



5G – Overview & Primer

Ford's Colony Computer & Technology Club

May 20, 2019

ANNOUNCEMENTS

- Next month's general meeting is Monday June 17 at 7:00pm, here at S&T
 - Guest speaker will be Bob Heath; topic is "Storing Photos and Data in the Cloud"
 - This is also our season finale and the annual end of season pizza party.
- iOS SIG will meet this Wednesday, May 23 at 7:00pm at S&T
- Visit our new club website at <http://fcct.club>
- Tonight's Program: 5G – an Overview & Primer – Rick Chase

WIRELESS GENERATIONS

- G in 5G means 5th generation of wireless technology
 - Generations have usually been defined by transmission speeds
 - But also, by major changes in encoding methods (CDMA, GSM, HSPA, LTE, etc.)
 - Resulting in different generations incompatible with prior generations
 - Hardware and infrastructure implications
- 1G (1970-80's) was analog cellular; 2G (1990-2000) using CDMA, TDMA and GSM were the first gen of digital cellular technologies
- 3G (2004-10) using EVDO, HSPA and UMTS brought data speeds from ~ 200 kbps to a few Mbps
- 4G (2010 - present) using WiMAX and LTE scaled data speeds to hundreds of Mbps to near Gbps
- 5G (ETA 2019) - rollout will be in evolving stages and geographies

GEN EVOLUTION



MOBILE TECHNOLOGY BY GENERATION

Generation	Speed	Technology	Key Features
1G (1970–1980s)	14.4 Kbps	AMPS,NMT, TACS	Voice only services
2G (1990 to 2000)	9.6/ 14.4 Kbps	TDMA,CDMA	Voice and Data services
2.5G to 2.75G (2001-2004)	171.2 Kbps 20-40 Kbps	GPRS	Voice, Data and web mobile internet, low speed streaming services and email services.
3G (2004-2005)	3.1 Mbps 500- 700 Kbps	CDMA2000 (1xRTT, EVDO) UMTS and EDGE	Voice, Data, Multimedia, support for smart phone applications, faster web browsing, video calling and TV streaming.
3.5G (2006-2010)	14.4 Mbps 1- 3 Mbps	HSPA	All the services from 3G network with enhanced speed and more mobility.
4G (2010 onwards)	100-300 Mbps. 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax, LTE and Wi-Fi	High speed, high quality voice over IP, HD multimedia streaming, 3D gaming, HD video conferencing and worldwide roaming.
5G (Expecting at the end of 2019)	1 to 10 Gbps	LTE advanced schemes, OMA and NOMA	Super fast mobile internet, low latency network for mission critical applications, Internet of Things, security and surveillance, HD multimedia streaming, autonomous driving, smart healthcare applications.

