Different Generations Of Mobile Technologies

@3g4gUK

In the beginning – 0 ‘G’ (pre-cellular)

- Mobile Telephony Service (MTS) was introduced in 1946, commercialised in 1947 and by 1948 there were 5,000 subscribers making 30,000 calls each week.
- In 1965, AT&T introduced Improved MTS (IMTS) that mainly removed the need for operator and improved capacity
- Improved systems started to appear in Sweden, USSR, etc.

Picture: Mobile Radio Phone

Other 0 ‘G’ (pre-cellular) Systems

- MTS – Mobile Telephone Service (USA, 1949 - 1965)
- Post Office Radiophone Service (UK, 1959 - ?)
- IMTS – Improved Mobile Telephone Service (USA, 1965 – ?)
- RCC – Radio Common Carrier (USA , 1960’s – 1980’s)
- OLT – Offentlig Landmobil Telefoni (Norway, 1966 – 1990)
- MTD – Mobile telephony system D (Denmark, 1971 – 1987)
- ARP – Autoradiopuhelin (Finland, 1971 – 2000)

D.H. Ring, Bell Labs - Telephony - Wide Area Coverage, 11 December 1947

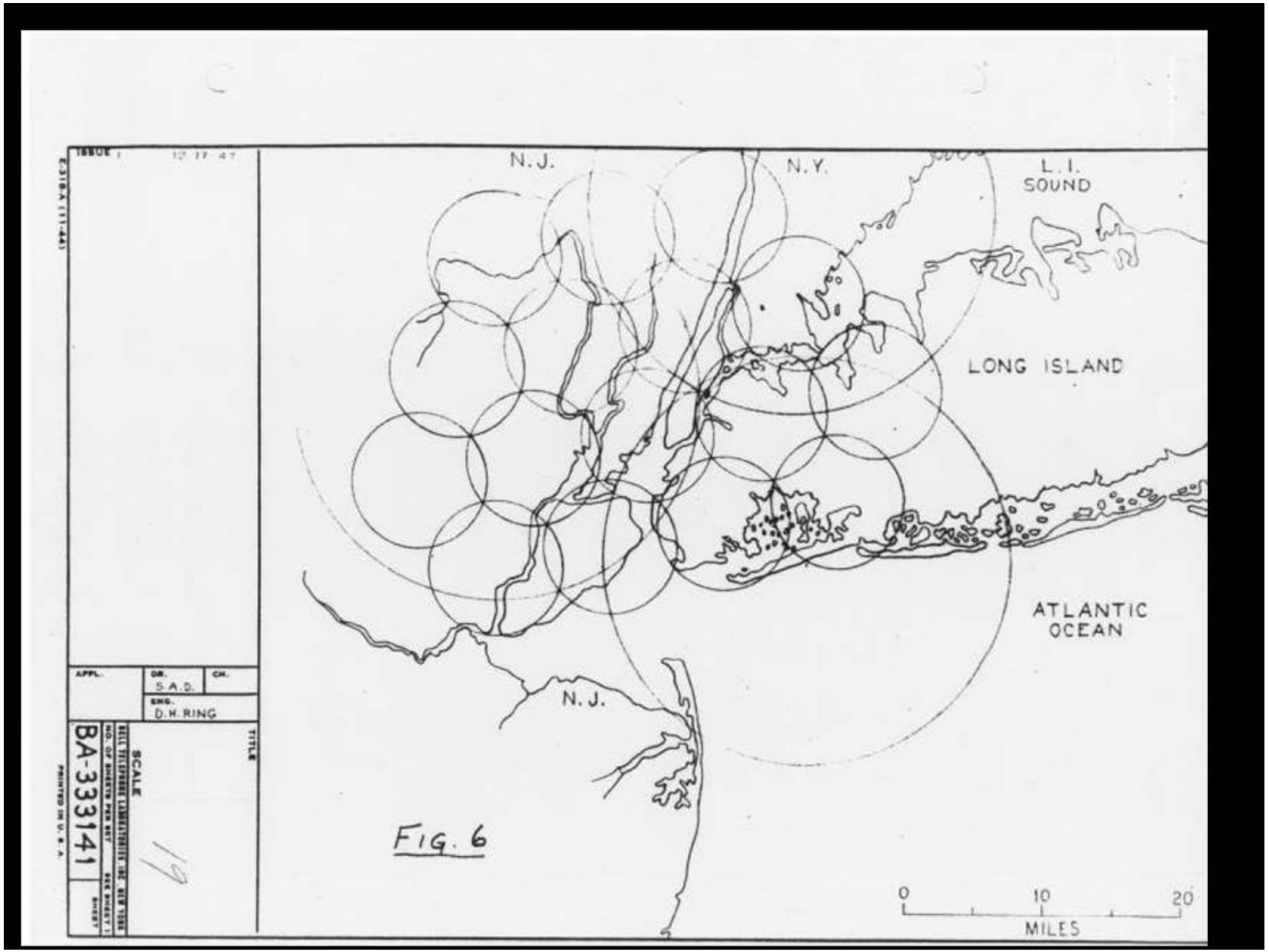
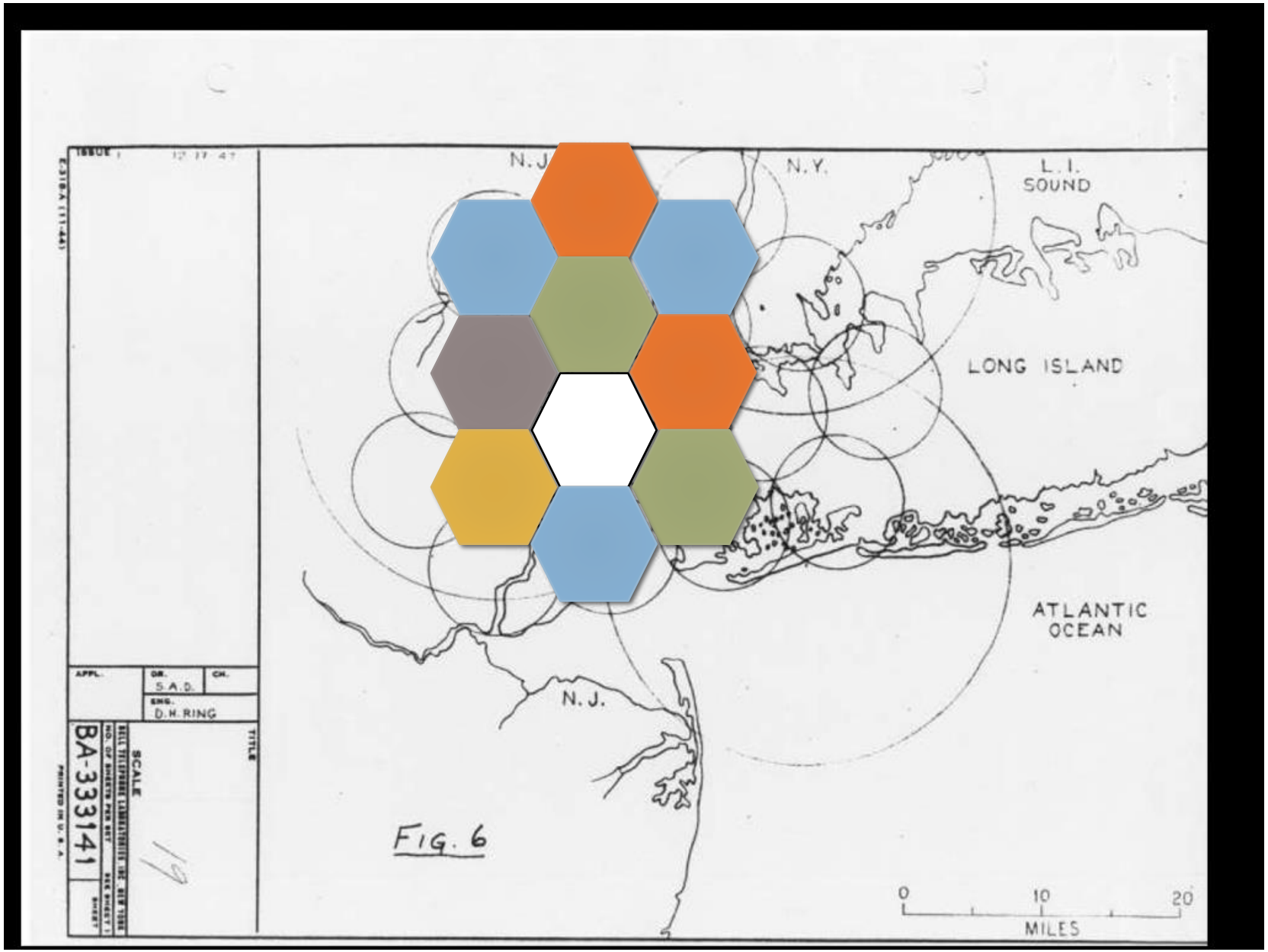


