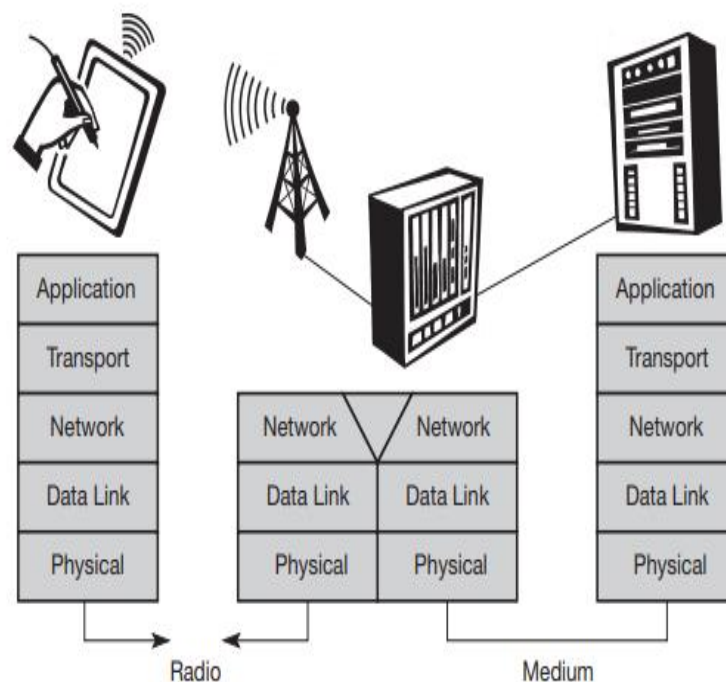
This PDA communicates with a base station in the middle of the picture. The base station consists of a radio transceiver (sender and receiver) and an interworking unit connecting the wireless link with the fixed link.

The communication partner of the PDA, a conventional computer, is shown on the right-hand side. Underneath each network element (such as PDA, interworking unit, computer),

the figure shows the protocol stack implemented in the system according to the reference model.

End-systems, such as the PDA and computer in the example, need a full protocol stack comprising the application layer, transport layer, network layer, data link layer, and physical layer. Applications

**Figure**  
Simple network and reference model used in this book



On the end-systems communicate with each other using the lower layer services.

Intermediate systems, such as the interworking unit, do not necessarily need all of the layers. Figure only shows the network, data link, and physical layers.

As (according to the basic reference model) only entities at the same level communicate with each other (i.e., transport with transport, network with network) the end-system applications do not notice the intermediate system directly in this scenario.

The following paragraphs explain the functions of each layer in more detail in a wireless and mobile environment.

- **Physical layer:** This is the lowest layer in a communication system and is responsible for the conversion of a stream of bits into signals that can be transmitted on the sender side.

The physical layer of the receiver then transforms the signals back into a bit stream. For wireless communication, the physical layer is responsible for frequency selection, generation of the carrier frequency, signal detection (although heavy interference may disturb the signal), modulation of data onto a carrier frequency and (depending on the transmission scheme) encryption.

These features of the physical layer are mainly discussed in chapter 2, but will also be mentioned for each system separately in the appropriate chapters.

- **Data link layer:** The main tasks of this layer include accessing the medium, multiplexing of different data streams, correction of transmission errors, and synchronization (i.e., detection of a data frame).

Discusses different medium access schemes. A small section about the specific data link layer used in the presented systems is combined in each respective chapter.

Altogether, the data link layer is responsible for a reliable point-to-point connection between two devices or a point-to-multipoint connection between one sender and several receivers.

- **Network layer:** This third layer is responsible for routing packets through a network or establishing a connection between two entities over many other intermediate systems.

Important topics are addressing, routing, device location, and handover between different networks. Presents several solutions for the network layer protocol of the internet (the Internet Protocol IP). The other chapters also contain sections about the network layer, as routing is necessary in most cases.

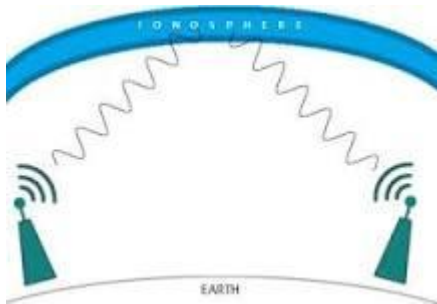
- **Transport layer:** This layer is used in the reference model to establish an end-to-end connection.

Topics like quality of service, flow and congestion control are relevant, especially if the transport protocols known from the Internet, TCP and UDP, are to be used over a wireless link.

- **Application layer:** Finally, the applications (complemented by additional layers that can support applications) are situated on top of all transmission-oriented layers.

## Wireless Transmission

What do you mean by wireless transmission?



Wireless transmission is **a form of unguided media**. Wireless communication involves no physical link established between two or more devices, communicating wirelessly.

Wireless signals are spread over in the air and are received and interpreted by appropriate antennas.

What are the different types of wireless transmission?



### The Different Types of Wireless Communication

- Satellite Communication. Satellite communication is a crucial form of wireless communication. ...
- Infrared Communication. ...
- Broadcast Radio. ...
- Microwave Communication. ...
- Wi-Fi. ...
- Mobile Communication Systems. ...
- Bluetooth Technology.

What are 3 types of wireless connections?

Below we discuss the different types of wireless networks and the various equipment and connections they require.

- Wireless LAN. Wireless LAN (WLAN) technology provides internet access within a building or a limited outdoor area. ...
- Wireless MAN
- Wireless PAN
- Wireless WAN

- **What are the uses of wireless transmission?**

- 



- Applications of wireless communication involve **security systems, television remote control, Wi-Fi, Cell phones, wireless power transfer, computer interface devices, and various wireless communication-based projects.**

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What are the characteristics of wireless transmission?

### Wireless Transmission Media

- Wireless transmission medium that distributes radio signals through the air over long distances such as between cities, regions, and countries.
- AM/FM radio is broadcast radio.
- Slower and more susceptible to noise than physical transmission media.
- Provides flexibility and portability.

## **What is example of wireless communication?**

### **Types of Wireless Communication**

Some of these terms may be familiar to you: radio and television broadcasting, radar communication, cellular communication, global position systems (GPS), WiFi, Bluetooth and radio frequency identification are all examples of “wireless”, with wildly different uses in some cases

While transmission over different wires typically does not cause interference, this is an important topic in wireless transmission.

The frequencies used for transmission are all regulated.

The following sections recall some basic facts about signals, antennas, and signal propagation.

The varying propagation characteristics create particular complications for radio transmission, frequently causing transmission errors. Multiplexing is a major design topic in this context, because the medium is always shared.

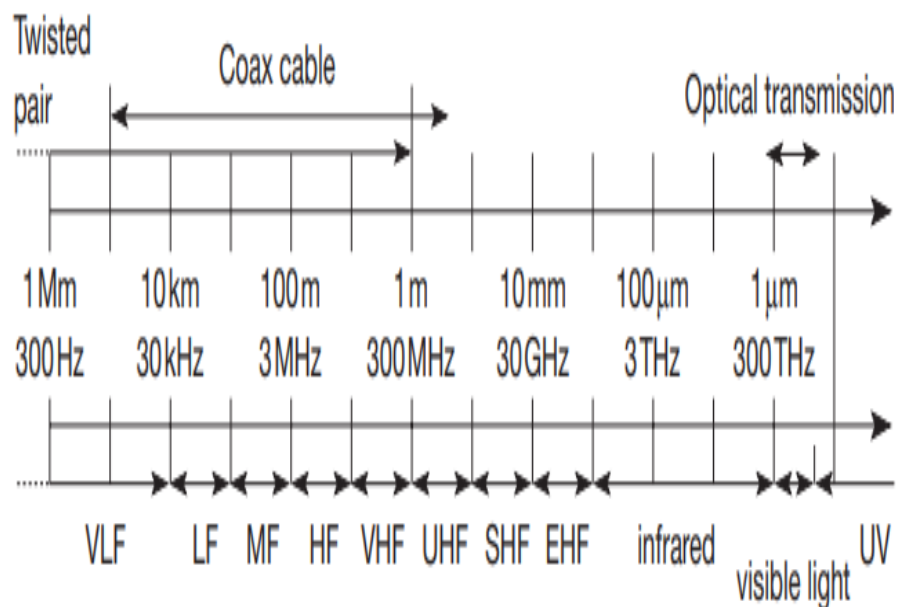
Multiplexing schemes have to ensure low interference between different senders

Modulation is needed to transmit digital data via certain frequencies.

A separate section of this chapter presents standard modulation schemes that will reoccur together with the wireless communication systems.

## Frequencies

**Figure**  
Frequency spectrum



### Frequencies for radio transmission

Radio transmission can take place using many different frequency bands.

Each frequency band exhibits certain advantages and disadvantages. Figure gives a rough overview of the frequency spectrum that can be used for data transmission.

The figure shows frequencies starting at 300 Hz and going up to over 300 THz.

Directly coupled to the frequency is the wavelength  $\lambda$  via the equation:  $\lambda = c/f$ ,

Where  $c \cong 3 \cdot 10^8$  m/s (the speed of light in vacuum) and  $f$  the frequency

For traditional wired networks, frequencies of up to several hundred kHz are used for distances up to some km with twisted pair copper wires, while frequencies of several hundred MHz are used with

coaxial cable (new coding schemes work with several hundred MHz even with twisted pair copper wires over distances of some 100 m).

