SVEUČILIŠTE U ZAGREBU

Fakultet elektrotehnike i računarstva

Master Programme

Computing

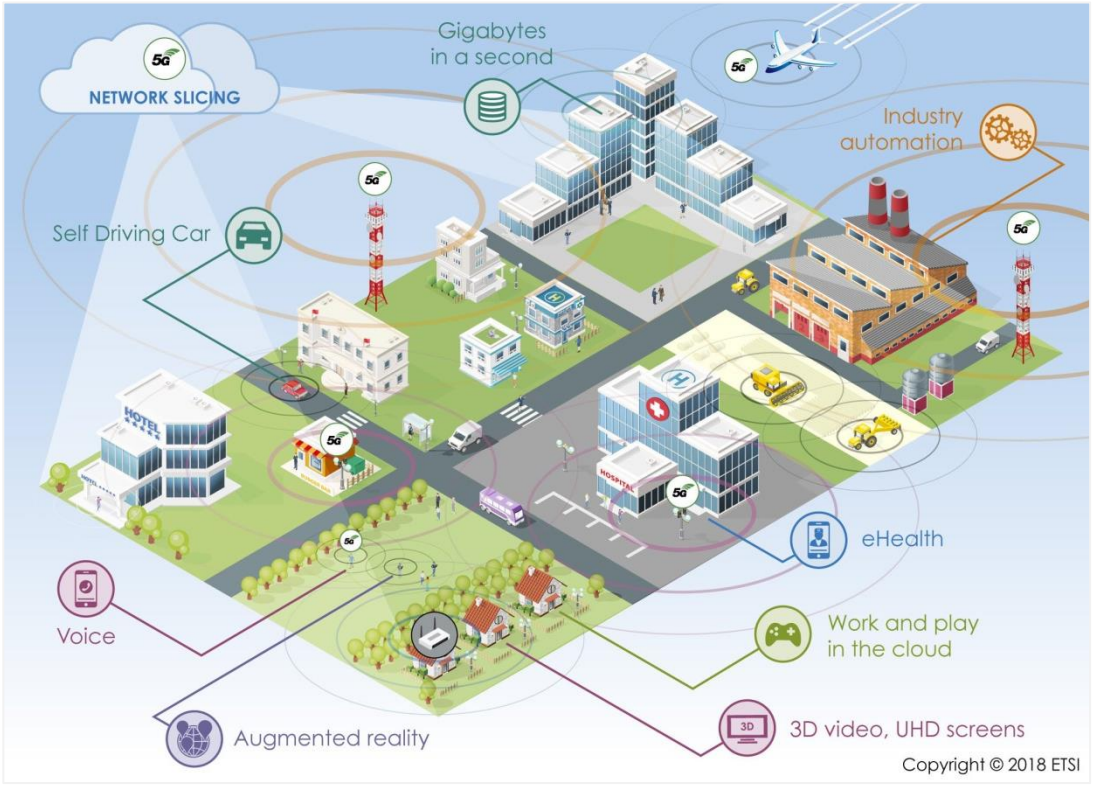
Advanced Architectures of Telecommunication Networks

Mobile network evolution towards 5G: 5G use cases and requirements

Ac. year 2022/2023

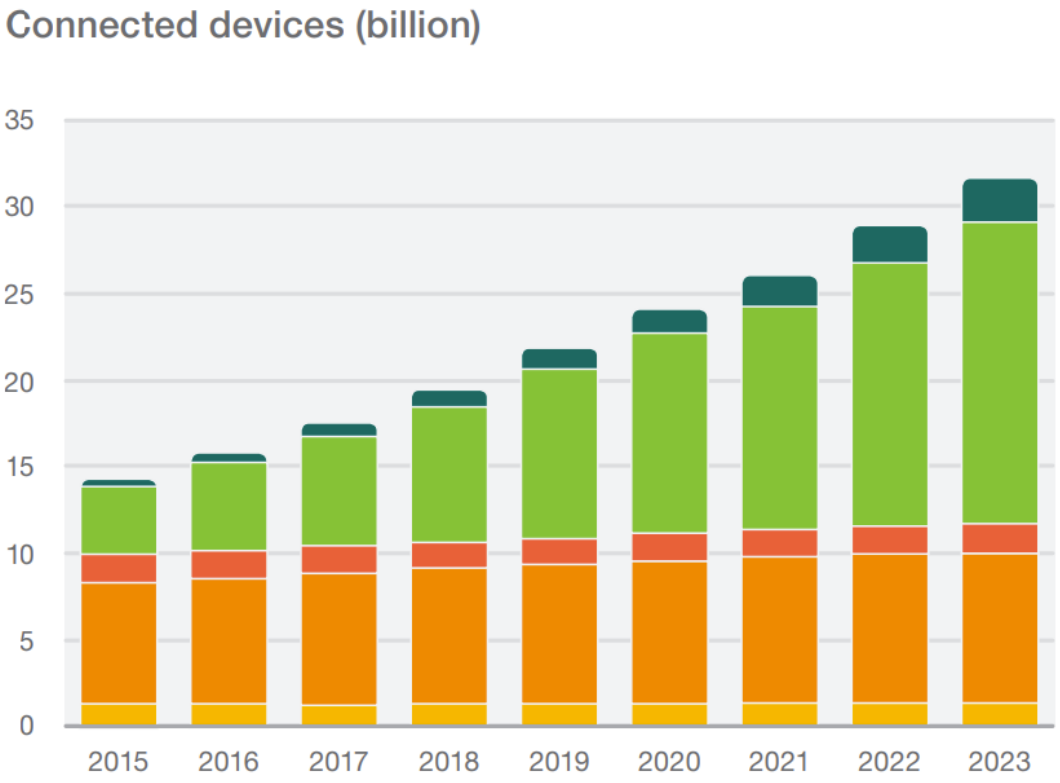
The need for 5G

- Mobile data **traffic is rising rapidly** (video streaming)
- Multiple devices, **growing number of connections** per user
- **Internet of Things** - networks must handle **billions of devices**
- Mobiles and networks need to **increase energy efficiency**
- Network operators need to **reduce operational expenditure**
- The mobile communication technology can enable **new use cases and applications**



https://www.etsi.org/technologies/5G

The need for 5G - number of devices



	2017	2023	CAGR
Wide-area IoT	0.6	2.4	26%
Short-range IoT	6.4	17.4	18%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.5	8.8	3%
Fixed phones	1.4	1.3	0%
	17.5 billion	31.6 billion	

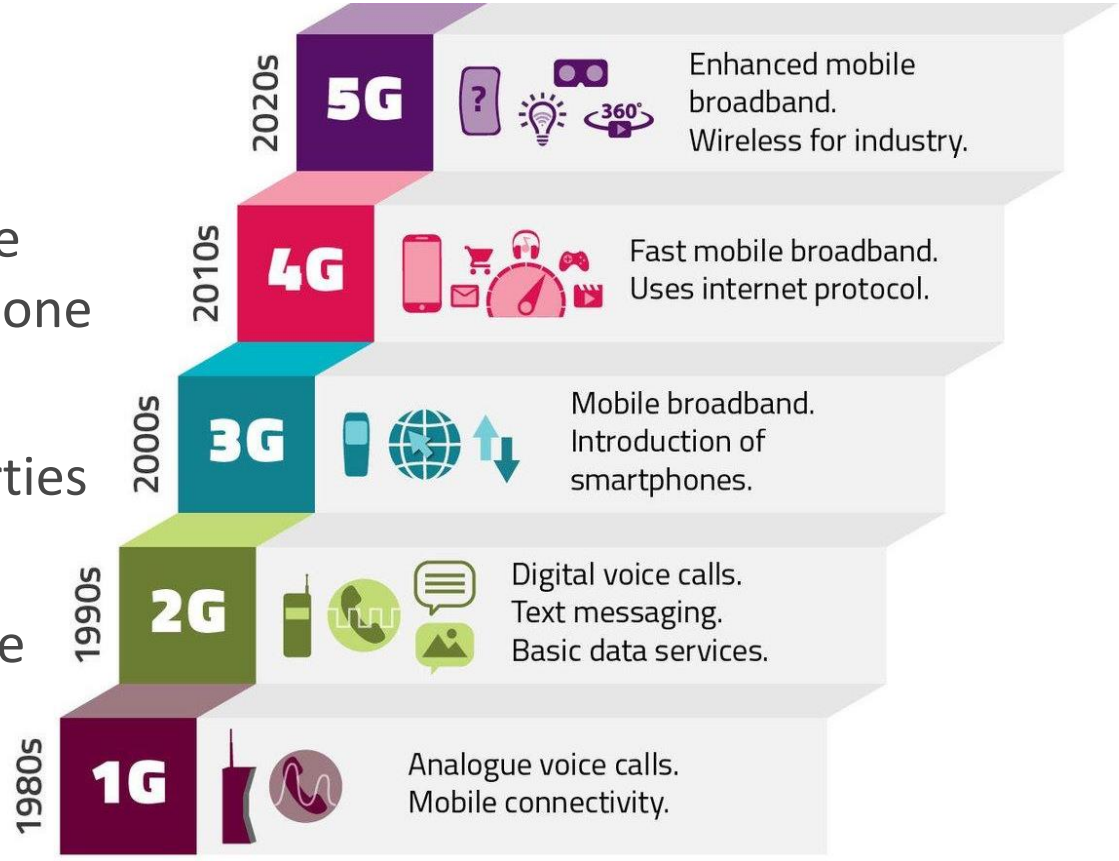
https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-november-2017-central-and-eastern-europe.pdf

What is 5G?

- The 5th generation mobile network
- Enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices
- 5G wireless technology is meant to deliver:
  - higher multi-Gbps peak data speeds,
  - ultra low latency,
  - more reliability,
  - massive network capacity,
  - increased availability, and
  - a more uniform user experience to more users

The evolution of 5G

- 0G devices or pre-cellular devices
- Vehicle-mounted mobile telephone systems
- **Bell Systems** launched the first automated mobile telephone system IMTS (Improved Mobile Telephone System) in **1964**
- No live operator, full-duplex operation – both parties could talk at the same time
- VHF/UHF radio that linked to the public telephone network



IEEE Region 4 - The evolution of cellular communications from 1G to 5G

1G

- Started in the 1980s
- Focused on voice communications in the **analog voice** form
- Unable to transmit any data, not even receiving and sending text messages or SMS, no roaming
- Speed up to **2.4 kbps**

https://pngimage.net/dynatac-8000x-png-3/

2G

- Started in the 1991s
- Focused on **digital voice** communication
- Can **send text** or **SMS** and **use the Internet, roaming**
- Limited speed up to **50 Kbps** (GPRS) or **1 Mbps** (EDGE)

https://www.pngfind.com/download/hiTxbTJ_nokia-3310-nokia-3310-old-png-transparent-png/

3G

- Beginning in the 1998s
- Emphasis on **high-speed wireless connections**
- Allows multimedia applications and can **transmit both video** and **audio**, roaming
- High speed up to **2 Mbps**

https://www.easytechjunkie.com/what-is-3g.htm

4G

- Starting in the 2008s
- Upgraded video quality and various games (full HD), smooth streaming, easy roaming
- Speed from **100 Mbps** (4G LTE) to **1 Gbps** (4G LTE Advanced)

https://www.hiclipart.com/free-transparent-background-png-clipart-xmqnh/download

5G

- Starting in the early 2020s
- Internet connections not limited to mobile phones; designed to support a large number of **heterogenuos devices**
- Speed from **1Gbps** up to **20 Gbps**

https://www.eenewseurope.com/news/total-announced-5g-devices-break-through-250-barrier/page/0/1

1G to 5G - summary

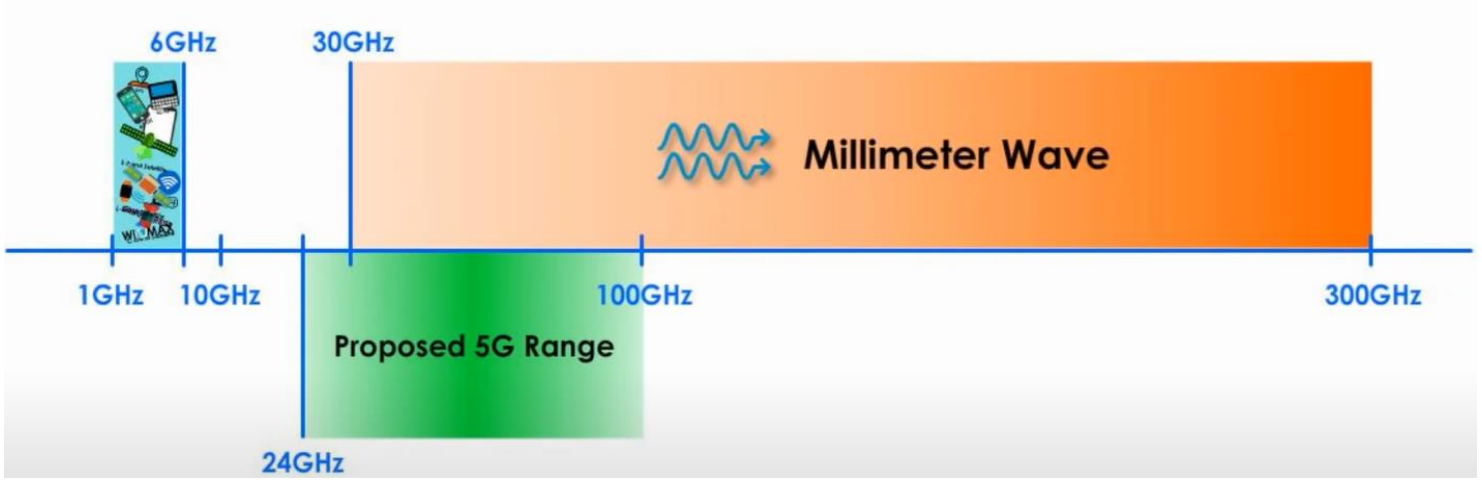
Characteristics	1G	2G	3G	4G	5G
Time period	1970 – 1980s	1990 - 2000	2000 - 2010	2010 – 2020	early 2020s
Bandwidth	2.4 kbps	64 kbps	2 Mbps	100 Mbps – 1 Gbps	> 1 Gbps
Technology	analog cellular	GSM	WCDMA	LTE	MIMO, mmWave
Core network	PSTN	PSTN	UMTS Core	Evolved Packet Core (EPC)	5G Core (5GC)
Applications	analog voice	digital voice, SMS	video conferencing, mobile TV, GPS, roaming...	high speed apps, streaming, mobile TV, wearables...	high resolution video streaming, remote control...

