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Cellular Communication

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Cell Phones

- Voice and Video Communication
- Social Media
- Web Surfing
- Games
- E-mail
- Video Streaming
- Take pictures

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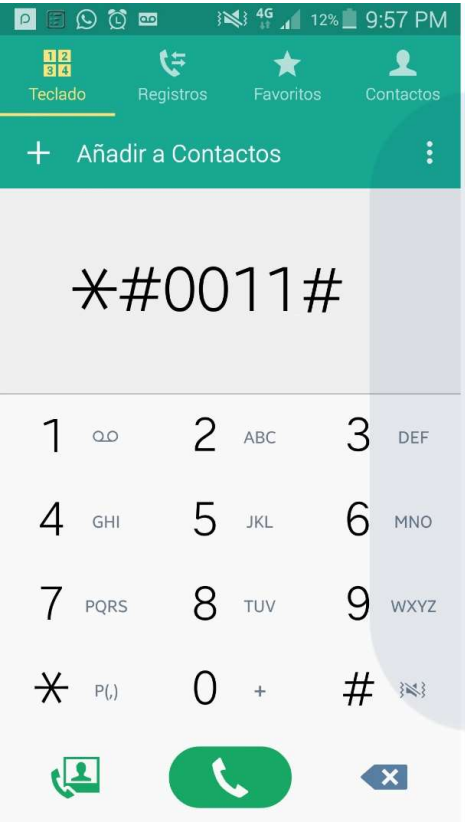
Cell Phones



Data rate?

Bandwidth?

BER?

RSRP, RSRQ?

SINR?

Multiple Access?

Throughput?

CQI?

Carrier Frequency?

MIMO?

CA?

3001#12345# Iphone

##7262626#*#* Huawei and Xiaomi

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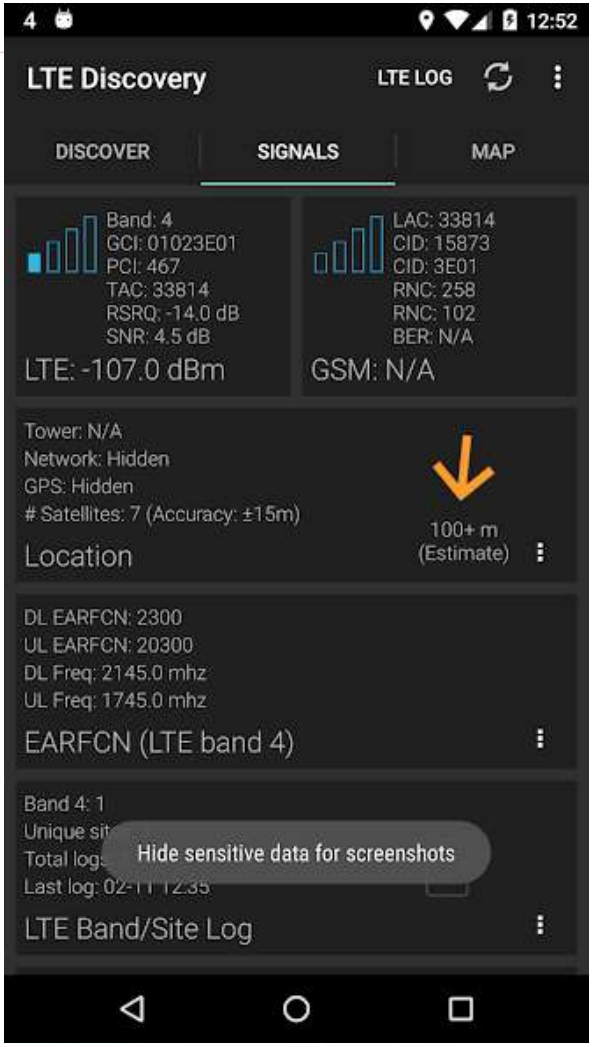
Cell Phones

Applications

Network Cell Info Lite

LTE Discovery (5G NR)



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History of Cellular Communication Systems

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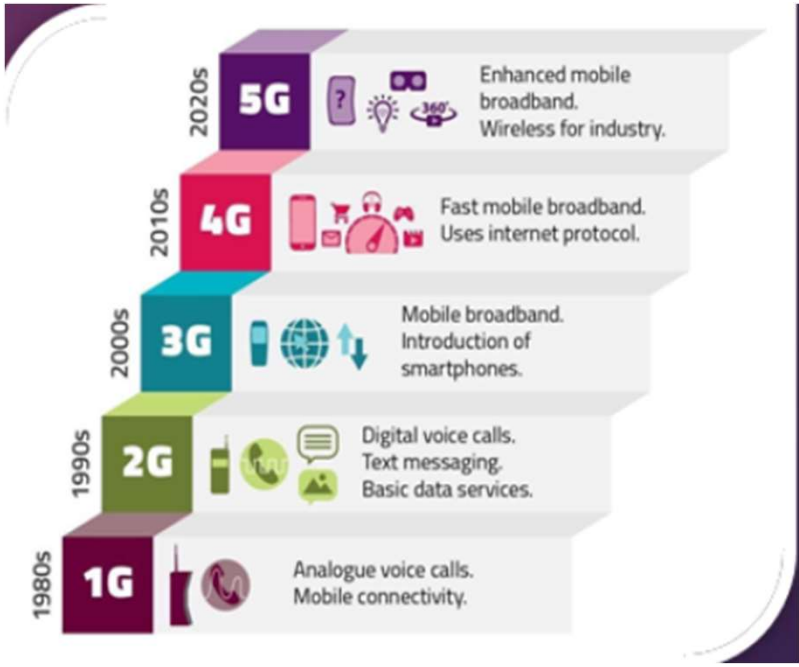
Summary (from 1G to 4G)

Gen. / Service	1G	2G	3G	4G, LTE
Release Year	1980s~	1990s~	2000s~	2010s~
# of Subscribers	20million (0.5%)	700million (11%)	18 billion (27%)	70 billion~ (over 100%)
Voice	Analog Type	Digital Type		VoLTE (Data Type)
Transmission	FM	Digital		
SMS	x	o	o	o
MMS	x	x	o	o
Video call	x	x	o	o
Data Rate	x	14.4kbps~ 384kbps	384kbps~ 10Mbps	100Mbps ~1Gbps
(800MB)		30min ~6hours	10min ~30min	6sec ~1min



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1G

- AT&T's Bell Labs invented the 1G system
  - Early 1970s
- Deployed in the early 1980s
  - **NMT** (Nordic Mobile Telephony, 1981)
  - **TACS** (Total Access Communication System, 1983)
  - **AMPS** (Advanced Mobile Phone System, 1983)
- Few Countries and Subscribers (not international)

