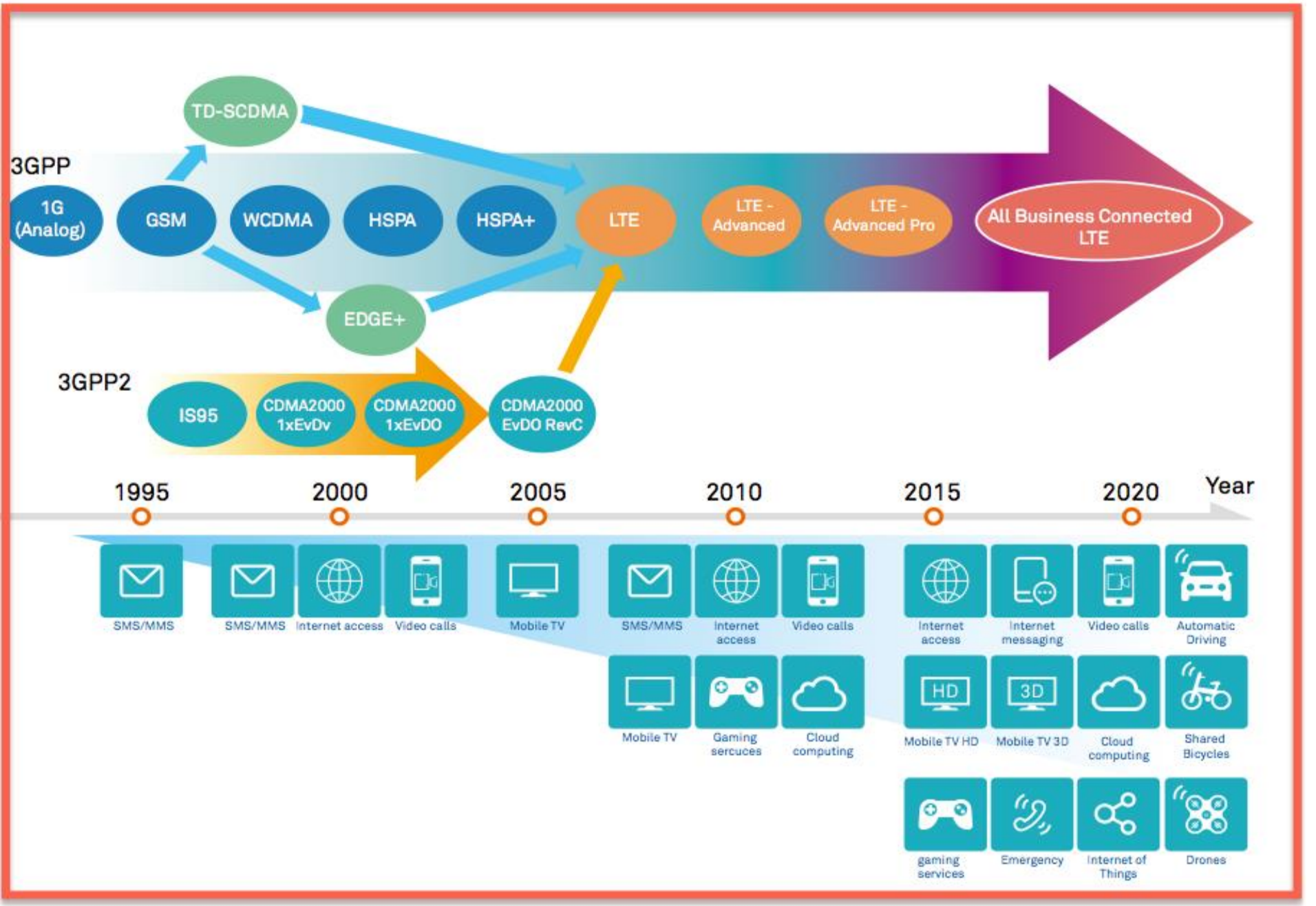
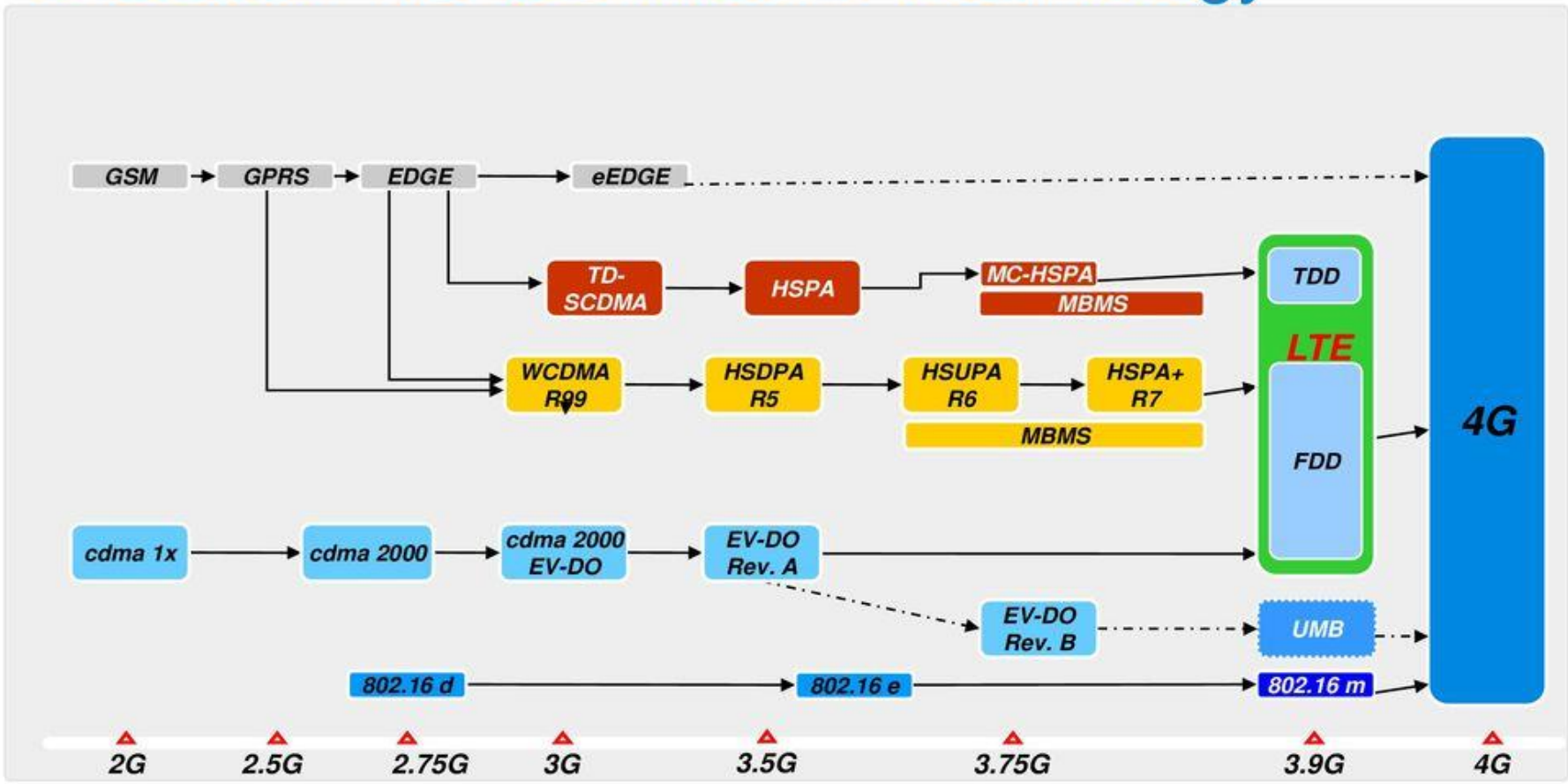
Evolution of Wireless Networks