5G brings new technologies

- Millimeter Wave (mmWave)
- Massive MIMO
- Small Cell
- Beamforming
- NOMA

Millimeter Wave

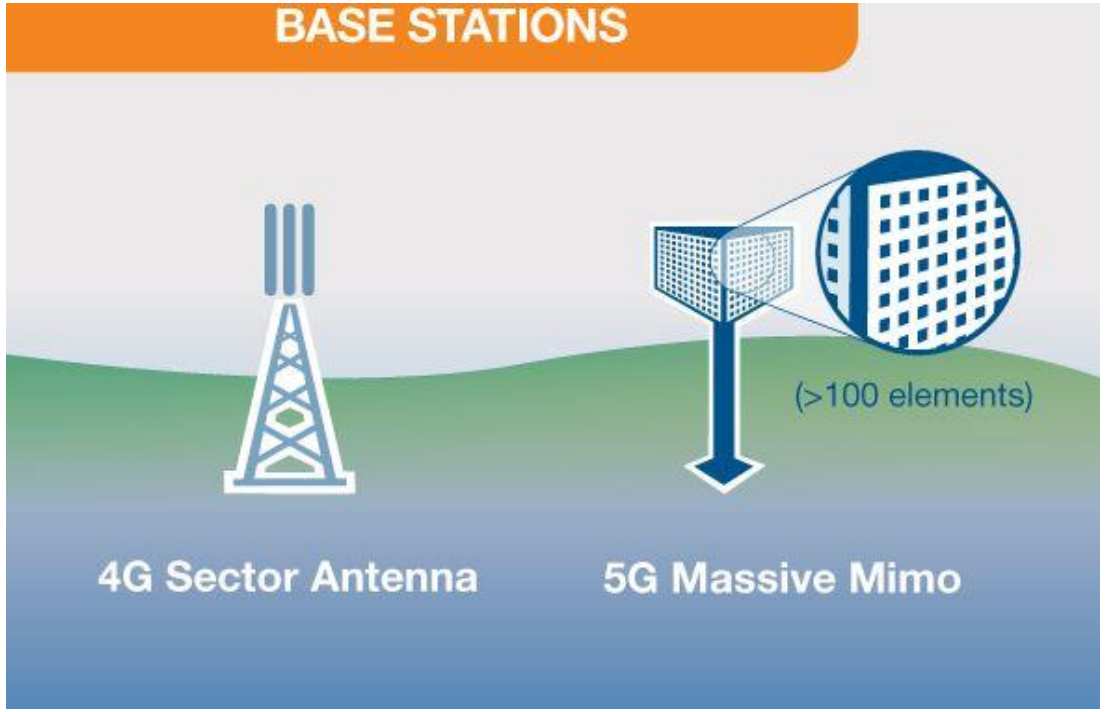
- Frequency spectrum from 1GHz to 6GHz – very crowded (GPS, WiFi, 3G, 4G, etc.)
- The mmWave has at least 3 advantages:
  1. new and less used band
  2. higher frequency wave carries much more data than lower frequency wave
  3. makes possible to have massive MIMO antenna



Sunny Classrom, „5G cellular networks: 6 new technologies"

Massive MIMO

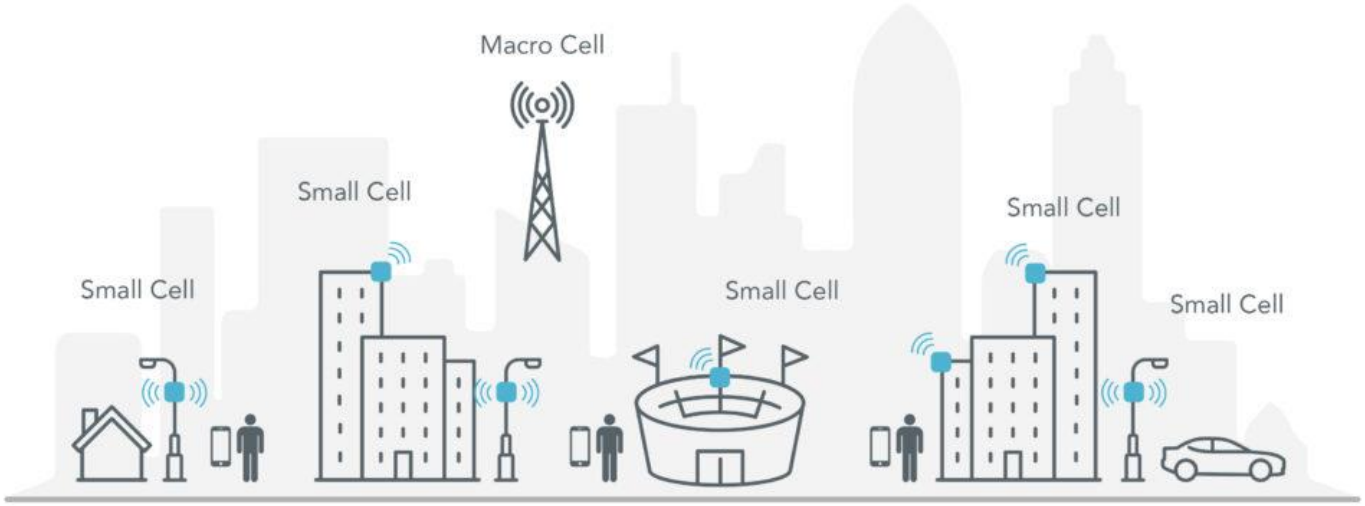
- Multiple Input Multiple Output
- Relationship between the wave frequency and antenna size is inversely proportional
- mmWave enables to have a lot of transmitters and receivers installed on a small size cell
- One small cell can handle many more users at the same time than in 4G



https://forum.huawei.com/enterprise/en/massive-mimo/thread/656041-100305?page=1

Small Cell

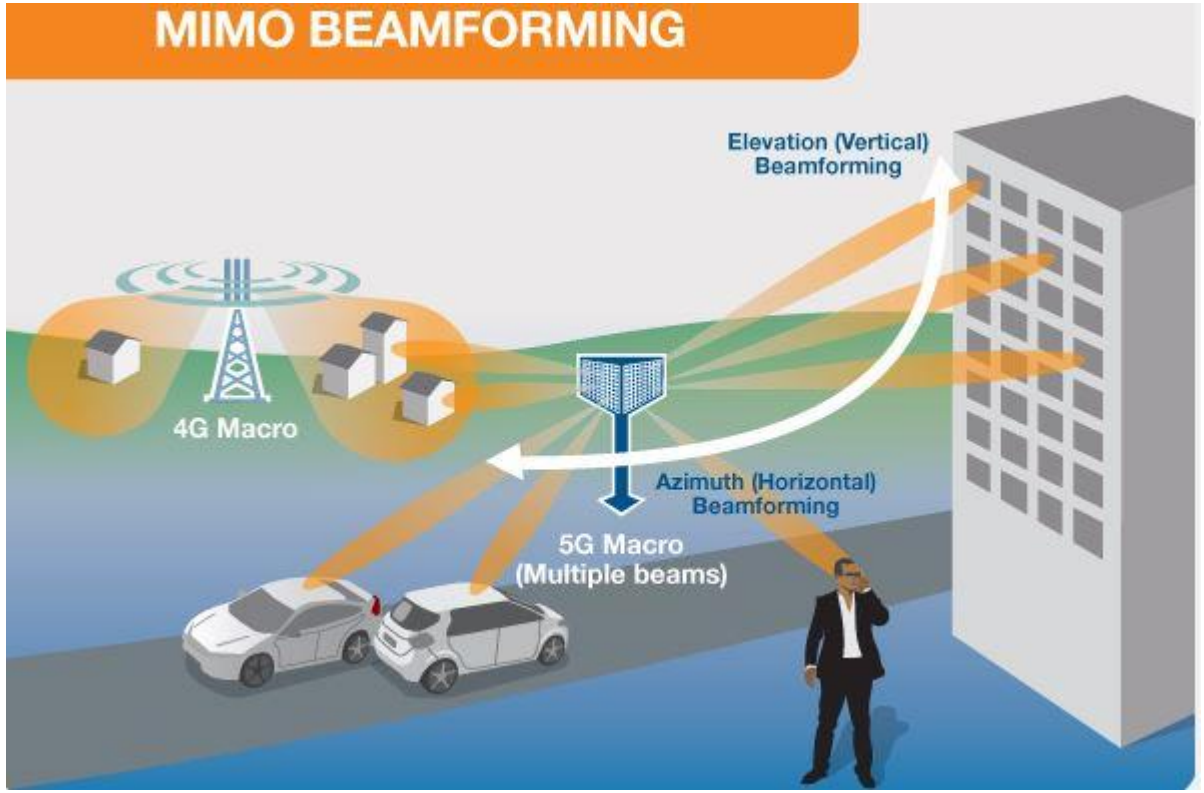
- Disadvantages of millimetar wave:
  - Higher frequency signals have more collisions with obstacles in the air – tend to lose more energy and cover shorter distance
  - Easily blocked by buildings and trees
- Small cell stations – fill the coverage gap between users and BS
- Cell size and distance between cells depends on the population of the location



https://www.litepoint.com/blog/an-introduction-to-the-5g-small-cell/

Beamforming

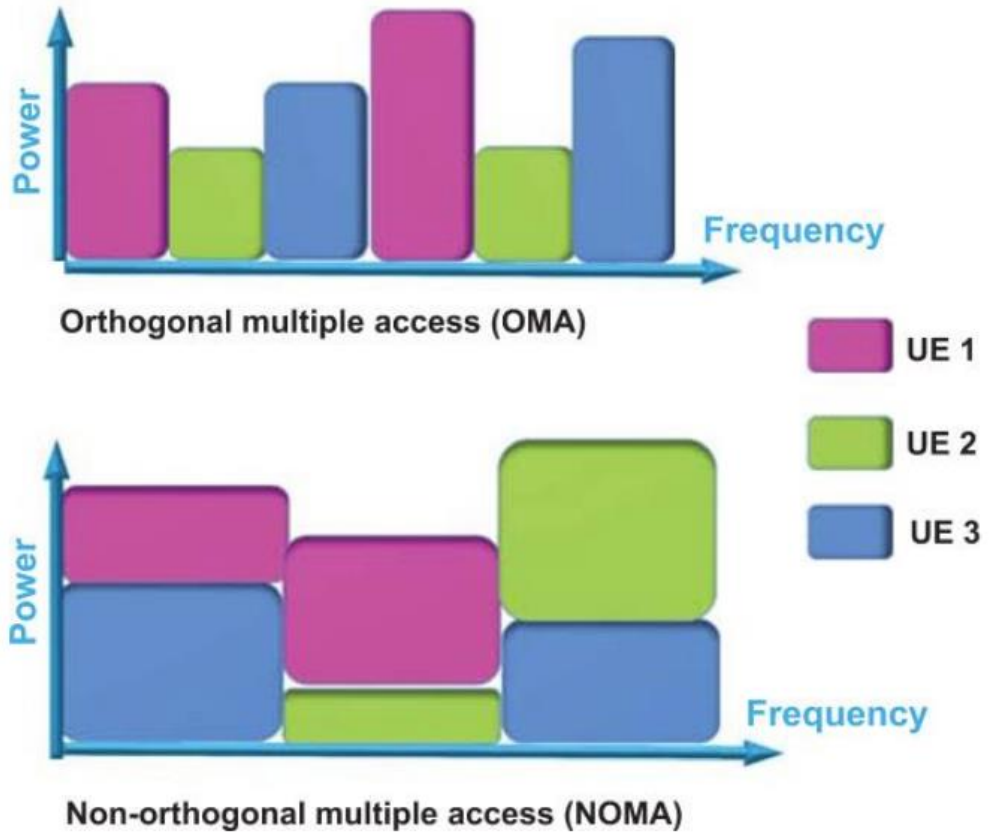
- In 4G, the wireless signals (if not omnidirectional), are spreading over a wide area
- Different users might interfere with each other if standing close
- Beamforming makes the transmission between users and base stations more directional
- Higher density of beamforming:
  - Less interference
  - Less energy consumption
  - Faster data rates



https://forum.huawei.com/enterprise/en/massive-mimo/thread/656041-100305?page=1

NOMA

- Non-Orthogonal Multiple Access
- Current cellular networks implement orthogonal multiple access (OMA) techniques such as TDMA, FDMA, CDMA
- The key idea of NOMA is to use the power level of user devices to access the base station
  - allows different signals to share the same channel simultaneously



Stella Ho, „NOMA for 5G Wireless Communication Systems", October 2017

5G standardization: ITU

- The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies – ICTs
  - founded in 1865 to facilitate international connectivity in communications networks
  - ITU makes **phone calls** possible, coordinates the world's **satellites** (TV, GPS, weather, online maps, etc.), makes **Internet** access possible and many more

5G standardization: ITU-R

	IMT – 2020
ITU - R	5G includes several features: • high data rate, • ultra low latency, • high reliability, • large number of devices, • high user density, • advanced antenna technology, • mmWave, • spectrum flexibility, etc.