Fiber optics are used for frequency ranges of several hundred THz, but here one typically refers to the wavelength which is, e.g., 1500 nm, 1350 nm etc. (infra red).

Radio transmission starts at several kHz, the very low frequency (VLF) range.

These are very long waves. Waves in the low frequency (LF) range are used by submarines, because they can penetrate water and can follow the earth's surface.

Some radio stations still use these frequencies, e.g., between 148.5 kHz and 283.5 kHz in Germany.

The medium frequency (MF) and high frequency (HF) ranges are typical for transmission of hundreds of radio stations either as amplitude modulation (AM) between 520 kHz and 1605.5 kHz, as short wave (SW) between 5.9 MHz and 26.1 MHz, or as frequency modulation (FM) between 87.5 MHz and 108 MHz

The frequencies limiting these ranges are typically fixed by national regulation and, vary from country to country.

Short waves are typically used for (amateur) radio transmission around the world, enabled by reflection at the ionosphere.

Transmit power is up to 500 kW – which is quite high compared to the 1 W of a mobile phone

The next step into higher frequencies involves optical transmission, which is not only used for fiber optical links but also for wireless communications. Infra red (IR) transmission is used for directed links, e.g., to connect different buildings via laser links.

The most widespread IR technology, infra red data association (IrDA), uses wavelengths of approximately 850–900 nm to connect laptops, PDAs etc.

## Signals

Signals are the physical representation of data. Users of a communication system can only exchange data through the transmission of signals.

Layer 1 of the ISO/OSI basic reference model is responsible for the conversion of data, i.e., bits, into signals and vice versa

Signals are functions of time and location. Signal parameters represent the data values.

The most interesting types of signals for radio transmission are periodic signals, especially sine waves as carriers. (The process of mapping of data onto a carrier is explained in section, the general function of a sine wave is:

$$g(t) = A \sin(2\pi f t + \phi t)$$

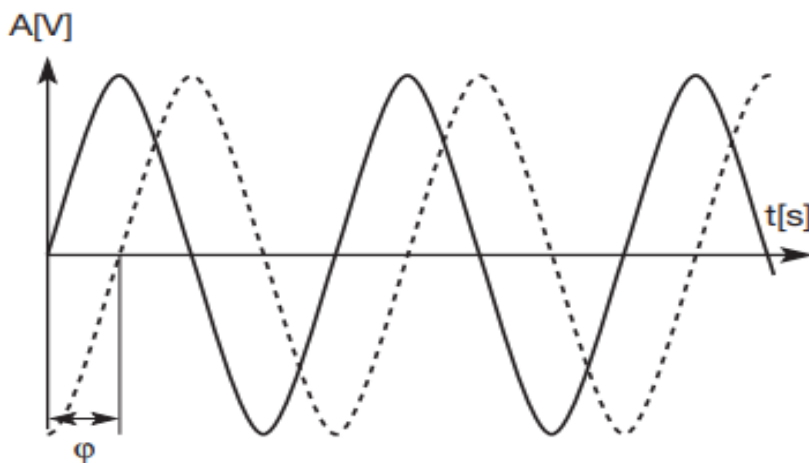
Signal parameters are the amplitude  $A$ , the frequency  $f$ , and the phase shift  $\phi$ .

The amplitude as a factor of the function  $g$  may also change over time, thus  $A t$ , The frequency  $f$  expresses the periodicity of the signal with the period  $T = 1/f$ .

(In equations,  $\omega$  is frequently used instead of  $2\pi f$ .) The frequency  $f$  may also change over time, thus  $f t$ ; finally, the phase shift determines the shift of the signal relative to the same signal without a shift.

An example for shifting a function is shown in Figure . This shows a sine function without a phase shift and the same function, i.e., same amplitude and frequency, with a phase shift  $\phi$ .

Shows how shifting the phase can be used to represent data. Sine waves are of special interest, as it is possible to construct every periodic signal  $g$  by using only sine and cosine functions according to a fundamental equation of Fourier



**Figure**  
Time domain  
representation of  
a signal

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

In this equation the parameter  $c$  determines the Direct Current (DC) component of the signal, the coefficients  $a_n$  and  $b_n$  are the amplitudes of the  $n$ th sine and cosine function.

The equation shows that an infinite number of sine and cosine functions is needed to construct arbitrary periodic functions.

However, the frequencies of these functions (the so-called harmonics) increase with a growing parameter  $n$  and are a multiple of the fundamental frequency  $f$ .

The bandwidth of any medium, air, cable, transmitter etc. is limited and, there is an upper limit for the frequencies.

A typical way to represent signals is the time domain (see Figure, Here the amplitude  $A$  of a signal is shown versus time (time is mostly measured in seconds  $s$ , amplitudes can be measured in, e.g., volt  $V$ ).

This is also the typical representation known from an oscilloscope. A phase shift can also be shown in this representation.

Representations in the time domain are problematic if a signal consists of many different frequencies (as the Fourier equation

indicates). In this case, a better representation of a signal is the frequency domain (see Figure) Here the amplitude of a certain frequency part of the signal is shown versus the frequency. Figure only shows one peak and the signal consists only of a single frequency part (i.e., it is a single sine function).

A third way to represent signals is the phase domain shown in Figure This representation, also called phase state or signal constellation diagram, shows the amplitude  $M$  of a signal and its phase  $\phi$  in polar coordinates.

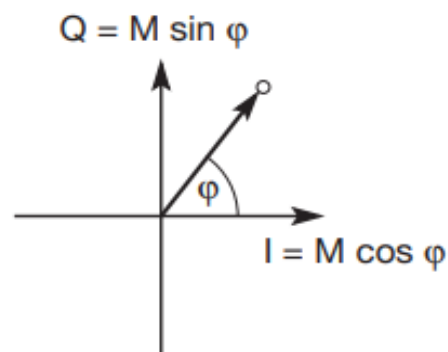
(The length of the vector represents the amplitude, the angle the phase shift.) The x-axis represents a phase of 0 and is also called In-Phase (I).

A phase shift of  $90^\circ$  or  $\pi/2$  would be a point on the y-axis, called Quadrature (Q)

**Figure**  
Frequency domain  
representation of  
a signal



**Figure**  
Phase domain  
representation of  
a signal



## Antennas

As the name wireless already indicates, this communication mode involves ‘getting rid’ of wires and transmitting signals through space without guidance.

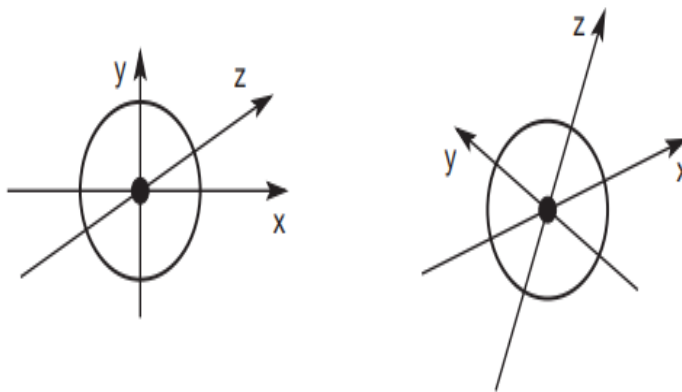
We do not need any ‘medium’ (such as ether) for the transport of electromagnetic waves.

Somehow, we have to couple the energy from the transmitter to the outside world and, in reverse, from the outside world to the receiver. This is exactly what antennas do.

Antennas couple electromagnetic energy to and from space to and from a wire or coaxial cable (or any other appropriate conductor).

A theoretical reference antenna is the isotropic radiator, a point in space radiating equal power in all directions, i.e., all points with equal power are located on a sphere with the antenna as its center.

The radiation pattern is symmetric in all directions (see Figure) a two dimensional cross-section of the real three-dimensional pattern).



**Figure**  
Radiation pattern of an isotropic radiator

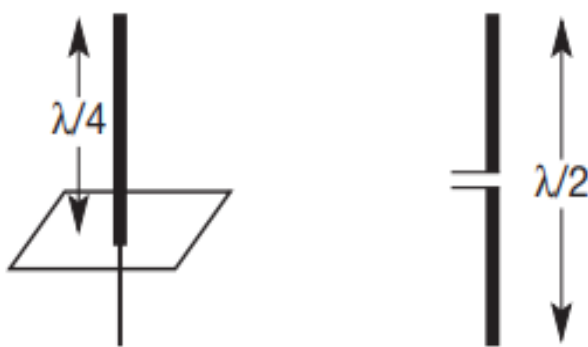
However, such an antenna does not exist in reality. Real antennas all exhibit directive effects, i.e., the intensity of radiation is not the same in all directions from the antenna.

The simplest real antenna is a thin, center-fed dipole, also called Hertzian dipole, as shown in Figure (right-hand side).

The dipole consists of two collinear conductors of equal length, separated by a small feeding gap.

The length of the dipole is not arbitrary, but, for example, half the wavelength  $\lambda$  of the signal to transmit results in a very efficient radiation of the energy.

