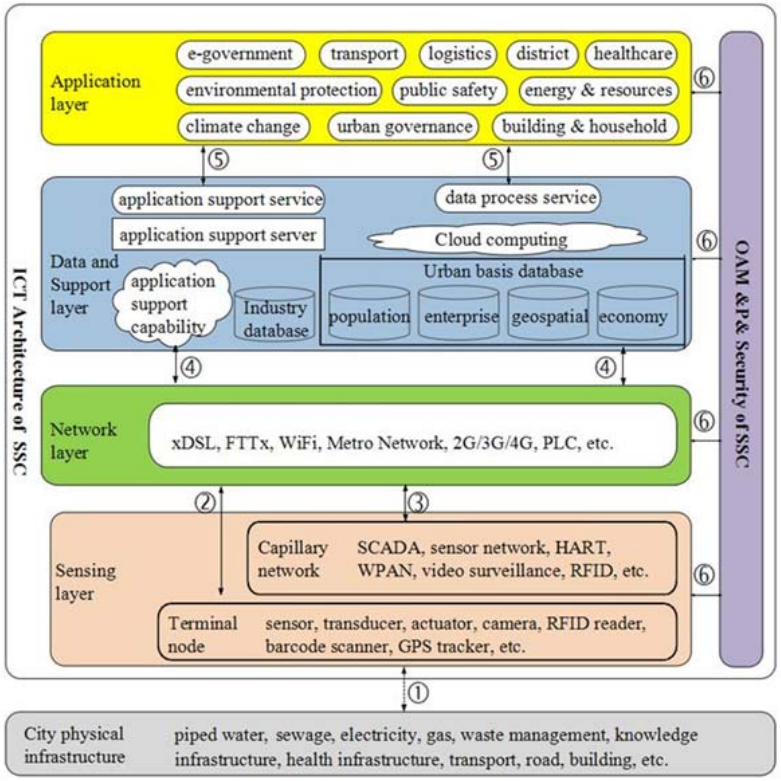
ITU Asia-Pacific Centre of Excellence Training
On
"Traffic engineering and advanced wireless network planning"

17-19 October 2018,
Bangkok, Thailand

Ashish Narayan & Aamir Riaz, ITU

Goals for a Sustainable Future : The SDGs

We are sitting on an opportunity curve in this digital society.....



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Enabling Environment , Digital Inclusion

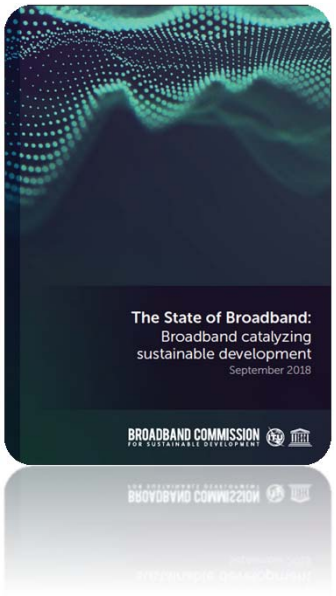
Skills and capacity Building

Innovation

Source: ITU-T Focus Group on Smart Sustainable Cities

Digital Transformation Process

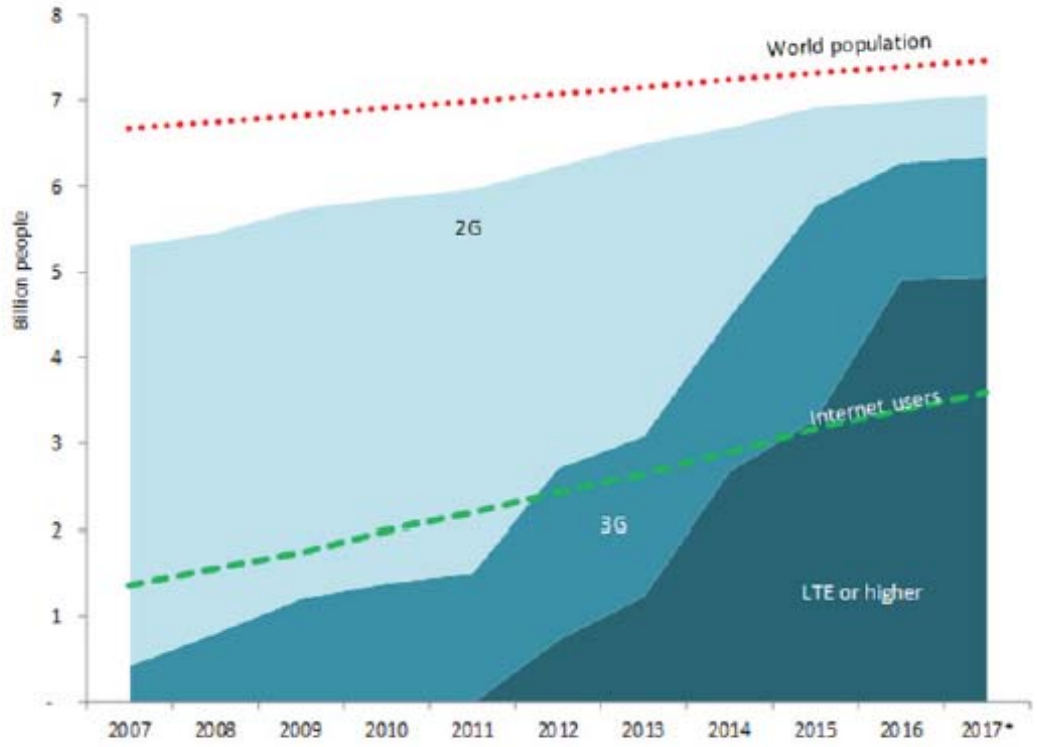
Estimates of the Global Market: 2015, 2016, 2017, 2020 and 2021



	2015	2016	2017	2020	2021
Mobile cellular subscriptions	7.2 bn (ITU) 7.2 bn (GSMA) 7.2 bn (E)	7.4 bn (ITU) 7.5 bn (GSMA) 7.5 bn (E)	7.74 bn (ITU) 7.8 bn (E)	8.3 bn (GSMA) 8.4 bn (E)	8.4 bn (GSMA) 8.6 bn (E)
Unique mobile phone users	4.6 bn (GSMA) 5.0 bn (E)	4.8 bn (GSMA) 5.1 bn (E)	5 bn (GSMA) 5.3 bn (E)	5.4 bn (GSMA) 5.7 bn (E) 5.4 bn (Cisco)[3]	5.5 bn (GSMA) 5.8 bn (E)
LTE subscriptions	1.1 bn (GSMA) 1.1 bn (E) 1.37 bn (ABI Research)[4] 1.068 bn (GSA)	1.8 bn (GSMA) 1.9 bn (E*) 2 bn (Strategy Analytics[5])	2.6 billion (GSMA) 2.8 bn (E*)	4.1 bn (GSMA) 3.5 bn (ABI) 4.8 bn (E) 3.6 bn (4G Am)	4.5 bn (GSMA) 5.3 bn (E)
5G subscriptions	-/-	-/-	-/-	70 m (GSMA) 55 million (E)	220 m (GSMA) 190 million (E)
Mobile broadband subscriptions	3.2 bn (ITU) 3.4 bn (GSMA) 3.6 bn (E)	3.65 bn (ITU); 4.1 bn (GSMA) 4.5 bn (E)	4.2 bn (ITU) 4.8 bn (GSMA) 5.3 bn (E*)	6.5 bn (GSMA) 7.0 bn (E)	6.9 bn (GSMA) 7.5 bn (E)
Smartphone subscriptions	3.3 bn (GSMA) 3.3 bn (E)	3.9 bn (GSMA) 3.8 bn (E)	4.5 bn (GSMA) 4.4 bn (E*)	5.9 bn (GSMA) 5.8 bn (E)	6.2 bn (GSMA) 6.3 bn (E*)
Fixed broadband (ITU)	820m (ITU)	884m (ITU)	979m (ITU) 1bn (E*)	1.1 bn (E*)	1.2 bn (E*)
Internet users (ITU)	3.21 bn (ITU)	3.49 bn (ITU)	3.58 bn (ITU)	4.16 bn (ITU)	-/-
Facebook users	1.59 bn MAU 1.04 bn DAU[6] (Dec 2015)	1.71 bn MAU 1.13 bn DAU	2.13 bn MAU 1.4 bn DAU	-/-	-/-
LINE users	215 million	217 million	207 million	203 million	-/-
Sina Weibo users	222 million	313 million	392 million	411 million	-/-
Vkontakte users	66.5 million	77.8 million	81.1 million	97 million	-/-
WeChat users	600 million*	806 million	963 million	1 billion	-/-
Smartphone stock	2.2 bn (Del)	-/-	-/-	2.1 bn (BI)[7]	-/

Source: Various. EST = Estimate. BI= Business Intelligence; Del = Deloitte; Facebook, E = Ericsson Mobility Report June 2018 at: https://www.ericsson.com/assets/local/mobility-report/documents/2018/ericsson-mobility-report-june-2018.pdf GSMA = GSMA database.
MAU = monthly active users; DAU = daily active users.
** Mid-year figures. https://investor.fb.com/investor-news/press-release-details/2018/Facebook-Reports-Fourth-Quarter-and-Full-Year-2017-Results/default.aspx and https://zephoria.com/top-15-valuable-facebook-statistics/*

Coverage of mobile-cellular networks in relation to world population

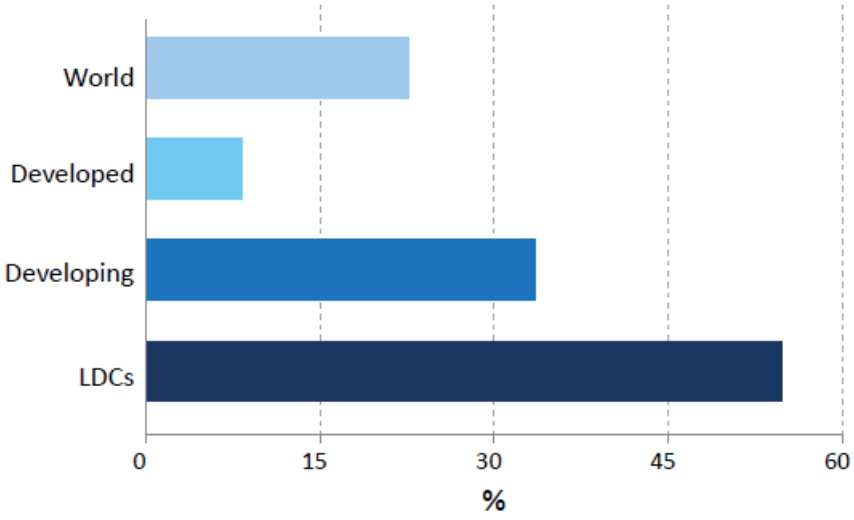


Source: ITU World Telecommunication/ICT Indicators database (* Estimate)

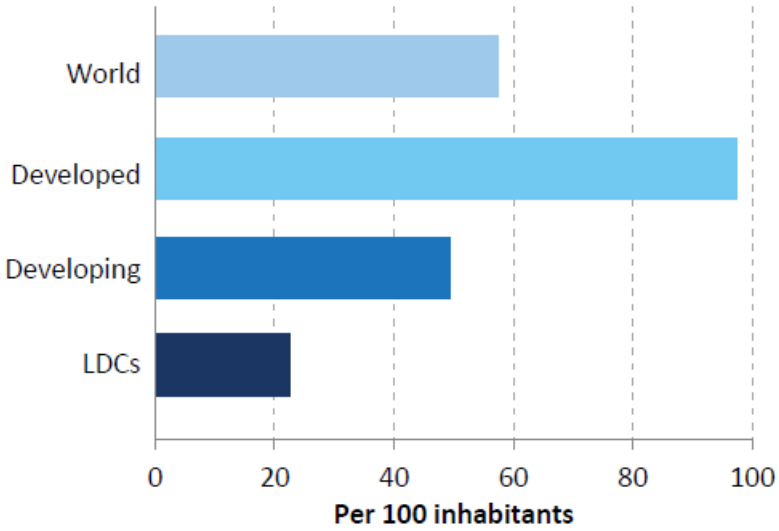
The number of subscriptions per 100 population has grown from 33.9 in 2005 to 76.6 in 2010, 98.2 in 2015 and an estimated 103.5 in 2017.

