18ECO127T :: 5G Technology - An Overview::

Familiarize the underlying principles, concepts, and architecture of 5G wireless communication systems. Perceive the knowledge of 5G network Architecture. Explore the different technologies for radio access in 5G   Explore the 5G Security and Privacy, and threats and countermeasures in 5GDevelop skills to design 5G networks based on real-world scenarios; Smart Cities and Autonomous Vehicles

Comprehend the underlying principles, concepts of wireless communication and 5G Technology, its utilization to 5G Use Cases,Apply the knowledge of Core a Network and Radio Access Network of 5G .and the concept of network slicing and virtualizationApply the knowledge radio access technologies like New Radio and Millimeter wave communicationExplore the unique requirements and challenges associated with 5G Security and Privacy.Design the integration of 5G network and IoT

18ECO127T
5G Technology – An Overview

MODULE 1:
Introduction to Wireless Communication Fundamentals and 5G Technology

Wireless Communication Fundamentals: Overview of Wireless Communication Systems;

Frequency Bands and Spectrum Allocation in 5G;

Multiple Access Techniques: FDMA, TDMA, CDMA

Modulation Techniques: QPSK, QAM, OFDM

Introduction to 5G Technology: Evolution of Cellular Networks: From 1G to 5G

Key Features and Objectives of 5G

5G Use Cases and Applications

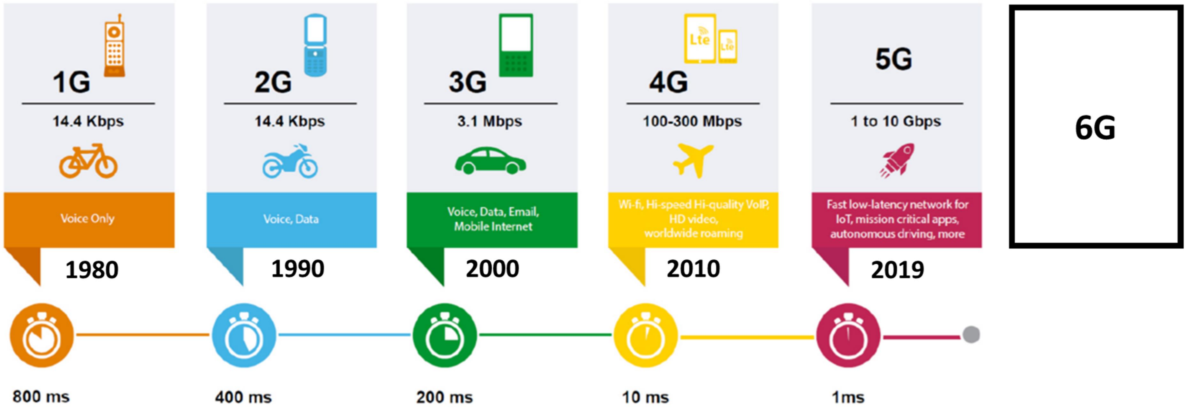
5G Use Cases and Applications

Challenges and Opportunities in 5G Deployment

Overview of 5G Technology

5th Generation mobile network,5G is a new global wireless standard after 1G, 2G, 3G, and 4G networks

3rd Generation Partnership Project (3GPP), the industry organization that defines the global specifications for 3G UMTS (including HSPA), 4G LTE, and 5G technologies



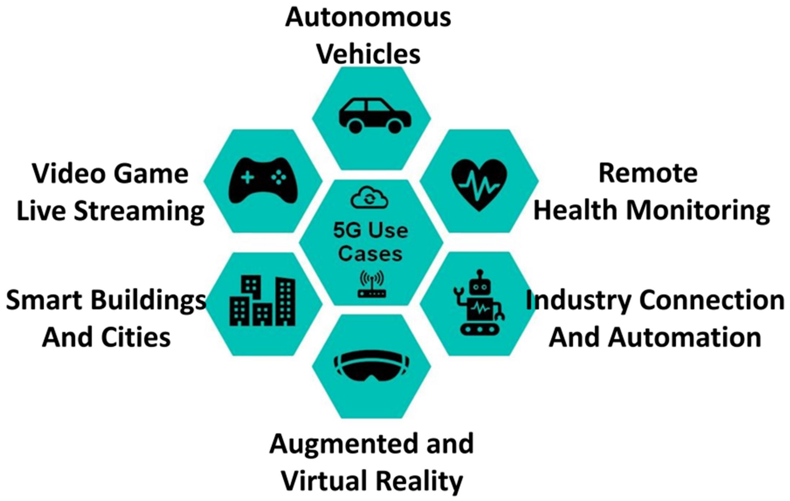
3 Key Point

- ❑ Technology:
- 5G NR (New Radio) is a new radio access technology (RAT) developed by 3GPP for the 5G (fifth generation) mobile network.
- Based on OFDM (Orthogonal Frequency Division Multiplexing)
- It also uses wider bandwidth technologies such as sub-6 GHz and milimeter wave (mmWave)
- ❑ Frequency Specifications:
- Can operate in both lower bands (e.g., sub-6 GHz) as well as mmWave (e.g., 24 GHz and up)
- In India now: sub-6 GHz
- This will bring extreme capacity, multi-Gbps throughput, and low latency
- ❑ Operation:
- Not only faster and better than 4G, but can be expanded to mission-critical communications and connecting the massive IoT

How 5G is better than 4G?

- ❑ 5G is a Unified Platform that is more capable than 4G
  - Not only for Broadband Telephone but also for mission-critical communications and connecting the massive IoT
  - Supports all Spectrum types (licensed, shared, unlicensed) and bands (low, mid, high)
- ❑ 5G uses Spectrum Better than 4G
  - Can use in bands - from low bands below 1 GHz, to mid bands from 1 GHz to 6 GHz, to high bands known as millimeter wave (mmWave).
- ❑ 5G is Faster than 4G:
  - Delivers up to 20 Gigabits-per-second (Gbps) peak data rates and 100+ Megabits-per-second (Mbps) average data rates
- ❑ 5G has More Capacity than 4G
  - Support a 100x increase in traffic capacity and network efficiency
- ❑ 5G has Lower Latency than 4G
  - 10x decrease in end-to-end latency

Potential Applications of 5G

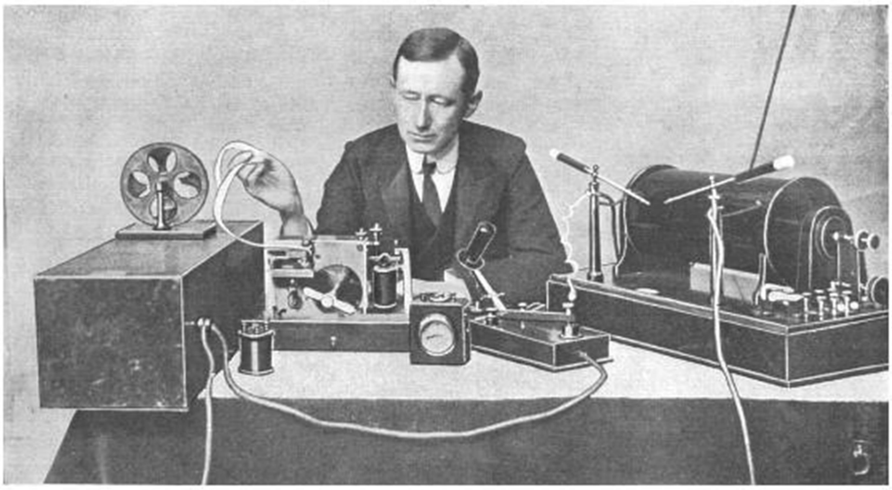


Challenges in 5G

- Frequency Bands:
  - 5G NR: for sub-6 GHz and millimeter-wave range
  - Design of hardware at millimeter waves are much complex than low frequency range
  - To support interoperability -> Needs multiband -> Addition of more band increases complexity
- High Data Volume:
  - To support high resolution video calling, live streaming, downloading -> huge volume data support is required
- MIMO Technology:
  - For High data speed -> MIMO/massive MIMO is need -> Algorithms becomes complex
- Beamforming:
  - Complex task to locate each devices under a particular cell
  - Needs high level processing at base stations High Data Volume:
  - To support high resolution video calling, live streaming, downloading -> huge volume data support is required
- D2D Communication:
  - Complex data transmission protocols required to implement this
- Ultra Low Latency:
  - Latency less than 1 millisecond is required - else critical services to be affected
- Security and Privacy:
  - Ensuring end-to-end security and privacy among multiples devices is challenging

Wireless Communication Fundamentals:
Overview of Wireless Communication Systems

Wireless communication, is a field that has been around for over a hundred years, starting around 1897 with Marconi's successful demonstrations of wireless telegraphy.


MARCONI READING A MESSAGE

By 1901, radio reception across the Atlantic Ocean had been established; thus rapid progress in technology has also been around for quite a while.

In the intervening hundred years, many types of wireless systems have flourished, and often later disappeared.

For example, television transmission,Now been replaced by DTH service,OTT services, Internet etc

In its early days, T.V. was broadcast by wireless radio transmitters, which is increasingly being replaced by cable transmission and then again replaced by DTH services and finally Now a days Fiber trend is going on.


In the first, wireless technology (RF transmission) became outdated when a wired distribution network (UHV-CA-TV) was installed;

in the second, a CA-TV is been replaced by wireless Technology (DTH) Now Today DTH services is replaced by (optical fiber) Technology.

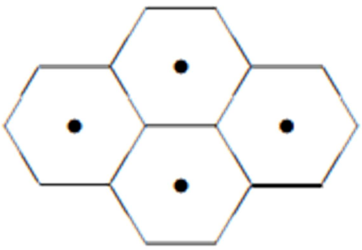
The point of these examples is that there are many situations in which there is a choice between wireless and wire technologies, and the choice often changes when the new technologies become available.

Here in this course we will concentrate on cellular networks, both because they are of great current interest and also because the features of many other wireless systems can be easily understood as special cases or simple generalizations of the features of cellular networks.

A cellular network consists of a large number of wireless subscribers

who have cellular telephones (users), that can be used in cars, in buildings, on the street, or almost anywhere.

There are also a number of fixed base stations, arranged to provide coverage of the subscribers.

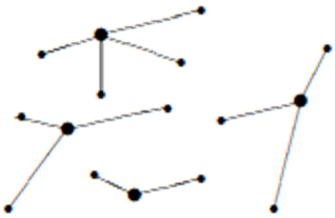


The area covered by a base station, i.e., the area from which incoming calls reach that base station, is called a cell.

One often pictures a cell as a hexagonal region with the base station in the middle.

