Cellular Telephony Networks

Table of Contents
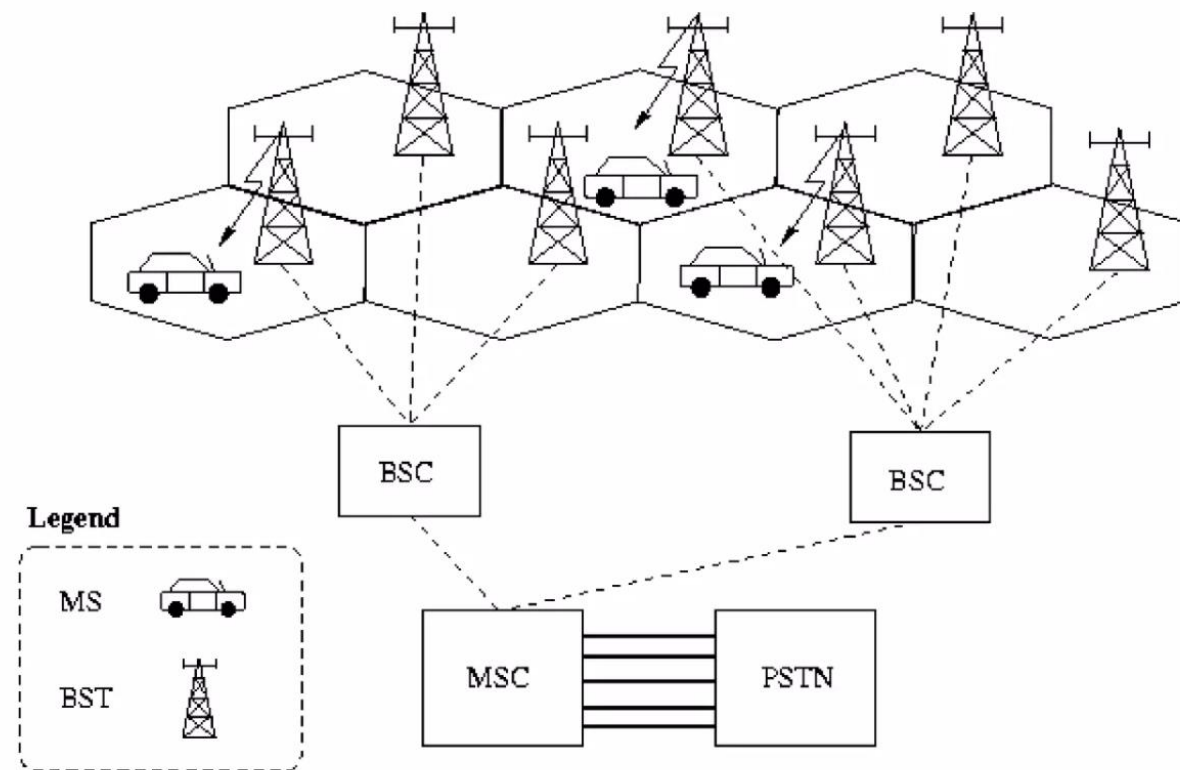
Introduction

A cellular network is a radio network made of multiple radio cells each served by at least one fixed location transceiver known as a cell site or base station.

Examples

MS→Mobile station; BST→Base station transceiver; MSC→Mobile switching center; BSC→Base station controller; PSTN→Public switched telephone network

- An example of a simple non-telephone cellular system is a taxi driver's radio system where the taxi company has several transmitters based around a city that can communicate directly with each taxi.

- A police squad's radio network with multiple mobile base stations for encrypted and interruption-free communication.

Working
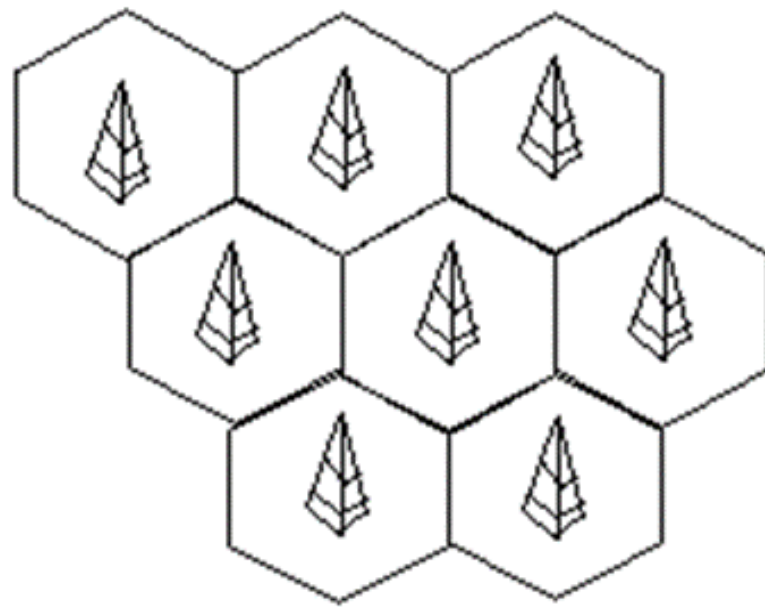
- The total coverage area is divided into hexagonal cells