The number of subscriptions worldwide now exceeds the global population, with subscriptions also exceeding population in 112 of the 176 countries included in IDI 2017

Growth of mobile-broadband subscriptions, CAGR, 2012-2017*

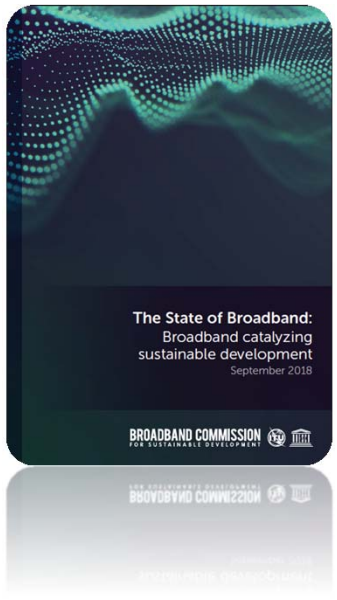


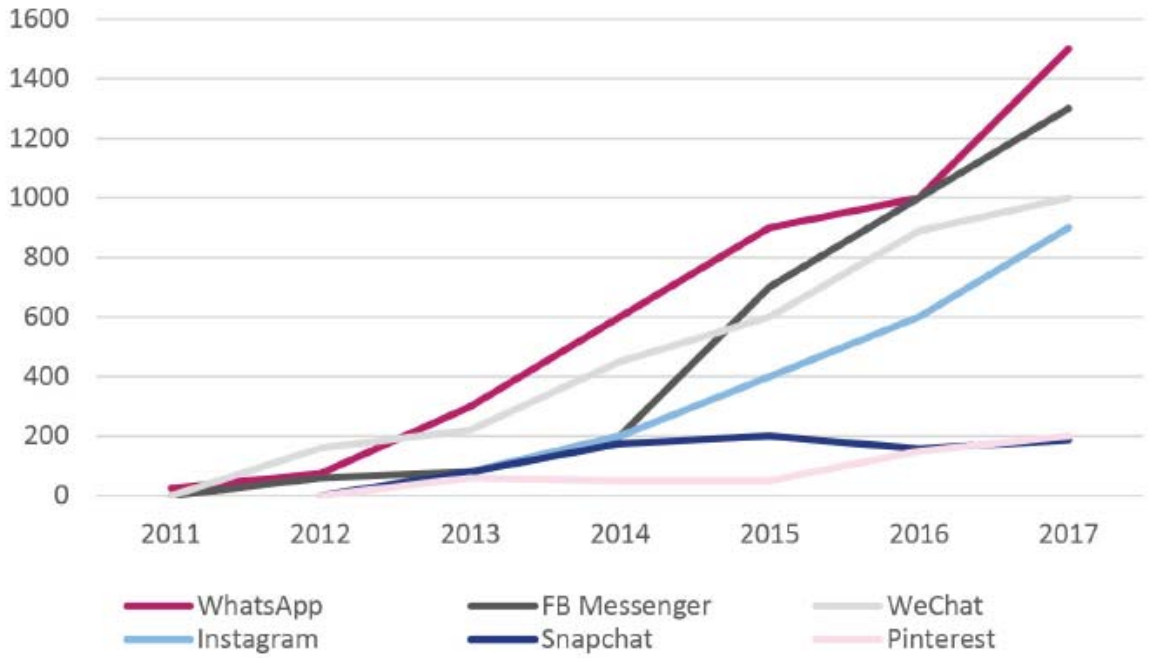
Mobile-broadband subscriptions, 2017*



Source: ITU.
Note: *Estimates. CAGR refers to the compound annual growth rate.

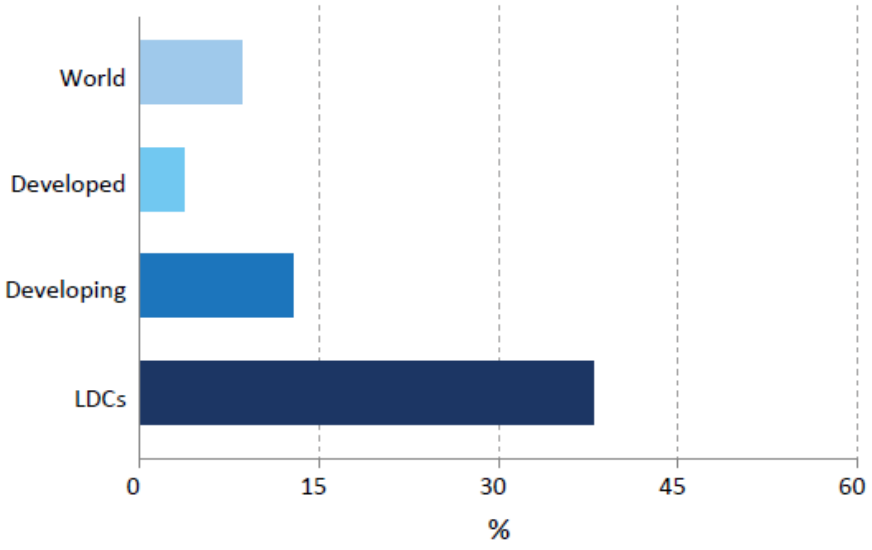
Growth in Number of Users of Messaging and Hybrid Networks, 2011-2017



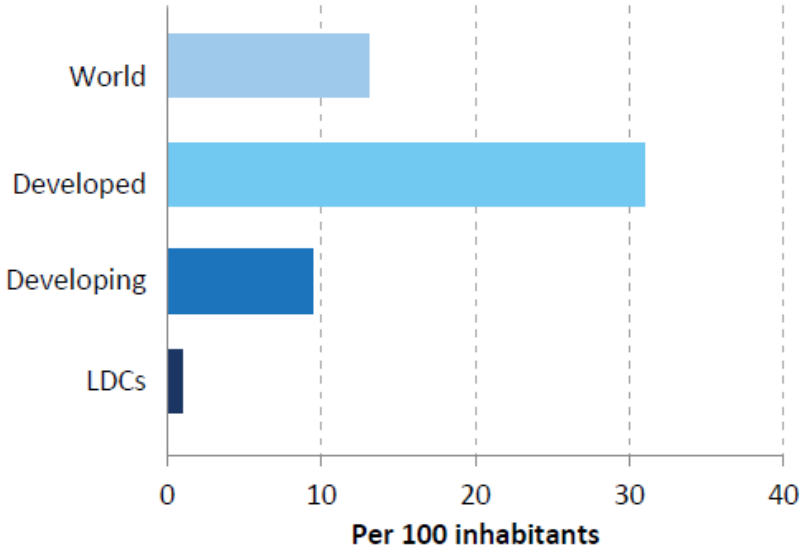


Source: Various, including Activate.com.

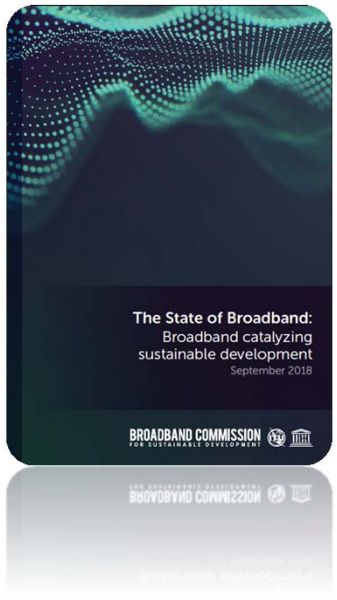
Growth of fixed-broadband subscriptions, CAGR, 2012-2017*



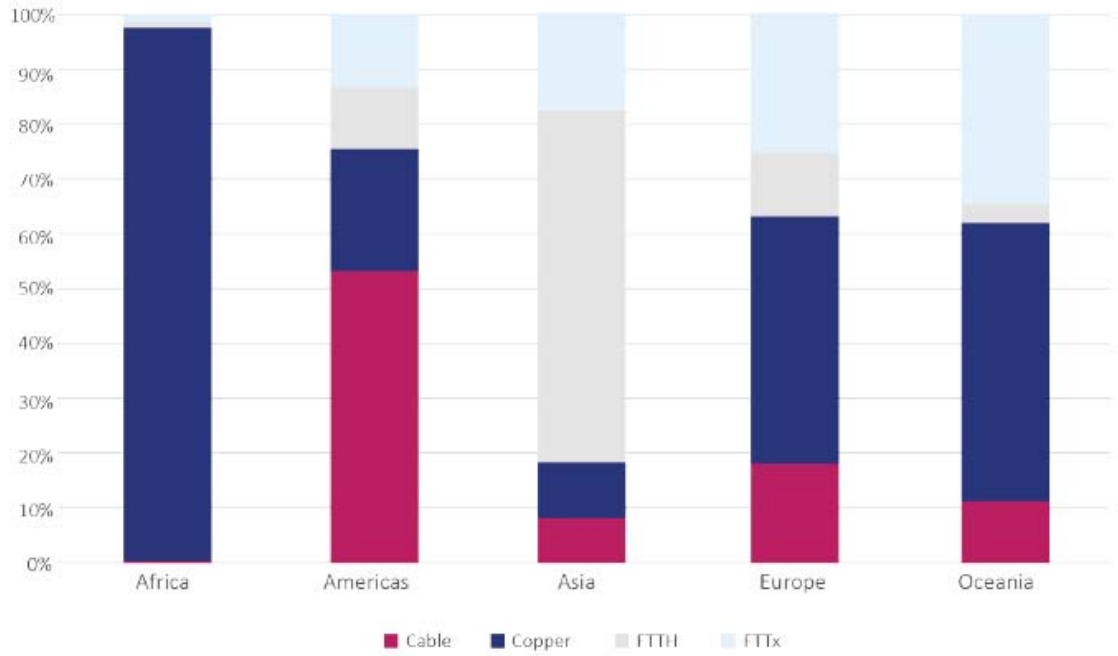
Fixed-broadband subscriptions, 2017*



Source: ITU.
Note: *Estimates. CAGR refers to the compound annual growth rate.

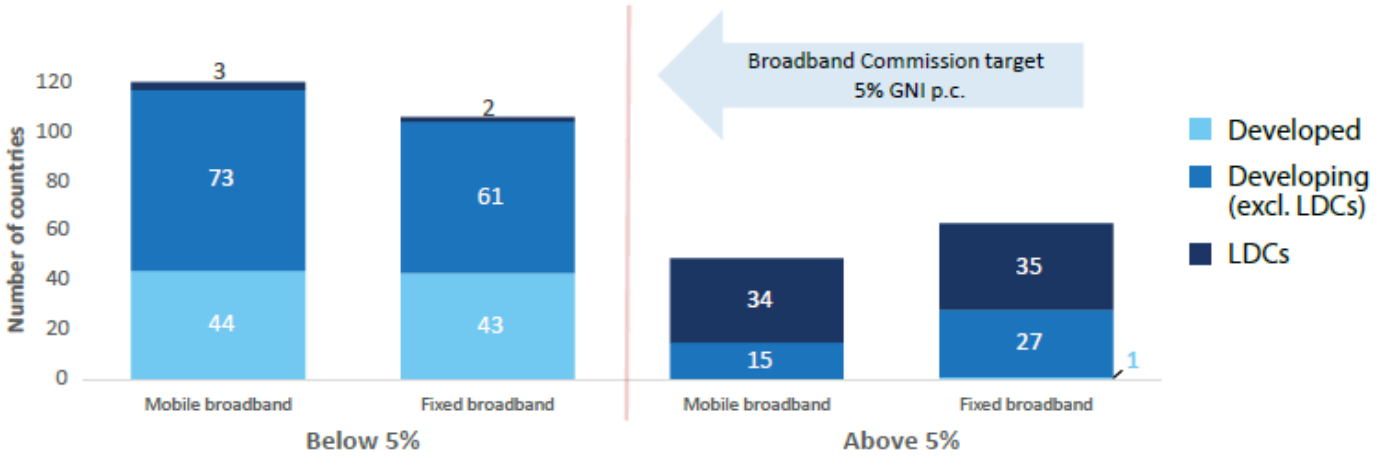


Fixed Network: Technology Market Share by Region, Q4 2017



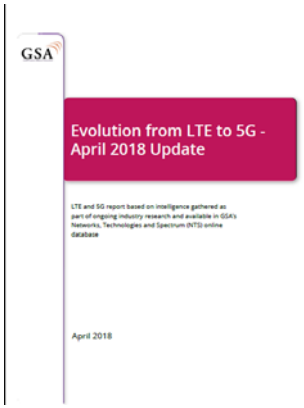
Source: Point Topic, available at: http://point-topic.com/free-analysis/world-broadband-statistics-q4-2017/.

Broadband prices as a percentage of GNI per capita, 2016



Mobile broadband is more affordable than fixed-broadband services in most developing countries. However, mobile-broadband prices represent more than 5% of GNI per capita in most LDCs and are therefore unaffordable for the large majority of the population.

Source: ITU.
Note: Based on data available for 169 countries. Prices are based on entry-level plans with a minimum data allowance of 1 GB per month.



Report: Evolution from LTE to 5G, GSA

https://gsacom.com/

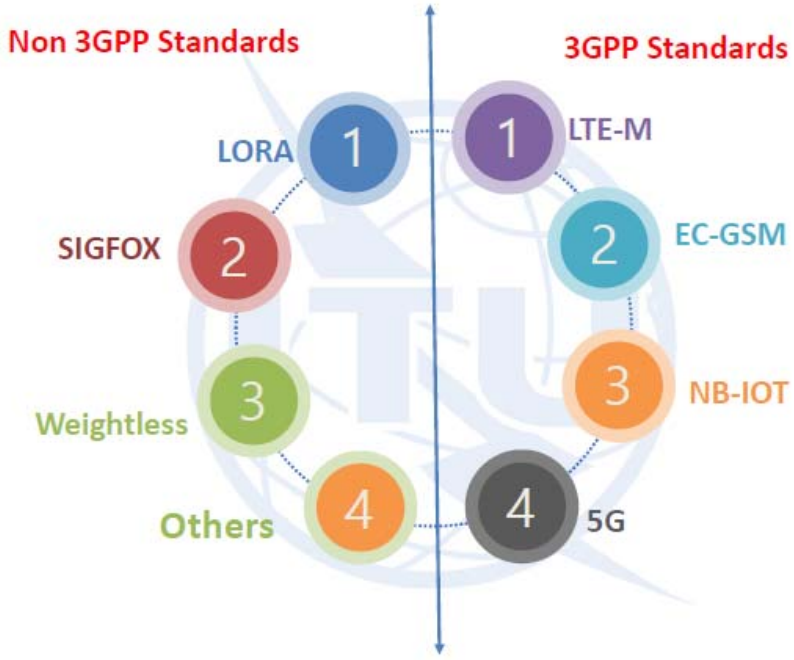
•• **858** operators investing in LTE, including pre-commitment trials.
•• **672** commercially launched LTE or LTE-Advanced networks in **204** countries, including those using LTE for FWA services, and including **111** LTE-TDD (TD-LTE) networks launched in **58** countries.
145 commercial VoLTE networks in **70** countries and **224** operators investing in VoLTE in **102** countries.
•• **241** launched networks that are LTE-Advanced in **115** countries.
•• **four** launched networks that are capable of supporting user equipment (UE) at Cat-18 DL speeds (within limited geographic areas)
•• **680–700** anticipated commercially launched LTE networks by end-2018 (GSA forecast).
•• **50** NB-IoT and **15** LTE-M/Cat-M1 networks commercially launched with **58** other operators investing in NB-IoT and **19** other operators investing in LTE-M/Cat-M1 in the form of tests, trials or planned deployments.
•• **134** operators that have been engaged in, are engaged in, plan to engage in, or have been licensed to undertake 5G demos, tests or trials of one or more constituent technologies.
•• at least **48** operators that have now made public commitments to time-lines for deployment of pre-standards '5G' or standards-based 5G networks in **33** countries.