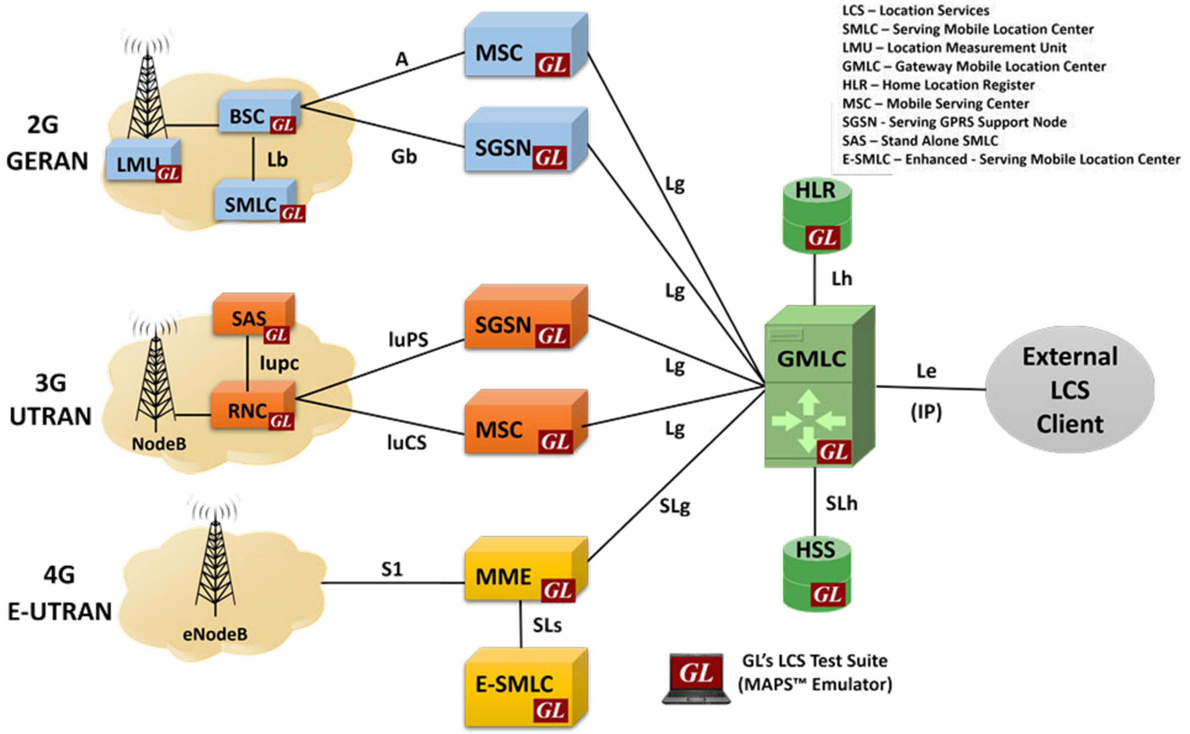
One then pictures a city or region as being broken up into a hexagonal lattice of cells

In reality,
the base stations are placed somewhat irregularly, depending on the location of places such as building tops or hill tops that have good communication coverage and that can be leased or bought



Similarly, mobile users connected to a base station are chosen by good communication paths rather than geographic distance

Call Example:



When a user makes a call, it is connected to the base station to which it appears to have the best path (often but not always the closest base station).

The base stations in a given area are then connected to a mobile telephone switching office (MTSO, also called a mobile switching center MSC) by high speed wire connections or microwave links.

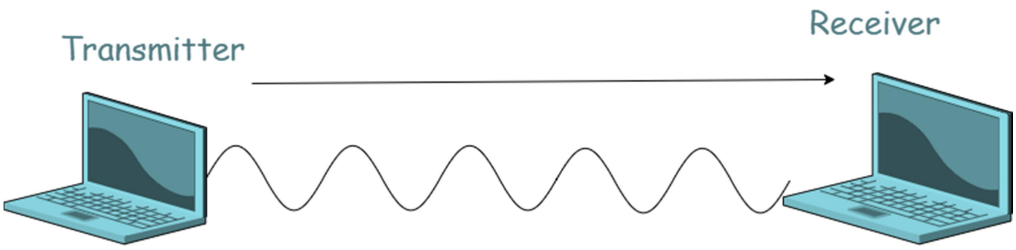
The MTSO is connected to the public wired telephone network.

Thus an incoming call from a mobile user is first connected to a base station and from there to the MTSO and then to the wired network.

From there the call goes to its destination, which might be an ordinary wire line telephone, or might be another mobile subscriber.

Thus, we see that a cellular network is not an independent network, but rather an appendage to the wired network.

Basics of Wireless Communication:



Unidirectional Communication

Wireless communication takes places over free space through RF (radio frequency), one device, a Transmitter, sends signal to another device, a Receiver.

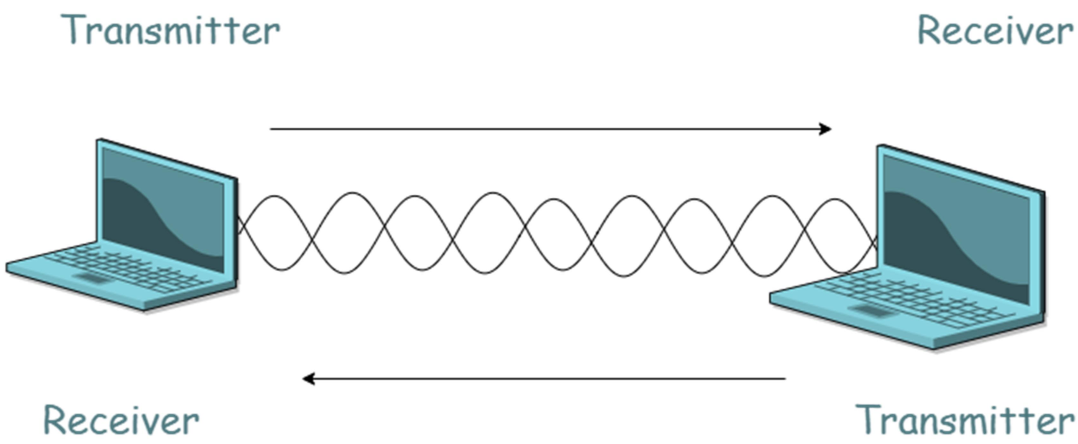
Two devices (transmitter and receiver) must use same frequency (or channel) to be able to communicate with each other.

If a large number of wireless devices communicate at same time, radio frequency can cause interference with each other.

Interference increases as no of devices increases.

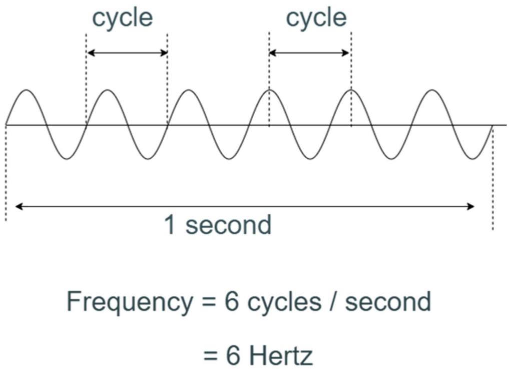
Wireless communication is always half duplex as transmission uses same frequency or channel.

To achieve full duplex mode, devices use different frequency or channel of transmission and receiving of signals.



Bidirectional Communication

Radio Frequency:



- In free space, the sender (transmitter) sends an alternating current into a section of wire (an antenna).
- This sets up a moving electric and magnetic fields that travel as travelling waves.
- The electric and magnetic field moves along each other at a right angle to each other as shown.
- The signal must keep changing or alternating by cycle up and down to keep electric and magnetic field cyclic and pushing forward.
- The no of cycles a wave taking in a second is called Frequency of the wave.

Features of Wireless Communication:

1. The evolution of wireless technology has brought many advancements with its effective features.
2. The transmitted distance can be anywhere between a few meters (for example, a television's remote control) and thousands of kilometers (for example, radio communication).
3. Wireless communication can be used for cellular telephony, wireless access to the internet, wireless home networking, and so on.
4. Other examples of applications of radio wireless technology include GPS units, garage door openers, wireless computer mice, keyboards and headsets, headphones, radio receivers, satellite television, broadcast television and cordless telephones.

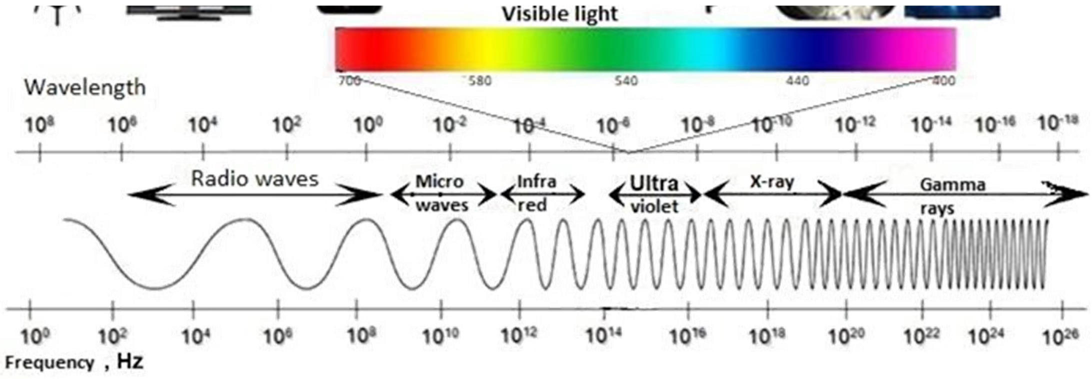
Wireless - Advantages:

Wireless communication involves transfer of information without any physical connection between two or more points.

Because of this absence of any 'physical infrastructure', wireless communication has certain advantages.

- Cost effectiveness
- Flexibility
- Convenience
- Speed
- Accessibility
- Constant connectivity

Frequency Bands and Spectrum Allocation in 5G

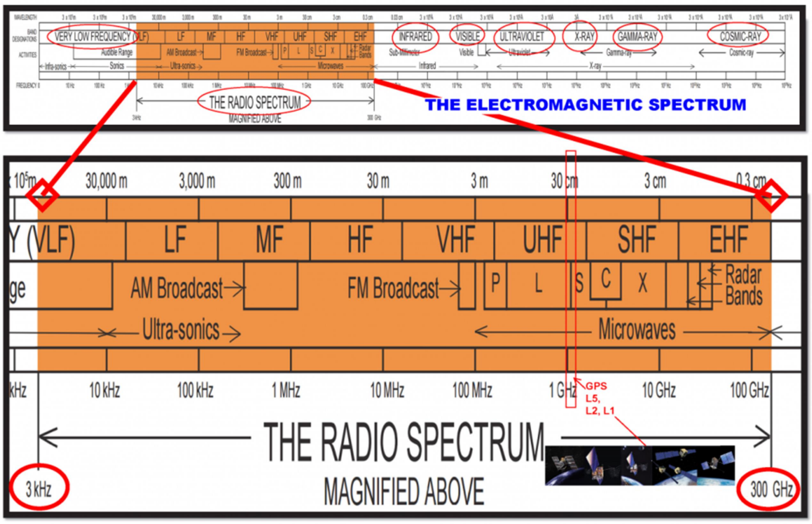


The electromagnetic spectrum is the set of all frequencies and the energy transmitted over electromagnetic waves is highly regulated based on frequency bands.

A frequency band can be described as a collection of frequencies ranging from a lower frequency to a higher frequency.

The radio spectrum is the part of the electromagnetic spectrum with frequencies from 3 Hz to 3,000 GHz.

Electromagnetic waves in this frequency range, called radio waves, are widely used in modern technology, particularly in telecommunication..

