
ایرانسل
MTN
5G
5G PHY Techniques
5G Air Interface
5G Novel RRC-State Machine
5G Spectrum
www.5GRC.ir

مقدمه ای بر

شبکه های مخابرات سیار نسل پنجم

و آخرین پیشرفت های آن در جهان

سید محمد رضوی زاده

دانشیار گروه مخابرات

دانشکده برق- دانشگاه علم و صنعت ایران

سرپرست مرکز تحقیقات نسل پنجم 5GRC و سرپرست آزمایشگاه تحقیقاتی شبکه های سیار باند وسیع MBNRG

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۱۳۹۸

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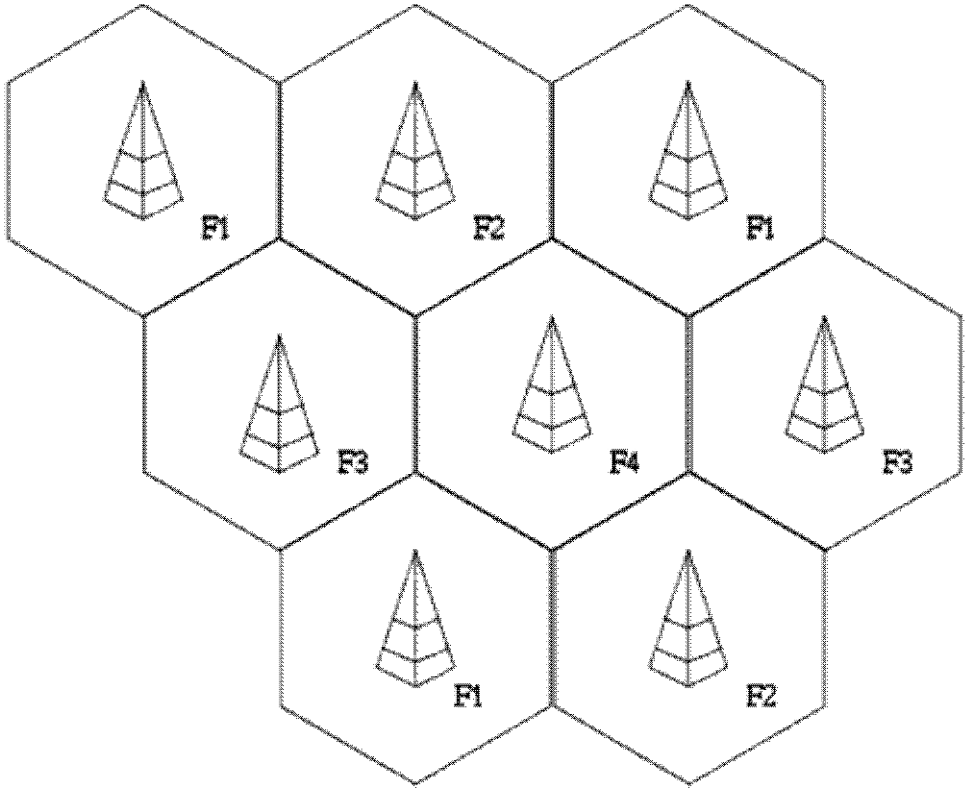
- تکامل نسل پنجم

مروری بر تکامل شبکه های سیار

و بررسی آخرین وضعیت فعلی

روزهای اولیه !

شبکه های سلولار و موبایل

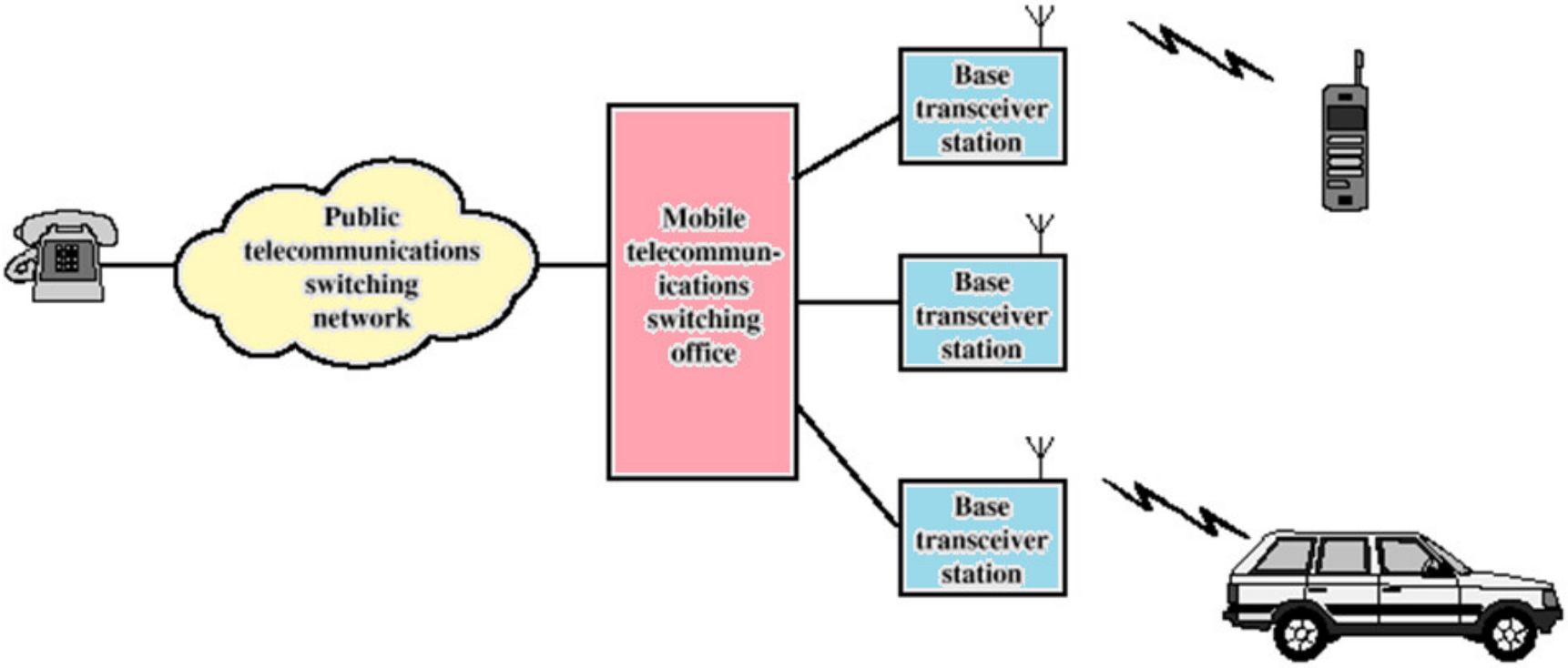


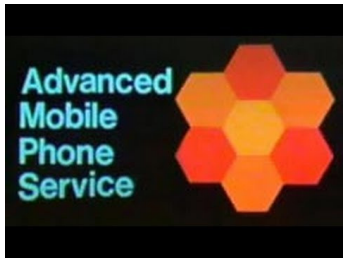
December 1947 by Douglas H. Ring and W. Rae Young
Bell Labs

April 3, 1973 Motorola DynaTAC

Article: The Mobile Phone: 46 Years Old and Going Strong

شبکه های سلولار و موبایل





نسل اول

- AMPS
- 1980 s
- Analog
- Voice
- FDMA
- FDD
- FM

- Macro Cells : 1-40 km radius
- 30 KHz
- 25 MHz in 800 MHz
- Frequency Reuse
- Handoff/Handover
- Adjustable Mobile Power levels

نسل اول

- اروپا
  - Nordic Mobile Telephony (NMT)
  - Total Access Communication System (TACS)
  - C450
  - C-Netz
  - Radiocom 2000
- ژاپن
  - NTT System - Nippon Telephone & Telegraph (NTT)

2G

نسل دوم

- 1990 s
- Digital
- Voice + low rate data
- FDMA/TDMA/CDMA
- Improve Security
- Increase System Capacity
- Reduce Cost
- Additional services and features (SMS, caller ID,..)

- Global System for Mobile Communication (GSM)
- Personal Digital Cellular (PDC)
- Digital AMPS (D-AMPS)
  - Interim Standard-54 (IS-54)
  - IS-136
- IS-95 or CDMA-one

GSM®

GLOBAL SYSTEM FOR
MOBILE COMMUNICATIONS

نسل دوم

- Based on TDMA/FDMA
- Each frequency carrier
  - 200 kHz
  - 8 voice channels
- Example Spectrum in Europe
  - Uplink (Mobile to BS): 890-915 MHz
  - Downlink (BS to Mobile): 935-960 MHz
- Modulation Scheme: GMSK
- Optional Frequency Hopping


CLR
MENU
OK
PRG
SAGEM
SAGEM RC 930 FM
C
Ok
SAGEM
RC 930
SAGEM
MC 922
C
Ok

تکامل نسل دوم

- **GPRS: General Packet Radio Service**
  - Data rates Up to 170 kbit/s
    - depending of number of Time slots allocated and coding scheme
  - Packet Switching
  - New Coding schemes
  - New Network elements

2.5 G

- **EDGE: Enhanced data rates for GSM evolution**
  - Data rates up to 300 kbit/s
  - New modulation: 8 PSK

2.75 G

3G

نسل سوم

- Better Performance in different multipath propagation
- Video Services
- Better voice quality
- Higher data rates
- Flexible assignment of spectrum
- Variable data rates

- Higher capacity
- Higher spectral efficiency
- Higher power efficiency
- Using current spectrum
- Worldwide agreed standard
- Worldwide roaming by design

ITU and 3G

- شروع فعالیت ITU پیرامون نسل سوم با پروژه IMT-2000
- ITU-R
- شروع فعالیت در ۱۹۹۲
- هدف گزاری برای سال ۲۰۰۰
- سرویسها
  - صوت با کیفیت بالا، پیام رسانی، مالتی مدیا، دسترسی به اینترنت
- تخصیص باندهای فرکانسی

International Mobile Telecommunications (IMT)

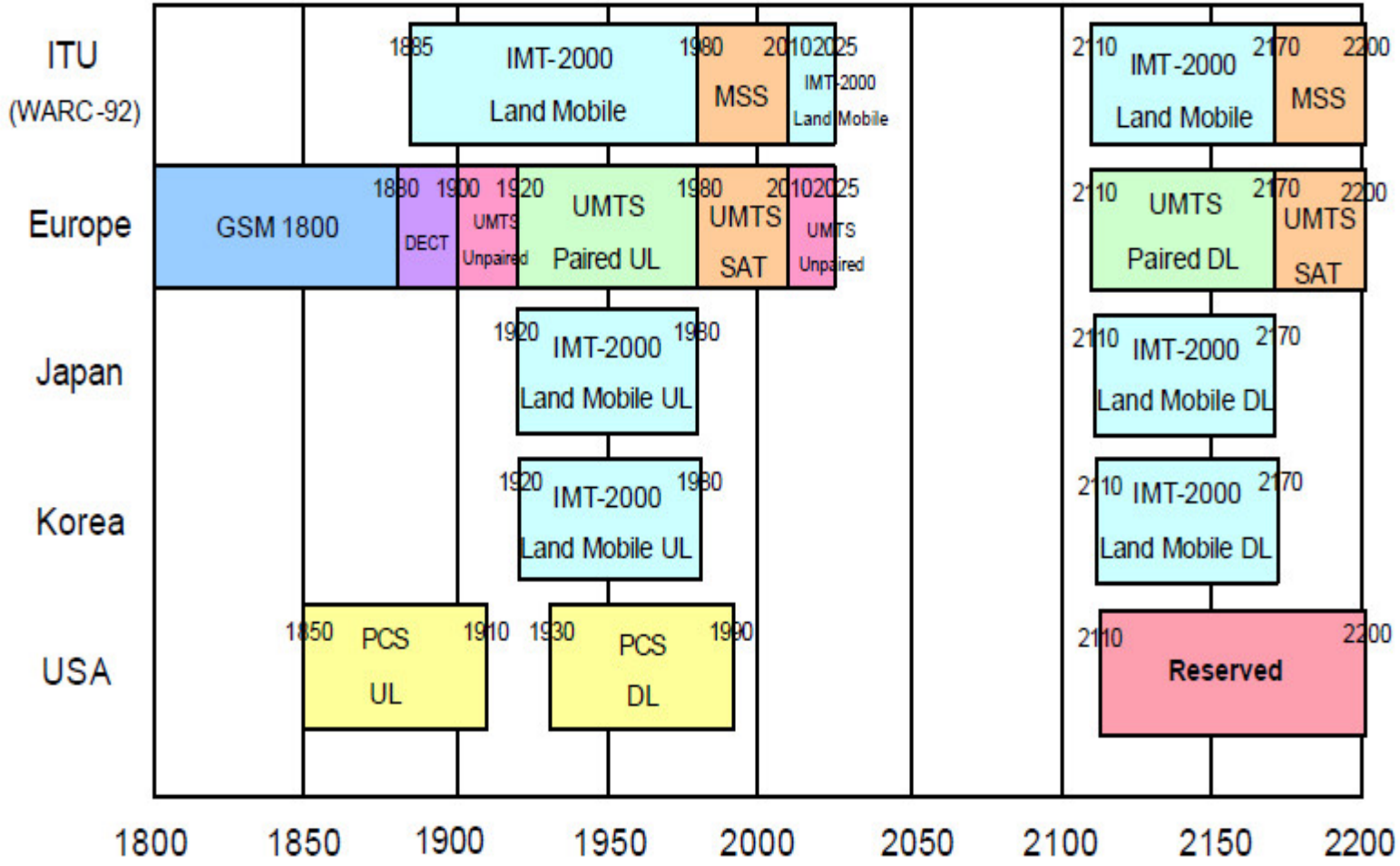
ITU and 3G

- **IMT-2000 objectives**
  - **High spectrum efficiency**
  - **High quality**
  - **Worldwide roaming capability**
  - **Capability for multimedia applications, and a wide range of services and terminals**

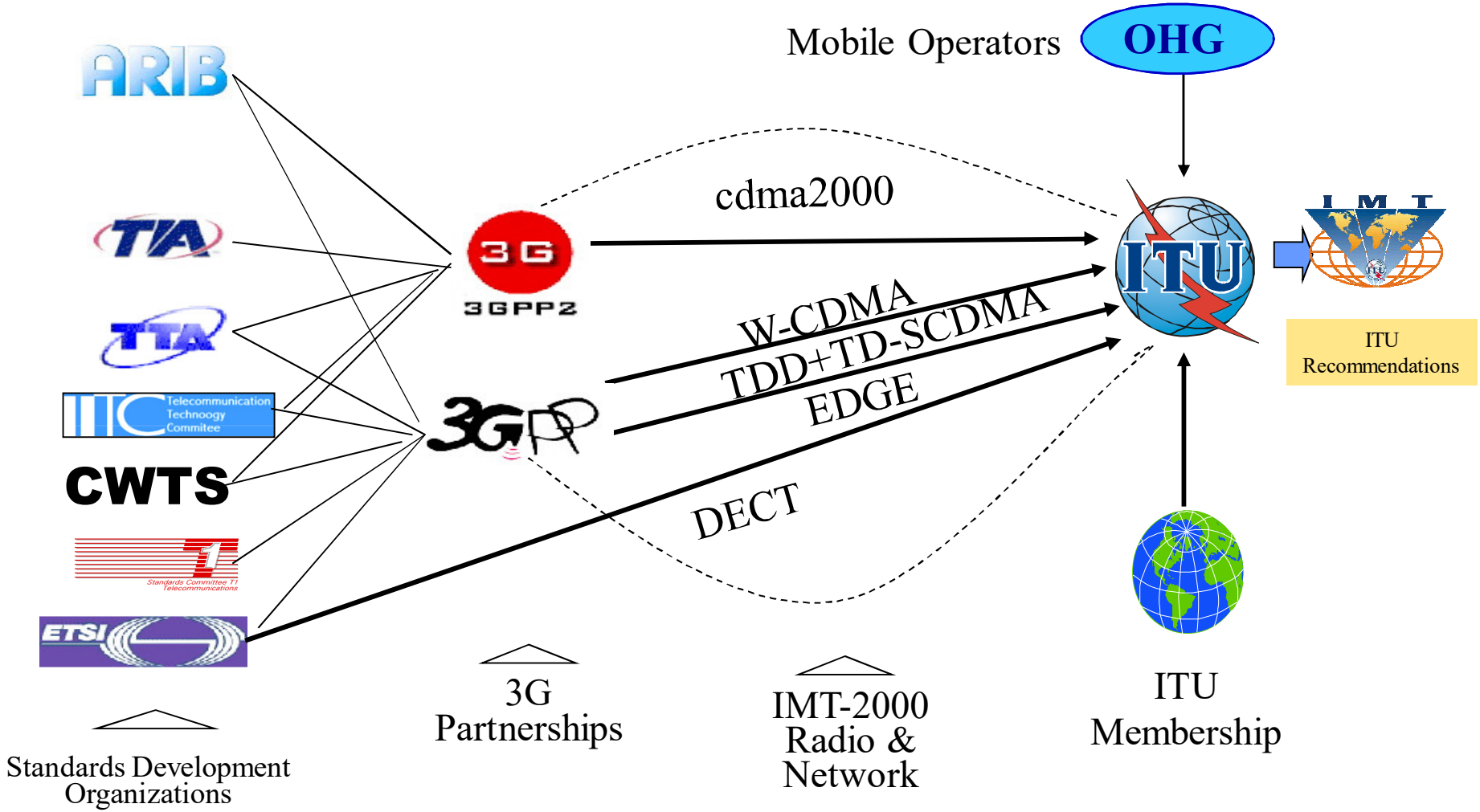
Recommendation ITU-R M.1457

- **IMT-2000 Data rates**
  - **Local area - 2 Mbps**
    - **In office, stationary**
  - **Limited mobility - 384 kbps**
    - **Urban pedestrian**
  - **Full mobility - 144 kbps**
    - **Rural in car**

IMT-2000 Spectrum



3G Standardization Process

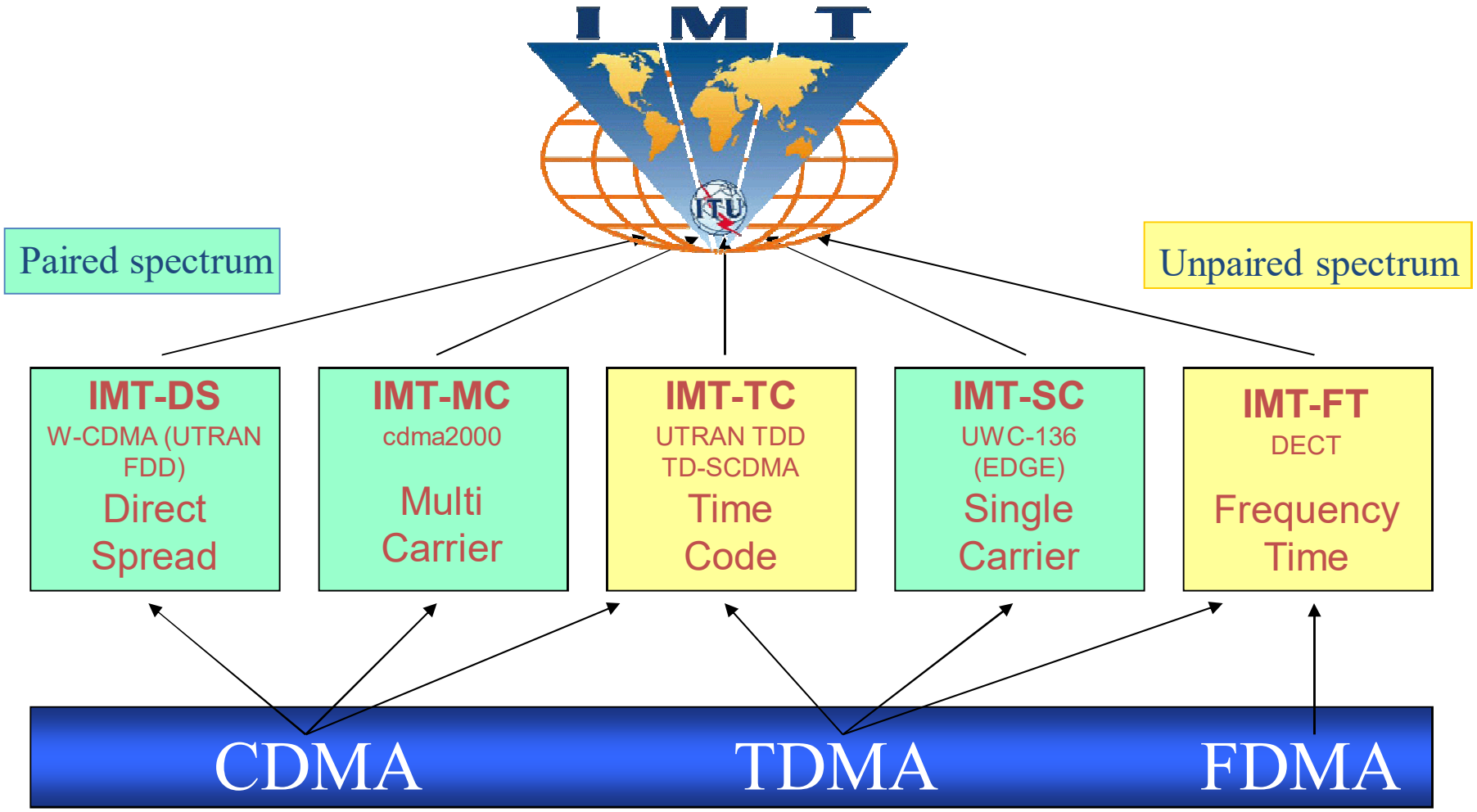


3GPP

- **3rd Generation Partnership Project**
- **Established in 1998**

3GPP Organizational Partners	
Organization	**Base region**
Association of Radio Industries and Businesses (ARIB)	Japan
Alliance for Telecommunications Industry Solutions (ATIS)	USA
China Communications Standards Association (CCSA)	China
European Telecommunications Standards Institute (ETSI)	Europe
Telecommunications Technology Association (TTA)	Korea
Telecommunication Technology Committee (TTC)	Japan
Telecommunications Standards Development Society India (TSDSI)	India

3G Standardization Process



3GPP Realeases

Rel. 99 2000 UMTS	**Rel. 4** 2001 TD-SDMA	**Rel. 5** 2002 HSDPA	**Rel. 6** 2004 HSUPA
Rel. 7 2007 HSPA Evolution	**Rel. 8** 2008 LTE EPC/SAE	**Rel. 9** 2009 LTE Home NB Location Services	**Rel. 10** 2011 LTE-Advanced
Rel. 11 2012 Enhanced CA	**Rel. 12** 2015	**Rel. 13** 2016	**Rel. 14** 2017

Rel. 99 (UMTS)

3G

Universal Mobile Telecommunication System

- Wideband CDMA
- Higher order modulations
- Variable spreading factors
- FDD - TDD
- Fast Power Control (1500 Hz)
  - in GSM 2Hz
- Rake Receiver
- Radio Resource Manag. for QoS
- Transmit Diversity
- Soft Handover

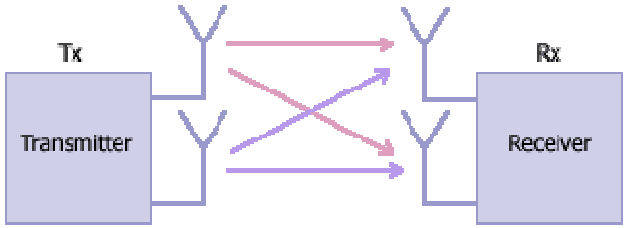
- سال ۲۰۰۰
- نرخ داده حداکثر تا 2Mbps
- پهنای باند 5MHz
- ارتباط ویدئویی
- تاخیر درراه اندازی

Rel. 5-6-7 (HSDPA)

- **Rel.5 در ۲۰۰۲ HSDPA**
  - **High Speed Downlink Packet Access**
  - افزایش نرخ بیت **DL** تا ۱۴ مگابیت بر ثانیه
- **Rel.6 در ۲۰۰۵ HSUPA**
  - **High Speed Uplink Packet Access**
  - افزایش نرخ بیت **UL** تا ۵ مگابیت بر ثانیه
- **Rel.7 در ۲۰۰۷ HSPA+**
  - **Evolved HSPA**
  - افزایش نرخ داده تا ۴۰ مگا بیت بر ثانیه

HSPA

- **AMC: Adaptive Modulation and Coding**
- **Higher order Modulation 64 QAM**
- **H-ARQ: Hybrid Automatic Repeat Request**
- **MIMO: Multiple Input Multiple Output**
- **Soft Handover**



- **DC-HSDPA: Dual Carrier-HSDPA** (rel. 8 for HSPA+)

Rel. 8 (LTE)

4G

- انتشار در سال ۲۰۰۸
- معرفی فناوری Long Term Evolution
- شروع مطالعات توسط 3GPP در Rel.7
  - امکان سنجی و تعیین مشخصات LTE
- تکمیل مشخصات و انتشار در Rel.8
- راه اندازی از ۲۰۱۰

First launch by TeliaSonera in Oslo and Stockholm on Dec. 14, 2009

- نسل جدید از شبکه های سیار
- نسل 3.9G

Rel. 8 (LTE)

4G

- استفاده از OFDM
  - OFDMA در DL
  - SC-FDMA در UL
- MIMO (تا 4x4)
- HARQ
- مدلاسیون های مرتبه بالاتر (تا 64QAM) و AMC
- پهنای باند وسیعتر (تا ۲۰ مگاهرتز)
- مدهای TDD و FDD

باندهای فرکانسی در LTE

LTE Bands	Uplink (MHz)	Downlink (MHz)	Duplex Spacing (MHz)	BW (MHz)	Duplex Mode	Deployment in the world
Band 1	1920 -1980	2110 -2170	190	60	FDD	China, Japan, EU, Asia, Australia
Band 2	1850 -1910	1930 -1990	80	60	FDD	North/South America
Band 3	1710 -1785	1805 -1880	95	75	FDD	EU, China, Asia, Australia, Africa
Band 4	1710 -1755	2110 -2155	400	45	FDD	North/South America
Band 5	824 -849	869 -894	45	25	FDD	North/South America, Australia, Asia, Africa
Band 6	830 -840	875 -885	45	10	FDD	Japan
Band 7	2500 -2570	2620 -2690	120	70	FDD	EU, South America, Asia, Africa, Australia
Band 8	880 -915	925 -960	45	35	FDD	EU, South America, Asia, Africa, Australia
Band 9	1749.9 -1784.9	1844.9 -1879.9	95	35	FDD	Japan
Band 10	1710 -1770	2110 -2170	400	60	FDD	North/South America
Band 11	1427.9 -1447.9	1475.9 -1495.9	48	35	FDD	Japan
Band 12	698 -716	728 -746	30	18	FDD	North America
Band 13	777 -787	746 -756	31	10	FDD	North America
Band 14	788 -798	758 -768	30	10	FDD	North America
Band 17	704 -716	734 -746	30	12	FDD	North America
Band 18	815 -830	860 -875	45	15	FDD	North/South America, Australia, Asia, Africa
Band 19	830 -845	875 -890	45	15	FDD	North/South America, Australia, Asia, Africa
Band 20	832 -862	791 -821	41	30	FDD	EU
Band 21	1447.9 -1462.9	1495.9 -1510.9	48	15	FDD	Japan
Band 22	3410 - 3500	3510 - 3600	100	90	FDD	
Band 24	1626.5 -1660.5	1525 -1559	101.5	34	FDD	
Band 33	1900 -1920		N/A	20	TDD	
Band 34	2010 -2025		N/A	15	TDD	China
Band 35	1850 -1910		N/A	60	TDD	
Band 36	1930 -1990		N/A	60	TDD	
Band 37	1910 -1930		N/A	20	TDD	
Band 38	2570 -2620		N/A	50	TDD	EU
Band 39	1880 -1920		N/A	40	TDD	China
Band 40	2300 -2400		N/A	100	TDD	China, Asia
Band 41	2496 -2690		N/A	194	TDD	
Band 42	3400 -3600		N/A	200	TDD	
Band 43	3600 -3800		N/A	200	TDD	

4G and IMT-Advanced

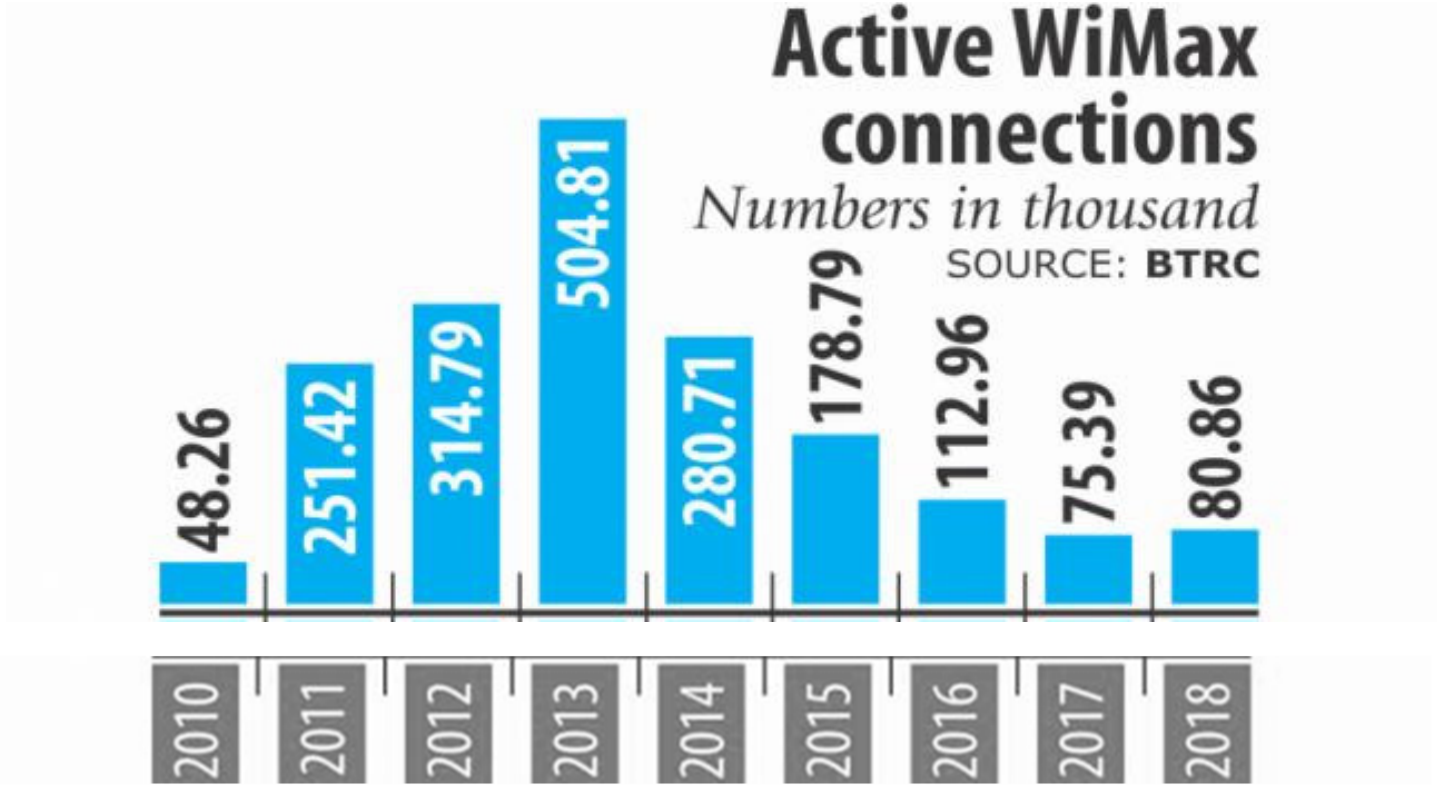
- تعریف مشخصات در **2008** توسط **ITU-R Working Party 5D**
- الزامات نسل بعد شبکه های سیار **4G**

- **1 Gbps** in relatively fixed positions
- Nominal data rate of **100 Mbps** at high speeds
- Peak link spectral efficiency of **15 bit/s/Hz** in the DL and 6.75 bit/s/Hz in the UL (1 Gbit/s over less than 67 MHz bandwidth)
- All-IP packet switched network
- Interoperability with existing wireless standards
- Dynamically share and use network resources to support more capacity
- Scalable channel bandwidth 5–20 MHz
- Seamless connectivity and global roaming

4G and IMT-Advanced

- In October 2010, two technologies were approved
- LTE Advanced
- WiMAX Release 2 (IEEE 802.16m)

مشترکان وایمکس



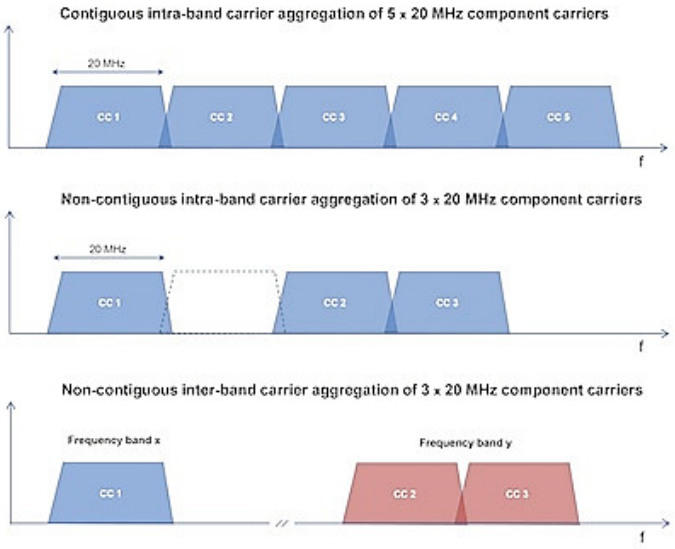
In 2015 Sprint Corporation began closing its WiMAX network

Rel.10 (LTE-A)

- انتشار در 2010
- شروع مطالعات در Rel.9 در ۲۰۰۹
- شروع راه اندازی از ۲۰۱۴
- تکامل مشخصات LTE
  - نرخ دیتا تا ۱ گیگابیت بر ثانیه
  - افزایش راندمان طیفی

		Rel. 8 LTE	LTE-Advanced
Peak data rate	DL	300 Mbps	1 Gbps
	UL	75 Mbps	500 Mbps
Peak spectrum efficiency [bps/Hz]	DL	15	30
	UL	3.75	15

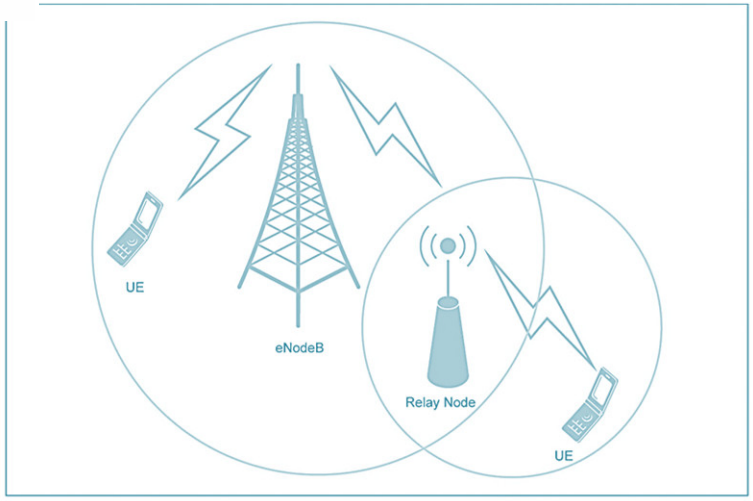
LTE-Advanced

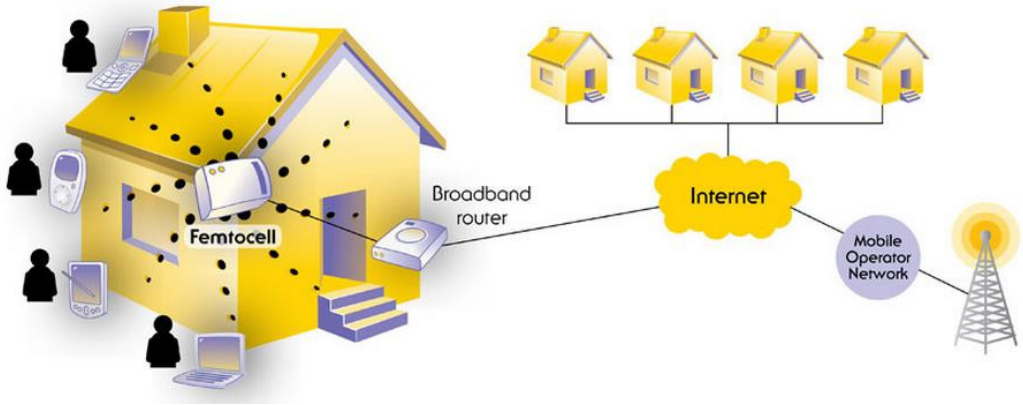


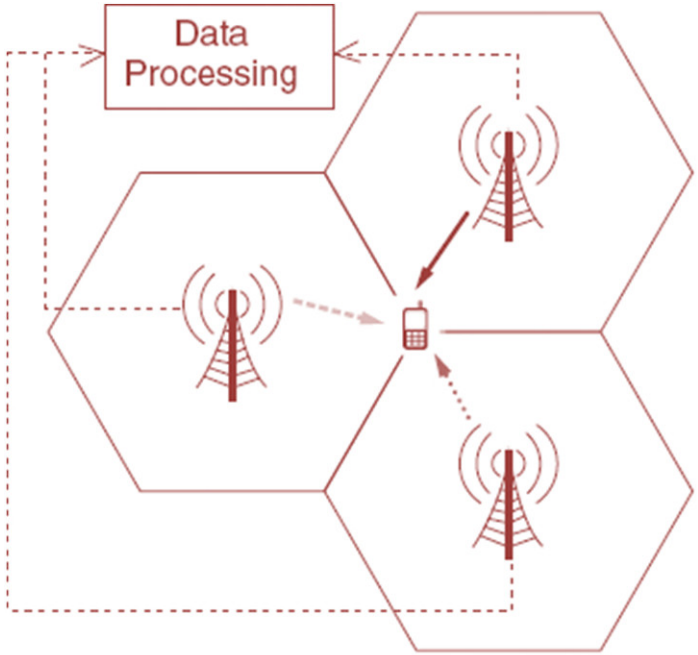
- **MIMO**
  - تا ۸ آنتن در DL
  - تا ۴ آنتن در UL
- **Carrier Aggregation**
- **Cognitive radio**
- **SONs, Self Organizing Networks methodologies**
- **Interference management and suppression**

LTE-Advanced

- Relay
- Femtocell
- CoMP



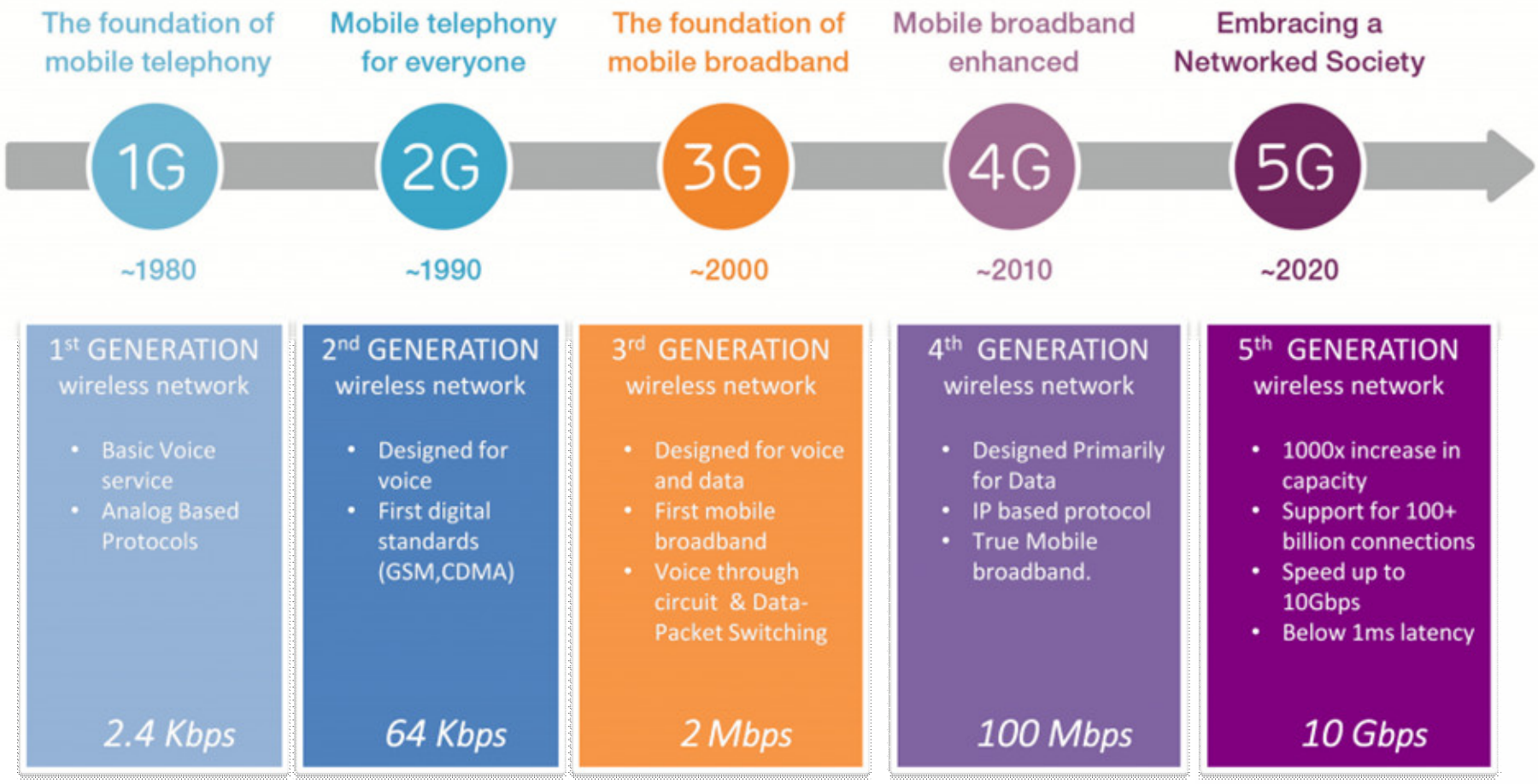




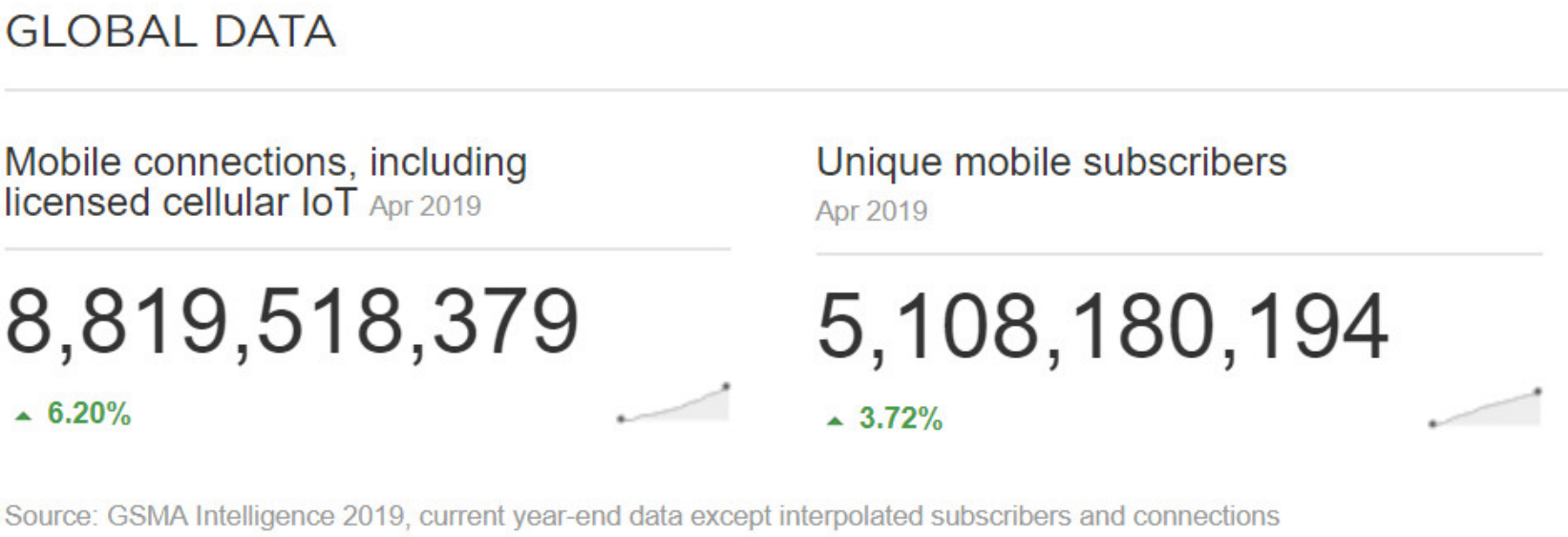
Symbol	Standard	Full Name	Maximum Download Speed (Theoretical)	Maximum Upload Speed (Theoretical)
2G	GSM	Global System for Mobile Communications	14.4 Kbits/s	14.4 Kbits/s
G	GPRS	General Packet Radio Service	53.6 Kbits/s	26.8 Kbits/s
E	EDGE	Enhanced Data rates for GSM Evolution	217.6 Kbits/s	108.8 Kbits/s
3G	UMTS	Universal Mobile Telecommunications System	384 Kbits/s	128 Kbits/s
H	HSPA	High-Speed Packet Access	7.2 Mbits/s	3.6 Mbits/s
H+	HSPA+	Evolved High-Speed Packet Access - Release 6	14.4 Mbits/s	5.76 Mbits/s
H+	HSPA+	Evolved High-Speed Packet Access - Release 7	21.1 Mbits/s or 28.0 Mbits/s	11.5 Mbits/s
H+	HSPA+	Evolved High-Speed Packet Access - Release 8	42.2 Mbits/s	11.5 Mbits/s
H+	HSPA+	Evolved High-Speed Packet Access - Release 9	84.4 Mbits/s	11.5 Mbits/s
H+	HSPA+	Evolved High-Speed Packet Access - Release 10	168.8 Mbits/s	23.0 Mbits/s
4G	LTE	Long Term Evolution	100 Mbits/s	50 Mbits/s
4G	LTE-A	Long Term Evolution - Advanced	1 Gbits/s	500 Mbits/s