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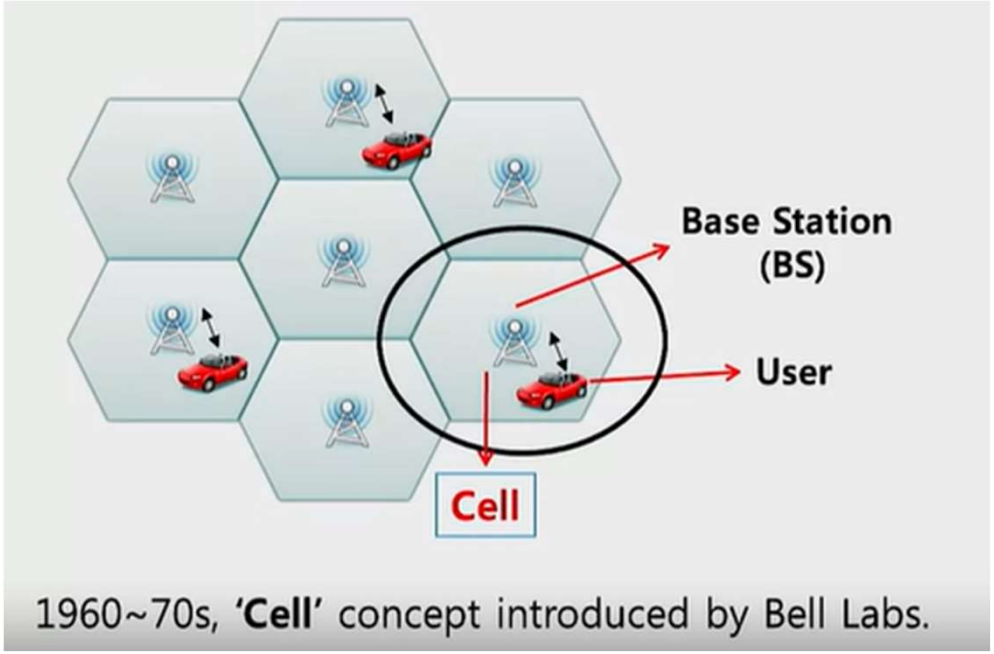
Key Technologies of 1G

- Cellular Structure
- Analog FM
- FDMA (Frequency Division Multiple Access)

Why Cellular Structure?



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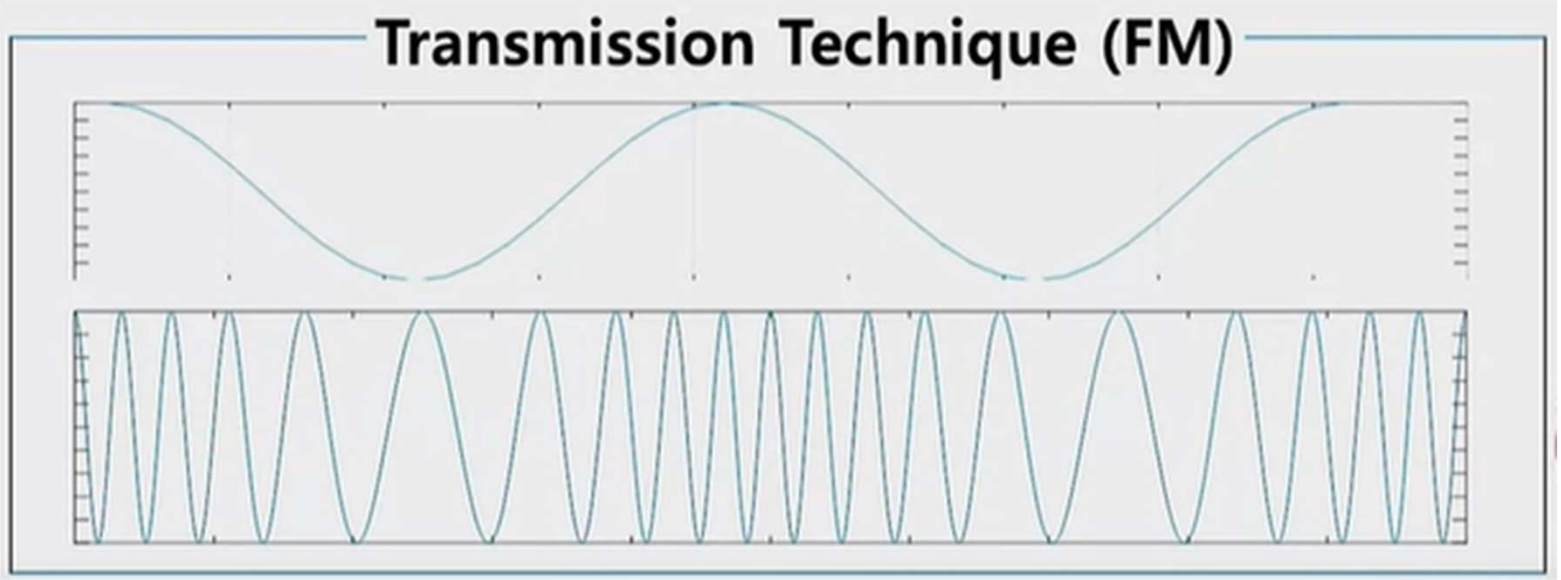
Key Technologies of 1G

- **Analog** FM (Frequency Modulation)



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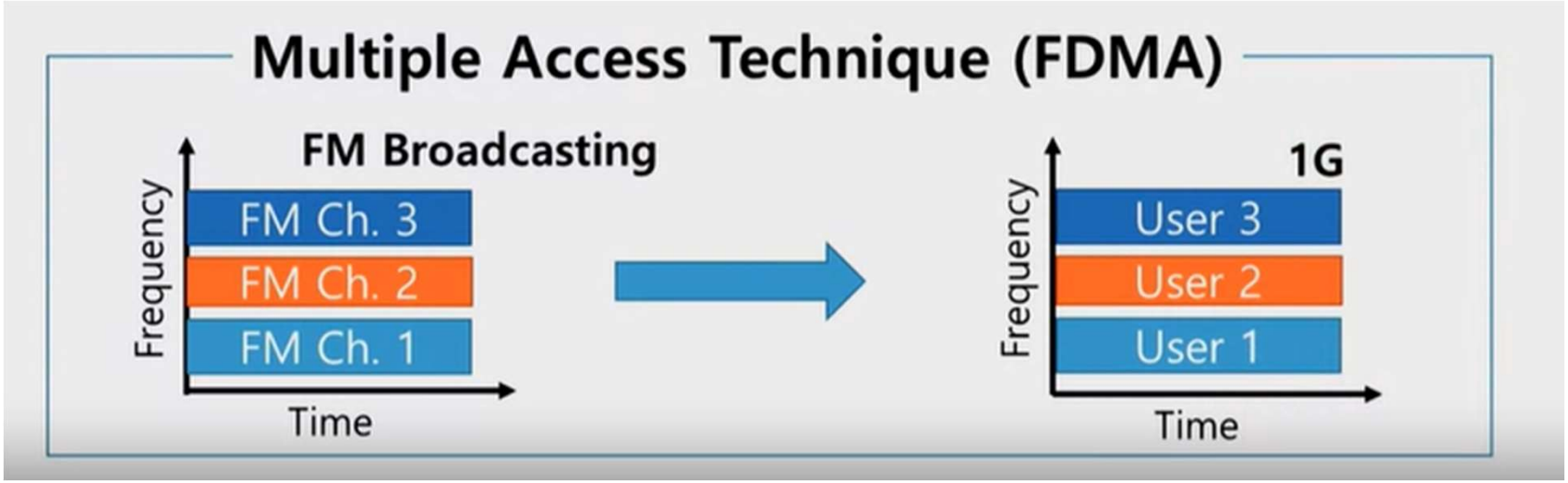
Key Technologies of 1G

- FDMA (Frequency Division Multiple Access)

Multiple Access



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Key Technologies of 1G

- Cellular Structure
- Analog FM
- FDMA (Frequency Division Multiple Access)

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Drawbacks of 1G

- Large Size (cell phone)
- Poor Battery
- Poor Voice Quality
- No Security
- Expensive Service Fee

Weighing in at 2 pounds, the Motorola DynaTac provided 30 minutes of talk time and took roughly 10 hours to charge.

https://www.youtube.com/watch?v=0WUF3yjgGf4&t=42s

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Summary of 1G

Gen. / Service	1G
Release Year	1980s~
# of Subscribers	20million (0.5%)
Voice	Analog
Transmission	FM, FDMA
SMS	x
MMS	x
Video call	x
Data Rate (800MB)	x

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2G Cellular System

Since mid 1990's...