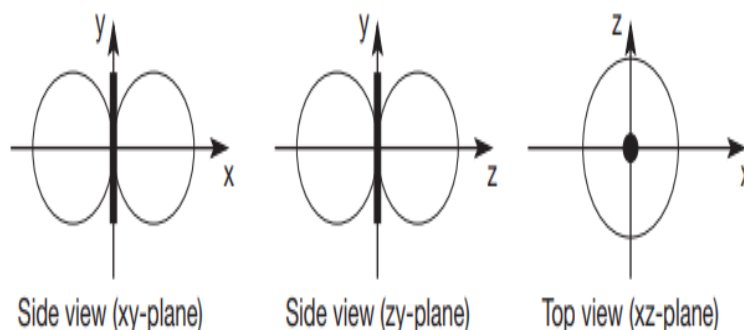
If mounted on the roof of a car, the length of  $\lambda/4$  is efficient. This is also known as Marconi antenna



**Figure**  
Simple antennas

A  $\lambda/2$  dipole has a uniform or Omni-directional radiation pattern in one plane and a figure eight pattern in the other two planes as shown in Figure

This type of antenna can only overcome environmental challenges by boosting the power level of the signal. Challenges could be mountains, valleys, buildings etc



**Figure**  
Radiation pattern of  
a simple dipole

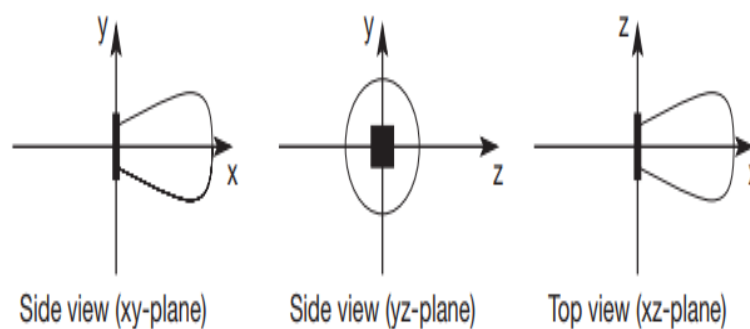
If an antenna is positioned, e.g., in a valley or between buildings, an Omnidirectional radiation pattern is not very useful

In this case, directional antennas with certain fixed preferential transmission and reception directions can be used.

Figure shows the radiation pattern of a directional antenna with the main lobe in the direction of the x-axis.

A special example of directional antennas is constituted by satellite dishes

**Figure**  
Radiation pattern of  
a directed antenna

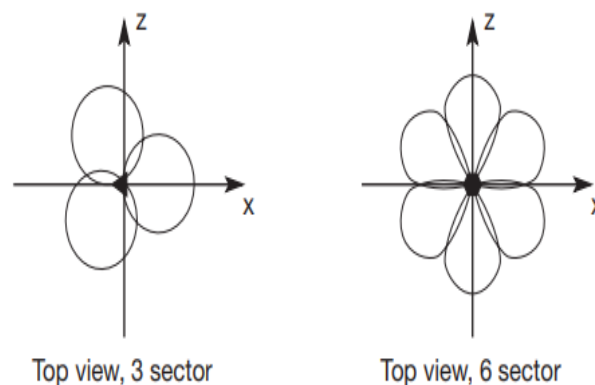


Directed antennas are typically applied in cellular systems as presented in section

. Several directed antennas can be combined on a single pole to construct a sectorized antenna.

A cell can be sectorized into, for example, three or six sectors, thus enabling frequency reuse as explained in section, and Figure shows the radiation patterns of these sectorized antennas

**Figure**  
Radiation patterns of  
sectorized antennas



## Signal propagation

Like wired networks, wireless communication networks also have senders and receivers of signals.

However, in connection with signal propagation, these two networks exhibit considerable differences.

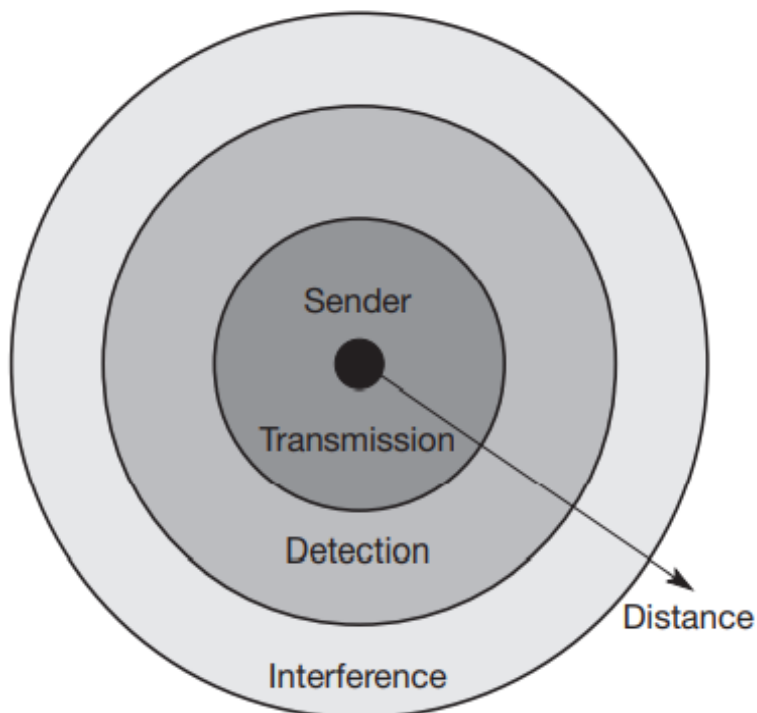
In wireless networks, the signal has no wire to determine the direction of propagation, whereas signals in wired networks only travel along the wire (which can be twisted pair copper wires, a coax cable, but also a fiber etc.).

As long as the wire is not interrupted or damaged, it typically exhibits the same characteristics at each point.

One can precisely determine the behaviour of a signal travelling along this wire, e.g., received power depending on the length.

For wireless transmission, this predictable behaviour is only valid in a vacuum, i.e., without matter between the sender and the receiver.

The situation would be as follows (Figure)



**Figure :**  
Ranges for transmission,  
detection, and  
interference of signals

## **Transmission range:**

Within a certain radius of the sender transmission is possible, i.e., a receiver receives the signals with an error rate low enough to be able to communicate and can also act as sender.

- **Detection range:**

Within a second radius, detection of the transmission is possible, i.e., the transmitted power is large enough to differ from background noise.

However, the error rate is too high to establish communication.

- **Interference range:**

Within a third even larger radius, the sender may interfere with other transmission by adding to the background noise

A receiver will not be able to detect the signals, but the signals may disturb other signals

### **Path loss of radio signals**

In free space radio signals propagate as light does (independently of their frequency), i.e., they follow a straight line (besides gravitational effects).

If such a straight line exists between a sender and a receiver it is called line-of-sight (LOS).

Even if no matter exists between the sender and the receiver (i.e., if there is a vacuum), the signal still experiences the free space loss.

The received power  $P_r$  is proportional to  $1/d^2$  with  $d$  being the distance between sender and receiver (inverse square law).

## Multiplexing

Multiplexing is not only a fundamental mechanism in communication systems but also in everyday life.

Multiplexing describes how several users can share a medium with minimum or no interference.

One example, is highways with several lanes.

Many users (car drivers) use the same medium (the highways) with hopefully no interference (i.e., accidents).

This is possible due to the provision of several lanes (space division multiplexing) separating the traffic.

In addition, different cars use the same medium (i.e., the same lane) at different points in time (time division multiplexing).

Space division multiplexing For wireless communication, multiplexing can be carried out in four dimensions:

space, time, frequency, and code. In this field, the task of multiplexing is to assign space, time, frequency, and code to each communication channel with a minimum of interference and a maximum of medium utilization.

The term communication channel here only refers to an association of sender(s) and receiver(s) who want to exchange data.

Characteristics of communication channels (e.g., bandwidth, error rate)

Figure shows six channels  $k_i$  and introduces a three dimensional coordinate system.

This system shows the dimensions of code  $c$ , time  $t$  and frequency  $f$ .

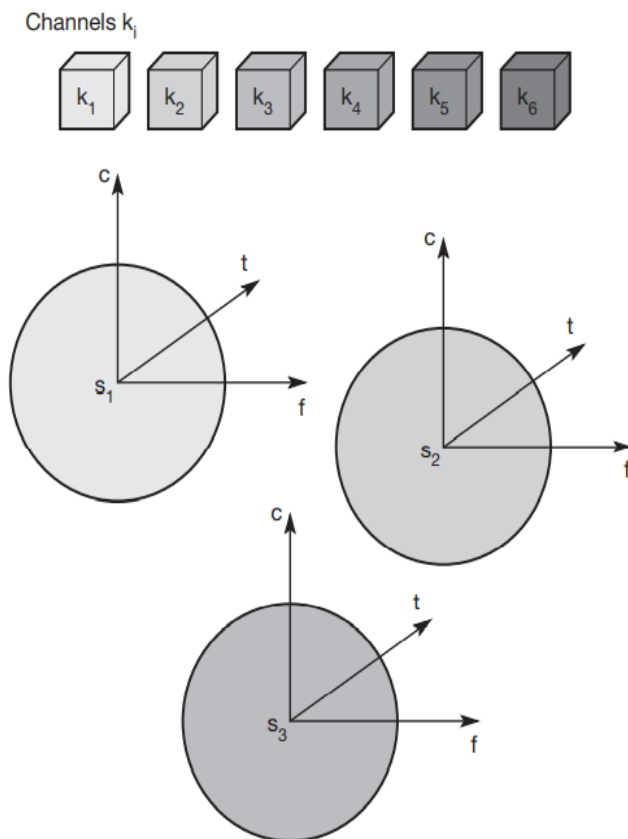
For this first type of multiplexing, space division multiplexing (SDM), the (three dimensional) space  $s_i$  is also shown.