IoT Technologies

Fixed & Short Range

i. RFID
ii. Bluetooth
iii. Zigbee
iv. WiFi

Long Range



LoRaWAN

Member's Login Contact

LoRa Alliance™

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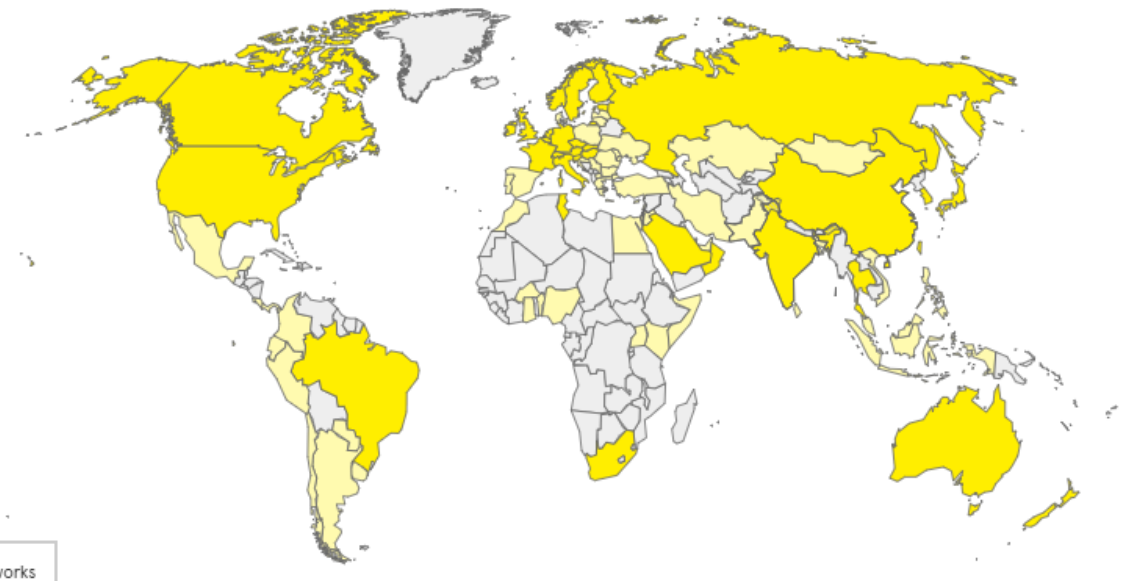
83
Network Operators

57
Alliance Member Operators

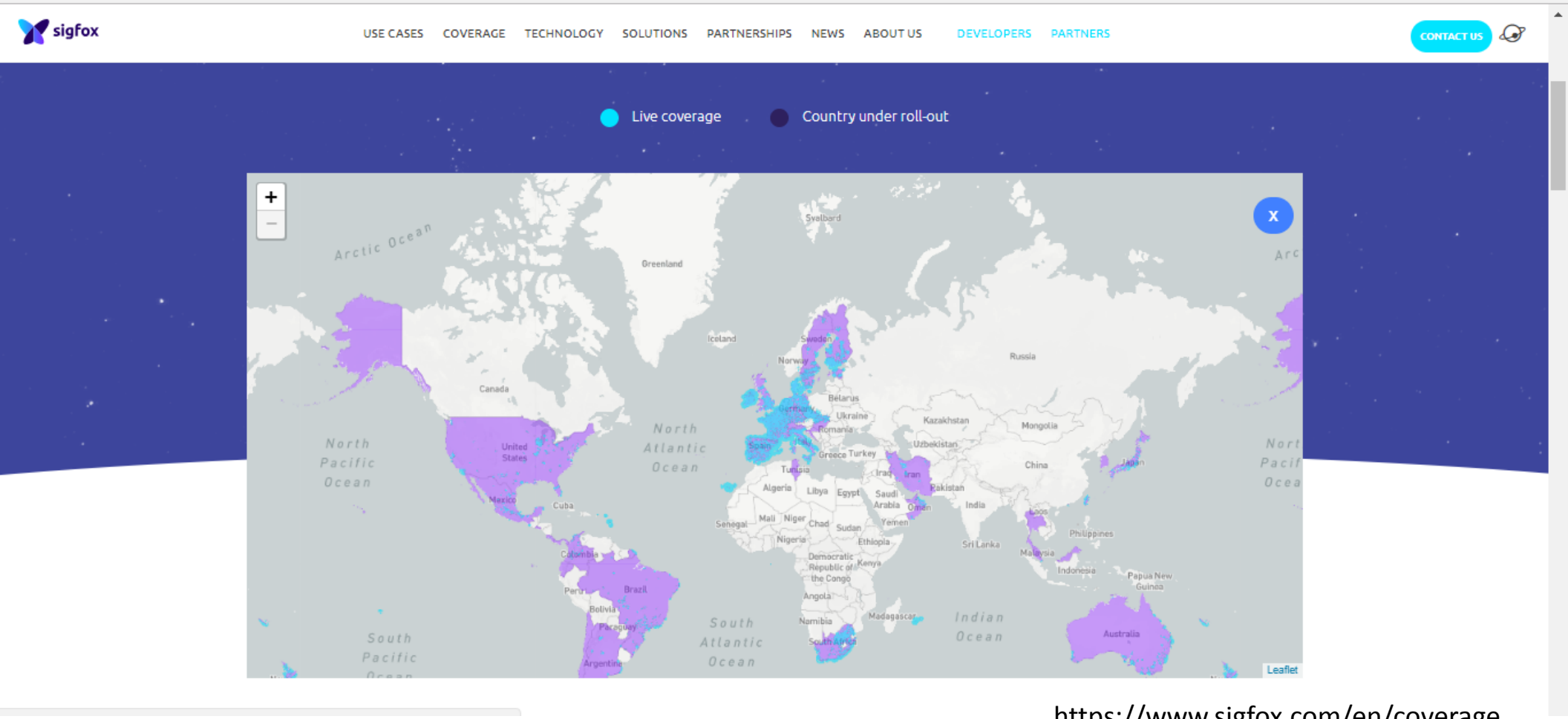
49
Countries operating in

95
Countries with LoRaWAN Deployments

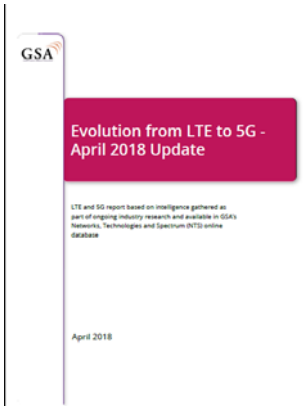


https://www.lora-alliance.org/

Sigfox



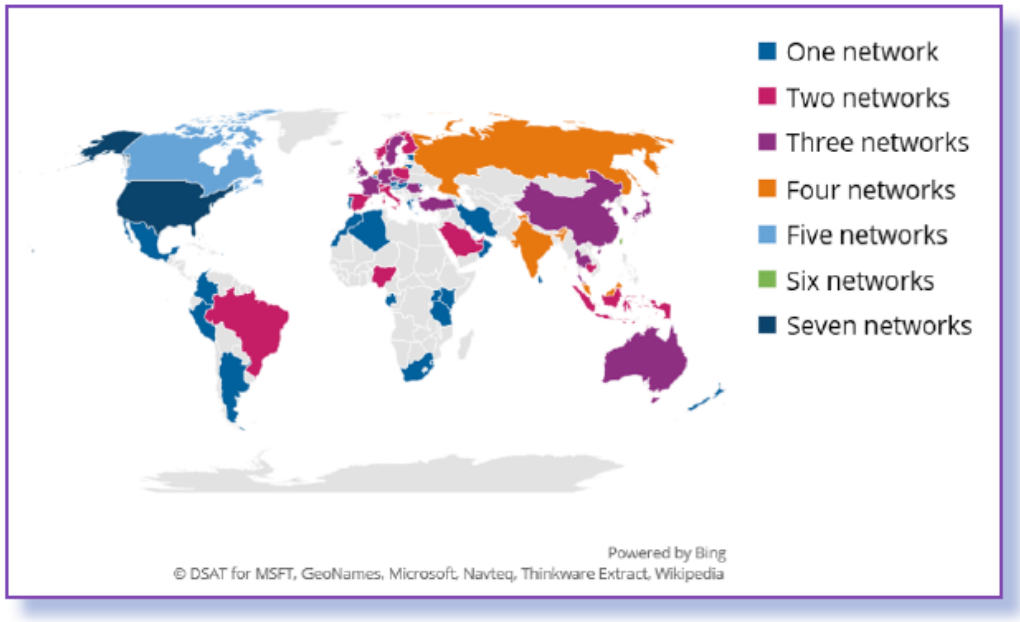
https://www.sigfox.com/en/coverage



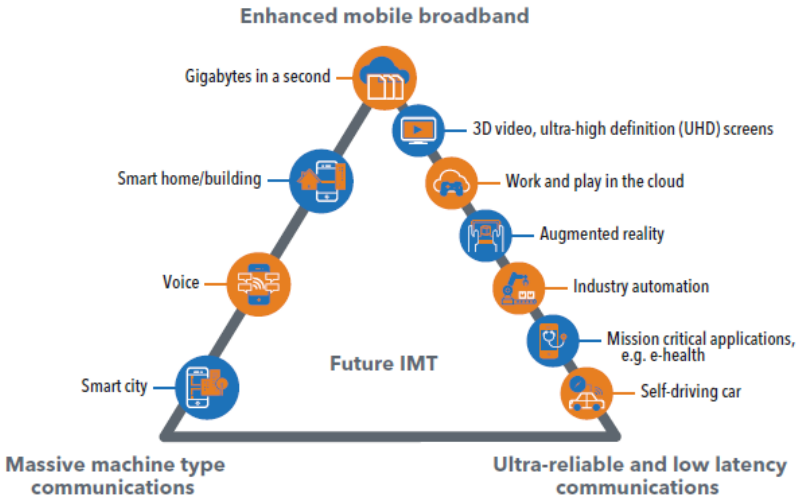
Report: Evolution from LTE to 5G, GSA

https://gsacom.com/

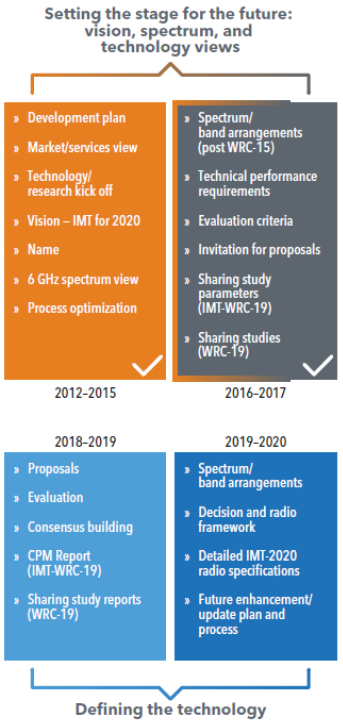
Figure 9: Number of launched VoLTE networks by country