- **Deployed in 1990s**
  GSM (Global Standard)(1991)
  CDMA (Code Division Multiple Access), IS-95
  US-TDMA (IS-136),PDC (Japan)

- **Techniques**
  Digital Modulation (BPSK, QPSK)

- **Service**
  Digital Voice Communication
  SMS
  Limited Data Service (14.4~64 kbps)

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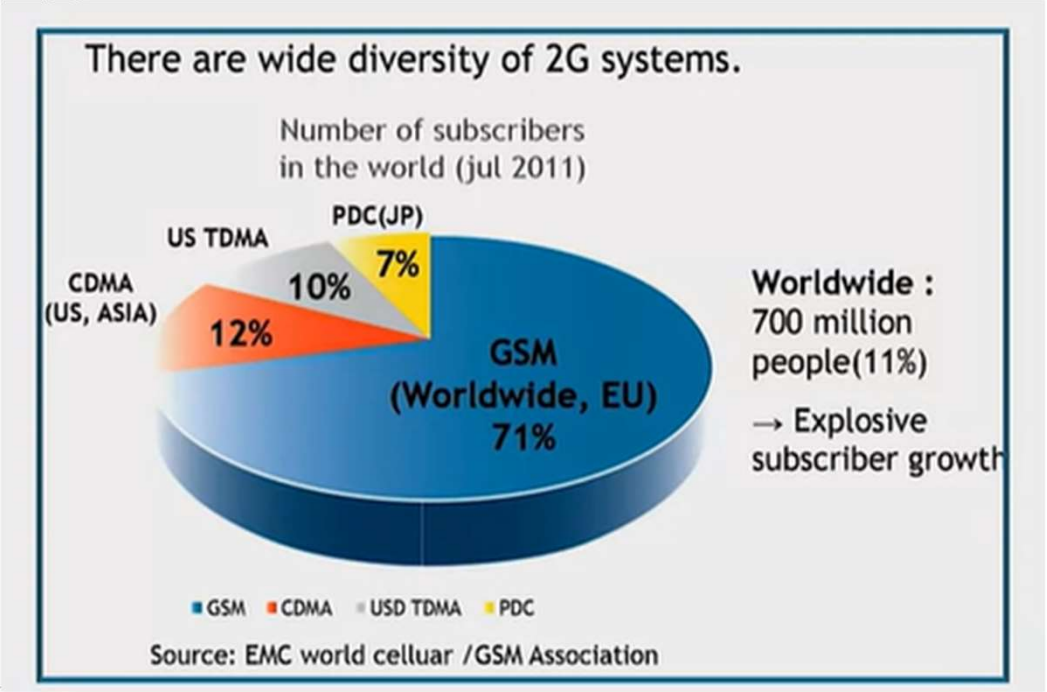

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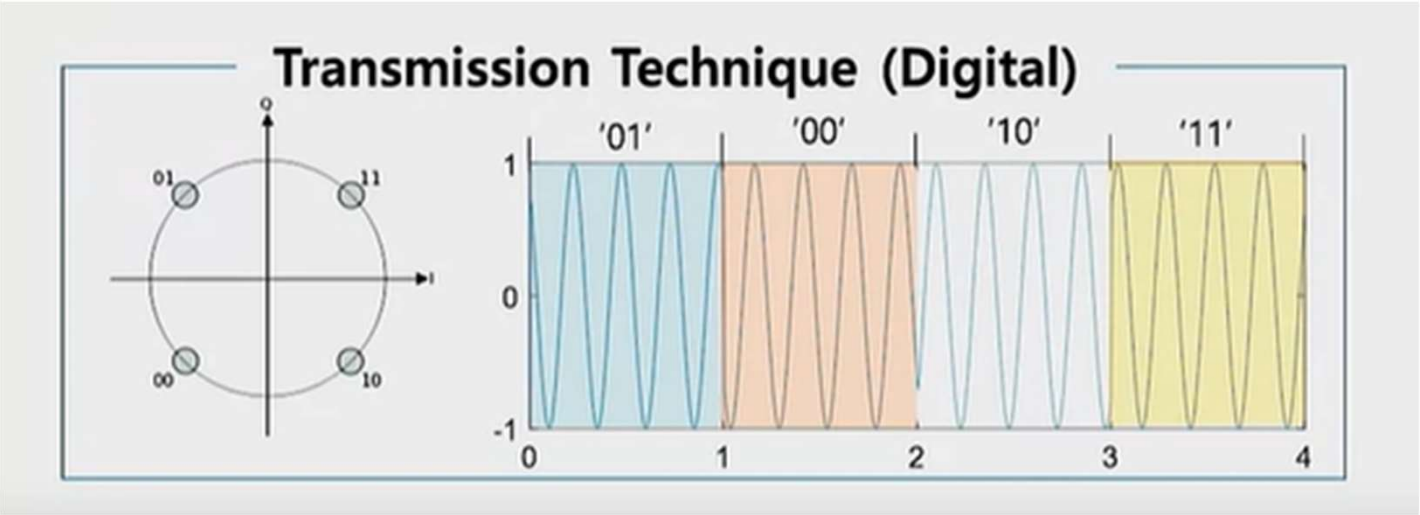
Key Technologies of the 2G

Digital Modulation (BPSK, QPSK)

TDMA, CDMA



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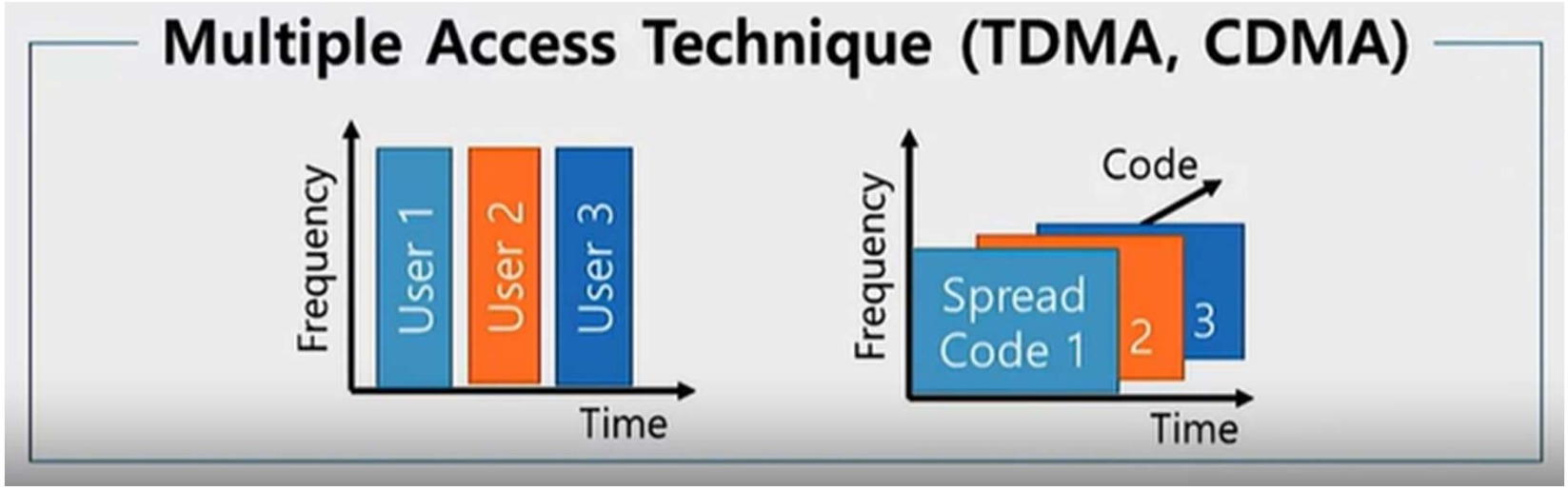
Key Technologies of the 2G