Here space is represented via circles indicating the interference range as introduced in Figure.

How is the separation of the different channels achieved? The channels  $k_1$  to  $k_3$  can be mapped onto the three ‘spaces’  $s_1$  to  $s_3$  which clearly separate the channels and prevent the interference ranges from overlapping.

The space between the interference ranges is sometimes called guard space. Such a guard space is needed in all four multiplexing schemes presented.

**Figure**  
Space division  
multiplexing (SDM)



For the remaining channels ( $k_4$  to  $k_6$ ) three additional spaces would be needed. In our highway example this would imply that each driver had his or her own lane.

Although this procedure clearly represents a waste of space, this is exactly the principle used by the old analog telephone system: each subscriber is given a separate pair of copper wires to the local exchange.

In wireless transmission, SDM implies a separate sender for each communication channel with a wide enough distance between senders.

This multiplexing scheme is used, for example, at FM radio stations where the transmission range is limited to a certain region many radio stations around the world can use the same frequency without interference.

If several radio stations want to broadcast in the same city. Then, one of the following multiplexing schemes must be used (frequency, time, or code division multiplexing).

### **Frequency division multiplexing**

Frequency division multiplexing (FDM) describes schemes to subdivide the frequency dimension into several non-overlapping frequency bands as shown in Figure.

Each channel  $k_i$  is now allotted its own frequency band as indicated. Senders using a certain frequency band can use this band continuously.

Again, guard spaces are needed to avoid frequency band overlapping (also called adjacent channel interference).

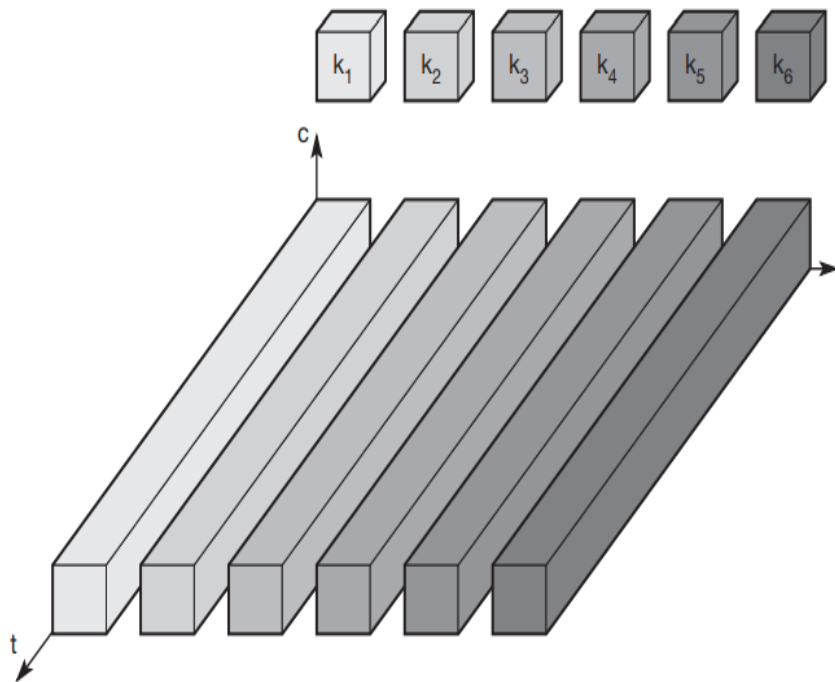
This scheme is used for radio stations within the same region, where each radio station has its own frequency.

This very simple multiplexing scheme does not need complex coordination between sender and receiver:

The receiver only has to tune in to the specific sender

However, this scheme also has disadvantages. While radio stations broadcast 24 hours a day, mobile communication typically takes place for only a few minutes at a time.

Assigning a separate frequency for each possible communication scenario would be a tremendous waste of (scarce) frequency resources



**Figure**  
Frequency division  
multiplexing (FDM)

### Time division multiplexing

A more flexible multiplexing scheme for typical mobile communications is time division multiplexing (TDM).

Here a channel  $k_i$  is given the whole bandwidth for a certain amount of time, i.e., all senders use the same frequency but at different points in time (see Figure). Again, guard spaces, which now represent time gaps, have to separate the different periods when the senders use the medium.

In our highway example, this would refer to the gap between two cars. If two transmissions overlap in time, this is called co-channel interference.

(In the highway example, interference between two cars results in an accident.)

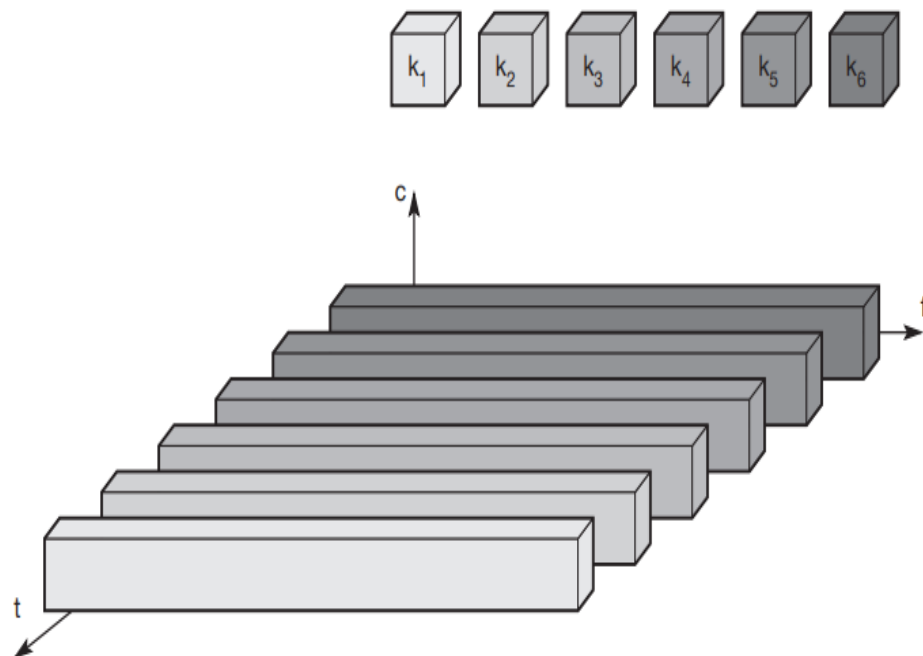
To avoid this type of interference, precise synchronization between different senders is necessary.

This is clearly a disadvantage, as all senders need precise clocks or, alternatively, a way has to be found to distribute a synchronization signal to all senders.

For a receiver tuning in to a sender this does not just involve adjusting the frequency, but involves listening at exactly the right point in time.

However, this scheme is quite flexible as one can assign more sending time to senders with a heavy load and less to those with a light load

**Figure.**  
Time division  
multiplexing (TDM)



Frequency and time division multiplexing can be combined, i.e., a channel  $k_i$  can use a certain frequency band for a certain amount of time as shown in Figure.

Now guard spaces are needed both in the time and in the frequency dimension.

This scheme is more robust against frequency selective interference, i.e., interference in a certain small frequency band.

A channel may use this band only for a short period of time.

The mobile phone standard GSM uses this combination of frequency and time division multiplexing for transmission between a mobile phone and a so-called base station

Two senders will interfere as soon as they select the same frequency at the same time.

However, if the frequency change (also called frequency hopping) is fast enough, the periods of interference may be so small that, depending on the coding of data into signals, a receiver can still recover the original data.

### Code division multiplexing

While SDM and FDM are well known from the early days of radio transmission and TDM is used in connection with many applications, code division multiplexing (CDM) is a relatively new scheme in commercial communication systems.

First used in military applications due to its inherent security features (together with spread spectrum techniques, see section,

it now features in many civil wireless transmission scenarios thanks to the availability of cheap processing power (explained in more detail in section.

Figure shows how all channels  $k_i$  use the same frequency at the same time for transmission.

Separation is now achieved by assigning each channel its own 'code', guard spaces are realized by using codes with the necessary 'distance' in code space, e.g., orthogonal codes.