FIG. 6

D.H. Ring, Bell Labs - Telephony - Wide Area Coverage, 11 December 1947



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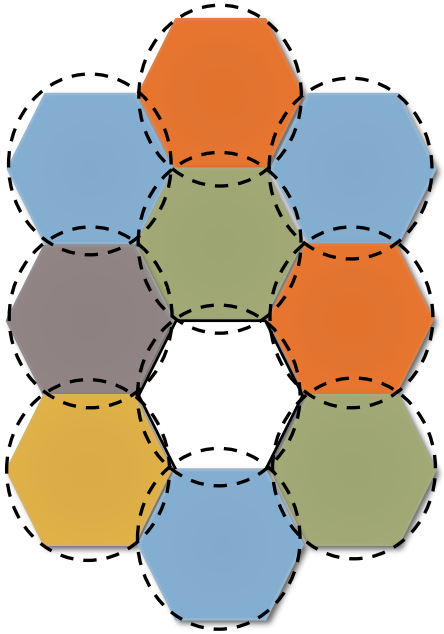
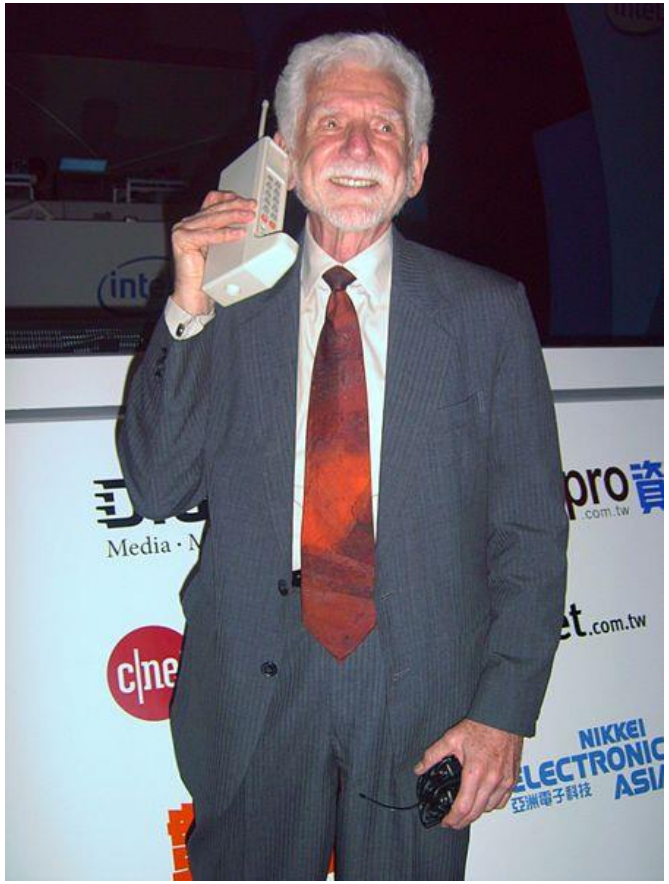