Prof.Dr.Adnan Kavak

Evolution Path of Mobile Radio

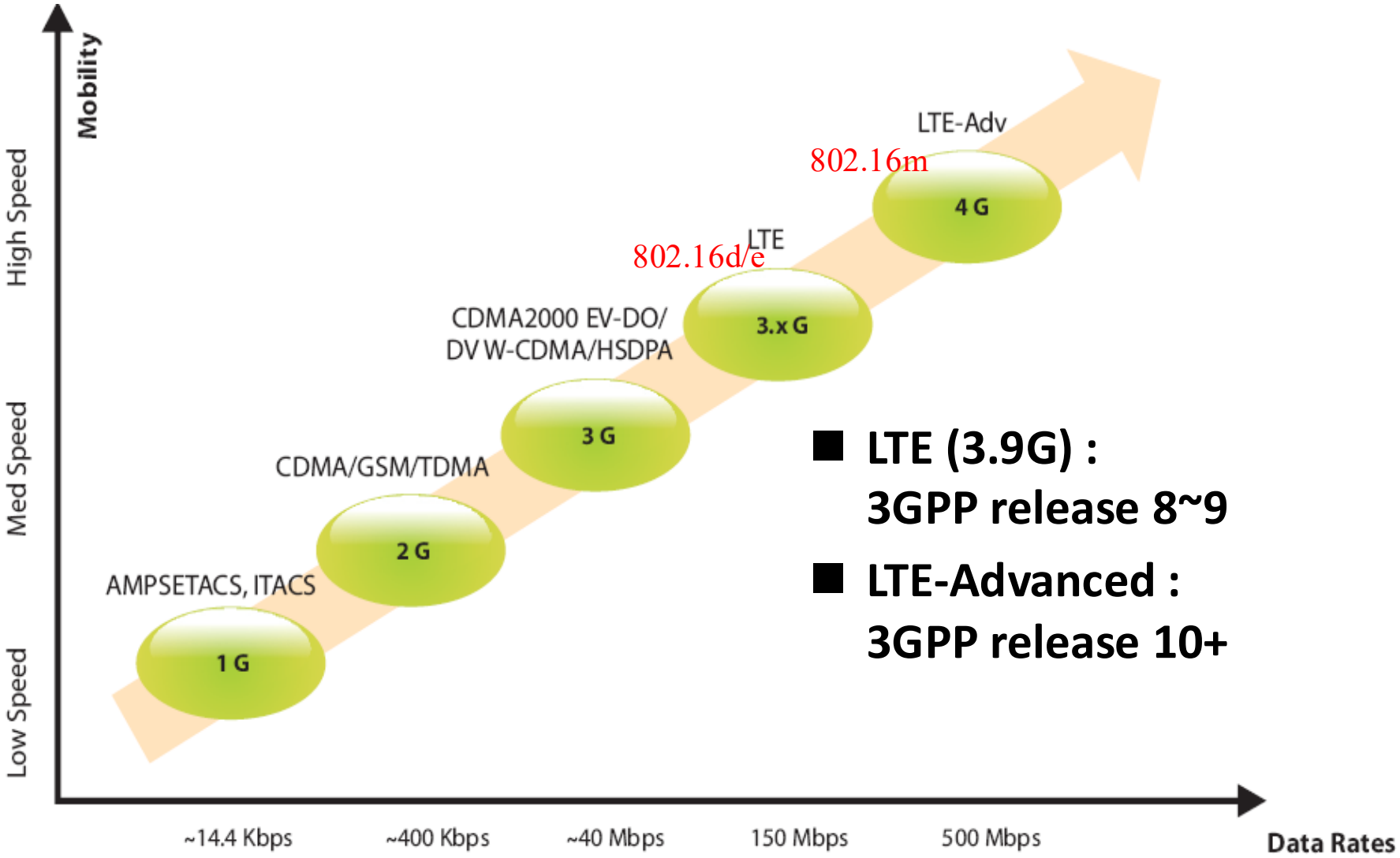


Evolution Trend of Mobile Technology



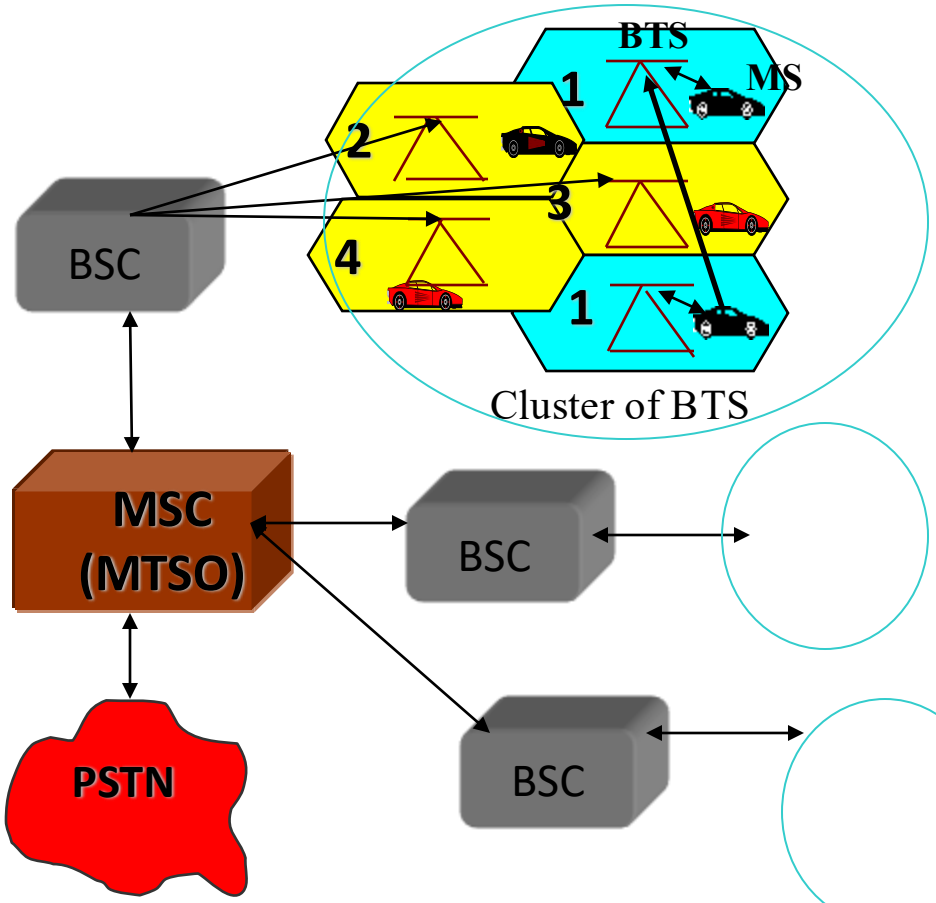
- Multi-Standards Coexist : OFDM, OFDMA and MIMO, basic technologies in different standards, are employed in multi wireless access technology.
- Multi-frequency Coexistence: More frequency bands are available and standardized.
- Mobile Broadband: Increase spectrum utilization; reduce the cost of wireless data services; ready for multimedia-based services.

Evolution of Radio Access Technologies



- **LTE (3.9G) : 3GPP release 8~9**
- **LTE-Advanced : 3GPP release 10+**

1G Network Architecture



Components:

MS: Mobile Station
BTS: Base Station Transceiver
BSC: Base Station Controller
MSC: Mobile Switching Center
MTSO: Mobile Telephone Switching Office
PSTN: Public Switched Telephone Network (wireline network)

Links:

Uplink (Reverse Link): A communication link where MS transmits and BTS receives
Downlink (Forward Link): A communication link where BTS transmits and MS receives

Transmission Scheme:

TDD (Time Division Duplexing): Transmissons in The uplink and downlink use the same carrier frequency but different time intervals

- **FDD** (Frequency Division Duplexing): Transmissons in the uplink and downlink use different carrier frequency but may occur at the same time intervals

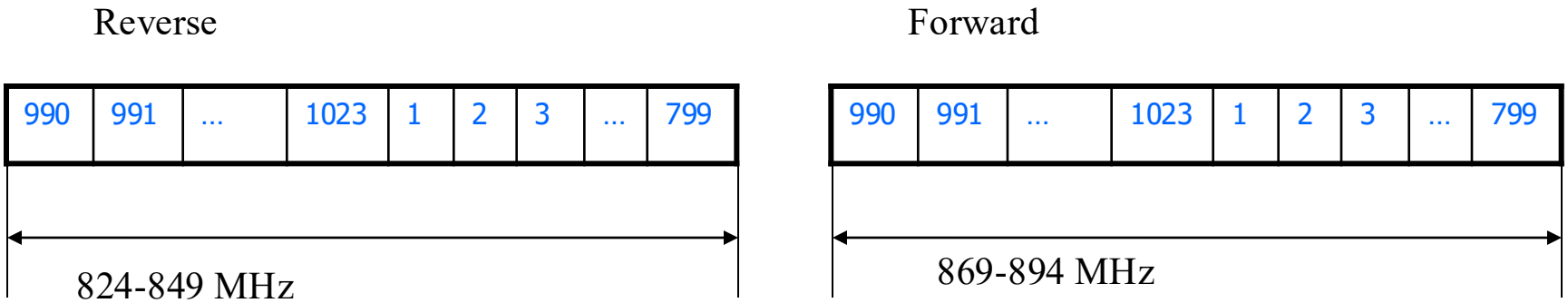
1G (AMPS) NETWORK HIGHLIGTHS

It was the first mobile phones used, which was introduced in 1982. It was used for voice services and was based on technology called as Advanced Mobile Phone System (AMPS). The AMPS system was frequency modulated. frequency
International Journal of Modern Trends in Engineering and Research (IJMTER)
Its basic features are:

- FDMA
- Channel capacity - 30 KHz
- Speed- 2.4 kbps
- Allows voice calls in 1 country
- Uses analog signal.
- Poor voice quality
- Poor battery life
- Large phone size
- Limited capacity
- Poor handoff reliability
- No security at all
- Offered very low level of spectrum efficiency

