NBTC-ITU-NECTEC Training
On
“IOT Platform and Application Development in Thailand”

Ashish Narayan
Programme Coordinator, ITU Regional Office for Asia-Pacific

6-9 November 2018,
Bangkok, Thailand

An overview of ICT ecosystem and IOT

Goals for a Sustainable Future : The SDGs

Realizing the potential of digital technologies countries and entities have embarked on digital nation, smart city, digital transformation programs…

(leveraging ICT infrastructure for digital payment is key to realizing this)

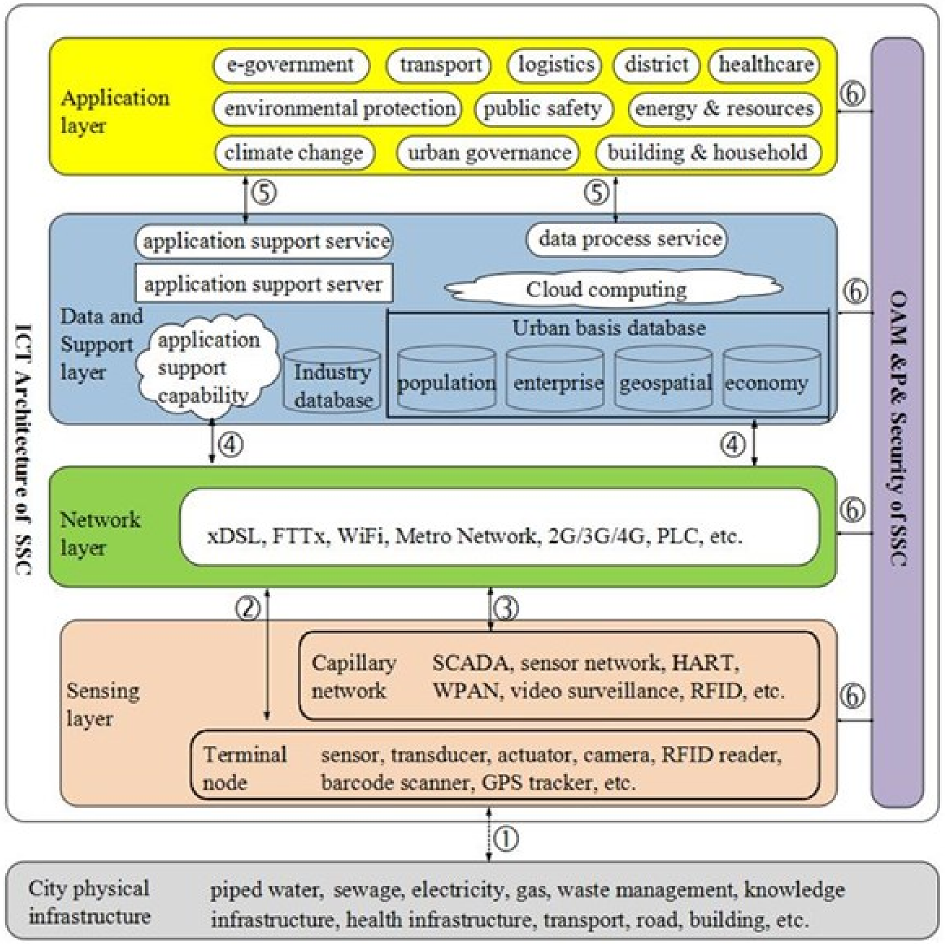
Digital India
Power To Empower

Smart Nation
SINGAPORE

Digital Agenda for Europe

Smart Cities (China)

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



Source: ITU-T Focus Group on Smart Sustainable Cities

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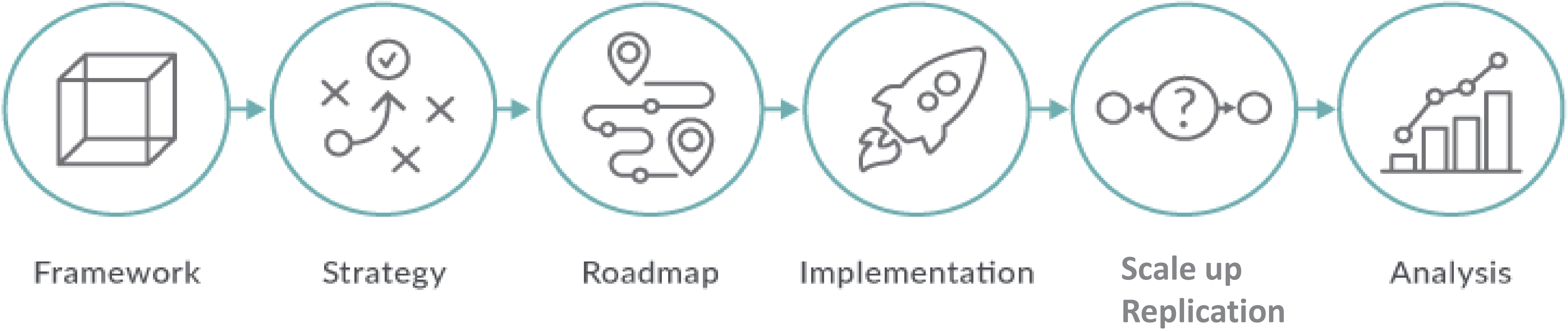
Enabling Environment , Digital Inclusion