- Each cell is serviced by at least one base station

- The client device broadcasts a message to all the base station to determine the optimal base station

- As a client moves from one cell to another, a handover process takes place wherein the client switches to a new base station

Advantages

- Spectral re-use leads to a more overall capacity

- Lower distance between transmitter & receiver means lower transmission power is required

- More easily scalable with higher coverage area

- Interference from other signals is reduced

Characteristics

Paging

Takes place by sending a broadcast message to all the cells

- For identification of optimal base station & to set up a channel for one-to-one communication
- For information transfer

Frequency Re-use

- TDMA
- FDMA
- CDMA

Frequency Re-use

TDMA

- Time Division Multiple Access
- Time slots allocated to each user within the channel.
- Allows large number of sequential accesses.
- Generally used in combination with FDMA or CDMA

FDMA

- Frequency Division Multiple Access
- The total capacity within the channel is sub-divided for each user
- Allows simultaneous accesses at the cost of bandwidth per user

CDMA

- Code Division Multiple Access
- Not to be confused with the mobile network standard
- Uses spread-spectrum technology and a special coding scheme
- Optimizes the use of available bandwidth as it transmits over the entire frequency range and does not limit the user's frequency range

Movement from cell to cell & handover

Manual Switching

In the primitive Police Squad's Radio Network, when a policeman transferred from one squad to another, they manually switched from one frequency to another as needed. If a communication is interrupted due to loss of signal, the policeman asked the base station operator to repeat message on a different frequency.

Frequency Re-use

In the cellular networks, as the distributed mobile transmitters move from one cell to another during an ongoing continuous communication, the switching of one cell frequency to another is also carried out automatically, without the user's manual interference. This is also popularly referred to as the Handover or Handoff.

Mobile Phone Networks

- The most well-known example of a cellular network

- Most mobile network standards (GSM, CDMA, AMPS) use cellular technology

- Each phone sends & receives calls via the transmission tower of its cell

- Satellite phones do not use cellular technology

Various kinds of digital cellular technologies

- Global System of for Mobile Communications (GSM)

- General Packet Radio Service (GPRS)

- Code Division Multiple Access (CDMA)

- Evolution-Data Optimized (EV-DO)

- Enhanced Data Rates for GSM Evolution (EDGE or GSM EDGE)

- 3GSM

- Digital Enhance Cordless Telecommunications (DECT)

- Digital Amps (IS-136 or TDMA)

- Integrated Digital Enhanced Network (iDEN)

Generation	Technology	Feature	Encoding	Year of first use	Roaming	Hand Interoperability	Signal Quality/coverage area	Frequency Utilization/Call Density	Handoff
1G	FDMA	NMT	Analog	1981	Nordics & several other European countries	None	Good coverage due to low frequencies	Very low Density	Hard
2G	TDMA & FDMA	GSM	Digital	1991	Worldwide, all countries except Japan & South Korea	SIM Card	Good coverage indoors on 850/900 MHz. Repeaters possible. 25km hard limit.	Very low Density	Hard
	CDMA	IS-95	Digital	1995	Limited	None	Unlimited cell size, low transmitter power permits large cells.	Very low Density	Soft
3G	CDMA	IS-2000	Digital	2000/2002	Limited	RUIM (rarely used)	Unlimited cell size, low transmitted power permits large cells.	Very low Density	Soft
	W-CDMA	UMTS	Digital	2001	Worldwide	SIM Card	Smaller cells & low indoors coverage on 2100 MHz; equivalent coverage indoors & superior range to GSM on 850/900 MHz.	Very low Density	Soft
4G	OFDMA	LTE	Digital	2009	Limited	SIM Card	Smaller cells & lower coverage on the S band.	Very low Density	Hard
5G	OFDMA	NR	Digital	2018	Limited	SIM Card	Dense cells on millimeter waves.	Very low Density	Hard