تکامل گوشی های موبایل

روند تکامل نسلهای شبکه های مخابرات سیار

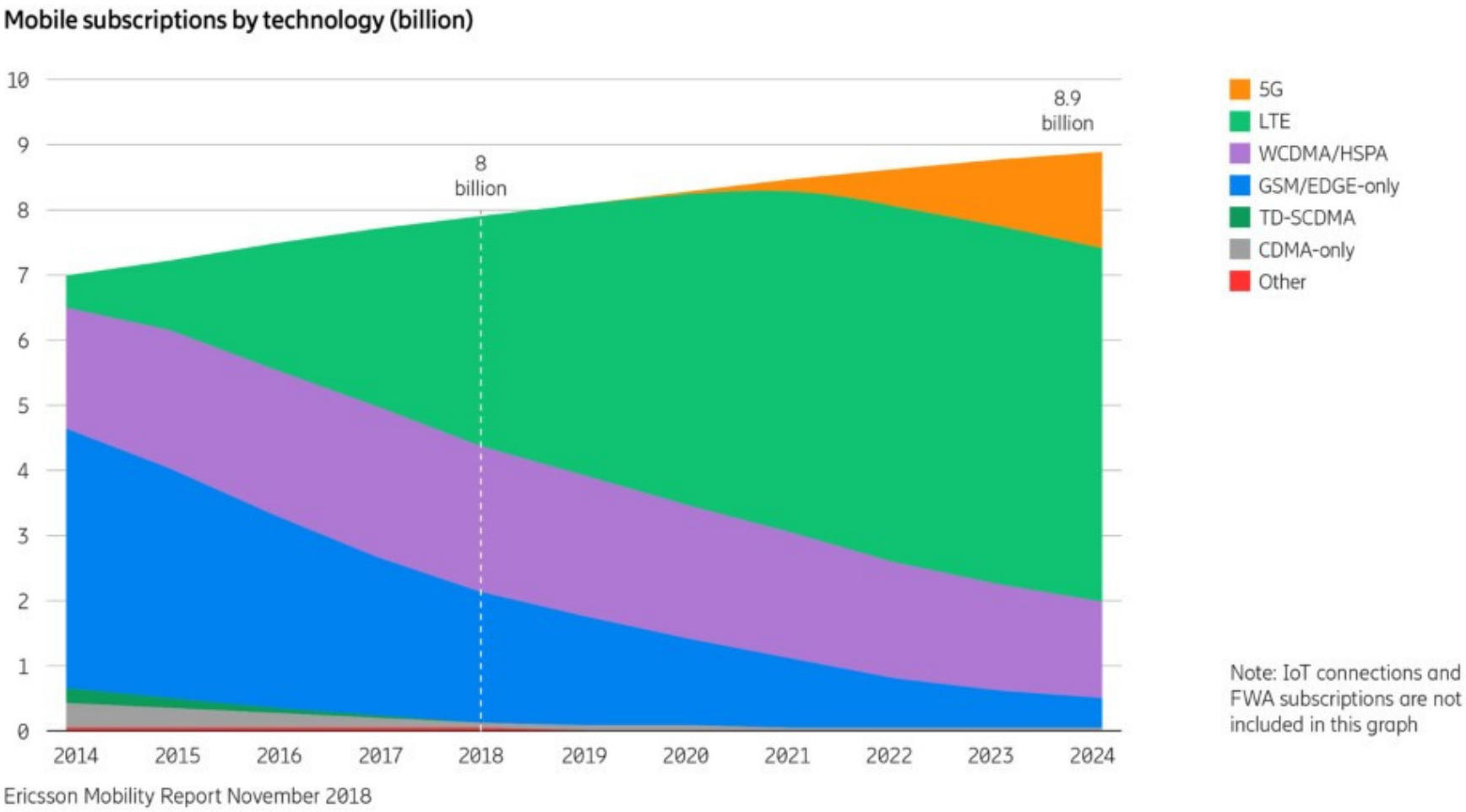


آخرین آمار کاربران سیار



April 15 , 2019

پیش بینی تعداد مشترکان



وضعیت فعلی

شبکه های سیار

افزایش سرعت دسترسی به اینترنت پرسرعت

- توسعه سنتی– دسترسی به اینترنت پرسرعت در همه جا و در همه زمان و با همه ابزارها

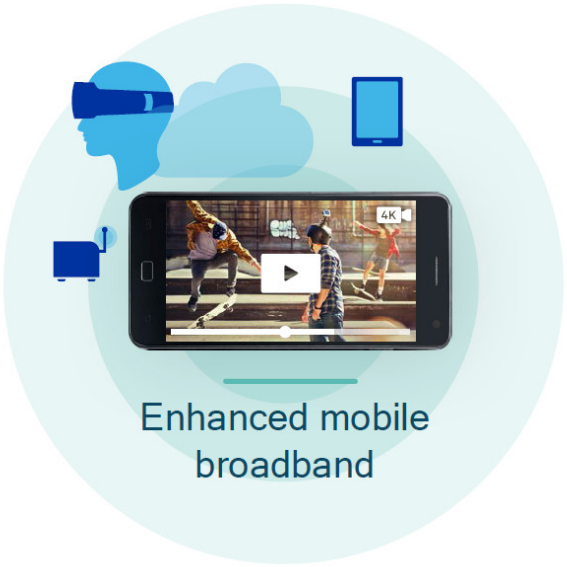
شبکه های اجتماعی

ارتباط فراگیر

Enhanced Mobile Broadband

- نرخ دیتا بالاتر
  - مناطق پرجمعیت
  - Indoor – outdoor
- اتصال بهبود یافته Enhanced connectivity
  - یکپارچگی سرویس در هر کجا و هر شرایط
- تحرک بهتر
  - وسایل نقلیه پر سرعت

حجم دیتا



~50B Gigabytes

Monthly global mobile data traffic in 2021; >100x growth since 2011

6.8 Gigabytes

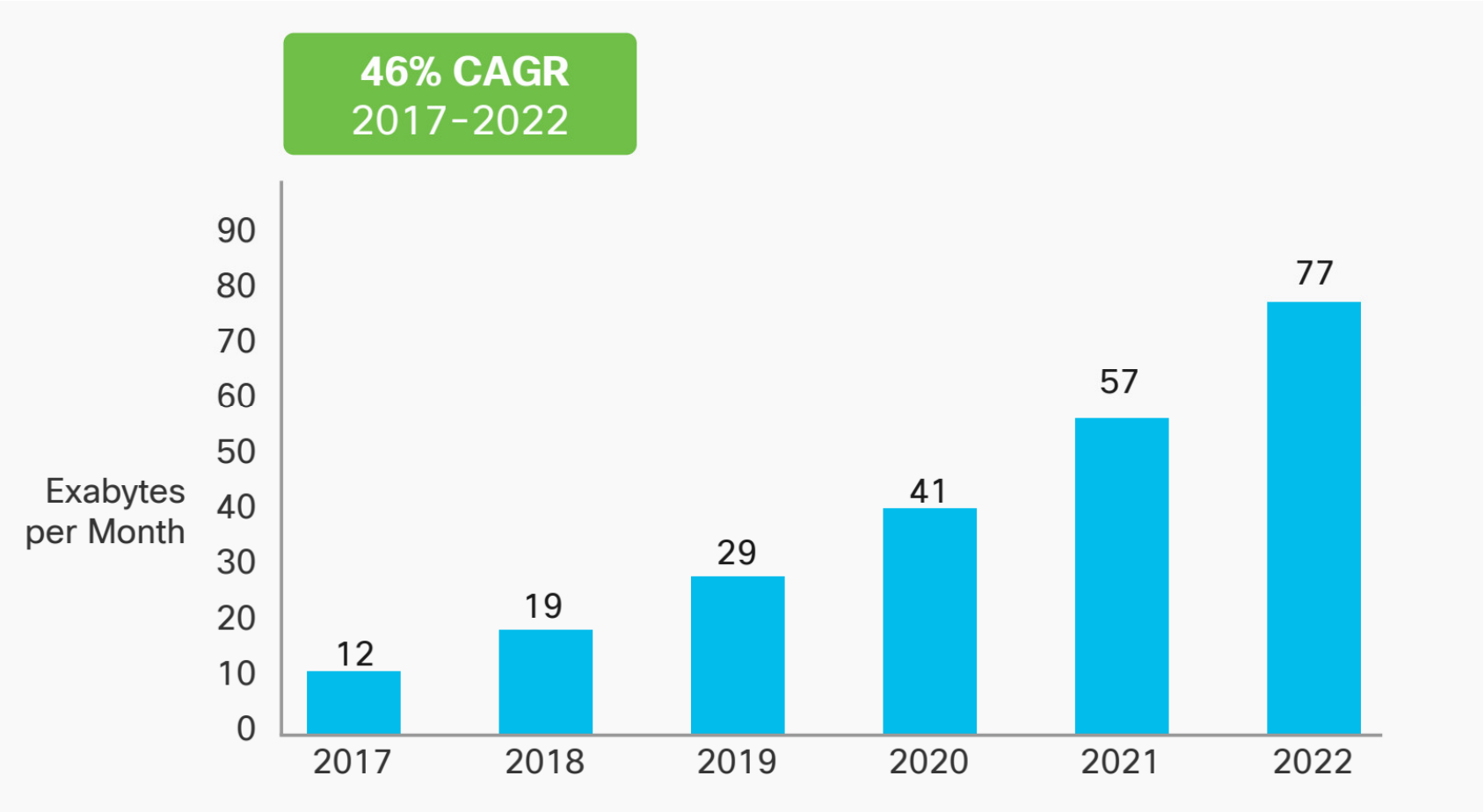
Average smartphone traffic per month; up from 1.6GB in 2016

>75%

Of global mobile data traffic will be video by 2021

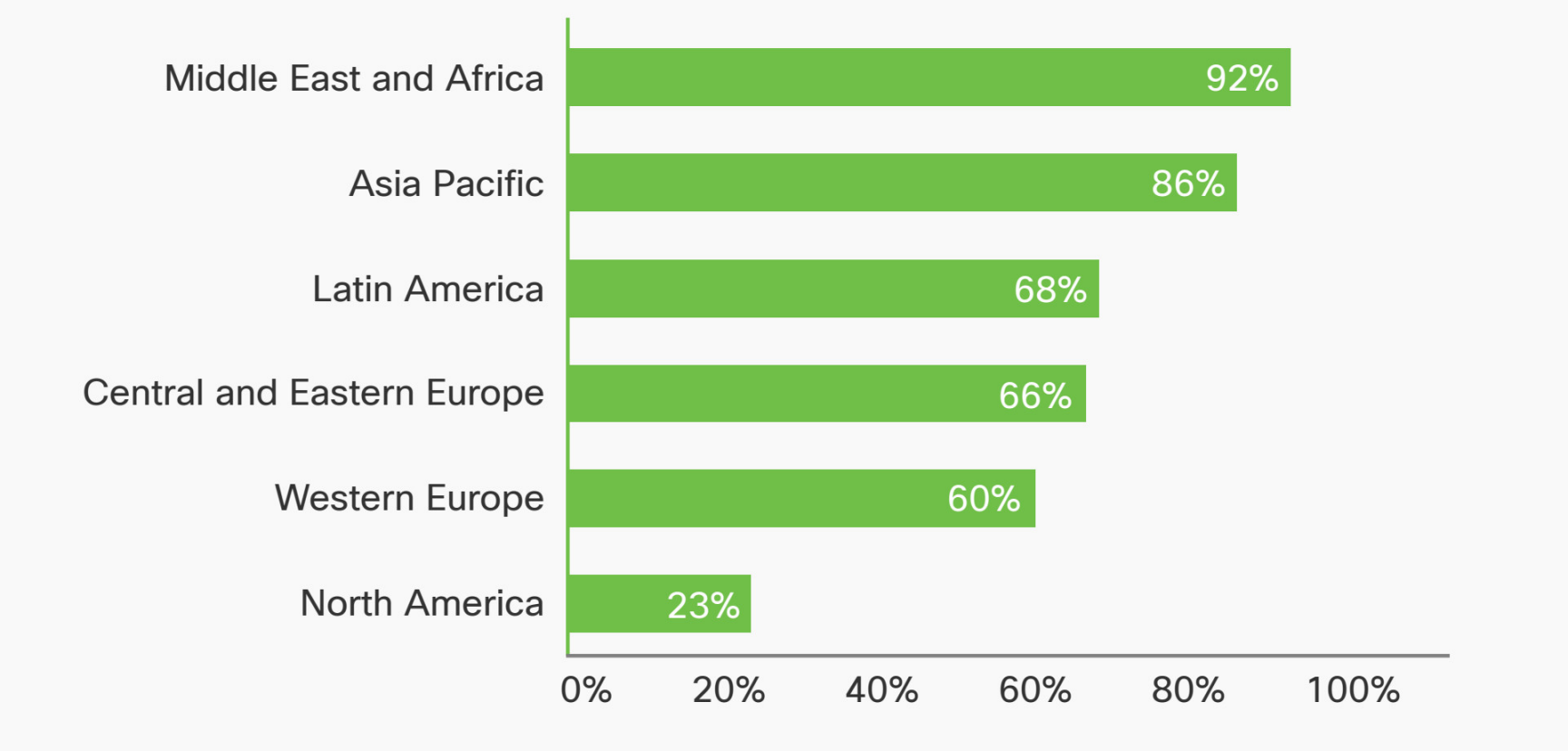
Source: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast (Feb'17)

Global Mobile Data Traffic Growth



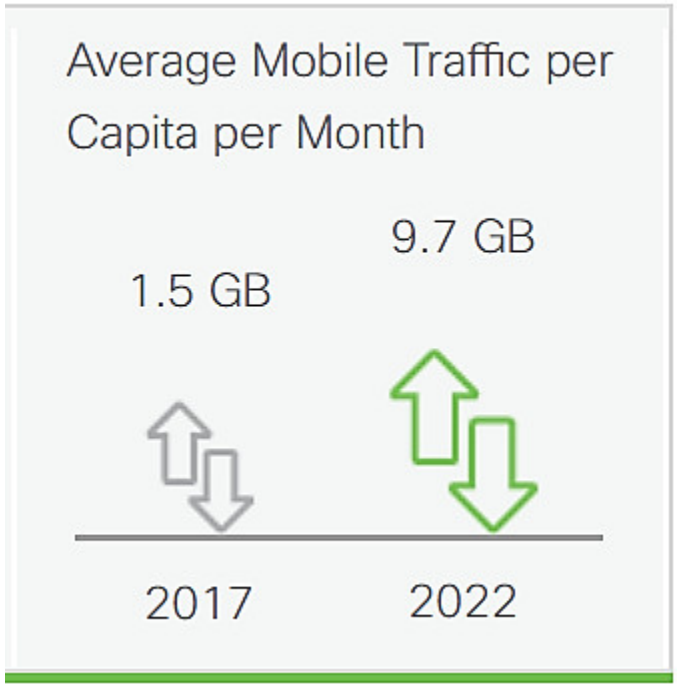
Source: Cisco VNI Mobile, 2019

Mobile Data Traffic Growth in 2017



Source: Cisco VNI Mobile, 2019

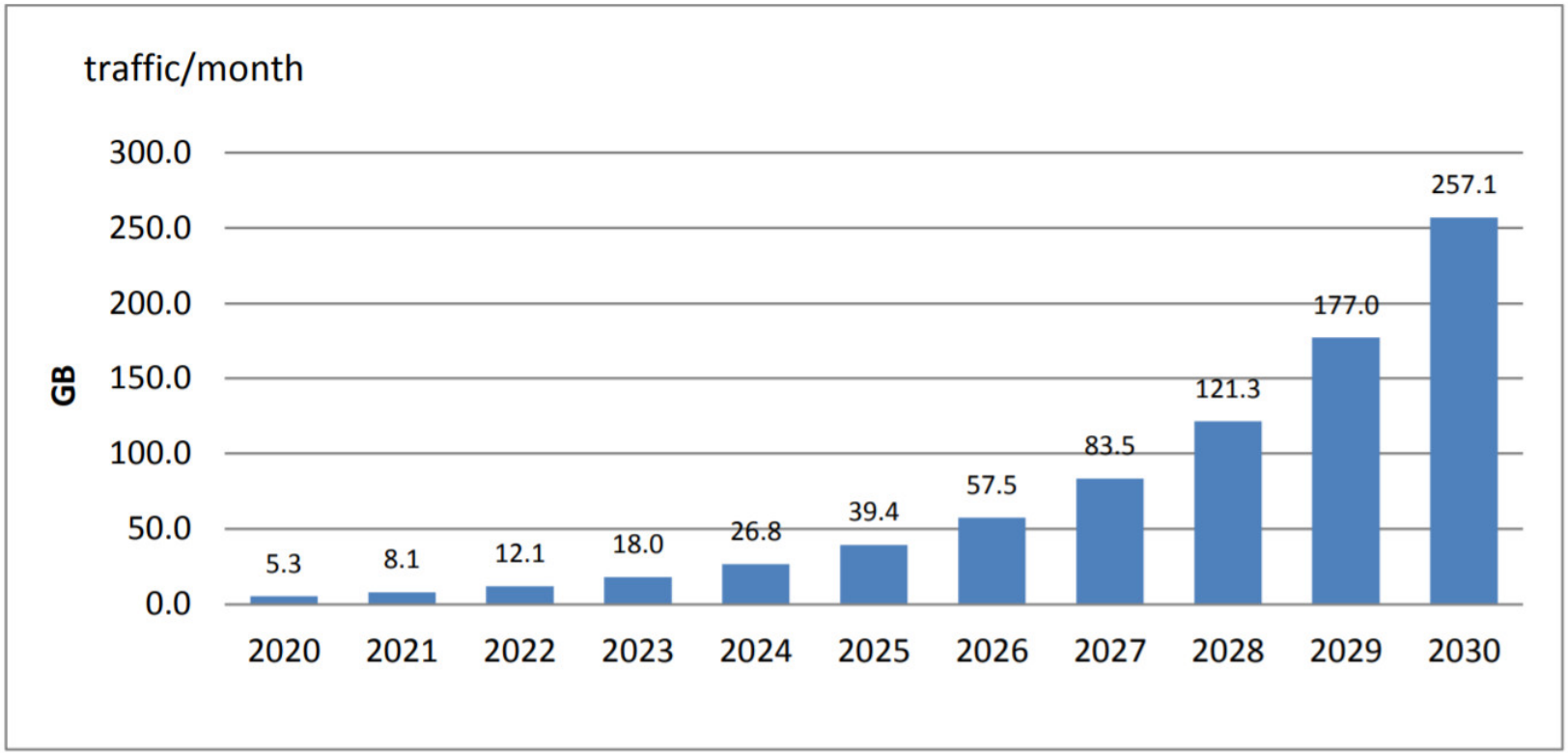
افزایش حجم دیتای کاربران



Source: Cisco VNI Mobile, 2019

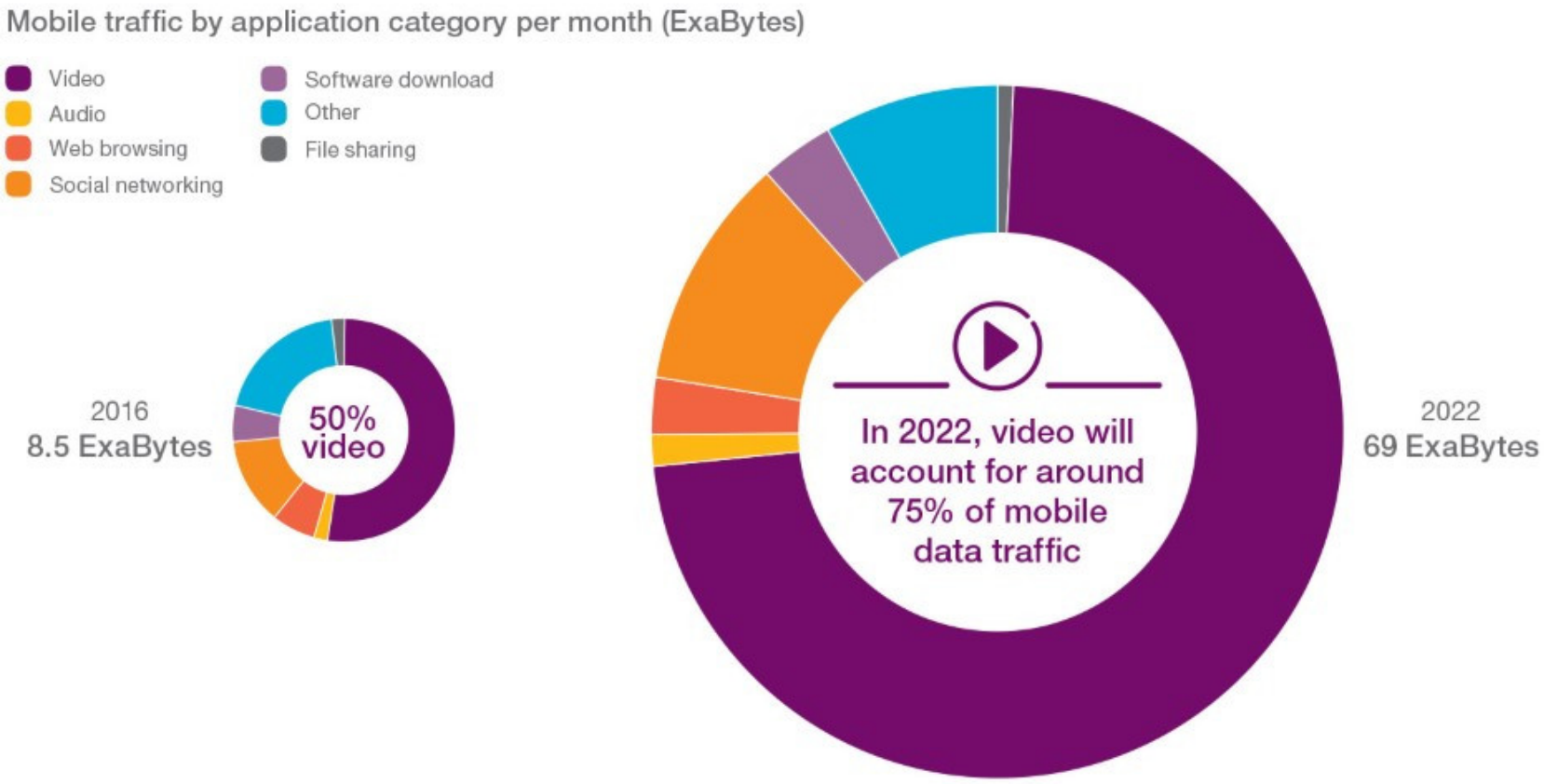
افزایش حجم دیتای کاربران تا ۲۰۳۰

Estimations of global mobile traffic per subscriptions per month from 2020 to 2030
(M2M not included)

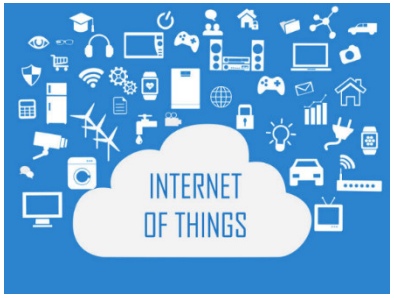


Rep. ITU-R M.2370-0

پیش بینی ترافیک داده



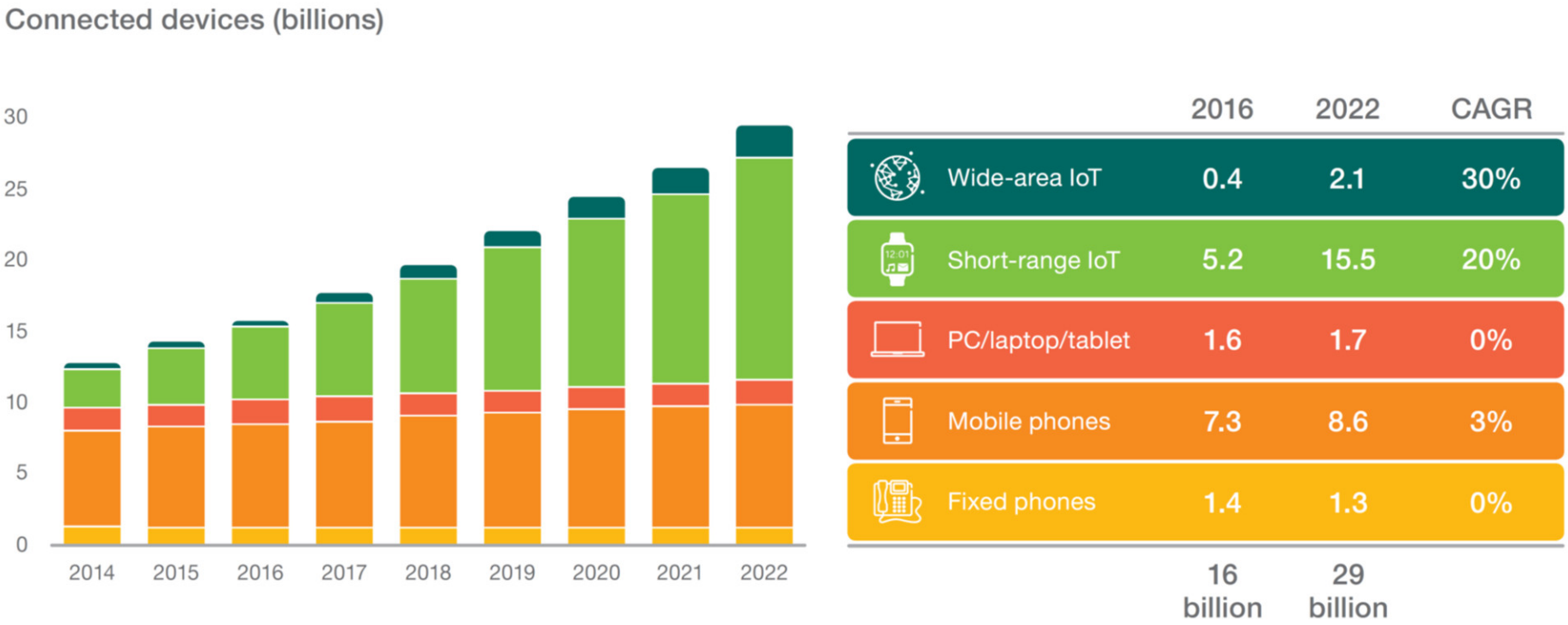
[1] Video is likely to form a major part of file sharing traffic in addition to the identified application type 'video'
[2] Ericsson ConsumerLab, TV and Media (2016)



اینترنت اشیا

- تعداد بسیار زیاد ابزار متصل به اینترنت (مقایسه با تعداد گوشی ها)

پیش بینی تعداد کاربران



Remote Healthcare

پزشکی از راه دور

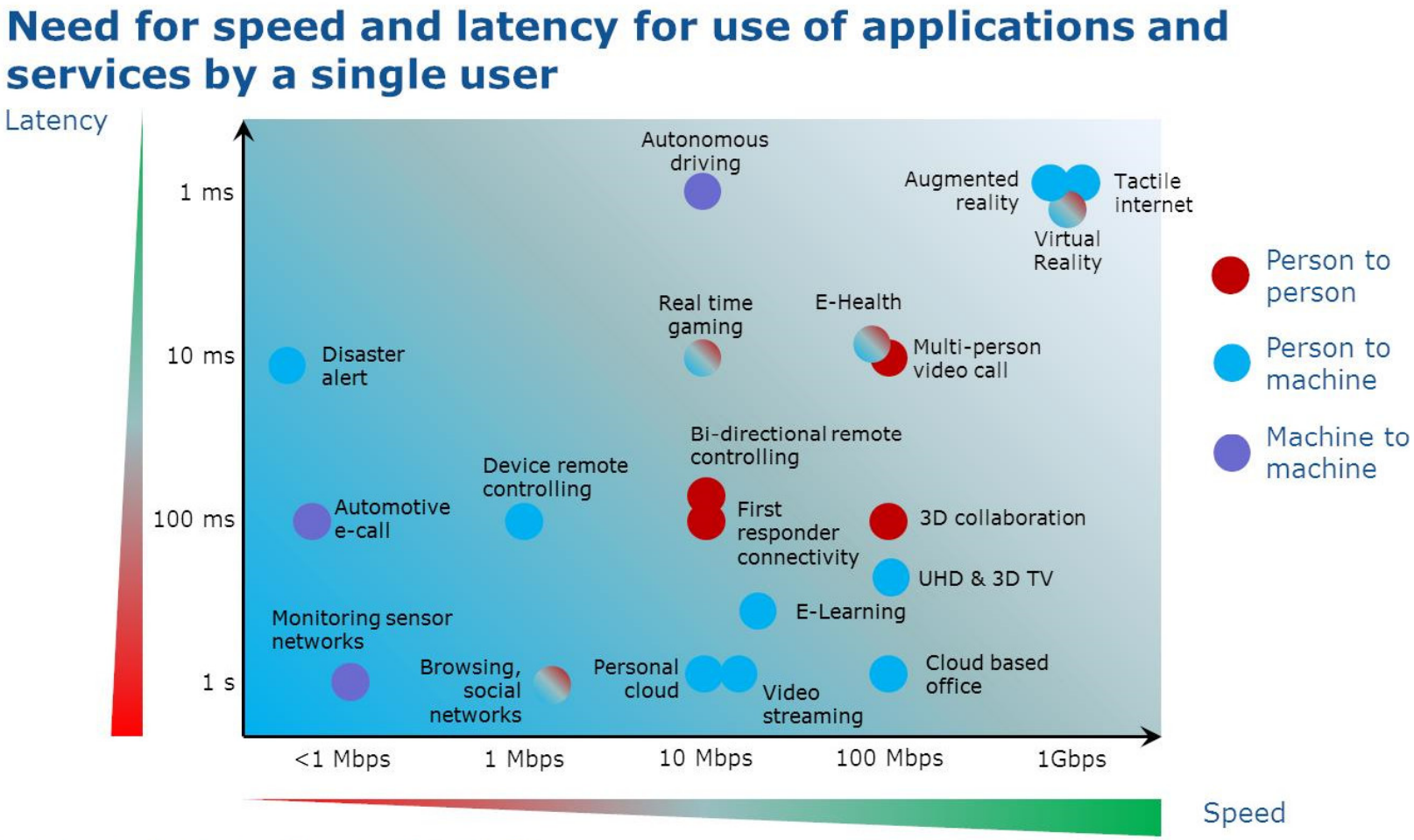
Intelligent Transportation Systems

Real Time Gaming

Latency Requirements

use case	Latency	Data rate	Remarks
Factory Automation	0.25-10 ms	1 Mbps	– Generally factory automation applications require small data rates for motion and remote control. – Applications such as machine tools operation may allow latency as low as 0.25 ms.
Intelligent Transport Systems (ITS)	10-100 ms	10-700 Mbps	– Road safety of ITS requires latency on the order of 10 ms. – Applications such as virtual mirrors require data rates on the order of 700 Mbps.
Robotics and Telepresence	1 ms	100 Mbps	– Touching an object by a palm may require latency down to 1 ms. – VR haptic feedback requires data rates on the order of 100 Mbps.
Virtual Reality (VR)	1 ms	1 Gbps	– Hi-resolution 360◦ VR requires high rates on the order of 1 Gbps while allowing latency of 1 ms.
Health care	1-10 ms	100 Mbps	– Tele-diagnosis, tele-surgery and tele-rehabilitation may require latency on the order of 1 ms with data rate of 100 Mbps.
Serious Gaming	1 ms	1 Gbps	– Immersive entertainment and human's interaction with the high-quality visualization may require latency of 1 ms and data rates of 1 Gbps for high performance.
Smart Grid	1-20 ms	10-1500 Kbps	– Dynamic activation and deactivation in smart grid requires latency on the order of 1 ms. – Cases such as wide area situational awareness require date rates on the order of 1500 Kbps.
Education and Culture	5-10 ms	1 Gbps	– Tactile Internet enabled multi modal human-machine interface may require latency as low as 5 ms. – Hi-resolution 360◦ and haptic VR may require data rates as high as 1 Gbps.

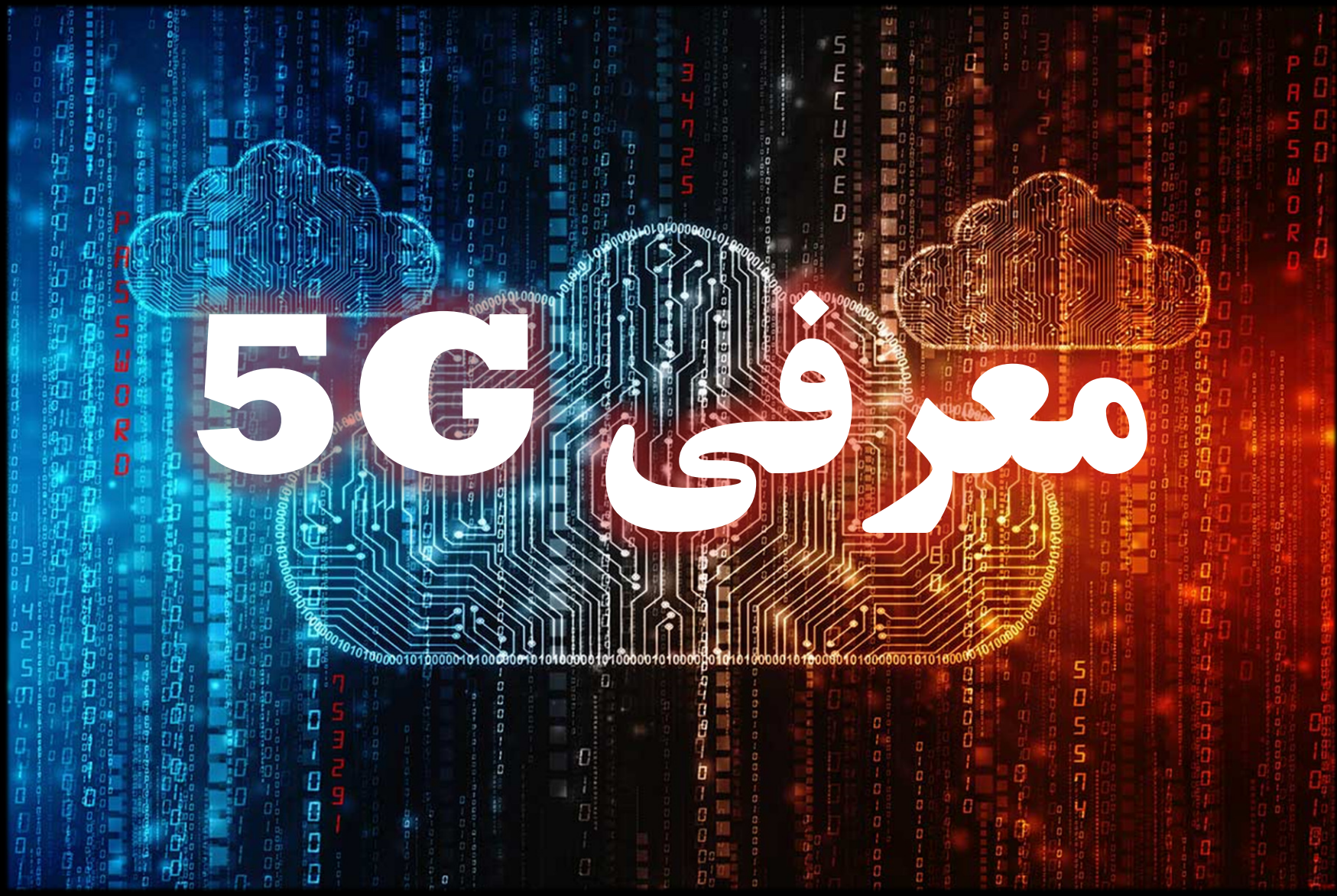
Latency and Reliability



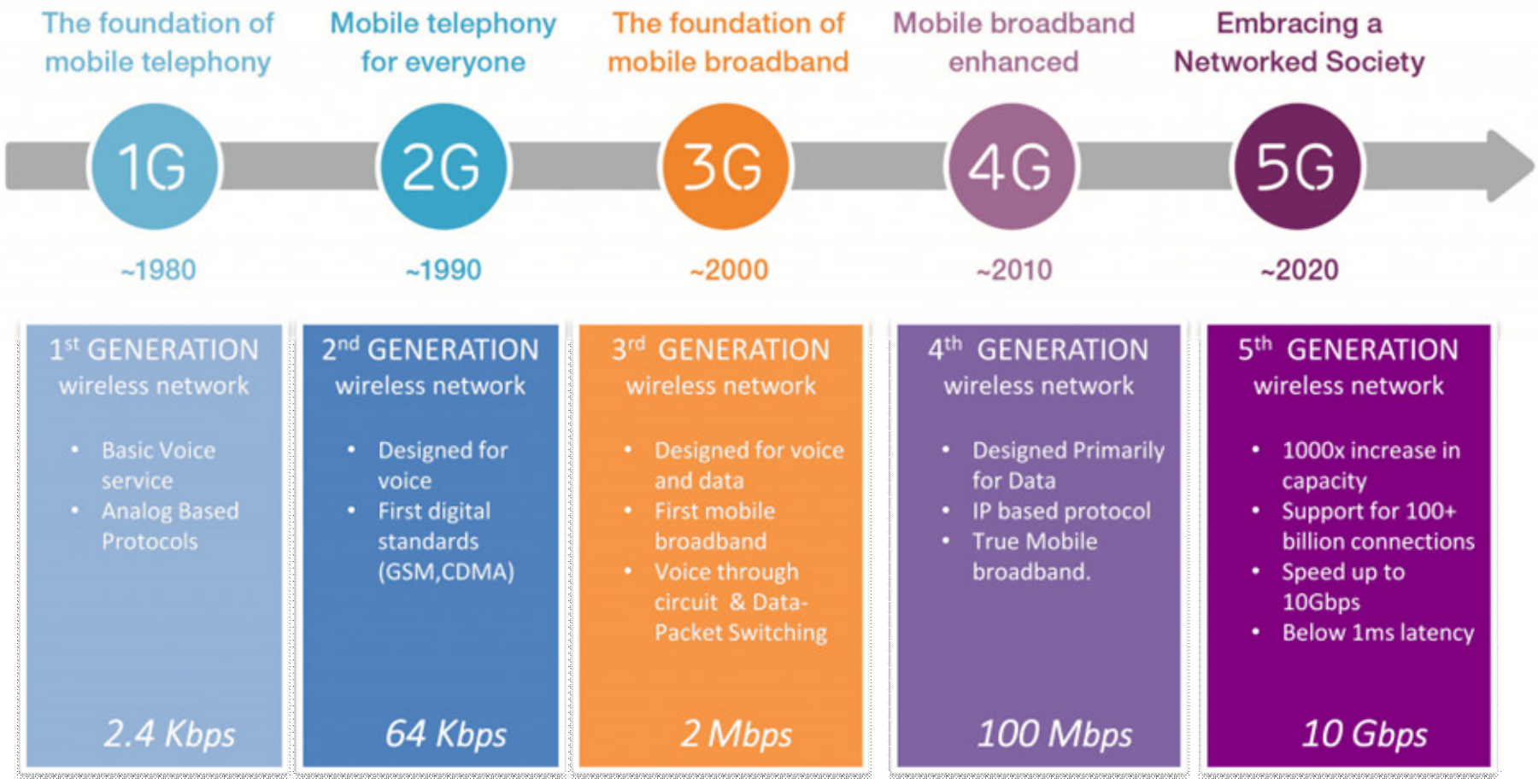
Source: Commission analysis based on GSMA and EIB

سایر مفاهیم

- پردازش ابری
- داده های عظیم


5G
معرفی

روند تکامل نسلهای شبکه های مخابرات سیار



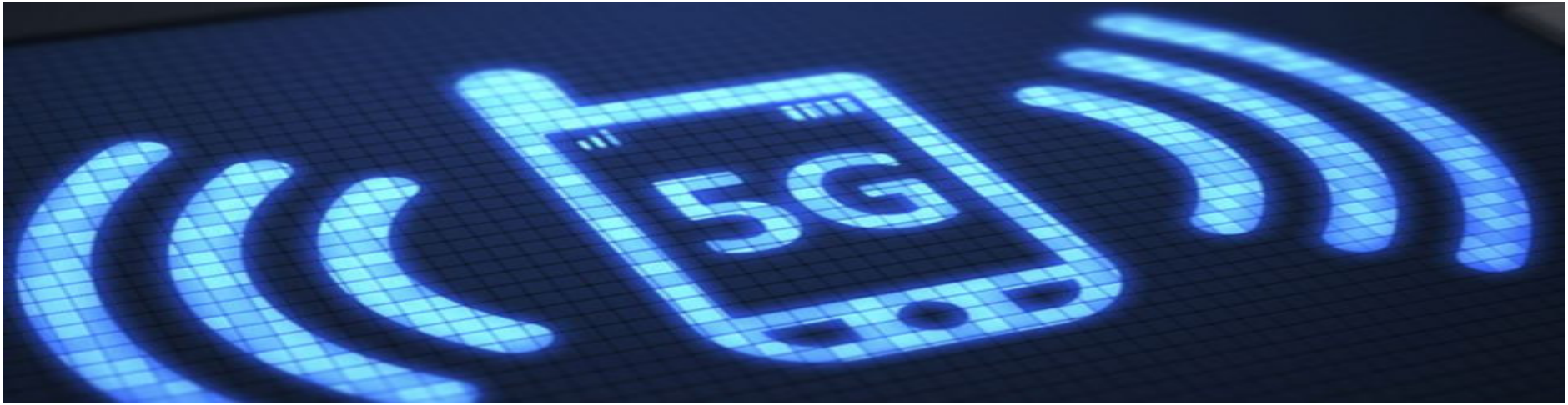
تعریف 5G

- نسل بعد شبکه های مخابرات سیار
- قابلیت پاسخگویی به نیازهای روزافزون سالهای آتی
- از دیدگاه نرخ دیتا، تعداد ابزارها، تاخیر و قابلیت اطمینان

- **"5G moves us to a truly connected society with very high data rates, low latency, and massively interconnected devices,"** Douglas Sicker, Carnegie Mellon University

تعریف 5G

نسل آینده شبکه های مخابرات سیار که ارتباط بی سیم با سرعت انتقال بسیار بالا (سرعت متوسط یک گیگا بیت بر ثانیه) و ارتباط مطمئن تر را برای تعداد زیادی از گوش های هوشمند و سایر ابزارهای بی سیم متحرک فراهم می نماید.