First Generation (1 ‘G’) Mobile System

- The first generation of cellular system was known as Advanced Mobile Phone System (AMPS).
  - USA – 1978
  - Israel – 1986
  - Australia – 1987

- It had several major issues:
  - No encryption so anyone can eavesdrop
  - It could be cloned very easily as there was no security
  - It was very inefficient technology

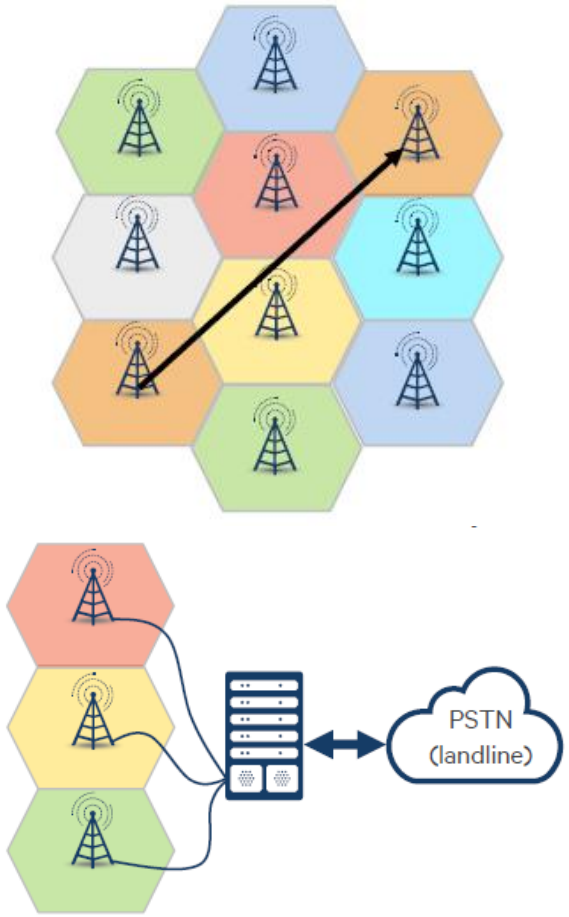
- AMPS was superseded by Digital AMPS (D-AMPS) and was shut down by 2008.



Dr. Martin Cooper of Motorola was part of the team that developed DynaTAC in 1973. Re-enactment in 2007

1 ‘G’ laid the foundations of Cellular Networks

- Use of licensed spectrum
- Frequency Reuse
  - Neighbour cells used different frequencies to avoid interference
- It defined the basic architecture of the cellular network



Second Generation (2 ‘G’) Mobile System

D-AMPS – Digital AMPS

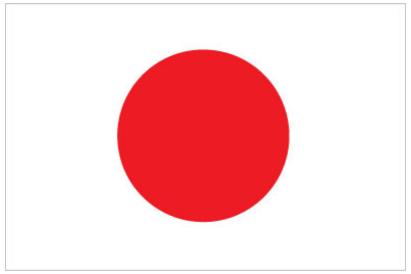
- 1993 – 2009
- IS-54 & IS-136
- TDMA based technology

cdmaOne

- 1995 – 2001
- Championed by Qualcomm
- IS-95
- CDMA based technology
- Supplanted by CDMA2000 (3G) technology

GSM – Global System for Mobile communications

- Originally ‘Groupe Spécial Mobile’
- 1991 - present
- First deployed in Finland, Dec. 1991
- Launched in UK, 1993
- Most popular 2G system in use worldwide
- Uses mainly 900MHz or 1800MHz
- Originally designed for voice only
- SMS was commercially launched in 1995
- Data was supported using High-Speed, Circuit-Switched Data (HSCSD) giving max data rates of 57.6Kbps



PDC – Personal Digital Cellular

- 1993 – 2012

GPRS (2.5 ‘G’) & EDGE (2.75 ‘G’)

General Packet Radio Service (GPRS) was an enhancement added on top of GSM to allow PS data to be transferred

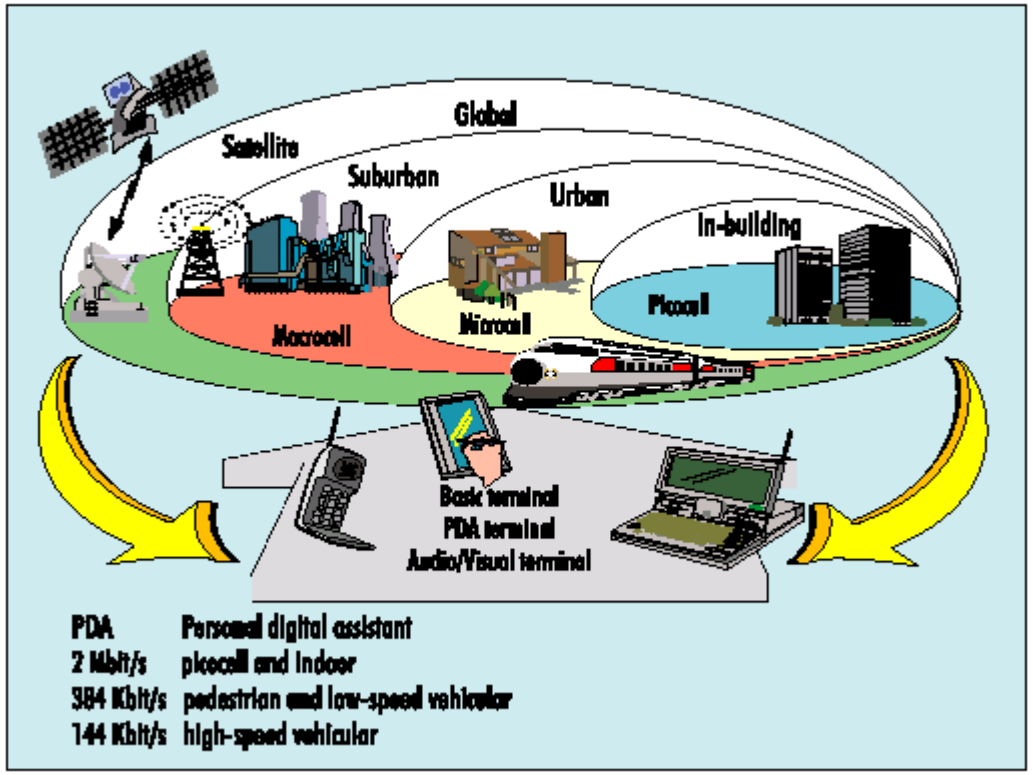
- Theoretical maximum data rate is 170Kbps but practically its around 40 Kbps
- Always-on data connection with billing based on amount of data transferred