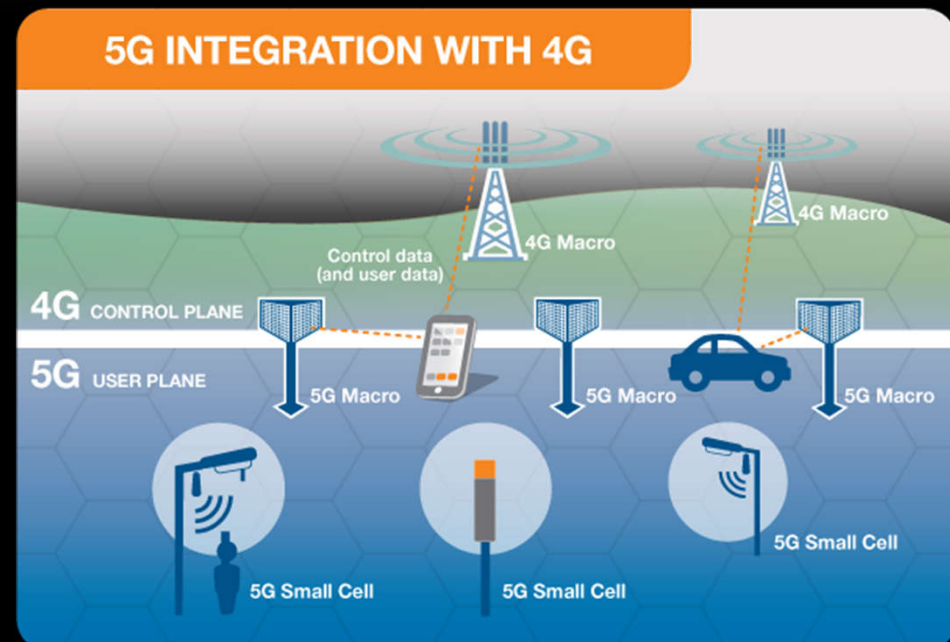
www.rfpage.com

KBPS VS. MBPS VS. GBPS

Typical Devices/Examples	Data Rates
standard dial-up modems	56 Kbps
typical encoding rates of MP3 music files	128 Kbps, 160 Kbps, 256 Kbps, 320 Mbps
maximum encoding rate of Dolby Digital (audio)	640 Kbps
T1 line	1544 Kbps
Ethernet	10 Mbps
802.11b Wi-Fi	11 Mbps
802.11a and 802.11g Wi-Fi	54 Mbps
Fast Ethernet	100 Mbps
typical 802.11n Wi-Fi data rates	150 Mbps, 300 Mbps, 450 Mbps, 600 Mbps
typical 802.11ac Wi-Fi data rates	433 Mbps, 867 Mbps, 1300 Mbps, 2600 Mbps
Gigabit Ethernet	1 Gbps
10 Gigabit Ethernet	10 Gbps

5G – CHARACTERISTICS

- Brings three (3) new aspects to cellular technology
 - Greater speeds to move more data (up to 20 Gbps)
 - Lower Latency – to be more responsive – 1 msec
 - Ability to connect a lot more devices at once and simultaneously (for sensors and smart devices)
- 5G-NR, the 5G radio system is incompatible with 4G
- Initially 5G devices in the US will also need 4G capability to make the initial connections before trading up to 5G infrastructure wherever it's available – know as Non Stand-alone (NSA) network
- Eventually, as 5G evolves and infrastructure builds out, 5G will become ubiquitous and no longer depend on 4G to establish initial connections – then a Stand-alone (SA) 5G network



LATENCY VS. BANDWIDTH?

- Internet connections, including satellite Internet connections, are advertised with speeds like “up to 15 Mbps.” You may look at a satellite Internet connection offering this speed and assume the experience of using it would be comparable to the experience of using a 15 Mbps cable Internet connection, but you would be wrong.
- Network latency describes a delay that takes place during communication over a network (including the Internet).
- Bandwidth: Bandwidth determines how fast data can be transferred over time. Bandwidth is the amount of data that can be transferred per second.
- Satellite Internet Connection (High Speed, High Latency): You would click a link on a web page and, after a noticeable delay, the web page would start downloading and show up almost all at once.
- Theoretical Connection (Low Speed, Low Latency): You would click a link on a web page and the web page would start loading immediately. However, it would take a while to load completely and you would see images load one-by-one.
- Cable Internet Connection (High Speed, Low Latency): You would click a link on a web page and the web page would appear almost immediately, downloading all at once.

LATENCY METRICS

Technology	Response time(milliseconds)
4G - LTE systems	20-30 ms
5G - enhanced mobile broadband	4-5 ms
5G - URLLC (Ultra Reliable Low Latency Communications) systems	1 ms

Latency for near real time experience (e.g. gaming) should be < 50 ms
Audio latency > 150 ms is noticeable and often objectionable

AN EXAMPLE OF LATENCY BY STEVEN WRIGHT



In my house there's this light switch that doesn't do anything. Every so often, I would flick it on and off just to check. Yesterday, I got a call from a woman in Germany. She said 'cut it out'

— *Steven Wright* —

AZ QUOTES

HOW 5G WORKS

- Uses a system of cell sites that divide their territory into sectors. Send encoded data through radio waves.
- Each cell is connected to a network backbone, through either a wired or wireless backhaul connection.
- 5G operates on much larger channels
 - Each channel 100MHz and bonded up to 800 MHz
 - 4G – 20 MHz channels with up to 160 MHz bonding
 - More BW requires smarter systems to juggle all this activity