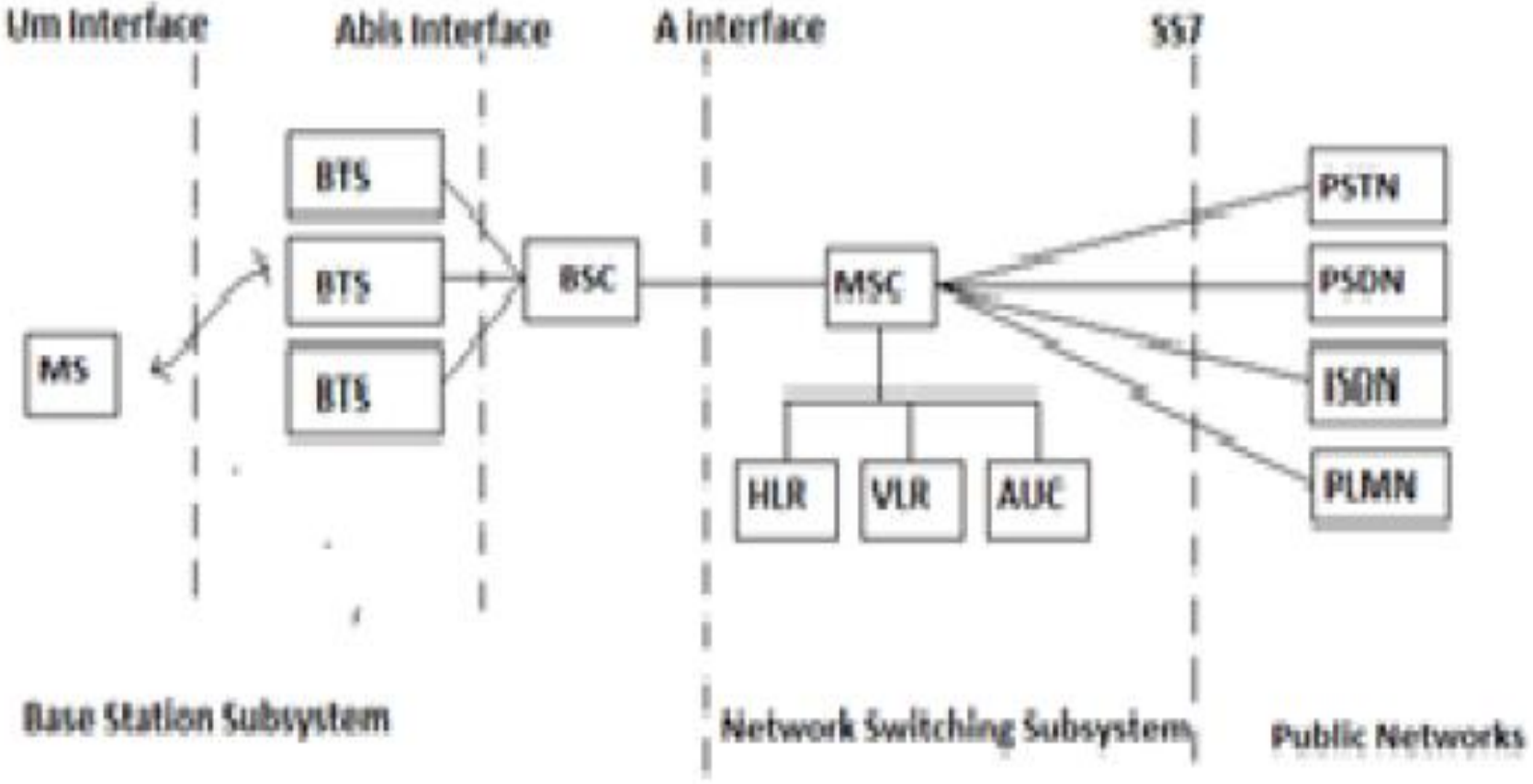
AMPS Frequency Allocations

Spectrum Currently Allocated for 850 MHz band (US Cellular Telephone) Use



	channel number	center frequency (MHz)
Reverse	$1 \le N \le 799$	$0.03N + 825.0$
	$990 \le N \le 1023$	$0.03(N - 1023) + 825.0$
Forward	$1 \le N \le 799$	$0.03N + 870.0$
	$990 \le N \le 1023$	$0.03(N - 1023) + 870.0$

2G (GSM) NETWORK ARCHITECTURE



2G (GSM), 2.5 G (EDGE) NETWORK HIGHLIGTHS

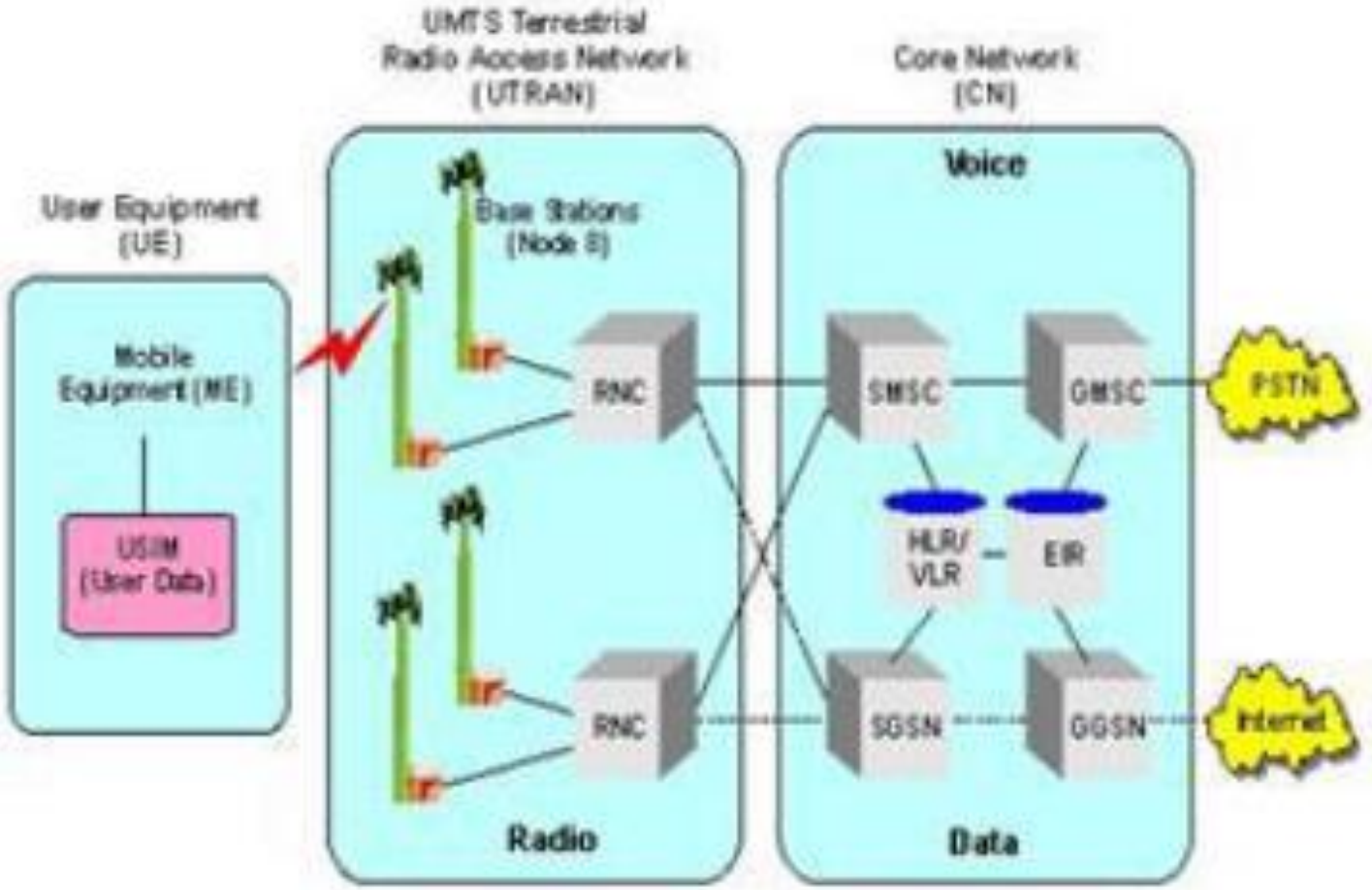
2G refers to the second generation based on GSM and was emerged in late 1980s. It uses digital signals for voice transmission. Main focus of this technology was on digital signals and provides services to deliver text and picture message at low speed (in kbps). Next to 2G, 2.5G system uses packet switched and circuit switched domain and provide data rate up to 144 kbps. e.g. GPRS, EDGE. **The main features of 2G are** :

- TDMA, CDMA
- Channel bandwidth of 200 KHz (GSM), 1.25 MHz (CDMA-IS95)
- Data speed was upto 64kbps
- Uses digital signals
- Enables services such as text messages, picture messages and MMS(Multimedia message)
- Provides better quality and capacity compared to 1G
- Unable to handle complex data such as videos.

Additional features with 2.5 G:

- Send/receive e-mail messages
- Web browsing
- Speed : 64-144 kbps
- Camera phones become available
- Take a time of 6-9 mins. to download a 3 mins. MP3 song

3G (WCDMA) NETWORK ARCHITECTURE



3G NETWORK HIGHLIGTHS

3G was launched in 2000. The aim of this technology was to offer high speed data. The original technology was improved to allow data up to 14 Mbps and more using packet switching. It employs Wide Band CDMA access, offers data services, access to television/video, new services like Global Roaming. It operates at a range of 2100MHz and has a bandwidth of 5 Hz. The main features of 3G are:

- WCDMA
- Called as UMTS(Universal Mobile Telecommunication System) or WCDMA in Europe,
- while CDMA2000 is the name of American 3G variant. Also the IMT2000 has accepted a new 3G standard from China, i.e TD-SCDMA.
- Speed 2 Mbps
- Typically called smart phones
- Increased bandwidth (of 5HHz) and data transfer rates compared to 2.5 G to accommodate web-based applications and audio and video files.
- Provides faster communication, high speed web/more security/video conferencing/3D gaming, TV streaming/mobile TV/Phone calls
- To download a 3 minute MP3 song only 11 sec-1.5 mins time required.
- Expensive fees for 3G licenses services
- It was challenge to build the infrastructure for 3G while switching from 2G