Enhanced-GPRS (E-GPRS) , a.k.a **Enhanced Data rates for GSM Evolution (EDGE)** enhances the air interface further to allow for even higher data rates

- Theoretical max data rates of 473.6Kbps but practically data rates would be 100Kbps.

International Mobile Telecommunications-2000 (IMT-2000)

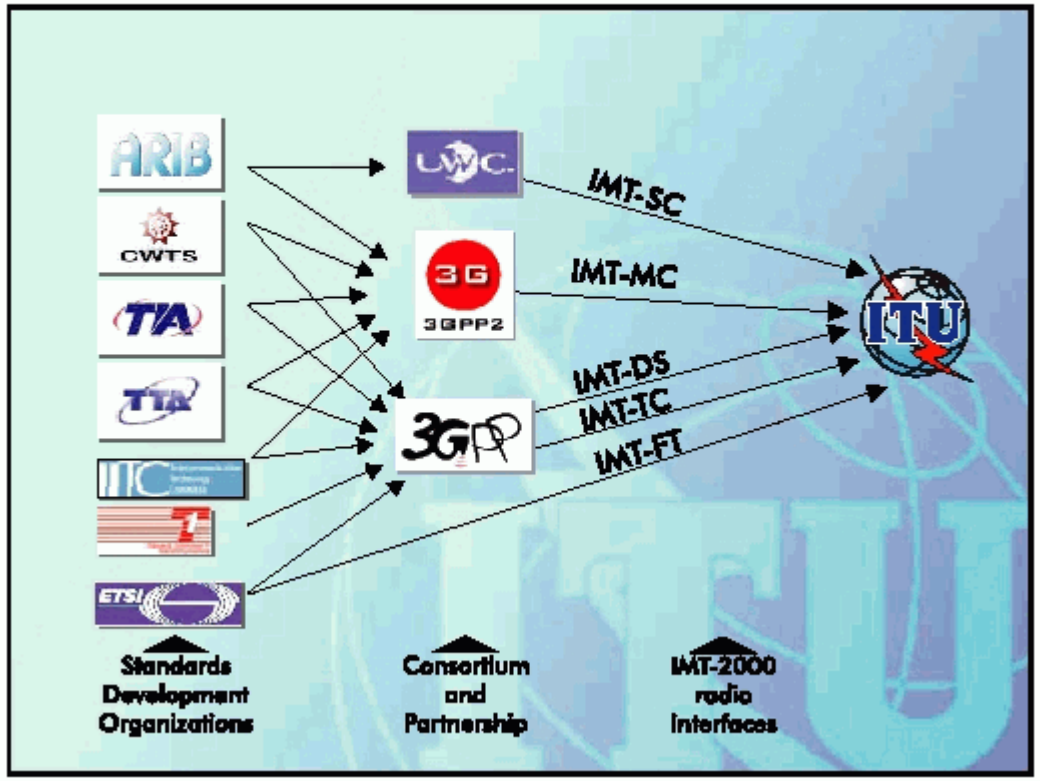
Figure 4 — IMT-2000, a flexible, multi-functional network



Source: European Commission.

International Mobile Telecommunications-2000 (IMT-2000)

Figure 2 — Collaboration between ITU and external organizations in the development of IMT-2000 radio interface specifications, approved in Istanbul as ITU–R Recommendation M.1457



Source: ITU, 2000.

Third Generation (3 ‘G’) Mobile System

CDMA2000 EV-DO

- Evolution Data Optimized
- Further evolved to
  - EV-DO Rev. A
  - EV-DO Rev. B

Universal Mobile Telecommunications System (UMTS)

- Based on Wideband CDMA (WCDMA)
- Uses FDD
- Foundation of 3G systems worldwide, except some networks

Time Division Synchronous code division multiple access (TD-SCDMA)

- Designed especially for China
- Used by only 1 operator, ‘China Mobile’
- Based on Narrowband TDD

Third Generation (3 ‘G’) Mobile System

3G 3RD GENERATION PARTNERSHIP PROJECT 2 "3GPP2"

MA V-DO

- ta Optimized
- Fu lved to ev. A EV- B

3GPP™ A GLOBAL INITIATIVE

Universal Mobile Telecommunications System (UMTS)

- Based on Wideband CDMA (WCDMA)
- Uses FDD
- Foundation of 3G systems worldwide, except some networks