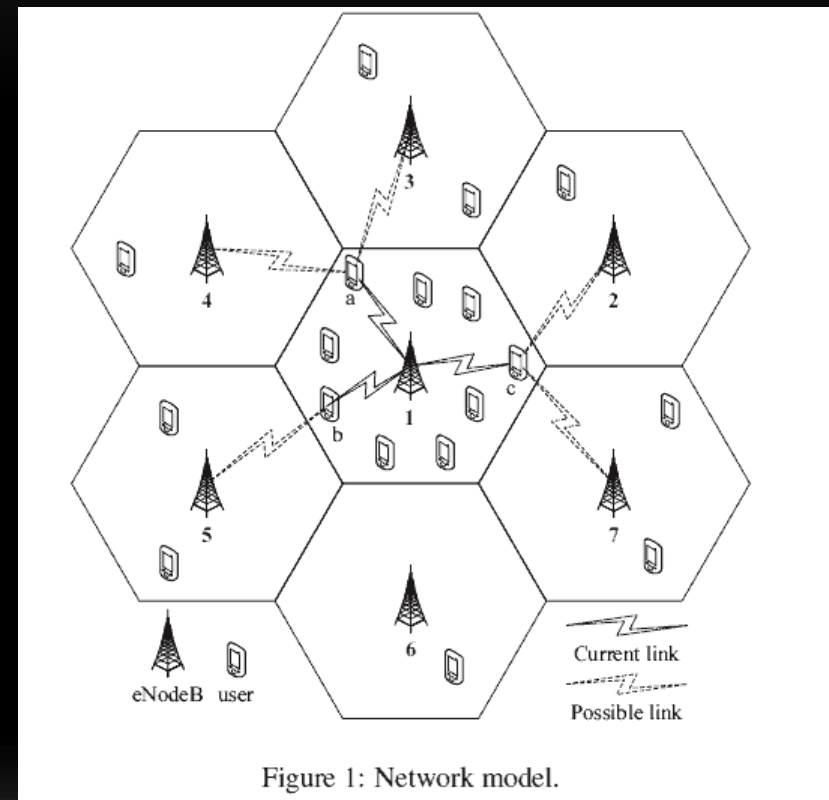
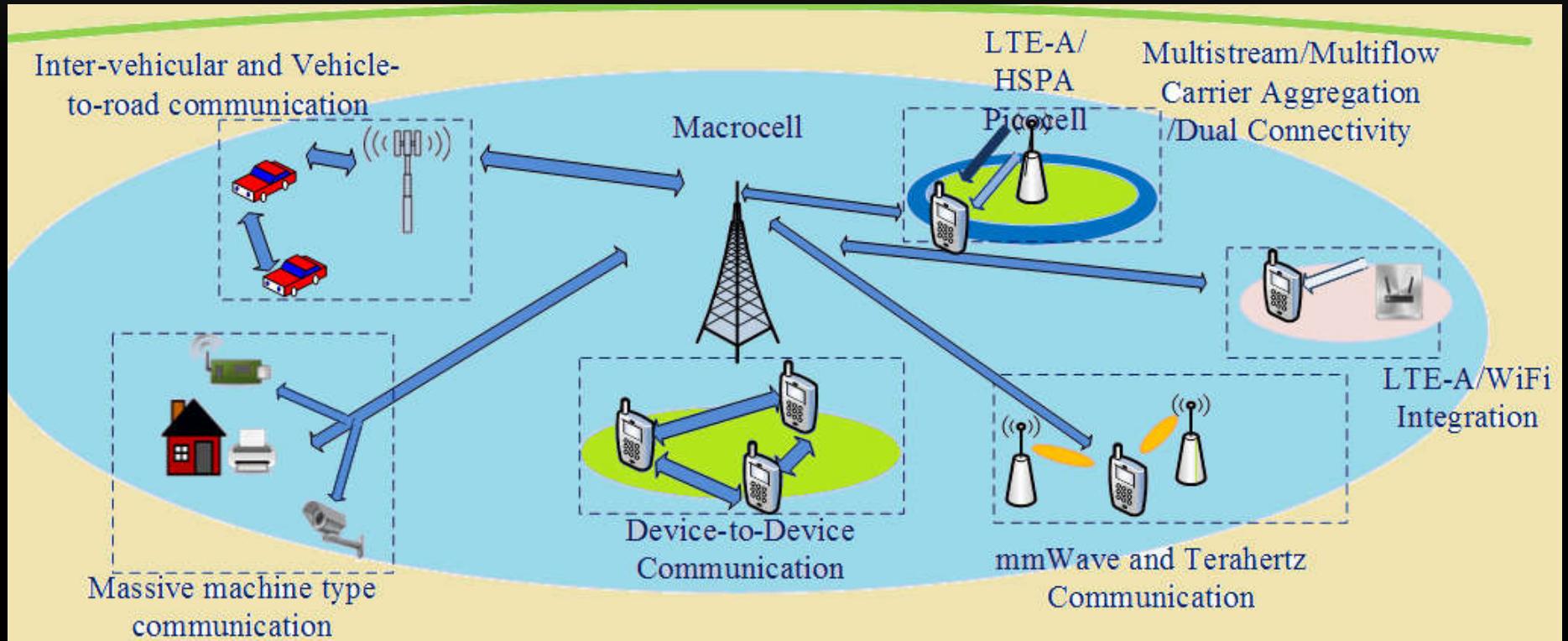