TDMA (Time Division Multiple Access)

CDMA (Code Division Multiple Access)



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Services with the 2G System

SMS

Data Service (14.4~64 kbps)

CDMA (Code Division Multiple Access)

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Limitation the 2G System

- Limited Data Rate (2G system : ~100kbps)

  (i.e.) 800 MB data download -> 1 hour

- Stable Web surfing/Video Call

  -> Need more than 1 Mbps

Gen. / Service	1G	2G
Release Year	1980s~	1990s~
# of Subscribers	20million (0.5%)	700million (11%)
Voice	Analog Type	Digital Type
Transmission	FM	Digital
SMS	x	o
MMS	x	x
Video call	x	x
Data Rate	x	14.4kbps~ 384kbps
(800MB)		30min ~6hours

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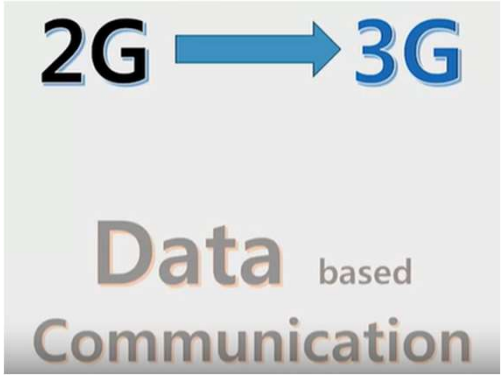
3G

Since the 2000's…

- Based on IMT-2000
  - WCDMA (Wideband CDMA, 2001)
  - CDMA200 (2002)
- Techniques
  - High Order Digital Modulation
  - CDMA
- Service
  - Enhanced Data Rate (384kbps~2Mbps)
  - Video Call
  - MMS



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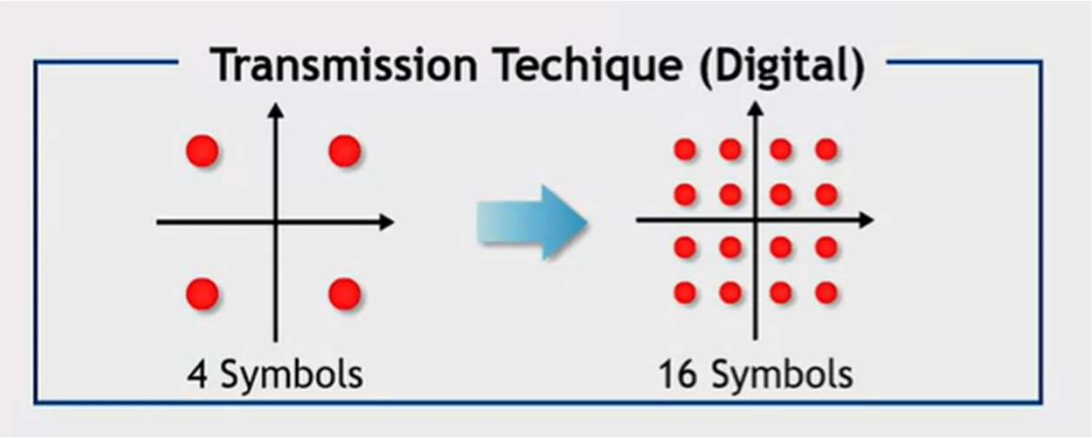
Key Technologies of the 3G

- High Order Digital Modulation

  2G: QPSK -> 3G: 16QAM



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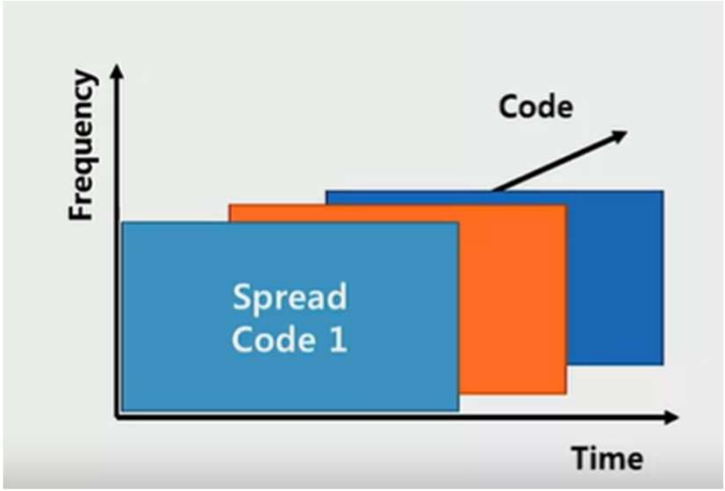
Key Technologies of the 3G

- Only CDMA

- High Order Digital Modulation
- CDMA



2G -> 3G
Revolution ?
Technical Evolution ✓

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Services with the 3G System

- Enhanced Data Rate
  - Around year 2002: 38kbps~2Mbps
  - Around year 2008: Up to 10Mbps

Thanks to Enhanced Data Rate -> Smartphones
-> New UX(Video Call, Web Surfing)

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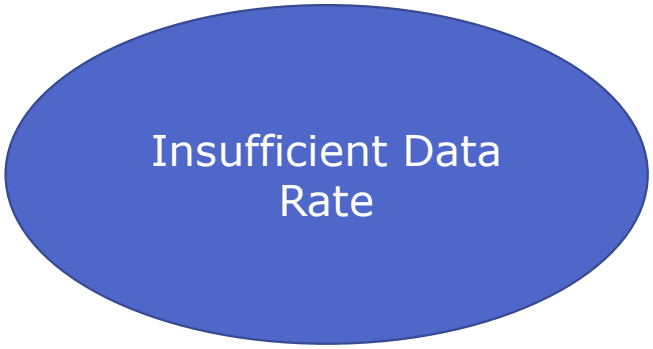
Limitation the 3G System

- Insufficent DataRate (3G: up to 10Mbps) for Real-Time High Qualty Multimedia Service

Need more than 100 Mbps

HD movies, high quality video calls, video conferencing…



Gen. / Service	2G	3G
Release Year	1990s~	2000s~
# of Subscriber	700million (11%)	1.8 billion (27%)
Voice	Digital Type	
Transmission	Digital	High-order Digital
SMS	o	o
MMS	x	o
Video call	x	o
Data Rate	14.4kbps~ 384kbps	384kbps~ 10Mbps
(800MB)	30min ~6hours	10min ~30min