الزامات 5G

- 10Gbps peak data rate
- 100 Mbps always
- 1M devices per km^2
- 50 GB/month/user
- <1 ms latency
- 10% of todays energy consump.- 10 years battery life
- Ultra reliability < 10^-5 E2E outage
- Zero mobility interruption

سرویس های 5G و الزامات مربوطه

eMBB

- 100 Mbps always
- 10Gbps peak data rate

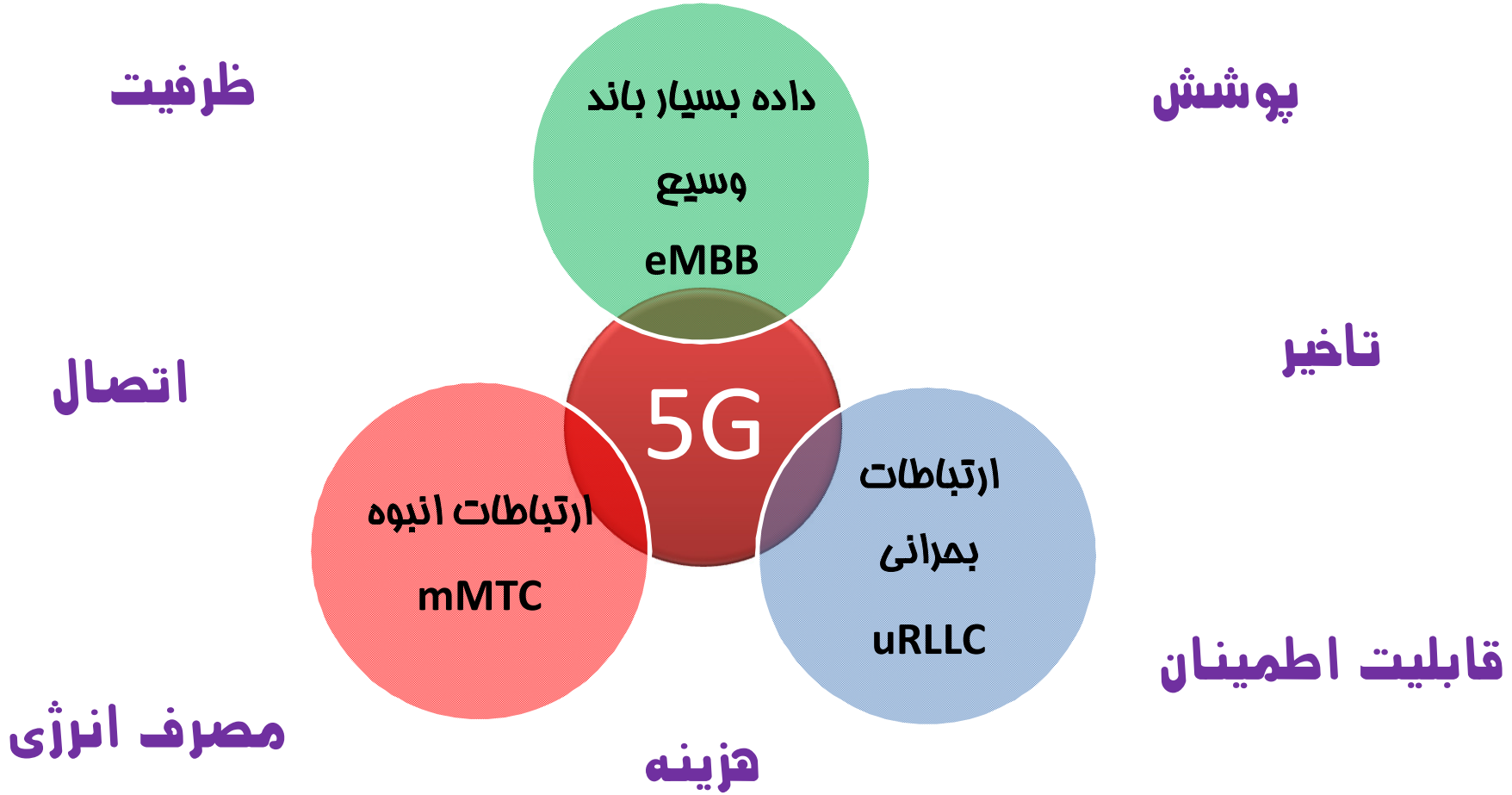
mMTC

- 1M devices per km^2
- 10000x more traffic
- 50 GB/month/user
- 10% of todays energy consump.- 10 years battery life

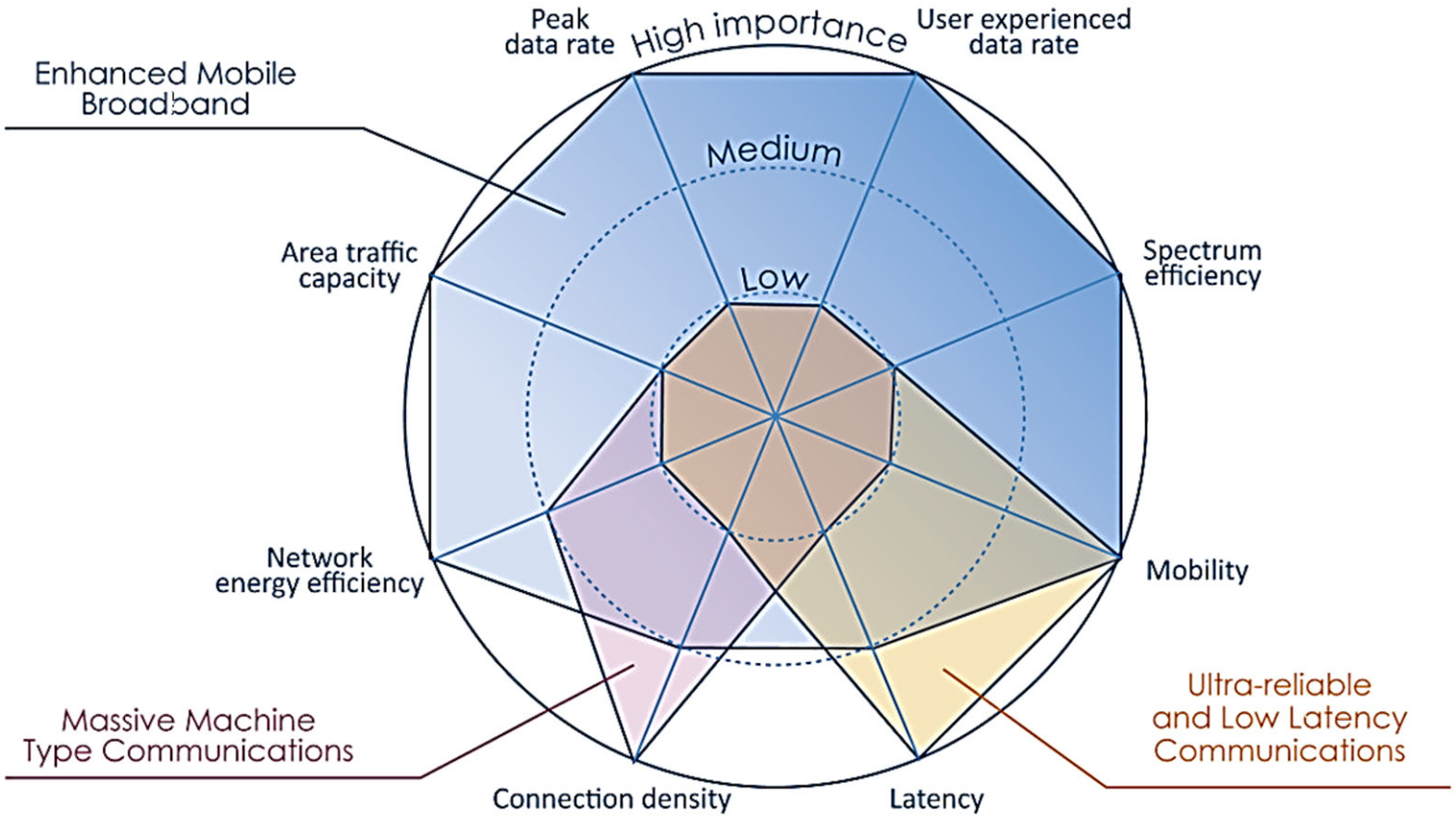
uRLLC

- <1 ms latency
- Ultra reliability < 10^-5 E2E outage
- Zero mobility interruption

سرویس های 5G و الزامات مربوطه



سرویس های 5G و الزامات مربوطه



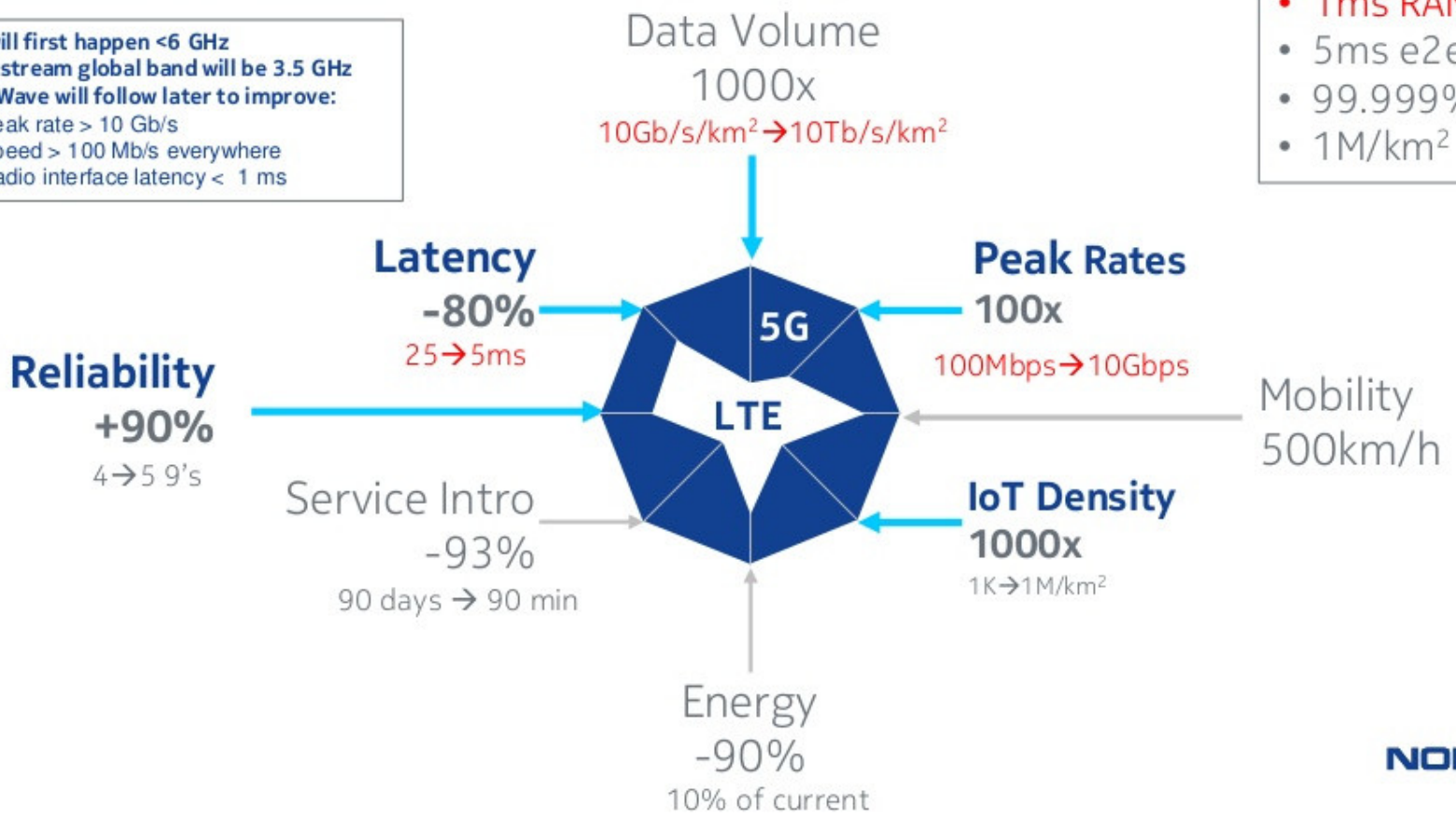
Ref: ETSI

Differences between 5G and LTE

Where mmWave system are positioned to meet the 5G requirements

- **5G will first happen <6 GHz**
- **Mainstream global band will be 3.5 GHz**
- **mm Wave will follow later to improve:**
  1. Peak rate > 10 Gb/s
  2. Speed > 100 Mb/s everywhere
  3. Radio interface latency < 1 ms

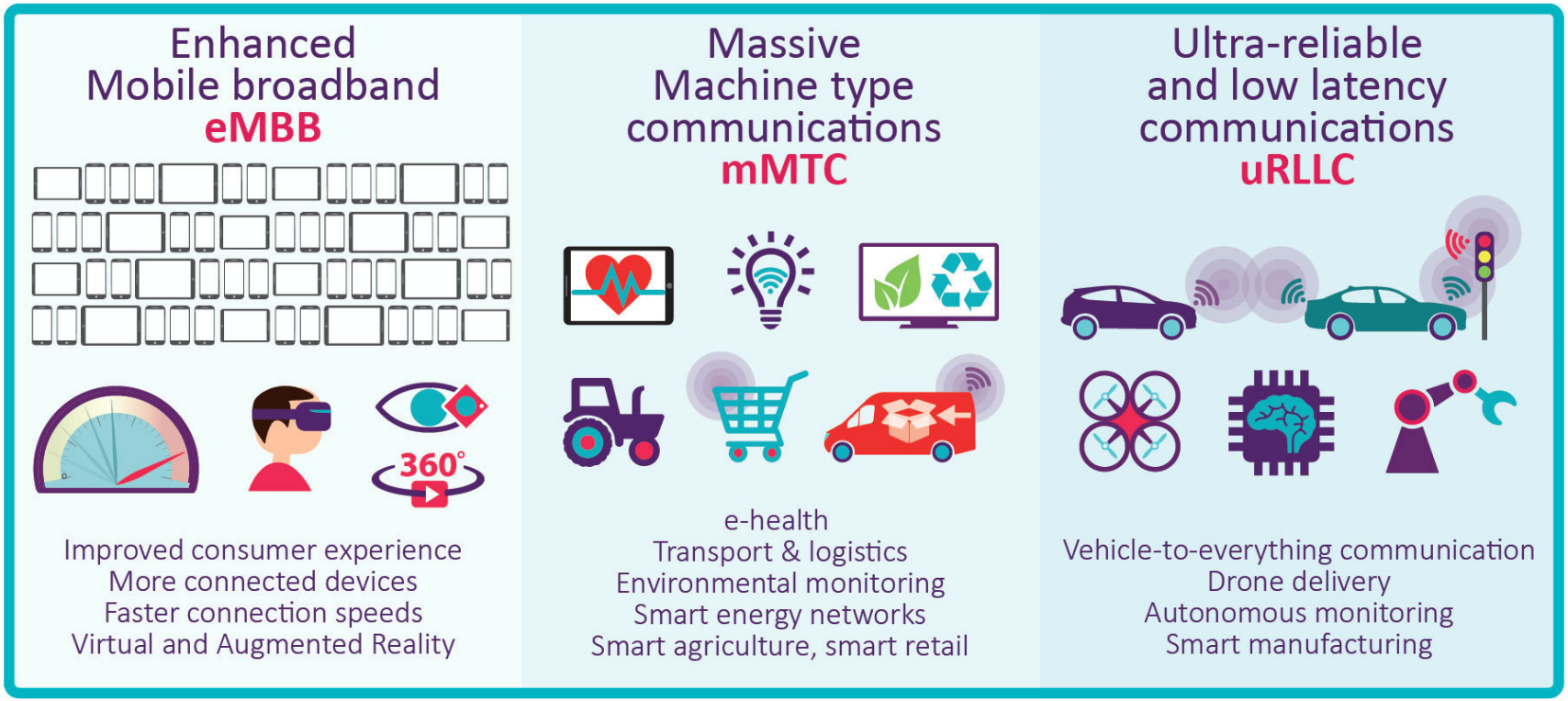
Key Metrics
- 10Gbps
- 1ms RAN
- 5ms e2e
- 99.999%
- 1M/km²



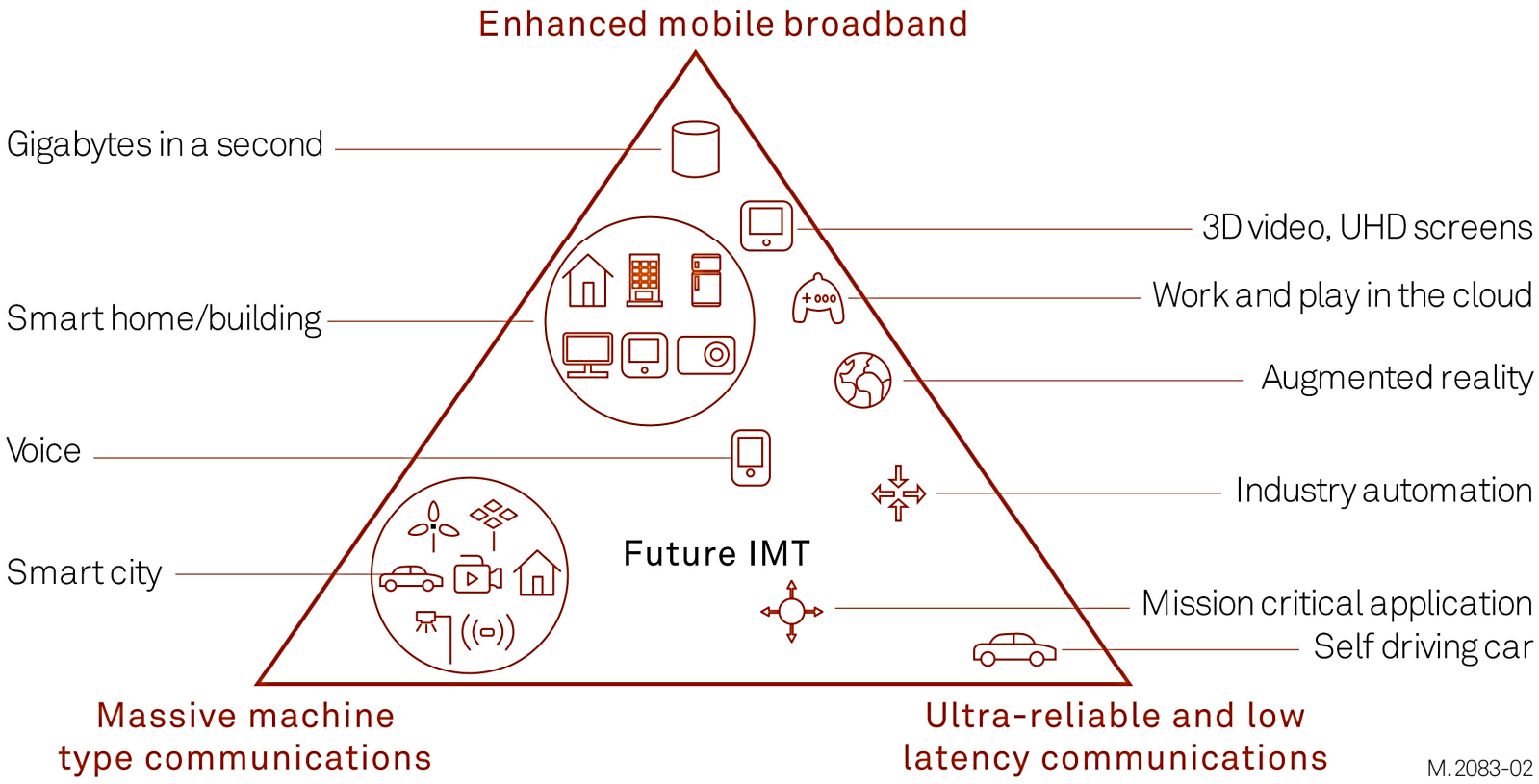
17

NOKIA

5G Applications



5G Services and Applications



ITU

Home broadband

- ارتباط باند وسیع بدون کابل (فیبر)

Tactile Internet

- **Real time communication**
- ارسال عمل و عکس العمل

Tactile Internet

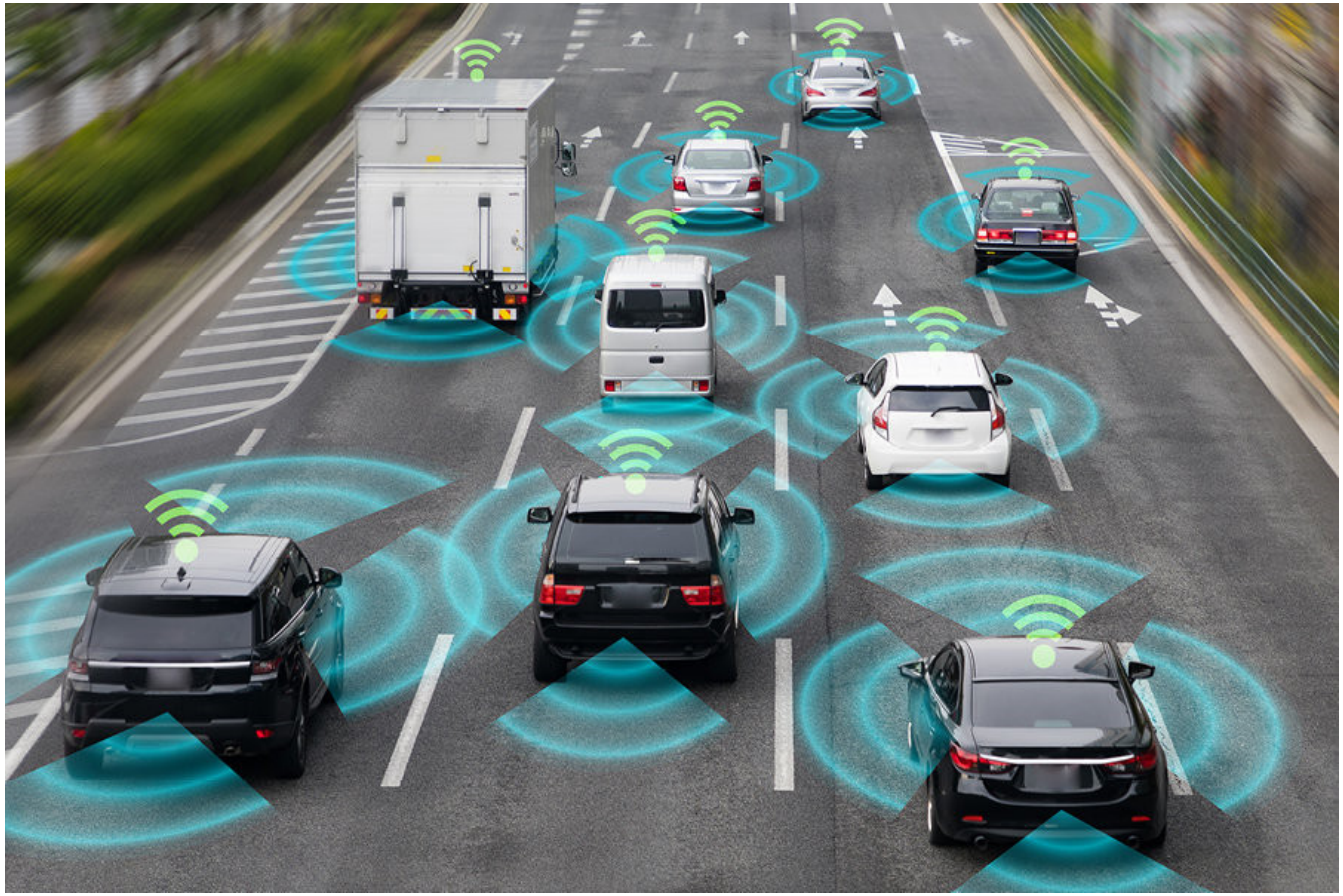
Intelligent Transportation Systems

- **Smart Cities , Autonomous Vehicles , Traffic Management Systems , Emergency Services**

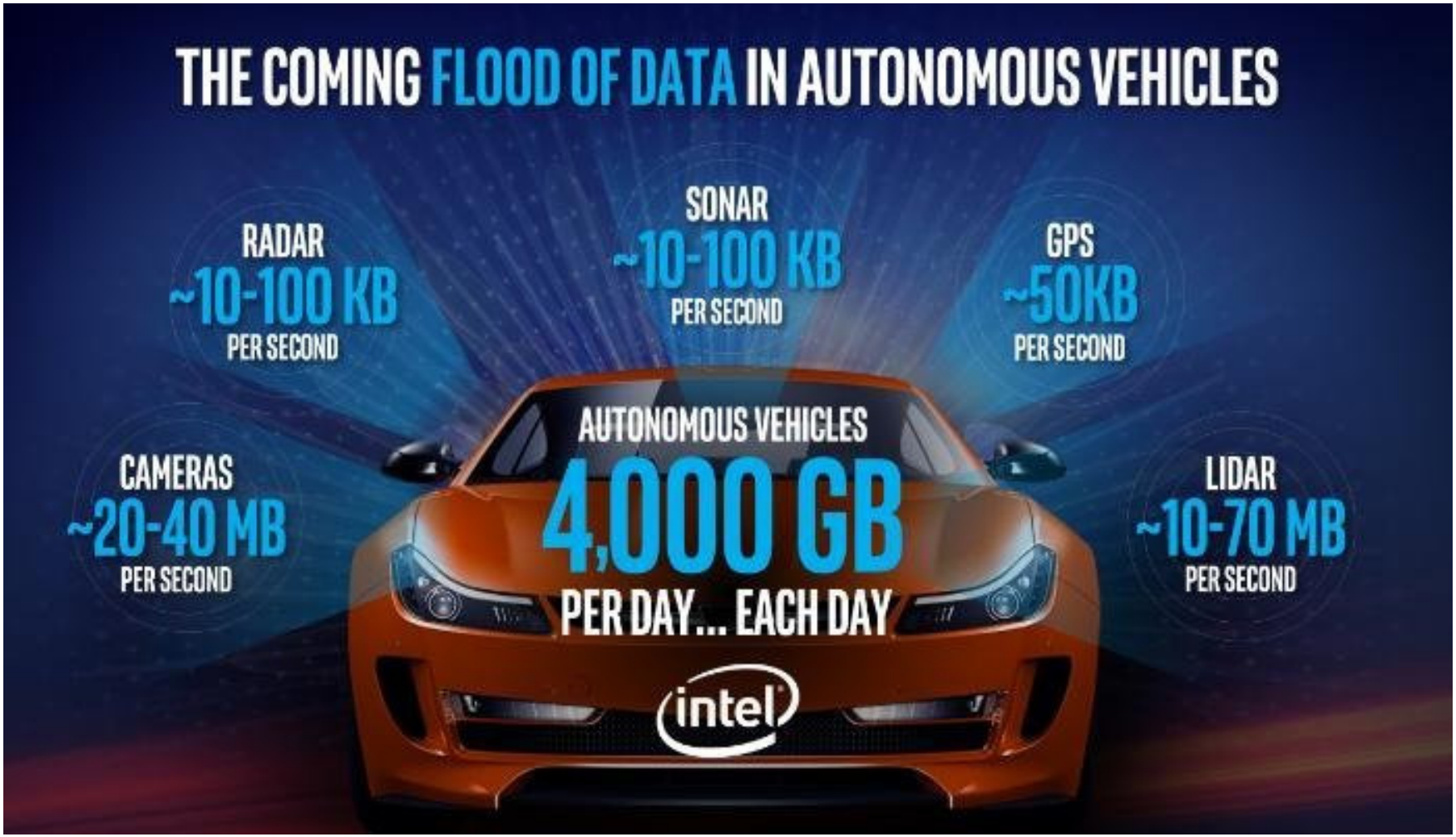
حمل و نقل هوشمند

Autonomous Vehicles

- اتوموبیل های خودران



Autonomous Vehicles



واقعیت مجازی/افزوده

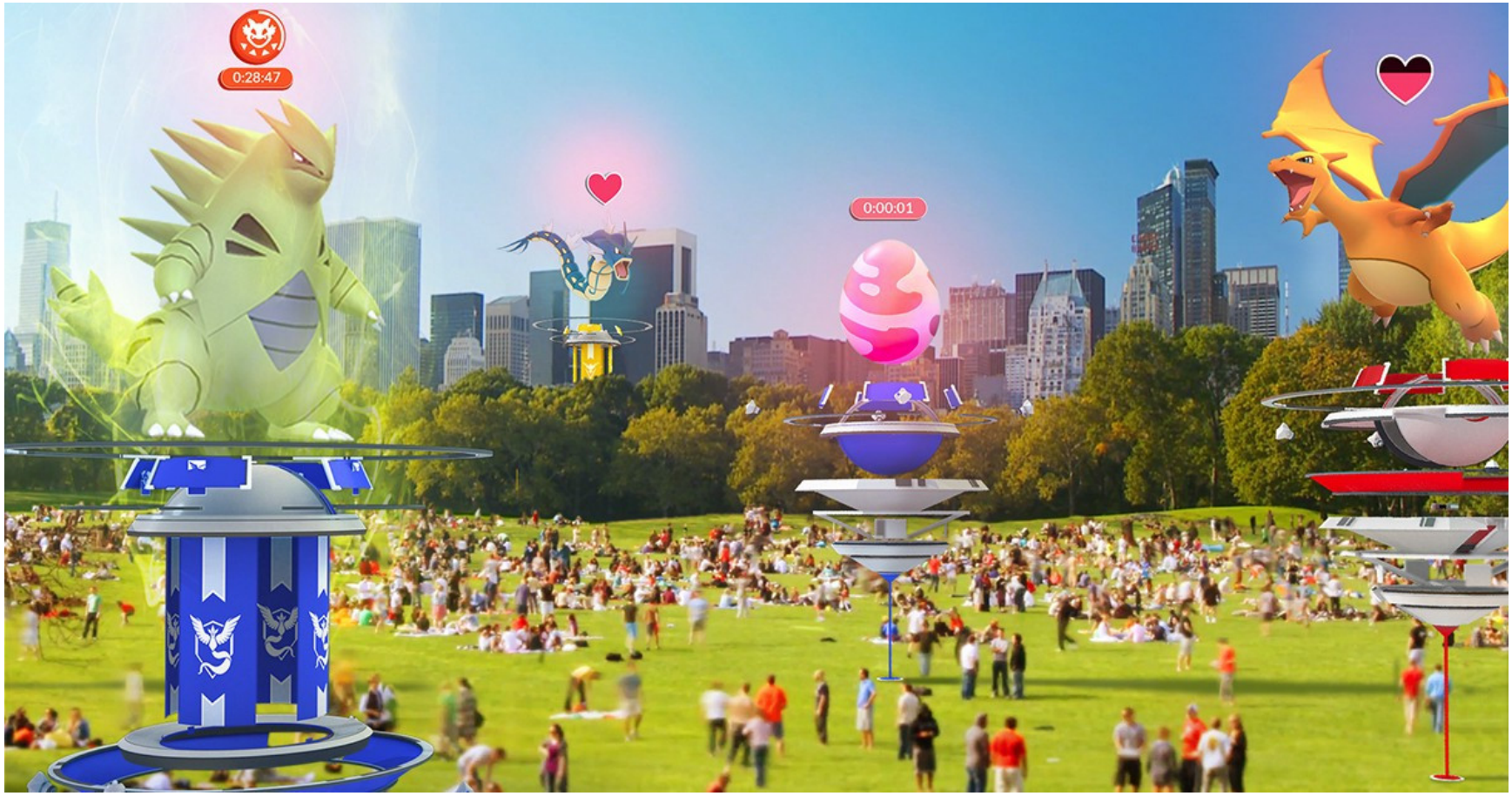
- AR/VR
- augmented reality / virtual reality

واقعیت مجازی/افزوده

واقعیت مجازی/افزوده

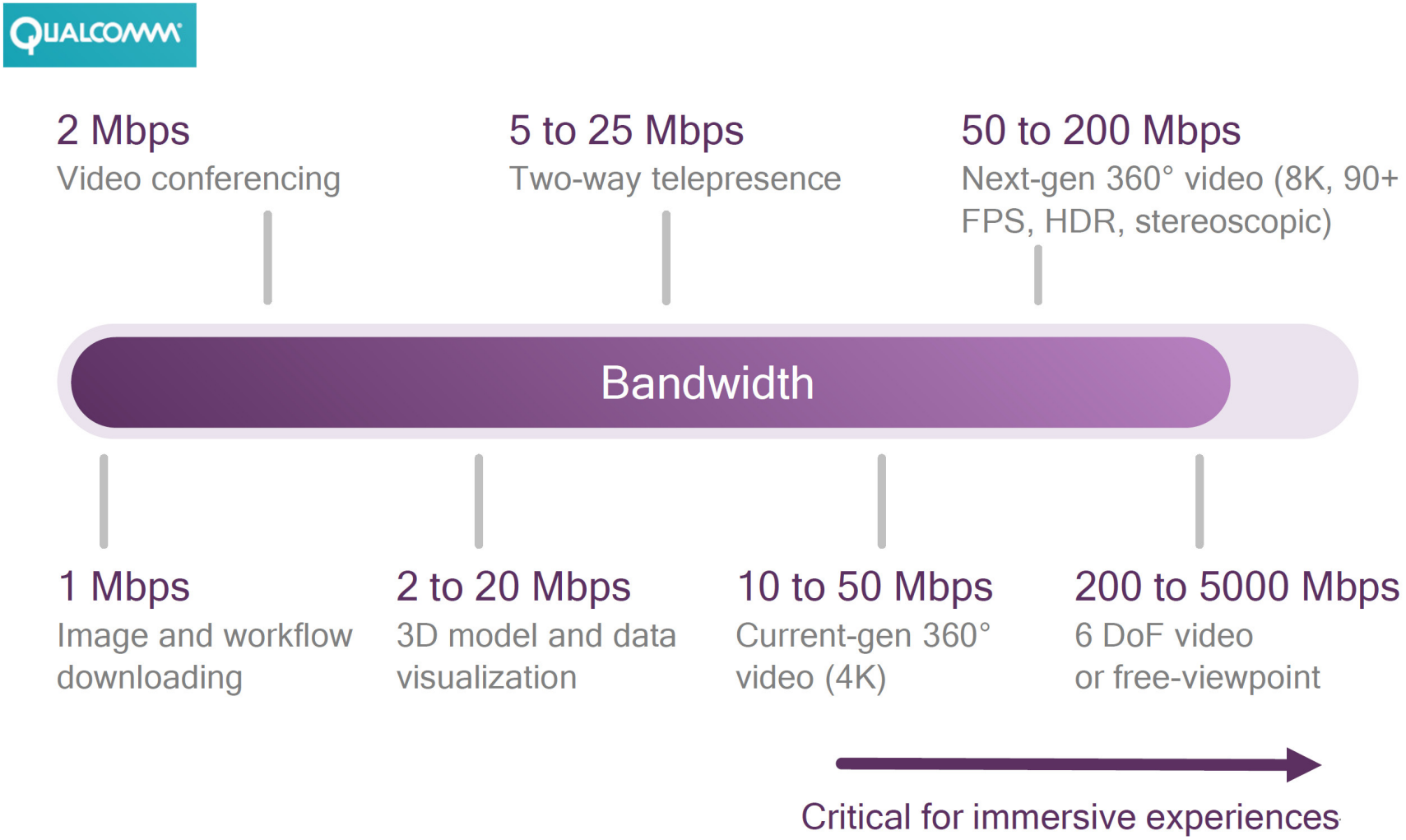
QUALCOMM

AR/VR



AR/VR

نرخ دیتا


2 Mbps
Video conferencing
5 to 25 Mbps
Two-way telepresence
50 to 200 Mbps
Next-gen 360° video (8K, 90+ FPS, HDR, stereoscopic)
Bandwidth
1 Mbps
Image and workflow downloading
2 to 20 Mbps
3D model and data visualization
10 to 50 Mbps
Current-gen 360° video (4K)
200 to 5000 Mbps
6 DoF video or free-viewpoint
Critical for immersive experiences

Real Time AR

پزشکی از راه دور

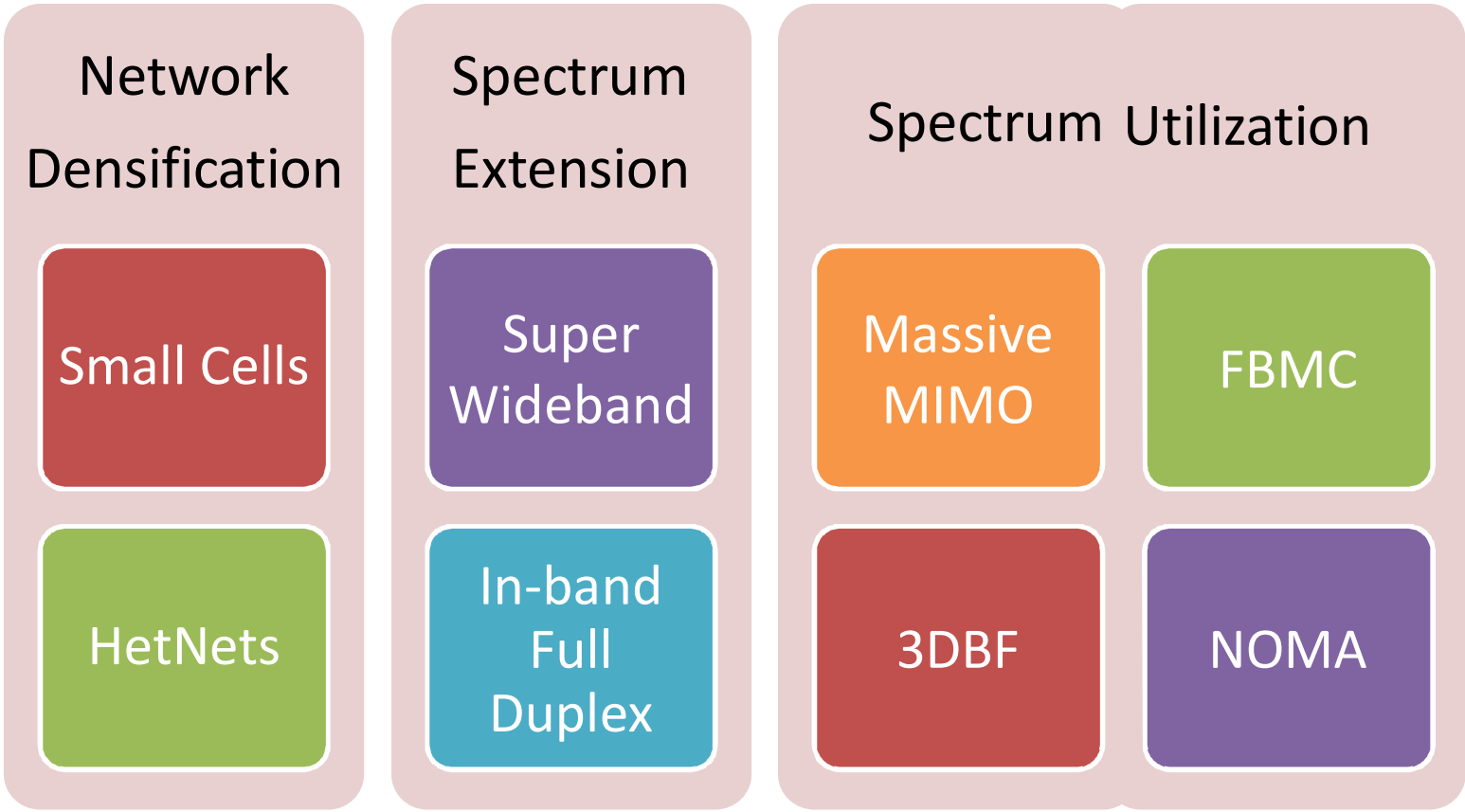
Cloud Gaming on smartphones

فناوری های مطرح در 5G

5G Core Network

Network Function Virtualization (NFV)	Software Defined Network (SDN)	Network Slicing
Multi-Access Edge Computing (MEC)	Cloud computing	Heterogeneous network