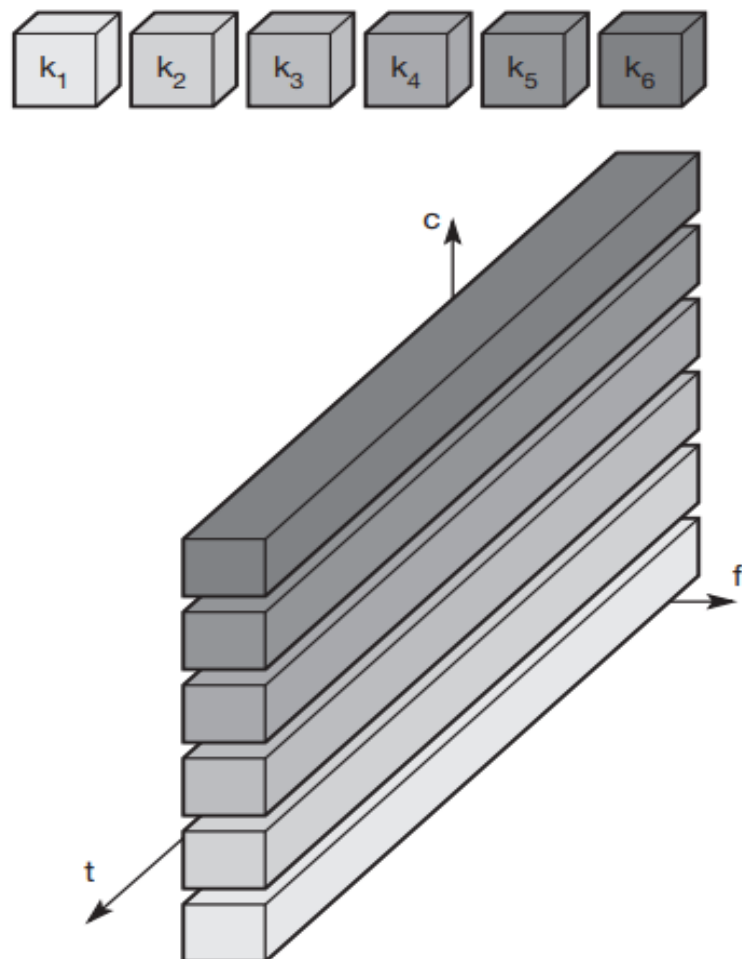
The typical everyday example of CDM is a party with many participants from different countries around the world who establish communication channels,

i.e., they talk to each other, using the same frequency range (approx. 300–6000 Hz depending on a person's voice) at the same time.

If everybody speaks the same language, SDM is needed to be able to communicate (i.e., standing in groups talking with limited transmit power).

But as soon as another code, i.e., another language, is used, one can tune in to this language and clearly separate communication in this language from all the other languages.

**Figure**  
Code division  
multiplexing (CDM)



The main advantage of CDM for wireless transmission is that it gives good protection against interference and tapping.

Different codes have to be assigned, but code space is huge compared to the frequency space.

Assigning individual codes to each sender does not usually cause problems. The main disadvantage of this scheme is the relatively high complexity of the receiver (see section).

A receiver has to know the code and must separate the channel with user data from the background noise composed of other signals and environmental noise.

## Modulation

This section introduced the basic function of a sine wave which already indicates the three basic modulation schemes (typically, the cosine function is used for explanation):

$$g(t) = A_t \cos(2\pi f_t t + \phi_t)$$

This function has three parameters: amplitude  $A_t$ , frequency  $f_t$ , and phase  $\phi_t$  which may be varied in accordance with data or another modulating signal.

For digital modulation, which is the main topic in this section, digital data (0 and 1) is translated into an analog signal (baseband signal).

Digital modulation is required if digital data has to be transmitted over a medium that only allows for analog transmission.

One example for wired networks is the old analog telephone system – to connect a computer to this system a modem is needed.

The modem then performs the translation of digital data into analog signals and vice versa.

Digital transmission is used, for example, in wired local area networks or within a computer

In wireless networks, however, digital transmission cannot be used. Here, the binary bit-stream has to be translated into an analog signal first.

The three basic methods for this translation are amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK).

Apart from the translation of digital data into analog signals, wireless transmission requires an additional modulation, an analog modulation that shifts the center frequency of the baseband signal generated by the digital modulation up to the radio carrier.

For example, digital modulation translates a 1 Mbit/s bit-stream into a baseband signal with a bandwidth of 1 MHz.

There are several reasons why this baseband signal cannot be directly transmitted in a wireless system:

### **Antennas:**

As shown in section, an antenna must be the order of magnitude of the signal's wavelength in size to be effective. For the 1 MHz signal in the example this would result in an antenna some hundred meters high, which is obviously not very practical for handheld devices. With 1 GHz, antennas a few centimetres in length can be used.

**Frequency division multiplexing:** Using only baseband transmission, FDM could not be applied. Analog modulation shifts the baseband signals to different carrier frequencies as required in section

The higher the carrier frequency, the more bandwidth that is available for many baseband signals.

**Medium characteristics:** Path-loss, penetration of obstacles, reflection, scattering, and diffraction – all the effects discussed in section depend heavily on the wavelength of the signal.

Depending on the application, the right carrier frequency with the desired characteristics has to be chosen:

Long waves for submarines, short waves for handheld devices, very short waves for directed microwave transmission etc

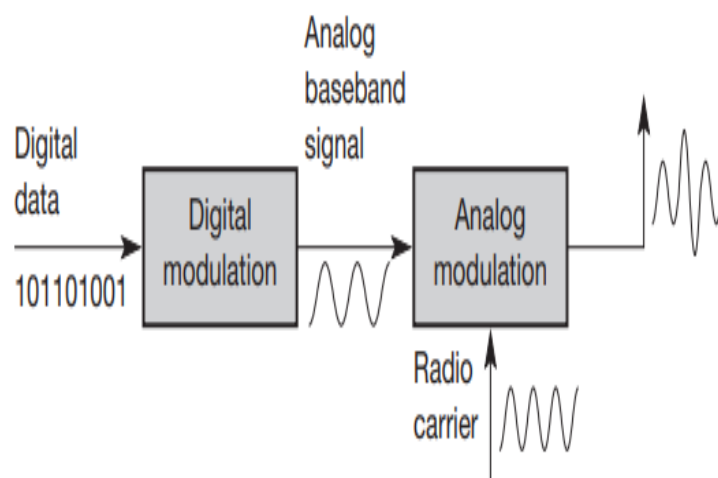
As for digital modulation, three different basic schemes are known for analog modulation: amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM).

Figure shows a (simplified) block diagram of a radio transmitter for digital data.

The first step is the digital modulation of data into the analog baseband signal according to one of the schemes presented in the following Wireless transmission.

The analog modulation then shifts the center frequency of the analog signal up to the radio carrier. This signal is then transmitted via the antenna

**Figure**  
Modulation in  
a transmitter



The receiver (see Figure receives the analog radio signal via its antenna and demodulates the signal into the analog baseband signal with the help of the known carrier.

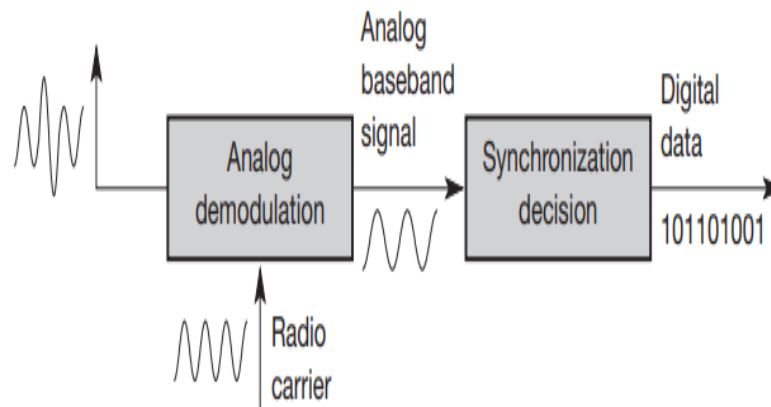
This would be all that is needed for an analog radio tuned in to a radio station. (The analog baseband signal would constitute the music.) For digital data, another step is needed

. Bits or frames have to be detected, i.e., the receiver must synchronize with the sender.

How synchronization is achieved, depends on the digital modulation scheme.

After synchronization, the receiver has to decide if the signal represents a digital 1 or a 0, reconstructing the original data.

**Figure**  
Demodulation and  
data reconstruction  
in a receiver



## Amplitude shift keying

Figure illustrates amplitude shift keying (ASK), the most simple digital modulation scheme.

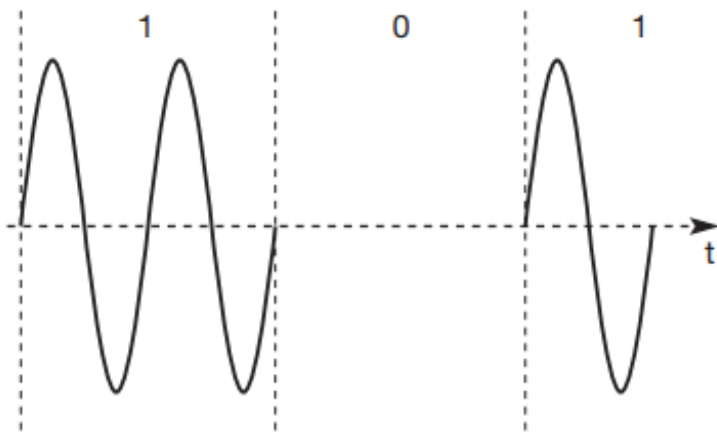
The two binary values, 1 and 0, are represented by two different amplitudes. In the example, one of the amplitudes is 0 (representing the binary 0).

This simple scheme only requires low bandwidth, but is very susceptible to interference. Effects like multi-path propagation, noise, or path loss heavily influence the amplitude.

In a wireless environment, a constant amplitude 48 Mobile communications Analog modulation Digital modulation Analog baseband signal Radio carrier Digital data 101101001

see Figure Modulation in a transmitter Analog demodulation Synchronization decision Analog baseband signal Radio carrier Digital data 101101001

See Figure Demodulation and data reconstruction in a receiver cannot be guaranteed, so ASK is typically not used for wireless radio transmission



**Figure**  
Amplitude shift  
keying (ASK)

### Frequency shift keying

A modulation scheme often used for wireless transmission is frequency shift keying (FSK) (see Figure

The simplest form of FSK, also called binary FSK (BFSK), assigns one frequency  $f_1$  to the binary 1 and another frequency  $f_2$  to the binary 0.