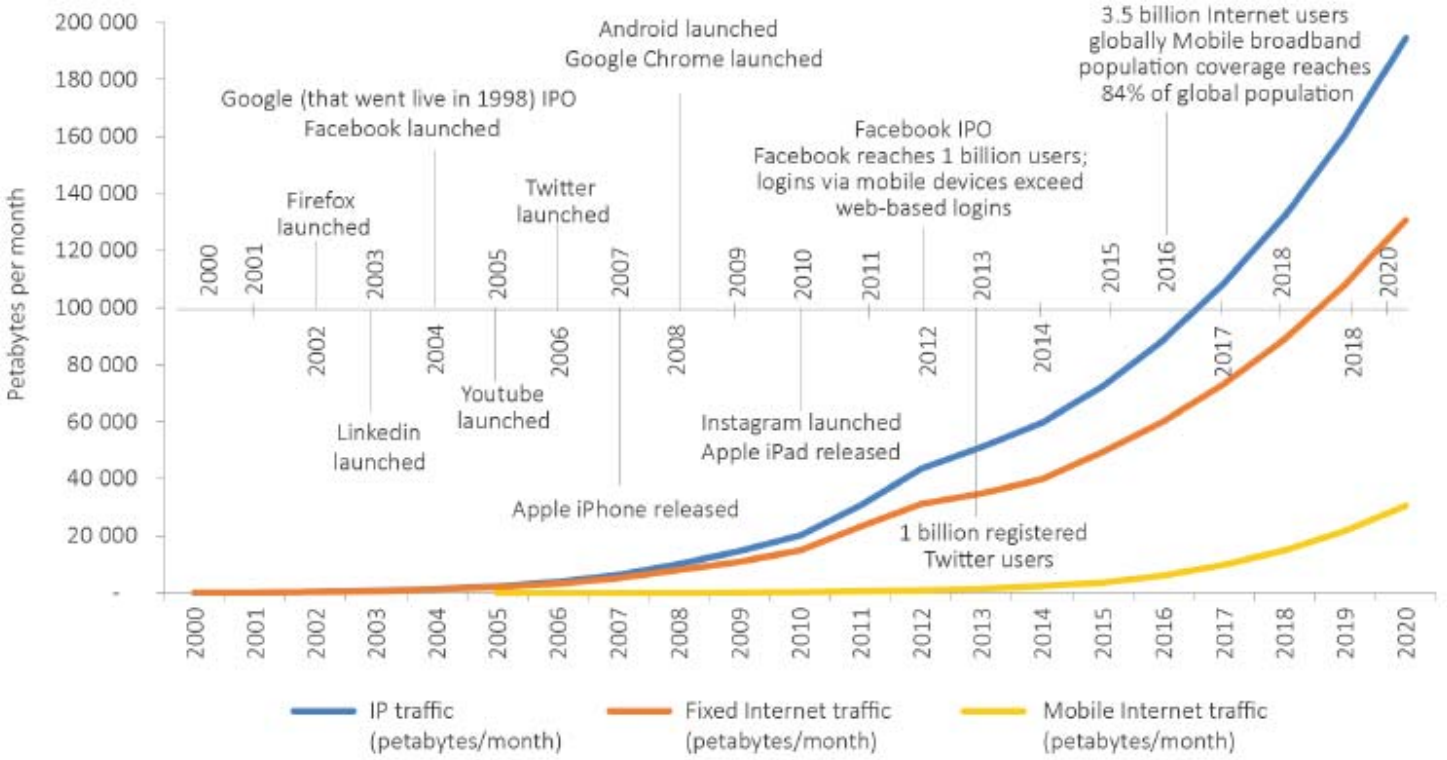
5G usage scenarios from the ITU-R IMT-2020 Vision Recommendation



IMT-2020 standardization process

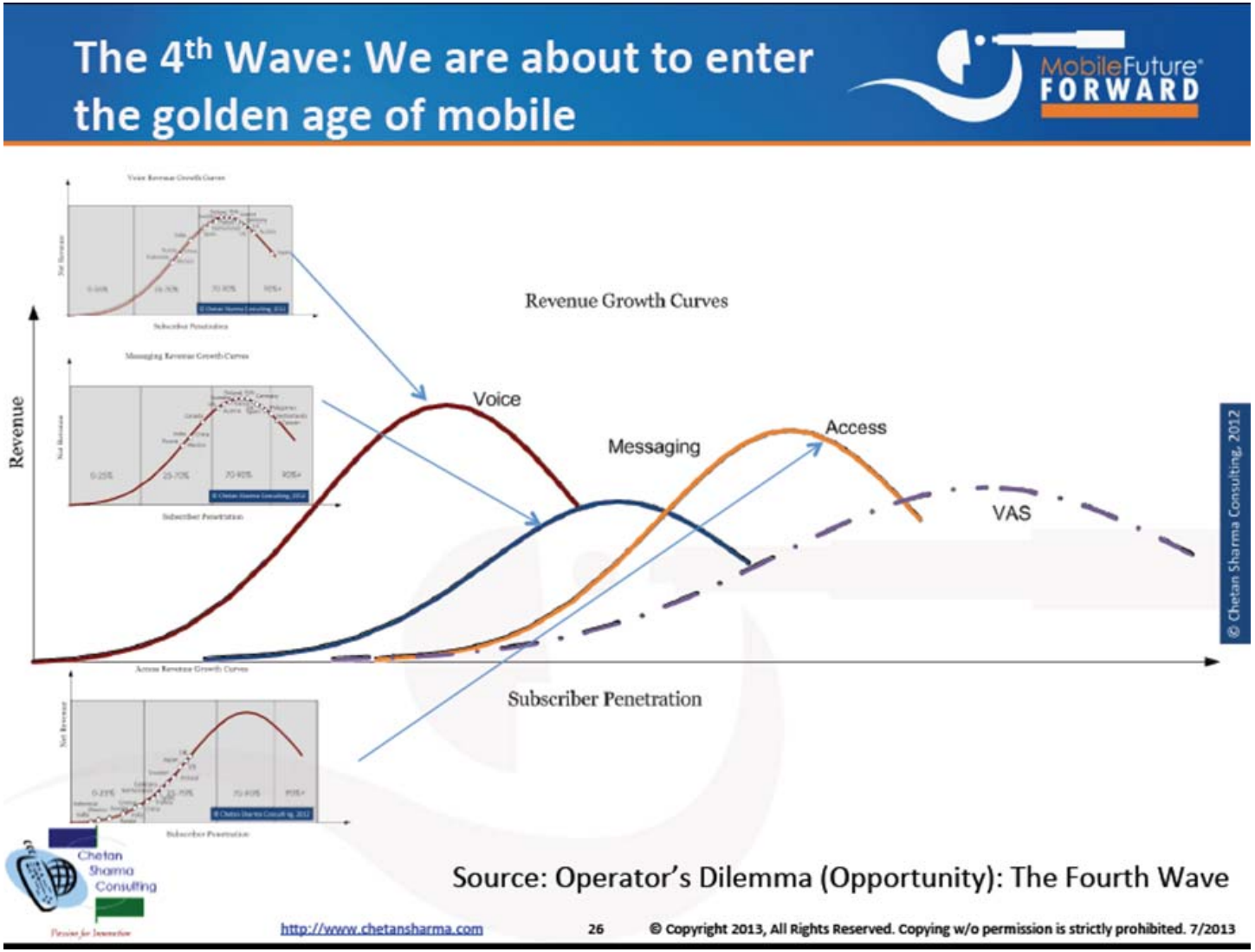


Internet and IP traffic



Note: Fixed Internet traffic refers to traffic through fixed network providers on different platforms. Mobile Internet traffic refers to traffic through mobile-cellular networks. IP traffic refers to the sum of fixed and mobile Internet traffic (denoting all IP traffic crossing an Internet backbone) as well as non-Internet IP traffic (e.g. IP WAN, IP transport of TV and video-on-demand).
Source: ITU based on Cisco and company reports.

4th Wave


The 4th Wave: We are about to enter the golden age of mobile
MobileFuture FORWARD
Revenue Growth Curves
Revenue
Voice
Messaging
Access
VAS
Subscriber Penetration
Chetan Sharma Consulting
Source: Operator's Dilemma (Opportunity): The Fourth Wave
http://www.chetansharma.com
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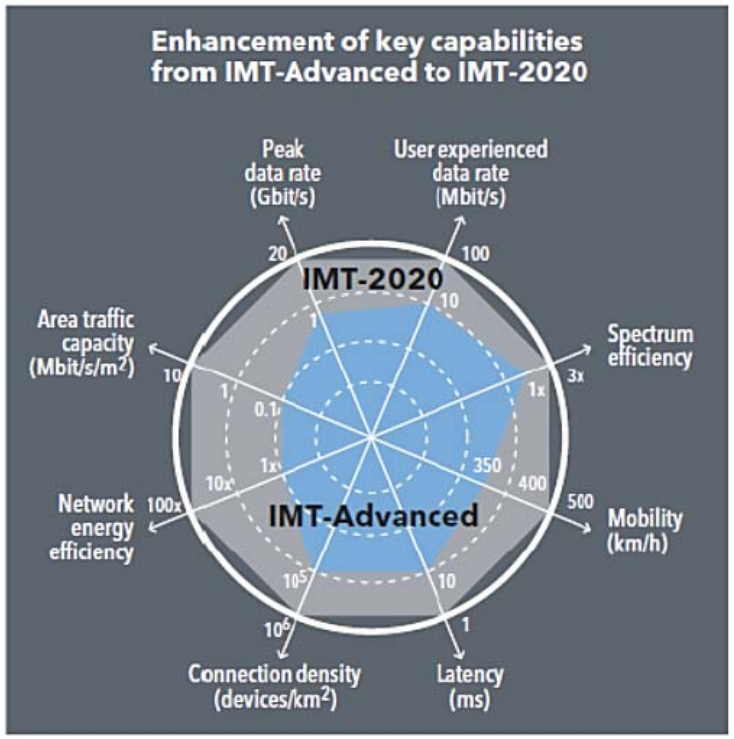
5G

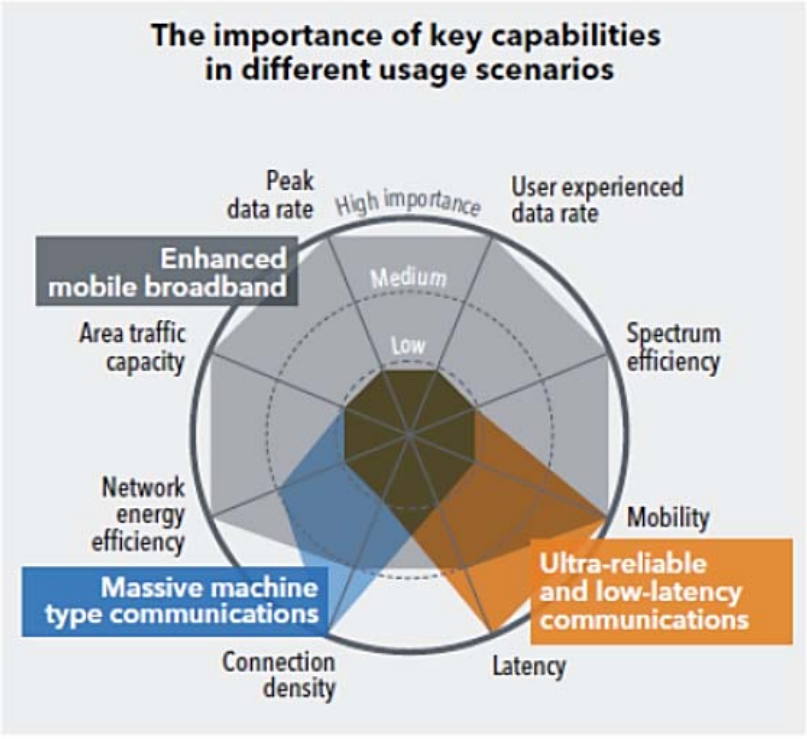
Commercial 5G networks are expected to start deployment after 2020 as 5G standards are finalized.

By 2025, the GSM Association (GSMA) expects 5G connections to reach 1.1 billion, some 12 per cent of total mobile connections. It also forecasts overall operator revenues to grow at a CAGR of 2.5 per cent, to reach USD 1.3 trillion by 2025.

	1G	2G	3G	4G	5G
Approximate deployment date	1980s	1990s	2000s	2010s	2020s
Theoretical download speed	2kbit/s	384kbit/s	56Mbit/s	1Gbit/s	10Gbit/s
Latency	N/A	629 ms	212 ms	60-98 ms	< 1 ms

IMT





The values in the figures above are targets for research and investigation for IMT-2020 and may be revised in the light of future studies. Further information is available in the IMT-2020 Vision ***(Recommendation ITU-R M.2083)***

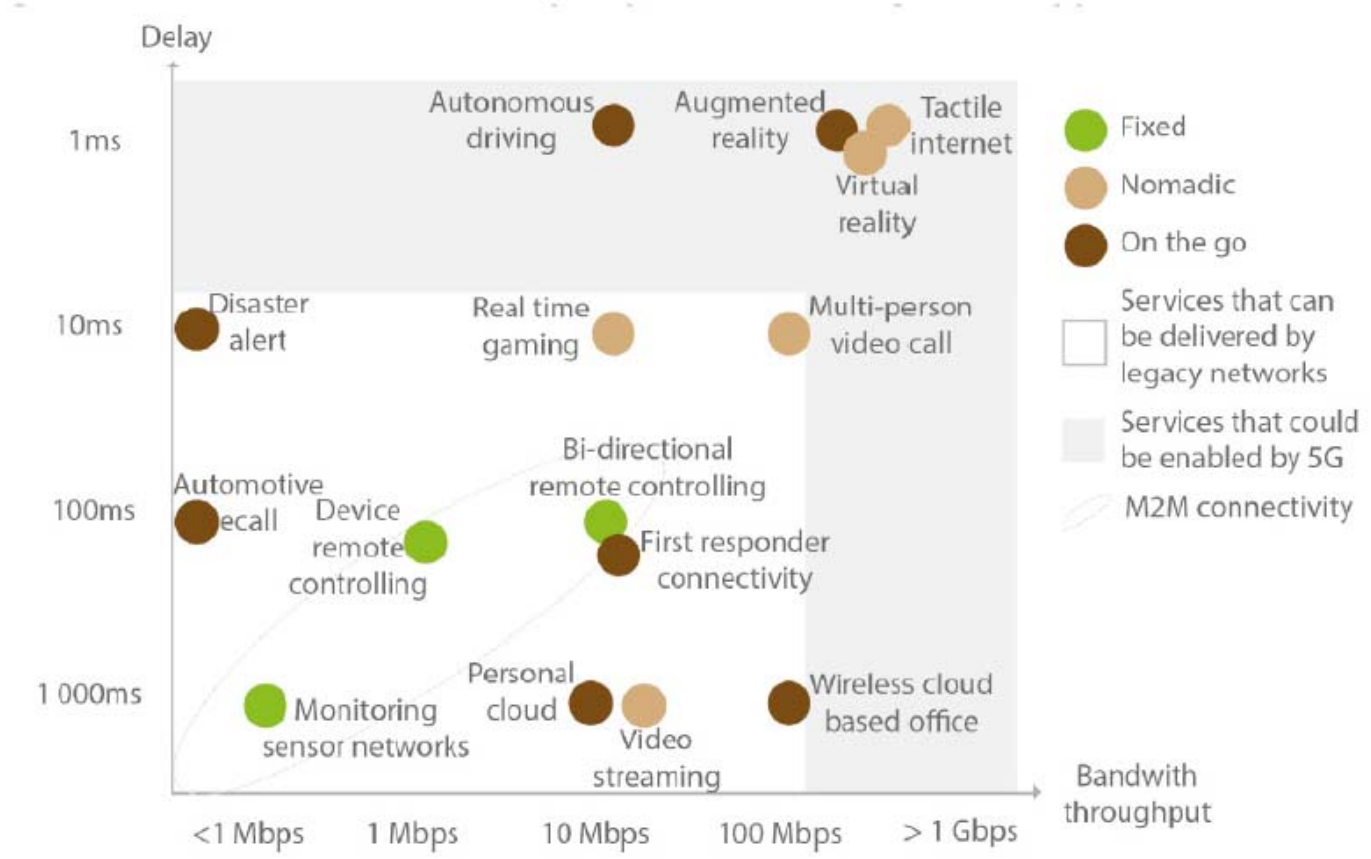
5G and Socio-Economic Benefits

One report estimates that 5G will underwrite USD 12.3 trillion of global economic output by 2035, with the greatest growth in sales activity coming from manufacturing because of an anticipated increase in spending on 5G equipment. This is followed by sales growth in the ICT sector driven by higher expenditure on communications services. Investment in the value chain is expected to generate a further USD 3.5 trillion in output and provide support for 22 million jobs by 2035.