Timeline
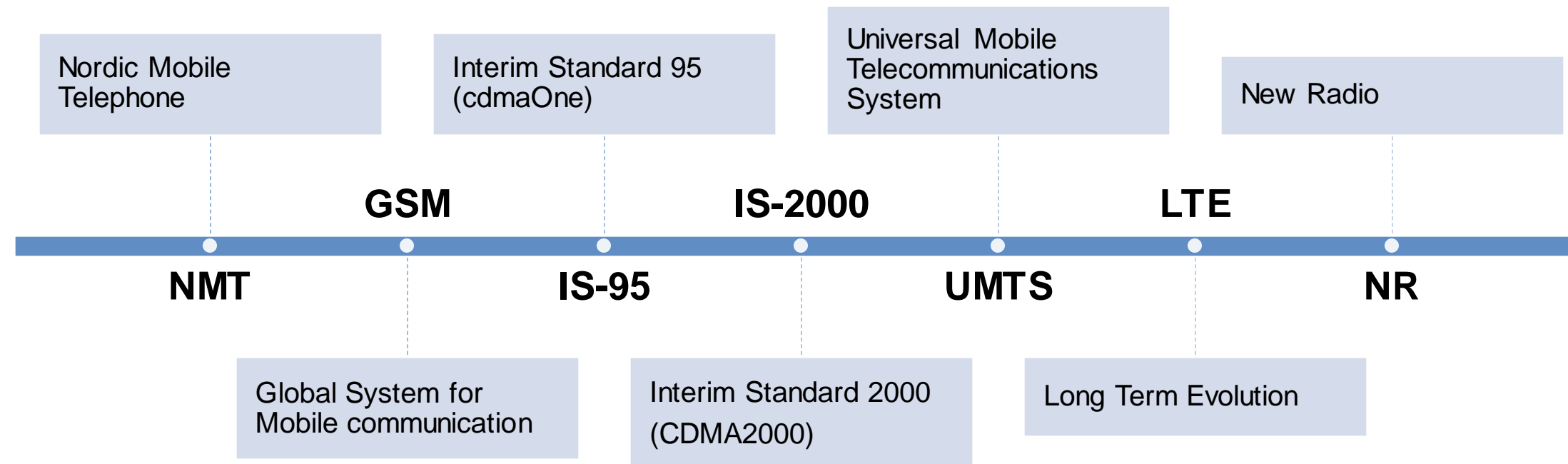
1G

NMT

- Nordic Mobile Telephone
- Cell sizes range from 2 km to 30 km.
- Voice channel was transmitted with Frequency Modulation.
- Signal speed varied between 600-1200 bits/sec.
- Earlier version of NMT Specification didn't support encryption but later version defined optional
  analog scrambling which was based on two-band audio frequency inversion.

2G

GSM

- Global System for Mobile Communication
- It is subdivided into 4 parts: Mobile Station, BSS, NSS, OSS
- Most 2G GSM networks operated in the 900 MHz or 1800 MHz bands.

IS-95

- Also known as CDMAOne
- Described as a three-layer stack: PHY, MAC or LAC, call-processing state machine.
- Physical layer deals with transmission of signals in both forward and reverse directions.

3G

IS-2000

- Also known as the CDMA2000
- Comes in 3 variations- 1x, 1xEV-DO (Evolution Data-optimised), 1x Advanced.

UMTS

- Many of the ideas that were incorporated into GSM have been carried over and enhanced for UMTS
- Allows both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes
- It employs a 5 MHz channel bandwidth

4G

LTE

- Long Term Evolution
- Cell sizes range up to 16 km
- First to use OFDMA (Orthogonal Frequency-Division Multiple Access), based on the idea of frequency-division multiplexing, which is a method to transmit multiple data streams over a channel

5G

NR

- New Radio
- Cell sizes range from 10 m to a few kilometers.
- Utilizes 2 different frequency spectrums to provide fast & reliable data connections
- FR2(24.25 GHz to 52.6 GHz) known as millimeter-wave 5G provides unparalleled data speeds but requires a direct line of sight with a transmitter as high-frequency radio waves can be blocked by physical objects
- FR1(450 MHz to 6 GHz) known as sub-6 5G provides wide coverage but only slight speed improvements over LTE
- To share frequencies used by LTE and 5G networks, frequency- and time division duplexing is used

Bibliography
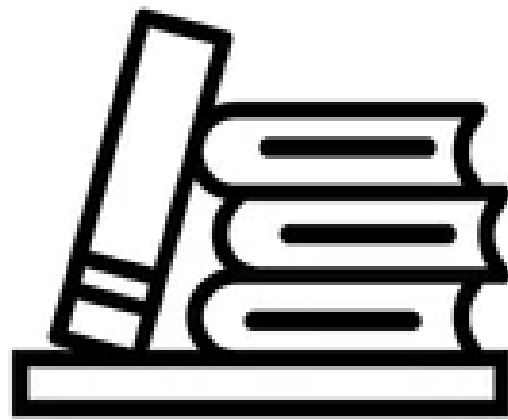
- Acm.org

- Springer.com

- Motorolasolutions.com

- Tnuda.org.il

- Techrader.com

- Electronics-notes.com

- Wikipedia.com

Thank you!

Sai Koushik Neriyanuri

Aayush Rautela