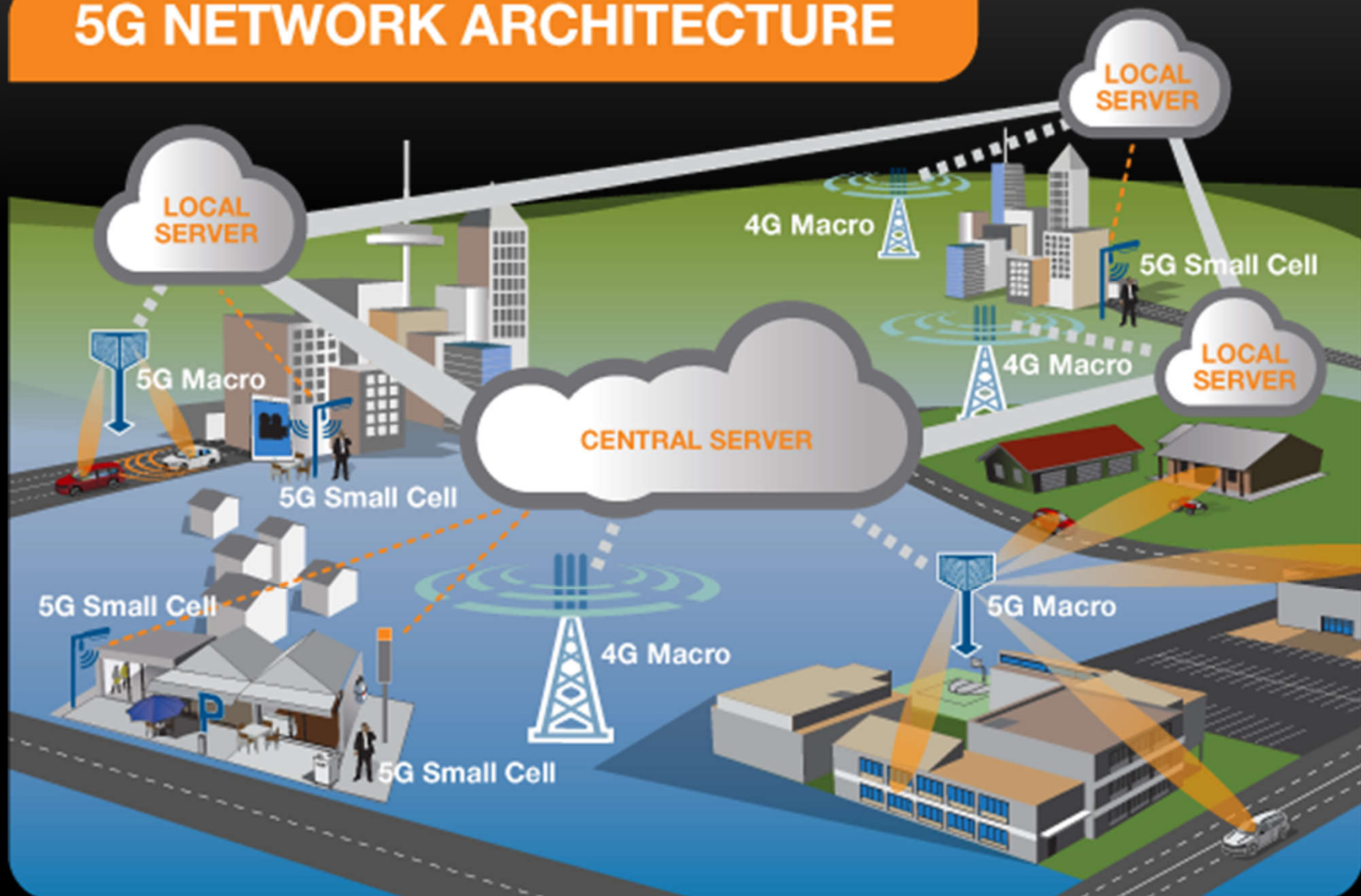