The European Commission (EC) estimates the total cost of 5G deployment across the 28 Member States will be EUR 56 billion, resulting in benefits of EUR 113.1 billion per annum arising from the introduction of 5G capabilities, and creating 2.3 million jobs. It is also estimated that benefits are largely driven by productivity in the automotive sector and in the workplace generally. Most of the benefits are expected in urban areas while only 8 per cent of benefits (EUR 10 billion per annum) will be realized in rural areas.

The ITU suggests that policy-makers undertake an independent economic benefits assessment since third party estimates are not endorsed by the ITU.

Services that 5G would enable



Source: GSMA Intelligence, 2015.

Government-led 5G initiatives

- The Government of Korea (Rep. of), via the NISA, established 5G pilot networks at the 2018 Winter Olympics, providing futuristic experiences such as augmented reality-based navigation.
- A GBP 17.6 million government grant has been awarded to a consortium led by the University of Warwick to develop a UK central test bed for connected autonomous vehicles (CAVs). Small cells will be deployed along a route through Coventry and Birmingham where the CAVs will be tested.
- The FCC (US) has encouraged applications from the research community for experimental licences for radio frequencies not granted or assigned, to promote innovation and research through experiments in defined geographic areas.
- The EC Horizon 2020 work programme (2018-2020) is promoting innovation in 5G involving the EU, China, Taiwan, China and the US. Activities include end-to-end testing of cross-border connected and automated mobility, and 5G trials across multiple vertical industries.
- The Federated Union of Telecommunications Research Facilities for an EU-Brazil Open Laboratory (FUTEBOL), is creating research that promotes experimental telecommunication resources in Brazil and Europe. FUTEBOL will also demonstrate use cases based on IoT, heterogeneous networks and C-RAN.
- The Russian Ministry of Communications concluded an agreement with Rostelecom and Tattelecom to create an experimental 5G zone in the hi-tech city of Innopolis.

Sources: https: / / goo .gl/ JWFBCY (Korea Rep. of), https: / / goo .gl/ FnLZCd (UK), https: / / goo .gl/ wNVZqs (US), https: / / goo .gl/ iXkYQ o (Europe), https: / / goo .gl/ VNeDwn (EU-Brazil), https: / / goo .gl/ 4DySs2 (Russia)

Commercially-led 5G initiatives

- Telstra (Australia) is working with Ericsson on key 5G technologies including massive MIMO, beamforming, beam tracking and waveforms. Telstra and Ericsson achieved download speeds of between 18 Gbit/s and 22 Gbit/s during the first live trial of 5G in Australia. Optus also completed a 5G trial with Huawei, reaching the fastest speeds in Australia so far of 35 Gbit/s.
- Italian mobile operator Wind Tre, Open Fibre (Italy's wholesale fibre operator) and Chinese vendor ZTE have announced a partnership to build what they say will be Europe's first 5G pre-commercial network in the 3.6– 3.8 GHz band. They will also collaborate with local universities, research centres and enterprises to test and verify 5G technical performance, network architecture, 4G/5G network integration and future 5G use cases – including augmented reality or virtual reality, smart city, public safety and 5G healthcare. The pilot project will run until December 2021.
- A 5G pilot network was deployed in and around the Kazan Arena stadium (Russia) for the World Cup 2018 football tournament in a project led by MegaFon. Rostelecom is also partnering with Nokia on a 5G pilot wireless network located at a Moscow business park to test various 5G usage scenarios.
- Verizon (US) announced it is planning 5G tests in several US cities. The roll-outs will be based on wireless backhaul rather than fibre. AT&T also indicated that it will launch 5G fixed-wireless customer trials based on its recent trials in Austin where it achieved 1 Gbit/s speeds and sub-10 milliseconds latency. The tests will be conducted using equipment from Ericsson, Samsung, Nokia and Intel.
- Comsol plans to launch South Africa's first 5G wireless network. Comsol's trial will test the performance of 5G in real-world conditions using small cells in addition to macro solutions. It is likely that Comsol will offer fixed-wireless service to compete with fibre-to-the-home (FTTH) services.
- Huawei and NTT DOCOMO achieved a 4.52 Gbit/s downlink speed over 1.2km. Huawei supplied one of its 5G base stations, which supports massive MIMO and beamforming technologies in addition to its 5G core network.

Sources: https: / / goo .gl/ cWTC31 (Australia), https: / / goo .gl/ tYspR9 (Italy), https: / / goo .gl/ EQftwd (Russia), https: / / goo .gl/ yxaoyy (US), https: / / goo .gl/ VeuiaW (South Africa), https: / / goo .gl/ Teq6e2 (Japan)

5G: 16 key issues for policy-makers to consider

1)	Investment case	Policy-makers may consider undertaking their own independent economic assessment of the commercial viability of deploying 5G networks
2)	4G network strategy	Until the case for 5G networks can be clearly made, policy makers may consider enhancing the availability of and boosting the quality of 4G networks
3)	Harmonize spectrum	NRAs may consider allocating/assigning globally harmonized 5G spectrum bands
4)	Spectrum roadmap	NRAs may consider adopting a spectrum roadmap and a predictable renewal process
5)	Spectrum sharing	NRAs may consider allowing sharing to maximize efficient use of available spectrum, particularly to benefit rural areas
6)	Spectrum pricing	NRAs may consider selecting spectrum award procedures that favour investment
7)	700Mhz spectrum	Policy-makers may consider supporting the use of affordable wireless coverage (e.g. through the 700 MHz band) to reduce the risk of digital divide
8)	Fibre investment incentives	Policy-makers, where the market has failed, may consider stimulating fibre investment and passive assets through PPPs, investment funds and the offering of grant funding, etc.

5G: 16 key issues for policy-makers to consider

9)	Fibre tax	Policy-makers may consider removing any tax burdens associated with deploying fibre networks to reduce the associated costs
10)	Copper migration to fibre	Policy-makers may consider adopting policies/financial incentives to encourage migration from copper to fibre and stimulate deployment of fibre
11)	Wireless backhaul	Operators may consider a portfolio of wireless technologies for 5G backhaul in addition to fibre, including point-to-multipoint (PMP), microwave and millimeter wave (mmWave) radio relays, high altitude platform systems (HAPS) and satellites
12)	Access/sharing of passive infrastructure	Policy makers may consider allowing access to government-owned infrastructure such as utility poles, traffic lights and lampposts to give wireless operators the appropriate rights to deploy electronic small cell apparatus to street furniture NRAs may consider continuing to elaborate existing duct access regimes to encompass 5G networks allowing affordable fibre deployments
13)	Access costs	Policy-makers/NRAs may consider ensuring reasonable fees are charged to operators to deploy small-cell radio equipment onto street furniture
14)	Asset database	Policy-makers may considerholding a central database identifying key contacts, showing assets such as utility ducts, fibre networks, CCTV posts, lampposts, etc. This will help operators cost and plan their infrastructure deployment more accurately
15)	Wayleave (rights of way) agreements	Policy-makers may agree upon standardized wayleave agreements to reduce cost and time to deploy fibre and wireless networks
16)	5G test beds	Policy-makers may consider encouraging 5G pilots and test beds to test 5G technologies, and use cases, and to stimulate market engagement

Network sharing (examples)

• In November 2017, the Netherlands passed a bill designed to accelerate broadband roll-outs. It mandated all owners/administrators of networks and related infrastructure to comply with reasonable requests for shared access and/or coordinated network deployment, and to share information about their infrastructure.
• Indonesia's Ministry of Communications and Information Technology is working toward new rules to encourage the development of passive infrastructure sharing such as ducts, poles, towers, cabinets, etc.
• UK telecoms regulator Ofcom is running a market consultation to mandate the incumbent operator and significant market player BT to offer duct fibre access to rival operators. Previous attempts to mandate dark fibre access failed.
• In Italy, ultra-fast broadband legislation has enabled TIM and UTILITALIA (the federation of electricity, gas, water and environment companies) to sign a memorandum of understanding to facilitate the use of pre-existing infrastructures of more than 500 local utility operators to deploy fibre networks.

Sources: https: / / goo .gl/ kqYCRM (Netherlands), https: / / goo .gl/ vWq7aD (Indonesia), https: / / goo .gl/ vdFxz9 (Ofcom, UK), https: / / goo .gl/ m24g32 (Italy)

Streamlining the deployment of small cells (examples)

In September 2017, a California bill was passed streamlining small cell deployment by per-mitting its use and making such deployment no longer subject to a local discretionary permit or with specified criteria. The new legislation standardizes small cell deployments across the state. In addition, the bill:

- Grants providers non-discriminatory access to public property
- Allows local governments to charge permit fees that are fair, reasonable, non-discriminatory and cost-based• Limits the costs charged by local governments of attaching equipment to USD 250
- Stops local governments putting an unreasonable limit on the duration of the permit on the telecom facility

A similar approach has been proposed in a bill in Florida, requiring an authority to process applications for siting small cell equipment on utility poles on a non-discriminatory basis and approving applications within set time-scales. The bill also proposes that authorities may not enter into any exclusive arrangements entitling providers to attach equipment to authority utility poles. Furthermore, the bill states that authorities may not charge more than USD 15 per year, per utility pole.

In Washington State, a bill proposes to authorize the installation of small cell facilities on publicly owned assets and limits charges to USD 500 per annum. In Illinois, a bill proposes that local government may not prohibit, regulate or charge operators to deploy small cell wireless equipment.
Sources: California SB-649, 2017; Florida SB-596, 2017; Washington SB-5711, 2017; Illinois SB-1451, 2017

Network sharing (examples)

• In November 2017, the Netherlands passed a bill designed to accelerate broadband roll-outs. It mandated all owners/administrators of networks and related infrastructure to comply with reasonable requests for shared access and/or coordinated network deployment, and to share information about their infrastructure.
• Indonesia's Ministry of Communications and Information Technology is working toward new rules to encourage the development of passive infrastructure sharing such as ducts, poles, towers, cabinets, etc.
• UK telecoms regulator Ofcom is running a market consultation to mandate the incumbent operator and significant market player BT to offer duct fibre access to rival operators. Previous attempts to mandate dark fibre access failed.
• In Italy, ultra-fast broadband legislation has enabled TIM and UTILITALIA (the federation of electricity, gas, water and environment companies) to sign a memorandum of understanding to facilitate the use of pre-existing infrastructures of more than 500 local utility operators to deploy fibre networks.

Sources: https: / / goo .gl/ kqYCRM (Netherlands), https: / / goo .gl/ vWq7aD (Indonesia), https: / / goo .gl/ vdFxz9 (Ofcom, UK), https: / / goo .gl/ m24g32 (Italy)

Network sharing (examples – commercially driven)

• In Spain, telecoms operator MASMOVIL has passed the ten million household threshold using a fibre network that it shares with Orange Espana through a network-sharing pact.
• In Portugal, Vodafone and operator NOS have signed an agreement to deploy and share a fibre network that will be marketed to around 2.6 million homes and businesses. The two companies provide access to each other's networks on agreed commercial terms.
• New Zealand's wholesale network operator, Chorus, is calling on the government to begin formulating plans for a single 5G mobile network – one which can be shared by all service providers, a more sustainable approach than having a separate 5G network for each of the country's three mobile operators.
• Vodafone Cameroon has recently signed a 'strategic national network sharing agreement' with CamTel, allowing Vodafone to use CamTel's existing network infrastructure in Douala and Yaounde and to expand its coverage to new locations across the country.
• Telenor Denmark and Telia Denmark have signed a services contract with Nokia to manage their shared mobile networks run by one infrastructure company (TT-Netvaerket).• Econet Wireless (Zimbabwe), has stated it is open to infrastructure sharing, under an equitable 'one-for-one' infrastructure.

Sources: https: / / goo .gl/ u2fojb (Spain), https: / / goo .gl/ bT9hZ4 (Portugal), https: / / goo .gl/ vh4LGP (New Zealand), https: / / goo .gl/ AAbapS (Cameroon), https: / / goo .gl/ JmuSnJ (Denmark), https: / / goo .gl/ iSb4sq (Zimbabwe)

Spectrum Needs of IoT

What are the spectrum needs of IoT?