3G NETWORK HIGHLIGTHS

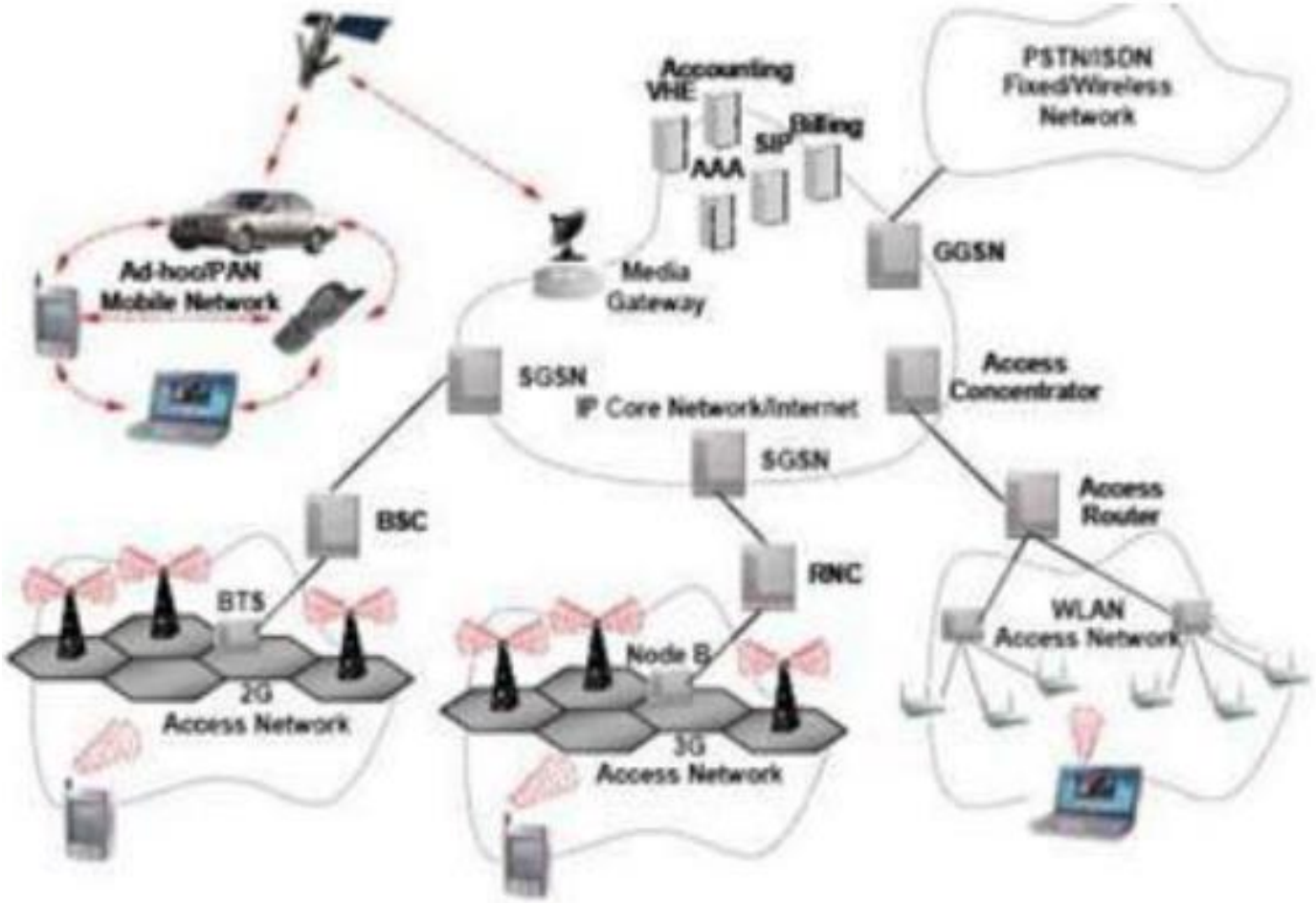
3.5 G – HSDPA (High-Speed Downlink Packet Access)

- Mobile telephony protocol, also called 3.5G (or "3½ G"), which provides a smooth evolutionary path for UMTS-based 3G networks allowing for higher data transfer speeds.
- packet-based data service in W-CDMA downlink with data transmission up to 8-10 Mbit/s (and 20 Mbit/s for MIMO systems) over a 5MHz bandwidth in WCDMA downlink.
- HSDPA implementations includes Adaptive Modulation and Coding (AMC), Multiple-Input Multiple Output (MIMO), Hybrid Automatic Request (HARQ), fast cell search, and advanced receiver design.

Technologies' Comparison

	802.16e (WiMAX)	HSPA+	LTE
FEATURE	TDD, OFDMA, MIMO, 64QAM, BW: 1.25 ~ 20MHz	FDD, WCDMA, MIMO, 64QAM DL, 16QAM UL, BW: 5MHz	FDD, OFDMA, TDD, SC-FDMA, MIMO, 64QAM, 1.4 | 3 | 5 | 10 | 20MHz
DATA RATE	63.36Mbps DL (2*2 10MHz) 28.22Mbps UL (2*2 10MHz)	42Mbps DL (2*2 5MHz) 11.5Mbps UL (5MHz)	150Mbps DL (2*2 20MHz) 75Mbps UL (2*2 20MHz)
STANDARD	2005.12 New spectrum	2008. Q3 3G spectrum	2009. Q3 3G spectrum New spectrum
	IEEE	3GPP	3GPP

4G NETWORK ARCHITECTURE



4G NETWORK HIGHLIGTHS

4G offers a downloading speed up to 100 Mbps. It is based on LTE (Long Term Evolution) is considered as 4G technology. 4G is developed to accommodate the QoS and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services
that utilize bandwidth. The main features of 4G are :

- LTE rel. 10+ is called as 4G
- Inter-operability between different sorts of networks, which is all about high speed data transfer such as 0-100MBPS
- OFDMA
- Support of IPv6
- Capable of providing 100Mbps (mobile access)-1Gbps (with less mobility local access)
- High quality streaming video
- **Combination of Wi-Fi (IEEE 802.16e) and LTE**
- High security
- Provide any kind of service at any time as per user requirements anywhere
- Expanded multimedia services
- Provides low cost per-bit
- Battery uses is more
- Need complicated hardware
- Expensive equipment required to implement

SUMMARY OF MOBILE TECHNOLOGY HIGHLIGHTS

Generation	Speed	Technology	Time period	Features
1G	14.4 Kbps	AMPS,NMT, TACS	1970 – 1980	During 1G Wireless phones are used for voice only.
2G	9.6/ 14.4 Kbps	TDMA,CDMA	1990 to 2000	2G capabilities are achieved by allowing multiple users on a single channel via multiplexing. During 2G Cellular phones are used for data also along with voice.
2.5G	171.2 Kbps 20-40 Kbps	GPRS	2001-2004	2.5G the internet becomes popular and data becomes more relevant.2.5G Multimedia services and streaming starts to show growth. Phones start supporting web browsing though limited and very few phones have that.
3G	3.1 Mbps 500-700 Kbps	CDMA 200 (1xRTT, EVDO) UMTS, EDGE	2004-2005	3G has Multimedia services support along with streaming are more popular. In 3G, Universal access and portability across different device types are made possible. (Telephones, PDA's, etc.)
3.5G	14.4 Mbps 1-3 Mbps	HSPA	2006 – 2010	3.5G supports higher throughput and speeds to support higher data needs of the consumers
4G	100-300 Mbps. 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax LTE Wi-Fi	Now (Read more on Transitioning to 4G)	Speeds for 4G are further increased to keep up with data access demand used by various services. High definition streaming is now supported in 4G. New phones with HD capabilities surface. It gets pretty cool. In 4G, Portability is increased further. World-wide roaming is not a distant dream.
5G	Probably gigabits	Not Yet	Soon (probably 2020)	Currently there is no 5G technology deployed. When this becomes available it will provide very high speeds to the consumers. It would also provide efficient use of available bandwidth

Evolution of LTE Standards

- LTE is a standard for wireless data communications technology and an evolution of the GSM/UMTS standards.
- The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations.
- A further goal was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture.
- The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate wireless spectrum.