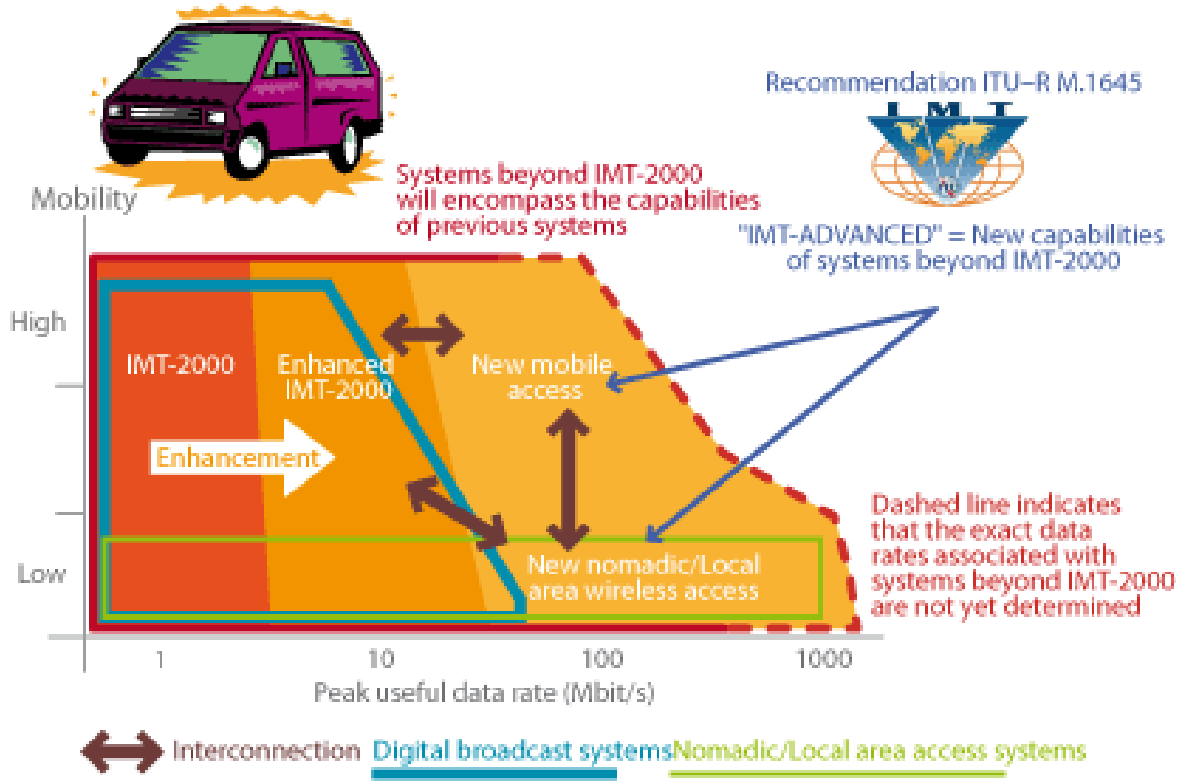
Time Divisi Synchrono ode division iple s (TD-S