Figure 1: Network model.

HOW 5G WORKS

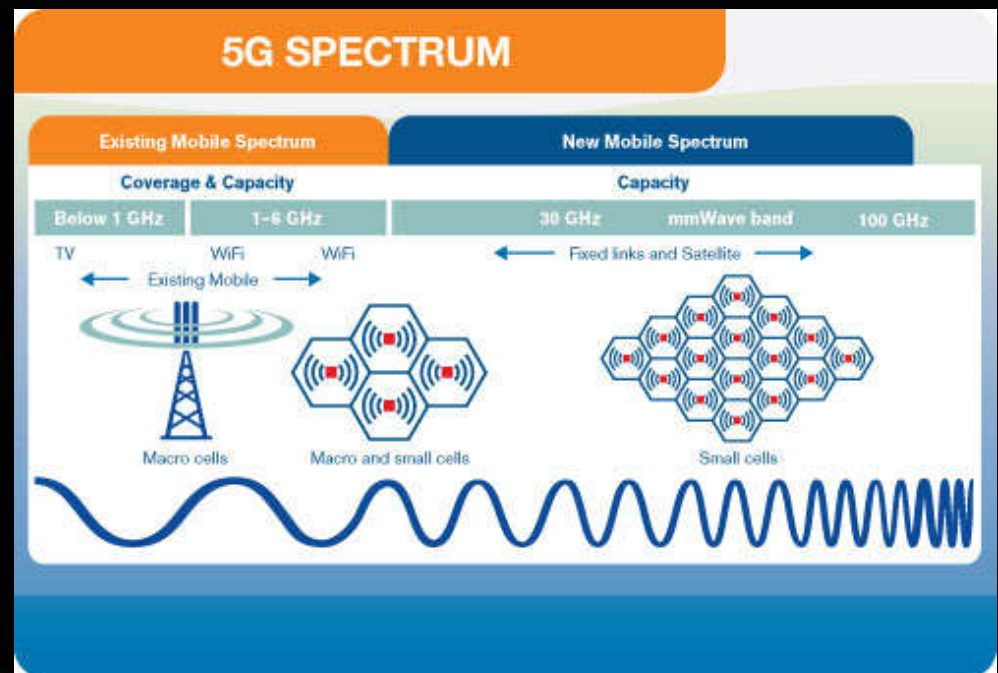


5G NETWORK ARCHITECTURE

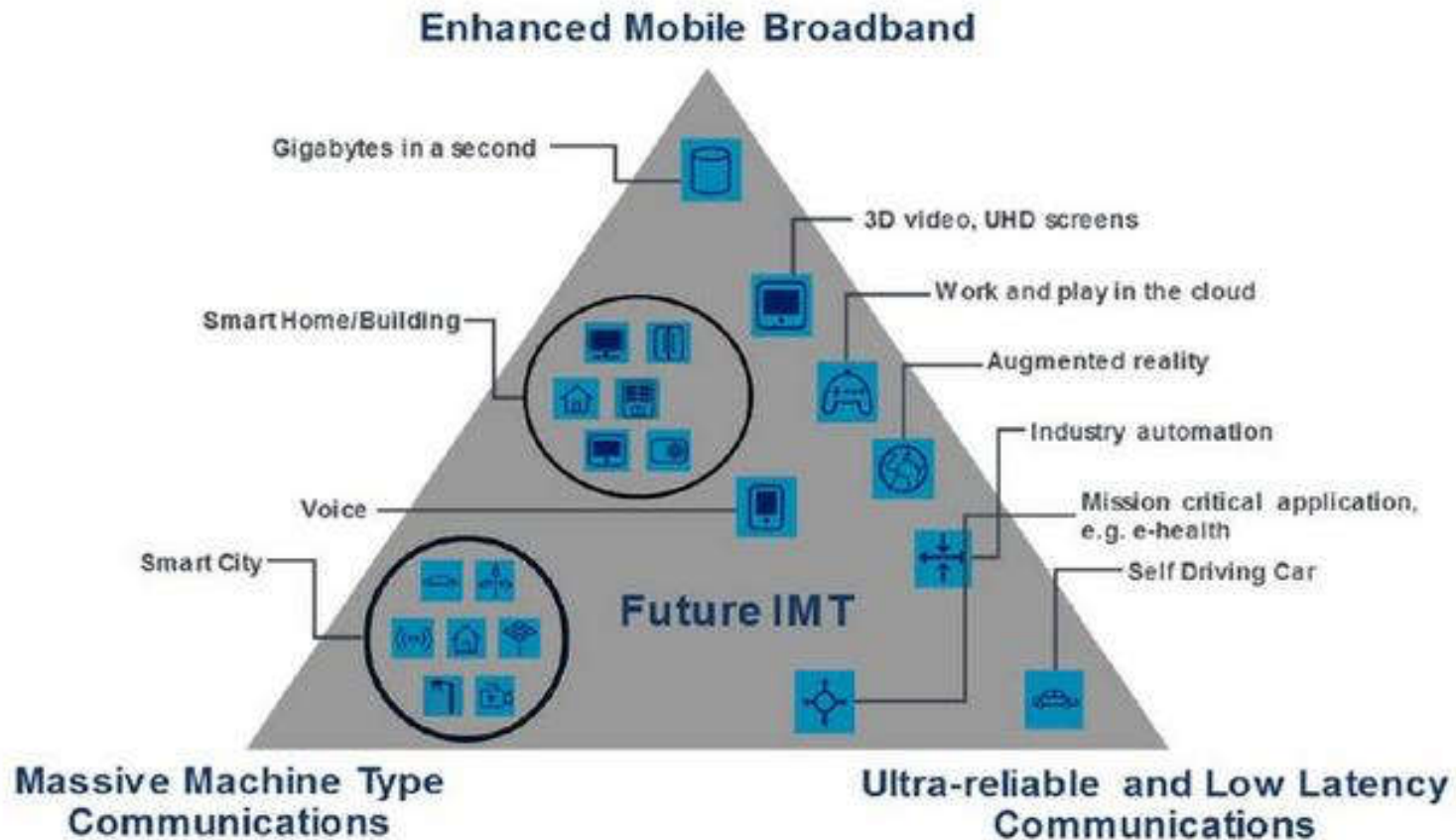


HOW 5G WORKS - FREQUENCIES

- Operates both above & below 6GHz
- Low Frequency (< 6 GHz) use existing cellular and WiFi bands – but w/increased BW, data rates up to 25-50% faster than 4G LTE (macro cells – 20-40 watts)
- To get super high, multi gigabit speeds, carriers will use spectrum above much higher frequencies (28 & 39 GHz) – called mmWave (small or picocells - 2-20 watts)
- Speed / Coverage Tradeoff
 - Low frequency – same coverage range and ability to penetrate buildings, etc.
 - mmWave – signal strength drops off faster with distance and less able to penetrate interfering entities