- Determined by each application's throughput requirements, but also latency
  - *For a given spectral efficiency (b/s/Hz), the lower the latency requirements the larger the bandwidth needed to send a given amount of data*
- While many IoT applications might not need high speed connections and/or have very stringent latency requirements, some do (e.g. remote surgery)

In what frequency bands?

- Determined by each IoT application's range and coverage requirements, but also bandwidth needs of the applications
- Range and coverage requirements also depend on deployment scenarios
  - *Point-to-point, mesh, broadcast, multi-cast, etc.*

Spectrum Licensing for IoT

Spectrum for MTC/IoT applications

Unlicensed spectrum

- *Low cost /no license fees Regulatory limits (EIRP restrictions)*
- *Non-guaranteed QoS*

• All devices can have access to spectrum, subject to compliance with technical conditions as specified in regulations

• Short range and delay-tolerant applications are typical use cases

Licensed spectrum

- *Better Inference management*
- *Network Security*
- *Reliability*

Mobile operator Network

Reuse cellular infrastructure and device eco-system for M2M/ IoT apps

- IMT spectrum can be used for supporting NB-IoT, eMTC and LTE-V2N (eNB-to–vehicle)
- MBB spectrum can also be used for M2M/IoT

Dedicated Network

Private network customized for specific M2M/IoT apps.

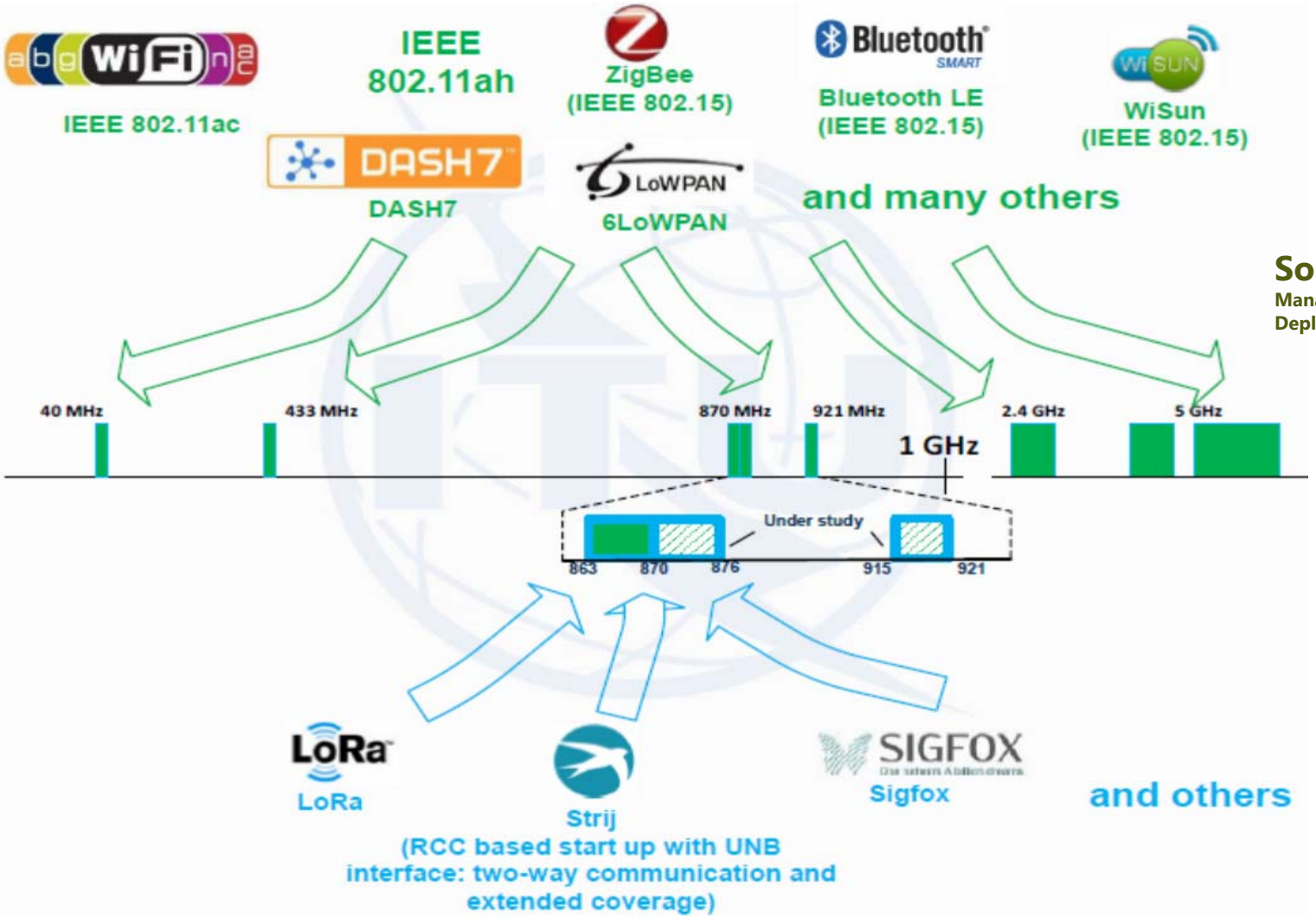
Example: In **China** New bands for M2M:

- 5 905 -5 925 MHz for LTE-V2X trials
- 2 x 2.3 MHz in 800MHz can be used for NB-IoT

Spectrum - New spectrum bands under study for WRC-19

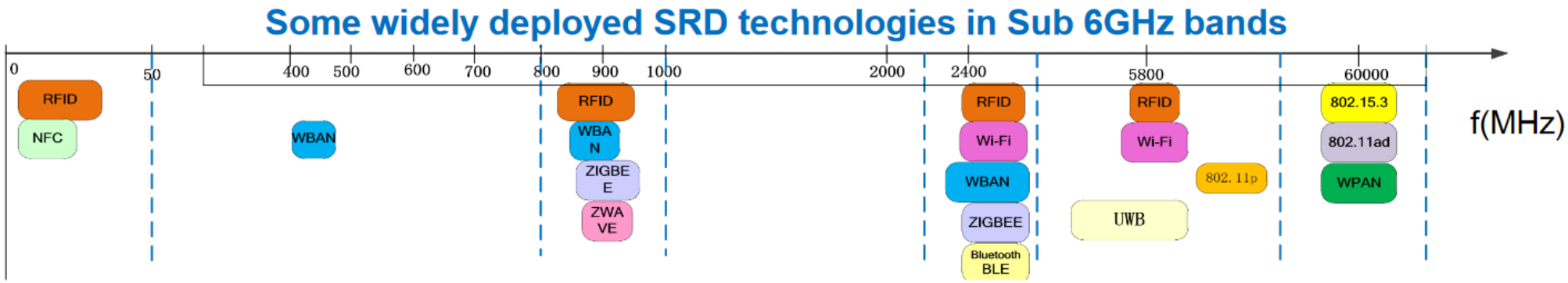
Existing mobile allocation	No global mobile allocation
24.25 – 27.5 GHz	31.8 – 33.4 GHz
37 – 40.5 GHz	40.5 – 42.5 GHz
42.5 – 43.5 GHz	
45.5 – 47 GHz	47 – 47.2 GHz
47.2 – 50.2 GHz	
50.4 GHz – 52.6 GHz	
66 – 76 GHz	
81 – 86 GHz	

Spectrum usage for IoT - SRDs



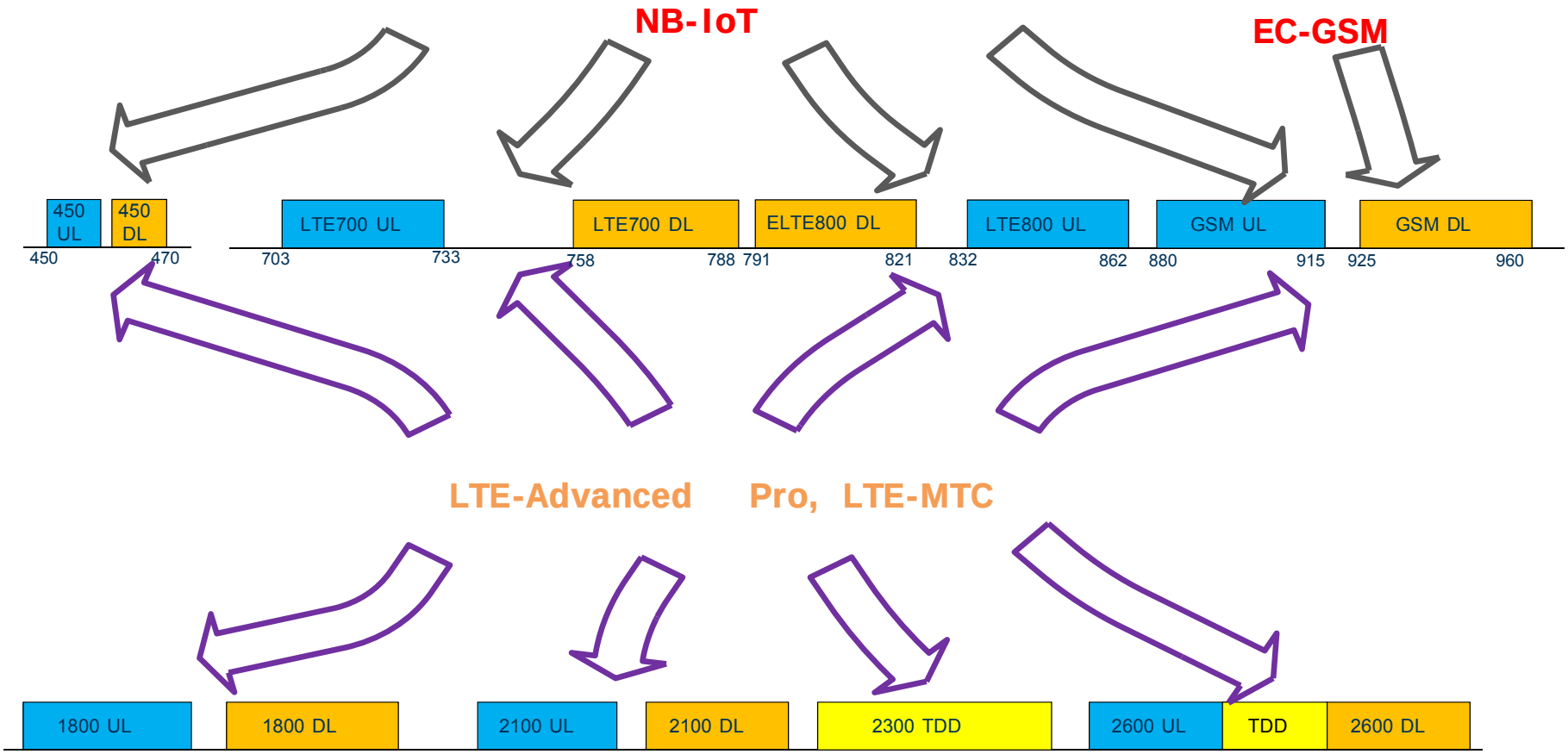
Source: ITU Workshop on Spectrum Management for Internet of Things Deployment, 22 November 2016, Geneva

Spectrum usage for IoT - SRDs



Source: ITU Workshop on Spectrum Management for Internet of Things Deployment, 22 November 2016, Geneva

IoT deployments in Licensed Spectrum - IMT



Spectrum Needs of IoT

M2M
Radiocommunication Technologies

Technology	Spectrum band
NB-IoT	MBB bands
eMTC	MBB bands
Sigfox	868MHz
LTE-V2X	MBB bands (Uu)
	5.8,5.9GHz (PC5)
Bluetooth	2.4GHz
ZigBee	868/2450MHz
RFID	13.56/27.12/433/ 860MHz …
NFC	13.56MHz
Z-WAVE	868 MHz
Ingenu	2.4GHz

Frequency range

- Sub-1 GHz band are most suitable for efficient provision of wide area coverage;

Authorization

- Sharing spectrum with unlicensed authorization to achieve low cost and low power requirements

- Licensed (exclusive) spectrum is more suitable for wide area coverage and/or higher reliability requirements for delay sensitive applications