- Designed esp for China
- Used by o ope ‘China M e’
- Based on Narrowband TDD

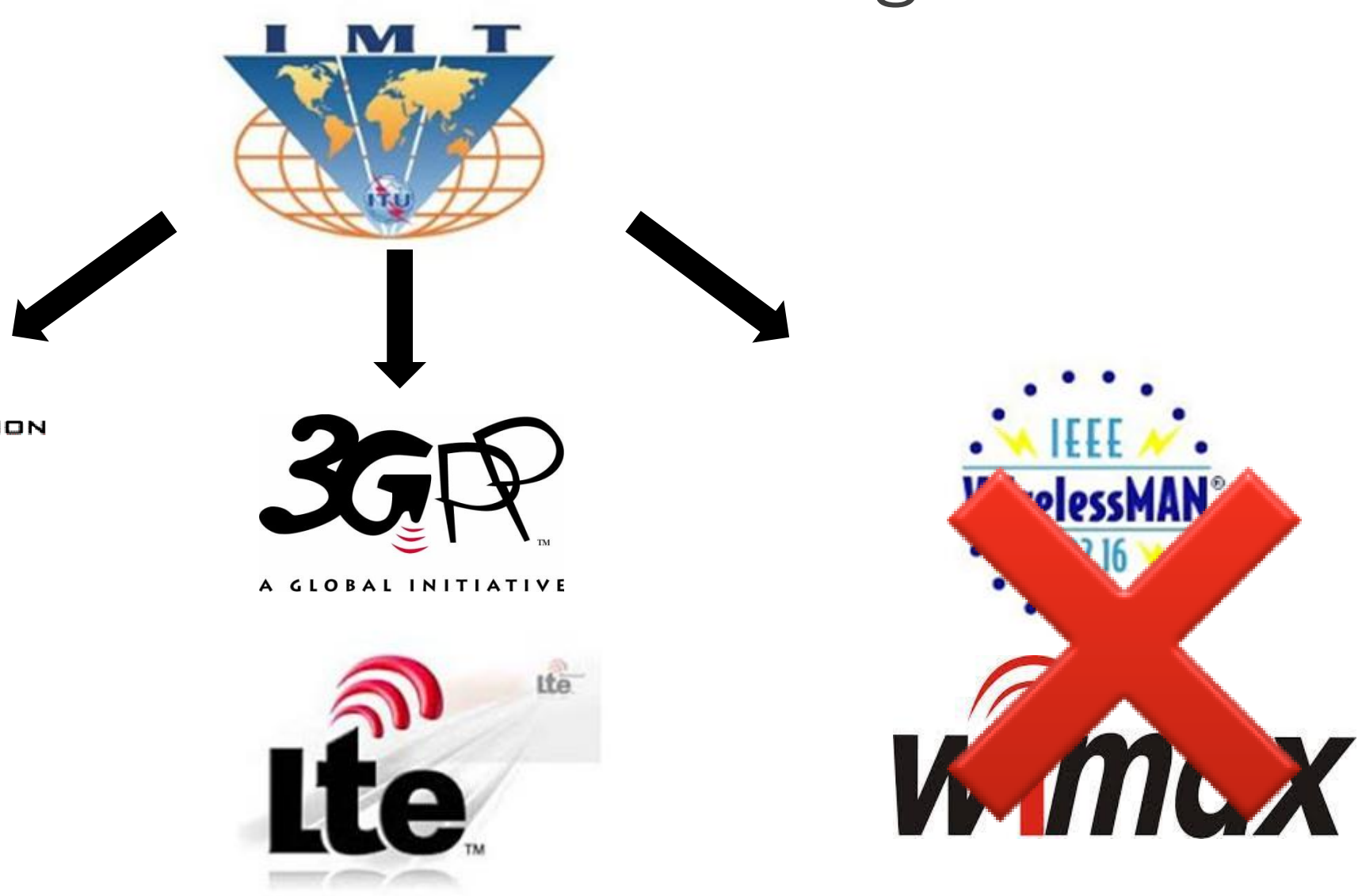
3 ‘G’ Evolution

- Rel-99: DL = 384Kbps, UL = 384Kbps
- Rel-5: HSDPA (3.5G) – DL = 14Mbps, UL = 384Kbps
- Rel-6: HSUPA (3.6G) – DL = 14Mbps, UL = 5.75Mbps
- Rel-7: HSPA+ (3.7G) – DL = 28Mbps, UL = 11.52Mbps
- Rel-8: HSPA+ (3.75G) – DL = 42Mbps, UL = 11.52Mbps
- Rel-9: HSPA+ (3.8G) – DL = 84Mbps, UL = 23Mbps
- Rel-10: HSPA+ (3.8G) – DL = 168Mbps, UL = 23Mbps
- Rel-11: HSPA+ (3.85G) – DL = 672Mbps, UL = 70Mbps