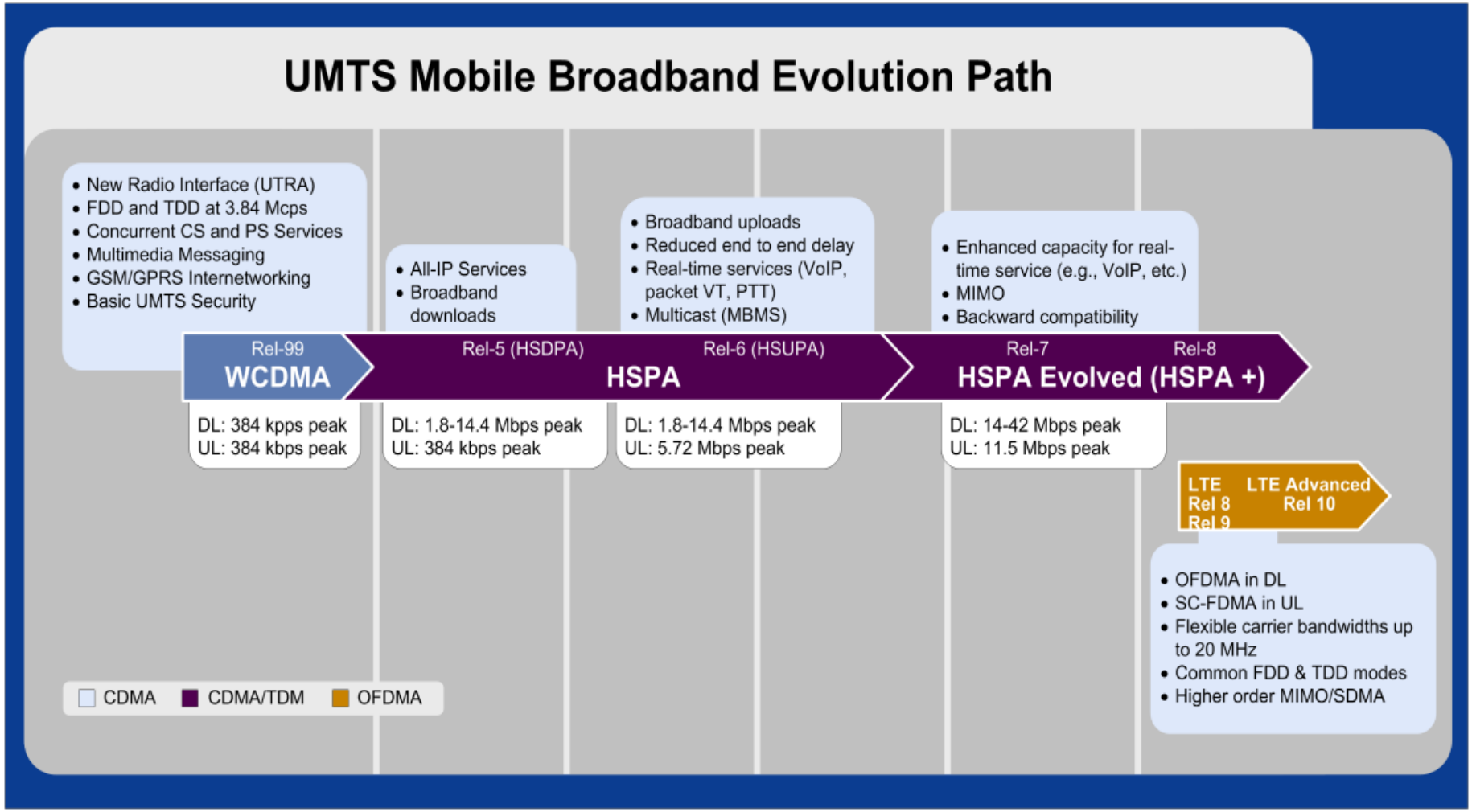
Evolution of LTE Standards

- LTE was first proposed by NTT DoCoMo of Japan in 2004, and studies on the new standard officially commenced in 2005.
- The LTE standard was finalized in December 2008, and the first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14, 2009 as a data connection with a USB modem.
- Samsung Galaxy Indulge being the world's first LTE smartphone starting on February 10, 2011.

Evolution of LTE Standards

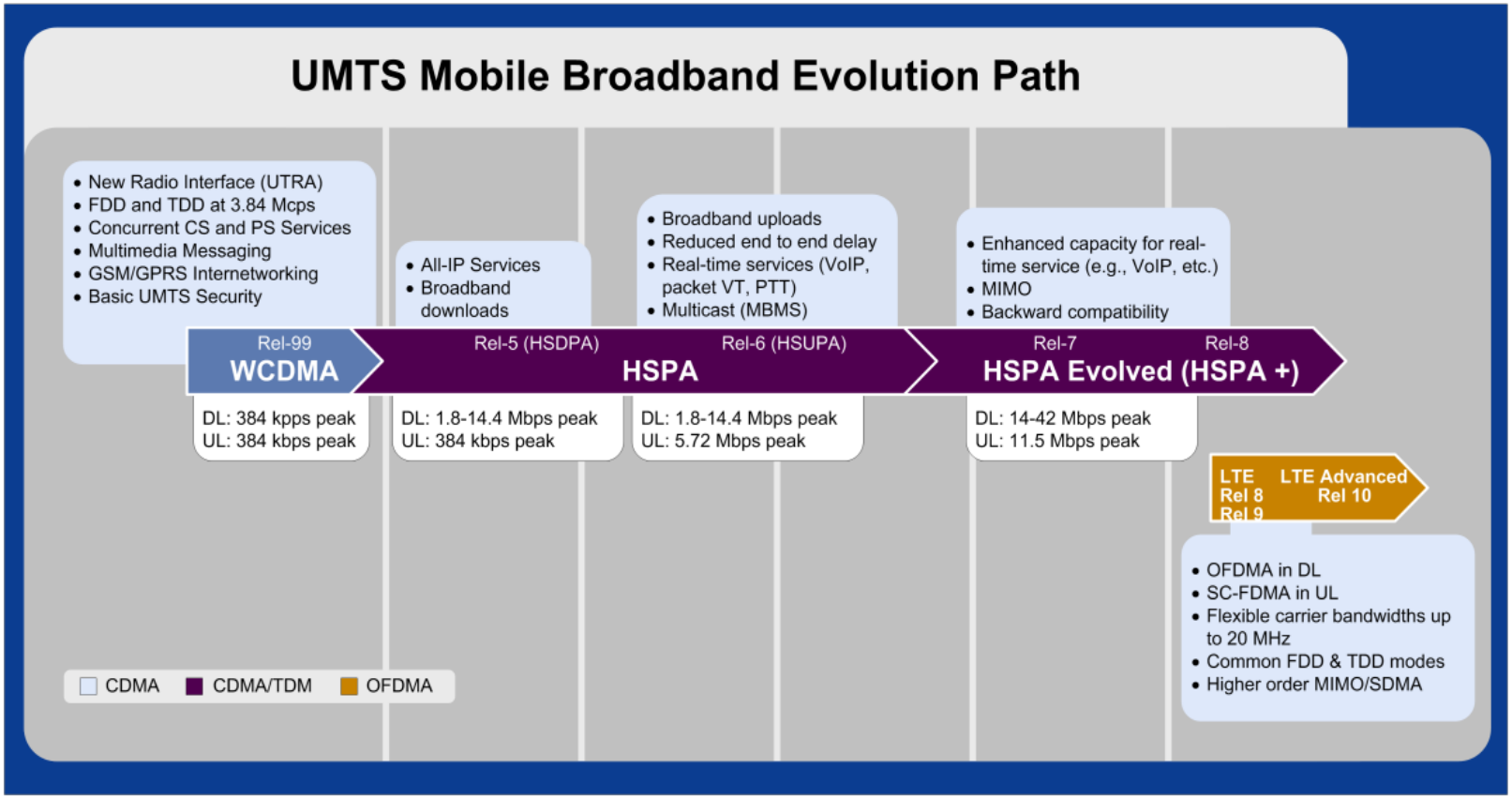
- Initially, CDMA operators planned to upgrade to rival standards called UMB and WiMAX
- But all the major CDMA operators (such as Verizon, Sprint and MetroPCS in the United States, Bell and Telus in Canada, au by KDDI in Japan, SK Telecom in South Korea and China Telecom/China Unicom in China) have announced that they intend to migrate to LTE after all.
- The evolution of LTE is LTE Advanced, which was standardized in March 2011.

Evolution of LTE Standards



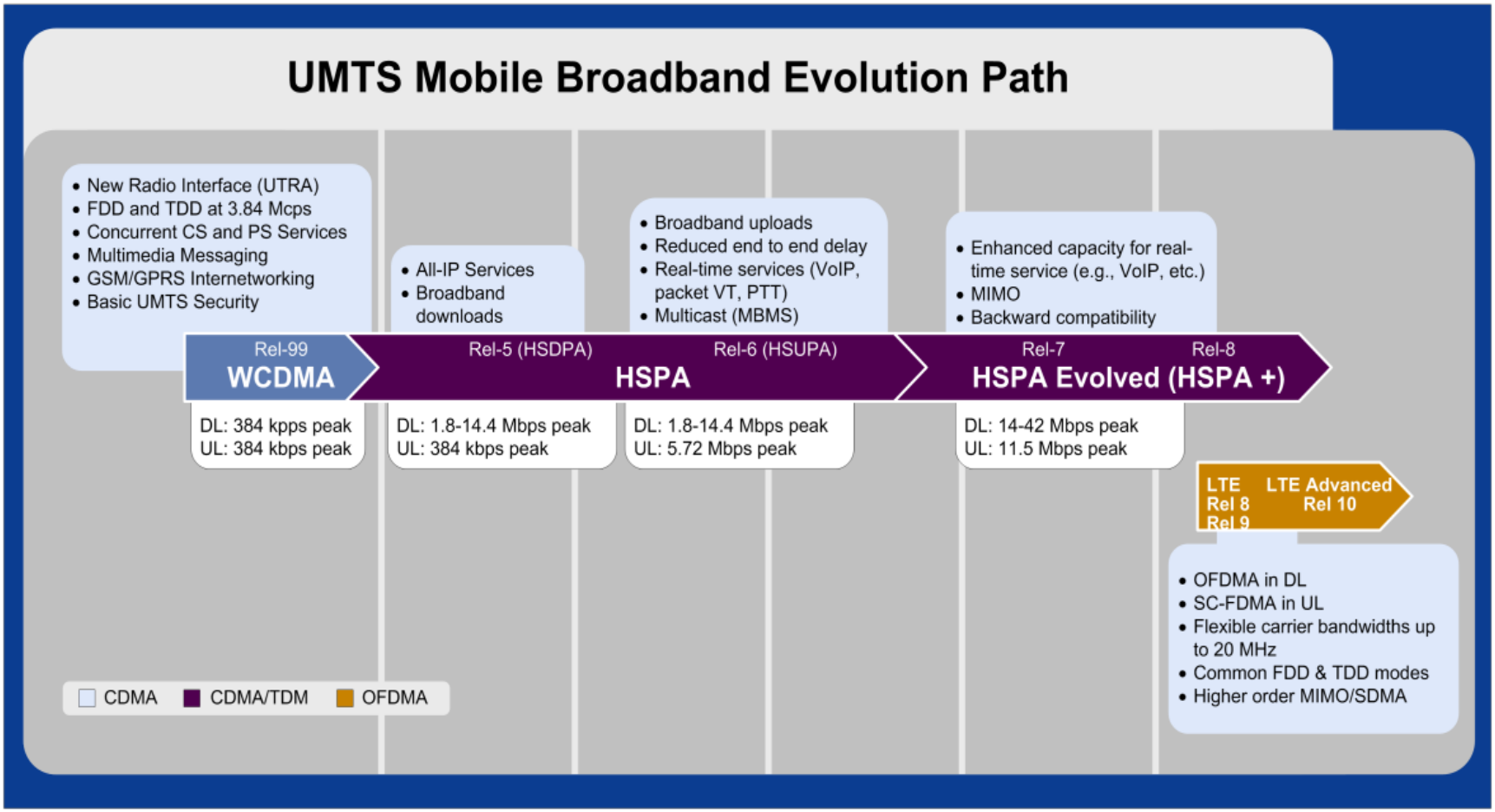
Release 99 – Specified the first UMTS 3G networks, incorporating a CDMA air interface