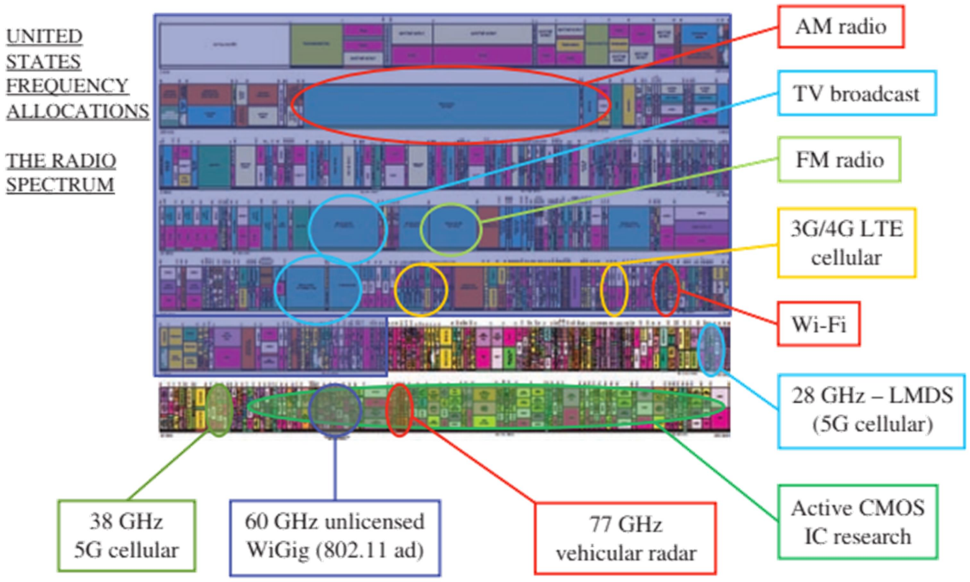


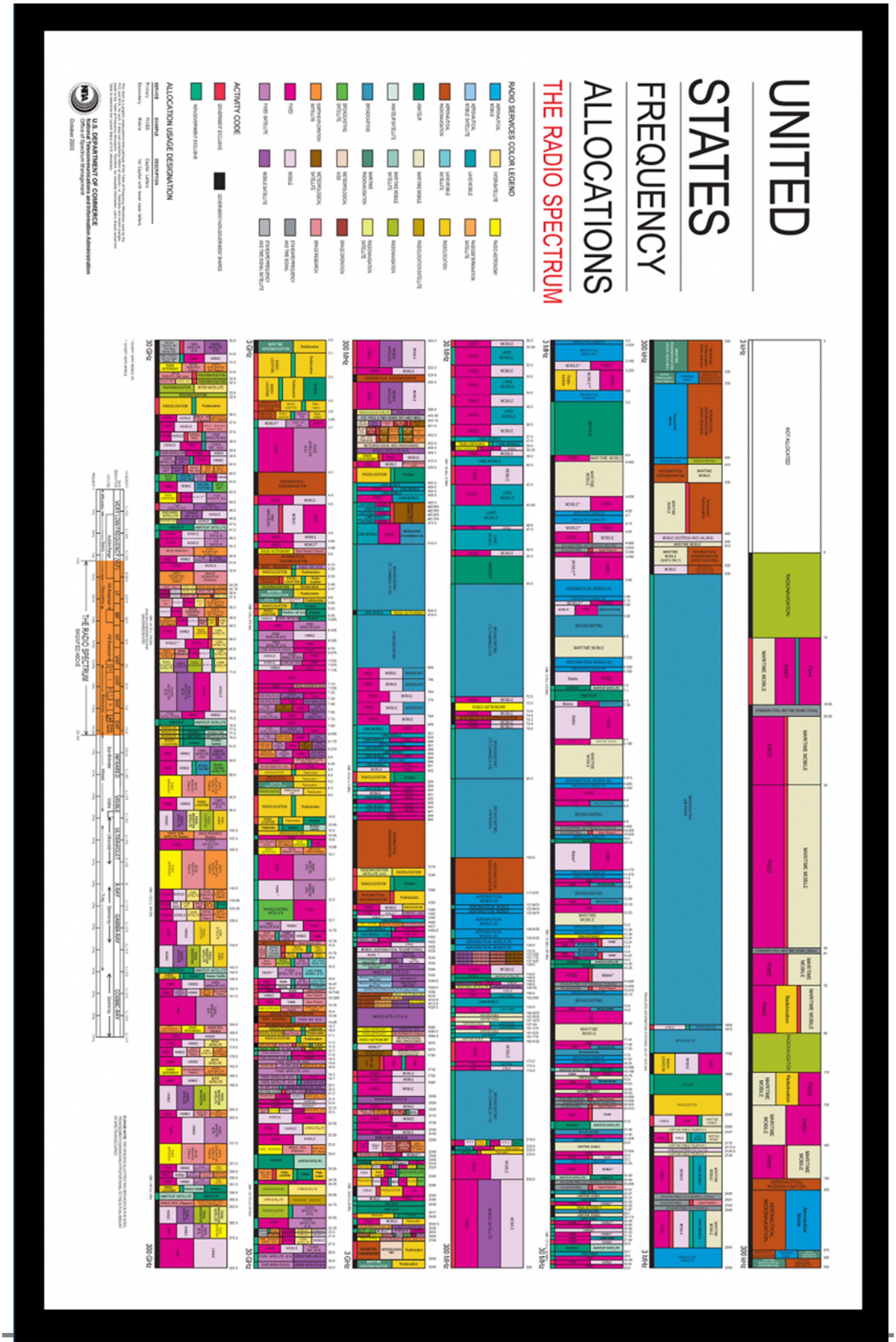
ITU divides the radio spectrum into 12 bands Find the Spectrum Frequency and wavelength

Band Name	Abbreviation	ITU band Number	Frequency and wavelength
Extremely low frequency	ELF	1	3–30 Hz 100,000–10,000 km
Super low frequency	SLF	2	30–300 Hz 10,000–1,000 kr
Ultra low frequency	ULF	3	300–3,000 Hz 1,000–100 km
Very low frequency	VLF	4	3–30 kHz 100–10 km
Low frequency	LF	5	30–300 kHz 10–1 km
Medium frequency	MF	6	300–3,000 kHz 1,000–100 m
High frequency	HF	7	3–30 MHz 100–10 m
Very high frequency	VHF	8	30–300 MHz 10–1 m
Ultra high frequency	UHF	9	300–3,000 MHz 100–10 cm
Super high frequency	SHF	10	3–30 GHz 10–1 cm
Extremely high frequency	EHF	11	30–300 GHz 10–1 mm
Terahertz or tremendously high frequency	THF	12	300–3,000 GHz 1–0.1 mm

One widely used standard is the IEEE radar bands established by the US Institute of Electrical and Electronics Engineers.

Band designation	Frequency range	Explanation of meaning of letters
HF	0.003 to 0.03 GHz	High frequency[15]
VHF	0.03 to 0.3 GHz	Very high frequency[15]
UHF	0.3 to 1 GHz	Ultra-high frequency[15]
L	1 to 2 GHz	Long wave
S	2 to 4 GHz	Short wave
C	4 to 8 GHz	Compromise between S and X
X	8 to 12 GHz	Used in World War II for fire control, X for cross (as in crosshair).
K_u	12 to 18 GHz	*Kurz*-under
K	18 to 27 GHz	German: *Kurz* (short)
K_a	27 to 40 GHz	*Kurz*-above
V	40 to 75 GHz	
W	75 to 110 GHz	W follows V in the alphabet
mm or G	110 to 300 GHz[not	Millimeter[14]




UNITED STATES
FREQUENCY
ALLOCATIONS
THE RADIO SPECTRUM
U.S. DEPARTMENT OF COMMERCE

Frequency Bands and Spectrum Allocation in 5G

Today’s 3G and 4G cellular and WiFi carrier frequencies are mostly in between 300 MHz and 3000 MHz.

For 5G refer following table

Band	Duplex mode	ƒ (MHz)	Common name	Subset of band	Uplink (MHz)	Downlink (MHz)	Duplex spacing (MHz	Channel bandwidths (MHz)
n1	FDD	2100	IMT	n65	1920 – 19	2110 – 21	190	5, 10, 15, 2
n2	FDD	1900	PCS	n25	1850 – 19	1930 – 19	80	5, 10, 15, 2
n3	FDD	1800	DCS		1710 – 17	1805 – 18	95	5, 10, 15, 20, 30
n5	FDD	850	CLR		824 – 84	869 – 89	45	5, 10, 15, 2
n7	FDD	2600	IMT-E		2500 – 25	2620 – 26	120	5, 10, 15, 20, 30, 40, 50
n8	FDD	900	Extended G		880 – 91	925 – 96	45	5, 10, 15, 2
n12	FDD	700	Lower SM		699 – 71	729 – 74	30	5, 10, 15
n14	FDD	700	Upper SM		788 – 79	758 – 76	−30	5, 10
n18	FDD	850	Lower 80 (Japan)		815 – 83	860 – 87	45	5, 10, 15
n20	FDD	800	Digital Divid (EU)		832 – 86	791 – 82	−41	5, 10, 15, 2

List of Supported 5G Bands in India

Low-band frequencies include 600 MHz, 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, and 2500 MHz.

Mid-band frequency is 3300 MHz.

High-band frequency of up to 26 GHz, known as mmWave. All telecom operators have acquired all kinds of frequency bands.

Multiple Access Techniques: FDMA, TDMA, CDMA

A cellular network consists of a number of fixed base stations, one for each cell.

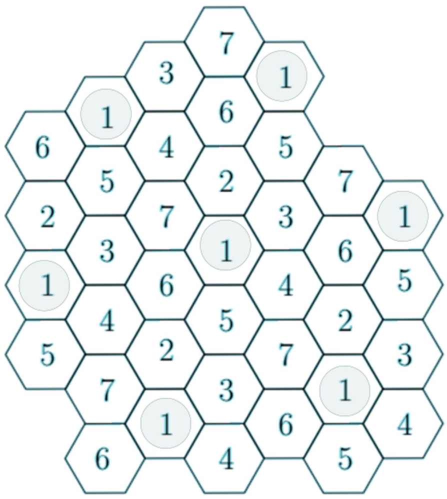
The total coverage area is divided into cells and a mobile communicates with the base station(s) close to it.

At the physical and medium access layers, there are two main issues in cellular communication: multiple access and interference management.

The first issue addresses how the overall resource (time, frequency and space) of the system is shared by the users in the same cell (intra-cell) and

the second issue addresses the interference caused by simultaneous signal transmissions in different cells (inter-cell)

At the physical and medium access layers, there are two main issues in cellular communication: multiple access and interference management.



In addition to resource sharing between different users, there is also an issue of how the resource is allocated between the uplink (the communication from the mobile users to the base station, also called the reverse link) and the downlink (the communication from the base station to the mobile users, also called the forward link).

There are two natural strategies for separating resources between the uplink and the downlink:

time division duplex (TDD) separates the transmissions in time and

frequency division duplex (FDD) achieves the separation in frequency.

Most commercial cellular systems are based on FDD.

Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.