- The ITU Radiocommunication Sector (ITU-R) plays a vital role in the global management of the radio-frequency spectrum and satellite orbits
- Several specifications and standards:
  - IMT-2000 (3G),
  - IMT-Advanced (4G),
  - IMT-2020 (5G),
  - Digital Television and sound Radio,
  - High Definition Television (HDTV),
  - Ultra High Definition Television (UHDTV), etc.

5G standardization: 3GPP

- The 3rd Generation Partnership Project (3GPP) unites 7 telecommunications standard development organizations known as “Organizational Partners” (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC)
- Provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies

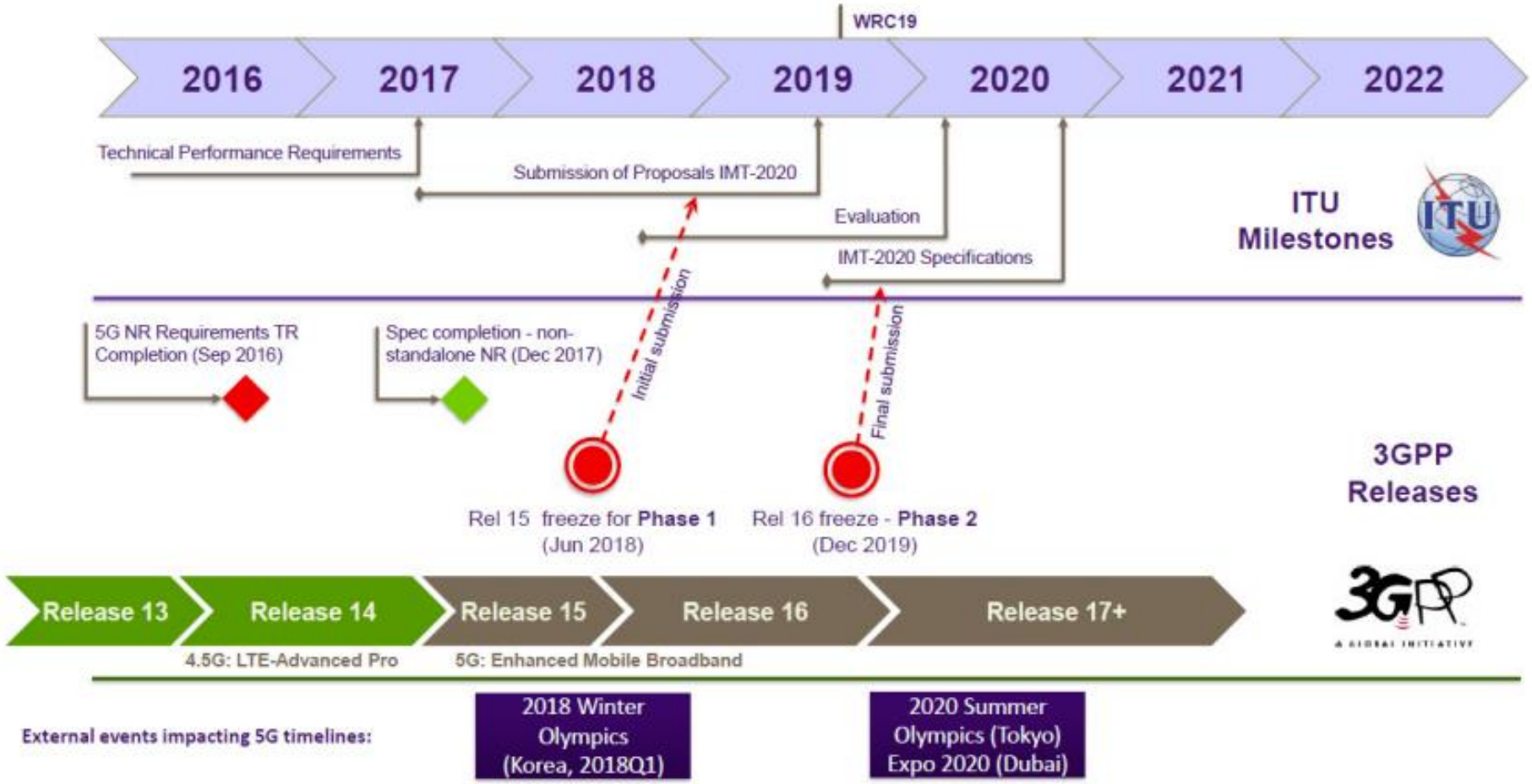
5G standardization: ETSI

- The European Telecommunications Standards Institute (ETSI) has standardization activities that specify requirements and potential enablers or building blocks for an overall 5G system
  - a number of ETSI Industry Specification Groups (ISGs), Technical Committees (TCs) and projects have active collaboration with 3GPP and, in some cases, provide direct input to 3GPP

5G standardization: IETF

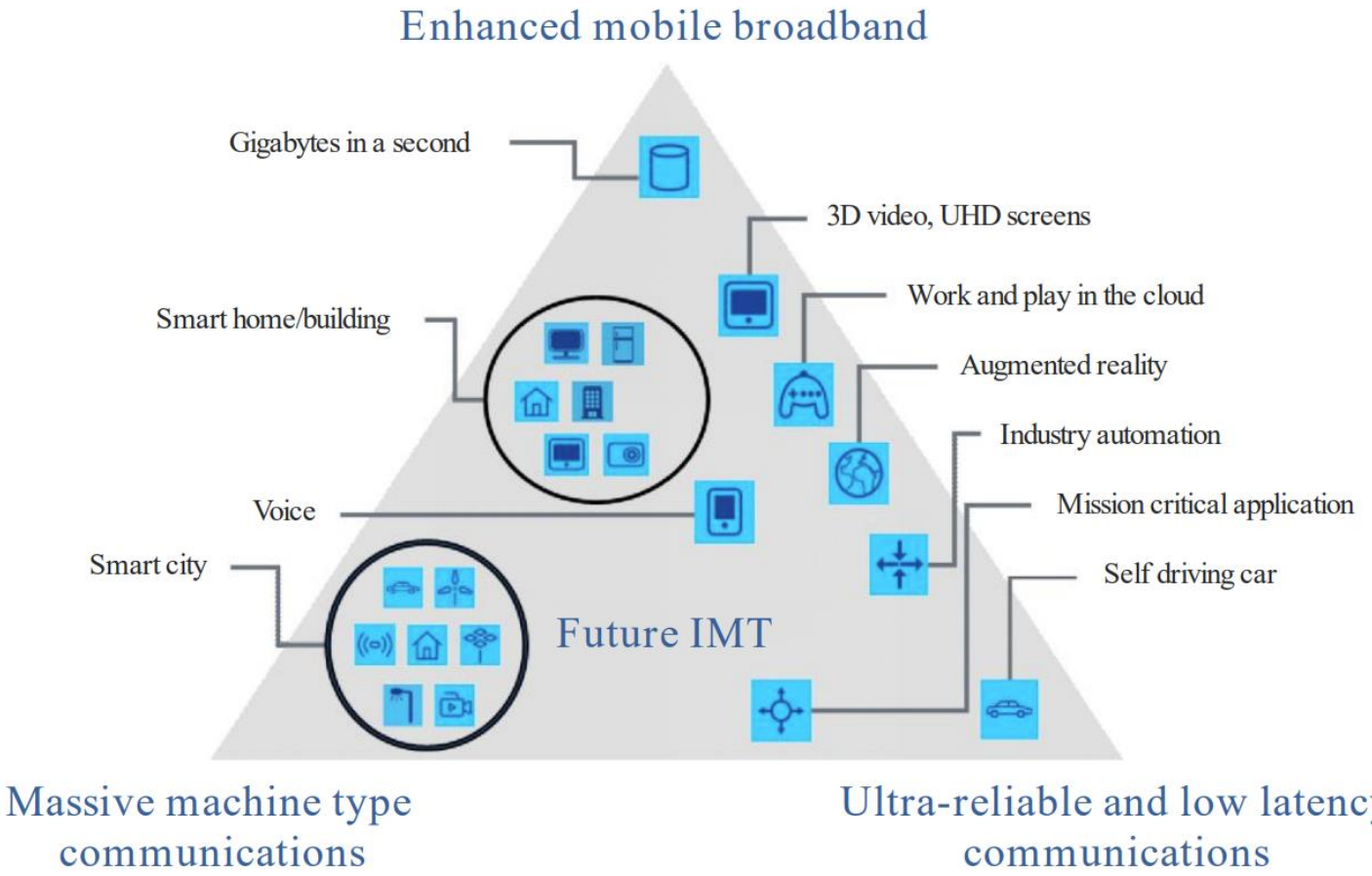
- The Internet Engineering Task Force (IETF) is an open standards development organization (SDO) in the area of Internet-related technologies
- In the context of 5G, the main areas that IETF is focusing on includes network slicing, mobile edge computing, machine learning at network level, and Low Power IoT Networking (LPWA)

5G Timelines: ITU-R and 3GPP



Sami Tabbane, „5G networks and 3GPP Release 15", ITU PITA Workshop on Mobile network planning and security, 23-25 October 2019

IMT – 2020 usage scenarios



ITU-R Recommendation M.2083-0, "IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond," Sep. 2015

enhanced Mobile Broadband (eMBB)

- Extension of the classic mobile broadband connectivity scenario
- Addresses human-centric connectivity
- Deals with hugely increased data rates, high user density and very high traffic capacity
- Covers a range of use cases including:
  - hotspot scenarios (a high user density and extremely high data rates, but low mobility)
  - wide-area coverage (lower user density and data rates, but high mobility)

Ultra-Reliable and Low Latency Communications (URLLC)

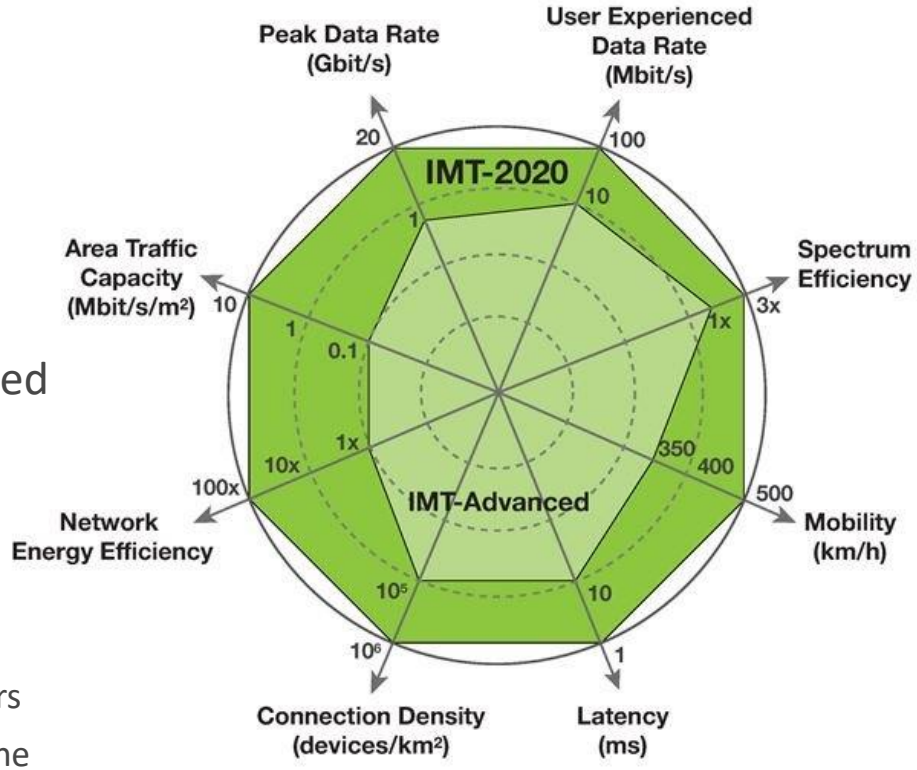
- Strict requirements on both latency and reliability
- Caters for safety-critical and mission critical applications
- Targets mainly machine-type communications (MTC)
- Covers a range of use cases including:
  - wireless control of industrial manufacturing and production processes,
  - remote medical surgery,
  - driverless and/or remotely driven vehicles, and
  - distribution automation in smart grids

massive Machine Type Communications (mMTC) for IoT

- Requires low power consumption and low data rates for very large number of connected devices
- mMTC devices:
  - expected to have a very long battery lifetime
  - to be extremely heterogeneous in terms of capabilities, cost, energy consumption, and transmission power