فناوری های رادیویی در 5G



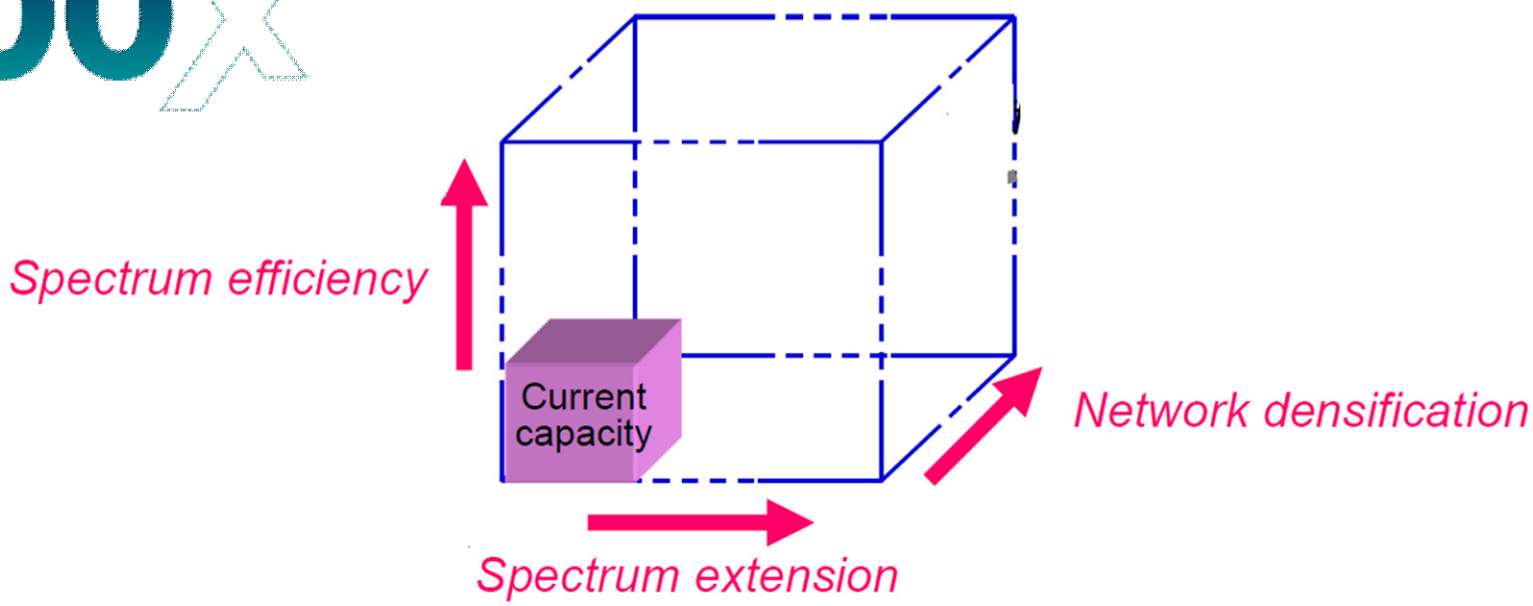
الزامات رادیویی در 5G

Area SE (bps/Km^2) = **Spectrum (Hz)** X

Spectral Efficiency(bps/Hz/cell) X

Cell Density (cell/km^2)

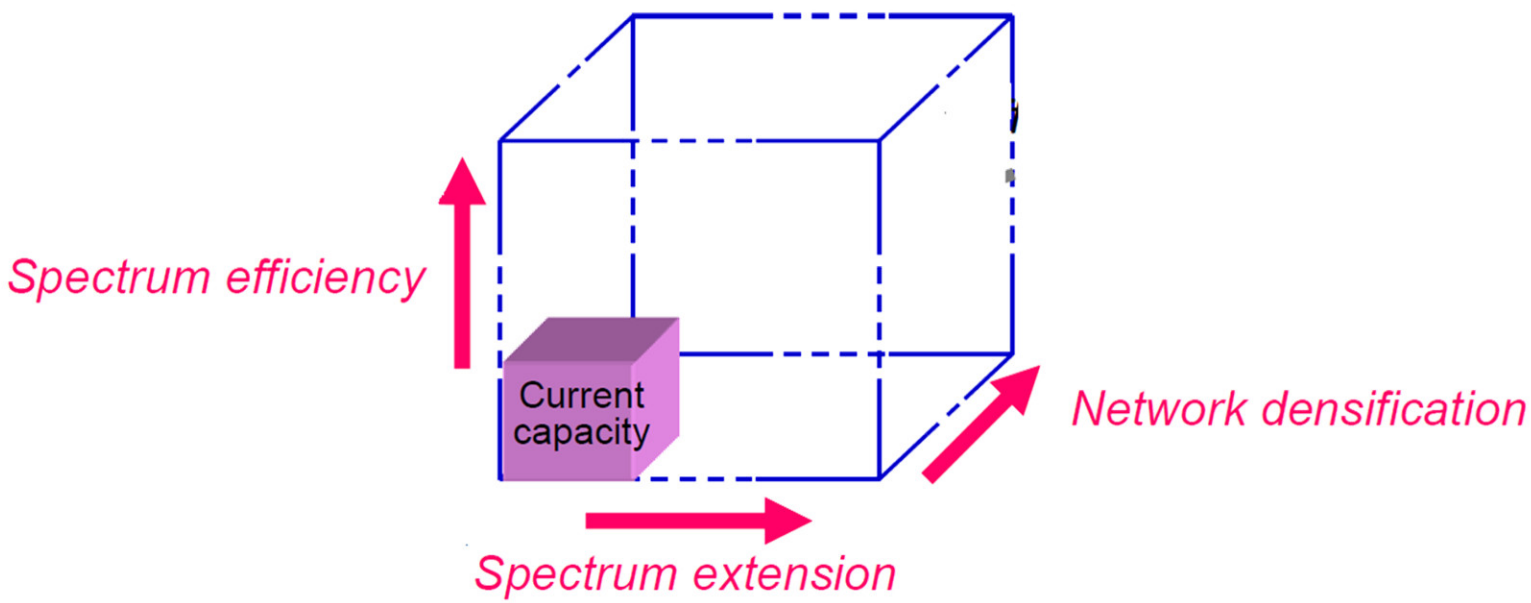
1000X



5G Radio Access Technologies

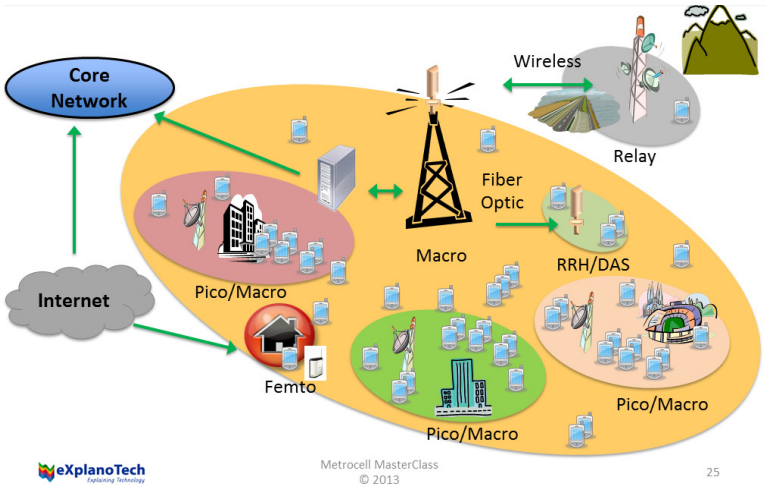
Company	Spectrum	Spectral Efficiency	Base Station Densification	Total capacity increase
Nokia	10	10	10	1000
Huawei	4	16-30	10	640-1200
NTT DoCoMo	2.8	24	15	1000
Ericsson	4	2.5	100	1000
RWTH Aachen	3	5	66	1000

1000x Improvement



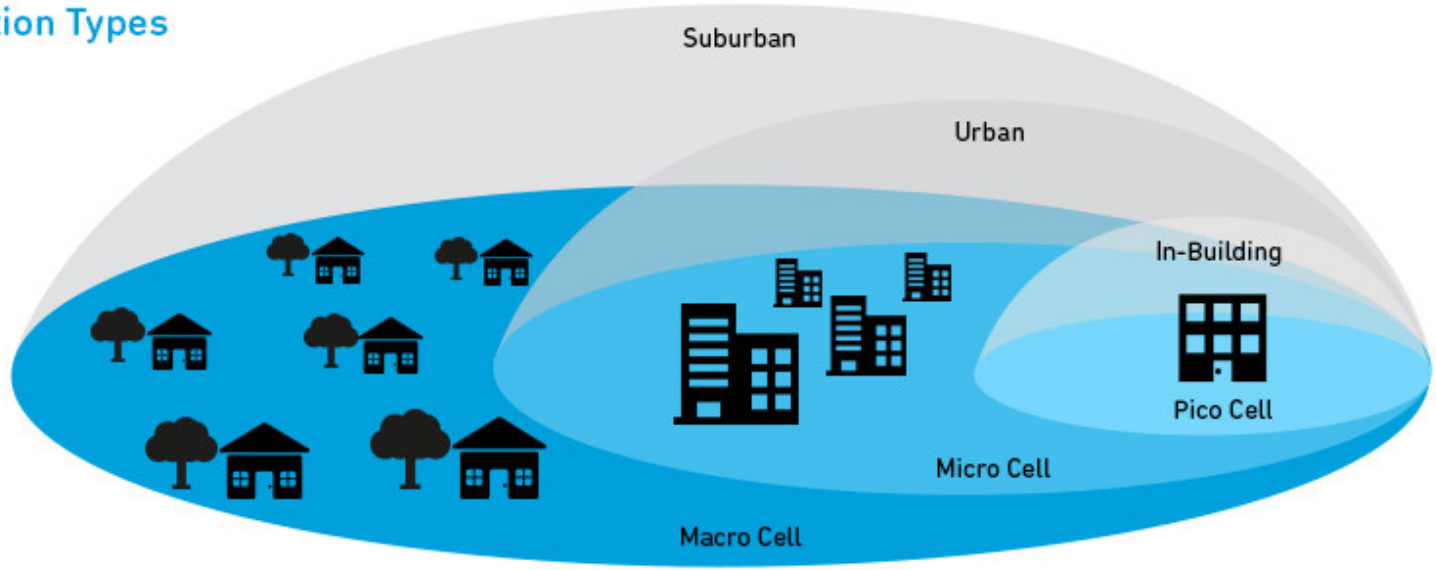
Network Densification

- استفاده از تعداد BS بیشتر
- استفاده از small cell
  - نقاط دسترسی با توان کم در فرکانسهای دارای مجوز
- ترکیب با سلولهای بزرگ و ایجاد شبکه های ناهمگن



Small Cells

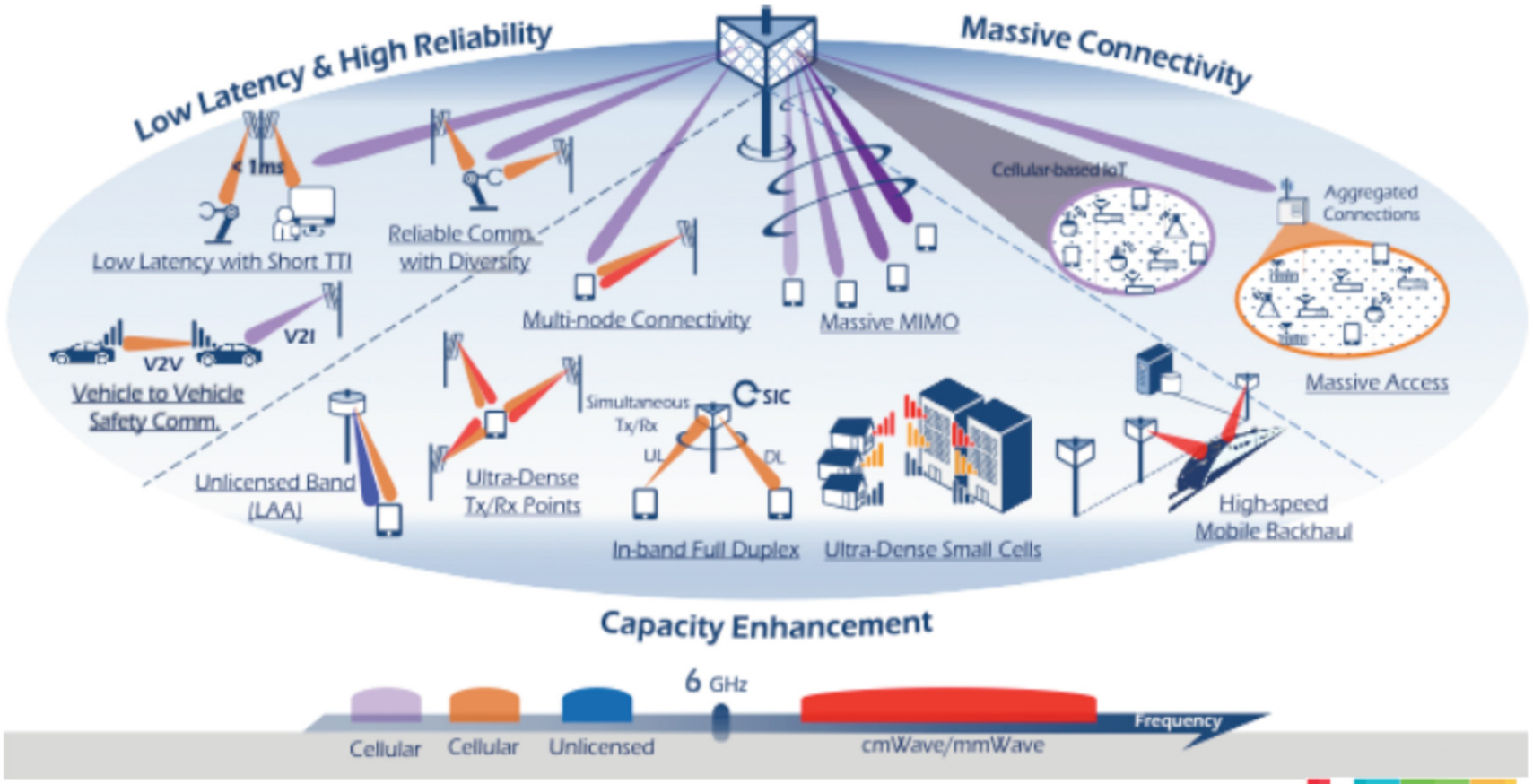
Base Station Types



Cell Type	Output Power (W)	Cell Radius (km)	Users	Locations
Femtocell	0.001 to 0.25	0.010 to 0.1	1 to 30	Indoor
Pico Cell	0.25 to 1	0.1 to 0.2	30 to 100	Indoor/Outdoor
Micro Cell	1 to 10	0.2 to 2.0	100 to 2000	Indoor/Outdoor
Macro Cell	10 to >50	8 to 30	>2000	Outdoor

qorvo

شبکه های ناهمگن Heterogeneous

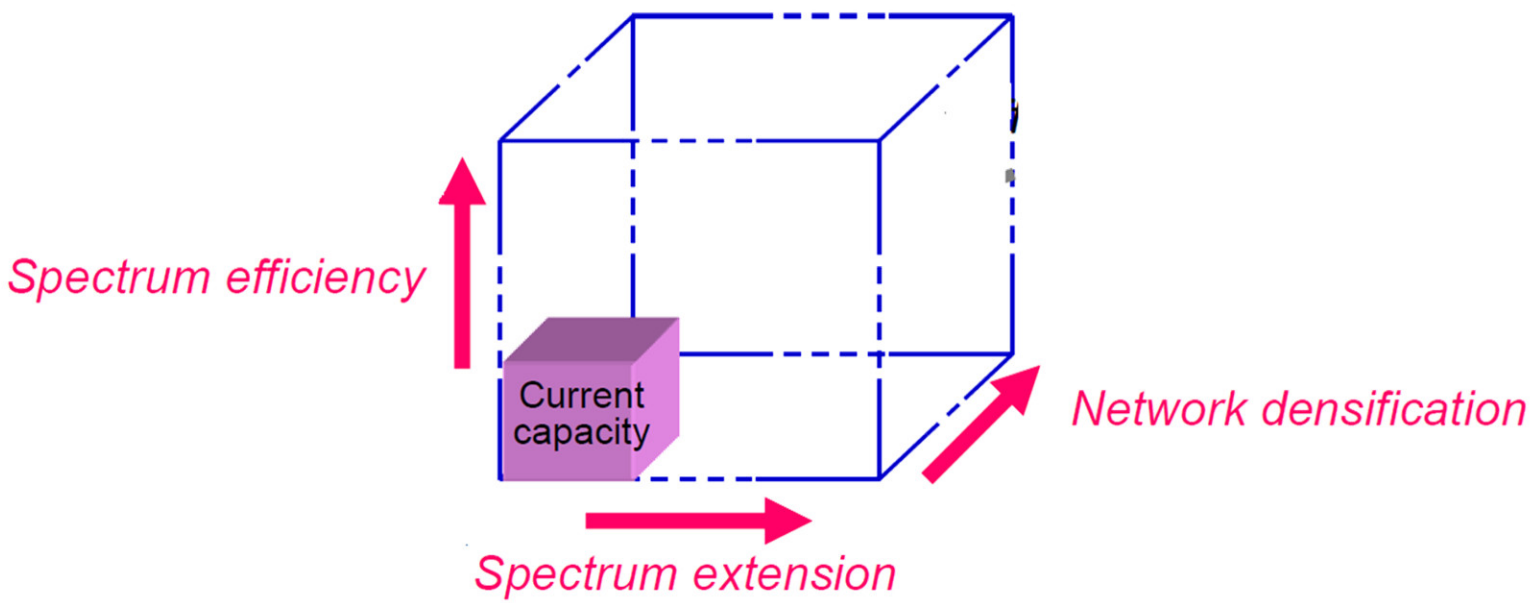


Source: ETRI

Samll Cells

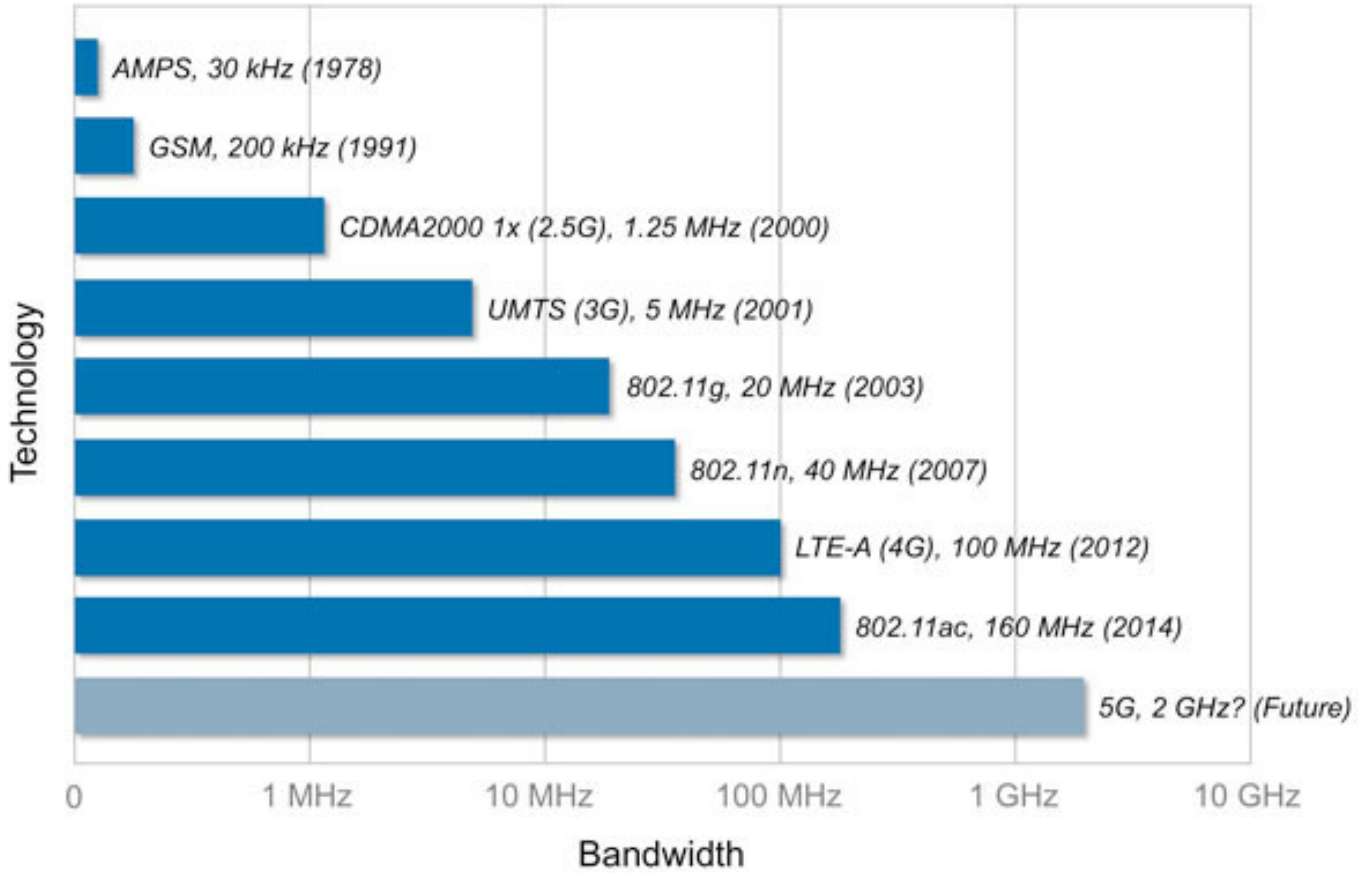
- مزایا:
  - ارسال دیتا با سرعت بیشتر - راندمان طیفی بالاتر
  - ظرفیت بالاتر
  - ابعاد کوچکتر- هزینه نصب پایین تر - جایابی سریع تر
  - سرعت بالای نصب
- معایب:
  - پوشش کمتر
  - بک هال
  - مدیریت تحرک و handoff
  - مدیریت تداخل

1000x Improvement



Spectrum Extension

- **BW requirements?**

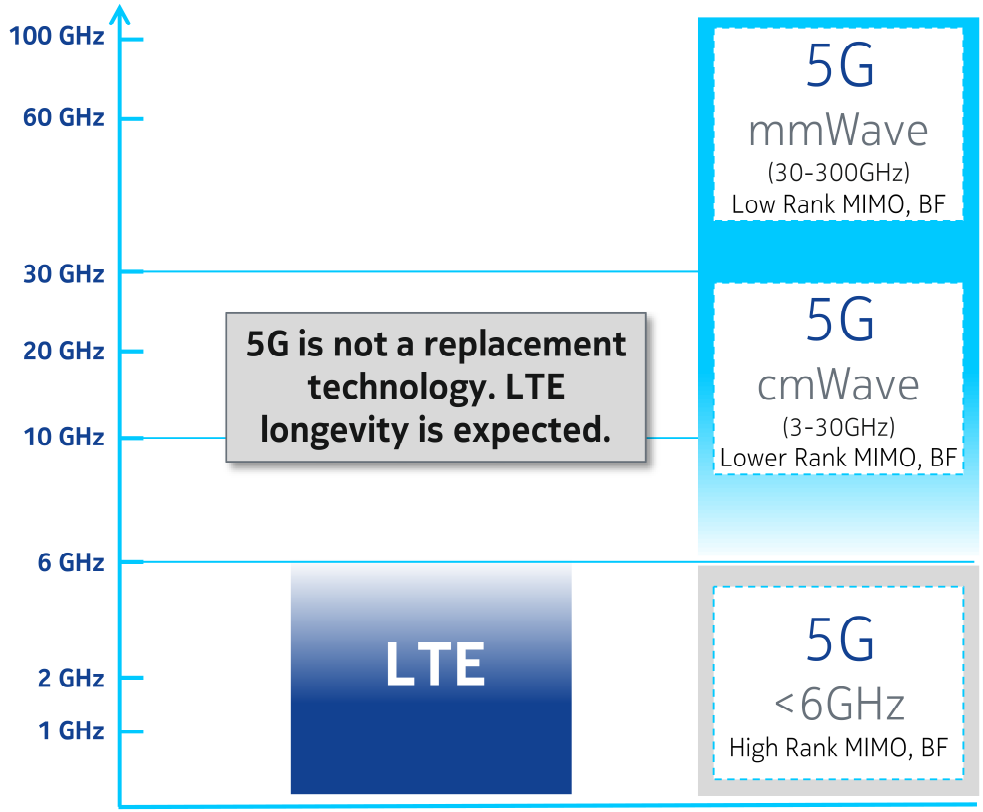


Spectrum Extension

- **BW requirements?**
- **Solutions**
  - **Higher frequencies → millimeter waves**
  - **Unlicensed bands**
  - **Spectrum Aggregation**
  - **Spectrum Sharing**
  - **Cognitive radio**

طیف فرکاسی در 5G

Spectrum

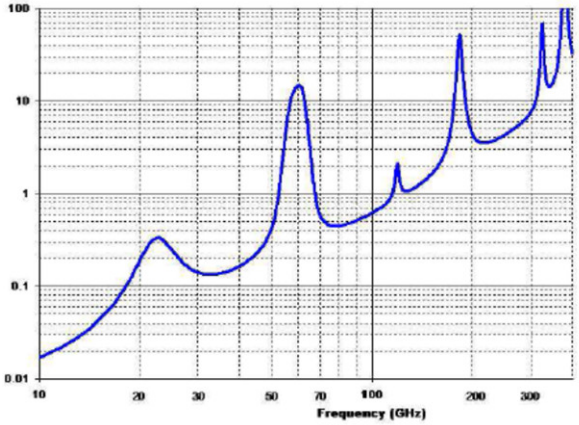


Current Focus

39	US
32	Europe
28	Korea Olympics, US Fixed Access, Japan, EU
4.5	Japan Olympics, China
3.5	China, Europe, Korea, Japan
2.5	Europe, US
1.7, 1.8, 1.9, 2.1	China, US
900	China
700, 800	Europe
600	US

NOKIA Bell Labs

امواج میلیمتری



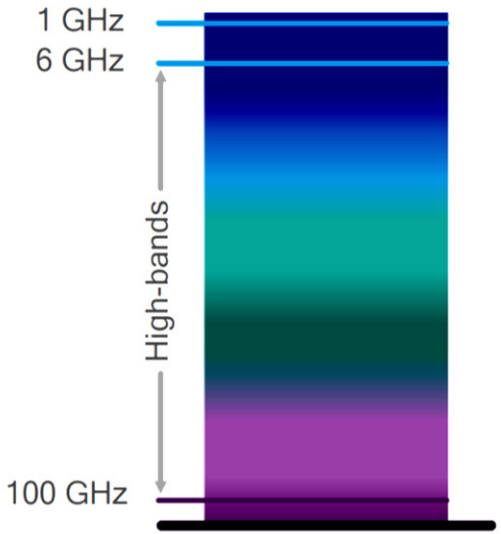
Atmospheric and molecular absorption

- **30 to 300 GHz**
  - **23, 29, 38, 40, 46, 47, 49GHz, and E-band**
- **Already used in LAN, PAN, and VANET**
- **backhaul in cellular networks**

Frequency range	6-20 GHz	20-40 GHz	40-60 GHz	60-100 GHz
Specific bands identified	***10 GHz band*** 10.125-10.225 GHz / 10.475-10.575 GHz	***32 GHz band*** 31.8-33.4 GHz	***40 GHz band*** 40.5-43.5 GHz ***'45 GHz' band*** 45.5-48.9 GHz	**66 GHz band** 66-71 GHz
Potential bandwidth	*2 x100 MHz*	*1.6 GHz*	*5.8 GHz total*	*5 GHz*

Ofcom

امواج میلیمتری



Large bandwidth

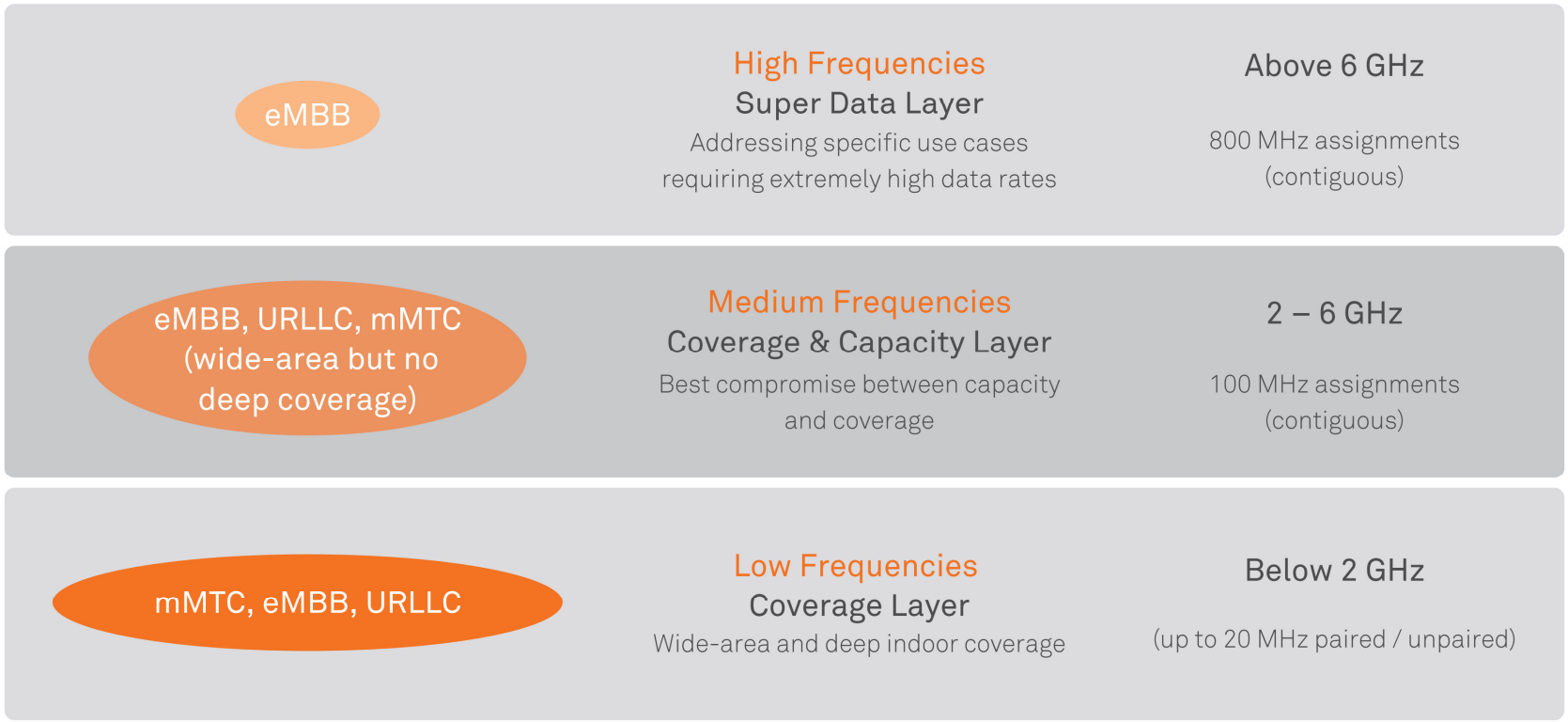
- مزایا
  - پهنای باند زیاد
  - ابعاد کوچک
  - تداخل کم
  - دیتاریت بالا

- معایب
  - مسیر مستقیم و سدشدگی
  - سخت افزار
  - تحرک
  - مصرف توان
  - فاصله
  - چالش های نظیم مقررات

تخصیص چندلایه ای طیف در 5G

- **Coverage and Capacity Layer**
  - در محدوده 2 to 6 GHz
    مصالحه خوب بین پوشش و ظرفیت
- **Super Data Layer**
  - > 6 GHz
  - e.g. 24.25-29.5 and 37-43.5 GHz
- **Coverage Layer**
  - < 2 GH
  - e.g. 700 MHz
  - پوشش وسیع تر و deep indoor

باندهای فرکانسی در 5G

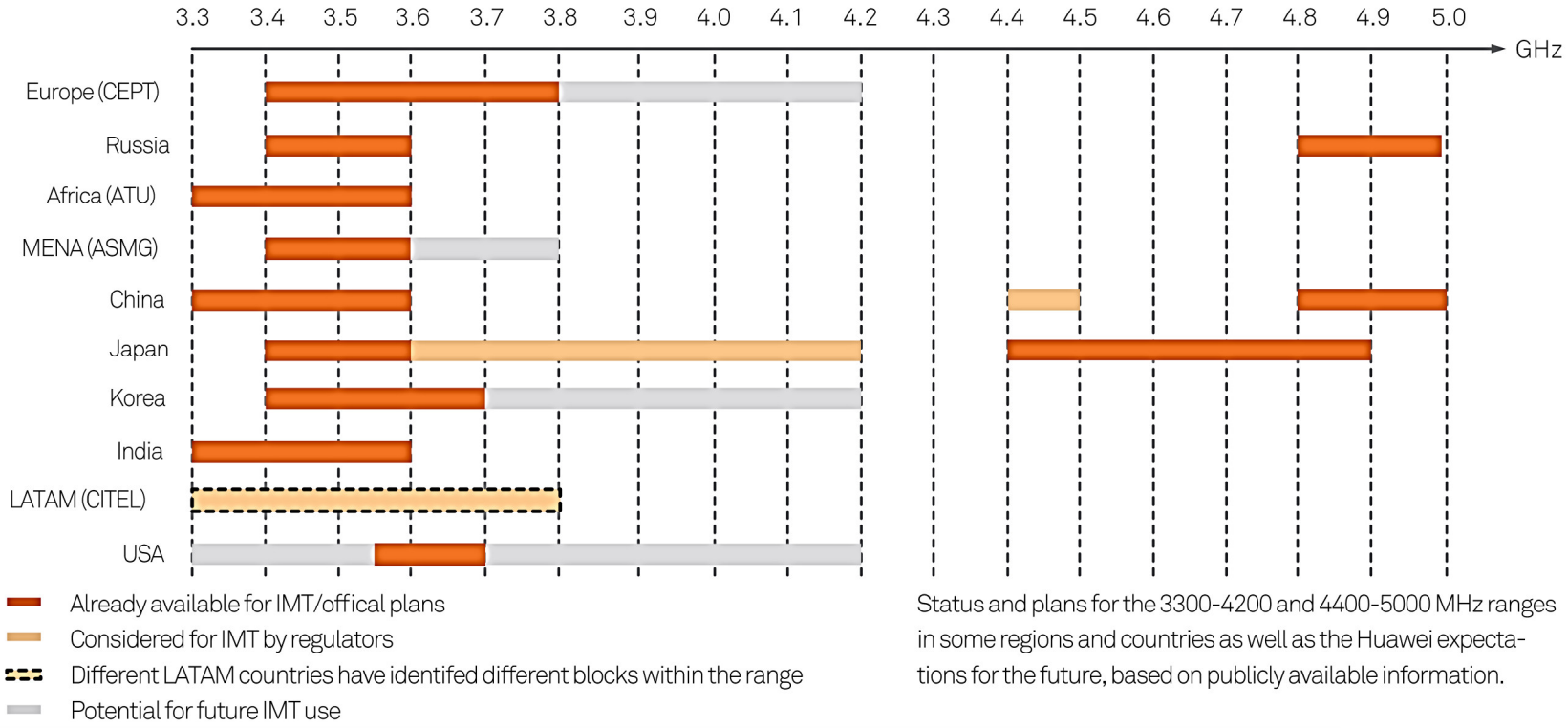


Source: Huawei

باندهای فرکانسی در 5G

- بیشترین توجه
- زیر ۶: باند C – 3300-4200 and 4400-5000 MHz
  - پهنای باند ۱۰۰ مگاهرتز
- میلیمتری: باندهای 24.25–29.5 GHz و 37-43.5 GHz
  - پهنای باند ۴۰۰ مگاهرتز تا ۱ گیگاهرتز
- تعیین باندهای فرکانسی در ITU و 3GPP
- یکی از چالش های اصلی در راه اندازی جهانی 5G

فرکانسهای زیر ۶ گیگاهرتز



Status and plans for the 3300-4200 and 4400-5000 MHz ranges in some regions and countries as well as the Huawei expectations for the future, based on publicly available information.