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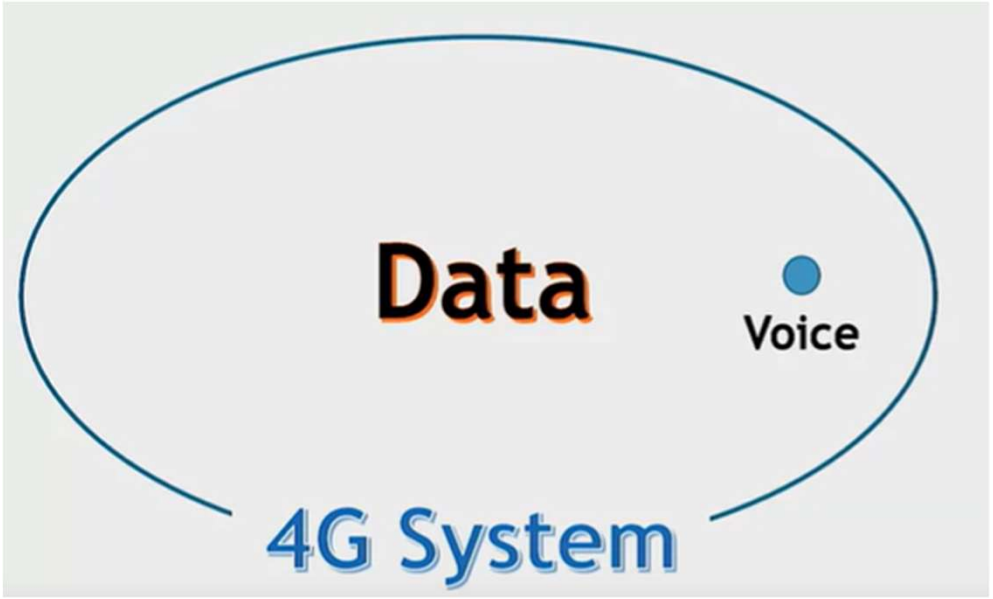
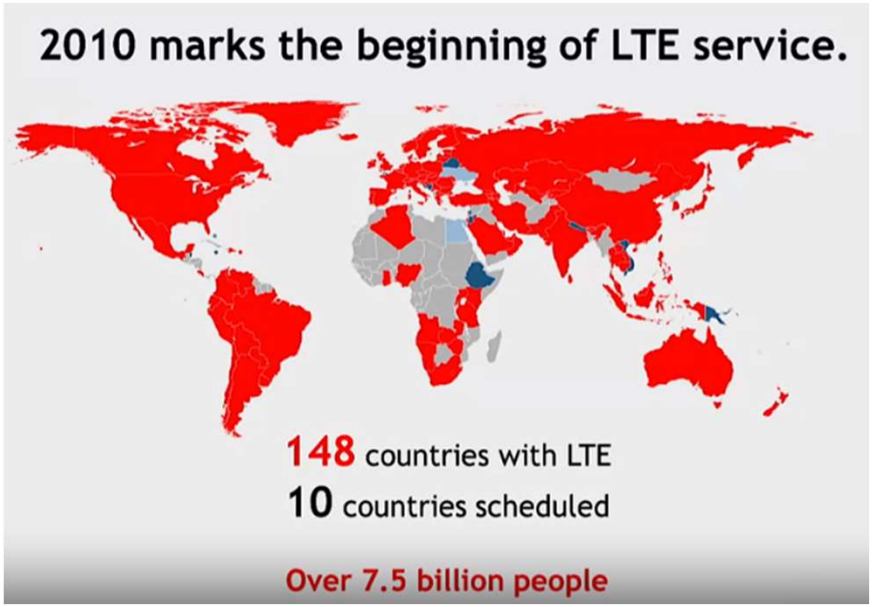
4G

- Designed primarily for Data





- LTE?

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4G - LTE

- LTE
  - Long Term Evolution

3rd Generation Partnership Project (3GPP)

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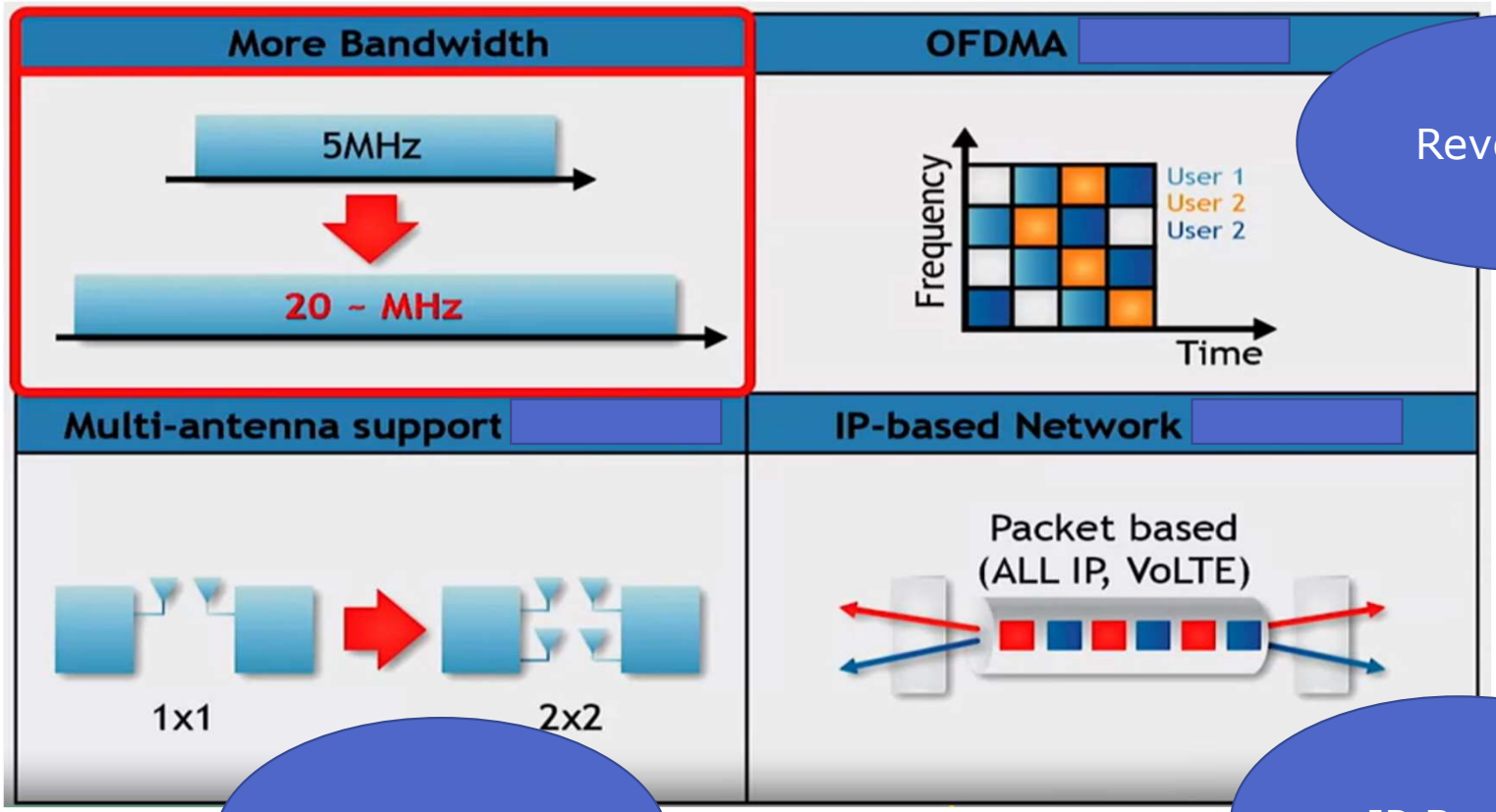
4G – LTE Key Technologies