Evolution of LTE Standards



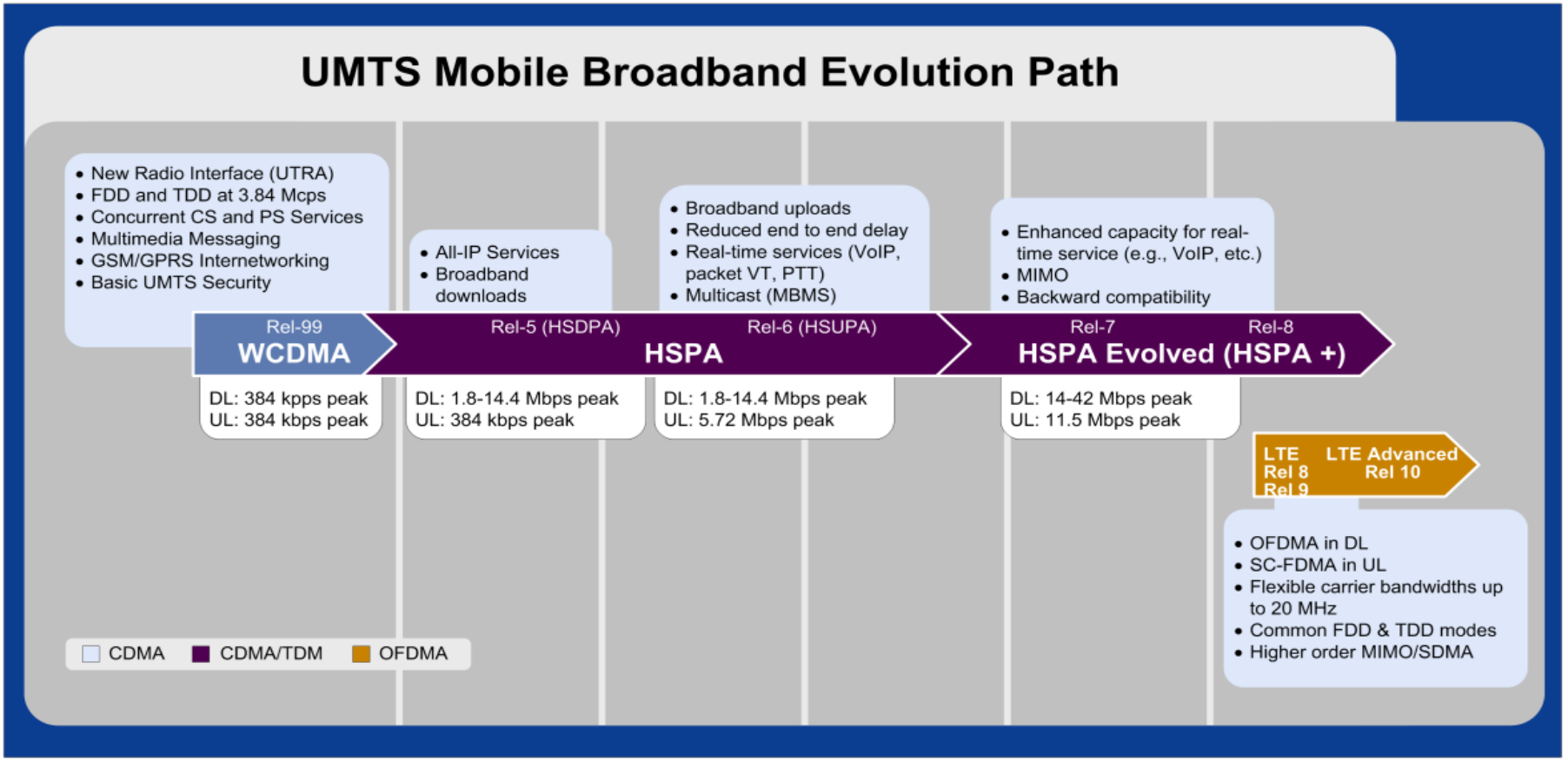
- Release 5 – Introduced mainly IMS, HSDPA (allowing broadband services on the Downlink), and other minor enhancements

Evolution of LTE Standard



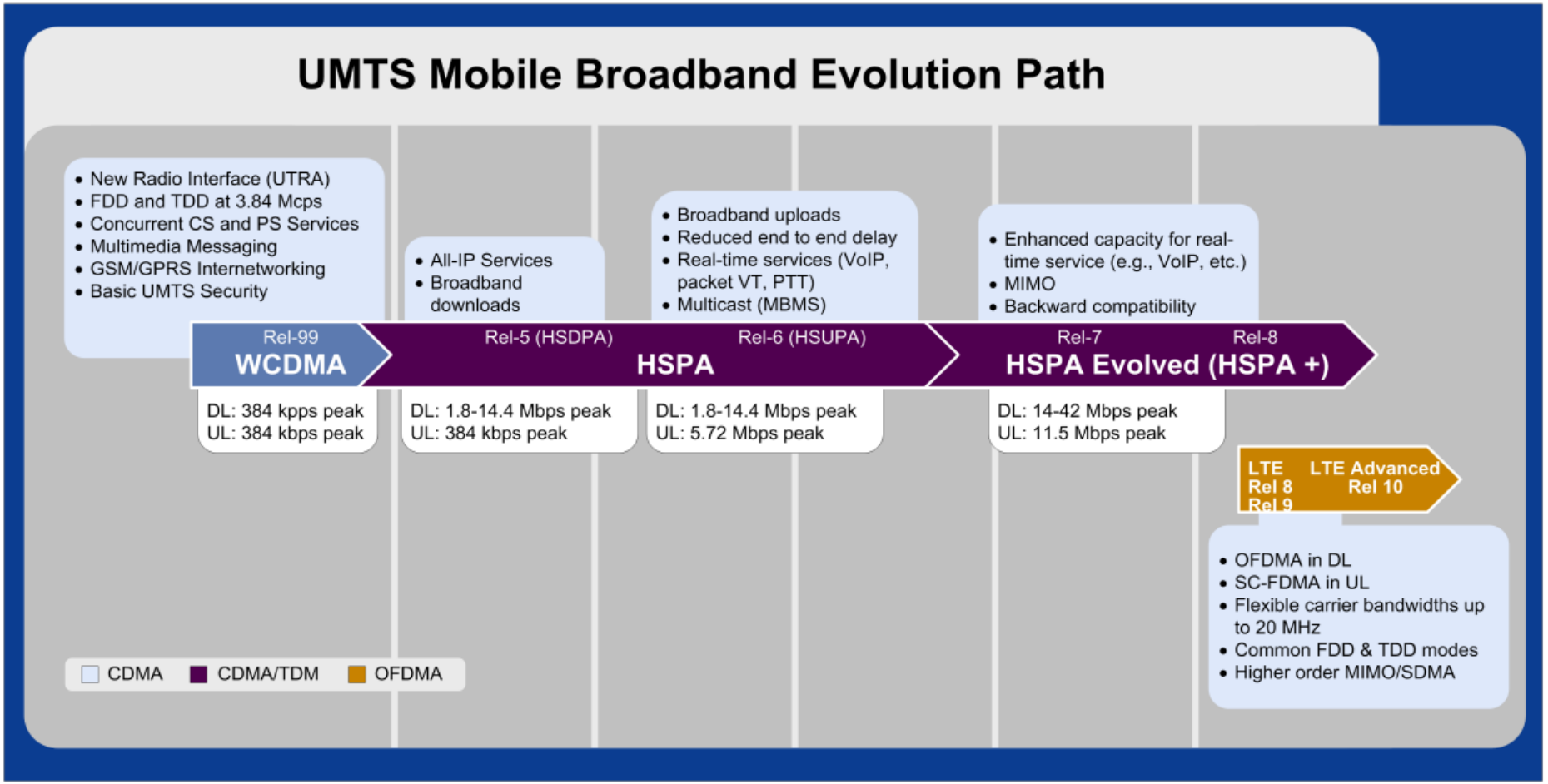
- Release 6 – Integrated operation with Wireless LAN networks and added HSUPA (enables broadband uploads and services), MBMS, and enhancements to IMS such as Push-to-Talk over Cellular (PoC), video conferencing, messaging, etc.