The sharing of spectrum is required to achieve high capacity by simultaneously allocating the available bandwidth (or the available amount of channels) to multiple users.

For high quality communications, this must be done without severe degradation in the performance of the system..

In wireless communications systems, it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station.

For example, in conventional telephone systems, it is possible to talk and listen simultaneously, and this effect, called duplexing, is generally required in wireless telephone systems...

Duplexing may be done using frequency or time domain techniques.

Frequency division duplexing (FDD) provides two distinct bands of frequencies for every user.

The forward band provides traffic from the base station to the mobile, and the reverse band provides traffic from the mobile to the base station.

In FDD, any duplex channel actually consists of two simplex channels (a forward and reverse), and a device called a duplexer is used inside each subscriber unit and base station to allow simultaneous bidirectional radio transmission and reception for both the subscriber unit and the base station on the duplex channel pair.

The frequency separation between each forward and reverse channel is constant throughout the system, regardless of the particular channel being used

Time division duplexing (TDD) uses time instead of frequency to provide both a forward and reverse link.

In TDD, multiple users share a single radio channel by taking turns in the time domain.

Individual users are allowed to access the channel in assigned time slots, and each duplex channel has both a forward time slot and a reverse time slot to facilitate bidirectional communication.

If the time separation between the forward and reverse time slot is small, then the transmission and reception of data appears simultaneous to the users at both the subscriber unit and on the base station side

Frequency division multiple access (FDMA),
time division multiple access (TDMA), and
code division multiple access (CDMA)
are the three major access techniques used to share the available bandwidth in a wireless communication system.

These techniques can be grouped as narrowband and wideband systems, depending upon how the available bandwidth is allocated to the users

Frequency division multiple access (FDMA),

Frequency division multiple access (FDMA) assigns individual channels to individual users.

It can be seen from Figure that each user is allocated a unique frequency band or channel.

These channels are assigned on demand to users who request service.

During the period of the call, no other user can share the same channel.

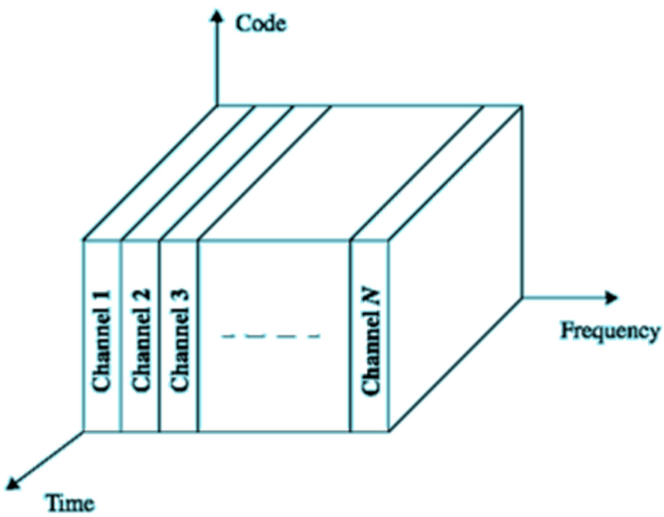
In FDD systems, the users are assigned a channel as a pair of frequencies; one frequency is used for the forward channel, while the other frequency is used for the reverse channel

The features of FDMA are as follows:

The FDMA channel carries only one phone circuit at a time.

If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share capacity. It is essentially a wasted resource.

After the assignment of a voice channel, the base station and the mobile transmit simultaneously and continuously



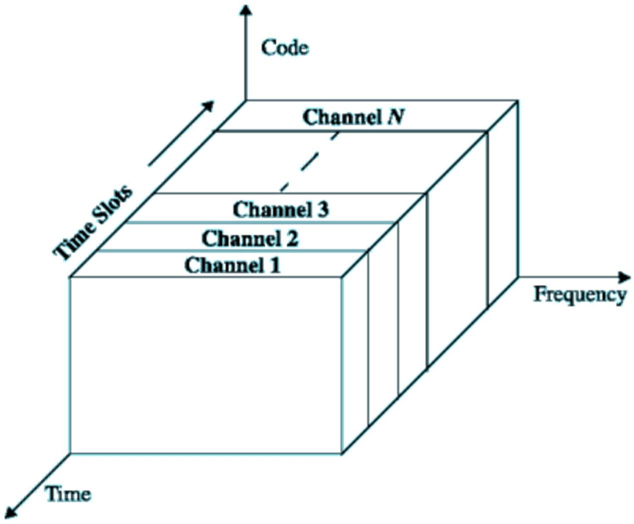
Time division multiple access (TDMA)

Time division multiple access (TDMA) systems divide the radio spectrum into time slots, and in each slot only one user is allowed to either transmit or receive.

It can be seen from Figure that each user occupies a cyclically repeating time slot, so a channel may be thought of as a particular time slot that reoccurs every frame, where N time slots comprise a frame.

TDMA systems transmit data in a buffer-and-burst method, thus the transmission for any user is non-continuous.

This implies that, unlike in FDMA systems which accommodate analog FM, digital data and digital modulation must be used with TDMA.



The transmission from various users is interlaced into a repeating frame structure as shown in Figure.

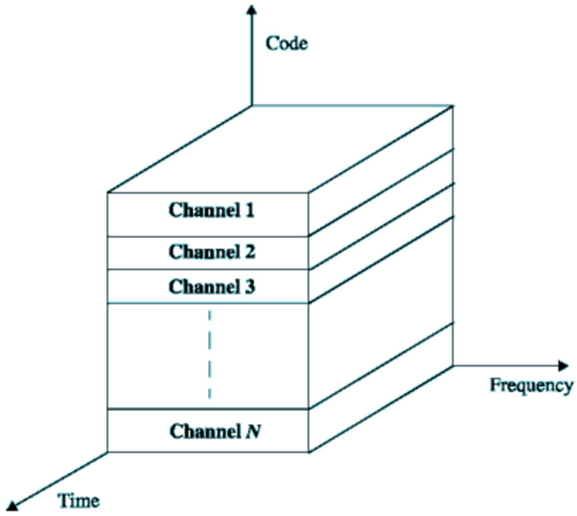
It can be seen that a frame consists of a number of slots.

Each frame is made up of a preamble, an information message, and tail bits.

In TDMA/ TDD, half of the time slots in the frame information message would be used for the forward link channels and half would be used for reverse link channels.

In TDMA/FDD systems, an identical or similar frame structure would be used solely for either forward or reverse transmission, but the carrier frequencies would be different for the forward and reverse links.

Code division multiple access (CDMA) systems,



In code division multiple access (CDMA) systems, the narrowband message signal is multiplied by a very large bandwidth signal called the spreading signal.

The spreading signal is a pseudonoise code sequence that has a chip rate which is orders of magnitudes greater than the data rate of the message.

All users in a CDMA system, as seen from Figure, use the same carrier frequency and may transmit simultaneously.

Each user has its own pseudorandom code word which is approximately orthogonal to all other codewords.

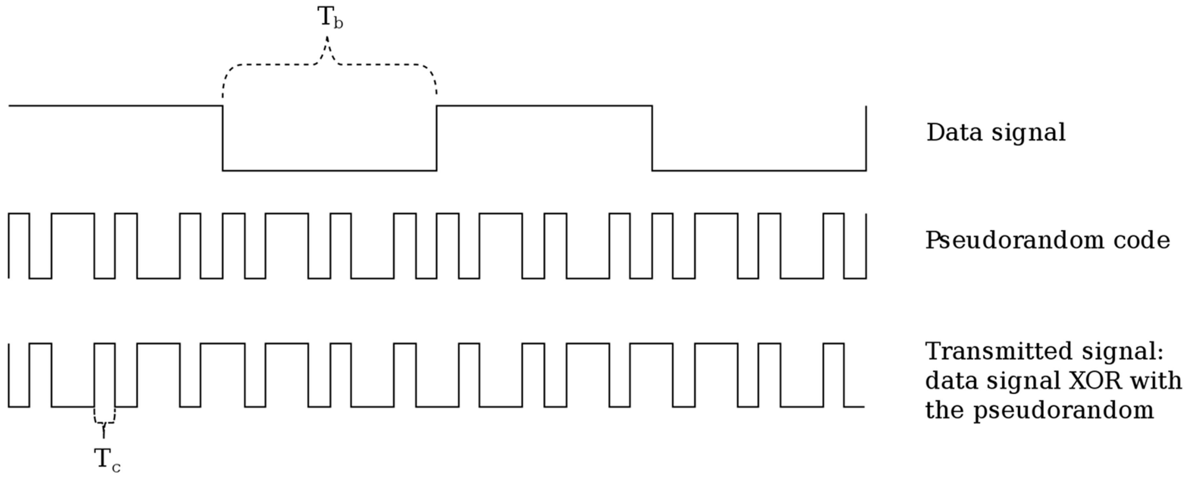
In code division multiple access (CDMA) systems,

The receiver performs a time correlation operation to detect only the specific desired codeword.

All other code words appear as noise due to de-correlation.

For detection of the message signal,the receiver needs to know the codeword used by the transmitter.

Each user operates independently with no knowledge of the other users...



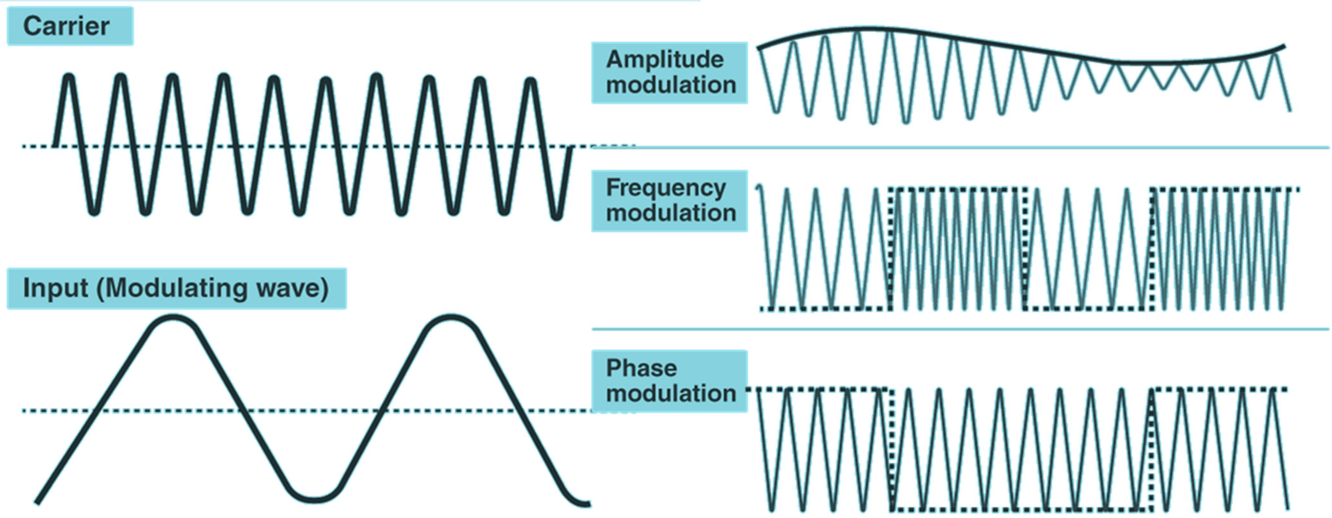
Modulation Techniques: QPSK, QAM, OFDM

What Is Modulation?