Revolution

MIMO

IP Based

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4G - LTE

LTE Features

- **High data rate**
  - (10x~faster than 3G, up to 1Gbps)
- **Connectivity (up to $10^5\ units/km^2$)**
- **High mobility (up to 350 km/h)**
- **IP-based Communication**
  - True All Ip Network (VoLTE)

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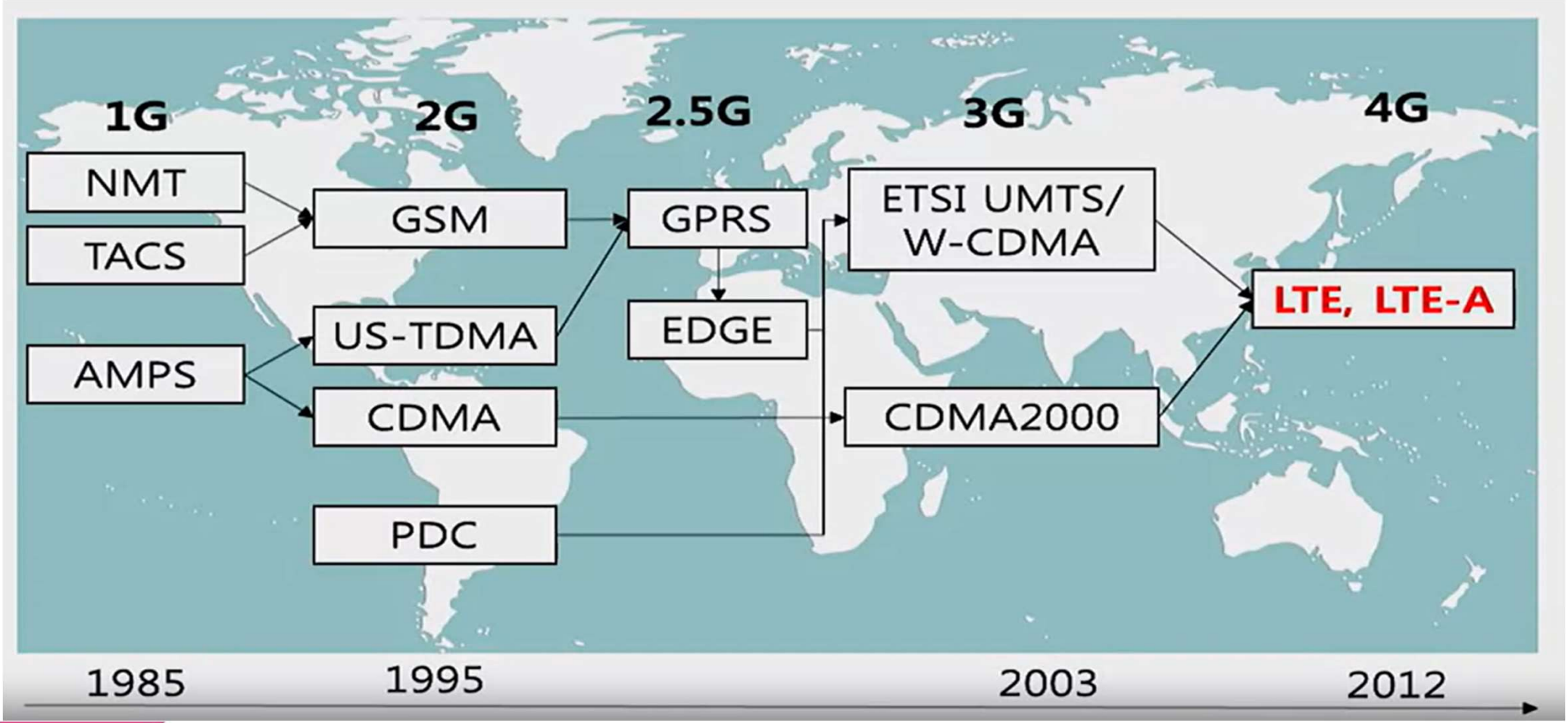
Standards



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Comparison (3G/4G)

Gen. / Service	3G	4G
Release Year	2000s~	2010s~
# of Subscribers	1.8 billion (27%)	7.5 billion~ (over 100%)
Voice	Digital	VoLTE (Data
Transmission	CDMA	OFDMA
SMS	o	o
MMS	o	o
Video call	o	o
Data Rate	384kbps~ 10Mbps	100Mbps ~1Gbps
(800MB)	10min ~30min	6sec ~1min

Revolution

Real-time Multimedia

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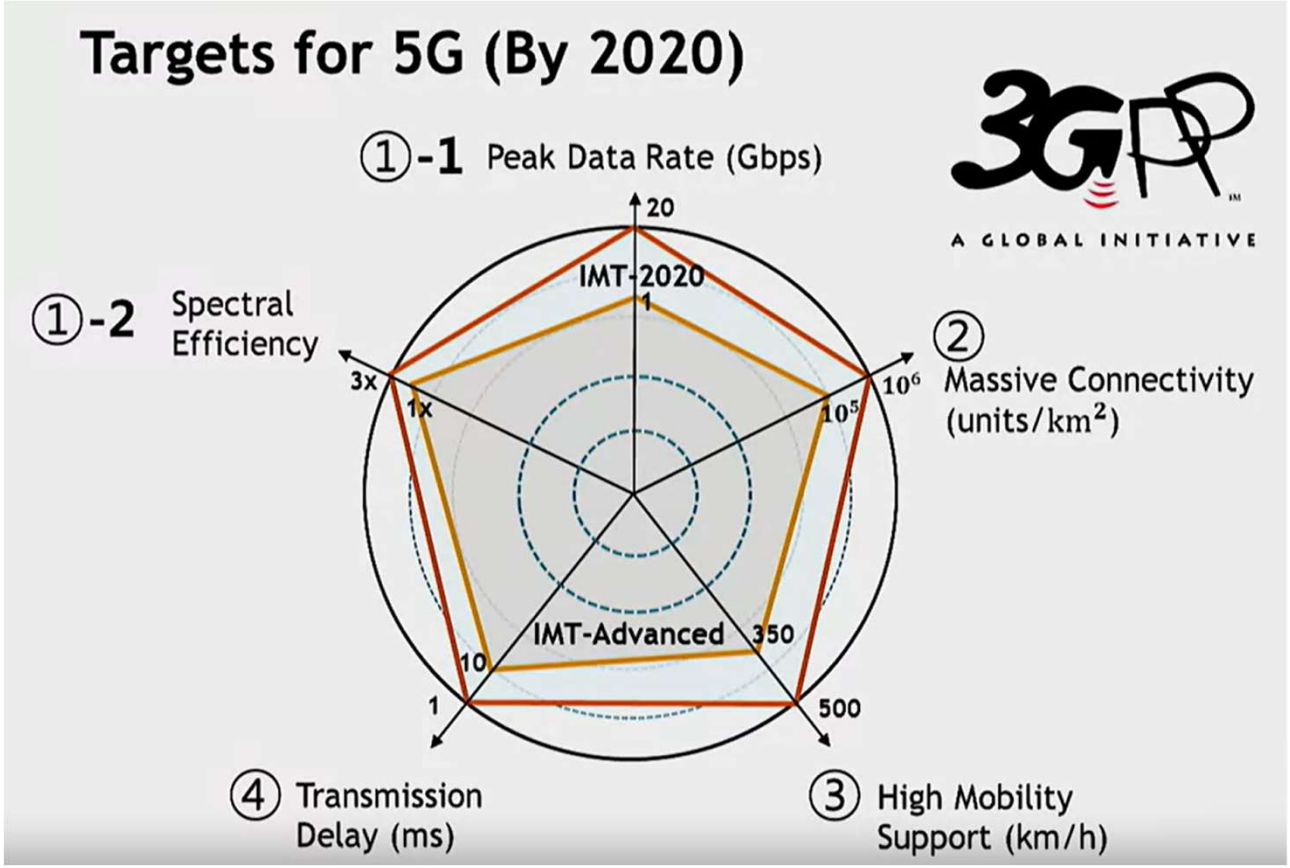
Future Cellular Systems 5G>>>6G