5G Usage scenarios



How will **5G** speed change things?

Time to download a **2-hour HD** movie:

2G:

4.5 Hours

3G:

3 Hours

4G:

30 Seconds

5G:

3 Seconds



ThePrint

WHO'S LAUNCHING 5G WHEN?

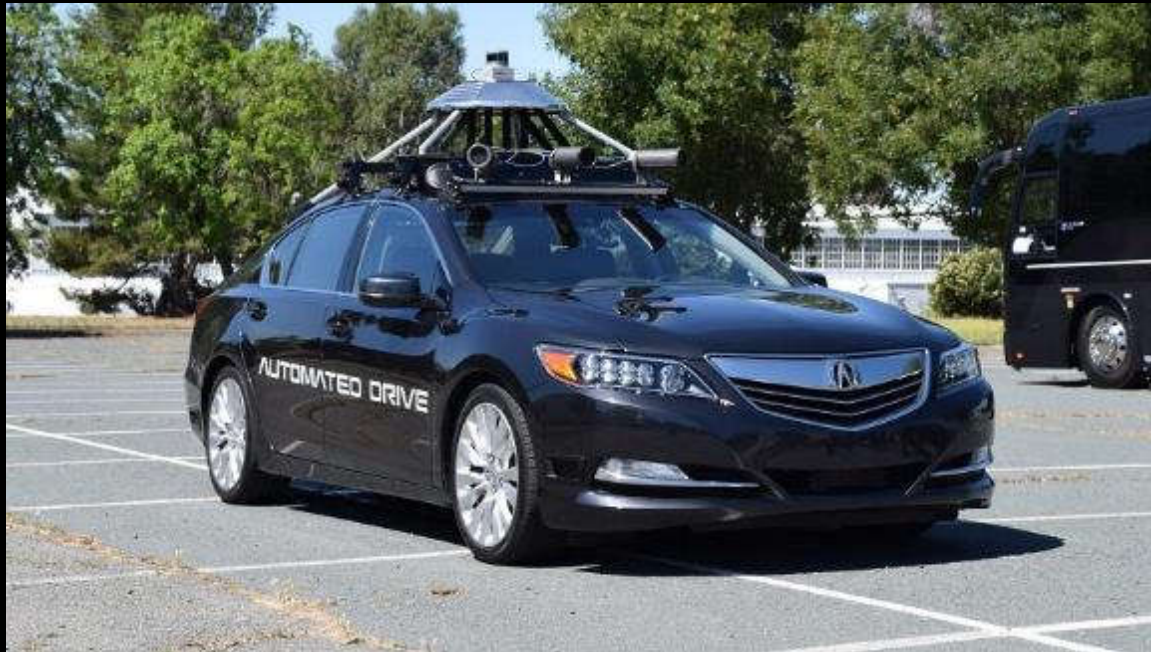
AT&T	Verizon	T-Mobile/Sprint
AT&T now has 19 cities in trial but very limited areas within those cities	Verizon has started out with a fixed 5G home internet service in a few neighborhoods in four (4) cities	T-Mobile – building out their 5G plan starting in 2019; expect nationwide in 2020
Only a few hotspots/city in a few neighborhoods		
Samsung Galaxy S10 5G – ETA June	Moto Z3 – April; Samsung Galaxy S10 5G – ETA June	Samsung Galaxy S10 5G – ETA June
Same pricing as 4G	\$10/mo more vs. 4G Unlimited	