Modulation is defined as the process of superimposing a low-frequency signal on a high-frequency carrier signal.

Or

The process of varying the RF carrier wave in accordance with the information in a low-frequency signal.



What is Quadrature Phase Shift Keying?

Quadrature Phase Shift Keying is a digital modulation method.

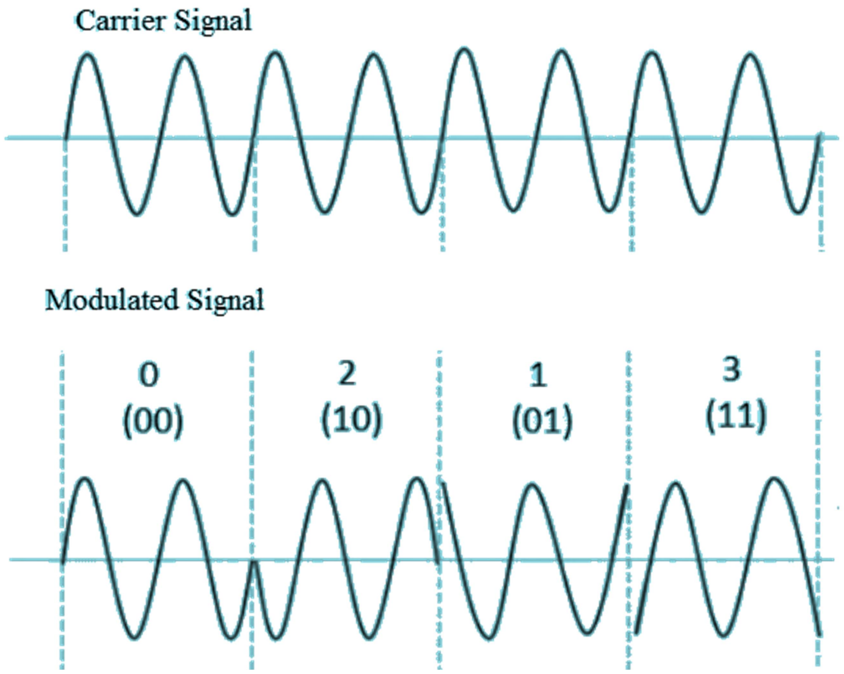
In this method, the phase of the carrier waveform is changed according to the digital baseband signal.

The phase of the carrier remains the same when the input logic is the 1 but goes a phase shift when the logic is 0.

In Quadrature Phase Shift Keying, two information bits are modulated at once, unlike Binary Phase Shift Keying where only one bit is passed per symbol.

Here, there are four carrier phase offsets with a phase difference of ±90° for four possible combinations of two bits(00, 01, 10, 11).

Symbol duration in this modulation is twice the bit duration.

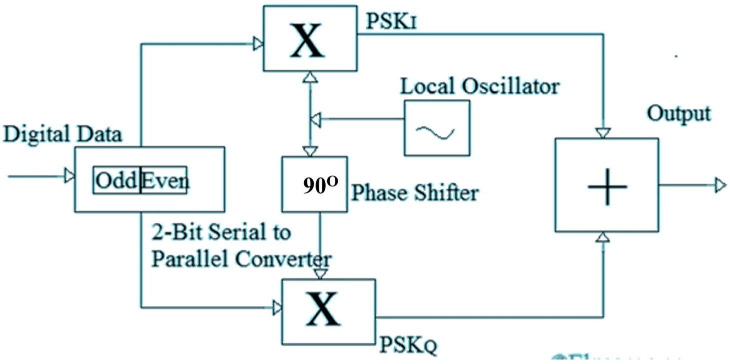


Circuit Diagram

Instead of converting bits into a digital stream, QPSK converts it into bit pairs.

This method is also known as the Double Side Band Suppressed Carrier modulation method.

QPSK modulation circuit consists of a bit-splitter, 2-bit serial to parallel converter, two multipliers, a local oscillator, and a summer.



At the transmitter input, the message signal bits are separated as even bits and odd bits using a bit splitter. These bits are then multiplied with the same carrier waveform to generate Even QPSK and Odd QPSK signals.

The Even QPSK signal is phase shifter by 90°, using a phase shifter, before modulation. Here, the Local Oscillator is used for generating the carrier waveform.

After separation of bits, a 2-bit serial to parallel converter is used.

After multiplying with the carrier waveform, both Even QPSK and Odd QPSK are given to the summer when modulation output is obtained

At the receiver end for demodulation, two product detectors are used. This product detectors convert the modulated QPSK signal into Even QPSK and Odd QPSK signals.

Then the signals are passed through two bandpass filters and two integrators.

After processing the signals are applied to the 2-bit parallel- to-series converter, whose output is the reconstructed signal

Advantages

It provides good noise immunity.

Compared to BPSK, bandwidth used by QPSK is reduced to half.

The information transmission rate of Quadrature Phase Shift Keying is higher as it transmits two bits per carrier symbol.

Carrier power remains constant as the variation in the QPSK amplitude is small.

Effective utilization of available transmission bandwidth.

Low error probability compared to other methods.

Disadvantages

The disadvantage of QPSK compared to BPSK is the circuit complexity

What is Quadrature Amplitude Modulation?

Quadrature amplitude modulation (QAM) is modulation techniques that we can utilize in analog modulation concept and digital modulation concept.

Depending upon the input signal form we can use it in either analog or digital modulation schemes.

In QAM, we can modulate two individual signals and transmitted to the receiver level.

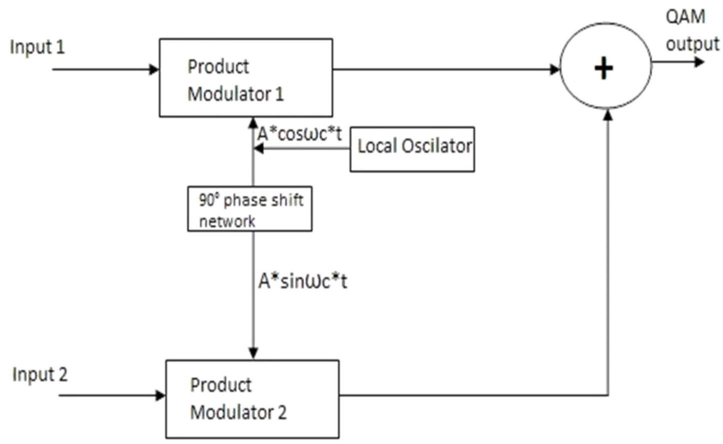
And by using the two input signals, the channel bandwidth also increases.

QAM can able to transmit two message signals over the same channel.

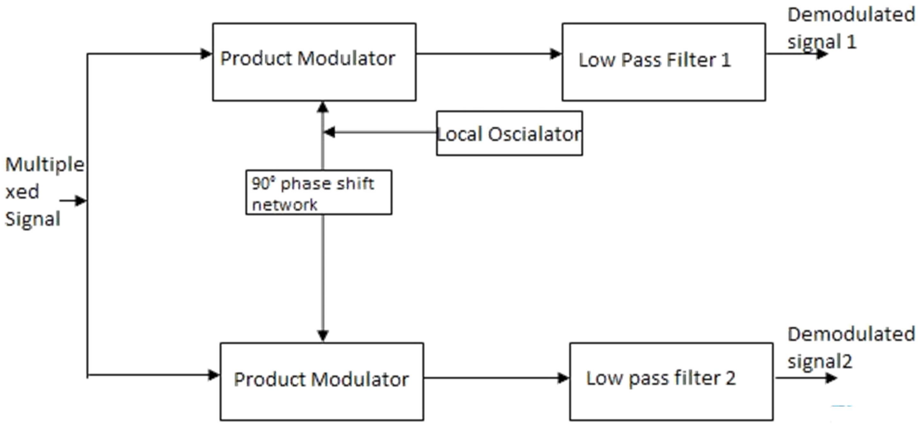
This QAM technique also is known as "quadrature carrier multiplexing"....

Quadrature Amplitude Modulation Block Diagram

In the QAM transmitter, the above section i.e., product modulator1 and local oscillator are called the in-phase channel and product modulator2 and local oscillator are called a quadrature channel. Both output signals of the in-phase channel and quadrature channel are summed so the resultant output will be QAM

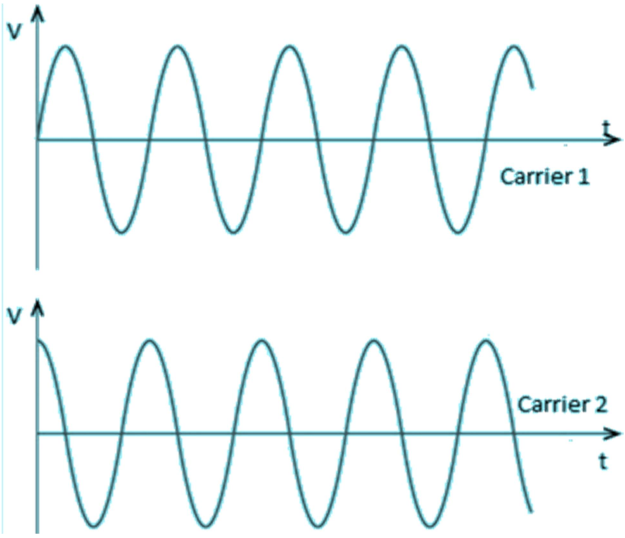


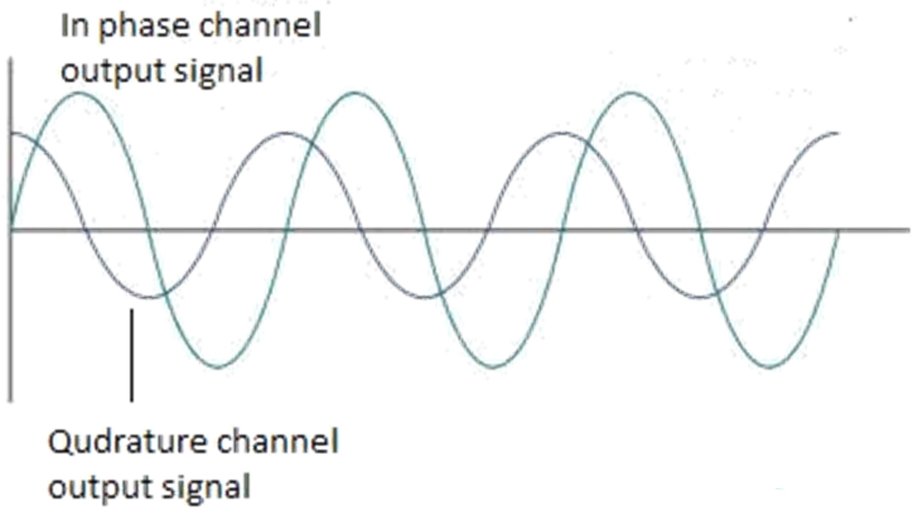
Quadrature Amplitude De-Modulation Block Diagram



At the receiver level, the QAM signal is forwarded from the upper channel of receiver and lower channel, and the resultant signals of product modulators are forwarded from LPF1 and LPF2. These LPF's are fixed to the cut off frequencies of input 1 and input 2 signals. Then the filtered outputs are the recovered original signals

Waveforms





Advantages of QAM

The quadrature amplitude modulation advantages are listed below.