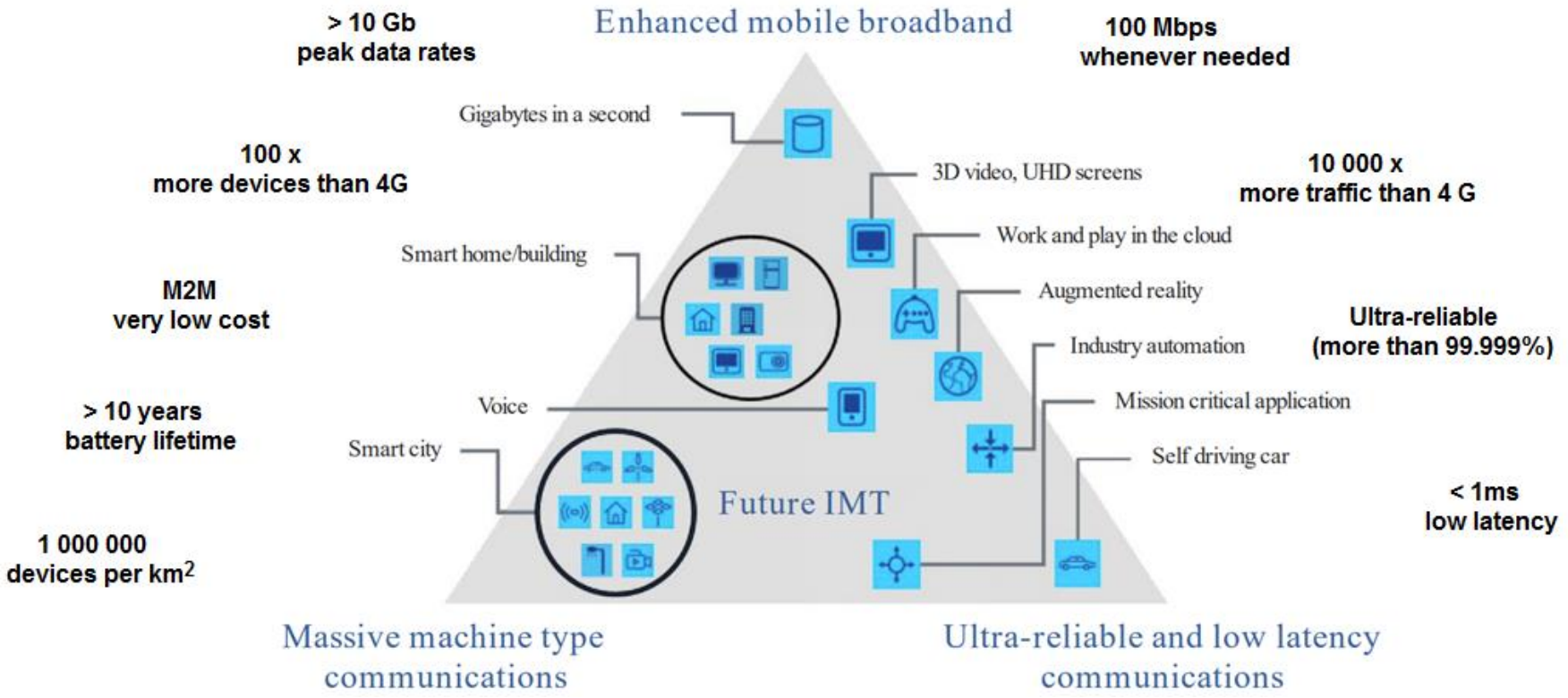
5G requirements

- **Peak Data Rate**: max rate per user under ideal conditions in Gbit/s
  - 10 Gbps for mobiles, 20 Gbps under certain conditions.
- **User Experienced Data Rate**: rate across the coverage area per user
  - 100 Mbps in urban/suburban areas, 1 Gbps hotspot.
- **Spectrum Efficiency**: throughput per Hz per cell
- **Mobility**: max speed at which seamless handover and QoS is guaranteed
- **Latency**: radio contribution to latency between send and receive
- **Connection Density**: total number of devices per km^2
- **Network Energy Efficiency**: bits/Joule
  - on the network side: quantity of information bits transmitted to/ received from users
  - on the device side: quantity of information bits per unit of energy consumption of the communication module
- **Area Traffic Capacity**: total throughput per m^2



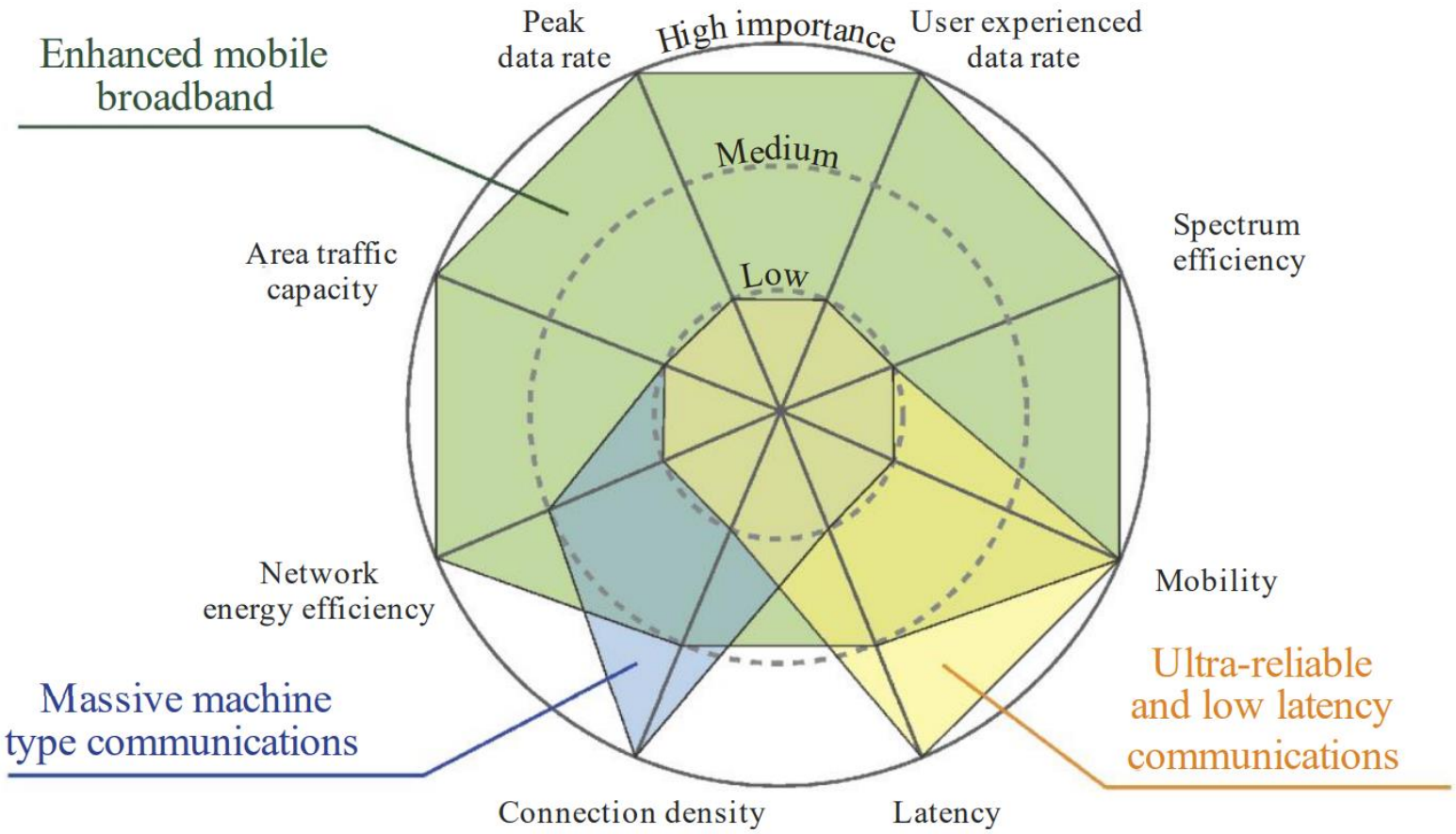
ITU-R Recommendation M.2083-0, "IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond," Sep. 2015

5G requirements - usage scenarios



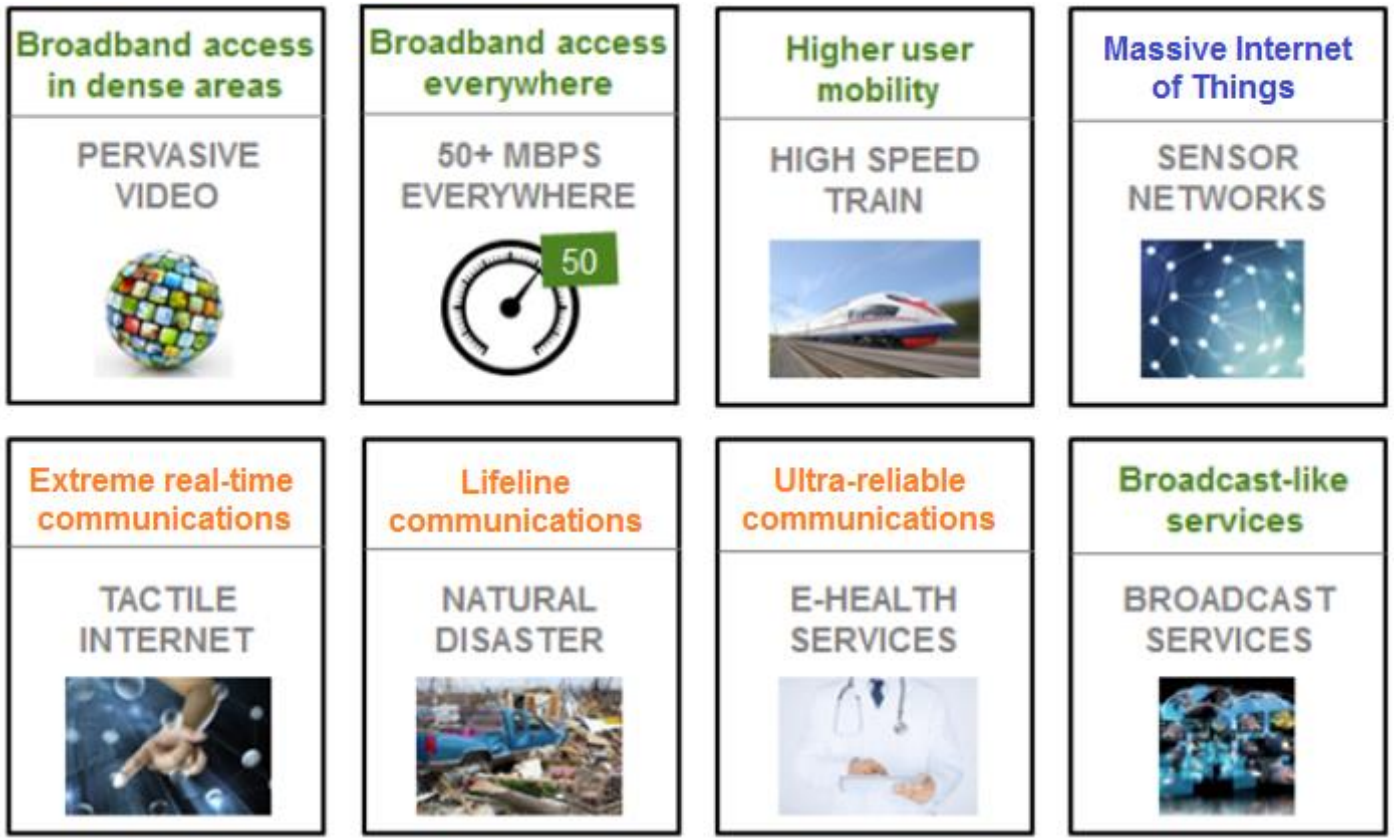
ITU-R Recommendation M.2083-0, "IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond," Sep. 2015

5G use cases



ITU-R Recommendation M.2083-0, "IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond," Sep. 2015

5G use cases example - NGMN



NGMN 5G White Paper, March 2015

Broadband Access in Dense Areas

- Focused on service availability in densely-populated areas where thousands of people per km^2 live and/or work
- Augmented reality, multi-user interaction, three-dimensional (3D) services, etc.
- Context recognition at the network edge to ensure delivery of consistent and personalized services to the customers

Zahid Ghadialy, 5G: An Advanced Introduction, 2018

https://ofis.bluepowertechnology.com/

Broadband Access Everywhere

- A consistent user experience with respect to throughput needs a minimum data rate guaranteed everywhere
- Further development of digital inclusion of people living in scarcely populated areas and in developing countries requires the infrastructure deployment cost to be a key factor in services

Zahid Ghadialy, 5G: An Advanced Introduction, 2018

Higher User Mobility

- A growing demand for mobile services in vehicles, trains and even aircrafts
- Requires enhanced connectivity for in-vehicle entertainment, accessing the Internet, enhanced navigation through instant and real-time information, autonomous driving, safety and vehicle diagnostics

https://ingenuity.siemens.com/2020/12/secure-remote-access-via-public-5g-network/

https://news.samsung.com/global/kddi-and-samsung-complete-first-successful-demonstration-of-5g-on-a-train-moving-at-100kmhour

https://www.capacitymedia.com/articles/3830566/at-and-t-and-verizon-5g-takes-flight-as-aviation-sector-grinds-to-a-halt

Massive Internet of Things

- Use cases with massive number of devices (e.g., sensors, actuators and cameras) with a wide range of characteristics and demands
- Includes both low-cost/long-range/low-power machine-type communication (MTC) as well as broadband MTC with some characteristics closer to human-type communication (HTC)

https://www.analyticsinsight.net/is-smart-clothing-the-future-of-fashion/

https://www.smartcitiesworld.net/news/news/outdoor-surveillance-cameras-to-be-biggest-iot-5g-sector-until-2023--4712