A very simple way to implement FSK is to switch between two oscillators,

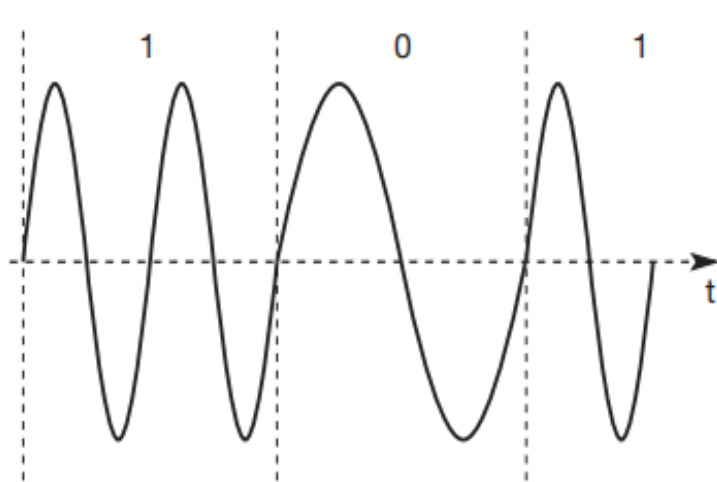
One with the frequency  $f_1$  and the other with  $f_2$ , depending on the input.

To avoid sudden changes in phase, special frequency modulators with continuous phase modulation, (CPM) can be used. Sudden changes in phase cause high frequencies, which is an undesired side-effect.

A simple way to implement demodulation is by using two bandpass filters, one for  $f_1$  the other for  $f_2$ .

A comparator can then compare the signal levels of the filter outputs to decide which of them is stronger.

FSK needs a larger bandwidth compared to ASK but is much less susceptible to errors.

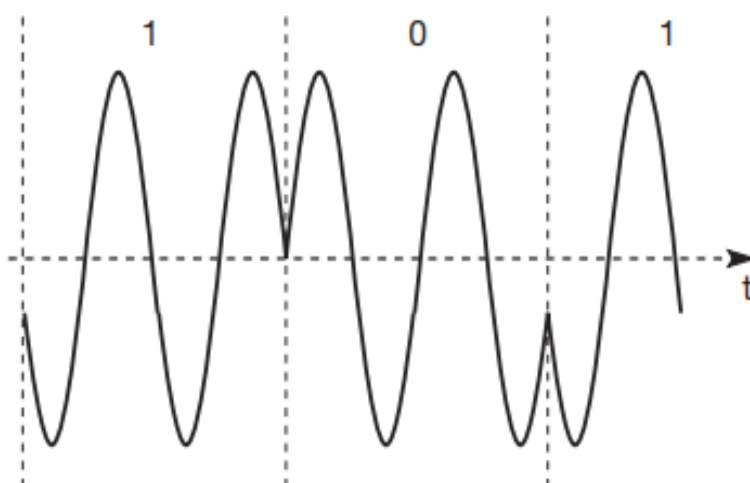


**Figure**  
Frequency shift  
keying (FSK)

### Phase shift keying

Finally, phase shift keying (PSK) uses shifts in the phase of a signal to represent data. Figure shows a phase shift of  $180^\circ$  or  $\pi$  as the 0 follows the 1 (the same happens as the 1 follows the 0).

This simple scheme, shifting the phase by  $180^\circ$  each time the value of data changes, is also called binary PSK (BPSK).



**Figure**  
Phase shift  
keying (PSK)

## **Spread spectrum**

**What do you mean by spread spectrum?**

**Definition(s):**

Telecommunications techniques in which a signal is transmitted in a bandwidth considerably greater than the frequency content of the original information.

Frequency hopping, direct sequence spreading, time scrambling, and combinations of these techniques are forms of spread spectrum.

What are the benefits of spread spectrum in mobile computing?

**Increase in operating distances:** Spread spectrum modulated signals possess non-interference properties and have higher transmitted power.

With these higher transmit power capabilities, spread spectrum signals can be transmitted to longer distances compared to analog wireless communication.

What is application of spread spectrum?

Current applications of spread spectrum technology include wireless LANs (local area networks), bar code scanners, and microphones.

This technology improves the efficiency and effectiveness of business processes, many of which are finding that wireless communications are requisite for success.

What is the example of spread spectrum?

**CDMA—Code Division Multiple Access**

In that sense, spread spectrum is a CDMA access. The key must be defined and known in advance at the transmitter and receiver ends.

Growing examples are IS-95 (DS), IS-98, Bluetooth, and WLAN.

## **What are the types of spread spectrum?**

There are four techniques of spread spectrum namely direct sequence spread spectrum (DSSS), frequency hopping spread spectrum (FHSS), chirp spread spectrum (CSSS) and time hopping spread spectrum (THSS).

Each of these techniques is described, with a brief mention about its basic mechanism

## **What are the features of spread spectrum?**

The spread spectrum is a type of modulation where modulated signal BW is much larger than the baseband signal BW

I.e. spread spectrum is a wide band scheme. A special code (pseudo noise) is used for spectrum spreading and the same code is to be used to despread the signal at the receiver.

## **What is narrowband vs. spread spectrum?**

Narrow band includes a modulation technique in which a signal is transmitted as a radio frequency (RF) signal at or within a frequency band.

Spread spectrum includes a modulation technique in which a signal is transmitted as an RF signal spread over a range of frequencies

As the name implies, spread spectrum techniques involve spreading the bandwidth needed to transmit data – which does not make sense at first sight.

Spreading the bandwidth has several advantages. The main advantage is the resistance to narrowband interference.

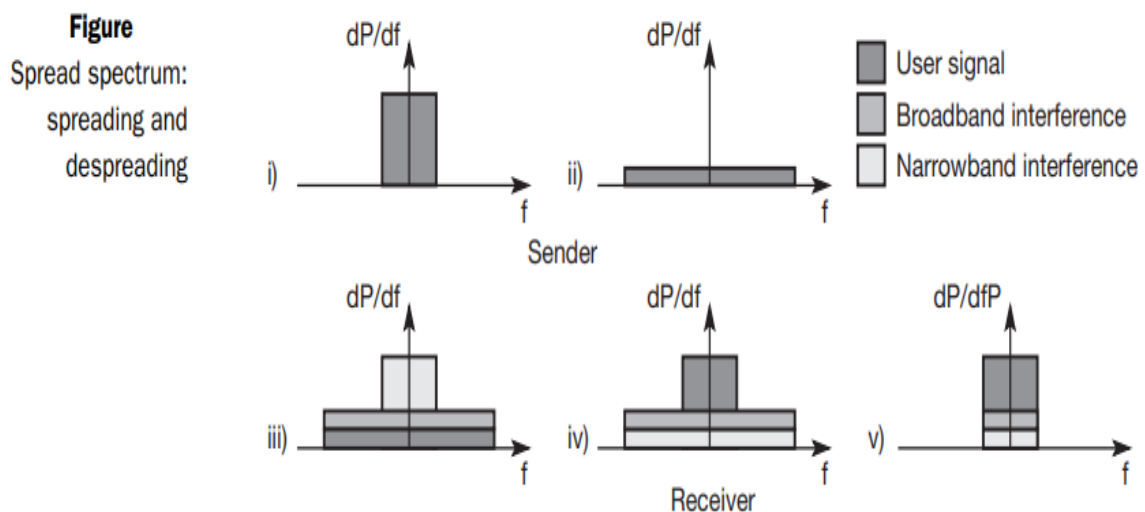
In Figure , diagram i) shows an idealized narrowband signal from a sender of user data (here power density  $dP/df$  versus frequency  $f$ ).

The sender now spreads the signal in step ii), i.e., converts the narrowband signal into a broadband signal. The energy needed to

transmit the signal (the area shown in the diagram) is the same, but it is now spread over a larger frequency range.

The power level of the spread signal can be much lower than that of the original narrowband signal without losing data.

Depending on the generation and reception of the spread signal, the power level of the user signal can even be as low as the background noise.



During transmission, narrowband and broadband interference add to the signal in step iii).

The sum of interference and user signal is received. The receiver now knows how to despread the signal, converting the spread user signal into a narrowband signal again,

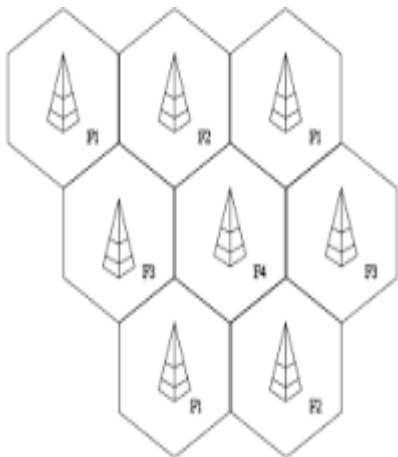
while spreading the narrowband interference and leaving the broadband interference.

In step v) the receiver applies a band pass filter to cut off frequencies left and right of the narrowband signal.

Finally, the receiver can reconstruct the original data because the power level of the user signal is high enough.

## Cellular systems

What is cellular system in mobile computing?



A cellular network or mobile network is **a communication network where the link to and from end nodes is wireless.**

The network is distributed over land areas called "cells", each served by at least one fixed-location transceiver (typically three cell sites or base transceiver stations).