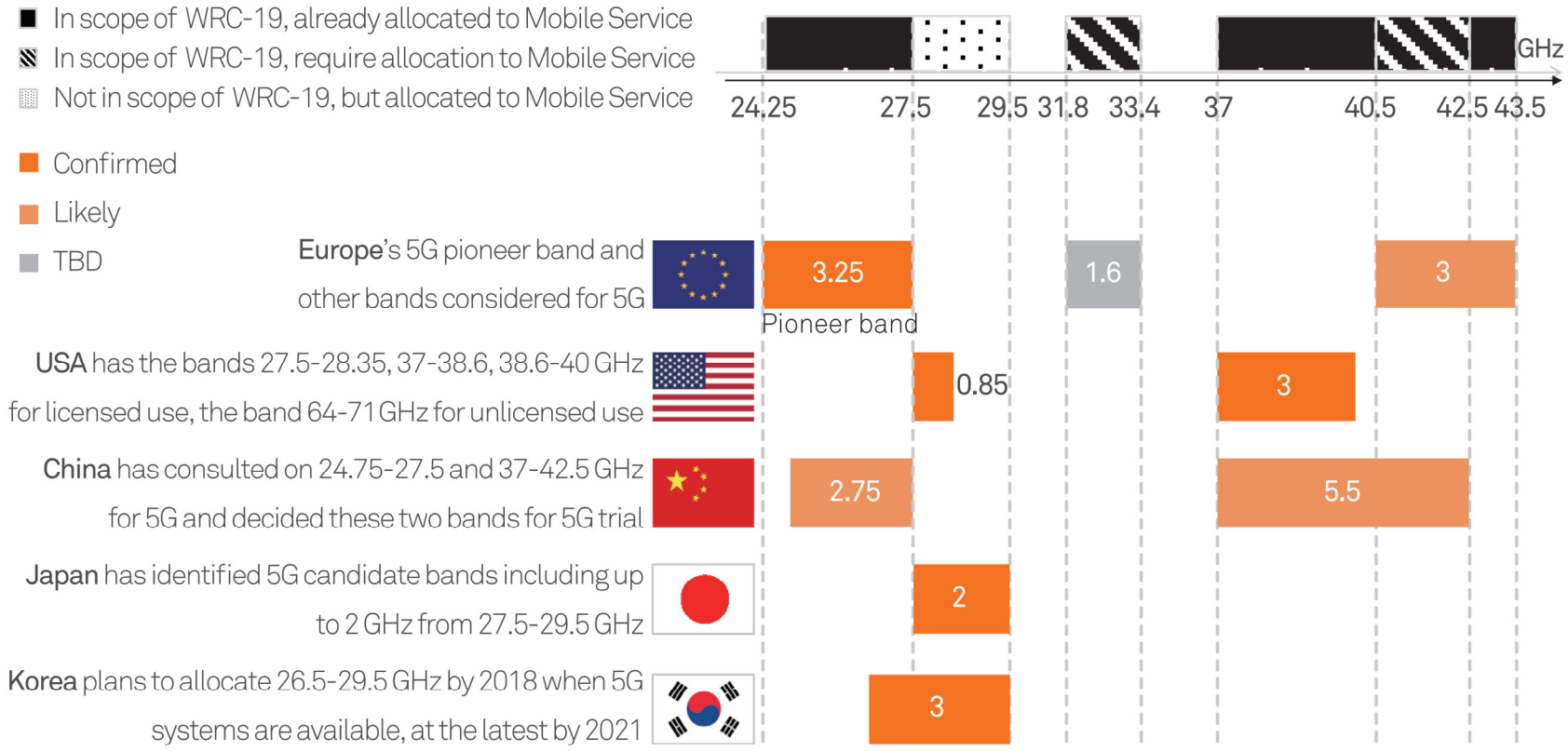
Source: Huawei

فرکانسهای بالای ۶ گیگاهرتز

Group 30 (GHz)	Group 40 (GHz)	Group 50 (GHz)	Group 70/80 (GHz)
24.25-27.5 31.8-33.4	37-40.5 40.5-42.5 42.5-43.5	45.5-47 47-47.2 47.2-50.2 50.4-52.6	66-71 71-76 81-86

Candidate frequency bands of WRC-19 Agenda Item 1.13

فرکانسهای بالای ۶ گیگاهرتز



Frequency bands for early deployment of 5G millimetre wave systems

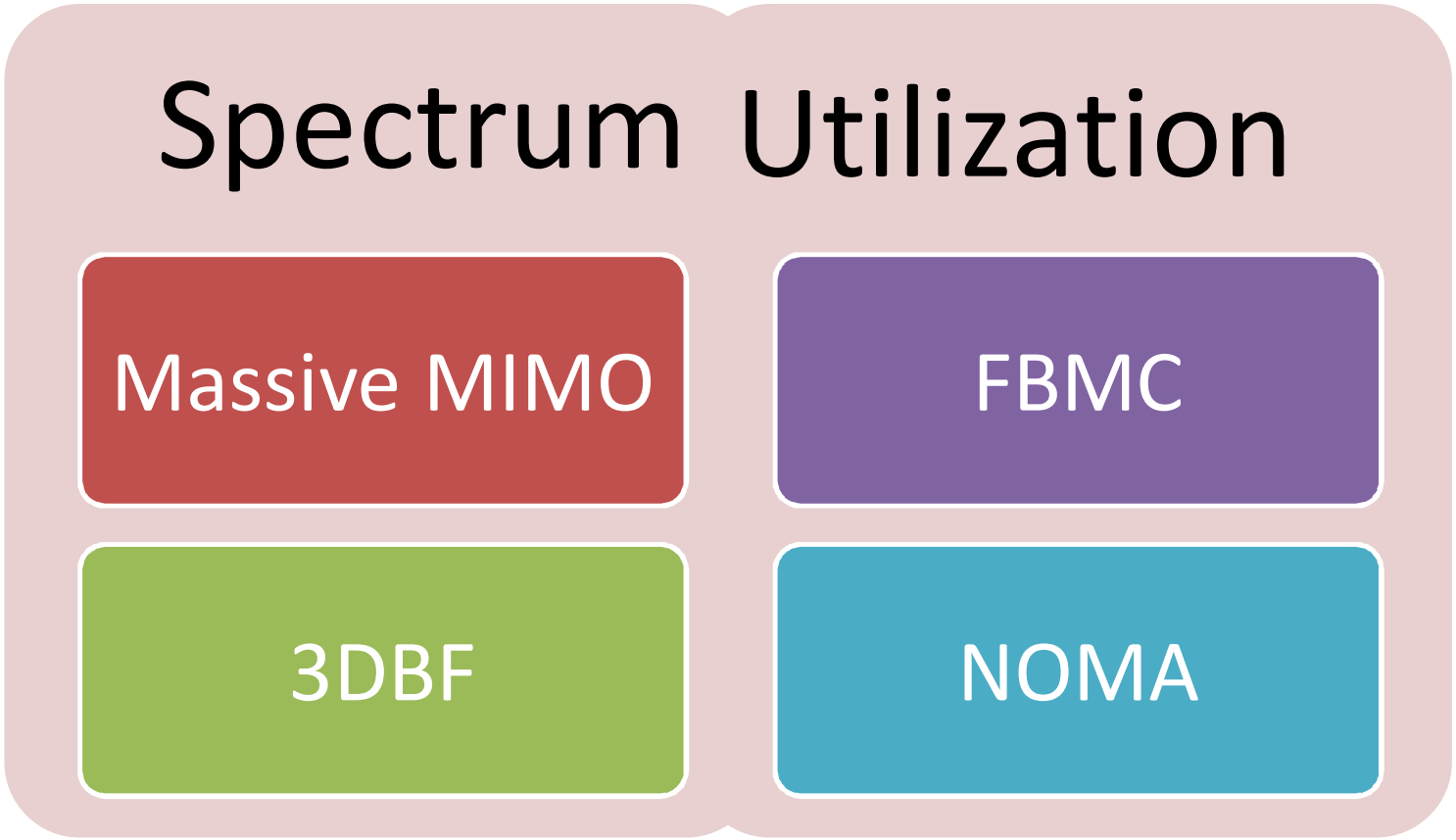
Source: Huawei

باندهای فرکانسی در 5G

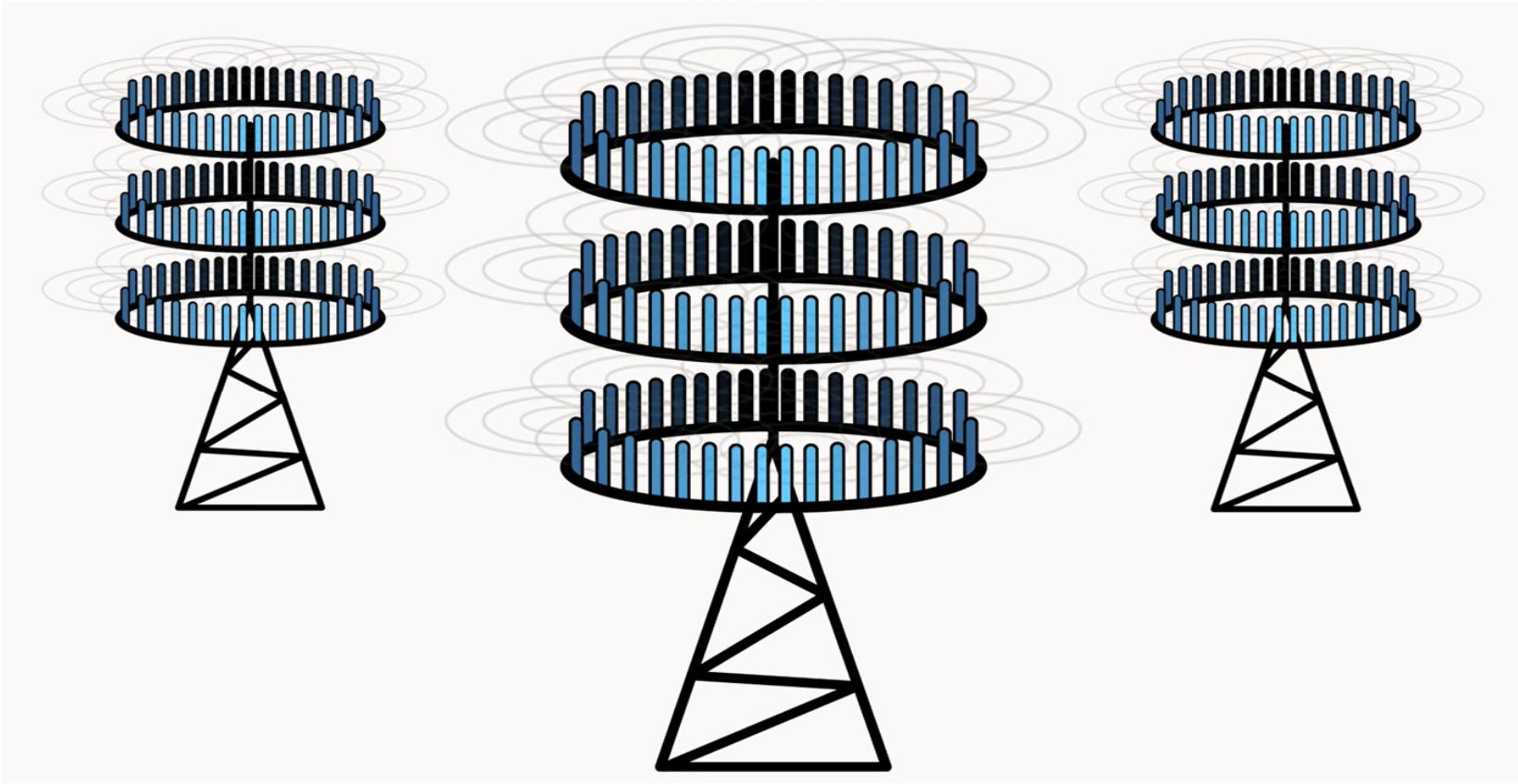
- لزوم هماهنگی با **LTE** در مد عملکردی **NSA**

		LTE Band														
		1	2	3	5	7	8	19	20	21	25	26	28	39	41	66
NR Freq. Range	3.3 GHz–4.2 GHz	YES		YES	YES	YES	YES	YES	YES	YES		YES	YES	YES	YES	
	4.4 G Hz–4.99 GHz	YES		YES	YES		YES	YES		YES		YES	YES	YES	YES	
	24.25 GHz–29.5 GHz	YES		YES	YES	YES	YES	YES	YES	YES		YES	YES	YES	YES	YES
	31.8 GHz–33.4 GHz			YES		YES			YES				YES			
	37 GHz–40 GHz															YES
	Band 7			YES			YES		YES							
	Band 28			YES		YES			YES							
	Band 41	YES	YES	YES	YES						YES	YES			YES	

راه کارهای رادیویی در 5G



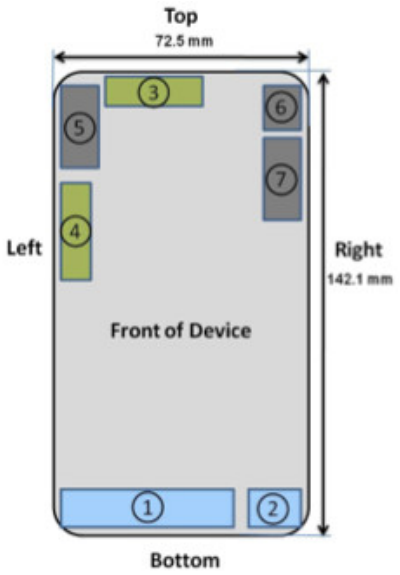
مایمو انبوه



Massive MIMO

Multiple Input Multiple Output

MIMO



1. **Main Antenna (Tx/Rx)**
   - CDMA/EVDO BC0/1/10
   - 850/1900 MHz GSM/GPRS/EDGE
   - UMTS Band 2/5
   - LTE Band 25/26
2. **LTE B41 Main Antenna (Tx/Rx)**
3. **BT/WLAN Antenna #1 (Tx/Rx)**
   - 2.4 GHz BT/WIFI
   - 5 GHz WIFI
4. **WLAN Antenna #2 (Tx/Rx)**
   - 2.4 GHz WIFI
   - 5 GHz WIFI
5. **MRD Antenna (Rx Only)**
6. **GPS Antenna (Rx Only)**
7. **LTE B41 Sub Antenna (Rx Only)**

MIMO Advantages and Techniques

Spectral efficiency

Diversity and link reliability

Space-Time Coding

Spatial Multiplexing

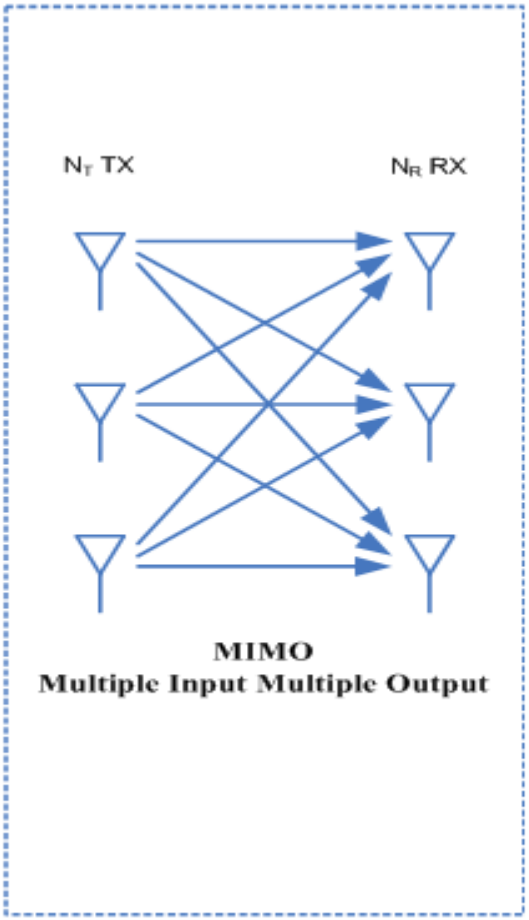
Beamforming (Precoding)

$$\text{Rate} \sim \min(n_r, n_t)\log(1+\text{SNR}) \quad \text{Reliability } p_e \sim \text{SNR}^{-n_r n_t}$$

Diversity Gain

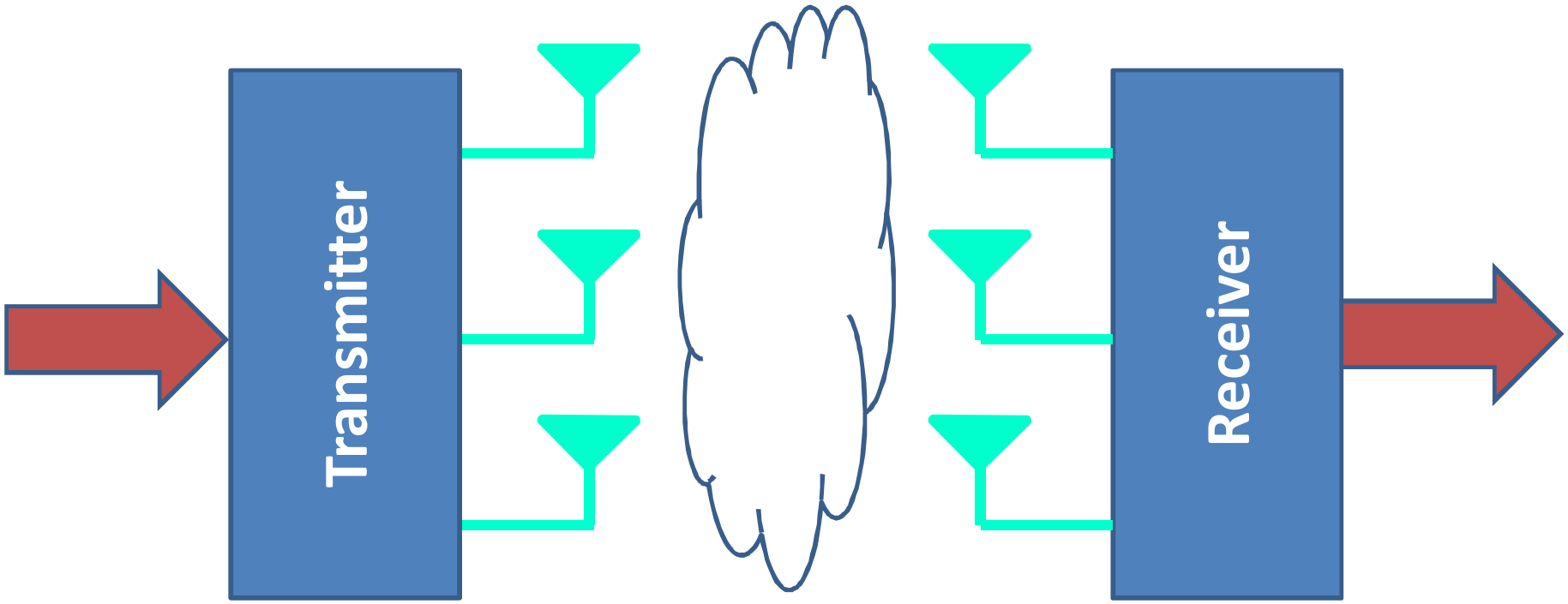
Multiplexing Gain

Array Gain

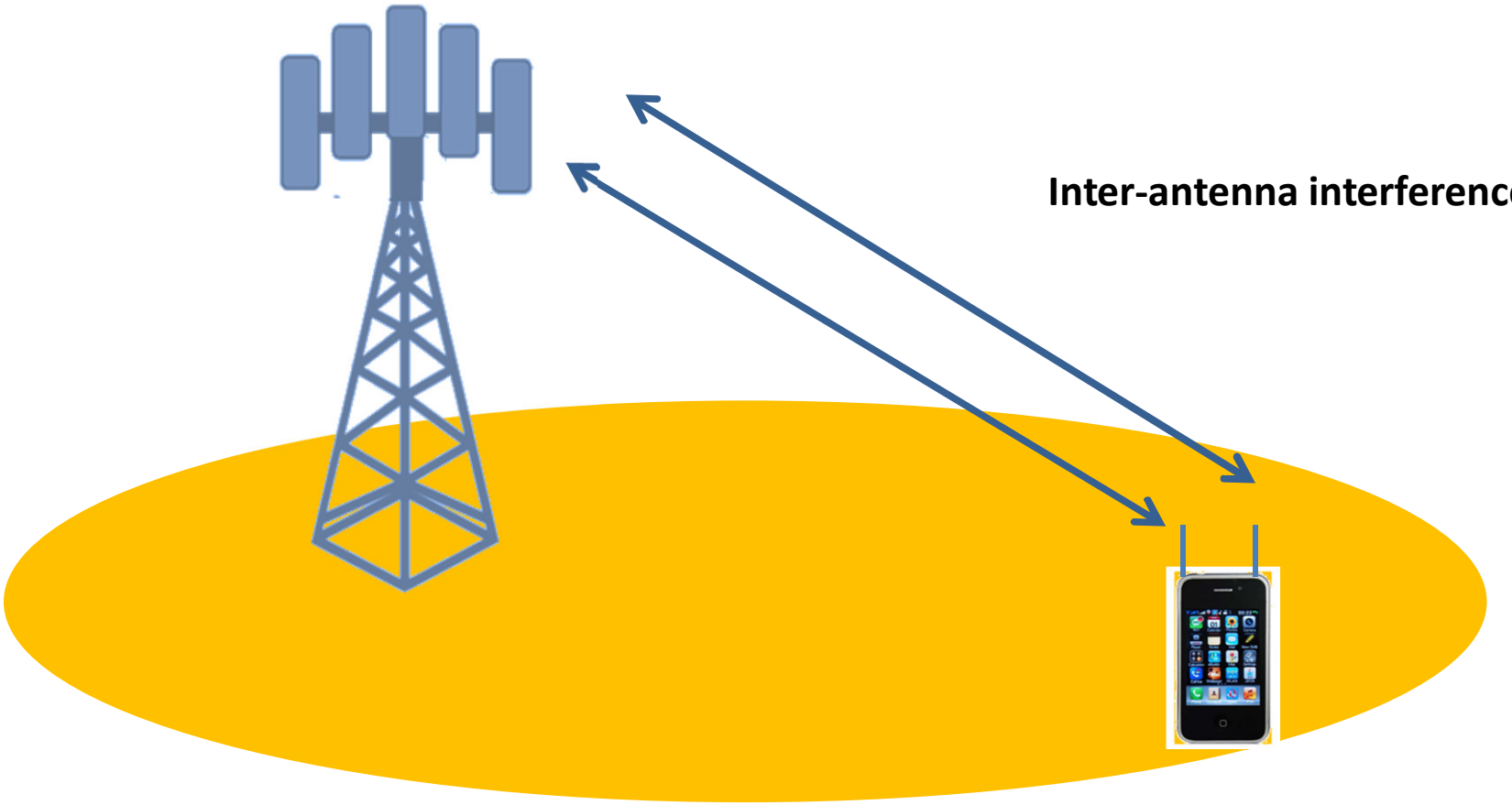


MIMO Categories

- Point –to-Point MIMO

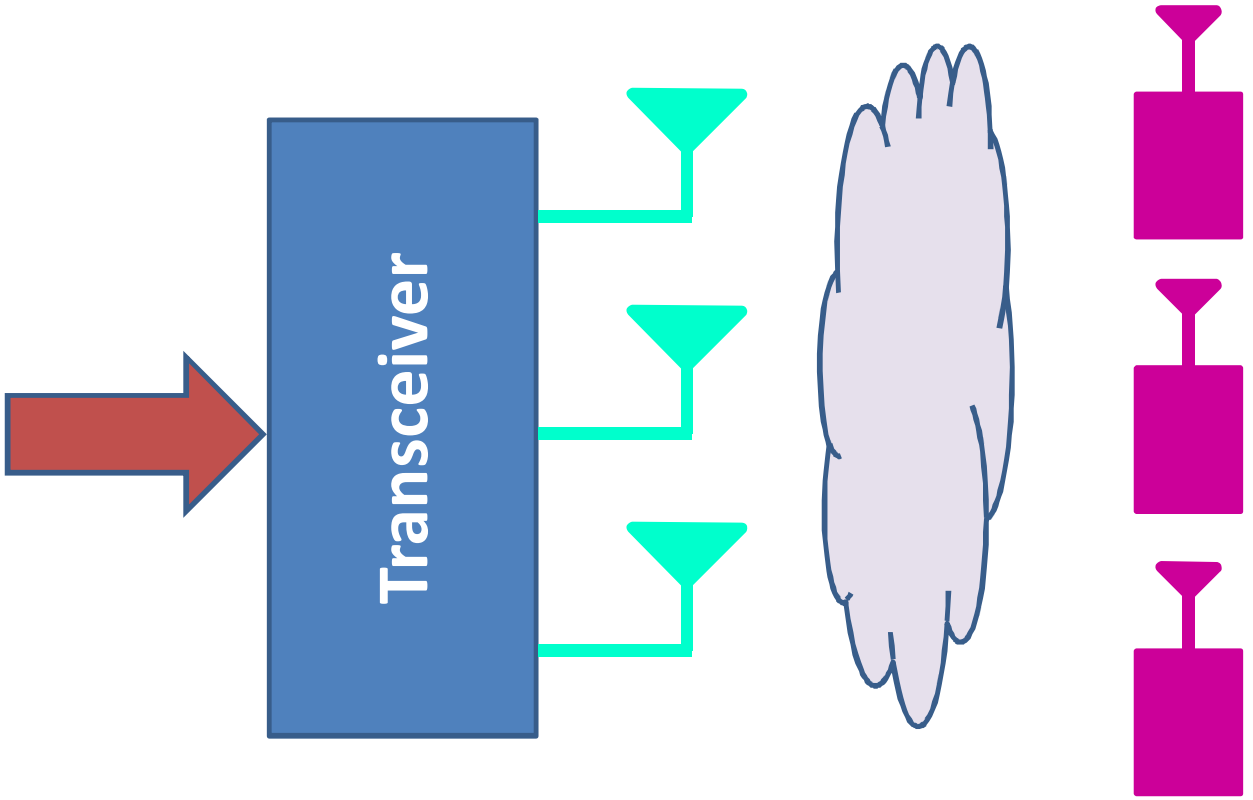


Single user MIMO



MIMO Categories

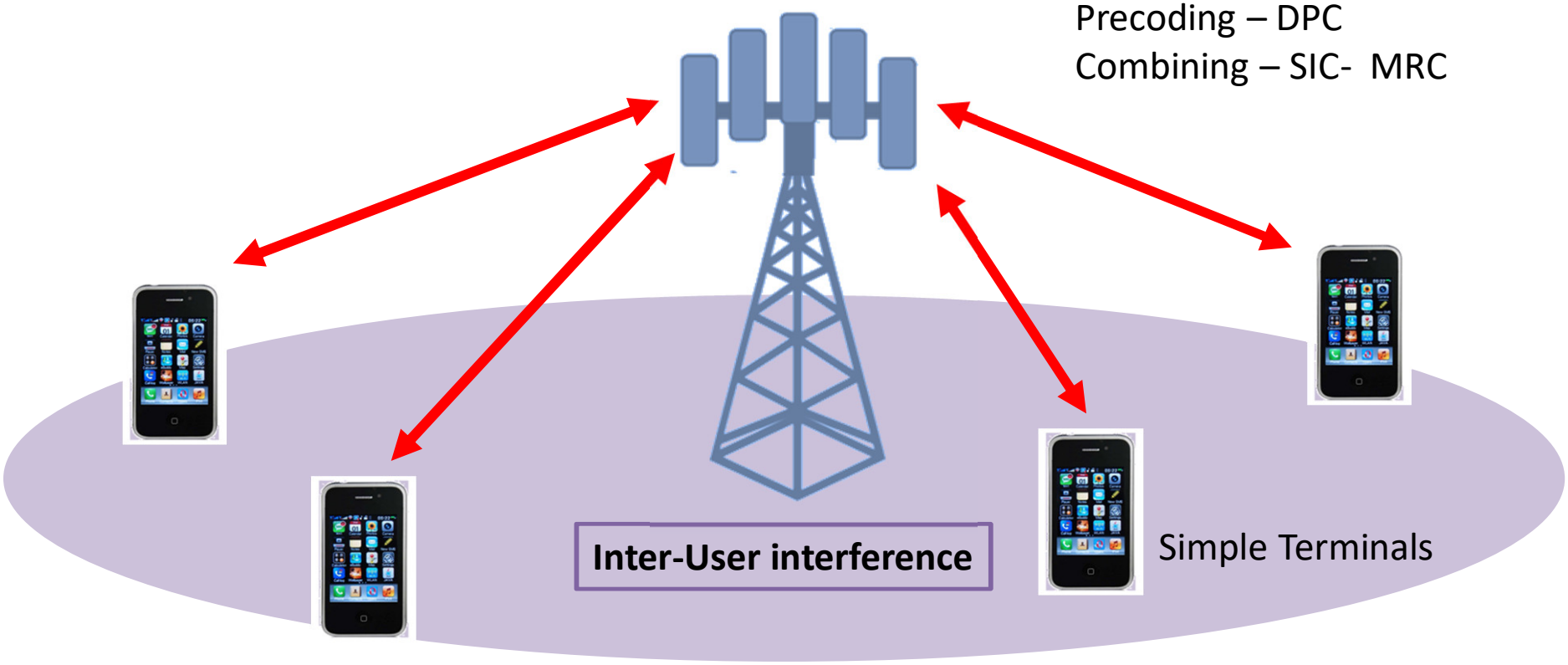
- Point to Mutil-Point MIMO (BC)
- Mutil-Point to Point MIMO (MAC)



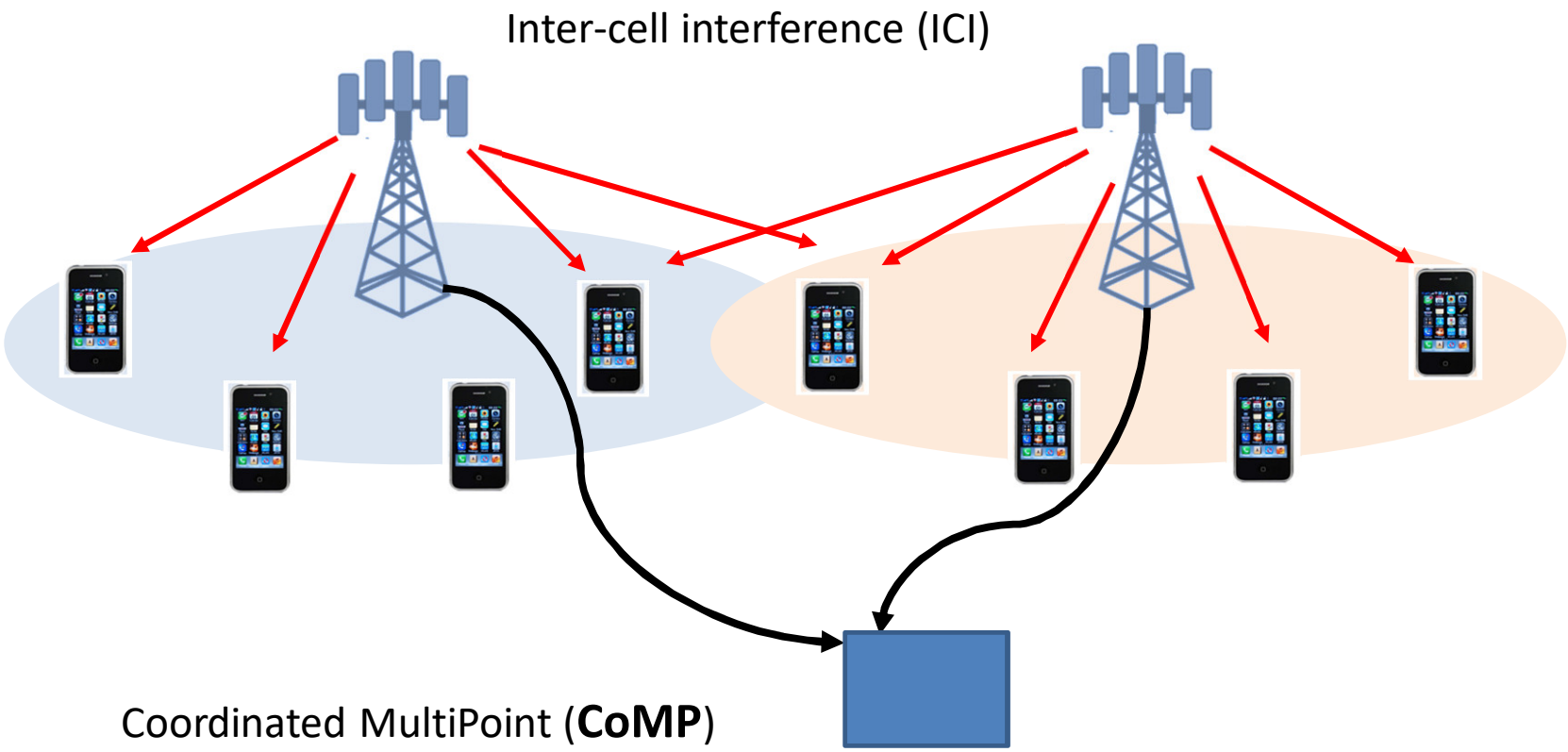
Multiuser MIMO

multiple data streams to multiple single antenna users

Expensive BS
Precoding – DPC
Combining – SIC- MRC



Multi-cell MIMO (Network MIMO)



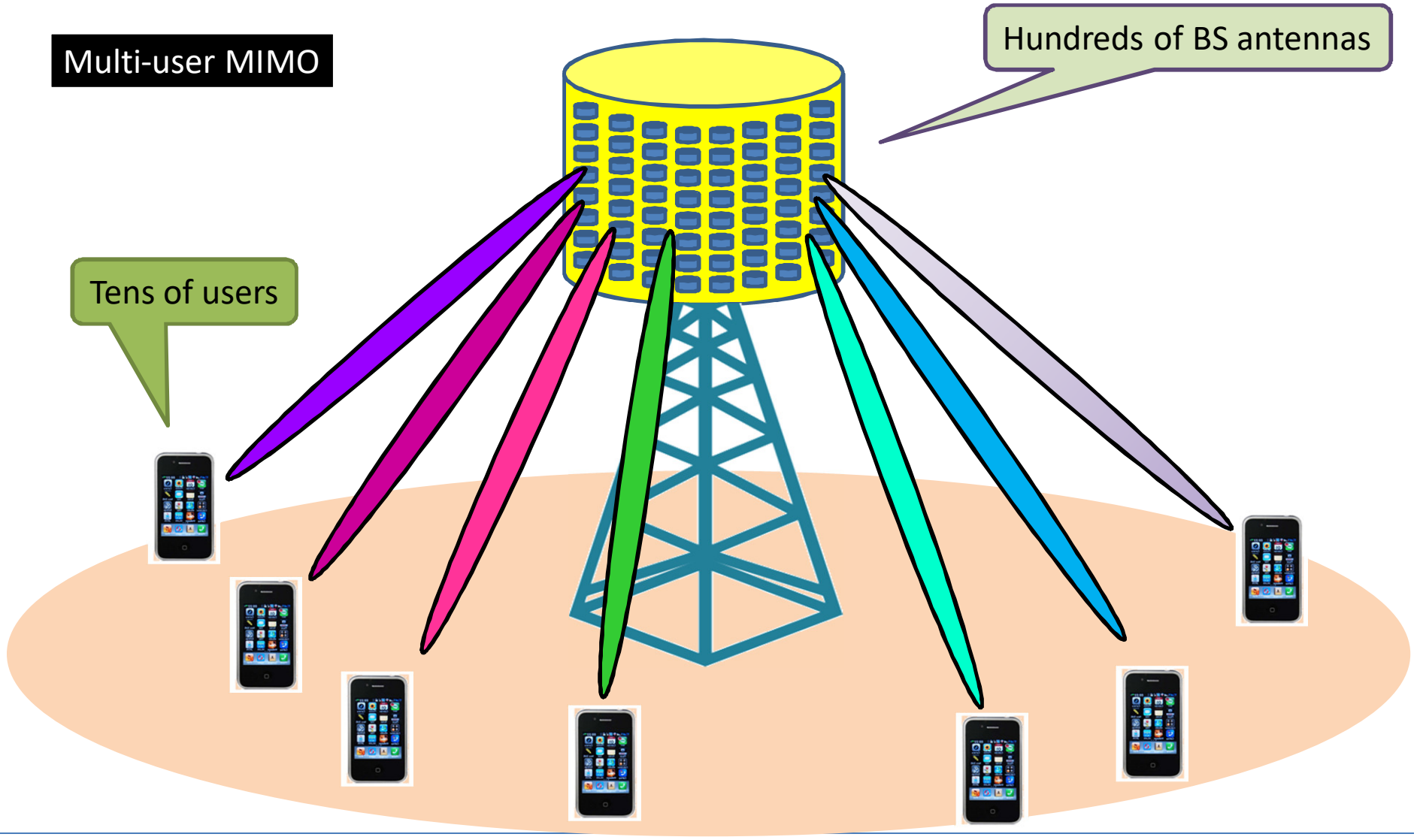
مایمو در 3GPP

Release 8	Release 9	Release 10	Release 11
• 4x4MIMO • 4x2MIMO • 8RX uplink • Uplink CRAN	• 8TX TM8	• 8TX TM9	• Downlink CoMP (TM10)

Release 12	Release 13	Release 14	Release 15+
• Downlink eCoMP • New 4TX codebook	• Massive MIMO 16TX	• Massive MIMO 32TX	• 5G massive MIMO 64TX+

NOKIA

Massive MIMO



مزایای MaMIMO

MaMIMO vs. Classic MuMIMO

	Classic multi-user MIMO	Massive MIMO (Canonical)
Antennas M, users K	$M \approx K$	$M \gg K$
Signal processing	Non-linear is preferred	Linear is near optimal
Duplexing mode	Designed for TDD and FDD	Designed for TDD w. reciprocity
Instantaneous channel	Known at BS and user	Only needed at BS (hardening)
Channel quality	Affected by frequency-selective and fast fading	Almost no channel quality variations (hardening)
Variations in user load	Scheduling needed if $K > M$	Scheduling seldom needed
Resource allocation	Rapid due to fading	Only on a slow time scale
Cell-edge performance	Only good if BSs cooperate	Improved by array gain of M
BS cooperation	Highly beneficial if rapid	Only long-term coordination

راندمان طیفی

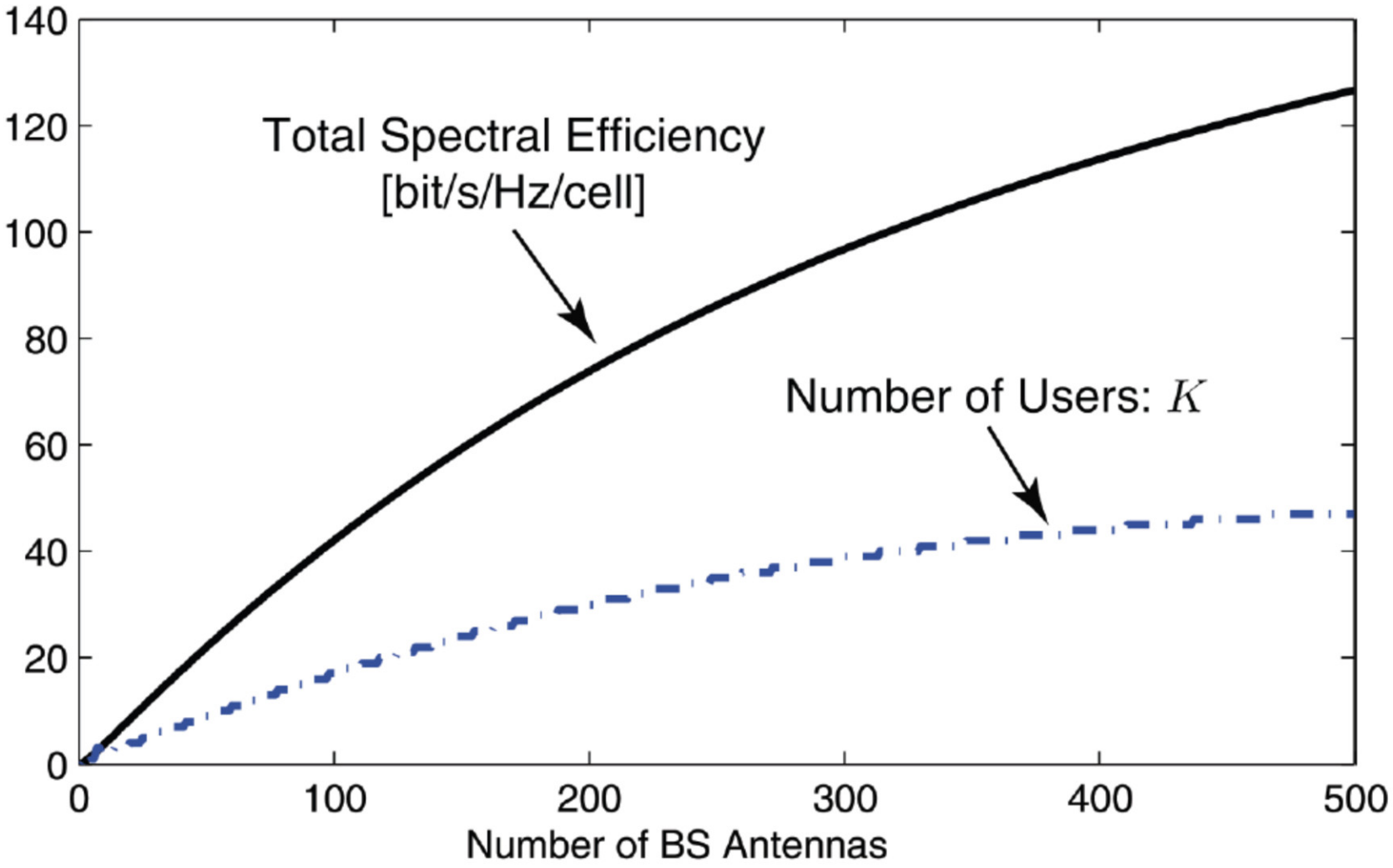
3590 IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 9, NO. 11, NOVEMBER 2010

Noncooperative Cellular Wireless with Unlimited Numbers of Base Station Antennas

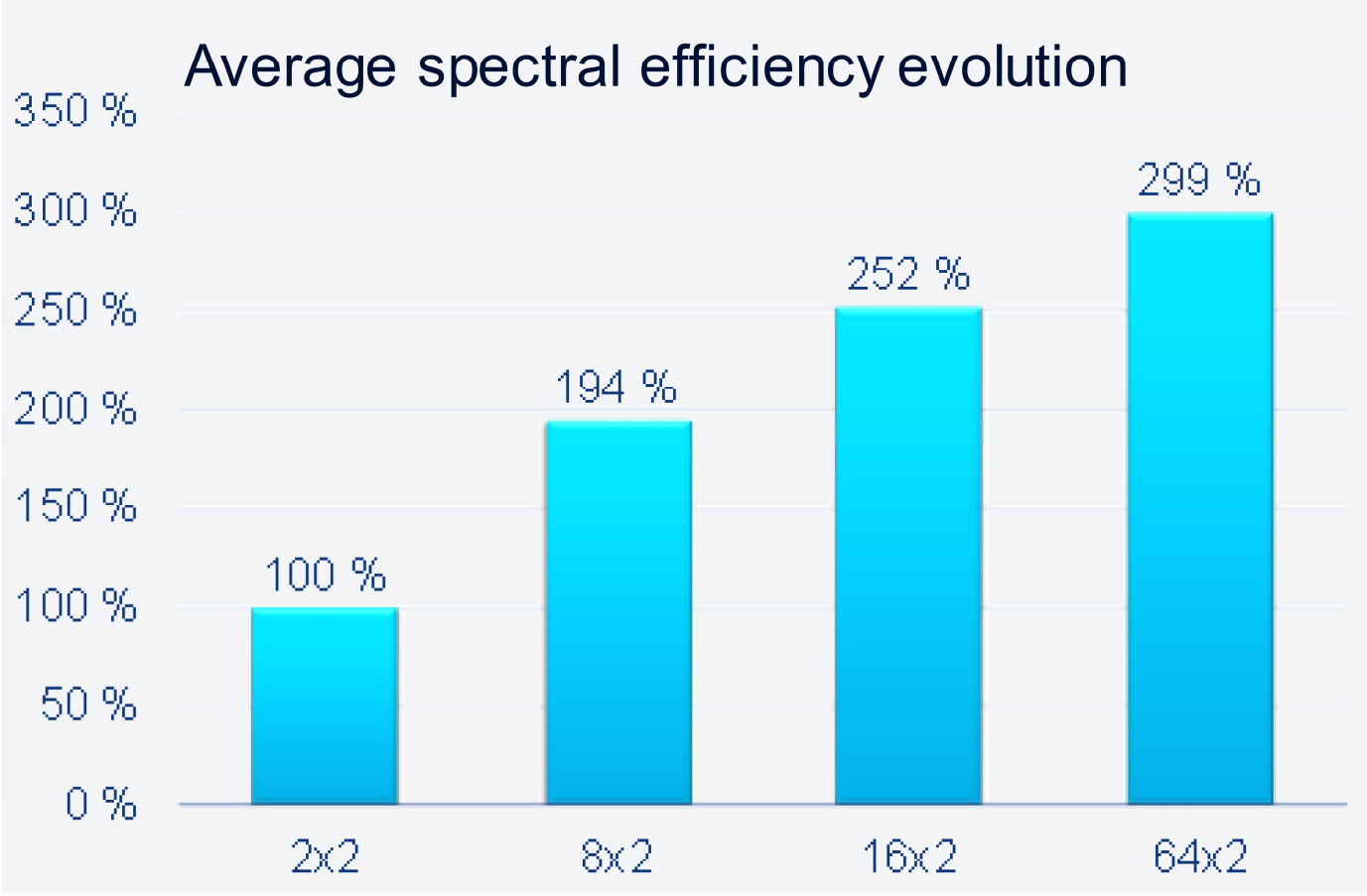
Thomas L. Marzetta

- **Example:**
  - **MF, non-cooperative**
  - **40 users, 20 MHz BW**
  - **17 Mbps each (both UL and DL)**
  - **730 Mbps total**
  - **Spectral efficiency : 26.5 bps/Hz**

بهبود راندمان طیفی

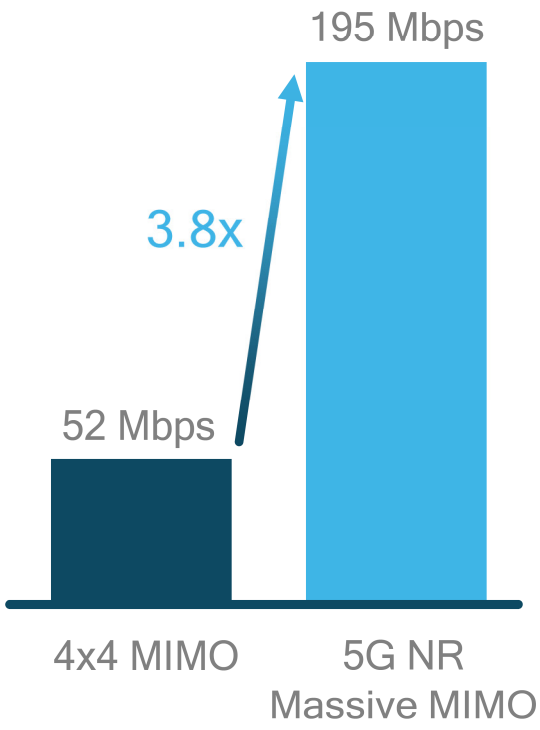


بهبود راندمان طیفی

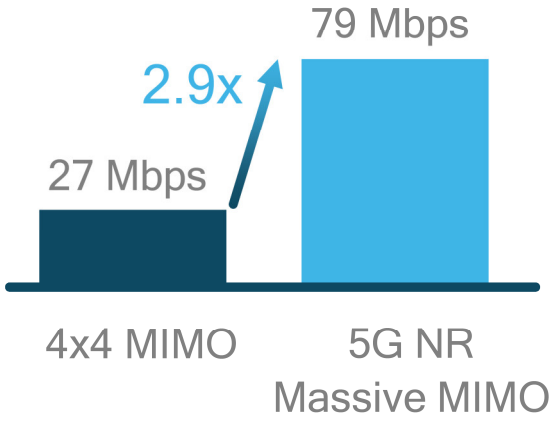


مایمو انبوه

Median user
perceived throughput



Cell edge user
perceived throughput

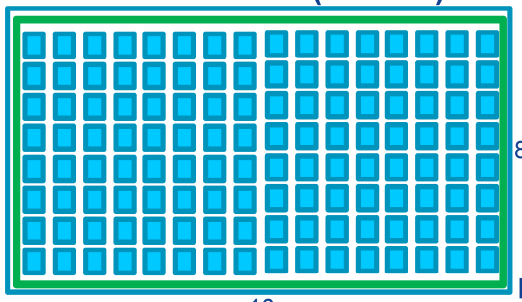


ابعاد آرایه ها

5dBi ant element gain, 7dBm AP Pout per element, 1dBm UE Pout per element, shown to scale