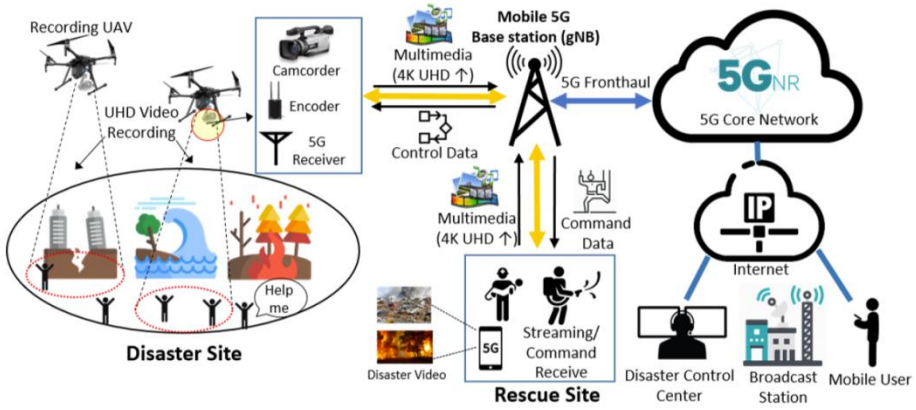
Extreme Real-Time Communications

- Use cases which have a strong demand in terms of real-time interaction
- May require one or more attributes such as extremely high throughput, mobility, critical reliability, etc.
- Tactile Internet: requires a tactile control signal and audio and/or visual feedback

https://5g.co.uk/guides/what-is-the-tactile-internet/

Lifeline Communication

- Use cases include emerging and new applications for authority-to-authority communication, emergency prediction and disaster relief
- Requires a very high level of availability in addition to the ability to support traffic surges



W. Na et al.: DL-TCP: Deep Learning-Based Transmission Control Protocol for Disaster 5G mmWave Networks, IEEE Access, 2019

Ultra-reliable Communications

- Includes automotive, health and assisted living applications, as well as applications for industries from manufacturing to agriculture which rely on reliable MTC
- Requires extreme low latency

https://www.nextpit.com/how-5g-will-change-mobility

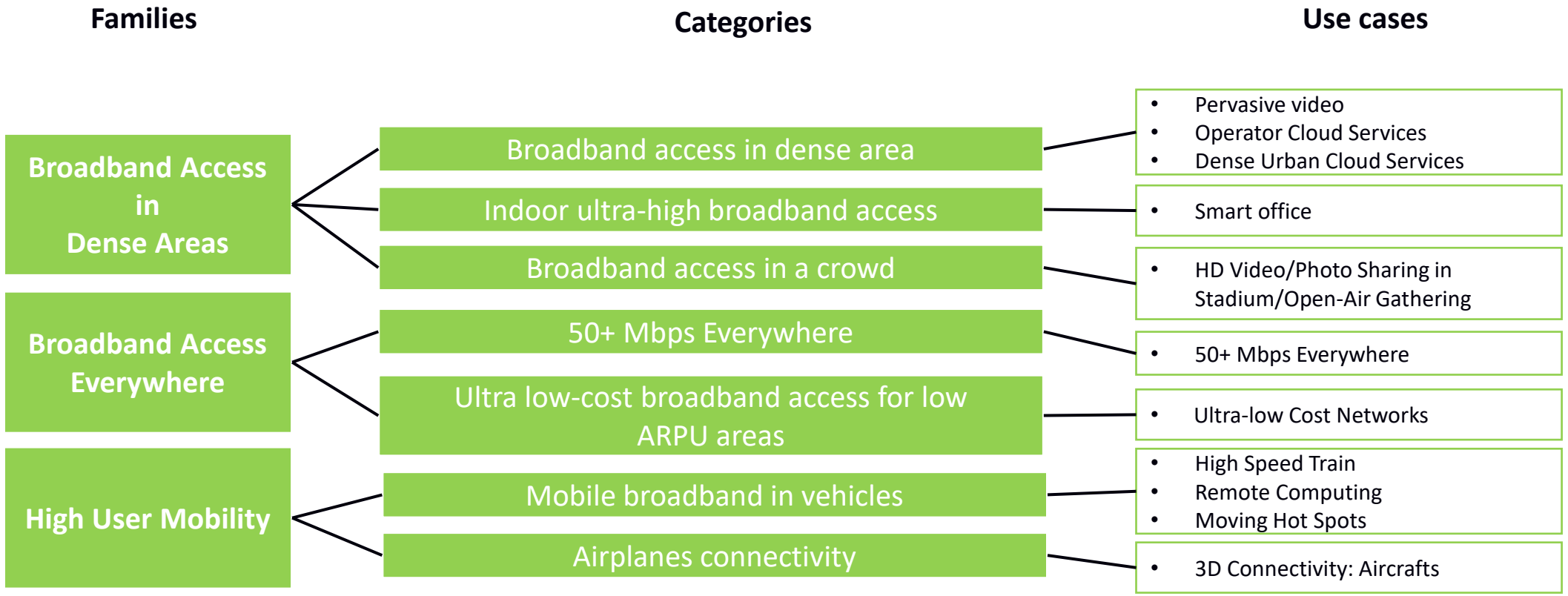
https://www.diagnosio.com/blog/general/technology-and-you-how-tech-can-help-with-improving-your-health/

Broadcast-like Services

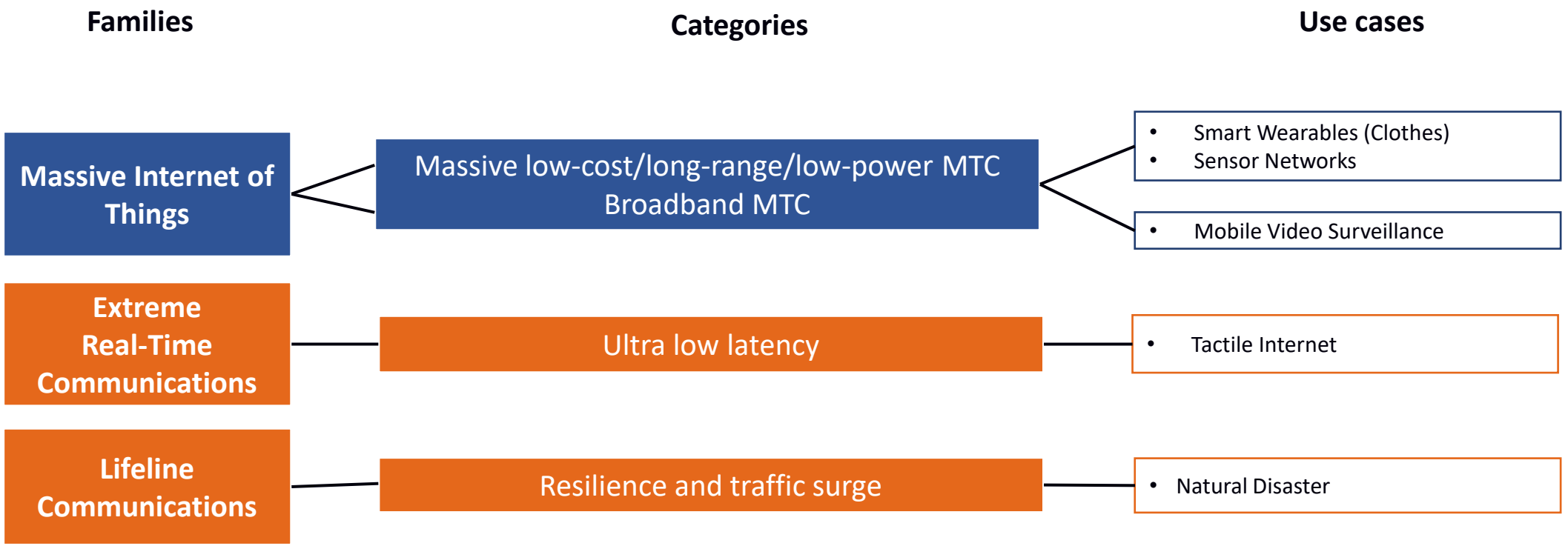
- Efficient distribution of information from one source to many destinations
- May have a feedback channel (uplink) for interactive services or acknowledgement information
- Includes both real-time and non-real time services

Zahid Ghadialy, 5G: An Advanced Introduction, 2018

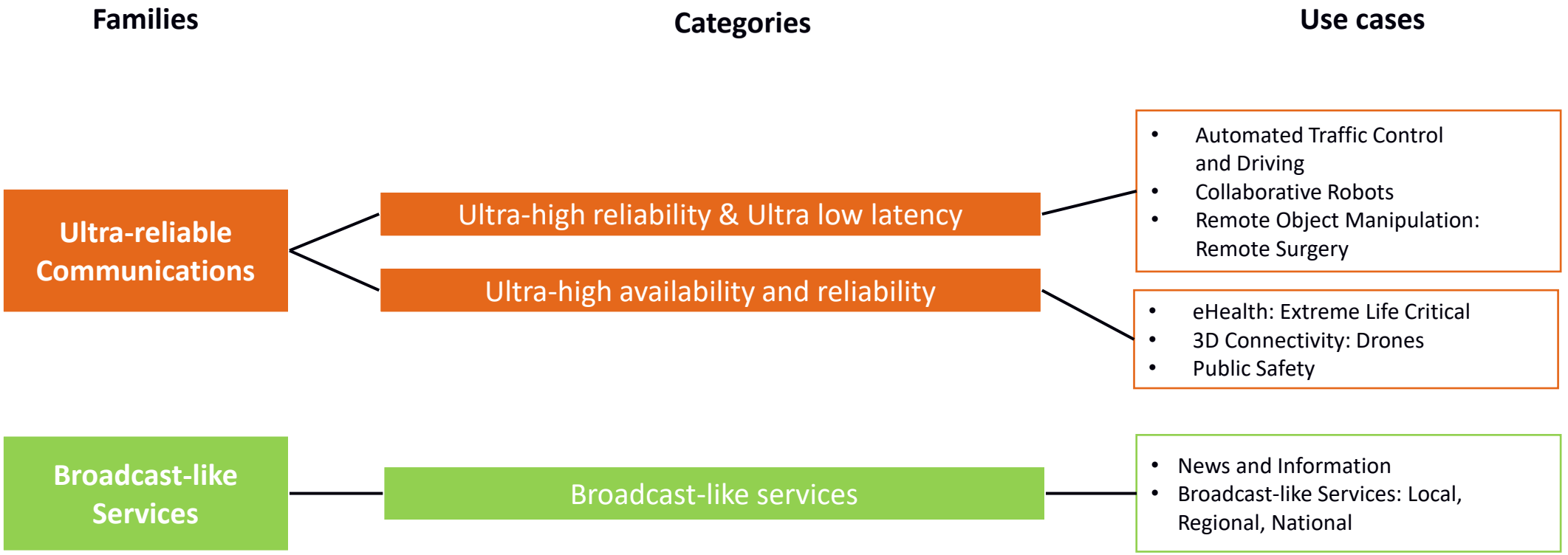
NGMN use cases



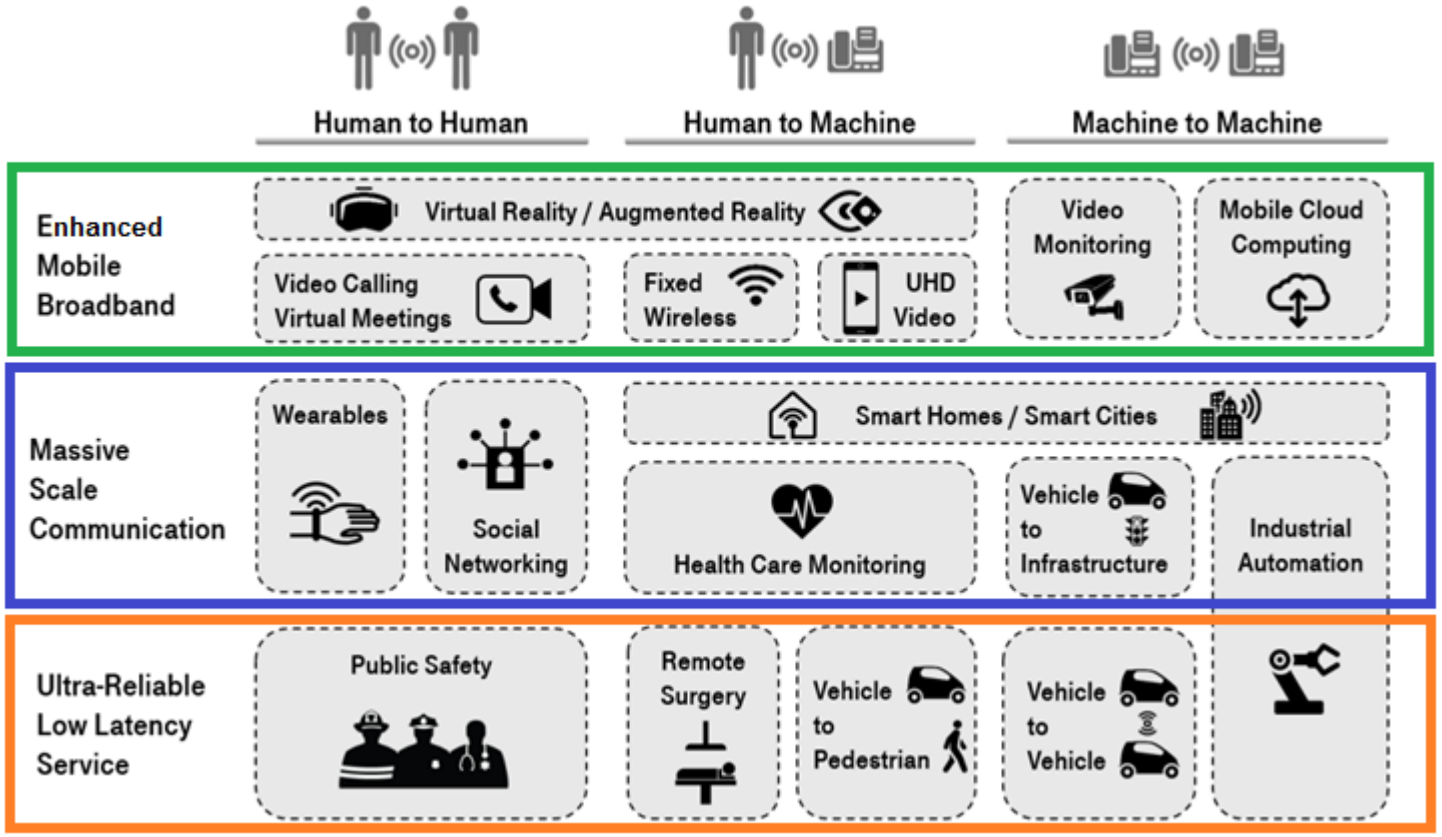
NGMN use cases



NGMN use cases



5G use cases - summary



5G Americas Whitepaper - 5G Services and Use Cases, November 2017

eMBB:
- 20/10 Gbps DL/UL*
- 4 ms user plane latency
- 500 km/h mobility

mMTC:
- 1 million devices / km^2
- 10+ years battery lifetime
- 20 dB coverage enhancement