IMT- Identified Spectrum

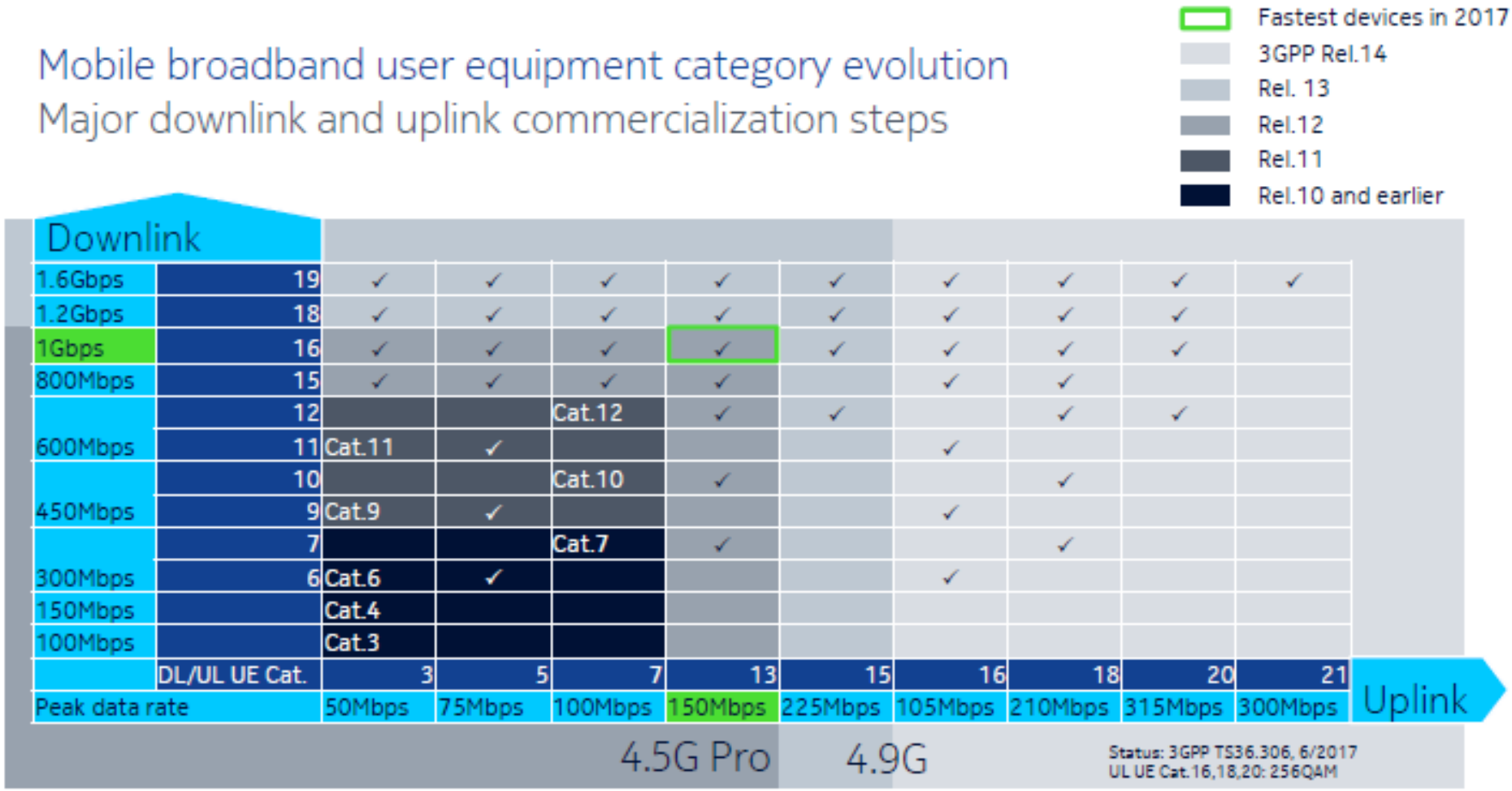
Definition

Res. ITU-R 56-1: *Naming for International Mobile Telecommunications*

Since ITU is the internationally recognized entity that has sole responsibility to define and to recommend the standards and frequency arrangements for IMT systems, with the collaboration of other organizations such as standard development organizations, universities, industry organizations and with partnership projects, forums, consortia and research collaborations, therefore the RA-15 debated especially on naming of IMT systems.

- *the existing term* **IMT-2000** *continues to be relevant and should continue to be utilized;*
- *the existing term* **IMT-Advanced** *continues to be relevant and should continue to be utilized;*
- *However for systems, system components, and related aspects that include new radio interface(s) which support the new capabilities of systems beyond IMT-2000 and IMT-Advanced, the term "***IMT-2020***" be applied*
- *In addition it was resolved that the term "IMT" would be considered the root name that encompasses all of IMT-2000, IMT-Advanced and IMT-2020 collectively.*

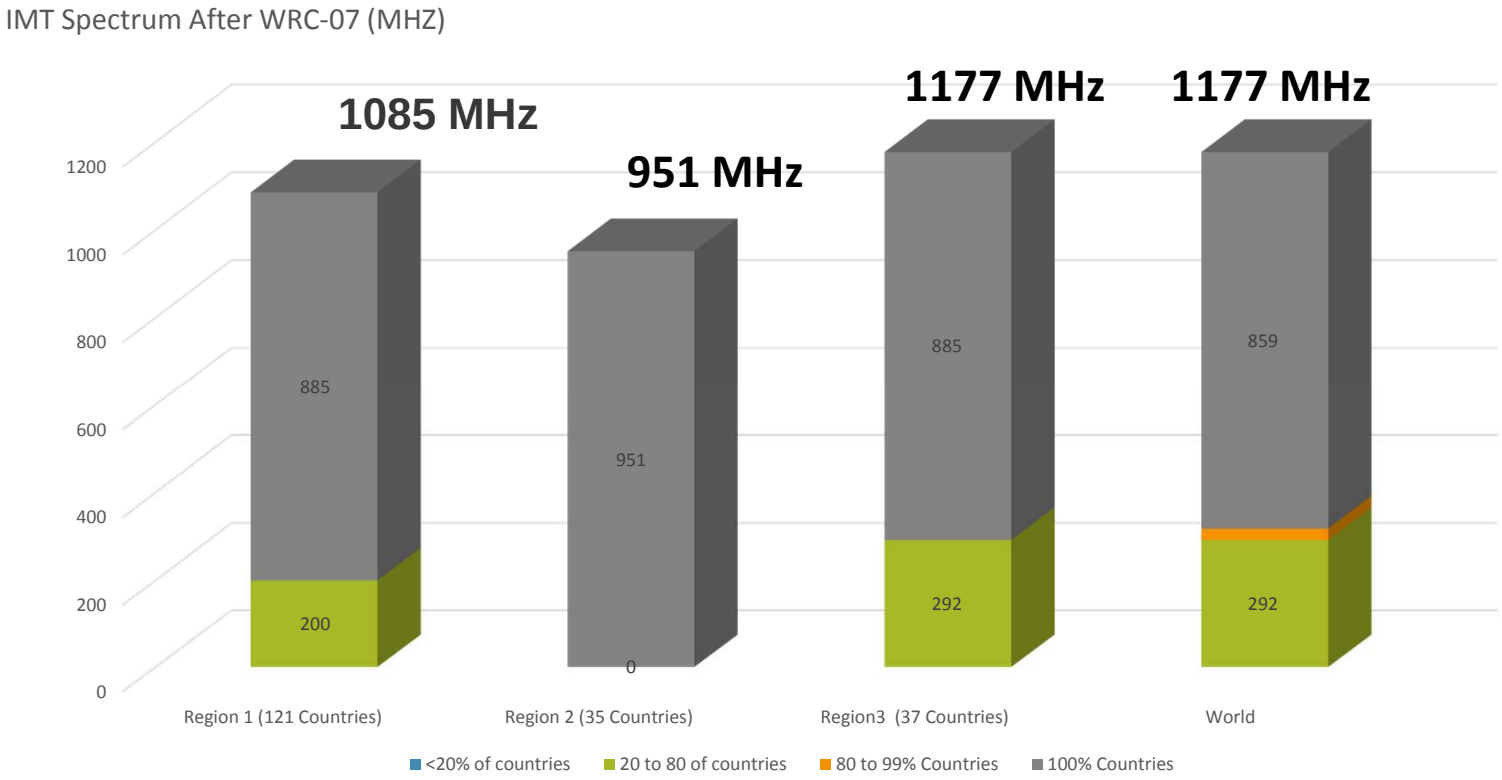
Mobile broadband user equipment category evolution
Major downlink and uplink commercialization steps



NOKIA

Recalling WRC-15 outcomes

IMT Spectrum after WRC-07



Outcomes of WRC-15

➢ Need for More spectrum

User density	Total requirement by 2020 (MHz)	Region 1		Region 2		Region 3	
		Already identified (MHz)	Additional demand (MHz)	Already identified (MHz)	Additional demand (MHz)	Already identified (MHz)	Additional demand (MHz)
Low	1 340	981-1 181	**159** – 359	951	389	885 - 1 177	163 – 455
High	1 960		779 - 979		1 009		783 - **1 075**

Estimated additional spectrum requirements by 2020 ranged from 159 to 1075 MHz depending on Region and user density)

Source: CPM-15 report (Additional Spectrum Requirements)

Outcomes of WRC-15

➢ New spectrum Identified

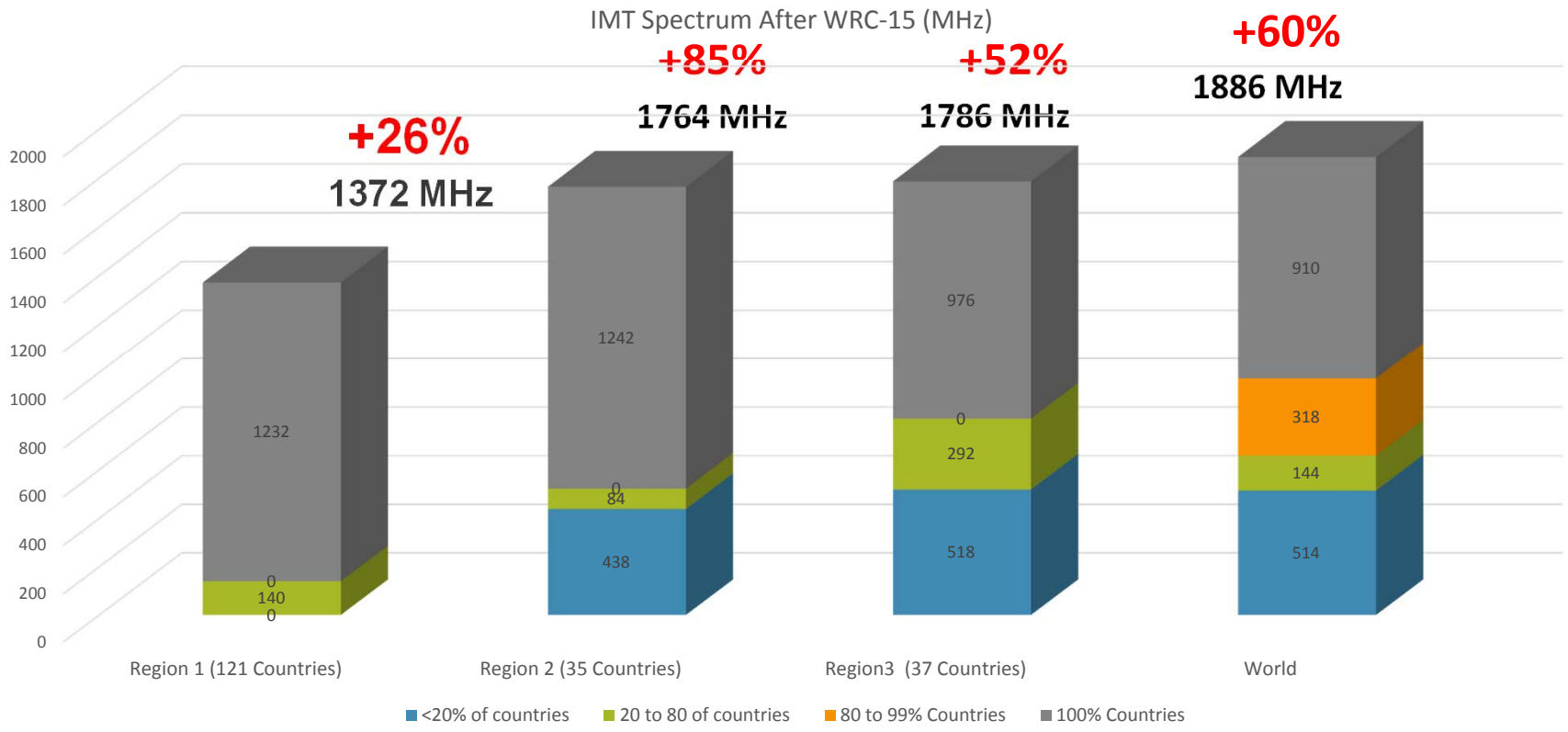
WRC - 15				
Band (MHz)	Bandwitdh (MHz)	R1	R2	R3
470 – 608	138		some	
608 – 698	84		some	
1427 – 1452	25	any	any	any
1452 – 1492	40	some	any	any
1492 – 1518	26	any	any	any
3300 – 3400	100	some	some	some
3600 – 3700	100		some	
4800 – 4990	190		some	some
	New BW 709			