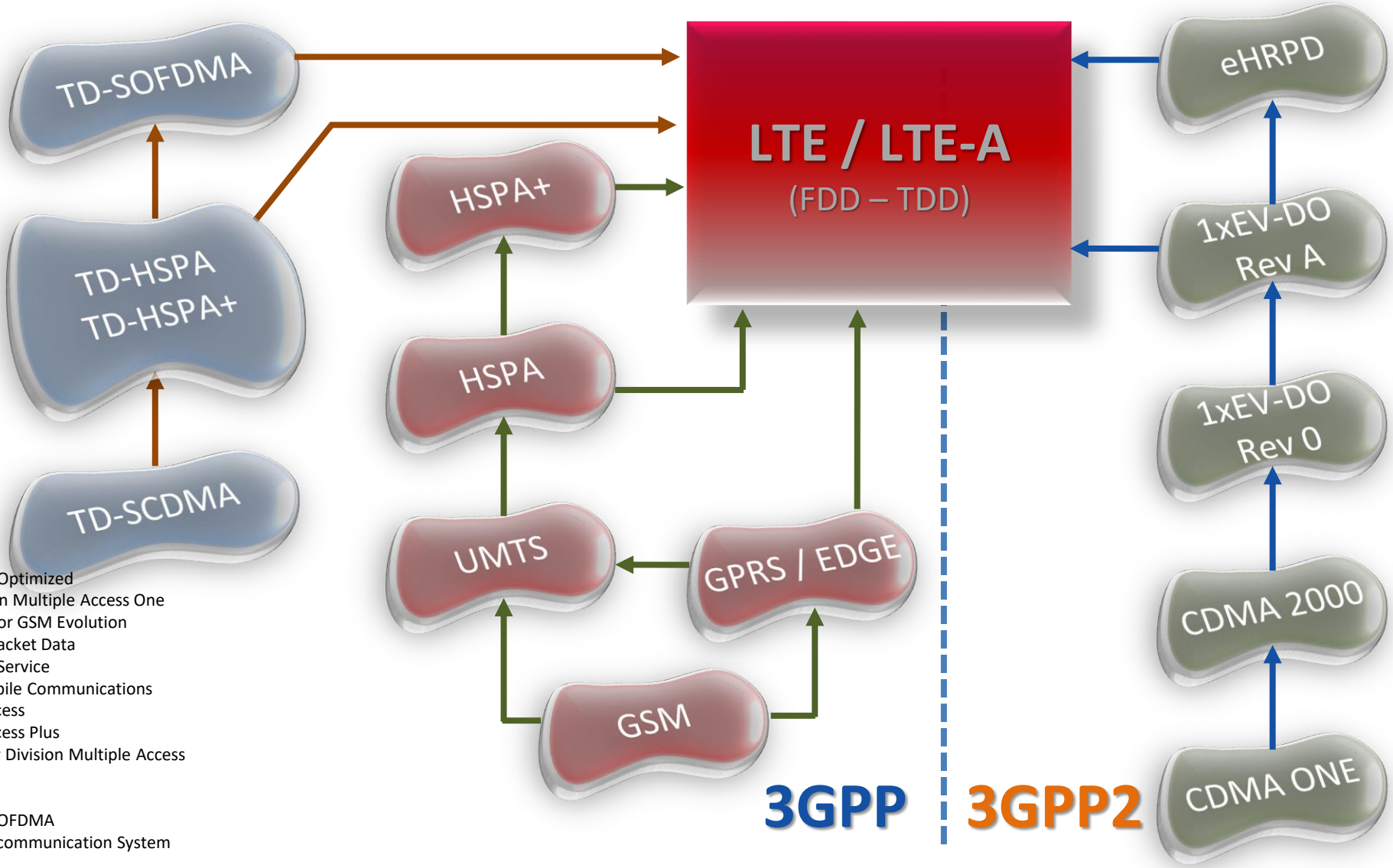
Fourth Generation (4 ‘G’) Mobile System



IMT-Advanced and 4G Technologies



All roads lead to LTE

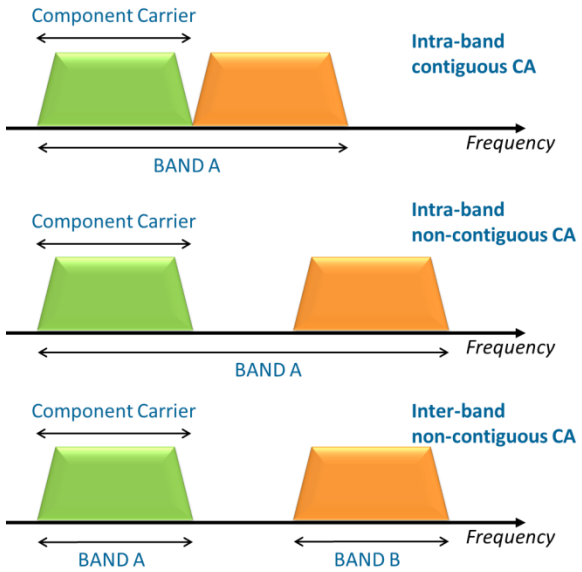


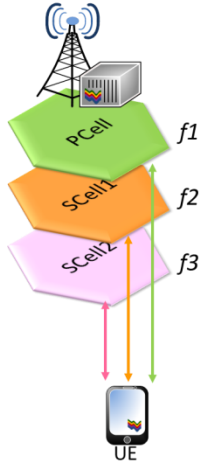
1xEV-DO: Enhanced Voice-Data Optimized
CDMA ONE: Code Division Multiple Access One
EDGE: Enhanced Data rates for GSM Evolution
eHRPD: Enhanced High Rate Packet Data
GPRS: General Packet Radio Service
GSM: Global System for Mobile Communications
HSPA: High Speed Packet Access
HSPA+: High Speed Packet Access Plus
OFDMA: Orthogonal Frequency Division Multiple Access
SCDMA: Synchronous CDMA
TD: Time Division
TD-SOFDMA TD Scalable OFDMA
UMTS: Universal Mobile Telecommunication System

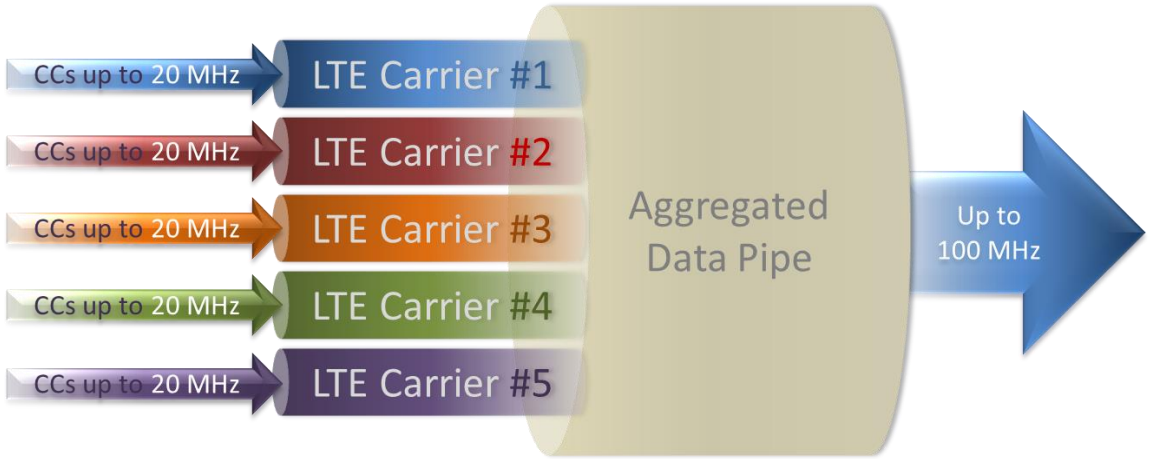
LTE: 3.9G or 4G?

		IMT-A	LTE (Rel.8)
Bandwidth		**Scalable** At least 40 MHz	**Scalable** 1.4 MHz – 20 MHz
Peak Data Rates		DL = 1 Gbps UL = 1 Gbps	DL = 150 Mbps (2x2) UL = 50 Mbps
Latency	User Plane (UP)	10 ms max	4.9 ms
	Control Plane (CP)	100 ms max	50 ms
Max peak spectral efficiency	Downlink (DL)	15 bps / Hz	16.3 bps / Hz
	Uplink (UL)	6.75 bps / Hz	4.32 bps / Hz