One of the best advantages of QAM – supports a high data rate.
So, the number of bits can be carried by the carrier signal.
Because of these advantages it preferable in wireless communication networks.

QAM's noise immunity is very high. Due to this noise interference is very less.

It has a low probability of error value.

QAM expertly uses channel bandwidth.

Orthogonal frequency-division multiplexing (OFDM)

Orthogonal frequency-division multiplexing (OFDM) is a type of digital transmission used in digital modulation for encoding digital (binary) data on multiple carrier frequencies.

OFDM has developed into a popular scheme for wideband digital communication, used in applications such as digital television and audio broadcasting, DSL internet access, wireless networks, power line networks, and 4G/5G mobile communications.

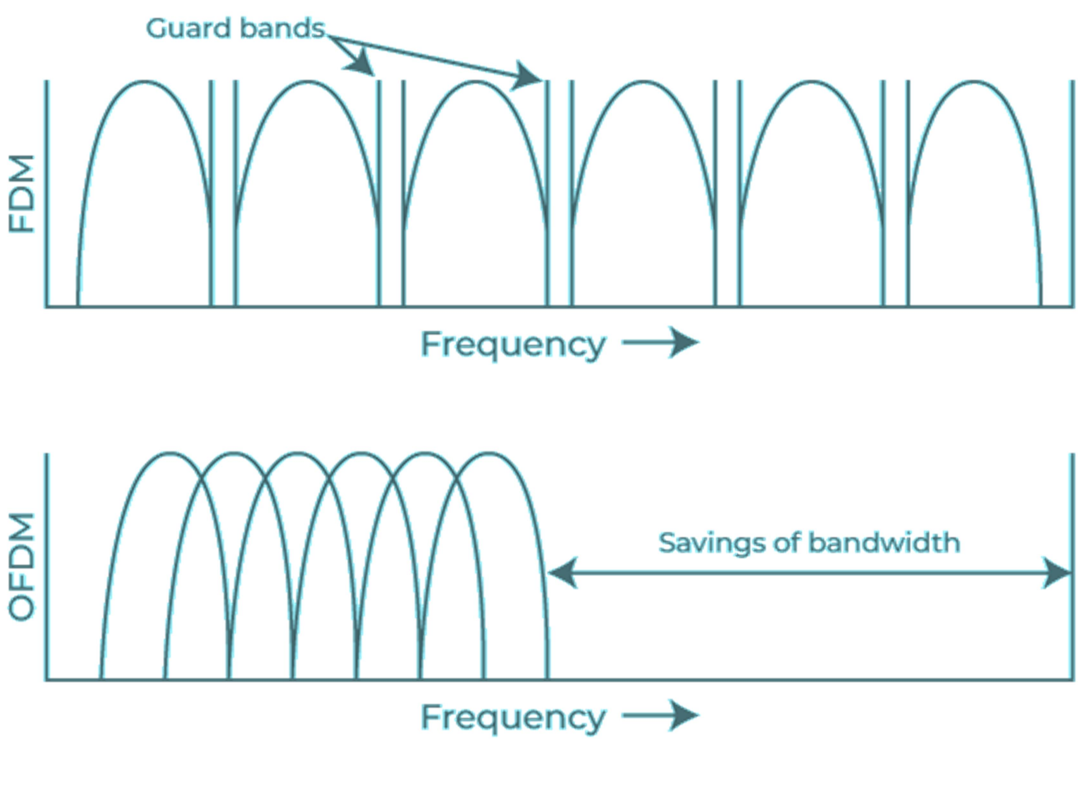
OFDM is a frequency-division multiplexing (FDM) scheme that was introduced by Robert W. Chang of Bell Labs in 1966

In OFDM, the incoming bitstream representing the data to be sent is divided into multiple streams.

Multiple closely spaced orthogonal subcarrier signals with overlapping spectra are transmitted, with each carrier modulated with bits from the incoming stream so multiple bits are being transmitted in parallel.

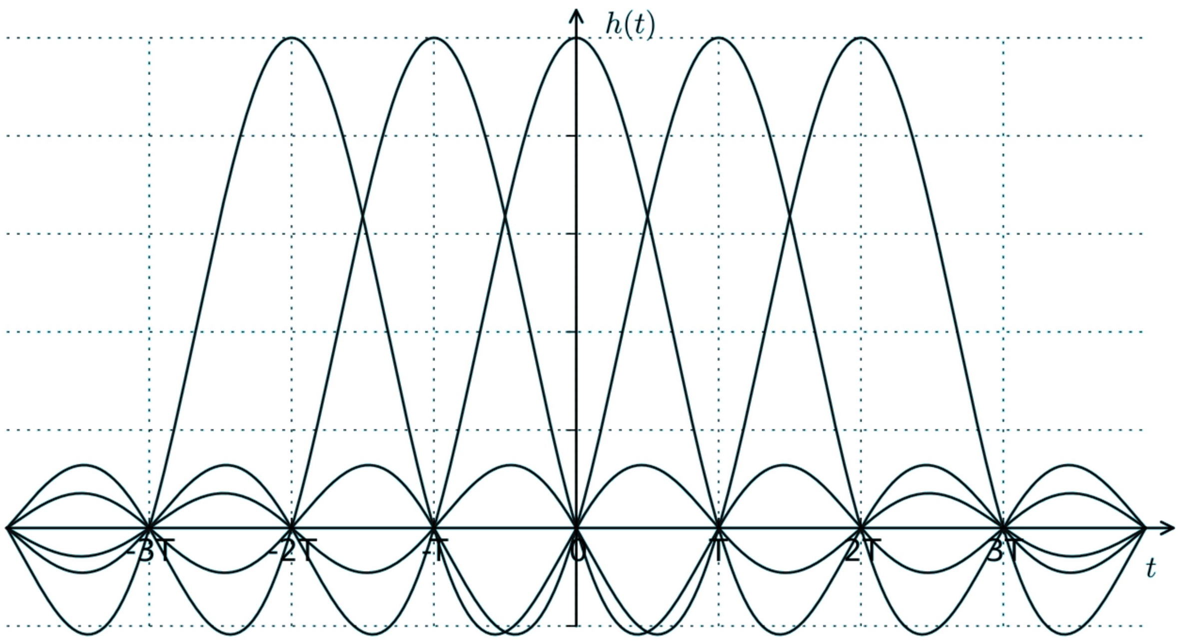
Demodulation is based on fast Fourier transform algorithms.

OFDM was improved by Weinstein and Ebert in 1971 with the introduction of a guard interval, providing better orthogonality in transmission channels affected by multipath propagation.



Each subcarrier (signal) is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate.

This maintains total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.



Designing OFDM Transmitter:

Consider that we want to send the following data bits using OFDM :
D = {d0,d1,d2,…).

The first thing that should be considered in designing the OFDM transmitter is the number of subcarriers required to send the given data.

As a generic case, lets assume that we have N subcarriers.

Each subcarriers are centered at frequencies that are orthogonal to each other (usually multiples of frequencies).

The second design parameter could be the modulation format that we wish to use.

An OFDM signal can be constructed using anyone of the following digital modulation techniques namely BPSK, QPSK, QAM etc..,

The data (D) has to be first converted from serial stream into parallel stream depending on the number of sub-carriers (N).

Since we assumed that there are N subcarriers allowed for the OFDM transmission, we name the subcarriers from 0 to N-1.

Now, the Serial to Parallel converter takes the serial stream of input bits and outputs N parallel streams (indexed from 0 to N-1).

These parallel streams are individually converted into the required digital modulation format (BPSK, QPSK, QAM etc..,).

Lets call this output S0, S1,..SN.

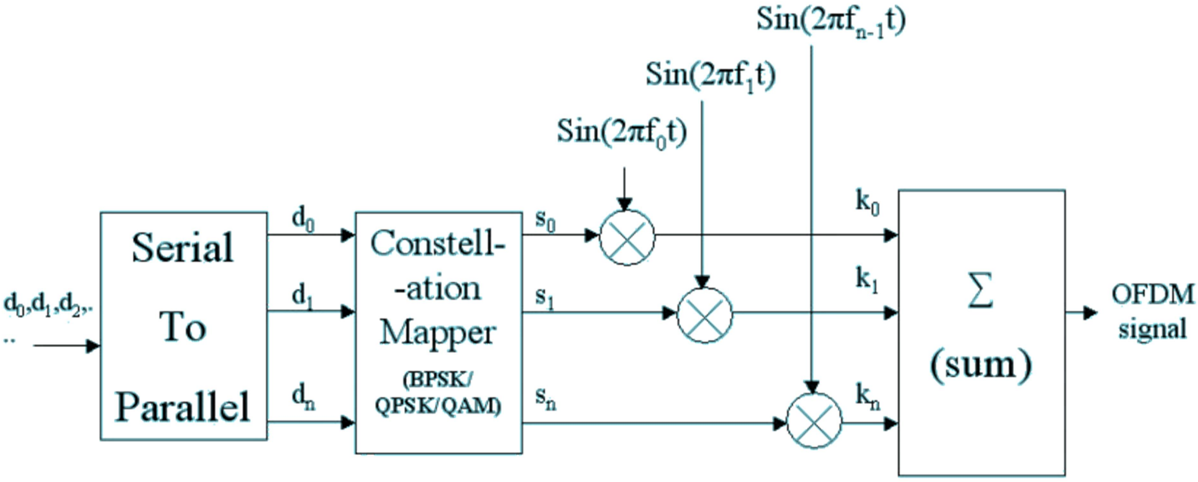
The conversion of parallel data (D) into the digitally modulated data (S) is usually achieved by a constellation mapper, which is essentially a look up table (LUT)

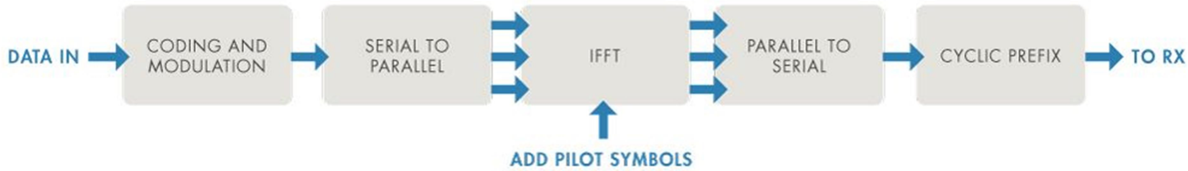
Once the data bits are converted to required modulation format, they need to be superimposed on the required orthogonal subcarriers for transmission.

This is achieved by a series of N parallel sinusoidal oscillators tuned to N orthogonal frequencies (f0, f1, … fN-1).