28 GHz
256 elements (8x16x2)

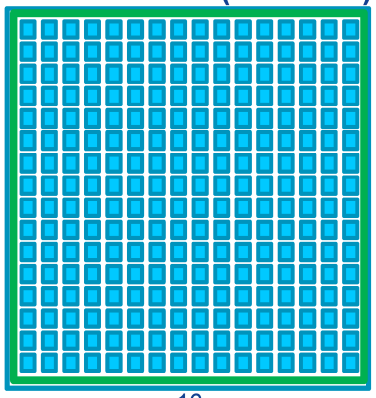
AP



2 TXRUs

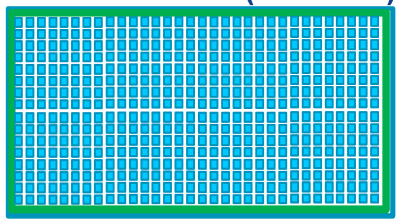
Max EIRP ≈ 60.2 dBm

39 GHz
512 elements (16x16x2)



Max EIRP ≈ 66.2 dBm
103% area relative to 28GHz

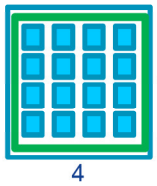
73 GHz
1024 elements (16x32x2)



Max EIRP ≈ 72.2 dBm
59% area relative to 28GHz
Room to grow…normalized array size is ~4.5dBm more than above

28 GHz, 32 elements, (4x4x2)

UE



2 TXRUs

Max EIRP ≈ 36.1 dBm

39 GHz, 32 elements, (4x4x2)

Max EIRP ≈ 36.1 dBm
52% area relative to 28GHz

73 GHz, 32 elements, (4x4x2)

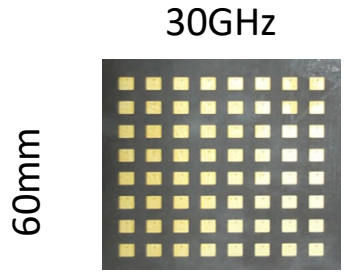
Max EIRP ≈ 36.1 dBm
15% area relative to 28GHz

NOKIA

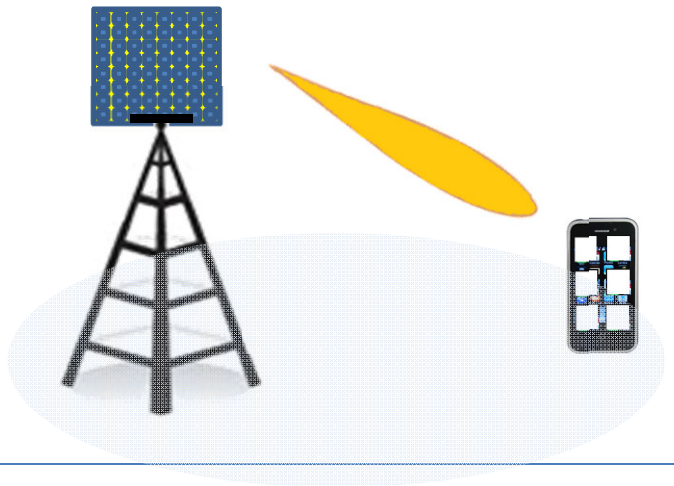
17

مایمو انبوه و موج میلیمتری

- **mmWave for Massive MIMO**
  - **Wavelength and coherence time**
  - **Velocity**
  - **Array size**
- **Massive MIMO for mmWave**
  - **Path loss**
  - **Blockage**
- **mmW is not necessary for MaMIMO**
  - **f = 2GHz (15cm)**
  - **400 dual-polarized antennas**
  - **1.5 x 1.5 m array**

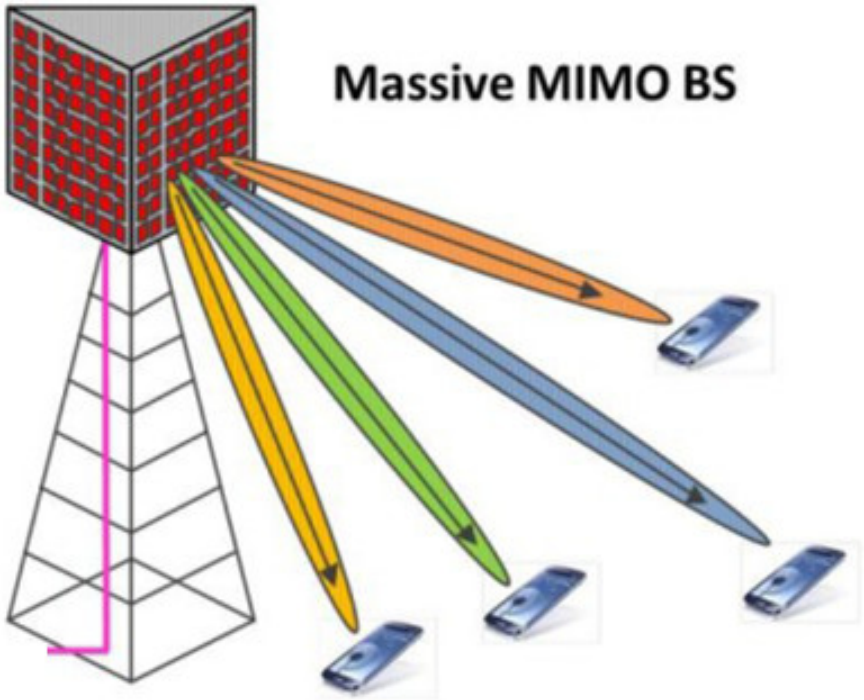


Fujitsu



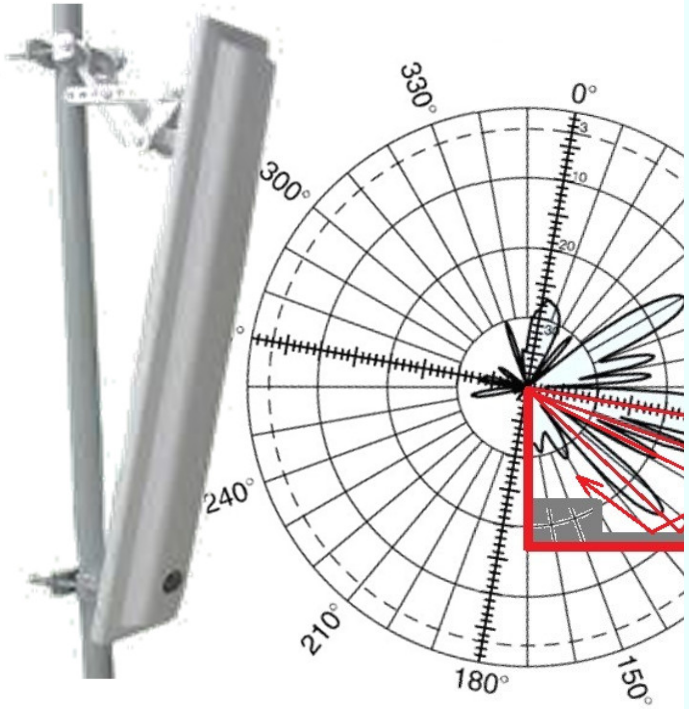
شکل دهی پرتو سه بعدی 3DBF

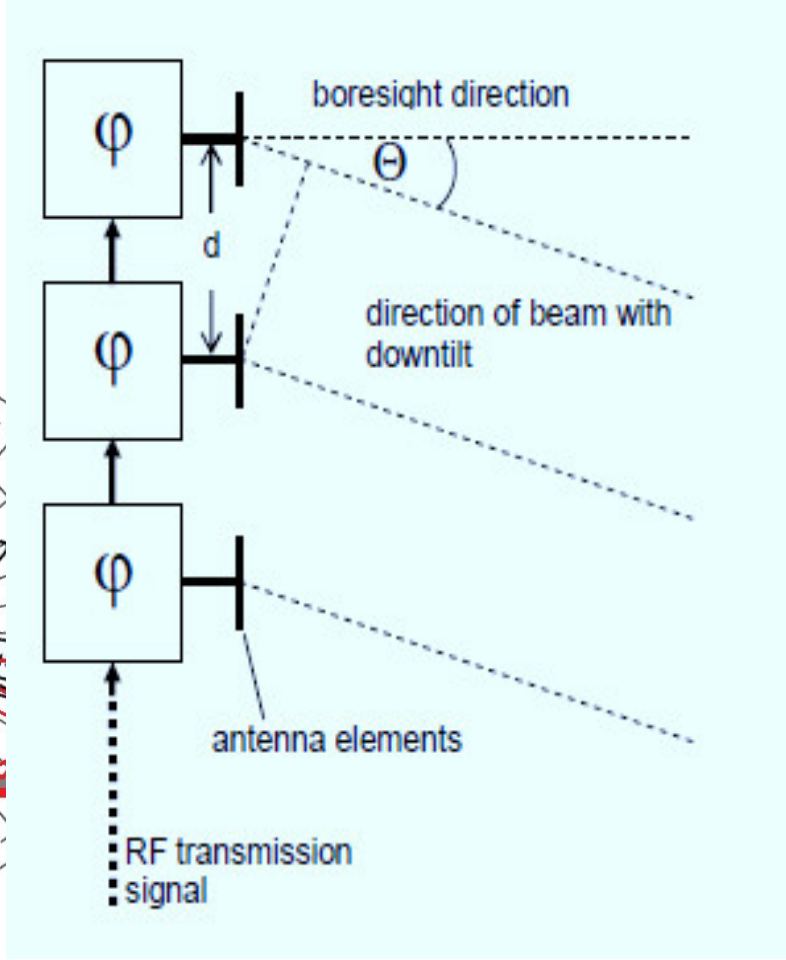
- Three dimensional Beamforming (elevation & azimuth)
- Full dimensional array
- 3GPP Release 13 for LTE



شکل دهی پرتو سه بعدی 3DBF

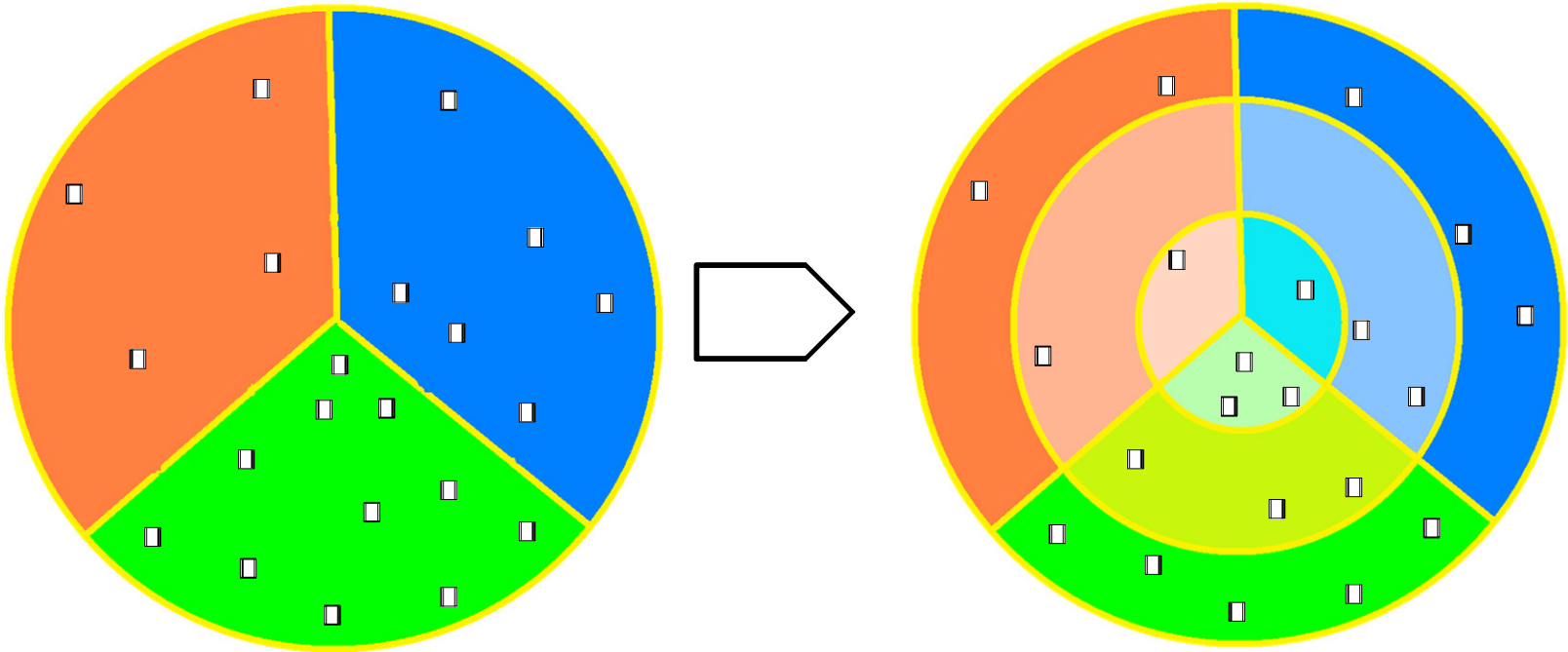
- **Mechanical tilting**
- **Electrical tilting**



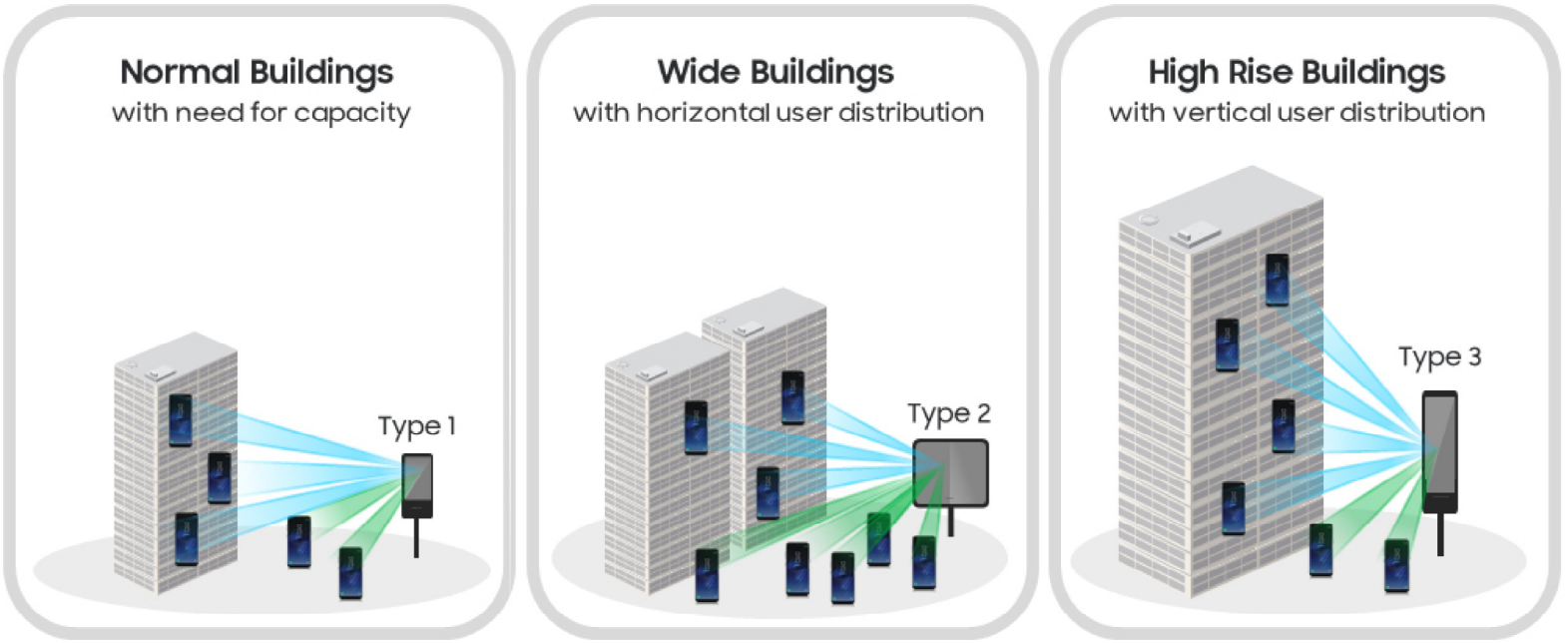


3D Beamforming

- **Higher order Sectorization**

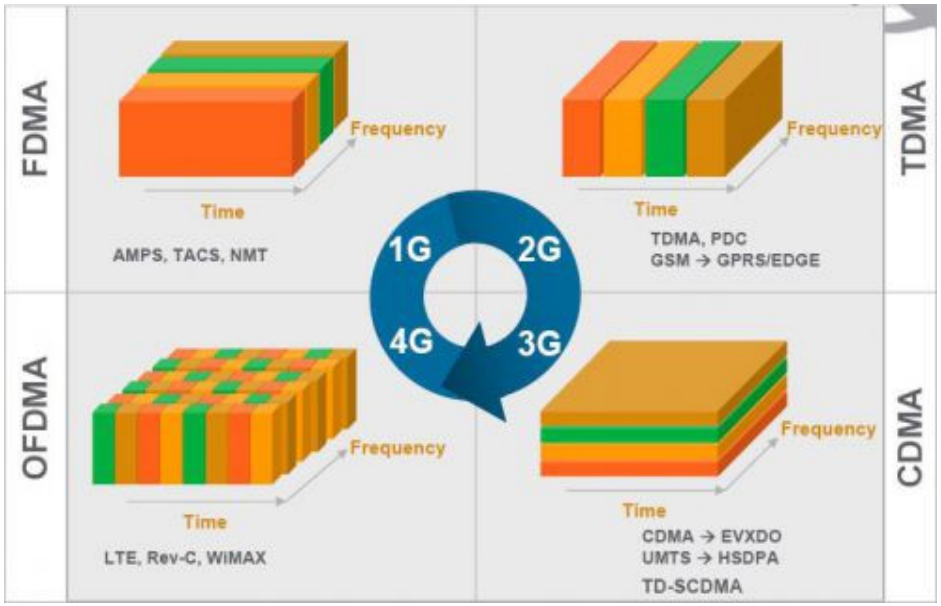


شکل دهی پرتو سه بعدی 3DBF



Source: Samsung

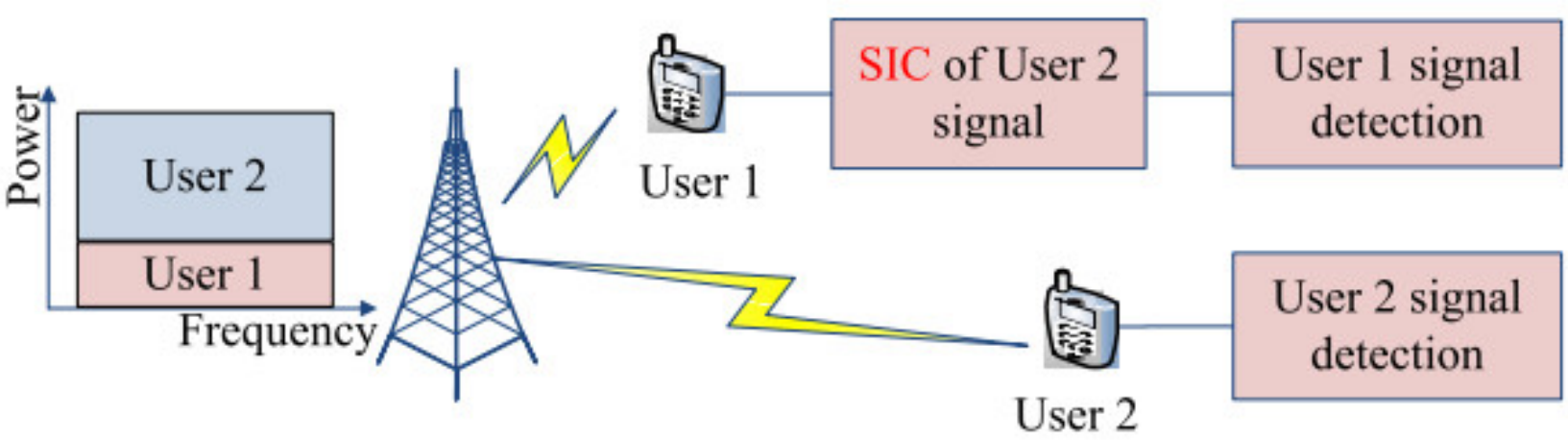
NOMA



- دستیابی چندگانه
- دستیابی چندگانه متعامد OMA
- چالش‌های عمده OMA
  - محدود بودن تعداد منابع متعامد
  - بی‌عدالتی کاربری و تاخیر زیاد
  - تخریب تعامد در اثر اختلالات ناشی از کانال

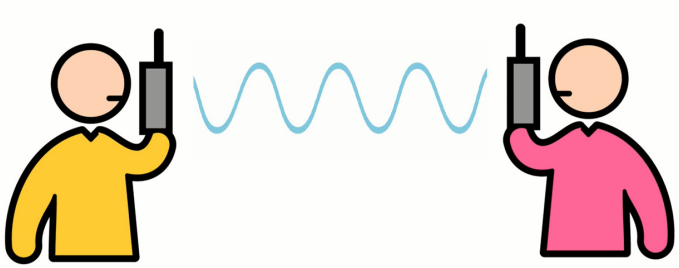
NOMA

- تخصیص منبع غیر متعامد برای کاربران
  - حوزه توان: اشتراک توان هر زیرحامل بین کاربران مختلف به صورت غیر متعامد
  - حوزه کد: رشته‌های کد تنک مخصوص به هر کاربر



سایر فناوری های رادیویی در 5G

- Enhanced Carrier aggregation
- FBMC
- Coordinated Multipoint
- Cognitive Radio
- In-band full duplex
- AI in 5G

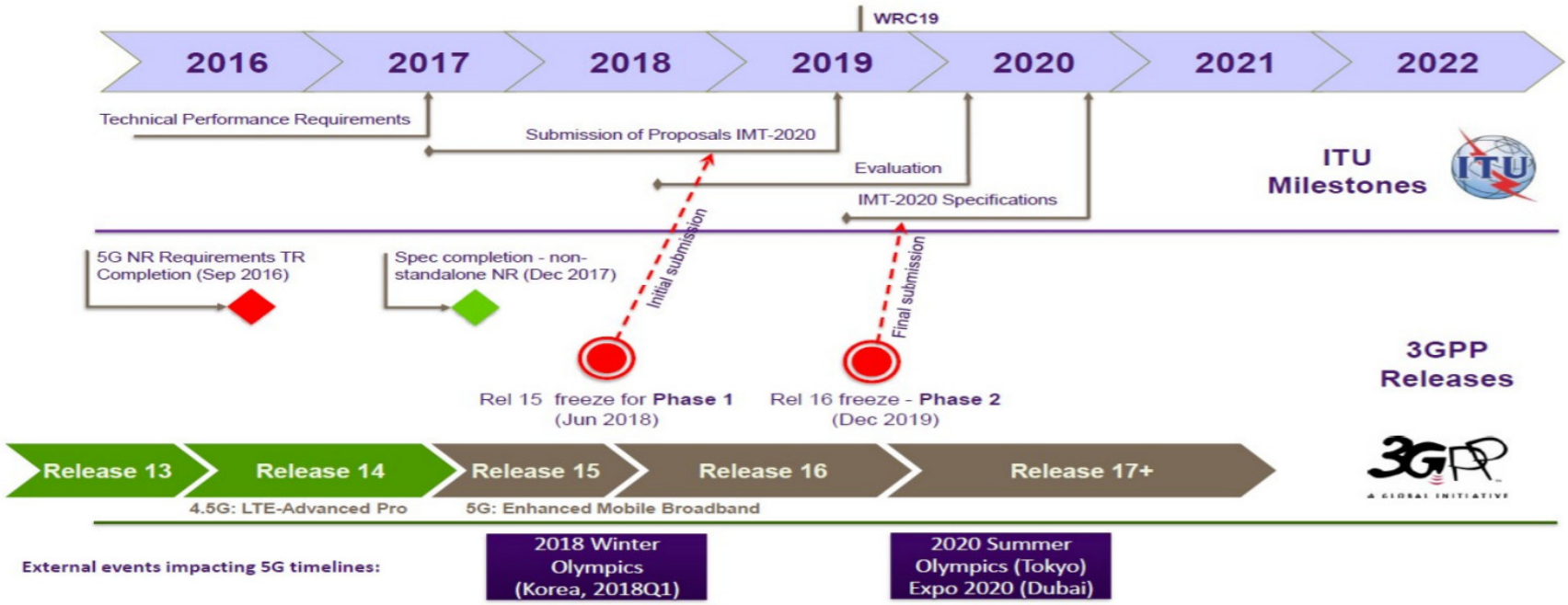


5G New Radio (5GNR)

3GPP Releases

Release 9	2009 Q4	SAES Enhancements, WiMAX and LTE/UMTS Interoperability. Dual-Cell HSDPA with MIMO, Dual-Cell HSUPA. LTE HeNB.
Release 10	2011 Q1	**LTE Advanced** fulfilling IMT Advanced 4G requirements. Backwards compatible with release 8 (LTE). Multi-Cell HSDPA (4 carriers).
Release 11	2012 Q3	Advanced IP Interconnection of Services. Service layer interconnection between national operators/carriers as well as third party application providers. Heterogeneous networks (HetNet) improvements, Coordinated Multi-Point operation (CoMP). In-device Co-existence (IDC).
Release 12	2015 Q1	Enhanced Small Cells (higher order modulation, dual connectivity, cell discovery, self configuration), Carrier Aggregation (2 uplink carriers, 3 downlink carriers, FDD/TDD carrier aggregation), MIMO (3D channel modeling, elevation beamforming, massive MIMO), New and Enhanced Services (cost and range of MTC, D2D communication, eMBMS enhancements)[14]
Release 13	2016 Q1	LTE in unlicensed, LTE enhancements for Machine-Type Communication. Elevation Beamforming / Full-Dimension MIMO, Indoor positioning.[15] LTE-Advanced Pro.
Release 14	2017 Q2	Energy Efficiency, Location Services (LCS), Mission Critical Data over LTE, Mission Critical Video over LTE, Flexible Mobile Service Steering (FMSS), Multimedia Broadcast Supplement for Public Warning System (MBSP), enhancement for TV service, massive Internet of Things, Cell Broadcast Service (CBS)[16]
Release 15	2018 Q2	First **NR ("New Radio")** release. Support for 5G Vehicle-to-x service, IP Multimedia Core Network Subsystem (IMS), Future Railway Mobile Communication System[17]

زمان بندی نسخه های جدید استانداردهای 3GPP



5G New Radio (NR)

- واسط رادیویی جدید 5G در 3GPP
- مبتنی بر فناوری های موجود و فناوری های جدید
- نسخه تکامل یافته یا نسخه جدید از آخرین واسط رادیویی موجود یعنی LTE Pro
- با هدف ارسال به ITU
- شروع مطالعات در Rel.14 در ۲۰۱۶
- فاز اول: Rel.15 در ۲۰۱۸
- فاز دوم: Rel.16 در ۲۰۲۰ (جهت ارسال به ITU)

5G New Radio (NR)

- در Release 14 (اتمام در June 2017) مطالعات اولیه
- هدف: معرفی اولین مجموعه مشخصات استاندارد 5G در Release 15
- البته: انتشار اولین نسخه Non-standalone (NSA) 5G NR در March 2018
  - با هدف تسریع در استانداردسازی 5G برای کاربردهای eMBB
  - استفاده از شبکه دسترسی و هسته شبکه LTE موجود
- انتشار استاندارد Standalone (SA) mode در Sep. 2018
- قابلیتهای کامل در بخش user plane و control plane
- استفاده از معماری هسته جدید 3GPP برای 5G

بازیگران 5G NR

- طبق توافقنامه March 2017 بیش از ۴۰ شرکت
- مدیریت و بیشترین فعالیت توسط Qualcomm
- در حوزه تجهیزات Ericsson , Nokia
- در بخش اپراتورها AT&T, NTT DoCoMo, SK Telecom, Vodafone

فناوری های چهارگانه در 5G NR

- 1) new modulation and coding algorithms including multiuser superposition and shared access, enhanced waveform generation and advanced error ▪correction coding
- 2) new system and network architectures including network slicing, device to device (D2D) communications, cloud radio access network (C RAN), and ultra dense network (UDN)
- 3) new spatial-domain processing such as massive MIMO, adaptive 3D beamforming and multi antenna diversity
- 4) new spectrum opportunities including millimeter- wave band and license assisted access (LAA)

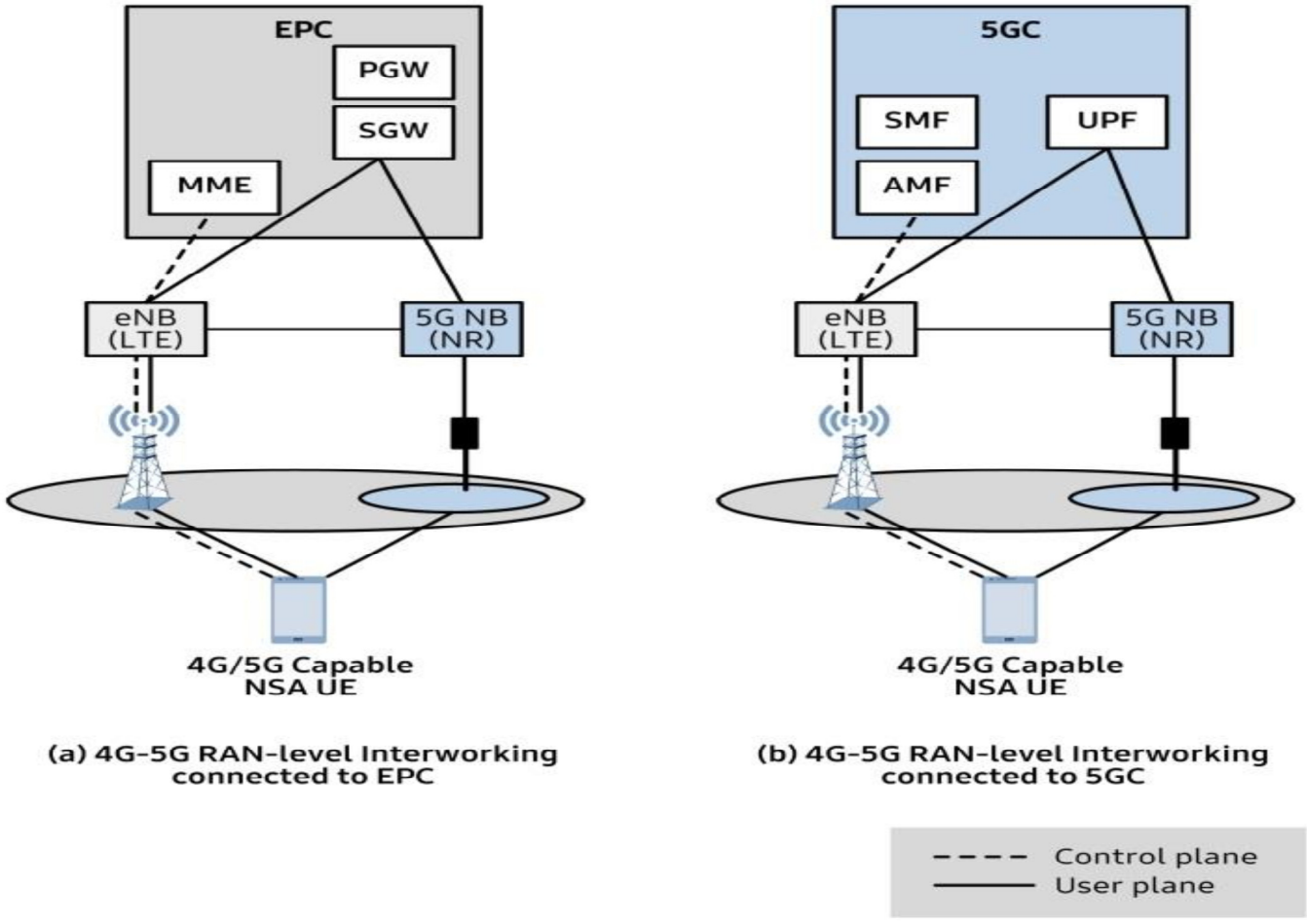
همکاری متقابل بین 4G و 5G

- هدف 5G : پوشش یکپارچه
- اشکالات پوششی در فازهای اولیه راه اندازی
- نیاز به همکاری با شبکه های LTE موجود
- مشابه شرایط قبلی برای 3G-4G
  - ارتباط بین SGSN و MME, S-GW
- دو نوع همکاری بین 4G-5G
  - RAN-level interworking
  - CN-level interworking

RAN-level Interworking

- ارسال سیگنالهایی کنترلی (RRC) روی LTE
- مدیریت تحرک توسط LTE
- ارسال سیگنالهای ترافیکی از طریق LTE eNB و 5G NB
- یک ضرورت در مد عملکردی NSA
- دو نوع شبکه هسته
  - 5G Core
  - LTE Core

RAN-level Interworking



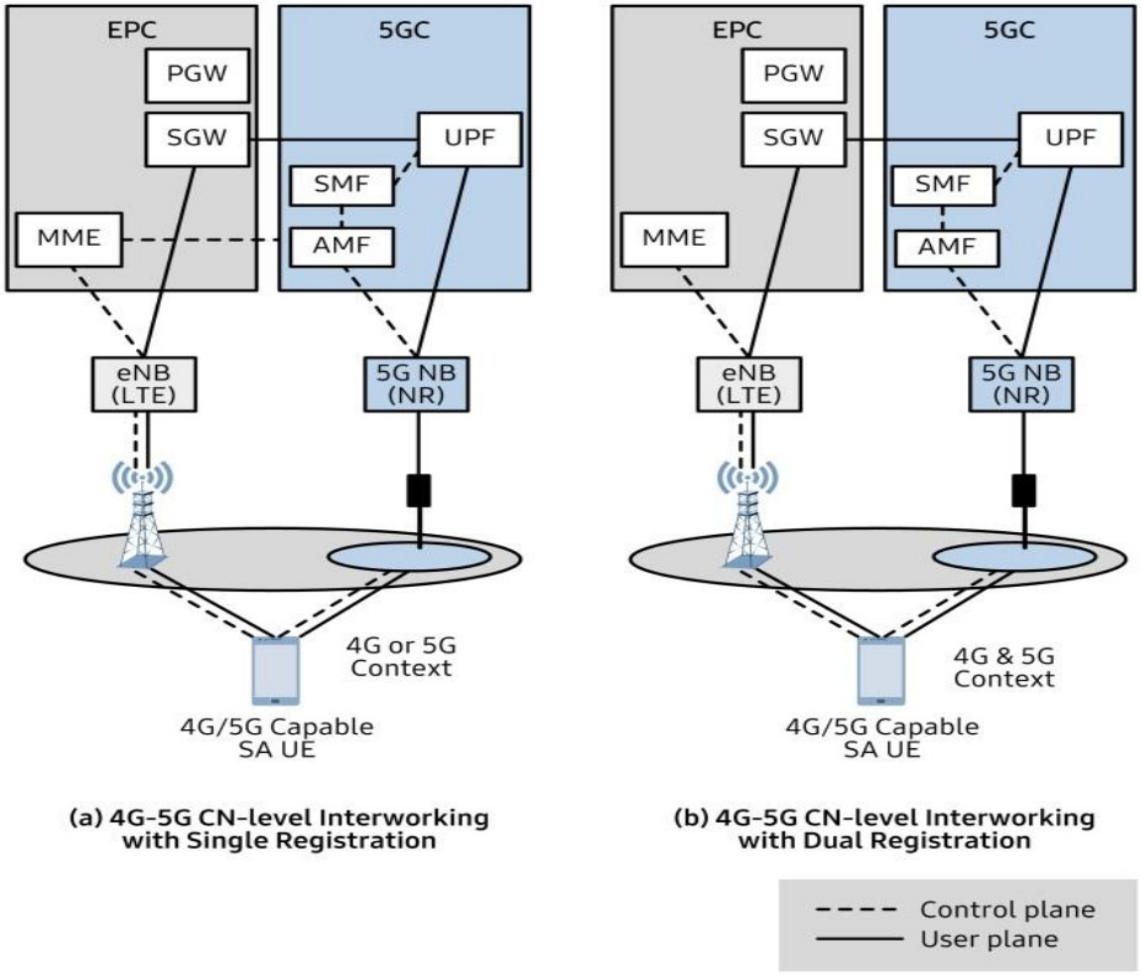
RAN-level Interworking

- هسته EPC
  - سرویس های مبتنی بر EPC
  - ارائه سرویس دیتای پرسرعت به کاربران با کمک 5G NR
  - نیاز به ارتقای eNB جهت اتصال به 5G NB
  - نیاز به ارتقای ظرفیت gateway
- هسته 5G
  - سرویس های 5G مانند network slicing
  - نیاز به ارتقای LTE eNB جهت اتصال به 5G core

CN-level Interworking

- اتصال EPC به 5GC
- عدم نیاز به ارتباط مستقیم بین NB ها
- یک ضرورت در مد عملکردی SA
- دو نوع اتصال: single registration و dual registration
- اینترفیس MME-AMF interface (Nx)
- ارتباط بین S-GW-UPF

CN-level Interworking

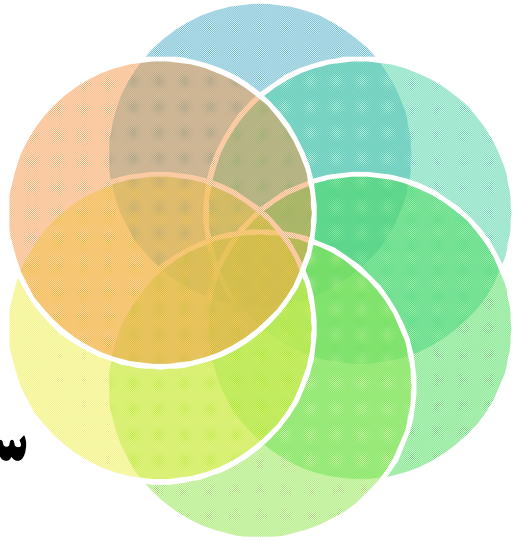



نگاهی به فعالیتهای جهانی
www.mobilebroadband.ir

بازیگران حوزه 5G

صنایع مخابراتی

نهادهای استانداردسازی



اپراتورها

نهادهای رگولاتوری

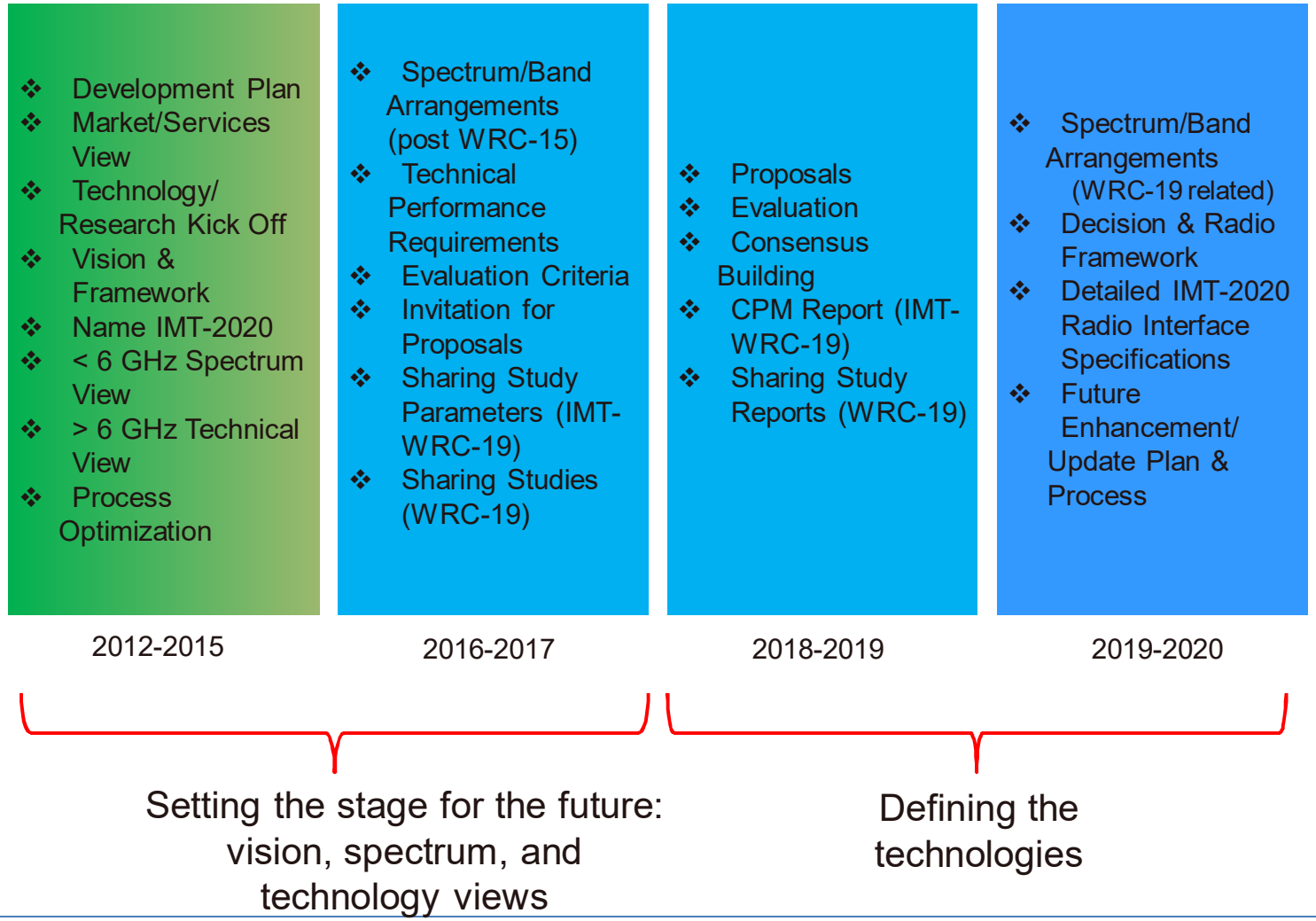
سیاست گزاران کلان

دانشگاه ها و مراکز تحقیقاتی

فعالیتها

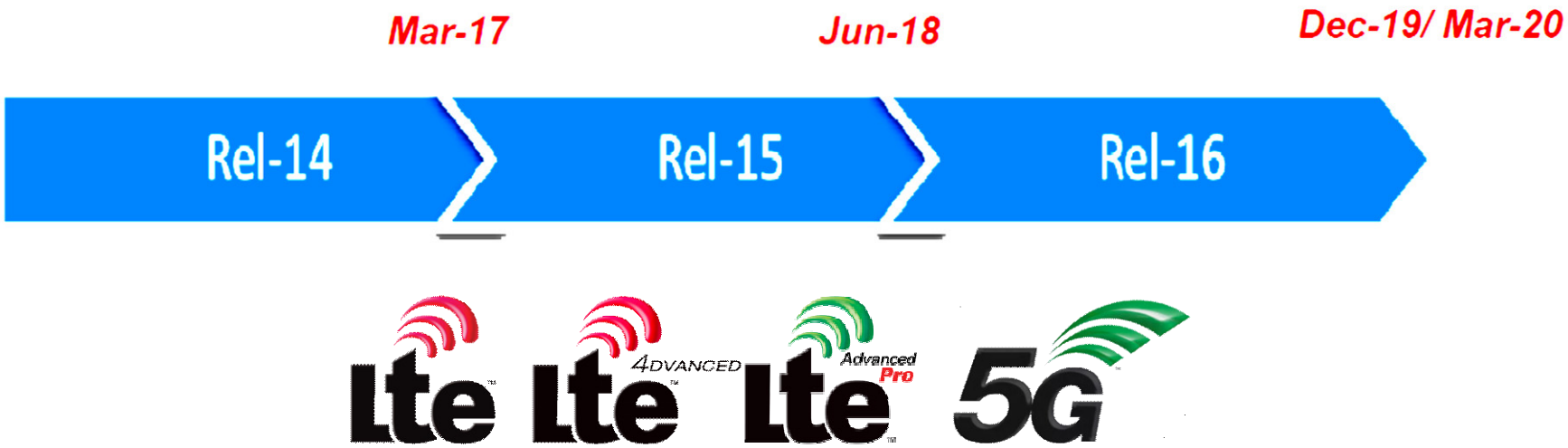
- **سیاست گزاری کلان**
  - National Broadband Plans
  - **مثال: اروپا (سال ۲۰۱۶ برای سال ۲۰۲۵)**
    - ≥ 100 Mb/s (up to 1 Gb/s) access for all EU households -5G Action Plan for Europe (5GAP)
- **نهادها رگولاتوری ها**
  - **تعیین باندهای فرکانسی**
  - **ضوابط و مقررات**
- **پروژه های کلان**
  - **مثال: 5G-PPP از سال ۲۰۱۳**

