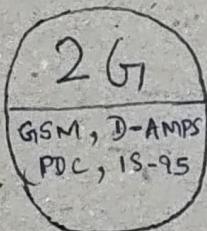


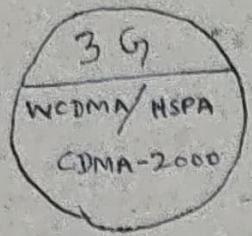
Brief History of Wireless Standards

- The Foundation of Mobile Telephony
- Based on Analog transmission
- Some main technologies include,
 - ① AMPS — Advanced Mobile Phone System
 - Developed within North America
 - ② NMT — Nordic Mobile Telephony
 - Developed by Nordic countries.
 - ③ TACS — Total Access Communication System
 - Used in UK.
- Limited to voice services only
- For first time, mobile telephony is made accessible to ordinary people.



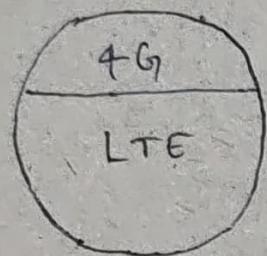
~ 1980s

- Mobile Telephony for everyone
- Based on Digital Transmission on Radio Link.
- Some main technologies include,
 - ① GSM — Global System for Mobile Comm.
 - Developed by European Countries
 - ② D-AMPS — Digital AMPS
 - Developed within North America
 - ③ PDC — Personal Digital Cellular
 - Developed and Solely used in Japan
 - ④ CDMA band IS-95 technology
 - Interim Standard 95
 - Developed at a somewhat later stage by Qualcomm.
- Target service was still voice
- Digital transmission allowed limited data services. Eg. SMS.



~ 2000

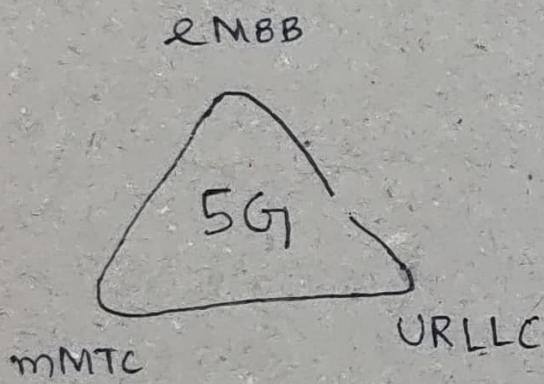
- The foundation of Mobile Broadband
 - True step to high-quality mobile broadband was taken
 - Enabling fast wireless internet access
 - Some main technologies include
 - ① HSPA — High Speed Packet Access
 - uses FDD, TD-SCDMA - TDD
 - ② CDMA - 2000
-



~ 2010

- Further enhanced Mobile Broadband
 - LTE supports both FDD and TDD operation
 - Unlike 3G, which had 2 different technologies
 - OFDM enables Wider transmission bandwidth
 - Advanced MIMO techniques
-

What is 5G ?



→ 5G is being designed for the following 3 use cases.

① eMBB — enhanced Mobile Broadband

- High data rates
- High traffic volumes

② mMTC — massive Machine Type Comm.

- Massive number of devices
- Low cost
- Low energy consumption

Eg. Remote sensors,
Monitoring of various equipment

③ URLLC — Ultra Reliable and Low Latency communication

- Very low latency
- Very high reliability and availability

Eg. Automatic control (Driverless cars)
Factory automation

Evolving 4G LTE to 5G

- LTE technical specifications (Release 8) were introduced in 2009.
- Since then, LTE has evolved (through Release 9 to 14) to provide enhanced performance / features.
 - High data rate, by increasing the number of tx / rx antennas.
 - Enable truly low-cost devices with very long battery life, in line with massive MTC applications.
 - Significant steps taken, to reduce the LTE air-interface latency.
- With these ongoing and future evolution steps, LTE will be able to support a wide range of the use cases envisioned for 5G.

Why are we developing 5G NR?