Finally, the resultant output from the N parallel arms are summed up together to produce the OFDM signal

Designing OFDM Transmitter:





BPSK Mapping:

Data = 1,0,1,0,1,1,1,1,0,1,0,0,0,1,0,1,0,0,1,1

Time	d0	d1	d2	d3	d4
t1	1	0	1	0	1
t2	1	1	1	0	1
t3	0	0	0	1	0
t4	1	0	0	1	1

Serial to Parallel Converter

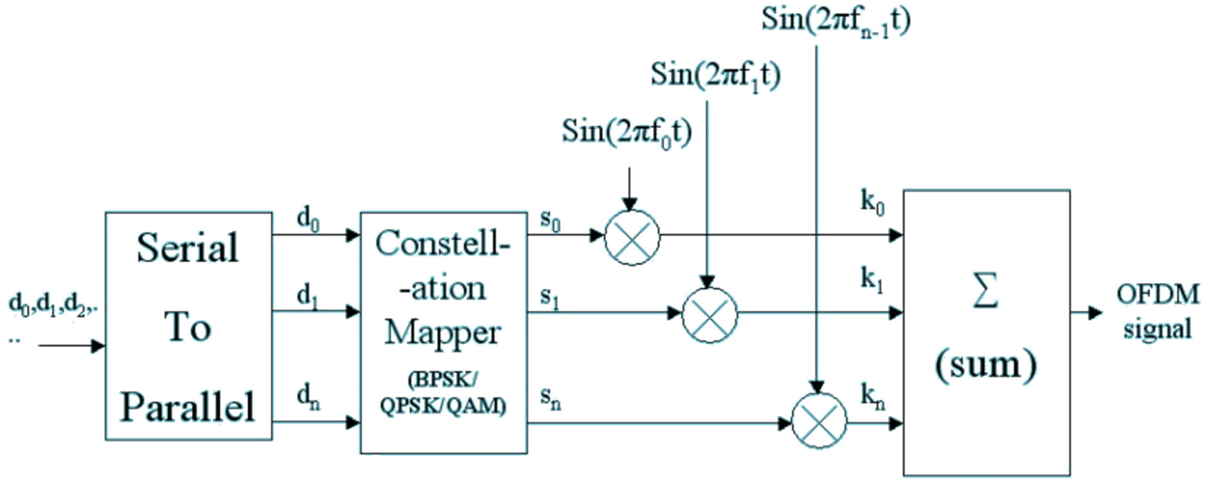
Time	S0	S1	S2	S3	S4
t1	1	-1	1	-1	1
t2	1	1	1	-1	1
t3	-1	-1	-1	1	-1
t4	1	-1	-1	1	1

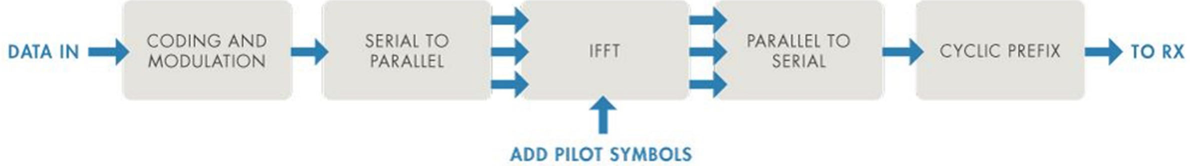
BPSK mapping

Multiplying by orthogonal frequency subcarriers

Time	k0	k1	k2	k3	k4	
t1+Δ	$1 \times \sin(2\pi F_0 t)$	$-1 \times \sin(2\pi F_1 t)$	$1 \times \sin(2\pi F_2 t)$	$-1 \times \sin(2\pi F_3 t)$	$1 \times \sin(2\pi F_4 t)$	Σ → $OFDM_0$
t2+Δ	$1 \times \sin(2\pi F_0 t)$	$1 \times \sin(2\pi F_1 t)$	$1 \times \sin(2\pi F_2 t)$	$-1 \times \sin(2\pi F_3 t)$	$1 \times \sin(2\pi F_4 t)$	Σ → $OFDM_1$
t3+Δ	$-1 \times \sin(2\pi F_0 t)$	$-1 \times \sin(2\pi F_1 t)$	$-1 \times \sin(2\pi F_2 t)$	$1 \times \sin(2\pi F_3 t)$	$-1 \times \sin(2\pi F_4 t)$	Σ → $OFDM_2$
t4+Δ	$1 \times \sin(2\pi F_0 t)$	$-1 \times \sin(2\pi F_1 t)$	$-1 \times \sin(2\pi F_2 t)$	$1 \times \sin(2\pi F_3 t)$	$1 \times \sin(2\pi F_4 t)$	Σ → $OFDM_3$

Designing OFDM Transmitter:





QPSK Mapping:

Data = 1,0,1,0,1,1,1,1,0,1,0,0,0,1,0,1,0,0,1,1

Time	d0	d1	d2	d3	d4
t1	1	0	1	0	1
t2	1	1	1	0	1
t3	0	0	0	1	0
t4	1	0	0	1	1

Serial to Parallel Converter

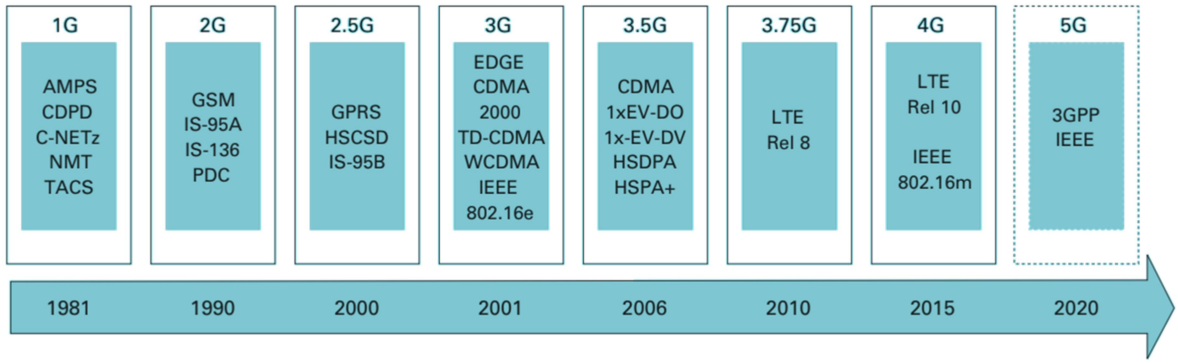
Time	S0	S1	S2	S3	S4
t2+Δ	-1-j	-1+j	-1-j	1+j	-1-j
t4+Δ	-1+j	1+j	1+j	-1-j	-1+j

Pi/4 shifted QPSK mapping (with gray coding)

Multiplying by orthogonal frequency subcarriers

Time	k0	k1	k2	k3	k4	
t2+Δ	(-1-j) x sin(2πF$_0$t)	(-1+j) x sin(2πF$_1$t)	(-1-j) x sin(2πF$_2$t)	(1+j) x sin(2πF$_3$t)	(-1-j) x sin(2πF$_4$t)	Σ → OFDM$_0$
t4+Δ	(-1+j) x sin(2πF$_0$t)	(1+j) x sin(2πF$_1$t)	(1+j) x sin(2πF$_2$t)	(-1-j) x sin(2πF$_3$t)	(-1+j) x sin(2πF$_4$t)	Σ → OFDM$_1$

Introduction to 5G Technology: Evolution of Cellular Networks: From 1G to 5G



Evolution of cellular standards.

Figure illustrates a short chronological history of the cellular radio systems from their infancy in the 1970s (i.e. 1G, the first generation) till the 2020s (i.e. 5G, the fifth generation).

The first commercial analog mobile communication systems were deployed in the 1950s and 1960s, although with low penetration.

1G

The year 1981 witnessed the birth of the first commercial deployments of the First Generation (1G) mobile cellular standards such as Nordic Mobile Telephone (NMT) in Nordic countries; C-Netz in Germany, Portugal and South Africa;

Total Access Communications System (TACS) in the United Kingdom; and Advanced Mobile Phone System (AMPS) in the Americas.

The 1G standards are called the analog standards since they utilize analog technology, typically frequency modulated radio signals with a digital signaling channel..

2G

The European Conference of Postal and Telecommunications Administrations (CEPT) decided in 1982 to develop a pan-European 2G mobile communication system.

This was the starting point of the Global System for Mobile communications (GSM), the dominant 2G standard, which was deployed internationally from 1991.

The introduction of 2G was characterized by the adoption of digital transmission and switching technology.

Digital communication allowed considerable improvements in voice quality and network capacity, and offered growth in the form of supplementary services and advanced applications such as the Short Message Service (SMS) for storage and forwarding of textual information.

These other main 2G standards include
(1) TIA/EIA-136, also known as the North American TDMA (NA-TDMA) std,
(2) TIA/EIA IS-95A, also known as CDMAOne
(3) Personal Digital Cellular (PDC), used exclusively in Japan.

The evolution of 2G, called 2.5G, introduced packet-switched data services in addition to voice and circuit-switched data.

The main 2.5G standards, General Packet Radio Service (GPRS) and TIA/EIA-951, were extensions of GSM and TIA/EIA IS-95A, respectively.

2G to 3G

Soon afterwards, GSM was evolved further into the Enhanced Data Rates for Global Evolution (EDGE) and its associated packet data component

Enhanced General Packet Radio Service (EGPRS), mainly by addition of higher order modulation and coding schemes.

GSM/EDGE has continued to evolve and the latest release of the 3GPP standard supports wider bandwidths and carrier aggregation for the air interface.

In parallel, the International

Telecommunications Union, Radio Communications (ITU-R) developed the requirements for systems that would qualify for the International Mobile Telecommunications 2000 (IMT-2000) classification

3G

In January 1998, CDMA in two variants – Wideband Code Division Multiple Access (WCDMA) and Time Division CDMA (TD-CDMA) – was adopted by the European Telecommunications Standards Institute (ETSI) as a Universal Mobile Telecommunication System (UMTS).

UMTS was the major 3G mobile communication system and was one of the first cellular systems that qualified for IMT-2000.

Six radio interfaces have been qualified to meet IMT-2000 requirements including three technologies based on CDMA, a version of GSM/EDGE known as UWC-1362 and two technologies based on OFDMA.

3G to 3.5G & 3.75G

Within the framework of the 3rd Generation Partnership Project (3GPP), new specifications were developed, together known as 3G Evolution as 3.5G.

For this evolution, two Radio Access Network (RAN) approaches and an evolution of the Core Network were suggested.

The first RAN approach was based on the evolution steps in CDMA 2000 within

3GPP2: 1xEV-DO and 1xEV-DV.

The second RAN approach was High Speed Packet Access (HSPA).

HSPA was a combination of High Speed Downlink Packet Access (HSDPA), added in 3GPP Release 5, and High Speed Uplink Packet Access (HSUPA), added in 3GPP Release 6

Both initially enhanced the packet data rate, to 14.6 Mbps in the downlink and to 5.76 Mbps in the uplink, and quickly evolved to handle higher data rates with the introduction of MIMO.

HSPAwas based on WCDMA and is completely backward compatible with WCDMA.

While CDMA 1xEV-DO started deployment in 2003, HSPA and CDMA 1xEV-DV entered into service in 2006.