URLLC:
- 1 ms user plane latency
- High secure/resilient
- 99.999% availability

*Peak theoretical rate

User experience requirements

Use case category	User Experienced Data Rate	E2E Latency	Mobility
Broadband access in dense areas	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 0-100 km/h
Indoor ultra-high broadband access	DL: 1 Gbps, UL: 500 Mbps	10 ms	Pedestrian
Broadband access in a crowd	DL: 25 Mbps UL: 50 Mbps	10 ms	Pedestrian
50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mbps	10 ms	0-120 km/h
Ultra-low cost broadband access f low ARPU areas			n demand: 0- 0 km/h
Mobile broadband i vehicles (cars, train			)n demand, up 500 km/h
Airplanes connectiv			lp to 1000 m/h
Massive low-cost/long-range/low power MTC			n demand: 0- 00 km/h
Broadband MTC			and 50+Mbps
Ultra-low latency			'edestrian
Resilience and traff surge			-120 km/h
Ultra-high reliability Ultra-low latency			n demand: 0- 00 km/h
Ultra-high availabili & reliability	UL: 10 Mbps		)n demand, 0- 500 km/h
Broadcast like services	DL: Up to 200 Mbps UL: Modest (e.g. 500 kbps)	<100 ms	on demand: 0-500 km/h

NGMN 5G White Paper, March 2015

Use case category	User Experienced Data Rate	E2E Latency	Mobility
Broadband access in dense areas	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 0-100 km/h
Indoor ultra-high broadband access	DL: 1 Gbps, UL: 500 Mbps	10 ms	Pedestrian
Broadband access in a crowd	DL: 25 Mbps UL: 50 Mbps	10 ms	Pedestrian
50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mbps	10 ms	0-120 km/h
Ultra-low cost broadband access for low ARPU areas	DL: 10 Mbps UL: 10 Mbps	50 ms	on demand: 0-50 km/h
Mobile broadband in vehicles (cars, trains)	DL: 50 Mbps UL: 25 Mbps	10 ms	On demand, up to 500 km/h
Airplanes connectivity	DL: 15 Mbps per user UL: 7.5 Mbps per user	10 ms	Up to 1000 km/h
Massive low-cost/long-range/low-power MTC	Low (typically 1-100 kbps)	Seconds to hours	on demand: 0-500 km/h
Broadband MTC	See the requirements for the Broadband access in dense areas and 50+Mbps everywhere categories		
Ultra-low latency	DL: 50 Mbps UL: 25 Mbps	<1 ms	Pedestrian
Resilience and traffic surge	DL: 0.1-1 Mbps UL: 0.1-1 Mbps	Regular communication: not critical	0-120 km/h
Ultra-high reliability & Ultra-low latency	DL: From 50 kbps to 10 Mbps; UL: From a few bps to 10 Mbps	1 ms	on demand: 0-500 km/h
Ultra-high availability & reliability	DL: 10 Mbps UL: 10 Mbps	10 ms	On demand, 0-500 km/h
Broadcast like services	DL: Up to 200 Mbps UL: Modest (e.g. 500 kbps)	<100 ms	on demand: 0-500 km/h

System

Use case category	Connection Density	Traffic Density
Broadband access in dense areas	200-2500 /km^2	DL: 750 Gbps / km2 UL: 125 Gbps / km2
Indoor ultra-high broadband access	75,000 / km^2 (75/1000 m^2 office)	DL: 15 Tbps/ km2 (15 Gbps / 1000 m2) UL: 2 Tbps / km2 (2 Gbps / 1000 m2)
Broadband access in a crowd	150,000 / km^2 (30.000 / stadium)	DL: 3.75 Tbps / km2 (DL: 0.75 Tbps / stadium) UL: 7.5 Tbps / km2
50+ Mbps everyw		stadium) ps / km2 in
Ultra-low cost br ARPU areas		s / km2 in s / km2 in rural ps / km2 in rural m^2
Mobile broadban		ps / km^2 er train, 50 Mbps ps / km^2 per train, 25 Mbps
Airplanes conne		ps / plane ps / plane
Massive low-cos MTC		
Broadband MTC		ess in dense areas
Ultra-low latency		high
Resilience and tr		high
Ultra-high reliabi		high
Ultra-high availability & reliability	Not critical	Potentially high
Broadcast like services	Not relevant	Not relevant

Use case category	Connection Density	Traffic Density
Broadband access in dense areas	200-2500 /km^2	DL: 750 Gbps / km2 UL: 125 Gbps / km2
Indoor ultra-high broadband access	75,000 / km^2 (75/1000 m^2 office)	DL: 15 Tbps/ km2 (15 Gbps / 1000 m2) UL: 2 Tbps / km2 (2 Gbps / 1000 m2)
Broadband access in a crowd	150,000 / km^2 (30.000 / stadium)	DL: 3.75 Tbps / km2 (DL: 0.75 Tbps / stadium) UL: 7.5 Tbps / km2 (1.5 Tbps / stadium)
50+ Mbps everywhere	400 / km^2 in suburban 100 / km^2 in rural	DL: 20 Gbps / km2 in suburban UL: 10 Gbps / km2 in suburban DL: 5 Gbps / km2 in rural UL: 2.5 Gbps / km2 in rural
Ultra-low cost broadband access for low ARPU areas	16 / km^2	16 Mbps / km^2
Mobile broadband in vehicles (cars, trains)	2000 / km^2 (500 active users per train x 4 trains, or 1 active user per car x 2000 cars)	DL: 100 Gbps / km^2 (25 Gbps per train, 50 Mbps per car) UL: 50 Gbps / km^2 (12.5 Gbps per train, 25 Mbps per car)
Airplanes connectivity	80 per plane 60 airplanes per 18,000 km^2	DL: 1.2 Gbps / plane UL: 600 Mbps / plane
Massive low-cost/long-range/low-power MTC	Up to 200,000 / km^2	Non critical
Broadband MTC	See the requirements for the Broadband access in dense areas and 50+Mbps everywhere categories	
Ultra-low latency	Not critical	Potentially high
Resilience and traffic surge	10,000 / km^2	Potentially high
Ultra-high reliability & Ultra-low latency	Not critical	Potentially high
Ultra-high availability & reliability	Not critical	Potentially high
Broadcast like services	Not relevant	Not relevant

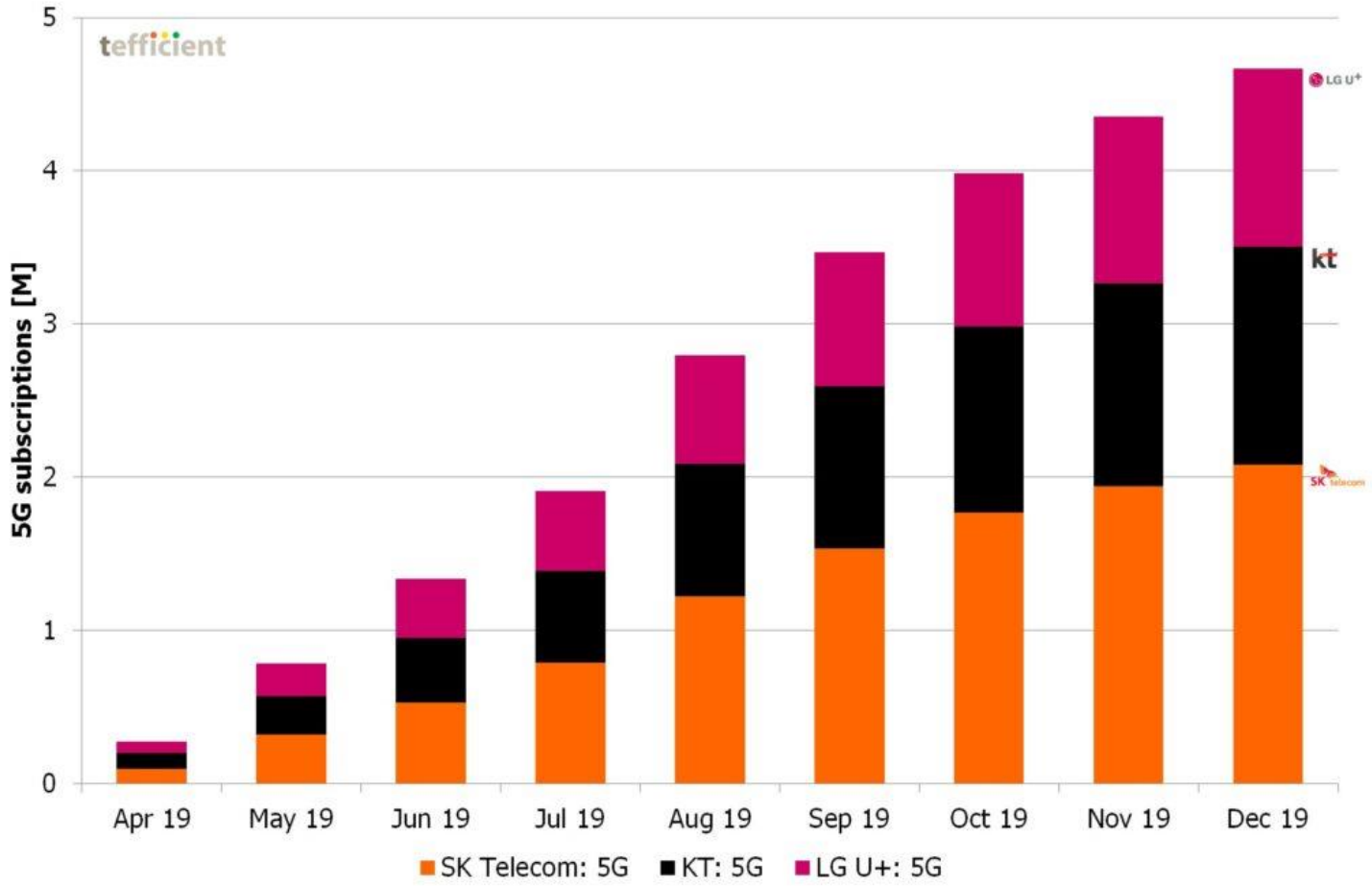
NGMN 5G White Paper, March 2015

5G launches: South Korea

https://www.voanews.com/a/south-korea-to-launch-world-s-first-national-5g-networks-/4860846.html