- LTE despite being a capable technology, certain requirements cannot be met by LTE or its evolution.
- LTE technical development was initiated a decade ago, now advanced technical solutions are available.
- To meet these requirements and to exploit new technologies, 3GPP initiated the development of a new radio access technology, known as NR (new radio).
- First version of NR specifications was available by end of 2017.
- NR reuses many of the structures and features of LTE.
- Since NR serves broad use cases than LTE, it uses partly different set of technical solutions.

Standardization of Mobile Communication

- Multi-national technology specifications and standards
 - Key to success of mobile communication
 - Allows deployment and interoperability of devices and infrastructure of different vendors.
 - Enables devices and subscriptions to operate on a global basis
- 1G NMT technology was created on a multinational basis
 - Allowed devices and subscription to operate over the national borders between the Nordic countries.
- 2G GSM was jointly developed between European countries by ~~Germany~~ ETSI (European Telecommunications Standards Institute)
 - GSM devices able to operate over a large number of countries - covering a large number of users.
- 3G WCDMA was developed with true global standardization of mobile.
 - Work on 3G was initially carried out separately by
 - * Europe (ETSI)
 - * North America (TIA) - Telecomm. Industry Association
 - * Japan (ARIB) - Association of Radio Industries & Businesses

Similar technologies were being pursued, but not interoperable with each other

3GPP - Third Generation Partnership Project

- Different regional standardization organizations have come together and jointly created 3GPP; have finalized the development of 3G technology based on WCDMA.
- A parallel organization (3GPP2) was later created by Qualcomm to develop an alternative 3G technology based on CDMA2000 (Evolution of 2G IS-95).
- For number of years, 3GPP and 3GPP2 co-existed.
- Over time, 3GPP came to completely dominate.
- 3GPP, despite its name, continued into the development of 4G and 5G technologies.
- Today, 3GPP is the only significant organization developing specifications for mobile communication.

3GPP documents

- 3GPP documents are divided into releases
 - Each release has a set of features added compared to the previous release.
- LTE / 4G is defined from Release 8 to 14.
- NR / 5G is defined from Release 15.
 - First set of specifications was published in December 2017
 - Full specifications were released in mid 2018.
- 3GPP Technical specifications (TS) are organized in multiple series.
 - 38-series : Transceiver design aspects for NR is of interest as a Communication Engineer.

Spectrum for Mobile Systems

- Frequency bands — Operating frequency range.
 - 1G and 2G — Around 800 to 900 MHz, but also in few lower and higher bands.
 - 3G (IMT-2000) — Focus was on 2GHz band.
 - 3G and 4G — Presently spanning from 450 MHz to 6 GHz,
 - (i). new bands were added at both lower and higher frequencies.
- Bands at different frequencies have different characteristics.
 - Lower frequency bands have good propagation properties
(Good for wide-area coverage deployments in urban, sub-urban and rural environments)
 - Higher frequency bands are difficult to use for wide area coverage, due to more path loss.
(Used for boosting bit-rate in dense indoor deployments)

Spectrum for 5G-NR

- ① Frequency Range 1 (FR1) — includes all existing and new bands below 6 GHz (approx)
- ② Frequency Range 2 (FR2) — includes new bands in the range from 24.25 to 52.6 GHz.

→ NR Frequency bands are in both

- ① paired FDD spectra
- ② unpaired TDD spectra

→ NR operating bands are named n1, n2, n3, ...

→ 3GPP release 15 NR specification (38.101) specifies 26 operating bands in FR1 and 3 operating bands in FR2.

Example NR frequency bands (38.101)

NR Band	UL Range (MHz)	DL Range (MHz)	Duplex Mode	Main regions
FR1	n41	2496 - 2690	TDD	US, China
	n50	1432 - 1517	TDD	
	n51	1427 - 1432	TDD	
	n66	1710 - 1780	FDD	Americas
	n70	1695 - 1710	FDD	
	n71	663 - 698	FDD	Americas
	n74	1427 - 1470	FDD	Japan
	n75	N/A	SDL	Europe
	n76	N/A	SDL	Europe
	n77	3300 - 4200	TDD	Europe, Asia
FR2	n78	3300 - 3800	TDD	Europe, Asia
	n257	26500 - 29500	TDD	Asia, Americas (global)
	n258	24250 - 27500	TDD	Europe, Asia (global)
mmWave	n259	37000 - 40000	TDD	US (global)