All 3GPP standards follow the philosophy of adding new features while still maintaining backward compatibility

4G

The second UMTS evolution, commercially accepted as 4G, is called Long Term Evolution (LTE) , and is composed of a new air interface based on Orthogonal Frequency Division Multiple Access (OFDMA) and a new architecture and Core Network (CN) called the System Architecture Evolution/Evolved Packet Core (SAE/EPC).

LTE is not backward compatible with UMTS and was developed in anticipation of higher spectrum block allocations than UMTS during World Radio Conference (WRC) 2007.

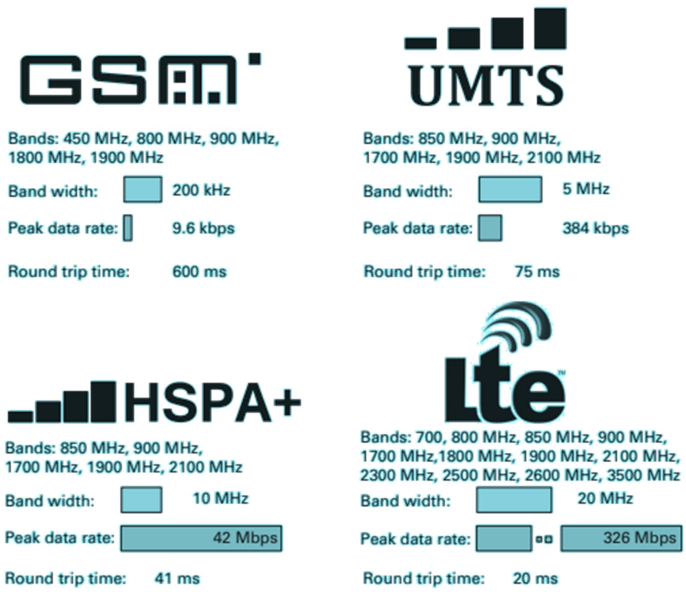
The standard was also designed to operate with component frequency carriers that are very flexible in arrangement, and supports carriers from 1.4 MHz in width to 20 MHz.

At the end of 2007, the first LTE specifications were approved in 3GPP as LTE Release 8.

The LTE Release 8 system has peak data rates of approximately 326 Mbps, increased spectral efficiency and significantly shorter latency (down to 20 ms) than previous systems.

Simultaneously, the ITUR was developing the requirements for IMT-Advanced, a successor to IMT-2000, and nominally the definition of the fourth generation.

LTE is uniformly accepted as 4G, 3GPP LTE Release 10 and IEEE 802.16 m (deployed as WiMAX) were technically the first air interfaces developed to fulfill IMT-Advanced requirements. Despite being an approved 4G technology, WiMAX has had difficulties in gaining widespread acceptance and is being supplanted by LTE



Key Features of 5G

Key Features of 5G

Let's take a closer look at some of the features and benefits of 5G for businesses.

Point-1

The most-discussed 5G feature is **increased speed and bandwidth.**

With a data rate of up to 10 Gbps, 5G will bring a 10 times to 100 times improvement over the existing 4G LTE technology. Cellular is now a potential technology for branch office automation because WAN connections finally have enough bandwidth.

For businesses, the real benefit of 5G might not be the actual bandwidth, but the pressure that 5G exerts on market prices of incumbent WAN connectivity.

Point-2

5G's low latency, under 5 milliseconds, is the other key benefit for WAN usage.

Customers are using MPLS or dedicated lines today primarily for low latency in line-of-business applications.

5G's low latency may bring additional flexibility that lets businesses jettison some of their branch office MPLS infrastructure in favor of the less expensive and more flexible 5G connections to branches.

This is especially true in retail or shared infrastructure or very remote environments.

Point-3

5G density enables up to 100 times more connected devices in the same physical area that 4G LTE operates today, while maintaining 99.999% availability.

While this density may bring business advantages for mobile workforces, the real benefit is increasing the size of the mobile customer market.

Mobile e-commerce is growing faster than retail and traditional computer-based e-commerce.

More customers than ever use mobile technologies to shop online, so greater density increases the overall addressable market...

Point-4

An estimated 90% reduction in power consumption for devices means minor power savings at the smartphone level.

But, from an infrastructure perspective, especially for IoT devices, the power savings could be significant.

Combining IoT devices with a cellular 5G communication means lower power overhead in design and actual consumption.

Remote devices can be expected to last significantly longer when running on battery alone.

Some estimates even show that a 10-year remote battery life may be achievable for IoT-based sensor devices deployed in remote locations....

Point-5

Security is always a concern for mobile devices and IoT devices because the latter live on the edge of the corporate network.

With 5G, stronger security than 4G LTE is available for designers, including hardware security modules, key management services, over the air, secure element and others.

This will help ensure that the data transmitted over the 5G network is secure while also hardening network endpoints.....

Objectives of 5G

Objectives of 5G

The 5G-SOLUTIONS main project objective is to conduct advanced field trials of innovative and thematically diverse digital services that require 5G capabilities and performance in the vertical domains of Factories of the Future, Smart Energy, Smart Cities, Smart Ports and Media & Entertainment, directly engaging with end-user actors, so as to validate the technological performance of 5G technology in successfully serving them, as well as validate the business models and potential of these use cases prior to commercial deployment. The main project's aim will be realized through 6 key interdisciplinary objectives, as listed in next slide

Objective 1: Innovation with vertical industry expert users:

To develop realistic, advanced and business relevant innovative use case scenarios in five key vertical industries.

Objective 2: Technology development and readiness:

To interface with key ICT-17 facilities and develop the technological enablers for the validation of the use cases.

Objective 3: Technological validation:

To demonstrate the potential and the user value of advanced 5G solutions through extensive technological validation in field trials directly involving end-users in Living Labs (LLs).

Objective 4: Business validation and innovation:

To develop and validate the business models of the use cases in 5G-SOLUTIONS LLs, whilst ensuring long-term social acceptance and economic sustainability, extending beyond the lifespan of the project through a joint commercialization plan..

Objective 5: Contribution to standardization, open source and communities:

To provide significant contribution to relevant 5G standardization bodies, to relevant open source communities, to relevant industry standardization and user/technology communities.

Objective 6: Dissemination and outreach:

To disseminate and exploit the project's results, to maximize the project's visibility and facilitate dissemination and communication activities, and to contribute to the objectives of the European 5G-PPP Programme.

Challenges and Opportunities in 5G Deployment

5G-New Radio (NR) Deployment Challenges Due to the Coverage

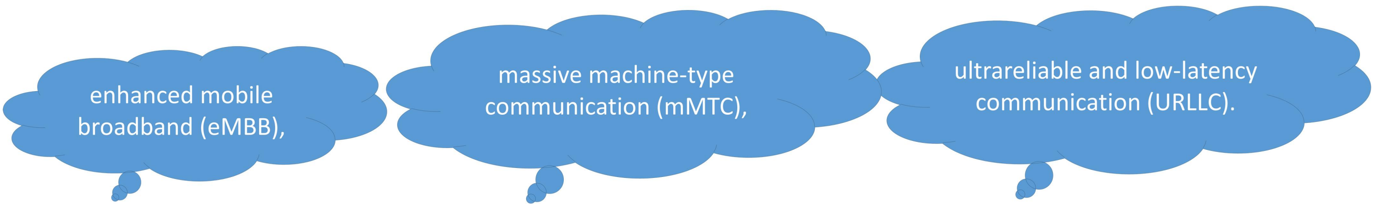
5G Band selection:
Wideband spectrum availability vs. coverage.

The availability of the bands below 3 GHz remains limited for 5G- New Radio in the near future and the lower bands fail to support high data rates due to their limited bandwidth.

On the other hand, the wider NR bands above 3 GHz experience increased propagation losses, leading to a limited coverage.

Therefore, independent usage of the spectrum below and above 3 GHz fails to strike a compelling trade-off between a high data rate and large coverage

DL/UL ratio:
Spectrum utilization effciency vs. DL/UL coverage balance vs. multi-service operation:



The NR TDD operation is usually configured for a limited number of UL transmission slots (e.g., DL:UL = 4:1) in a frame due to the heavy DL traffc load, even though more slots should be allocated to the UL for improving the UL coverage.

This can increase the UL data rates, when the bandwidth can not be further increased due to the maximum transmission power constraint.

Since the DL spectral efficiency is usually higher than that of the UL, having more UL slots would, then, further reduce the spectral utilization efficiency.

Therefore, there is a **clear trade-off between the UL coverage and spectral utilization efficiency.**

In addition, 5G system is required to provide diverse services

It is hard for a single-network TDD configuration to fit to multiple type of services.

Efficient transmission requires high DL resource proportion, while IoT services for low power wide-area scenario (LPWA) are highly dependent on the UL coverage and thus need continuous UL transmission and preferably as low path loss as possible.

Therefore, **efficient 5G spectrum exploitation mechanism is desired to support all kinds of services using a unified TDD configuration**

TDD DL/UL switching period:

Transmission efficiency vs. latency.

For the TDD operation, frequent DL/UL switching is required for cellular services to provide very quick DL/UL scheduling and almost immediate ACK/NACK feedback.

However, a certain guard period is also needed at each DL/UL switching point (e.g., 130μs is used in TD-LTE networks) for avoiding serious blocking of the UL receiver due to the strong DL interference emanating from other cells..

Frequent DL/UL switching would lead to a high idle time (14.3% vs. 2.8% for 1 ms and 5 ms switch period).

Such a short DL/UL switching period in a single TDD band network operation will lead to an unacceptable degradation of spectrum efficiency for eMBB transmission, which is generally in favor of a larger DL/UL switching period, e.g., 2.5 ms or 5 ms.

Site planning:

seamless coverage vs. deployment investment and mobility:

For early 5G-NR deployment, co-site installation with the existing LTE networks would be cost effective and convenient.

However, due to the higher propagation loss above 3 GHz, one has to introduce denser cells and new sites.

Otherwise, 5G-NR cannot attain the same seamless
UL coverage as that of LTE

In summary, for a fast and cost-effective 5G network deployment, to accommodate multi-services of both eMBB and IoT applications effciently,
and to balance the spectrum effciency, coverage,
as well as low latency,
5G network has to operate on both high-frequency wideband TDD band for high capacity and low-frequency band with good coverage.

5G Applications and use cases

5G Applications and use cases

This **next-generation technology** will benefit societies and machines in various ways. There are several 5G use cases and 5G applications that can restructure the entire world. The 5G uses range from device communication to business support.

Enhanced mobile services with broadband-like connectivity

Using the Internet of Things (IoT) to its optimum capabilities

Better business management | High-quality streaming and gaming

More accurate information regarding location tracking

Production of autonomous vehicles

Revolutionizing the entertainment and education industries

Waste management and water treatment

Smart cities infrastructure

5G use cases

5G use cases

Sr. No.	Case Study Topic
1	Smart cities
2	Autonomous vehicles
3	Improved viewing experience at sporting events
4	5G drones
5	Immersive entertainment
6	Over ground trains going underground
7	Connected cows and calving
8	Healthcare
9	Construction & Energy preservation
10	IP broadcasting

!!THANK YOU!!
!! Have a Nice Day!!