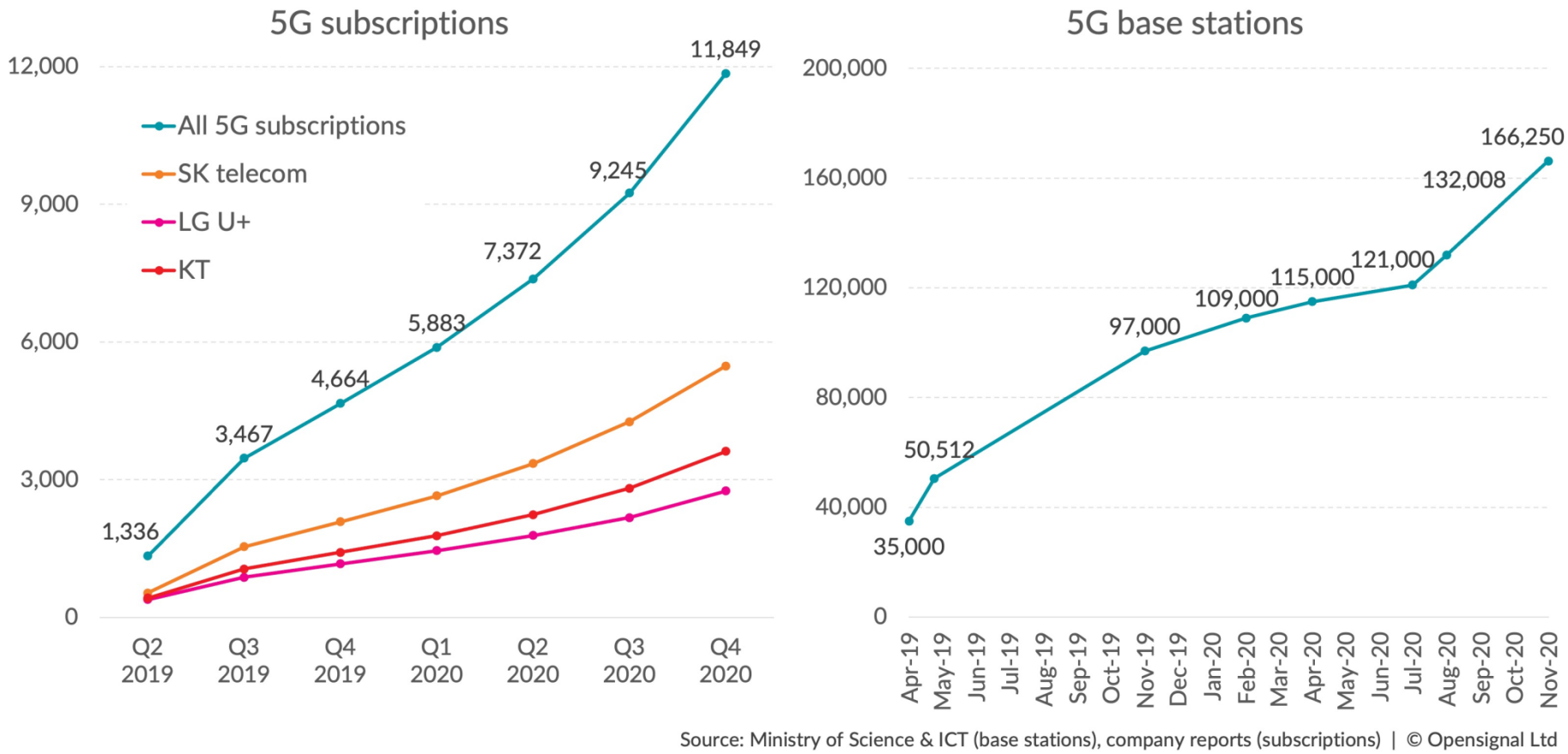
- First nation in Asia that launched 5G network at midnight on **December 1st, 2018**
- 3 operators: SK Telecom, KT and LG UPlus
- The South Korean government mandated the operators to collaborate on 5G deployments by sharing core fiber infrastructure

South Korea: December 1st, 2019



https://tefficient.com/nine-months-with-5g-4-7-million-subs-each-using-27-gb-per-month/

South Korea: December 1st, 2020



Source: Ministry of Science & ICT (base stations), company reports (subscriptions) | © Opensignal Ltd

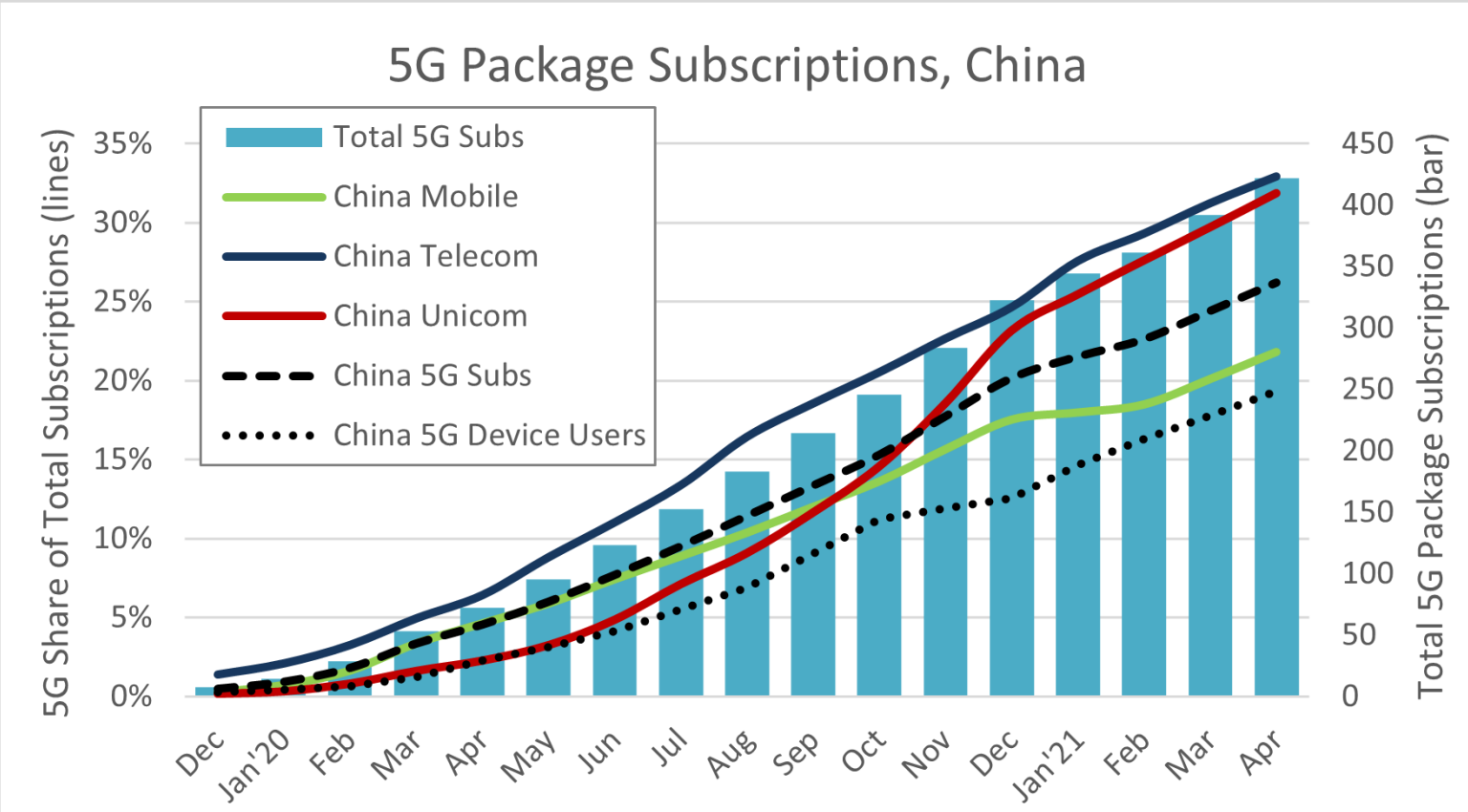
https://www.opensignal.com/2021/02/25/understanding-where-and-when-users-can-experience-5g-in-south-korea

5G launches: China

https://www.bbc.com/news/business-50258287

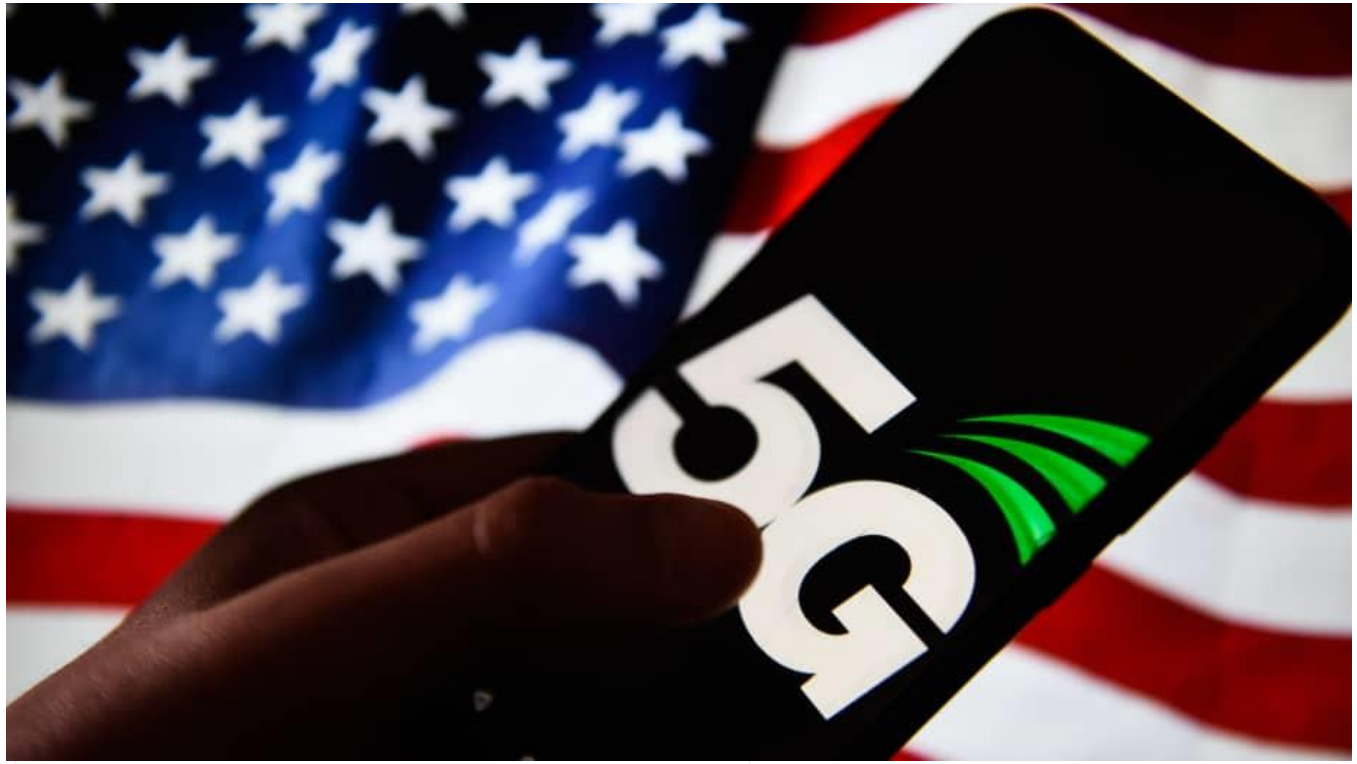
- China launched world's largest 5G network on **November 1st, 2019**
- 3 operators: China Mobile, China Telecom, and China Unicom
- The initial 5G services were available in about 50 Chinese cities
- Nearly 12,000 5G base stations have been activated in Shanghai

China: April 2021



Source: Operators, MIIT, Strategy Analytics

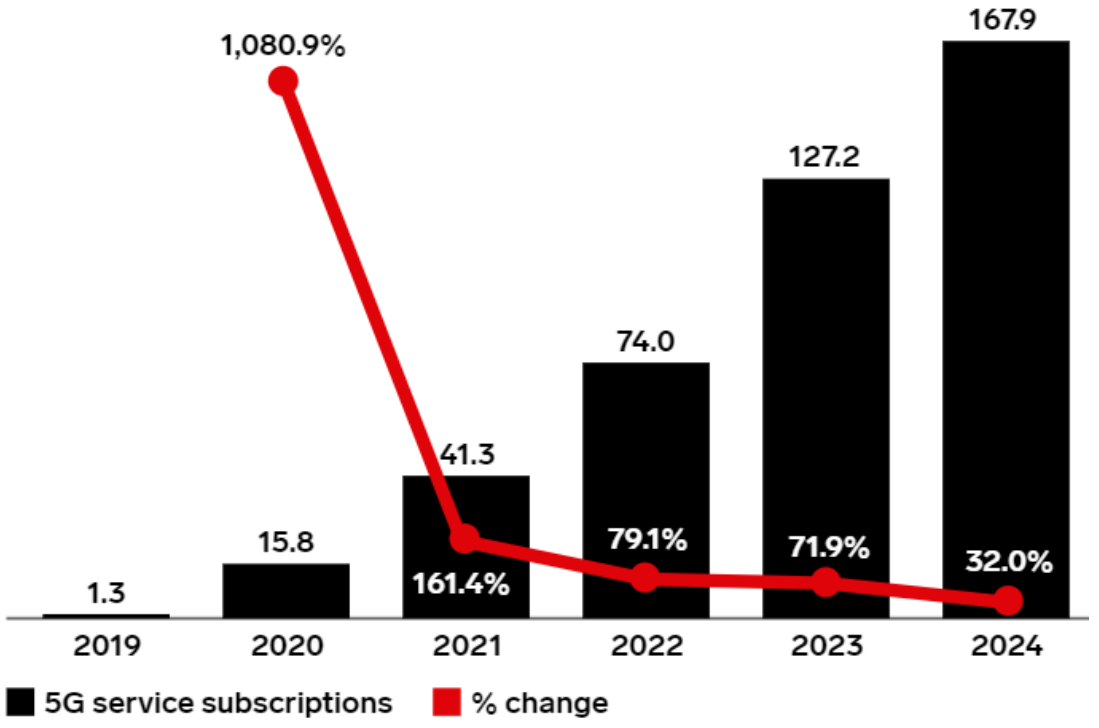
5G launches: US



https://www.cnbc.com/2020/03/20/why-the-coronavirus-pandemic-may-fast-forward-5g-adoption-in-the-us.html

- Verizon first "turned on" its 5G wireless service in Chicago and Minneapolis on **April 3rd, 2019**
- T-Mobile lit up the country's first nationwide 5G network, covering more than 200 million people and more than 5,000 cities and towns all across the country on **December 2nd, 2019**
- First in the world to have a 5G-enabled smartphone connected to a 5G network