Why 5G?



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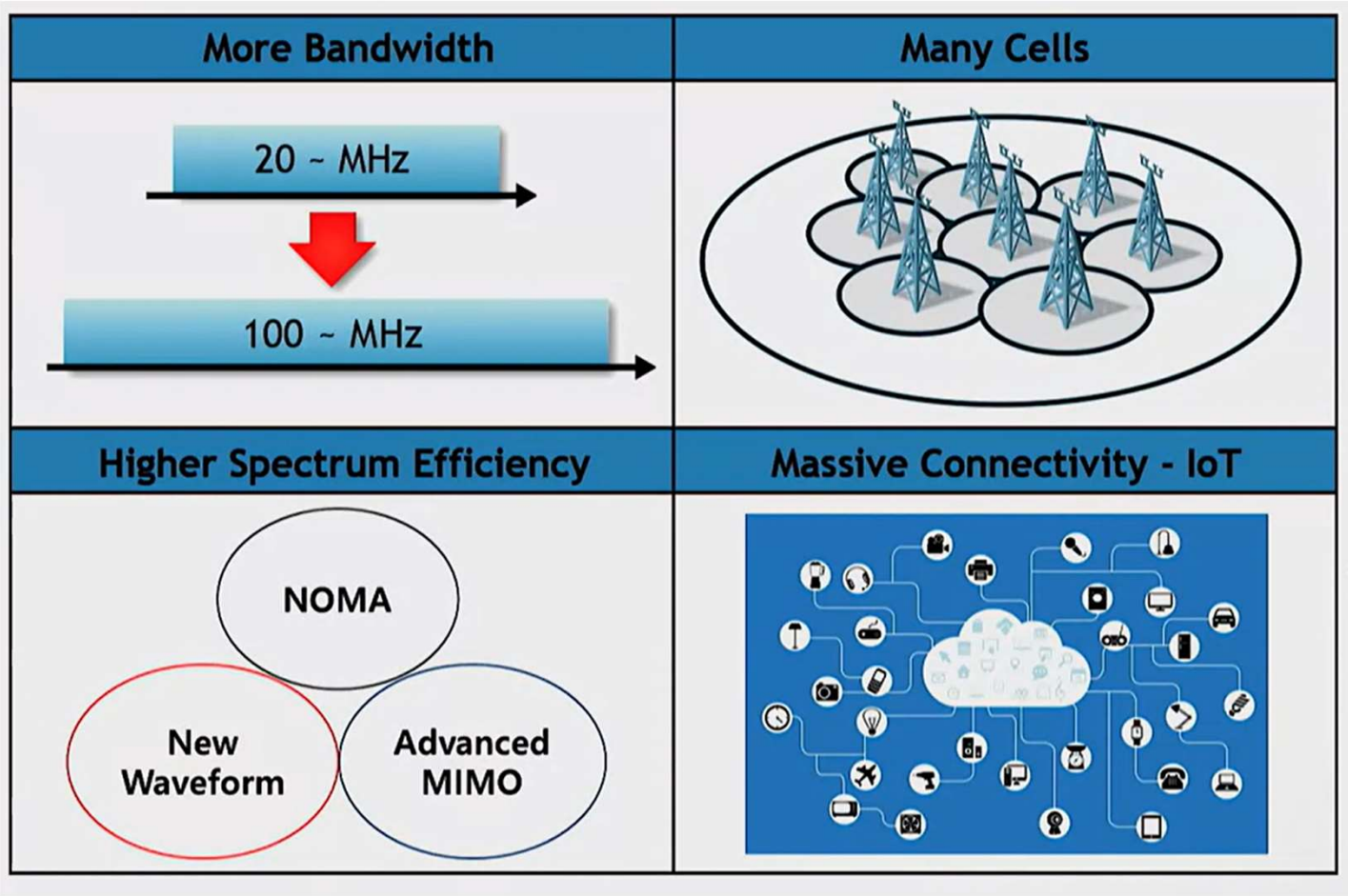
5G

Why 5G?