WHAT'S 5G FOR?

- Home Internet
 - Verizon focus; all other carriers are targeting faster smartphones
 - 5G's huge capacity (BW), a big advantage
 - Average monthly home usage is 190 GBytes
 - Less infrastructure and sunk cost vs. FiOS



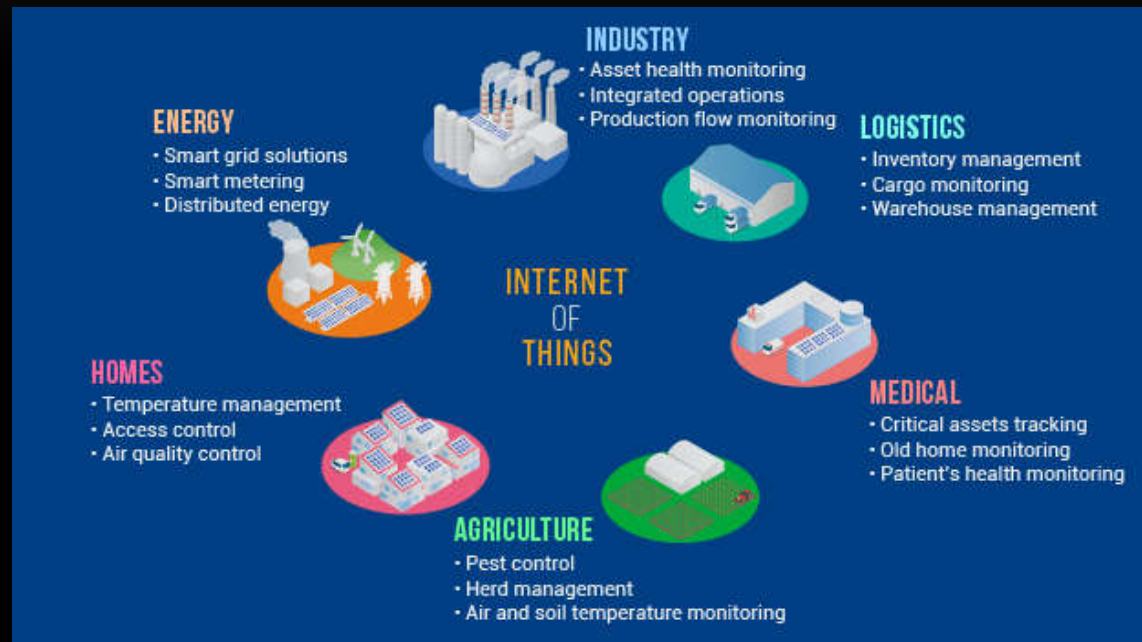
WHAT'S 5G FOR?



- Driverless Vehicles
 - Ability to interact directly with other vehicles and smart roads
 - Ultra low latency needed for safety and traffic management
 - End game = everything on the road will be talking to everything else
 - 1 light millisecond \sim 186 miles; so majority of the 1 ms latency is still processing time

WHAT'S 5G FOR?