Carrier Aggregation







LTE-Advanced: Real 4G

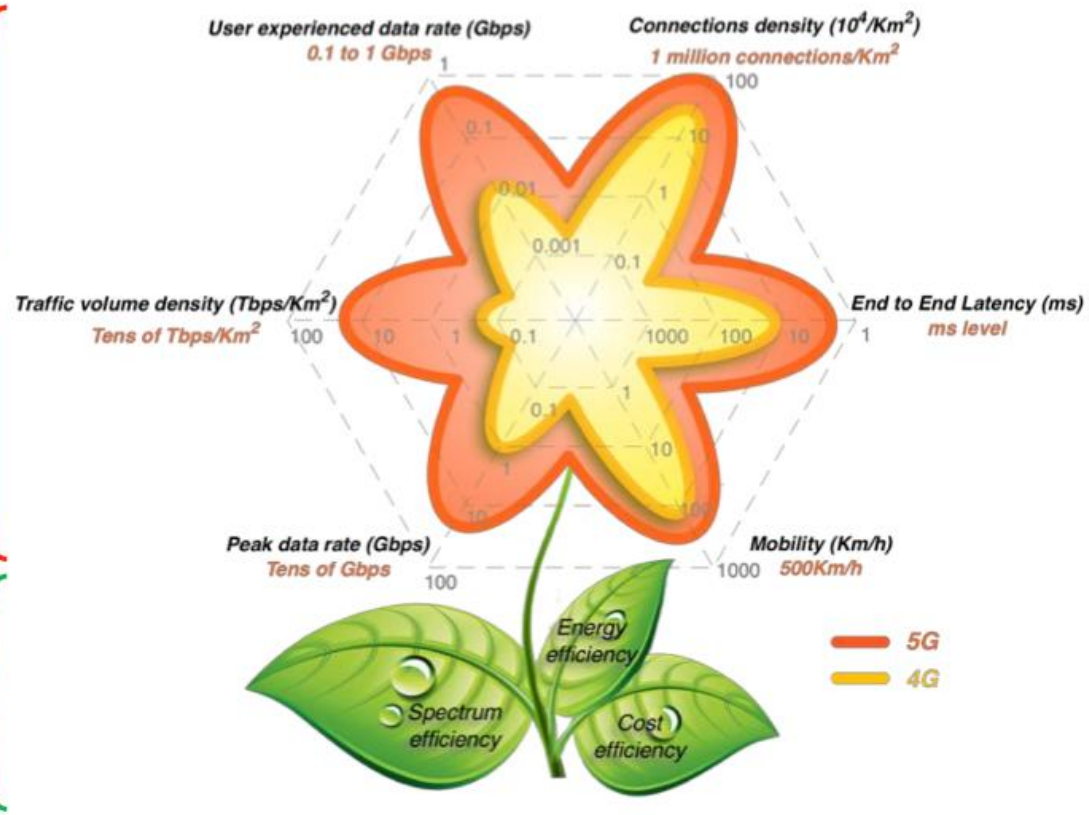
		IMT-A	LTE (Rel.8)	LTE-A (Rel.10)	LTE-A THEORETICAL
Bandwidth		**Scalable** At least 40 MHz	**Scalable** 1.4 MHz – 20 MHz	Max 2x20 (40 MHz)	**Scalable** Up to 5x20 (100 MHz)
Peak Data Rates		DL = 1 Gbps UL = 1 Gbps	DL = 150 Mbps (2x2) UL = 50 Mbps	DL = 300 Mbps (2x2) UL = 100 Mbps (2x2)	DL = 3 Gbps (8x8) UL = 1.5 Gbps (4x4)
Latency	User Plane (UP)	10 ms max	4.9 ms	4.9 ms	4.9 ms
	Control Plane (CP)	100 ms max	50 ms	50 ms	50 ms
Max peak spectral efficiency	Downlink (DL)	15 bps / Hz	16.3 bps / Hz	16.8 bps / Hz	30 bps / Hz
	Uplink (UL)	6.75 bps / Hz	4.32 bps / Hz	8.4 bps / Hz	15 bps / Hz

LTE-Advanced Pro: 4.5G – on path to 5G

4G vs 5G

Performance Requirements

Efficiency Requirements



5G Requirements

Optimize for data rate

Optimize for connection numbers

Optimize for delay

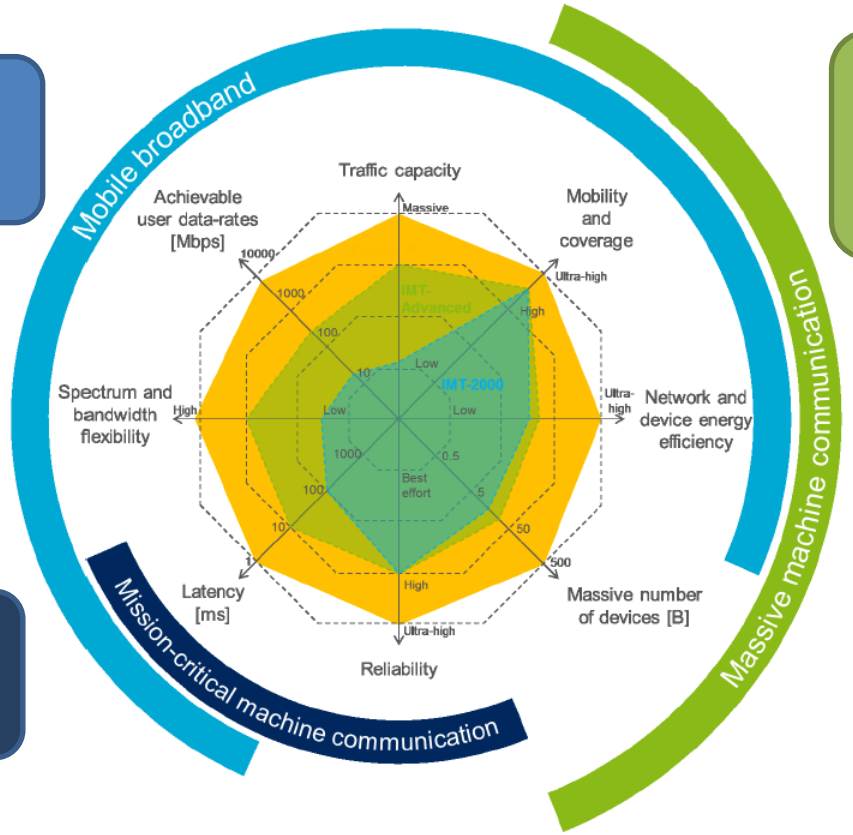


Image Source: 5G-From Research to Standardisation - Bernard Barani European Commission, Globecom2014

Summary: 1G & 2G

1981

European Commission

Summary: 3G & 4G

Summary: 5G

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