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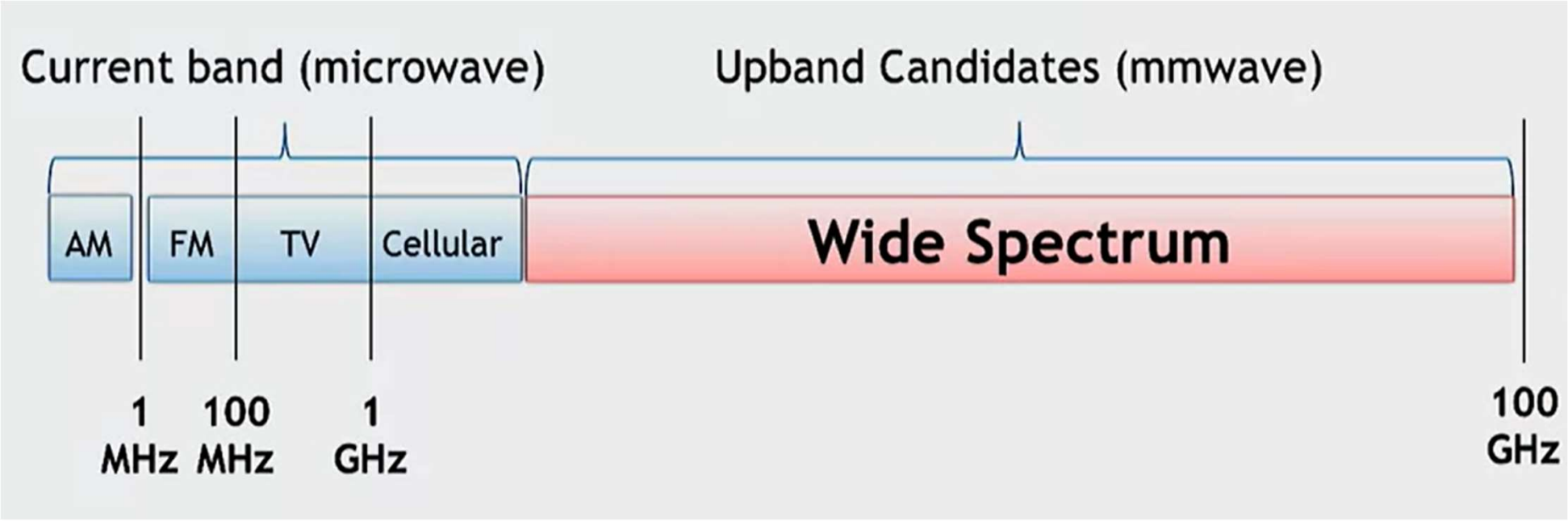
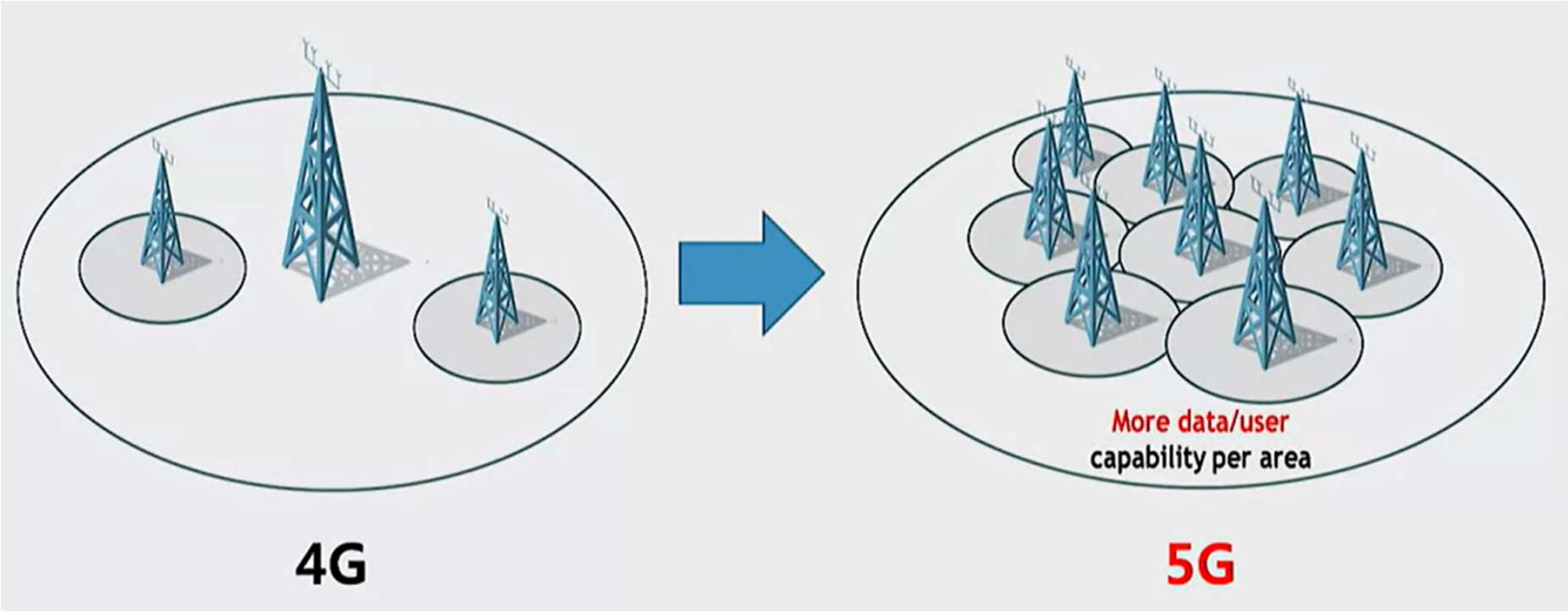
5G

Wide Spectrum – above 6GHz, mmWave



Many Cells – Cell Densification, (Small Cell)



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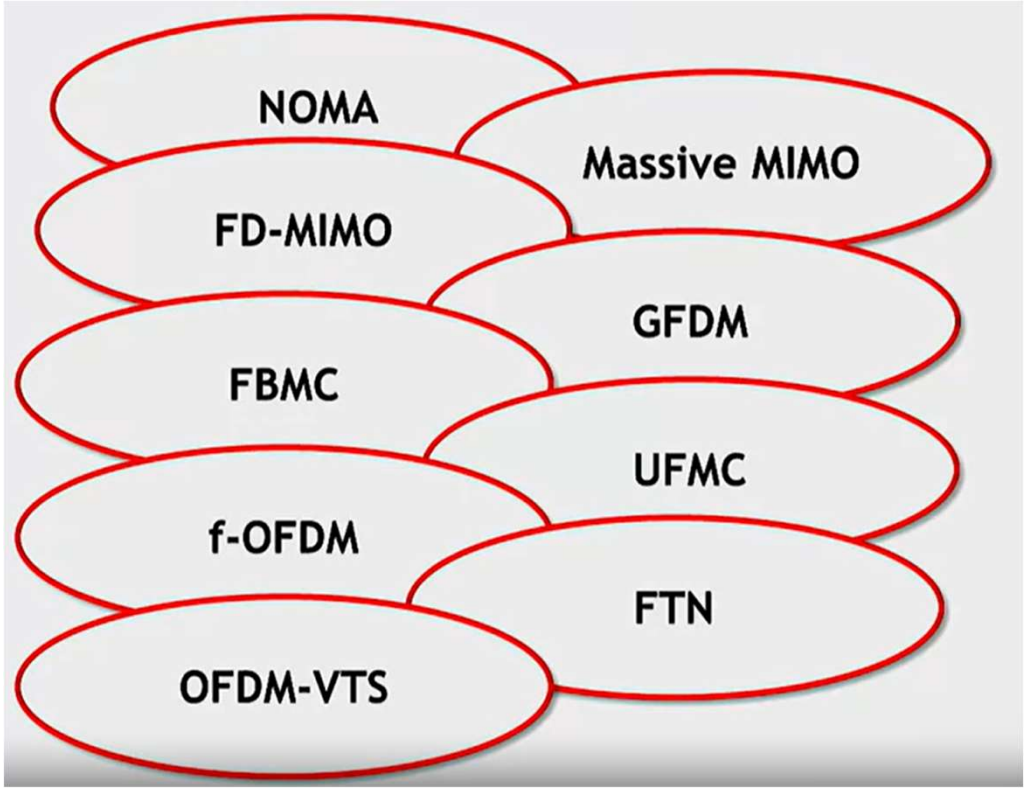
5G

Higher Spectral Efficiency



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5G

Massive Connectivity – IoT (Internet of Things)

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Summary

Gen. / Service	1G	2G	3G	4G	5G
Voice	Analog	Digital		VoLTE	
SMS	x	o	o	o	o
MMS	x	x	o	o	o
Video call	x	x	o	o	o
Data Rate	x	14.4kbps~ 384kbps	384kbps~ 10Mbps	100Mbps ~1Gbps	20Gbps
(800MB)		30min ~6hours	10min ~30min	6sec ~1min	~0.5sec
Transmission	FM	Digital			?
Multiple Access	FDMA	TDMA/CDMA	CDMA	OFDMA	OFDMA
Service/ Standards	NMT TACS AMPS	GSM/CDMA US-TDMA PDC GPRS/EDGE	WCDMA CDMA 2000	LTE	Single spec