فعالیتهای ITU



3GPP

- فاز اولیه در Rel. 15 در Jun. 2018
- فاز دوم و تکمیلی در Re. 16 در March 2020
  - جهت ارسال به IMT-2020



پارامترهای 5G در 3GPP

Peak data rate	• 20Gbps DL 10Gbps UL
Peak Spectral efficiency	• 30bps/Hz - 15bps/Hz
Control plane latency	• 10ms
User plane latency	• URLLC: 0.5ms UL&DL
Mobility interruption time	• 0 ms
Inter-system mobility	• With other IMT systems
Reliability	• URLLC: P=10-5 in 1ms
Coverage	• mMTC 164dB
Extreme Coverage	• 100-400 km voice/low data
UE battery life	• mMTC 15 years
Connection density	• mMTC 1M device/km2
Mobility	• 500 km/h

تحقیقات دانشگاهی

تحقیقات دانشگاهی

تحقیقات دانشگاهی

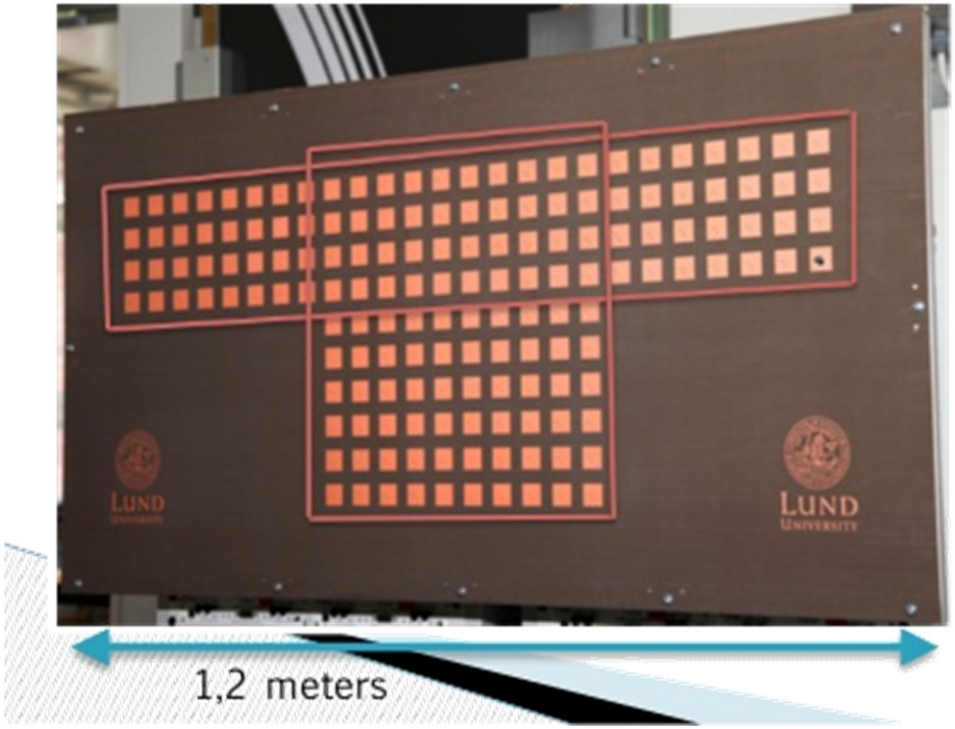
Experimental Results for Massive MIMO

Lund University - Sweden

128 antennas freq. 1.2 ~ 6 GHz

10 users

National Instrument Plataform - USRP



تحقیقات دانشگاهی

صنعت مخابرات

May, 2013

صنعت مخابرات

Jan - 2017

شبکه های پیاده سازی شده

- میزان پوشش
- زمان
- عمومیت
- ابزارهای دسترسی به 5G
- تکیه بر 4G
- شایعه تا واقعیت

South Korea

- April, 2019
- SK Telecom claimed 38,000 base stations
- KT 30,000
- LG U Plus 18,000
- 3.5 GHz (sub-6) spectrum
- tested speeds : from 193 to 430 Mbps Dl
- All use Samsung base stations and equipment

Nov. 13, 2018

EE in UK

- EE was the first in the UK to launch 4G in 2012
- Planning to launch 5G in 16 different UK cities in 2019
- Upgrade 1,500 sites
- 10 per cent of sites
- Busiest sites in the busiest cities
- Will serve 25 percent of all EE customers
- One site (Waterloo station) carries more than 100TB of data per day

Dec 18, 2018

AT&T in US

- AT&T's 5G network goes live in 12 cities
- First operator to launch 5G standard
- Mobile hot spot (not available at stores !)
- $70 per month for 15GB
- Modem $499
- Theoretical speeds of 1.2 Gbps
  - actual speeds ~ 140 Mbps
- 39 GHz

Feb 25, 2019

Sprint in US

- Currently being tested in downtown Chicago
- To launch its 5G network in May 2019 in 9 cities
- Millimeter wave coverage
- Massive MIMO
- First 5G phones : LG V50 ThinQ 5G & Samsung's Galaxy S10 5G
- Hotspot from HTC

Feb 21, 2019

Verizon in US

- 5G will be launched in 30 cities by the end of 2019
- Phone: Samsung's Galaxy S10 5G
- Using 400 MHz of 28 GHz millimeter wave spectrum
- Download speeds : from 80 to 634 Mbps
- Upload speeds : from 12 to 57 Mbps
- Latency : 25 ms

Feb 25, 2019

T-Mobile in US

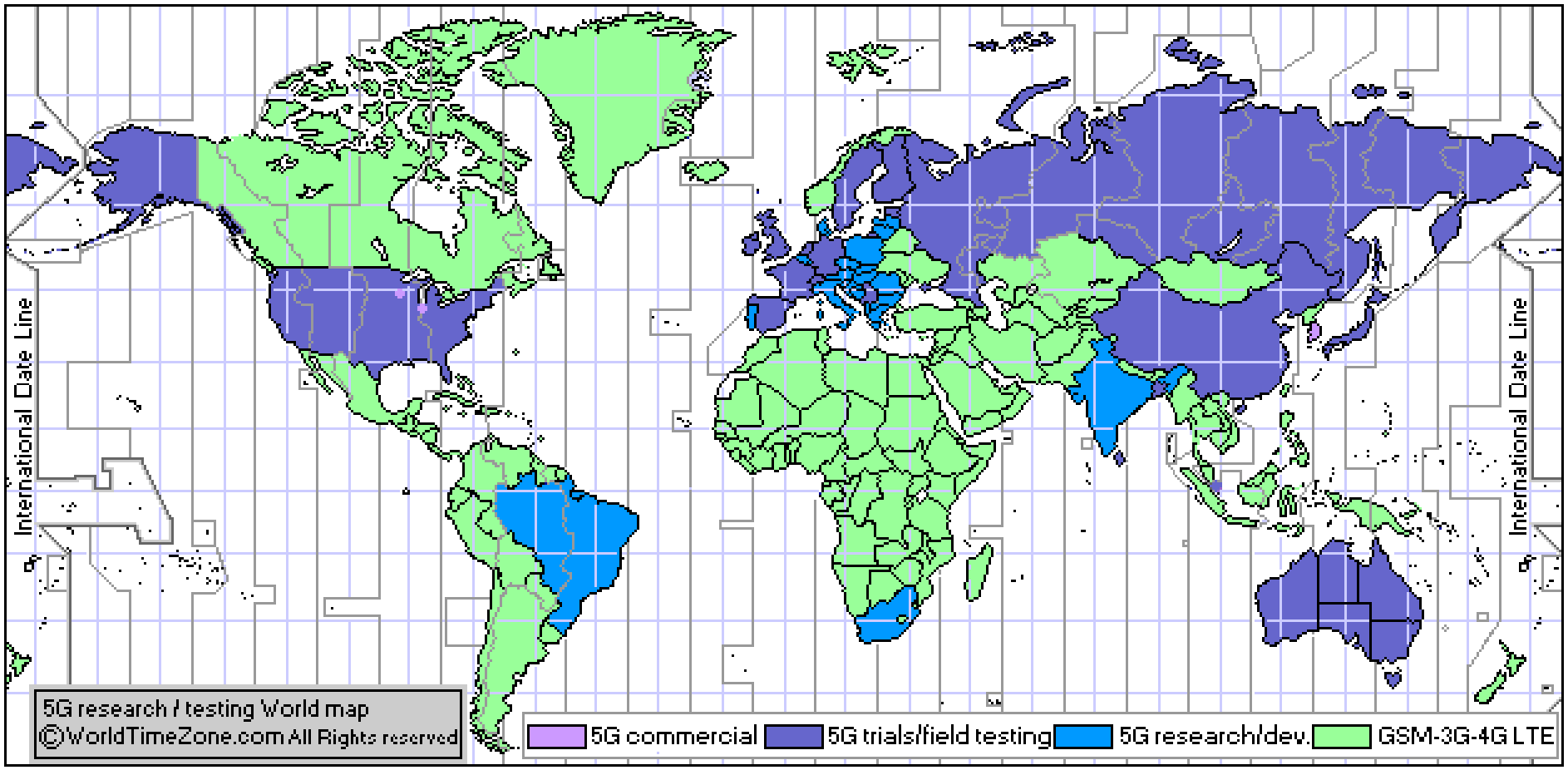
- T-Mobile's 5G network won't launch in full until the second half of 2019 because phones aren't ready yet
- Last year announced it would have 30 cities with 5G by the end of 2018
- The problem is, there aren't any phones yet that fully support T-Mobile's 5G network

5 Apr 2019

Sunrise in Switzerland

- Initial coverage of 150 towns, villages and cities
- 700MHz and 2.4GHz-2.5GHz bands
- NO mmWave
- High-bandwidth internet
- Jointly with Huawei

5G Map


International Date Line
International Date Line
5G research / testing World map
©WorldTimeZone.com All Rights reserved
5G commercial
5G trials/field testing
5G research/dev.
GSM-3G-4G LTE


5G Devices

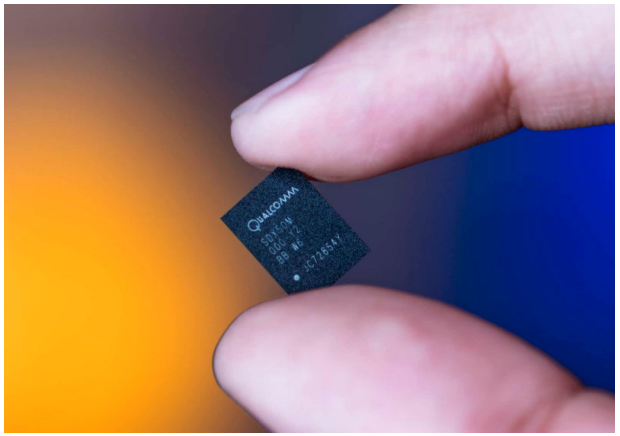
5G Devices

- Smartphones
- Home broadband devices (CPE)
- Vehicle-mounted devices (Mobile CPE)
- 5G modules (usb adapters)

5G Chipsets

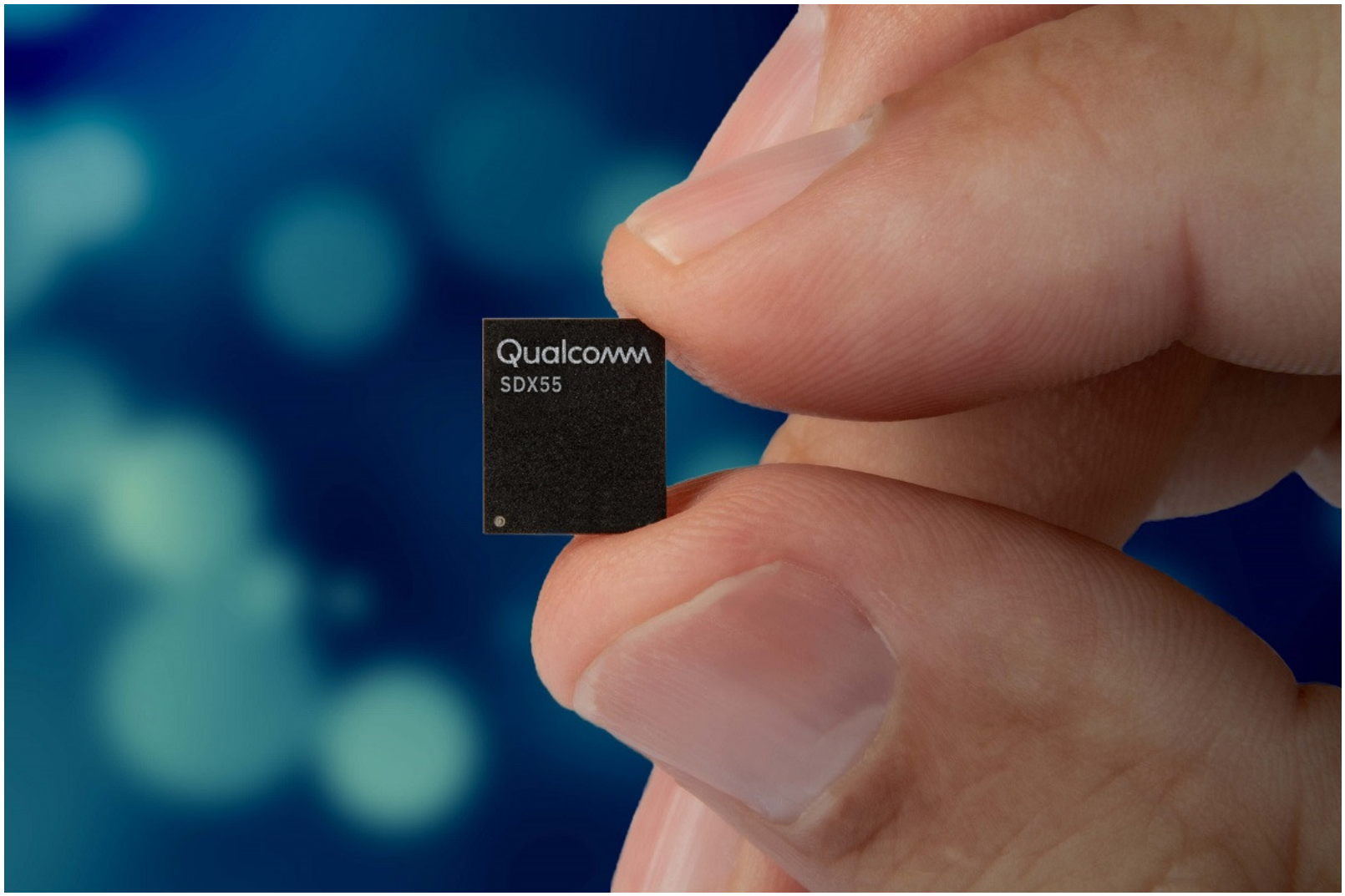
Qualcomm Snapdragon X50 5G modem

- زیر ۶ گیگاهرتز و همچنین موج میلیمتری
- تولید عمده از ۲۰۱۹



Qualcomm Snapdragon X55

Qualcomm Snapdragon X55



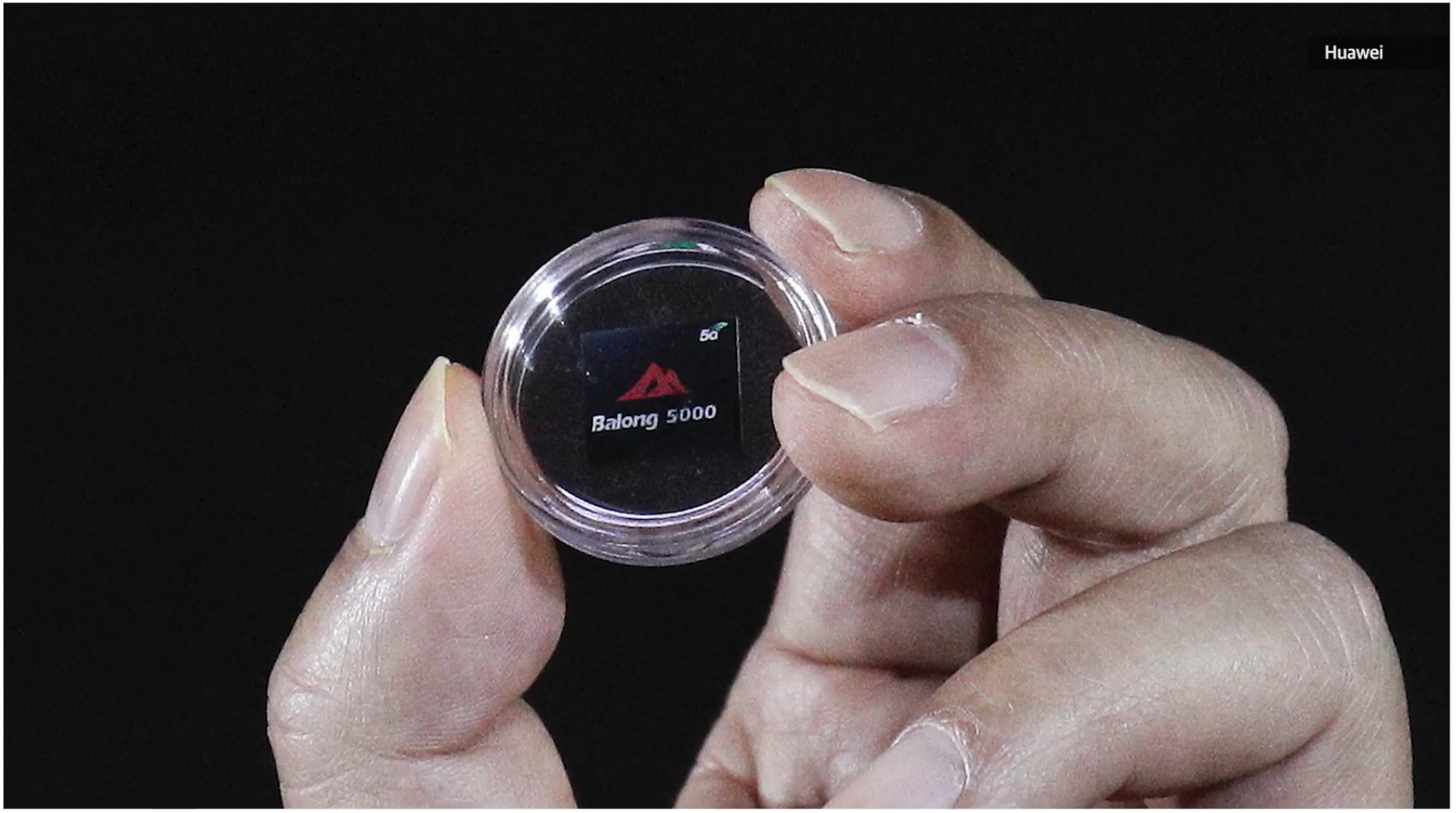
Qualcomm Snapdragon X55

- supports 5G NSA and SA modes
- 5G/4G spectrum sharing
- full-dimension MIMO (FD-MIMO)
- 4x4 MIMO
- 1024-QAM.

Huawei Balong 5000

Huawei Balong 5000

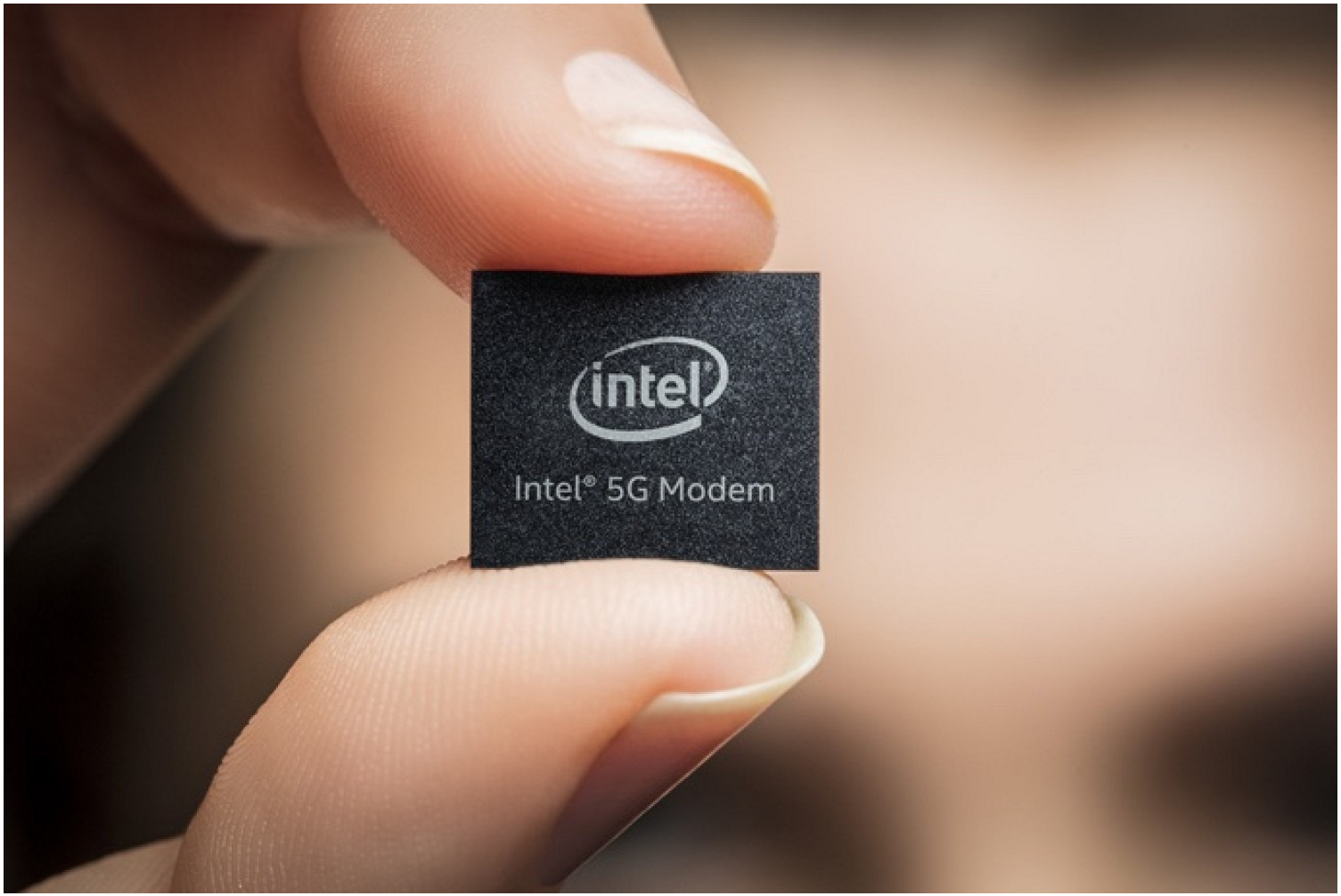
Huawei Balong 5000



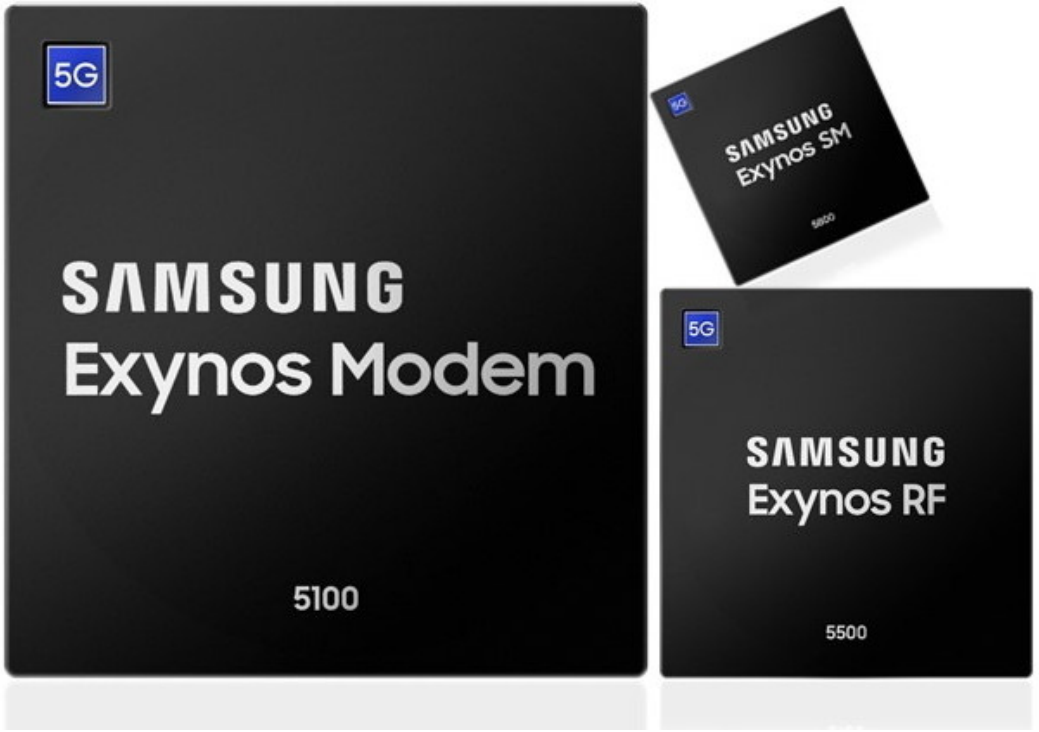
Huawei Balong 5000

- Supports 2G, 3G, 4G, and 5G on a single chip
- At Sub-6 can achieve download speeds up to 4.6 Gbps
- On mmWave spectrum can achieve download speeds up to 6.5 Gbps
  - 10times faster than top 4G LTE speeds on the market today
- Supports both standalone (SA) and non-standalone (NSA) network architectures

Intel XMM 8160



Samsung Exynos Modem 5100



April 4, 2019

single-chip radio frequency transceiver,Exynos RF 5500
modulator solution,Exynos SM 5800

Samsung Exynos Modem 5100

- Sub-6-gigahertz (GHz) spectrum
- mmWave spectrums
- up to 100MHz bandwidth
- 5G-NR
- 2G GSM/CDMA, 3G WCDMA, TD-SCDMA, HSPA and 4G LTE networks in a single chip
- supports 4×4 MIMO
- higher-order 256 QAM

April 4, 2019

5G Devices

Phones

Huawei Mate X Foldable

LG V50 ThinQ

Motorola Moto Mod (an accessory for Moto Z3 phone)

OnePlus 5G

Oppo Find X 5G (prototype)

Samsung SM-G977 Galaxy S10 5G

Samsung Galaxy Fold 5G

TCL Alcatel 7

Xiaomi Mi Mix 3 5G

ZTE Axon 10 Pro 5G

by March 2019

5G Devices

CPEs

D-Link DWR-2010 5G NR Enhanced Router/Gateway

HTC 5G Hub (mobile hotspot)

Huawei 5G CPE Pro mmWave

Huawei 5G CPE Pro sub 6GHz

Huawei 5G Outdoor CPE

Huawei 5G Mobile WiFi (mobile hotspot)

Inseego R1000 5G Home Router

Netgear Nighthawk M2 5G (mobile hotspot)

Netgear Nighthawk M5 Fusion MR5000 5G (mobile hotspot)

Nokia FastMile 5G home gateway

Samsung SFG-D0100 5G

TCL 5G USB data terminal

by March 2019

5G Phones

- الزام هندست های جدید
- از شایعات تا واقعیت !
- Prototype vs. Completed phone
- ابهام در تاریخ فروش و قیمت
- معرفی اخیر گوشی ها در MWC 2019 در Feb.
  - در کنفرانس CES 2019 در ژانویه
- پذیرش از سوی اپراتورها

5G Phones

- پارامترها
  - مشخصات فنی (mmwave, MIMO, advanced coding, low power)
  - Processor
  - Screen – سایز و رزولوشن
  - Camera
  - 4K-8K video
  - Gaming
- زمان معرفی
- قیمت !

Samsung Galaxy S10 5G

$999

Samsung Releasing First 5G Smartphone on April 5, 2019.

Huawei Mate X

$2,600

Huawei Mate X

$2,600

Huawei Mate 20 X

Balong 5000 chipset

Huawei Mate 20 X

Huawei Mate 20 X

OnePlus

$200 -$300

Google Pixel 4

LG V50 ThinQ


Sprint
5G
9:00
SUN, FEBRUARY 24
5G
5G
V50 ThinQ
LG
Sprint
5G
9:00
SUN, FEBRUARY 24
5G

Apple iPhone 12

Motorola Moto Z3

Xiaomi Mi Mix 3 5G

$680

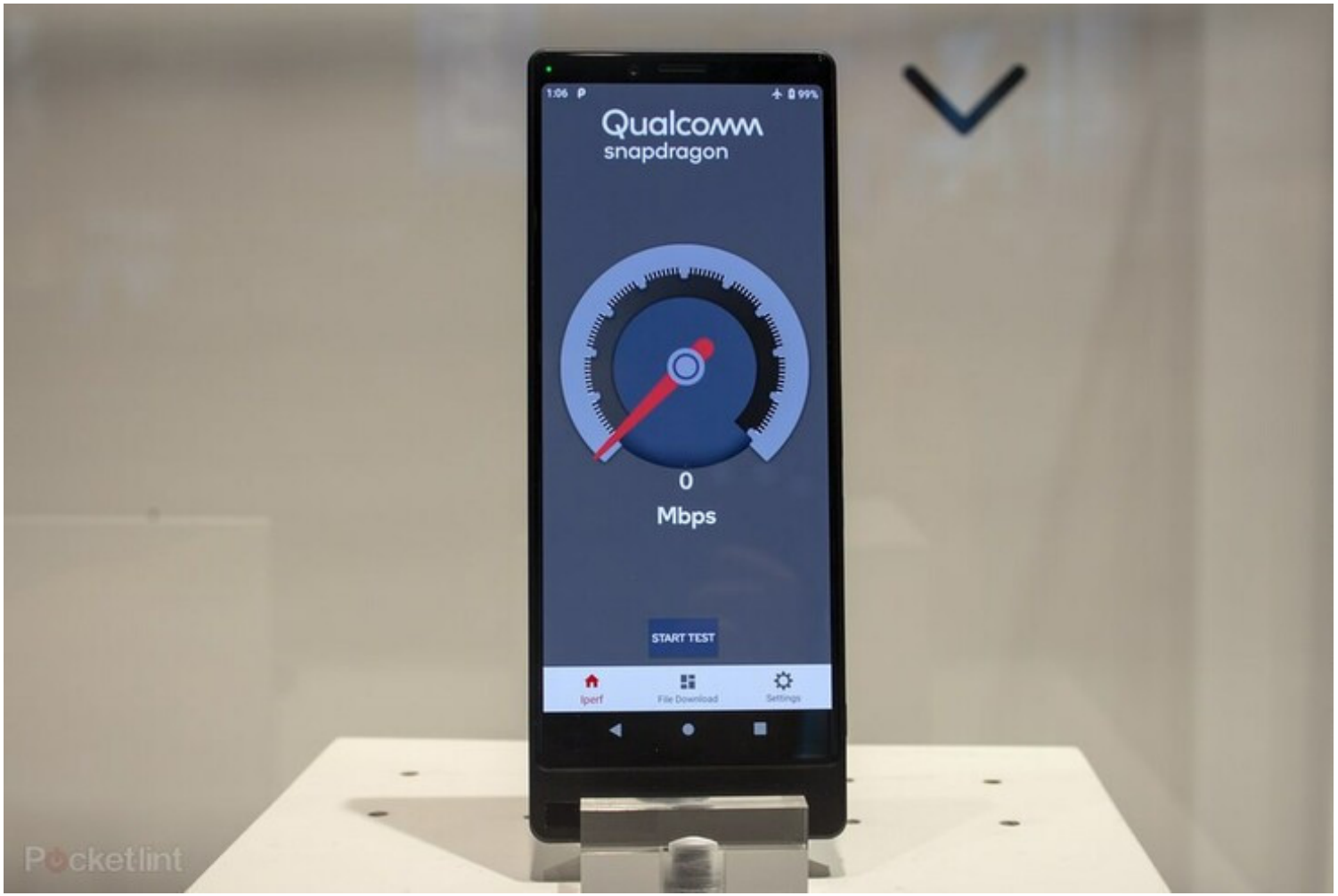
Oppo

ZTE Axon 10 Pro 5G

Vivo

Royole FlexPai

Sony Xperia 5G



Sony Xperia 5G

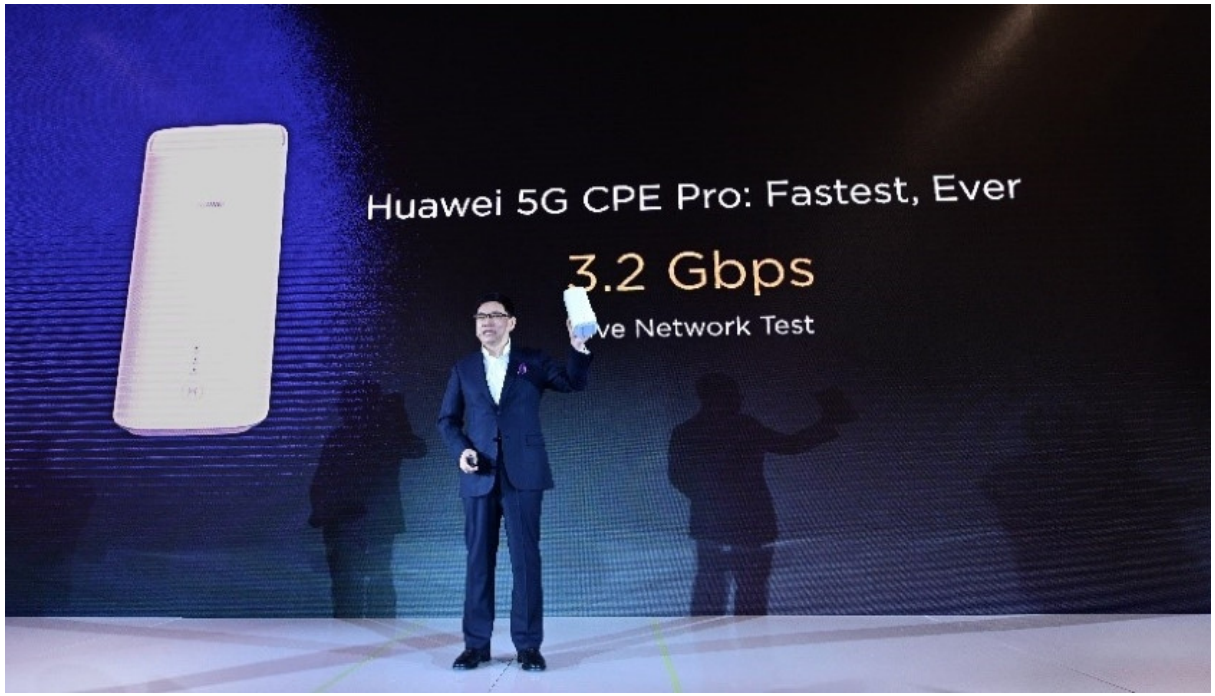
HMD Global (Nokia)