What is called cellular system?

A Cellular network or Mobile network is **a radio network distributed over land areas called cells**, each served by at least one fixed-location transceiver, known as a cell site or base station.

**What are the basic cellular systems?**

There are two basic cellular systems; one is the **circuit-switched system** and the other is the packet-switched system.

**What is cellular system and its advantages?**

**Advantages of the cellular system:**

**Reduced set up times.** It reduced the interference which increases the total system capacity.

It improved S/N ratio. Reduced the cluster size. More robust against the failure of single components.

### **What is the importance of cellular system?**

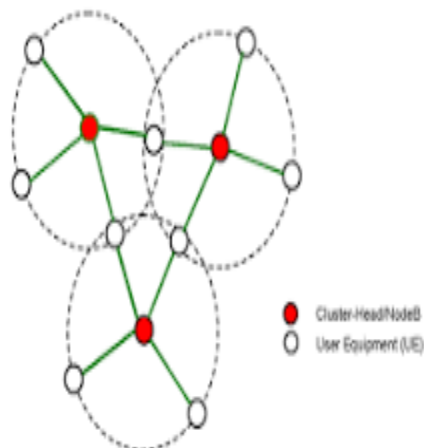
Cellular technologies offer additional ways for networking of mobile devices.

The worldwide coverage of cellular networks means that such facilities are often available in places where other types of networking, such as local area networks (LANs) and wireless LANs, cannot reach.

### **What are the disadvantages of cellular system?**

#### **Disadvantages:**

- As communication is done through open space, it is less secure.
- Unreliability.
- More open to interference.
- Increased chance of jamming.
- Transmission speed is comparably less.
- it has a limited amount of bandwidth for communication and breaches of network security.
- Wireless networks can be easily hacked.
  - What is cellular topology?
  -



- Cellular topology

- **Each cell represents a portion of the total network area.**  
Devices that are in the cell communicate through a central hub.  
Hubs in different cells are interconnected.
- They route data across the network and provide a complete network infrastructure.

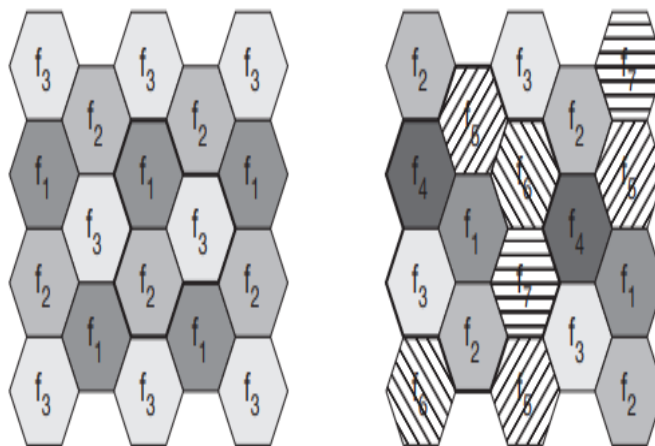
Cellular systems for mobile communications implement SDM. Each transmitter, typically called a base station, covers a certain area, a cell.

Cell radii can vary from tens of meters in buildings, and hundreds of meters in cities, up to tens of kilometres in the countryside.

The shape of cells are never perfect circles or hexagons (as shown in Figure , but depend on the environment (buildings, mountains, valleys etc.), on weather conditions, and sometimes even on system load.

Typical systems using this approach are mobile telecommunication systems where a mobile station within the cell around a base station communicates with this base station and vice versa

**Figure .**  
Cellular system  
with three and seven  
cell clusters



### **Advantages of cellular systems with small cells are the following**

Higher capacity

Less transmission power

Local interference only:

Robustness:

## **Small cells also have some disadvantages**

Infrastructure needed

Handover needed

Frequency planning

## **Frequency Management**

Frequency management refers to designating setup channels and voice channels (done by the FCC), numbering the channels (done by the FCC), and grouping the voice channels into subsets (done by each system according to its preference).

### **What is frequency management?**

The function of frequency management is to divide the total number of available channels into subsets which can be assigned to each cell either in a fixed fashion or dynamically (i.e., in response to any channel among the available channels).

### **How many setup channels are there in frequency management scheme?**

The 42 set-up channels are assigned as follows. Channels 313-333 block A Channels 334-354 block B The voice channels are assigned as follows. Figure 8.2 New additional spectrum allocations.

### **What are channels in frequency?**

A channel is **the band of RF used for the wireless communication**. Each IEEE wireless standard specifies the channels that can be used.

The 802.11a standard specifies radio frequency ranges between 5.15 and 5.875GHz.

In contrast, 802.11b and 802.11g standards operate in the 2.4 to 2.497GHz range

What is different between channel and frequency?

Channel is a number assigned to a frequency tuner so humans can remember a simple number and where the information is for the tuner to show. The frequency is where the information is riding it is a carrier for the channel. For example channel 2 analog information is at 55.25 mhz.

## **Frequency management**

Designating set-up channels and voice channels (done by the FCC),

Numbering the channels (done by the FCC), and

Grouping the voice channels into subsets (done by each system according to its preference).

## **What is Channel Assignment**

- Channel assignment is the process of assigning separate orthogonal channel or partially over-lapped orthogonal channels to all the nodes in the communication range. ...
- Channel assignment means assigning channels or spectrum bands to radio interfaces for communication.

What is channel assignment and its types?

Channel Assignment Strategies are designed in such a way that there is efficient use of frequencies, time slots and bandwidth.

There are three types of Channel Assignment Strategies they are: **Fixed, Dynamic, and Hybrid Channel Assignment.**

## What are channel assignment strategies in mobile communication?



Channel Allocation means to allocate the available channels to the cells in a cellular system. When a user wants to make a call request then by using channel allocation strategies their requests are fulfilled.

## What is channel in mobile computing?

A channel is used for information transfer of, for example, a digital bit stream, from one or several senders to one or several receivers.

A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second.

## What is the advantage of channel assignment?

Advantages. Dynamic channel allocation schemes allot channels as needed.

This results in optimum utilization of network resources. There are less chances of denial of services and call blocking in case of voice transmission

## What are the three channel allocation or channel assignment algorithms?

There are three main types of channel allocation schemes (a) Fixed channel allocation (FCA) (b) Dynamic channel allocation (DCA), (c) Hybrid channel allocation (HCA)

## What are the three data channels?

Three commonly used guided/wired media for data transmission are twisted pair, coaxial cable, and fiber optic cable.

Twisted-pair and coaxial cable carry the electric signals whereas the optical fiber cable carries the light signals.

Channel Assignment strategies means to allocate the available channels to the cells in a cellular system whenever a user wants to make a call request then by using channel assignment strategies their requests are fulfilled.

Channel Assignment Strategies are designed in such a way that there is efficient use of frequencies, time slots and bandwidth.

There are three types of Channel Assignment Strategies

They are: Fixed, Dynamic, and Hybrid Channel Assignment.

- **Fixed Channel Assignment (FCA):** It is a strategy in which fixed number of channels or voice channels is allocated to the cells.
- Once the channels are allocated to the specific cells then they cannot be changed. Fixed channel assignment is very simple and requires least amount of processing.
- Cells in this strategy are allowed to borrow channels from adjacent cells if their channels are fully occupied while adjacent cells have free channels.
- No interference occurs by moving the channel from one cell to another.
- **Dynamic Channel Assignment (DCA):** Dynamic Channel Assignment is a strategy in which channels are not permanently allocated to the cells.
- When a User makes a call request then Base Station send that request to the MSC (Mobile Station Cente) for the allocation of channels or voice channels.

- Each time a call request is made, serving BS requests a channel from the MSC.
- MSC assigns a channel only if it is not used and if it will not cause co-channel interference with any cell in range.
- In this MSC has to collect real time data on channel occupancy, traffic distribution, radio signal strength indication of all channels on continuous basis, thus increasing the computational load on MSC.
- **Hybrid Channel Assignment (HCA):** Hybrid Channel Allocation is a combination of both Fixed Channel Allocation (FCA) and Dynamic Channel Allocation (DCA).
- In this total number of channels or voice channels are divided into fixed and dynamic sets.
- If a user make a call then first fixed set of channels are utilized but if all the fixed sets are busy then dynamic sets are used.
- The main purpose of HCA is to work efficiently under heavy traffic.

## **Types of Handoff Hand their characteristics**

Handoff Types. Handoff can be categorized as hard handoff, soft handoff, and softer handoff.

The hard handoff can be further divided into intrafrequency and interfrequency hard handoffs.

During the handoff process, if the old connection is terminated before making the new connection, it is called a hard handoff.