USA: October 2020



Note: an active prepaid or postpaid wireless service agreement with a wireless carrier for a 5G-capable mobile device that connects to a wireless carrier's 5G network at least once per month
Source: eMarketer, Oct 2020

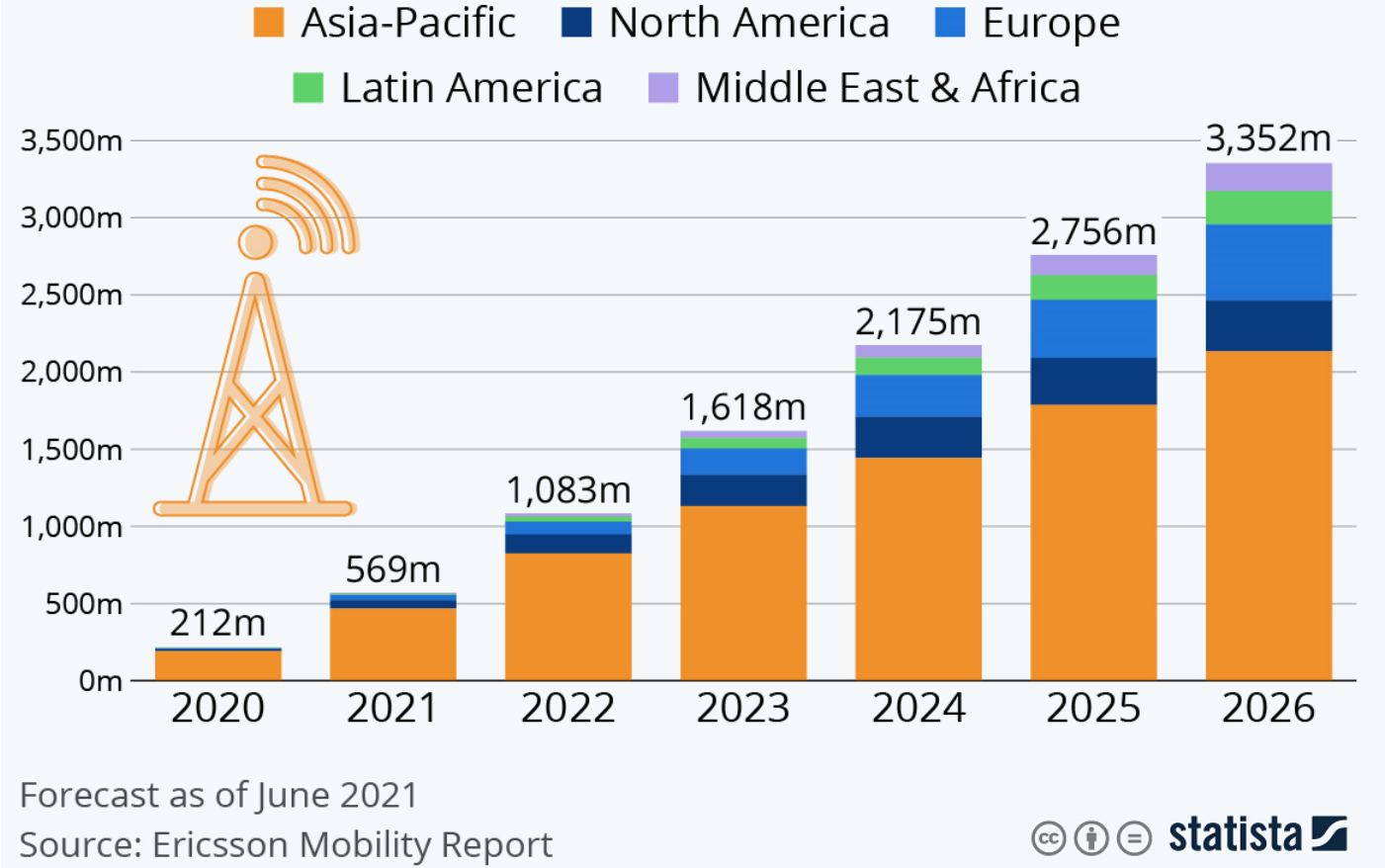
https://www.emarketer.com/chart/244032/us-5g-service-subscriptions-2019-2024-millions-change

5G launches: Croatia

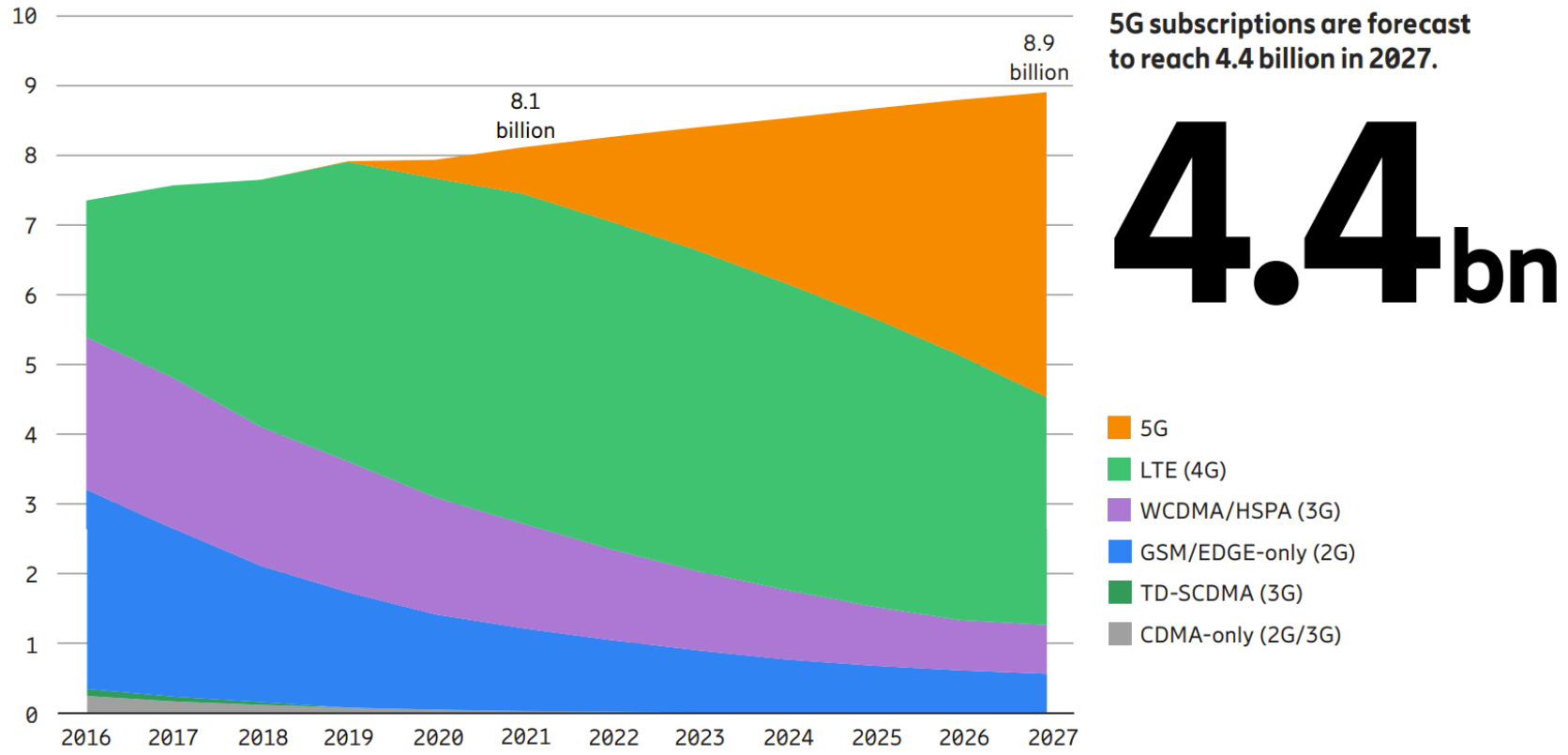
https://www.fer.unizg.hr/intranet/studenti/obavijesti?@=2t29u

- Hrvatski Telekom (HT) lit up the country's first nationwide 5G network in Zagreb, Rijeka, Split, Osijek, Samobor and Sveta Nedelja on **October 29th, 2020**
- HT and FER launched the **first 5G Campus network** in Croatia on **December 16th, 2020**
- HAKOM made decisions on the allocation of radio frequency bands, after a public auction, on **August 12th, 2021**
- After the auction, A1 Croatia, HT and Telemach Croatia started providing commercial services via the 5G network

Worldwide: 5G mobile subscriptions - forecast

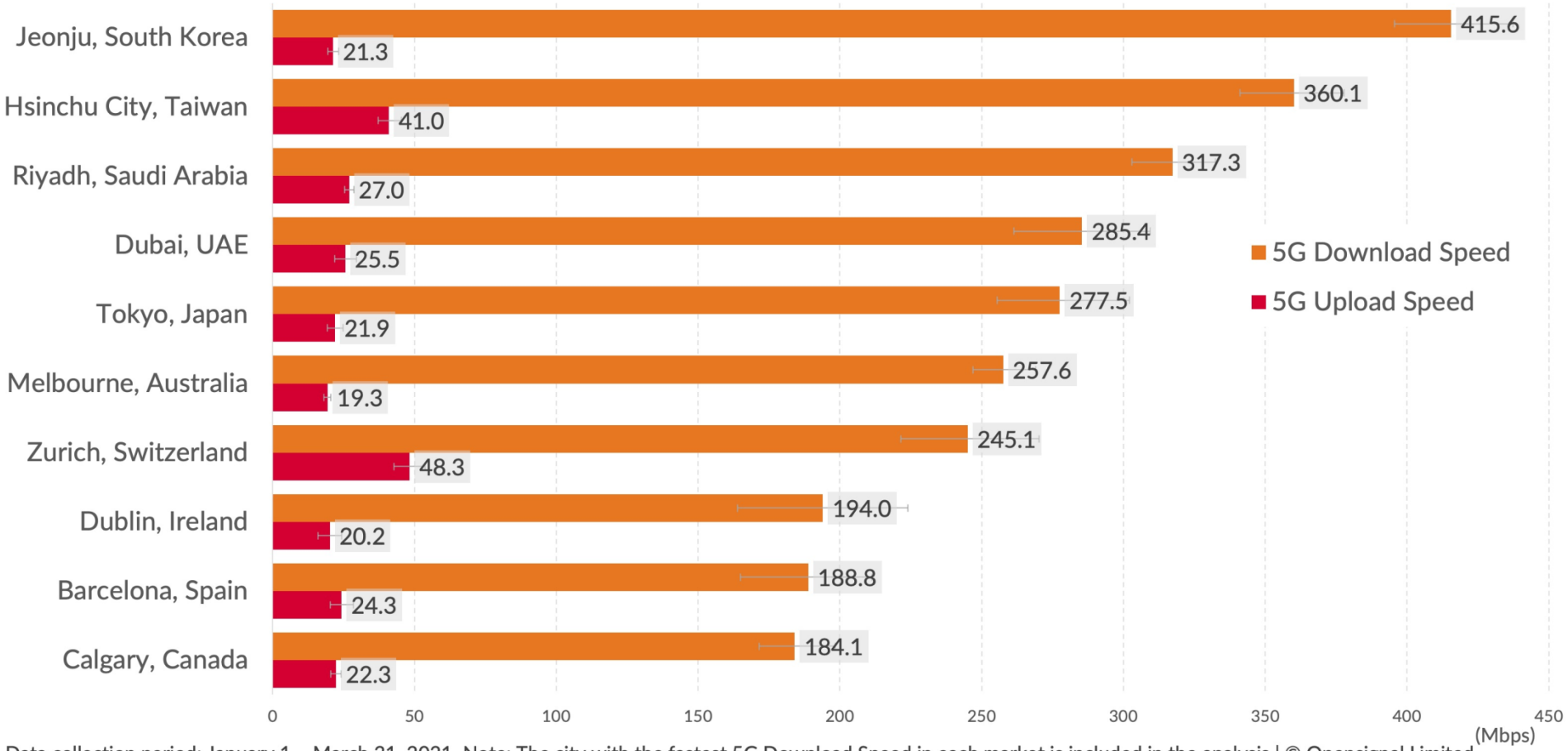


Worldwide: 5G mobile subscriptions - forecast



https://www.ericsson.com/4ad7e9/assets/local/reports-papers/mobility-report/documents/2021/ericsson-mobility-report-november-2021.pdf

Worldwide: 5G top 10 cities



Data collection period: January 1 – March 31, 2021. Note: The city with the fastest 5G Download Speed in each market is included in the analysis | © Opensignal Limited

https://www.opensignal.com/2021/04/15/benchmarking-the-global-5g-experience-april-2021

Worldwide: 5G revenue

Segment	2020 Revenue	2021 Revenue	2022 Revenue
5G	13,768.0	19,128.9	23,254.6
LTE and 4G	17,127.8	14,569.1	12,114.0
3G and 2G	3,159.6	1,948.2	1,095.2
Small Cells Non-5G	6,588.5	7,117.9	7,113.9
Mobile Core	5,714.6	6,056.2	6,273.3
Total	**46,358.5**	**48,820.2**	**49,851.0**

https://www.gartner.com/en/newsroom/press-releases/2021-08-04-gartner-forecasts-worldwide-5g-network-infrastrucutre-revenue-to-grow-39pc-in-2021