Evolution of LTE Standard



- Release 7 – Significant progress made in 2006 and 2007 toward completion of this release. Introduced, among other features, enhancements to High-Speed Packet Access (HSPA+), QoS, and improvements to real-time applications like VoIP

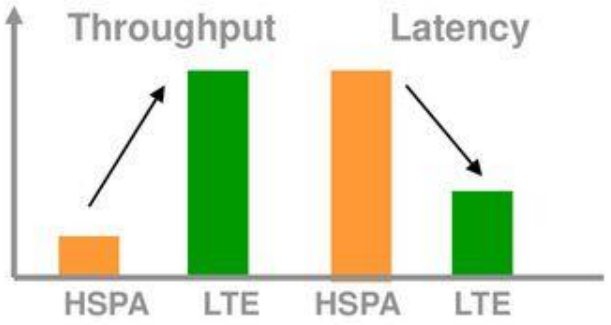
Evolution of LTE Standard (3GPP rel.8 named LTE)



- Release 8 –, E-UTRA (also called LTE, based on OFDMA), All-IP Network (also called SAE), and Femto cells operation. Release 8 constitutes a refactoring of UMTS as an entirely IP based fourth-generation network. 3GPP RAN approved the LTE Physical Layer specifications in September 2007.

LTE Benefits for Operators and Users

User Experience →ARPU



Investment Protection

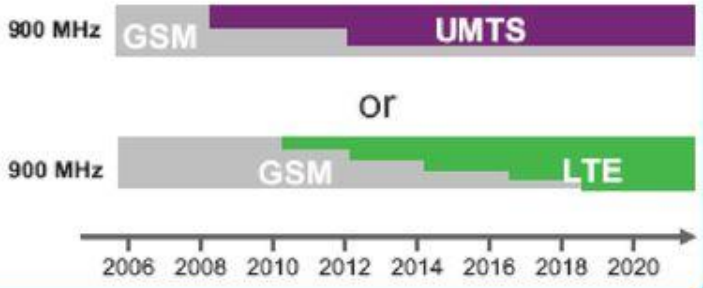
Reuse of

- Sites and infrastructure
- Backhauling
- Frequency bands

Low Cost per Mbps

Scalable bandwidth

Optimized spectrum usage



LTE Improves Broadband Applications

Online Gaming <50 ms Latency

Live Video/ Video Blogging
DL 6-8Mbps/UL 2Mbps

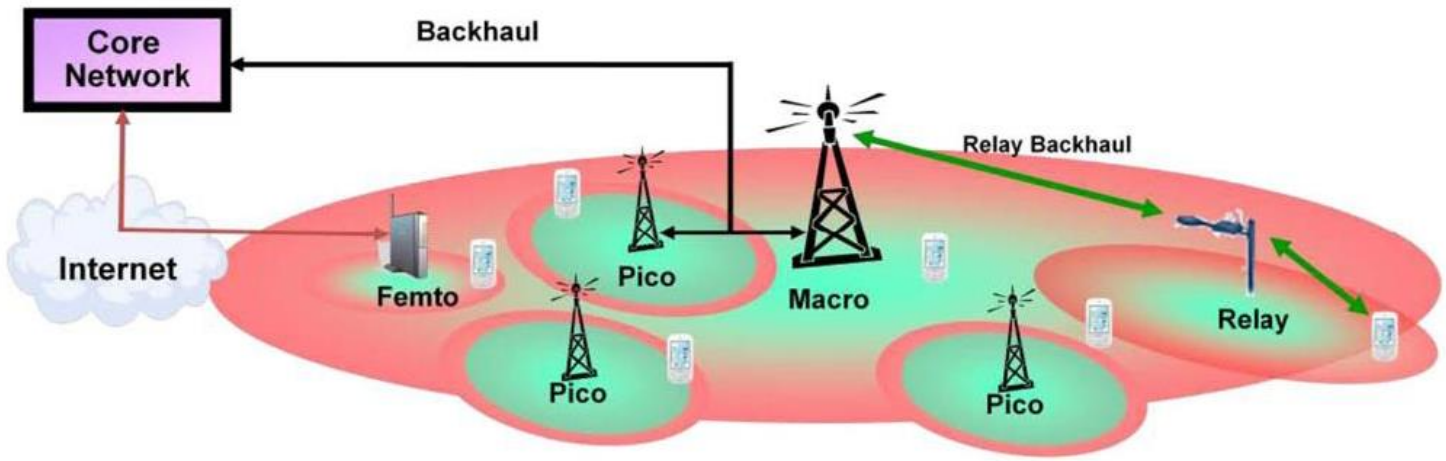
Permanent Sync.
DL/UL 1-2Mbps

HD Video Streaming (720i or 1080i)
DL 6-10Mbps

LTE Benefits

- LTE provides a path to 4G performance
- Waveform processing (modulation/demodulation) has reached a mature status in 3G and shows little room for improvement
- LTE achieves increased performance over 3G by using wider RF bandwidth
- New network topologies are required to increase performance such as Heterogeneous networks

Heterogeneous Networks with LTE



- Heterogeneous networks are comprised of Macro, Pico and Femto Cells
- In fact, an analysis of Cooper's law - which holds that wireless capacity doubles every 30 months – shows that the dominant factor in improvements to date has been the use of smaller cells as opposed to other methods such as revised modulation techniques, better coding, or the use of more frequencies.
- Having lots of cells provides more opportunities for the user to connect to a cell with low pass loss
- Low path loss between cell and user increases capacity and data rates
- More sophisticated interference management and cancelation techniques also increase capacity and data rates

LTE Benefits

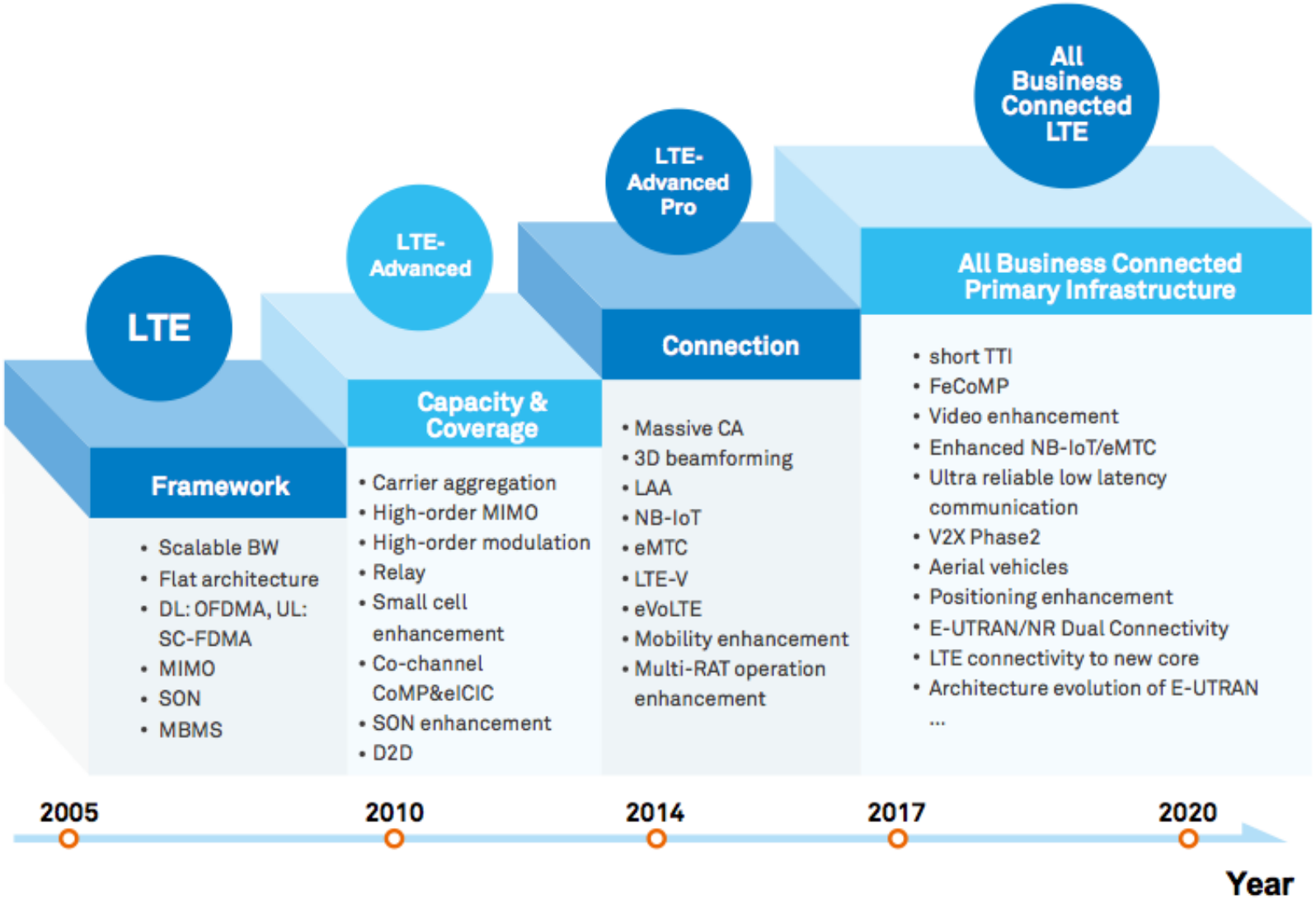
- LTE benefits Include
  - High Data Rates
  - Reduced Latency
  - Improved end-user throughputs

- LTE gains are realized by
  - Increased bandwidth
    - Flexible deployments in 1.4,3,5,10,15,20 MHz
  - MIMO (Multiple Antennas)
    - Using 2 antennas on Based Station and mobile device can provide up to 2x improvement
    - A second receiver is required in the mobile device raising costs
    - Same gain is available in 3G in HSPA+
  - Flatter all IP network