Outcomes of WRC-15

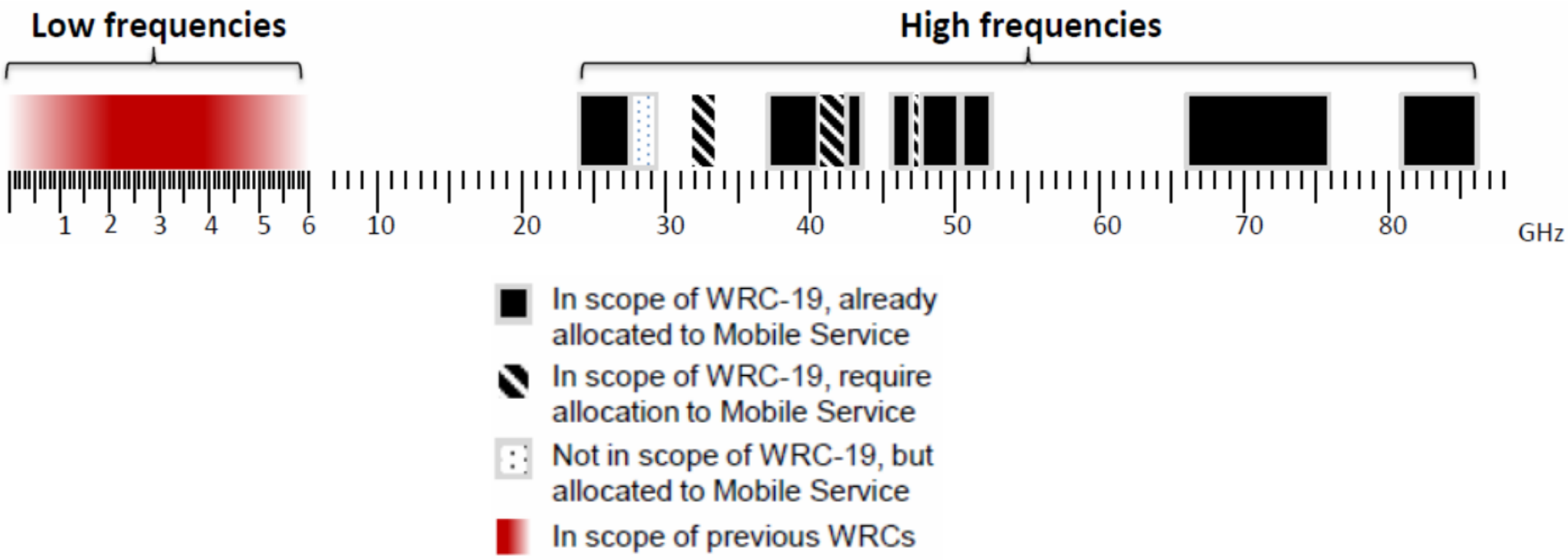
➢ Spectrum for IMT

Band (MHz)	Footnotes identifying the band for IMT			Bandwidth
	Region 1 or parts thereof	Region 2 or parts thereof	**Region 3 or parts thereof**	
450-470		**5.286AA**		20
470-698	-	5.295, 5.308A	**5.296A**	228
694/698-960	5.317A	5.317A	**5.313A, 5.317A**	262
1 427-1 518	5.341A, 5.346	5.341B	**5.341C, 5.346A**	91
1 710-2 025		**5.384A, 5.388**		315
2 110-2 200		**5.388**		90
2 300-2 400		**5.384A**		100
2 500-2 690		**5.384A**		190
3 300-3 400	5.429B	5.429D	**5.429F**	100
3 400-3 600	5.430A	5.431B	**5.432A, 5.432B, 5.433A**	200
3 600-3 700	-	5.434	-	100
4 800-4 990	-	5.441A	**5.441B**	190
Total Bandwidth	**1,886 (Regional allocations vary and therefore totals can be different for a specific region)**			

IMT Bands after WRC-15



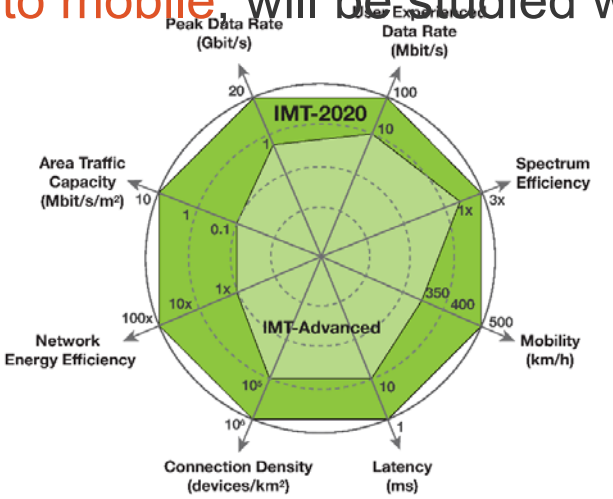
IMT spectrum requirements and WRC-19



BB applications in MS

(WRC-19 Agenda item 1.13 and 1.16)

- The following bands, which are already allocated to mobile, will be studied with a view to an IMT-2020 identification:
  - 24.25 – 27.5 GHz
  - 37 – 40.5 GHz
  - 42.5 – 43.5 GHz
  - 45.5 – 47 GHz
  - 47.2 – 50.2 GHz
  - 50.4 – 52.6 GHz
  - 66 – 76 GHz
  - 81 – 86 GHz



- The following bands will also be studied, although they do not currently have global mobile allocations: Res. 238 (WRC-15)
  - 31.8 – 33.4 GHz
  - 40.5 – 42.5 GHz
  - 47 - 47.2 GHz

Overlapping Bands in WRC-19 Agenda Items

1.6 – NGSO FSS Res. 159 (WRC-15)	1.13 – IMT Res. 238 (WRC-15)	1.14 – HAPS Res. 160 (WRC-15)	9.1 (9.1.9) – FSS Res. 162 (WRC-15)
	24.25 - 27.5	24.25 - 27.5 (Reg. 2)	
37.5 - 39.5 (s-E*)	37 - 40.5	38 - 39.5 (globally)	
39.5 - 42.5 (s-E*)	40.5 - 42.5		
47.2 - 50.2 (E-s*)	47.2 - 50.2		
50.4 - 51.4 (E-s*)	50.4 - 52.6		51.4 - 52.4 (E-s*)

- **E-s: Earth-to-space; s-E: space-to-Earth.**
- **All bands in GHz**

Studies to **address mutual compatibility & sharing feasibility** among the **services/applications** for which **allocation/identification is envisaged**
under the corresponding Res. relating to the AI in the overlapping bands

Future Spectrum need estimation for IMT

(24.25 GHz - 86 GHz)

	Examples	Associated conditions for different examples (For details, please see the corresponding sections in the Annex A)	Spectrum needs in total (GHz)	Spectrum needs (GHz) per range
Application-based approach ITU-R M.1651	1	Overcrowded, Dense urban and Urban areas	**18.7**	➢ 3.3 (24.25-33.4 GHz range) ➢ 6.1 (37-52.6 GHz range) ➢ 9.3 (66-86 GHz range)
		Dense urban and Urban areas	**11.4**	➢ 2.0 (24.25-33.4 GHz range) ➢ 3.7 (37-52.6 GHz range) ➢ 5.7 (66-86 GHz range)
	2	Highly crowded area	**3.7**	➢ 0.67 (24.25-33.4 GHz range) ➢ 1.2 (37-52.6 GHz range) ➢ 1.9 (66-86 GHz range)
		Crowded area	**1.8**	➢ 0.33 (24.25-33.4 GHz range) ➢ 0.61 (37-52.6 GHz range) ➢ 0.93 (66-86 GHz range)

Source: Chairman's report TG 5/1 Annex 2: *Working document towards Draft CPM text for WRC-19 AGenda Item 1.13*

Future Spectrum need estimation for IMT

(24.25 GHz - 86 GHz)

	Examples	Associated conditions for different examples (For details, please see the corresponding sections in the Annex A)	Spectrum needs in total (GHz)	Spectrum needs (GHz) per range
Technical performance -based approach (Type 1) *Calculated on single technical performance requirement, i.e. user experienced data rate.*	1	User experienced data rate of 1 Gbit/s with N simultaneously served users/devices at the cell-edge, e.g., Indoor	➢ 3.33 (N=1), ➢ 6.67 (N=2), ➢ 13.33 (N=4)	Not available
		User experienced data rate of 100 Mbits/s with N simultaneously served users/devices at the cell-edge, for wide area coverage	➢ 0.67 (N=1), ➢ 1.32 (N=2), ➢ 2.64 (N=4)	Not available
	2	eMBB Dense Urban	➢ 0.83-4.17	Not available
		eMBB Indoor Hotspot	➢ 3-15	Not available
	3	With a file transfer of 10 Mbits by a single user at cell-edge in 1 msec	➢ 33.33 GHz (one direction)	Not available
		With a file transfer of 1 Mbit by a single user at cell-edge in 1 msec	➢ 3.33 GHz (one direction)	
		With a file transfer of 0.1 Mbits by a single user at cell-edge in 1 msec	➢ 333 MHz (one direction)	

Source: Chairman's report TG 5/1 Annex 2: *Working document towards Draft CPM text for WRC-19 Agenda Item 1.13*

Future Spectrum need estimation for IMT

(24.25 GHz - 86 GHz)

	Examples	Associated conditions for different examples (For details, please see the corresponding sections in the Annex A)	Spectrum needs in total (GHz)	Spectrum needs (GHz) per range
Technical performance-based approach (Type 2) *Calculated taking into account different technical performance requirements, i.e. user experienced data rate, peak data rate and area traffic capacity*	–	Dense urban micro	**14.8-19.7**	5.8-7.7 (24.25-43.5 GHz range)
		Indoor hotspot		9-12 (24.25-43.5GHz and 45.5-86 GHz range)
Information from some countries based on their national considerations	–	–	**7-16**	2-6 (24.25-43.5 GHz range) 5-10 (43.5-86 GHz range)

Source: Chairman's report TG 5/1 Annex 2: *Working document towards Draft CPM text for WRC-19 Agenda Item 1.13*

Note: The spectrum needs estimates of the different approaches and examples should be considered separately.

Future Spectrum need estimation for IMT

(24.25 GHz - 86 GHz)

Deployment scenarios	Indoor hotspot	Dense urban		Urban macro
		Micro	Macro	
Frequency range	24.25-86 GHz	24.25-43.5 GHz	<6 GHz	<6 GHz

Deployment scenario	Micro	Indoor hotspot
Total spectrum needs for 24.25-86 GHz	14.8-19.7 GHz*	
Spectrum needs for 24.25-43.5 GHz	5.8-7.7 GHz	9-12 GHz
Spectrum needs for 45.5-86 GHz	–**	

* *Considering the coexistence between multiple network operators (e.g. the guard band(s) may be required in the case of multiple network operators scenarios), the total spectrum needs are expected to be increased.*

** *The division in this table regarding frequency ranges and deployment scenarios is just an indicative example on how spectrum needs could be distributed for different spectrum sub-ranges within 24.25-86 GHz and different deployment scenarios. This table should not be understood nor used to exclude any possible IMT-2020 deployment options in the range 45.5-86 GHz.*

Source: WP 5D Liaison statement to Task Group 5/1

Some 5G Deployments strategies

Regulator	Low (1 GHz)	Medium (<6GHz)	High (mmWave)
FCC	600MHz auctioned – T-Mobile using for 5G	3.5GHz band to be shared under CBRS	28GHz available; 64GHz for unlicensed
Ofcom	700MHz spectrum available by 2020	3.5GHz cleared; 3.7GHz under consultation	26GHz to be repositioned for mobile data
MSIT (KOR)	700MHz and 1.3GHz to be freed up in 2018	3.5GHz to be allocated	28GHz – 1GHz available; 38GHz to be allocated
MIIT (CHN)	800MHz for NB-IoT	3.3GHz, 3.5GHz, 4.4GHz, 4.9GHz being considered	26GHz and 40GHz reallocation underway
MIC (JPN)	700MHz assigned for LTE	3.4GHz & 4.4-4.9GHz under review, 3.5GHz done	27.5-29.5GHz to be reassigned for mobile BB
	For coverage – mobile BB and massive IoT	**3.5GHz has wide support – for eMBB and mission-critical apps**	**26 – 28GHz has wide support – high density and high capacity**

3.5GHz IMT vs FSS will be evaluated and coordinated with neighbouring countries

IOT and regulatory issues

Numbering , addressing and number portability issues

- Public Numbers
  - National E.164 numbers;
  - International/global E.164 numbers assigned by the ITU;
  - National E.212 IMSI (International Mobile Subscriber Identity);
  - International/global E.212 IMSI with MNCs under MCC40 901 assigned by the ITU.
- Eligibility to receive MNCs
- Sufficiency of numbering resources
- IP addresses (IPv4 to IPv6 transition)
- MAC addresses
- How to switch the IoT devices when changing operators?
- OTA (Over-the-air) programming of SIMs

Source: BEREC **Report "Enabling the Internet of Things"**12 February 2016,

IoT and regulatory issues

- Licensed Vs Non Licensed spectrum
- Area of license
- Numbering
- Standardization
- Infrastructure sharing
- Access to data and open IOT platforms
- Data analytics
- Mobile data roaming
- Consumer protection
- Quality of Service
- USO
- Taxation

https://news.itu.int/one-world-one-global-sim/

! Global International Mobile Subscriber Identity (IMSI) ranges are signified by the shared Mobile Country Code '**901**', a code without ties to any particular country.

PRIVACY AND SECURITY ISSUES

- Privacy Issues as in IoT environment, data is collected and shared automatically by devices, and some may be critical in nature
  - Data protection vs Open data
  - Applicable laws
  - Entity responsible for data protection
  - Who can have access to the data collected?
  - Data classification and processing
  - Consent of data owner?
  - National vs International collection and sharing of data
- Security of device and data
- Consumer protection
- IoT devices should follow a security and privacy “by design” approach

Open data and APIs	IoT data is often held in “silos” that are difficult to integrate without time-consuming data discovery and licensing. IoT platforms can be industry and vendor-specific, limiting opportunities for SMEs and startups to participate.	City and country initiatives to provide for the sharing of information by individuals and organizations under non-proprietary, open source licences.	Further work to encourage cataloguing of and contributions to open datasets. National and local government authorities are in a key position to do this, and could collaborate through Open Government Partnership.

IOT and regulatory issues

INTEROPERABILITY AND STANDARDS

- IoTs have both public and proprietary standards currently
- Standardization is important for Interoperability, reducing costs and barriers to entry
  - ITU-T SG 20 (IOT and Smart Cities, Smart Communities)
  - National Standardization bodies
  - International Standardization bodies
- How to coordinate interoperability amongst public and private sector entities?
  e.g. parking meters, thermostats, cardiac monitors, tires, roads, car components, supermarket shelves
- Cross-sectoral collaboration is very important as IoT are deployed in multiple sectors

Thank You