- IoT: Internet of Things
 - 5G BW and ultra low latency enabling capacity to handle many more sensors
 - Design is to be able to interface with lower cost, low power devices
 - Device to device communication

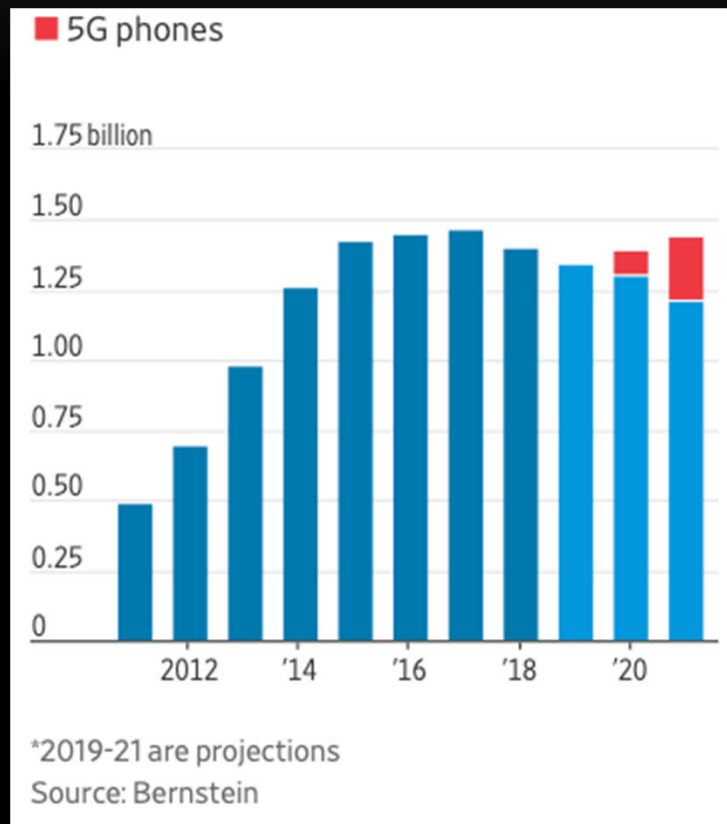


WHAT'S 5G FOR?



- Phones
 - May bring Augmented and Virtual Reality into the mainstream
 - Small cell aspects may help with in-building coverage
 - Every home router becomes a micro cell site

5G PHONE SALES PROJECTIONS



- At present, Apple has yet to announce a 5G iPhone.
 - Insiders believe the need to develop a 5G iPhone was a contributing factor in Apple and Qualcomm settling their patent infringement suits.
- Huawei's Mate X foldable 5G phone will not be available for sale in the US due to the US banning all things Huawei. Price tag of the Mate X is \$2,600!

- [WSJ 5G Myths](#)
- [PC MAG 5G](#)



GLOSSARY OF TECHNOLOGY ABBREVIATIONS

- AMPS - Advanced Mobile Phone System
- CDMA - Code-division multiple access
- TDMA - Time-division multiple access
- LTE - Long-Term Evolution
- GSM - Global System for Mobile Communications
- GPRS - General Packet Radio Services
- OFDM - Orthogonal Frequency-Division Multiplexing

GLOSSARY OF TECHNOLOGY ABBREVIATIONS

- EDGE - Enhanced Data Rates for GSM Evolution
- kbits
- Mbits
- Mbytes
- Gigabits
- HSPA -High Speed Packet Access
- UMTS - Universal Mobile Telecommunications Service
- RAT/RAN – Radio Access Technology/Networks

MOBILE DATA RATES BY GENERATION

Second generation (2G) from 1991:	
Speeds in kbit/s	down and up
GSM CSD	9.6
CDPD	up to 19.2
GSM GPRS (2.5G)	56–115
GSM EDGE (2.75G)	up to 237

The download (to the user) and upload (to the Internet) data rates given above are peak or maximum rates and end users will typically experience lower data rates.

Third generation (3G) from 2001:		
Speeds in Mbit/s	down	up
UMTS W-CDMA	0.4	
UMTS HSPA	14.4	5.8
UMTS TDD	16	
CDMA2000 1xRTT	0.3	0.15
CDMA2000 EV-DO	2.5–4.9	0.15–1.8
GSM EDGE-Evolution	1.6	0.5

MOBILE DATA RATES BY GENERATION

Fourth generation (4G) from 2006:

Speeds in Mbit/s	down	up
HSPA+	21–672	5.8–168
LTE	100–300	50–75
LTE-Advanced:		
while moving at high speeds	100	
while stationary or moving at low speeds	up to 1000	

Fifth generation (5G) from 2018:

Speeds in Mbit/s	down	up
HSPA+	400–25000	200–3000
5G	400–3000	500–1500

1,000 Mbit/s = 1 Gbit/s