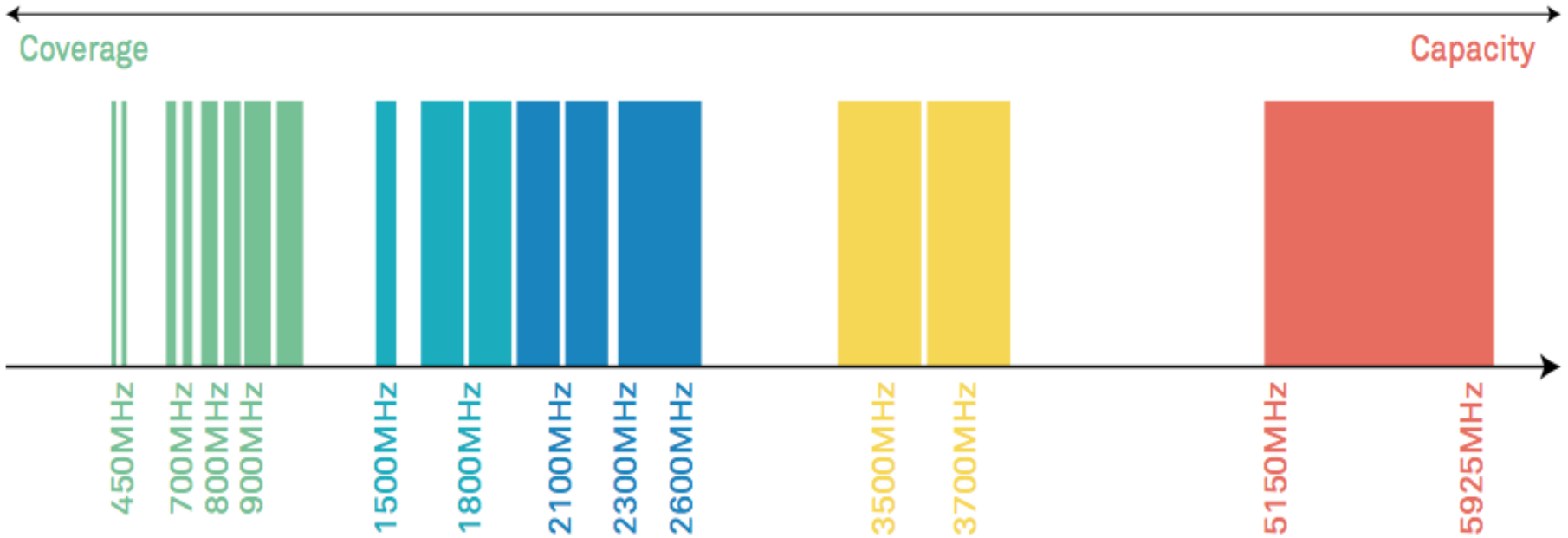
LTE Benefits

- Lower equipment costs than circuit switched 2G and 3G wireless infrastructure
- Increased interoperability between equipment from different vendors
- Flexibility to handle voice, data and future traffic requirements
- Open interfaces offer an easier path for development, future improvements and support

Major Phases of LTE



LTE Operating Bands



5G HIGHLIGTHS

5G was started from late 2010s. LTE rel 15+ is referred to as 5G by 3GPP. Facilities that might be seen with 5G technology includes far better levels of connectivity and coverage. The main focus of 5G will be on world-Wireless World Wide Web (WWWW). It is a complete wireless communication with no limitations. The main features of 5G are :

- It is highly supportable to WWWW (wireless World Wide Web). A more connected world.
- Significantly faster data rates (up to 10 Gbps) and high capacity
- Ultra-low latency: “Latency” refers to the time it takes one device to send a packet of data to another device. In 4G, the latency rate is around 50 milliseconds, but 5G will reduce that to about one millisecond. This will be very much important for industrial applications and driverless cars.
- Provides large broadcasting of data in Gbps.
- Support of virtual private network
- Multi-media newspapers, watch TV programs with the clarity(HD Clarity)
- Large phone memory, dialing speed, clarity in audio/video

5G HIGHLIGTHS

- High resolution for cell phone users and bi- directional large bandwidth sharing.
- Large broadcasting of data in Gigabit which supports almost 65,000 connections.
- Terminals with software defined radios and modulation schemes as well as new error control schemes that can be downloaded from the Internet.
- The terminals will have access to different wireless technologies at the same time and the terminal should be able to combine different flows from different technologies.
- The remote diagnostic is a great feature offered by 5G, through which a user can get better and fast solution.

TECHNOLOGY CHALLENGES FOR 5G

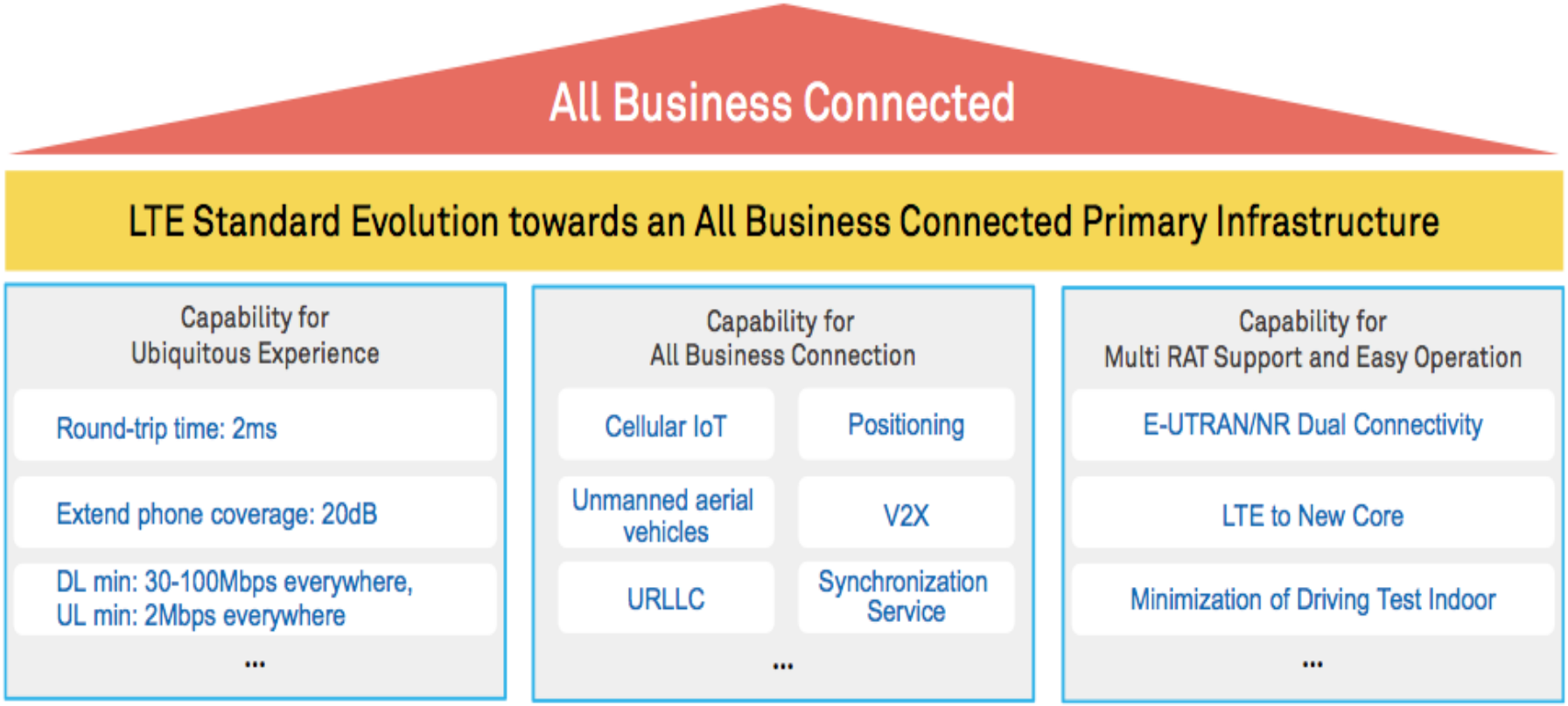
- Integration of various standards: One of the big challenges facing 5G is standardization. There are already multiple groups working to come up with standards around interoperability, backward compatibility with older technologies (4G, 3G), and making sure the network will be future-proof.
- Common Platform: There is no common architecture for interconnecting various engineering practices. One common governing body is required, which creates a common platform for all engineering practices to regularize the interconnectivity issues as well as knowledge sharing.
- Building the infrastructure: It is a huge task, with issues around spectrum and installing new antennas. 5G is likely going to rely, at least in part, on higher-frequency bands (millimeter waves) . There is more space in those airwaves available, but at such high frequencies, signals can’t travel nearly as far as they can over the frequencies used for 4G, resulting in a poor connection.

- ADS

TECHNOLOGY CHALLENGES FOR 5G

- Future PHY/MAC: New multiple access schemes such as NOMA, GFDM, etc.
- Massive MIMO: Using microwave frequencies opens up the possibility of using many tens of antennas on single equipment becomes a real possibility
- Dense Networks: Reducing the size of cells provide a much more overall effective use of the available spectrum.
- Dynamic Adhoc Wireless Network (DAWN)
- Internet Protocol Version6 (IPv6)
- High altitude stratospheric platform station (HAPS) systems
- Worldwide wireless web (WWWW), i.e. comprehensive wireless based web applications that include full multimedia capability beyond 4G speeds

LTE Path to 5G



- about 5G…….

https://www.youtube.com/watch?v=GEx_d0SjvS0

https://www.youtube.com/watch?v=PAqEjQjxgdY

https://www.qualcomm.com/invention/5g/what-is-5g

https://www.ericsson.com/en/5g/what-is-5g