ALCATEL 7 5G

Other devices

- HUAWEI 5G CPE Pro

- 4G and 5G dual-modes
- 3.2 Gbps speeds

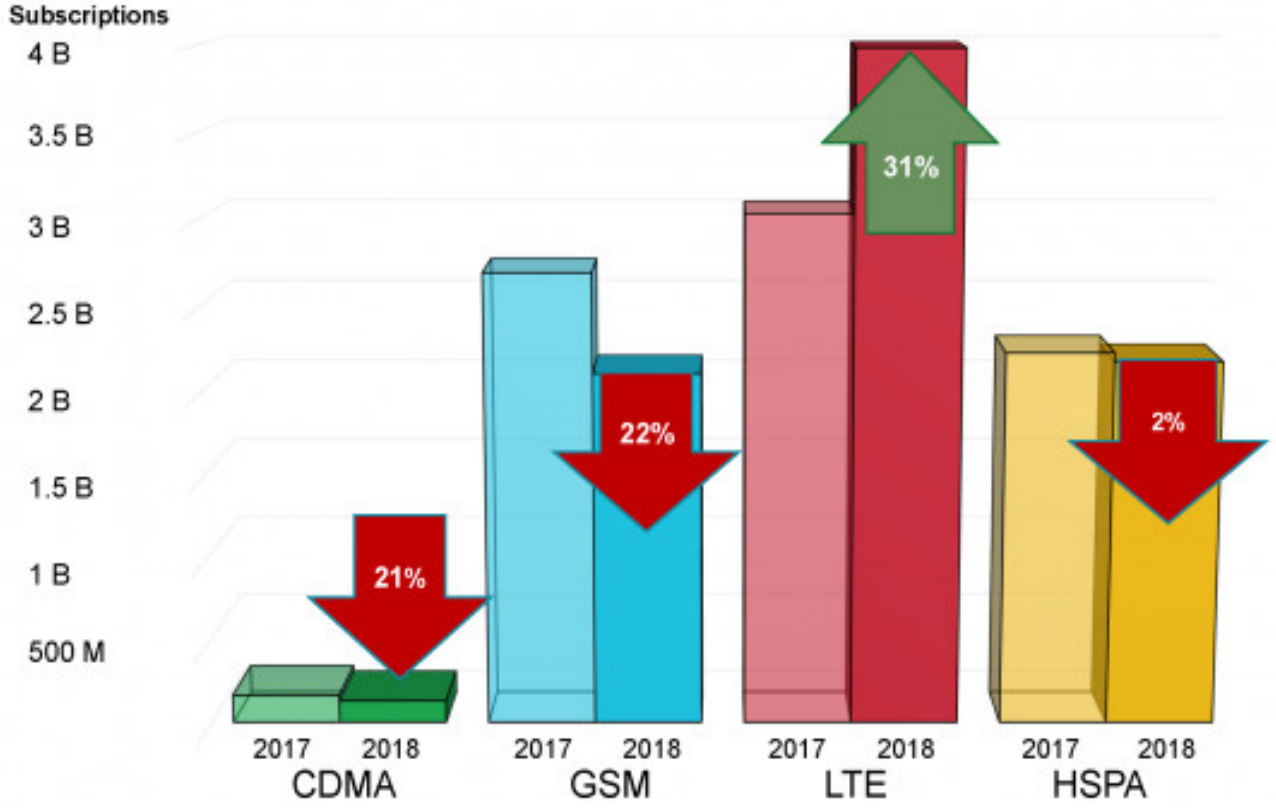


Inseego R1000 Router

Nokia's FastMile 5G Gateway


پیش بینی آینده

Annual Global Technology Growth
4Q 2017 – 4Q 2018

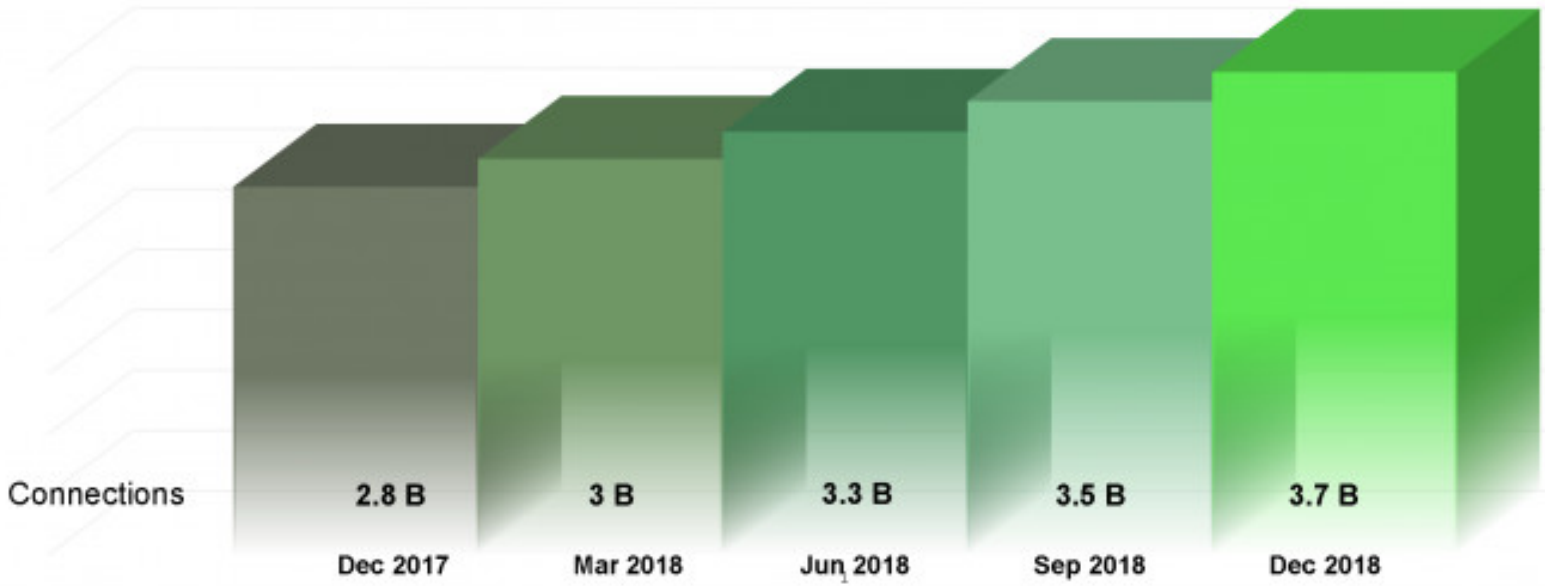


Source: Ovum December 2018

www.5gamericas.org

Global LTE Connections by Quarter
December 2017 – December 2018

www.5gamericas.org

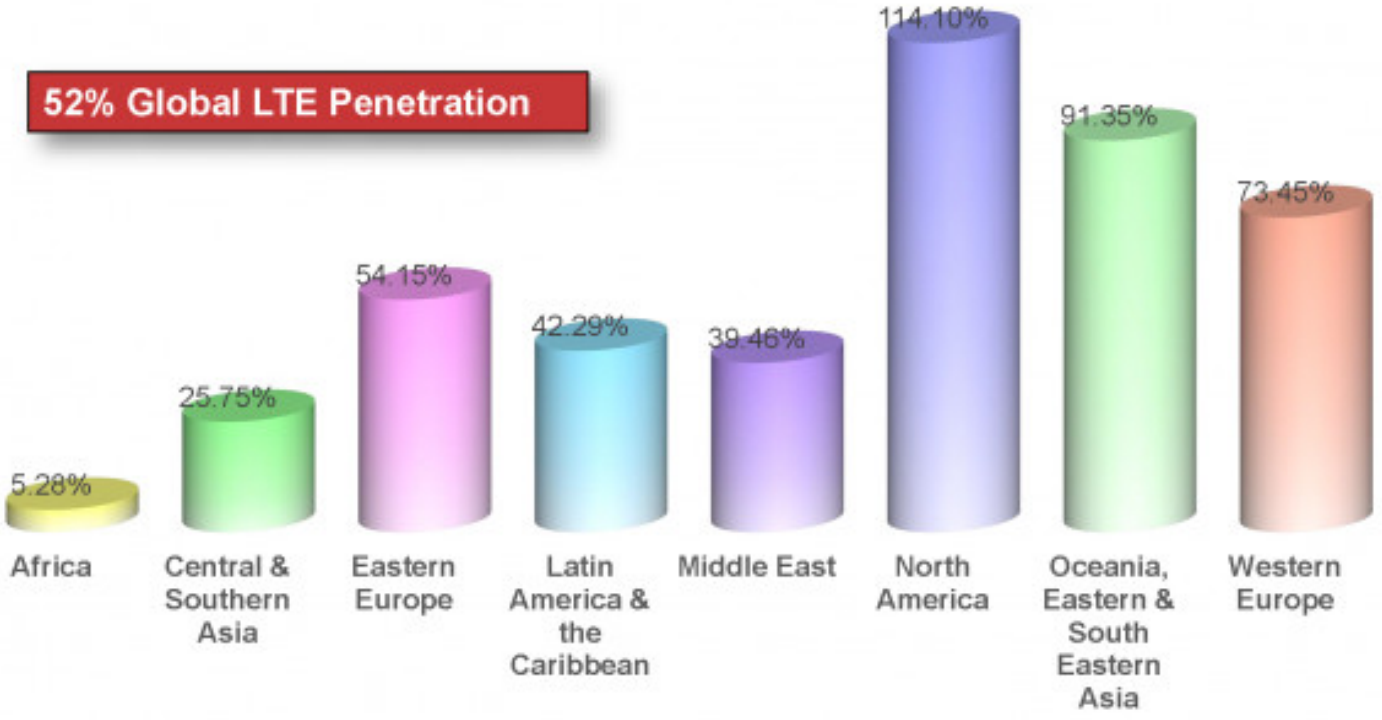


Source: Ovum December 2018

LTE

LTE Penetration by World Region
December 2018

www.5gamericas.org



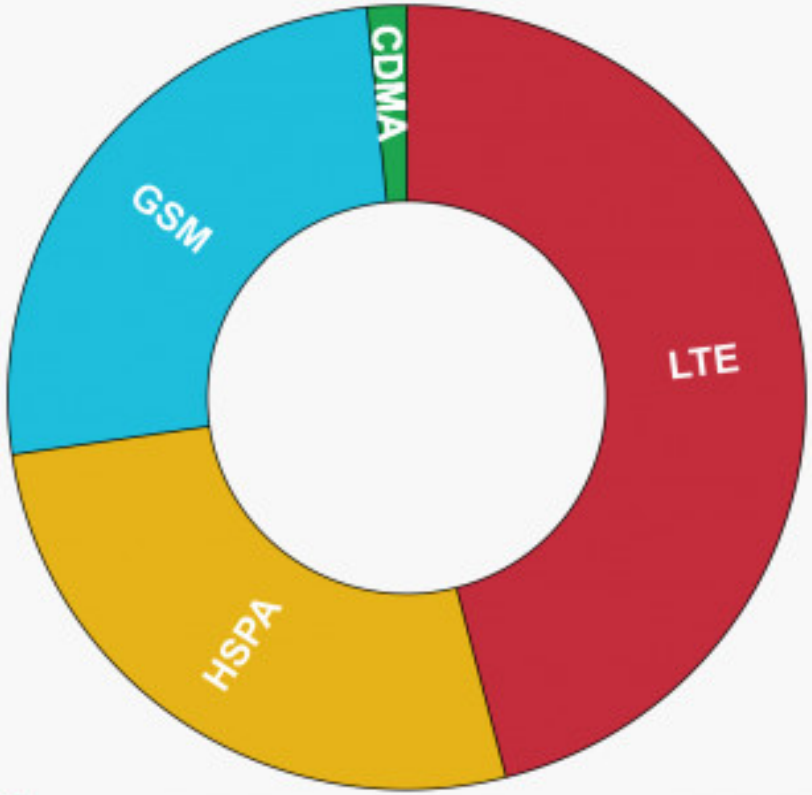
Penetration rate is determined by comparing number of connections to total population

Source: Ovum December 2018

Global Mobile Connections and Market Share by Technology

www.5gamericas.org

8.5 Billion Connections Worldwide

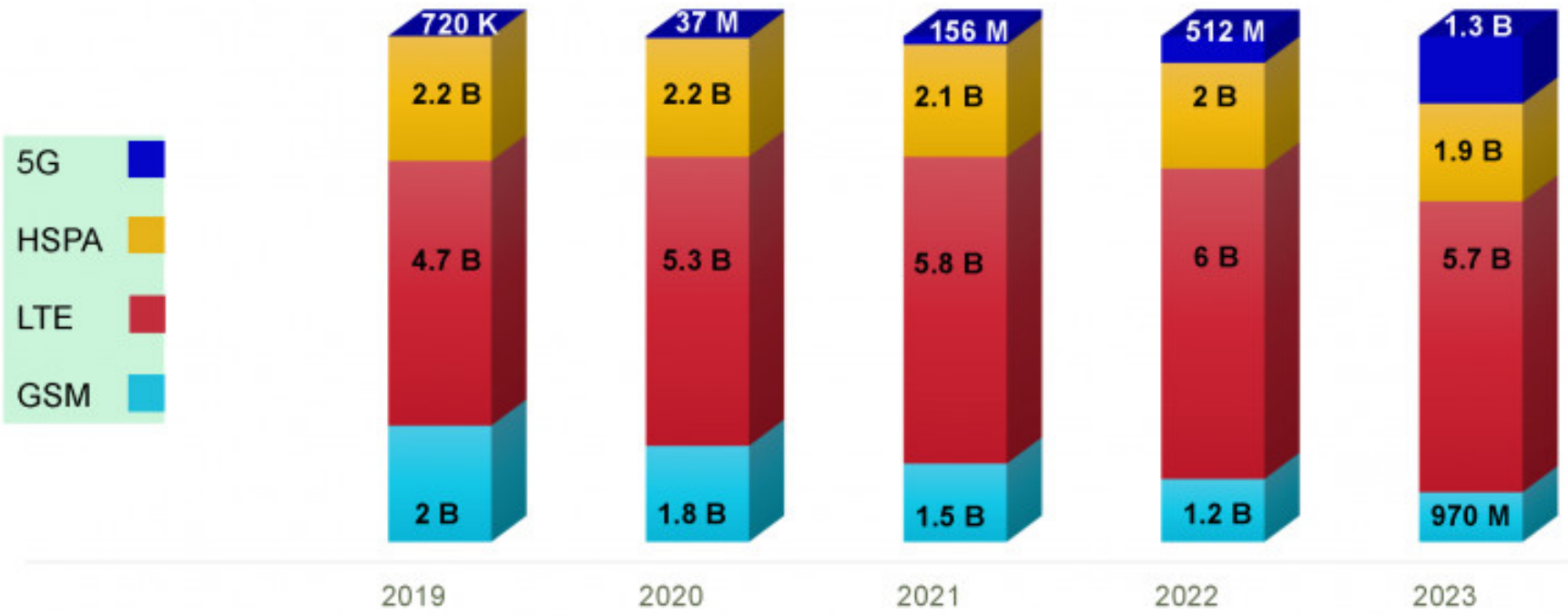


GSM	2.1 B Connections 25% Market Share
HSPA	2.2 B Connections 26% Market Share
LTE	4 B Connections 44% Market Share
CDMA	131 M Connections 1.5% Market Share

Source: Ovum December 2018

Annual Global Technology Subscriptions Forecast 2019-2023

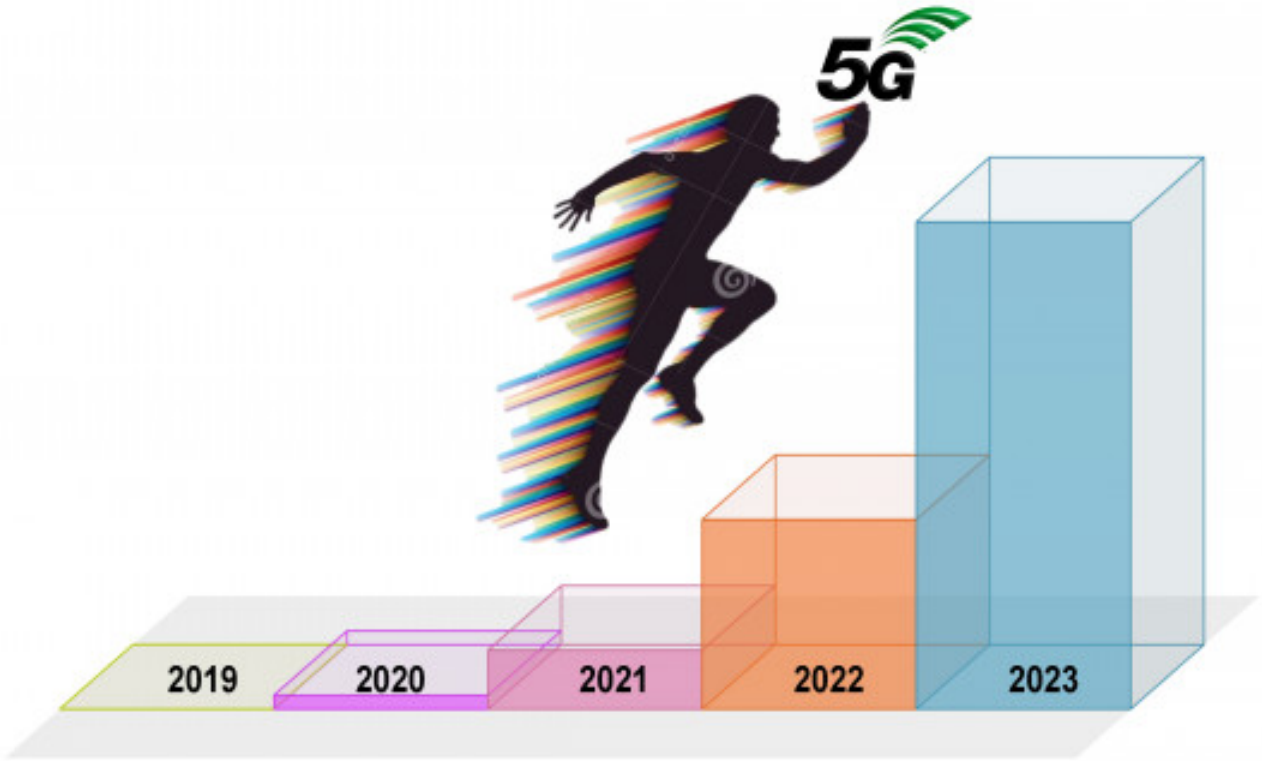
www.5gamericas.org



Source: Ovum December 2018 Forecast includes M2M

Global 5G Subscription Forecast
2019 - 2023

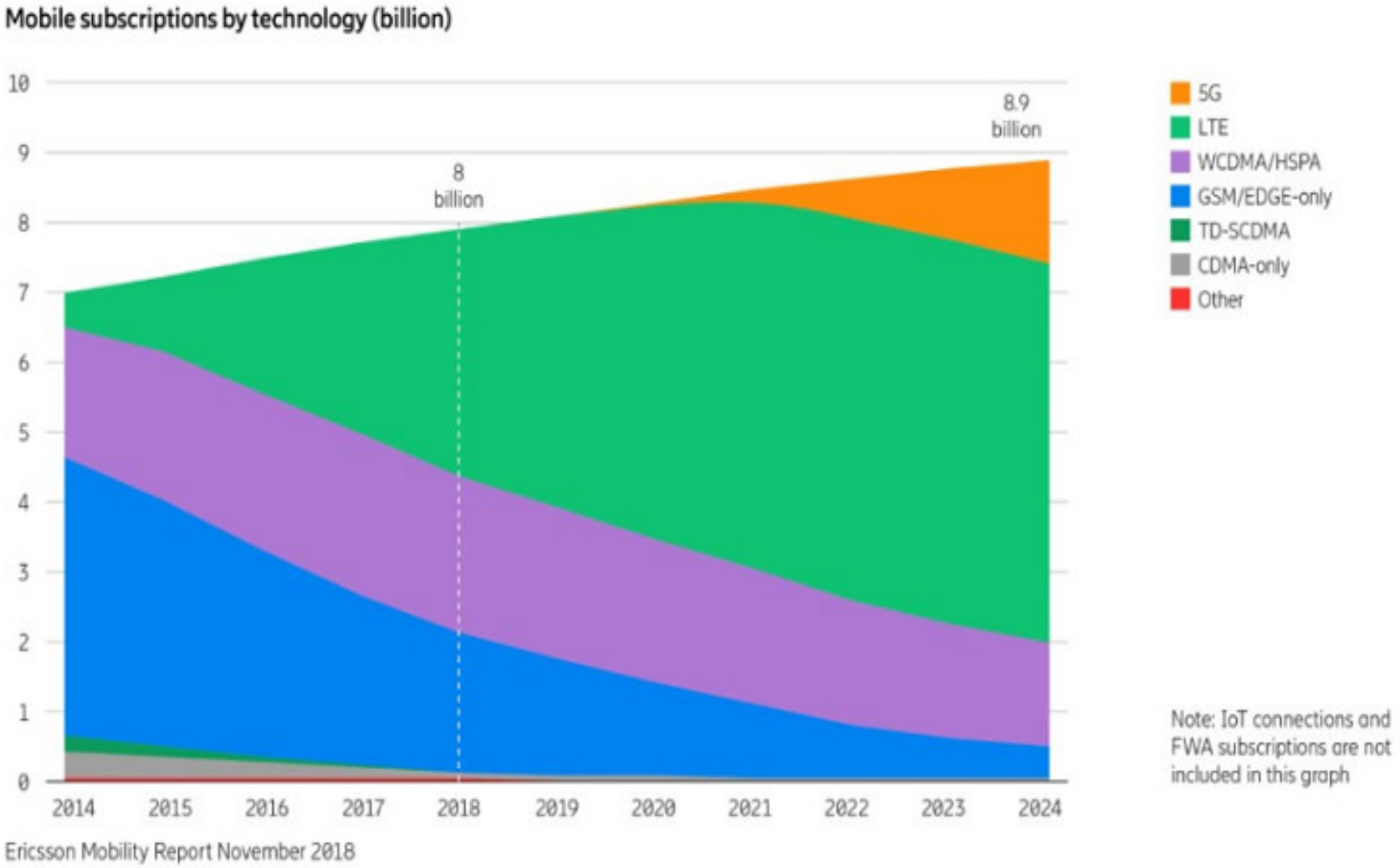
www.5gamericas.org



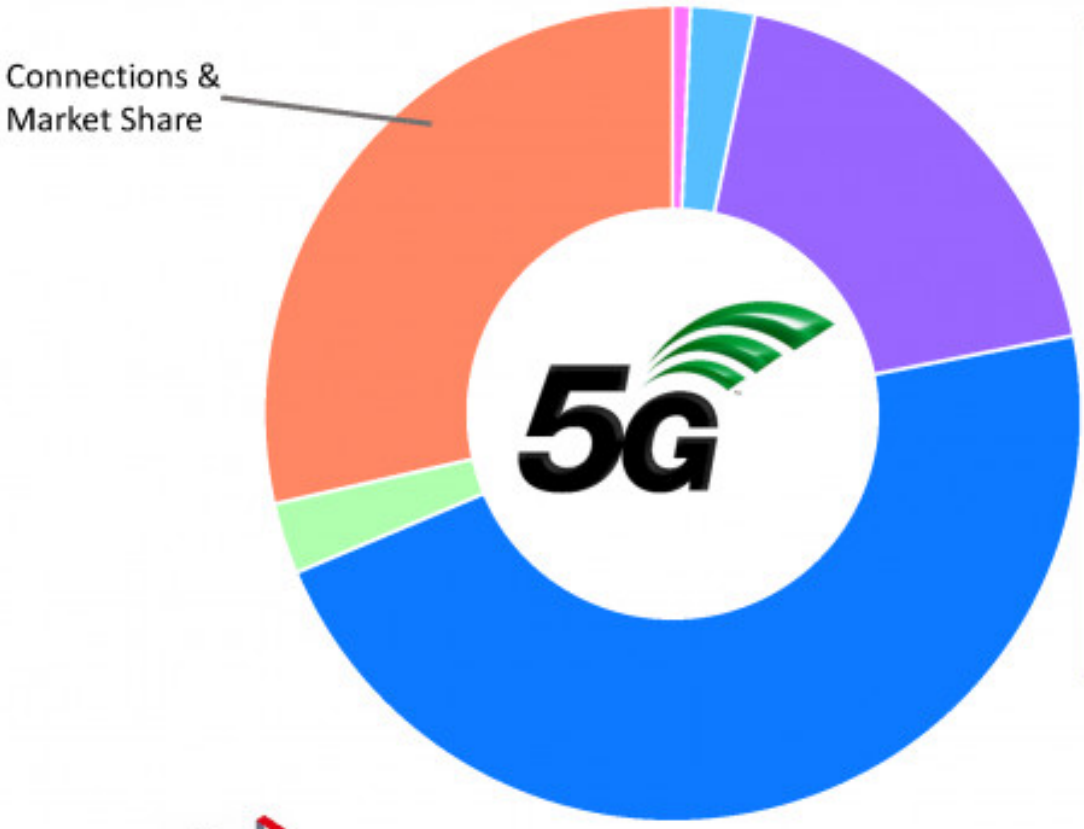
	2019	2020	2021	2022	2023
Connections	720 K	37 M	159 M	512 M	1.3 B

Source: Ovum September 2018 Forecast includes M2M

MBNRG


Mobile subscriptions by technology (billion)
10
9
8
7
6
5
4
3
2
1
0
8.9 billion
8 billion
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
5G
LTE
WCDMA/HSPA
GSM/EDGE-only
TD-SCDMA
CDMA-only
Other
Note: IoT connections and FWA subscriptions are not included in this graph
Ericsson Mobility Report November 2018

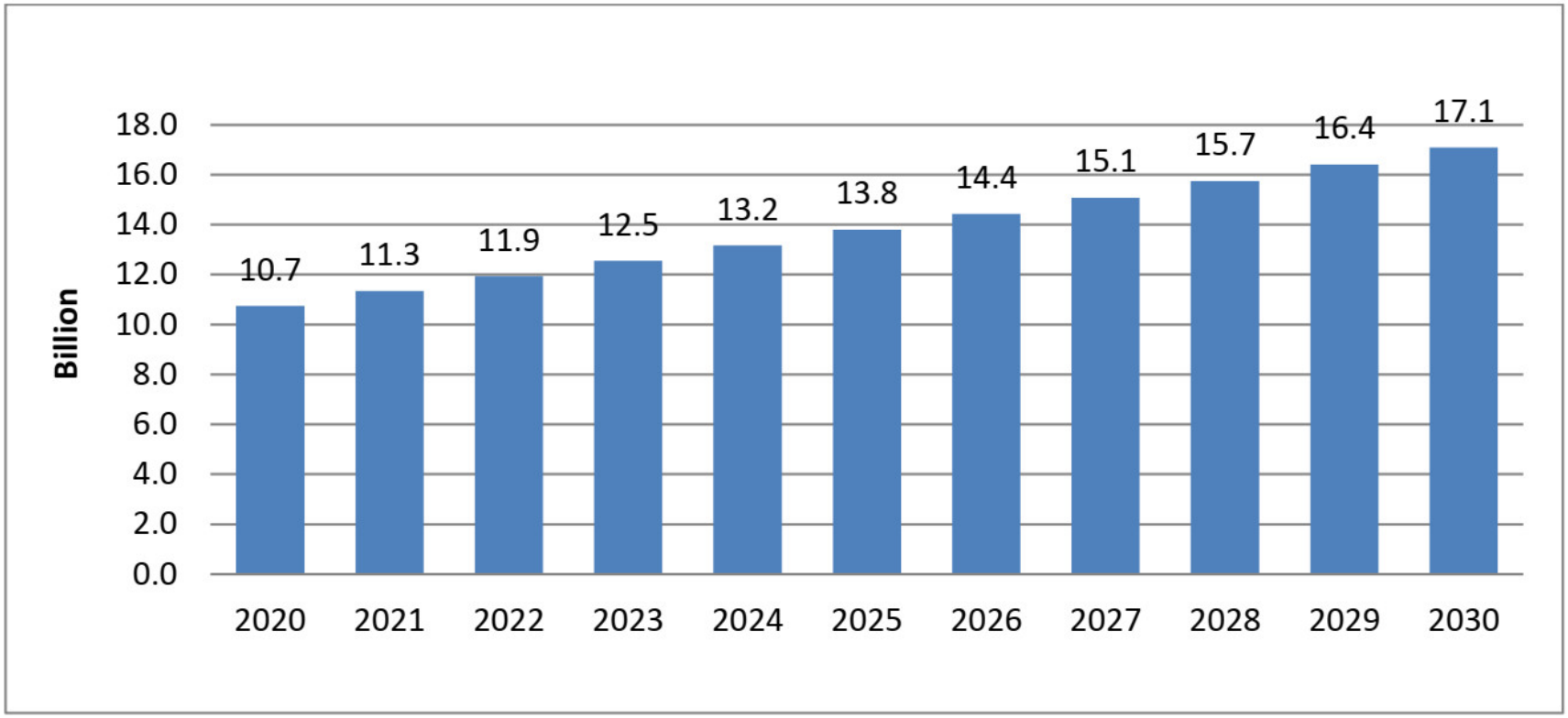
Global 5G Connections and Market Share
2019 Forecast



	Connections	Market Share
Africa	0.00	0.00%
Central & South Asia	0.00	0.00%
Eastern Europe	5 K	0.70%
Latin America & the Caribbean	18 K	2.54%
Middle East	135K	18.69%
North America	336 K	46.7%
Oceania, Eastern & South-Eastern Asia	20 K	2.81%
Western Europe	206 K	28.56%

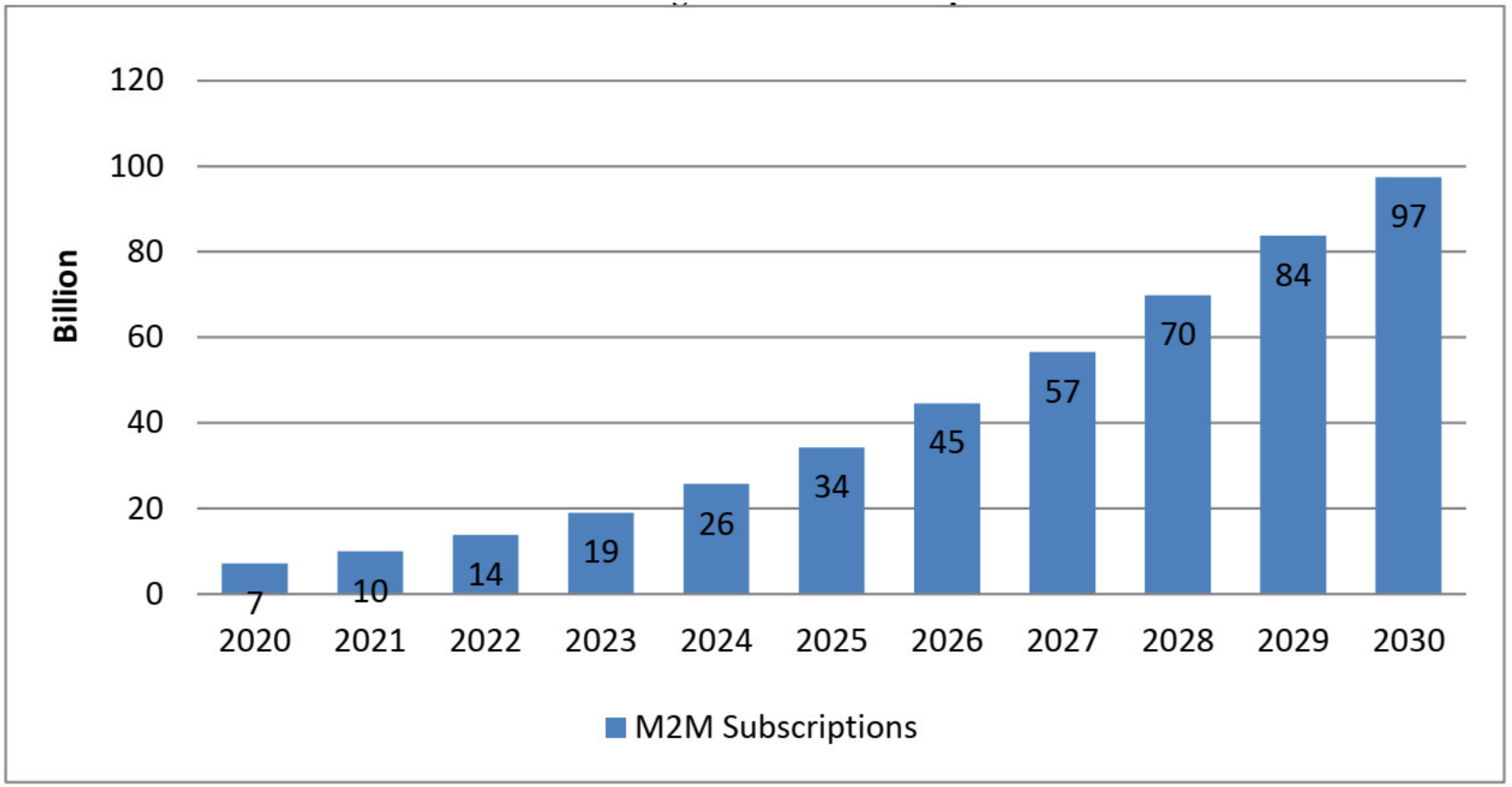
Source: Ovum September 2018

Estimation of global mobile subscriptions



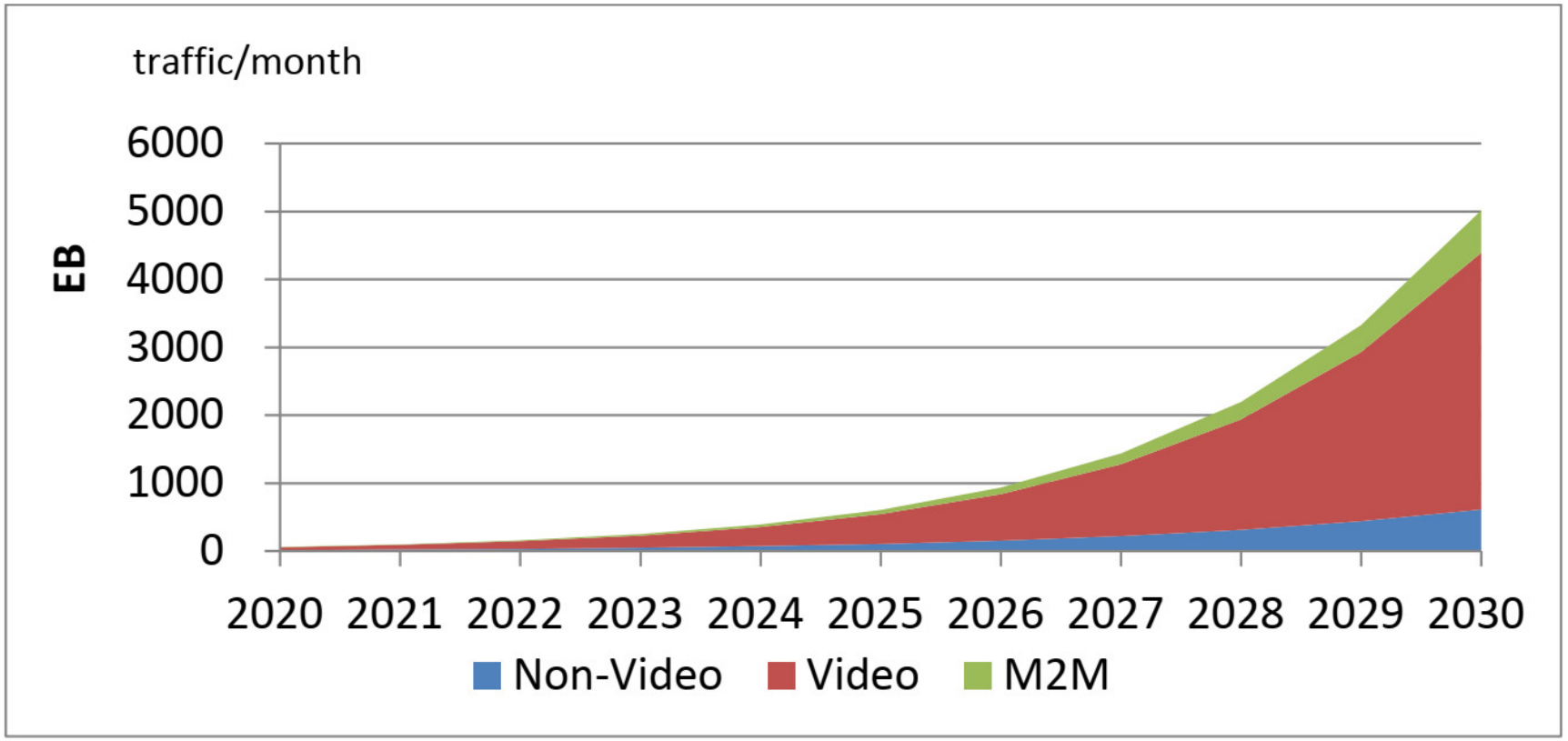
Rep. ITU-R M.2370-0

Estimation of global M2M subscriptions

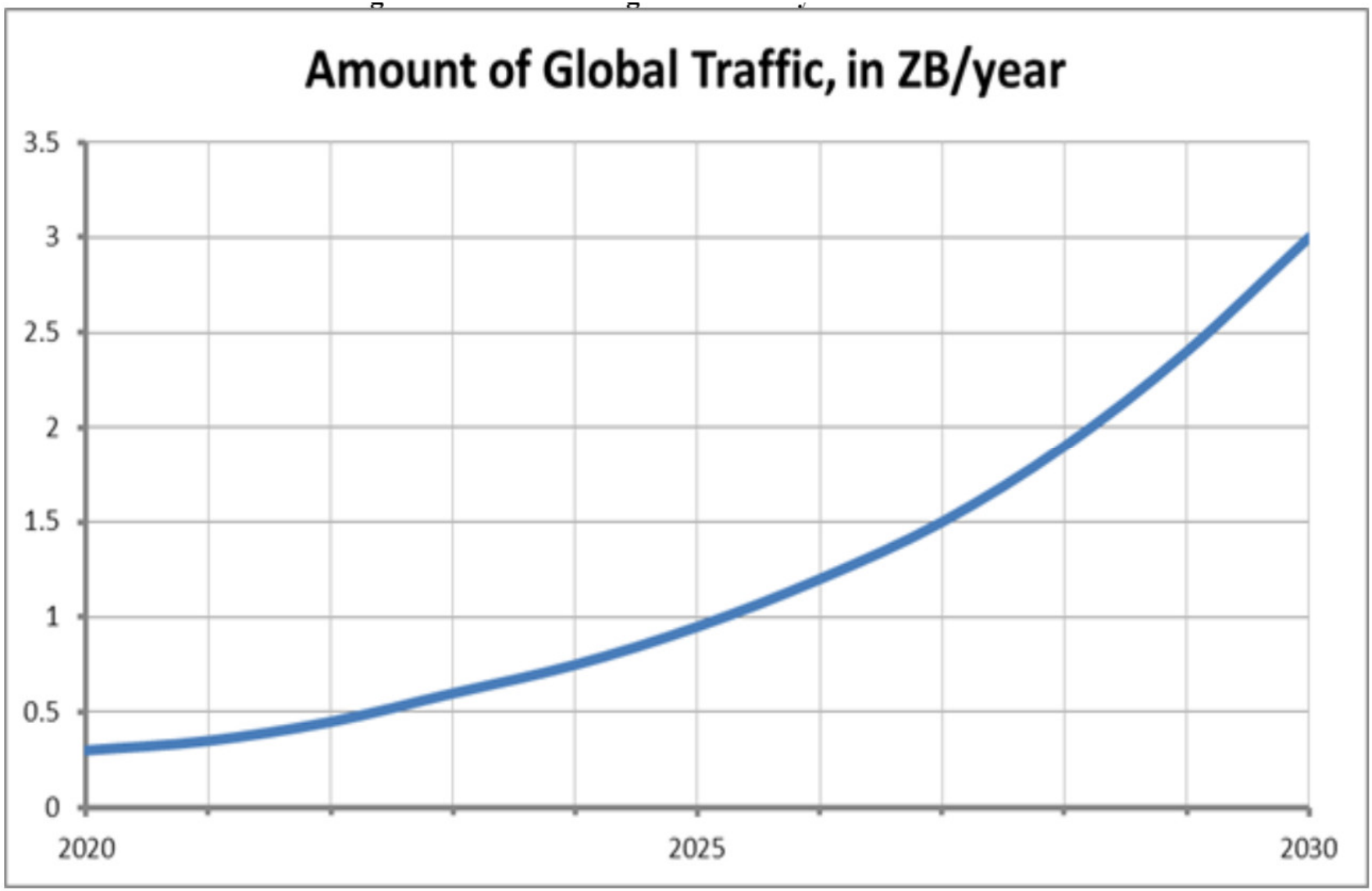


Rep. ITU-R M.2370-0

Estimation of mobile traffic by different service types globally



Global mobile traffic growth

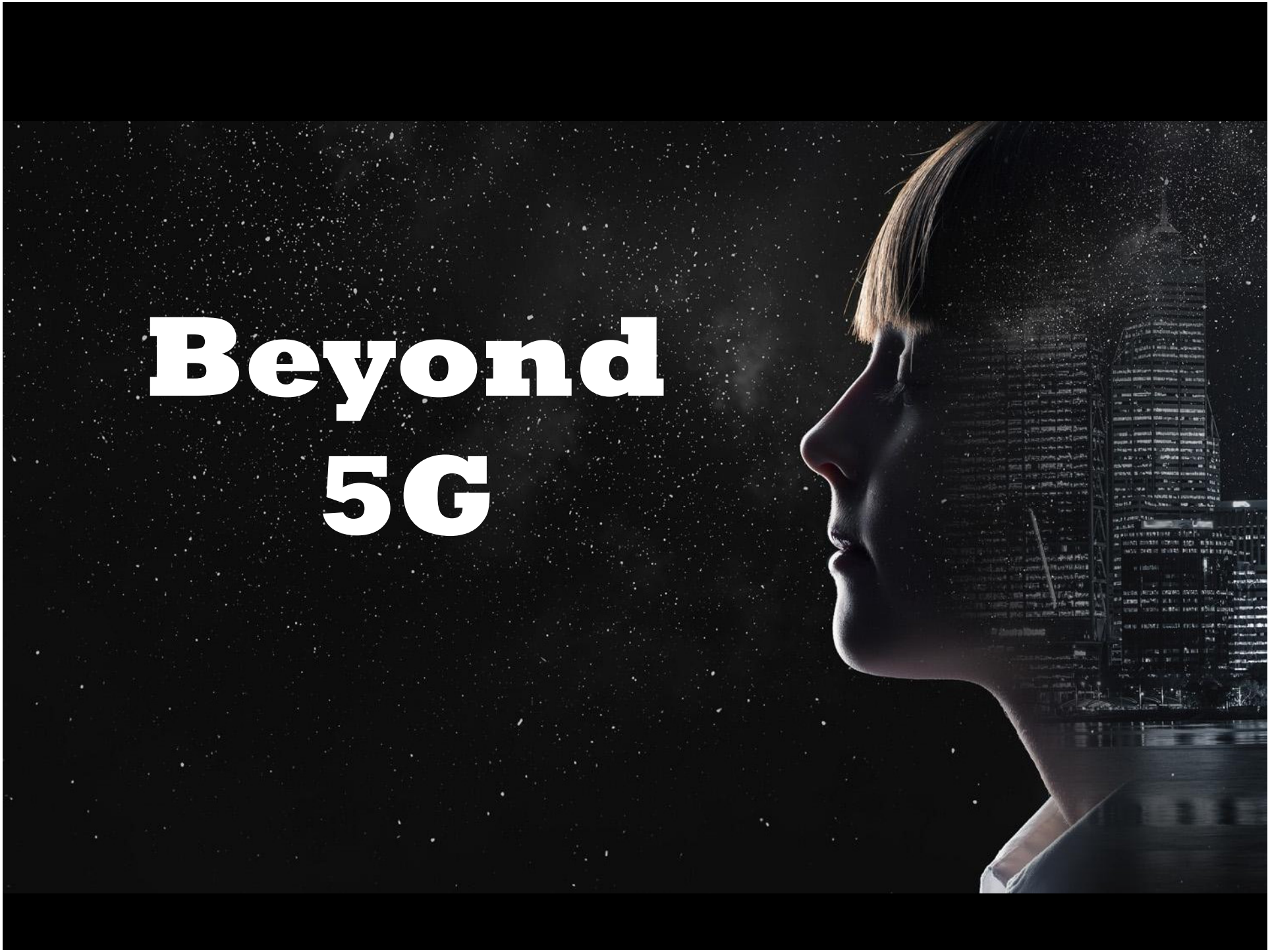


Global Mobile Data Trafic

Table 4. Global Mobile Data Traffic, 2017–2022

	2017	2018	2019	2020	2021	2022	CAGR 2017–2022
By Application Category (PB per Month)							
Video	6,821	12,051	19,279	29,149	42,734	60,889	55%
Non-Video	4,691	6,959	9,281	11,621	14,064	16,604	29%
By Device Type (PB per Month)							
Smartphones	10,132	17,172	26,122	37,548	52,560	71,975	48%
Tablets and PCs	1,021	1,311	1,675	2,140	2,744	3,525	28%
M2M	211	346	549	840	1,234	1,725	52%
Nonsmartphones	147	180	214	242	260	268	13%
Other portable devices	0.43	0.36	0.31	0.29	0.33	0.38	-3%
By Region (PB per Month)							
Asia Pacific	5,877	10,351	15,908	22,815	31,807	43,166	49%
Middle East and Africa	1,222	2,052	3,251	5,009	7,564	11,171	56%
Central and Eastern Europe	1,379	2,153	3,119	4,317	5,834	7,752	41%
North America	1,261	1,804	2,500	3,405	4,485	5,846	36%
Western Europe	1,022	1,471	2,062	2,807	3,801	5,120	38%
Latin America	752	1,178	1,720	2,418	3,308	4,439	43%
Total (PB per Month)							
Total Mobile Data Traffic	11,512	19,009	28,560	40,770	56,799	77,493	46%

Source: Cisco Mobile VNI, 2019


Beyond
5G

Beyond 5G

Beyond 5G

- **More advanced terahertz speeds**

جمع بندی

- تغییرات عمده در 5G
- سرعت بالاتر
- قابلیت اطمینان بیشتر
- جایگزینی گوشی ها با اشیا
- سرویس های جدید
- فناوری های جدید
- مدلهای جدید کسب و کار

با تشکر از شما

سوال؟ نظر؟ مطلب تکمیلی؟

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