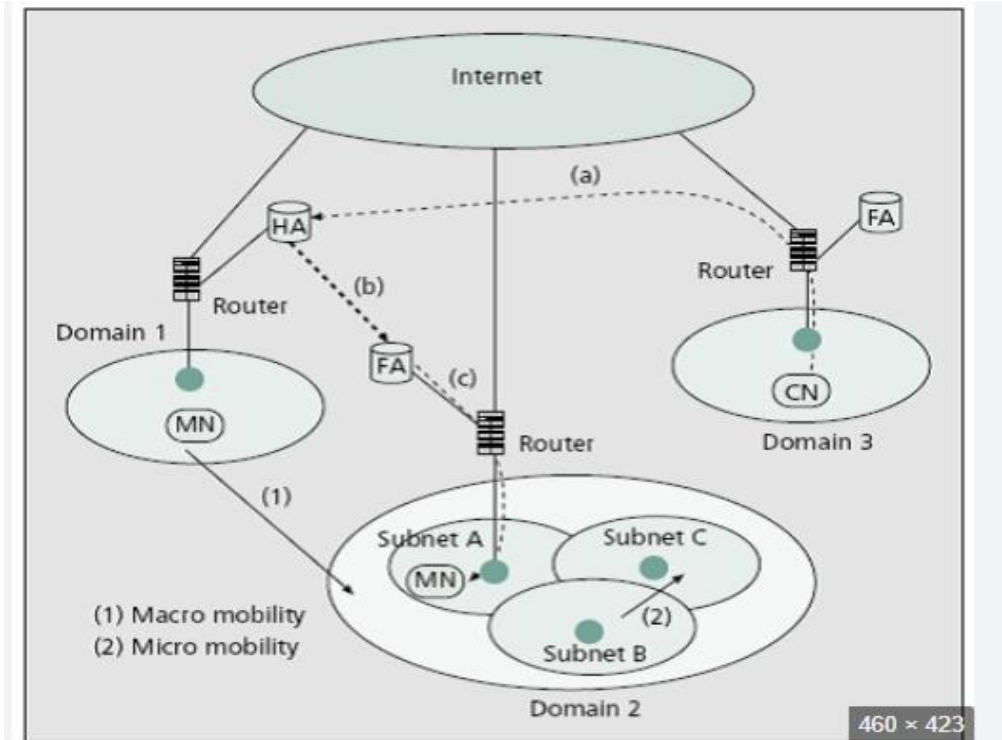
What are the types of handover in mobile computing?

There are two types of handover, **vertical and horizontal**. Horizontal handover occurs when a device moves within one type of network technology under one operator. For instance a mobile phone user moving within their provider's network must switch cellular towers as they move in and out of range of different towers.

What is hand off in mobile computing?

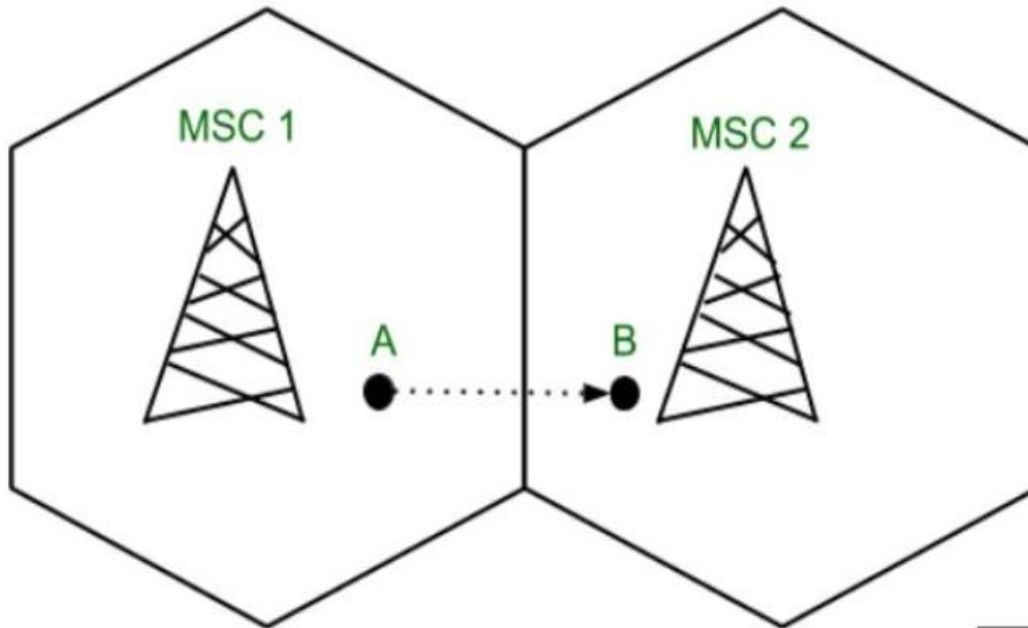
**Process of transferring a mobile telephone call from one cell to another without dropping the call.**

What are the different types of handoffs in mobility management?



Depending on the movement of the mobile device, it may undergo various types of handoff. In a broad sense, handoffs may be of two types: (i) **intra-system handoff (horizontal handoff)** and (ii) **inter-system handoff (vertical handoff)**. Handoffs in homogeneous networks are referred to as intra-system handoffs.

What are the two types of handoff?

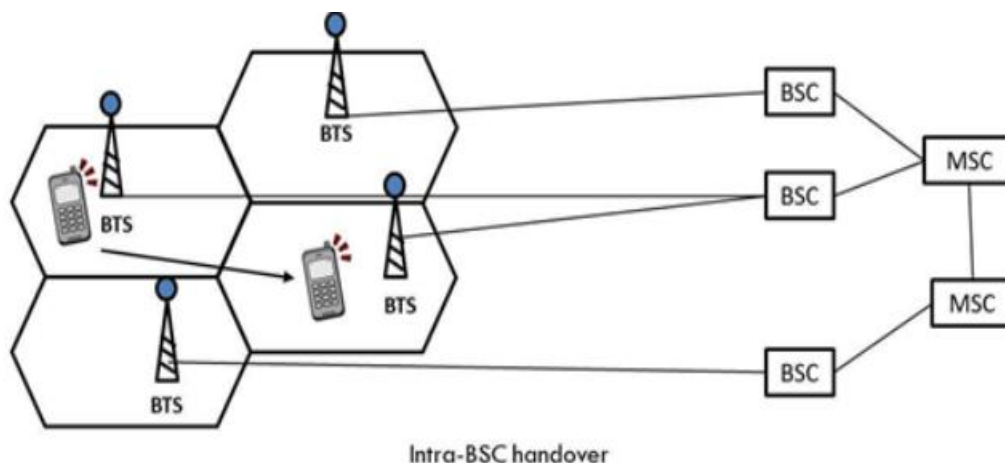


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### Types of Handoff:

- Hard Handoff: When there is an actual break in the connectivity while switching from one Base Station to another Base Station. ...
- Soft Handoff: In Soft Handoff, at least one of the links is kept when radio signals are added or removed to the Base Station.
  - What are handoffs in a process?
  - Hand-offs are **the moments of communication between teams or individuals as they pass information and/or processes to one another**. In the context of the business process, the hand-off is the moment when the responsibility for a particular task passes from one person to another.

What are the four types of handover?



## **What is Hand-off ? List different types of hand-off.**

- When a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station. This procedure is called handoff.
  - The handoffs are of following types:
    1. Hard Handoff
    2. Soft Handoff
    3. Queued Handoff
    4. Delayed Handoff
    5. Intersystem Handoff
    6. Intrasystem Handoff
    7. Network controlled Handoff (NCHO)
    8. Mobile Assisted Handoff (MAHO)

### **Hard Handoff:**

- The definition of a hard handover or handoff is one where an existing connection must be broken before the new one is established.
- Hard handoff allocate different frequency of user.
- In hard hand off a handset always communicates with one BS at any given time
- Hard handoff is typically used in TDMA and FDMA systems.
- Hard handoff is not very complicated.
- Since the radio link between the BS and the handset is broken before it is connected in hard handoff, the link transfer may fail due to long network response time even if radio channels are available in the new BS.

### **Soft handoff:**

- Soft handoff is defined as a handover where a new connection is established before the old one is released.
- Soft hand off allocate same frequency.
- In soft handoff a handset may connect up to three or four radio links at the same time.

- Soft handoff used in CDMA and some TDMA systems.
- Soft handoff is more complicated than hard handoff.
- On the other hand, soft handoff degrades channel availability because a handset may consume multiple radio channels.

### **Delayed handoff**

- A Delayed handoff is a two hand off level algorithm. It provides more opportunity for a successful hand off.
- The MTSO always handles the handoff first and the originating calls second. If no neighboring cells are available after the second handoff level is reached, the call continues until the signal strength drops below the threshold level then the call is dropped.
- Lower handoffs help in handling call processing more adequately.
- It makes the hand off occur at the proper location and eliminates possible interference in the system.

### **Queued hand off:**

- Queued hand off is more effective than two threshold level handoffs.
- The MTSO will queue the requests of handoff calls instead of rejecting them if the new cell sites are busy..
- With Queuing of originating calls only, the probability of blocking is reduced.
- It is effective when implementing a simple queue for hand off calls which reduces call drops.

### **Intersystem Handoff:**

- In Intersystem Handoff, If during an ongoing call a mobile unit moves from one cellular system to a different cellular system which is controlled by different MTSO, a handoff procedure which is used to avoid dropping of call referred as Intersystem Handoff takes place.
- An MTSO engages in this handoff system when a mobile signal becomes weak in a given cell and MTSO cannot find another

cell within its system to which it can transfer the call then in progress.

### **Mobile Assisted Handoff (MAHO)**

- In Mobile Assisted Handoff (MAHO) every mobile station measures the received power from surrounding base stations and continually reports the results of these measurements to the serving base station.
- A handoff is initiated, when the power received from the base station of a neighboring cell begins to exceed the power received from the current base station by a certain level or for a certain period of time.
- In MAHO method call handed over between base stations is much faster than first generation analog systems .As handoff measurements are made by each mobile . MSC no longer constantly monitors signal strengths