Skills and capacity Building

Innovation

Digital Transformation Process



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

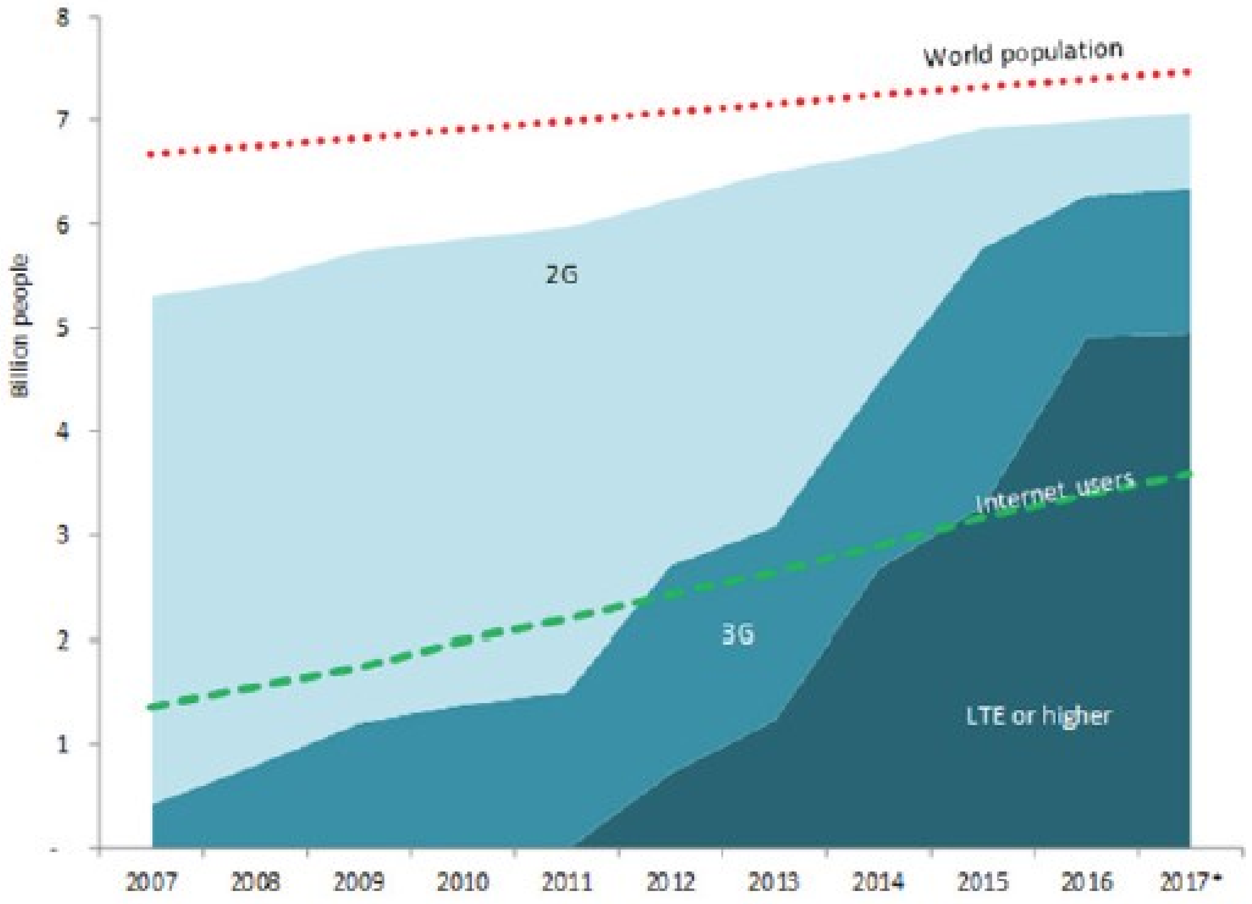
	2015	2016	2017	2020	2021
Mobile cellular subscriptions	7.2 bn (ITU) 7.2 bn (GSMA) 7.2 bn (E)	7.4 bn (ITU) 7.5 bn (GSMA) 7.5 bn (E)	7.74 bn (ITU) 7.8 bn (E)	8.3 bn (GSMA) 8.4 bn (E)	8.4 bn (GSMA) 8.6 bn (E)
Unique mobile phone users	4.6 bn (GSMA) 5.0 bn (E)	4.8 bn (GSMA) 5.1 bn (E)	5 bn (GSMA) 5.3 bn (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

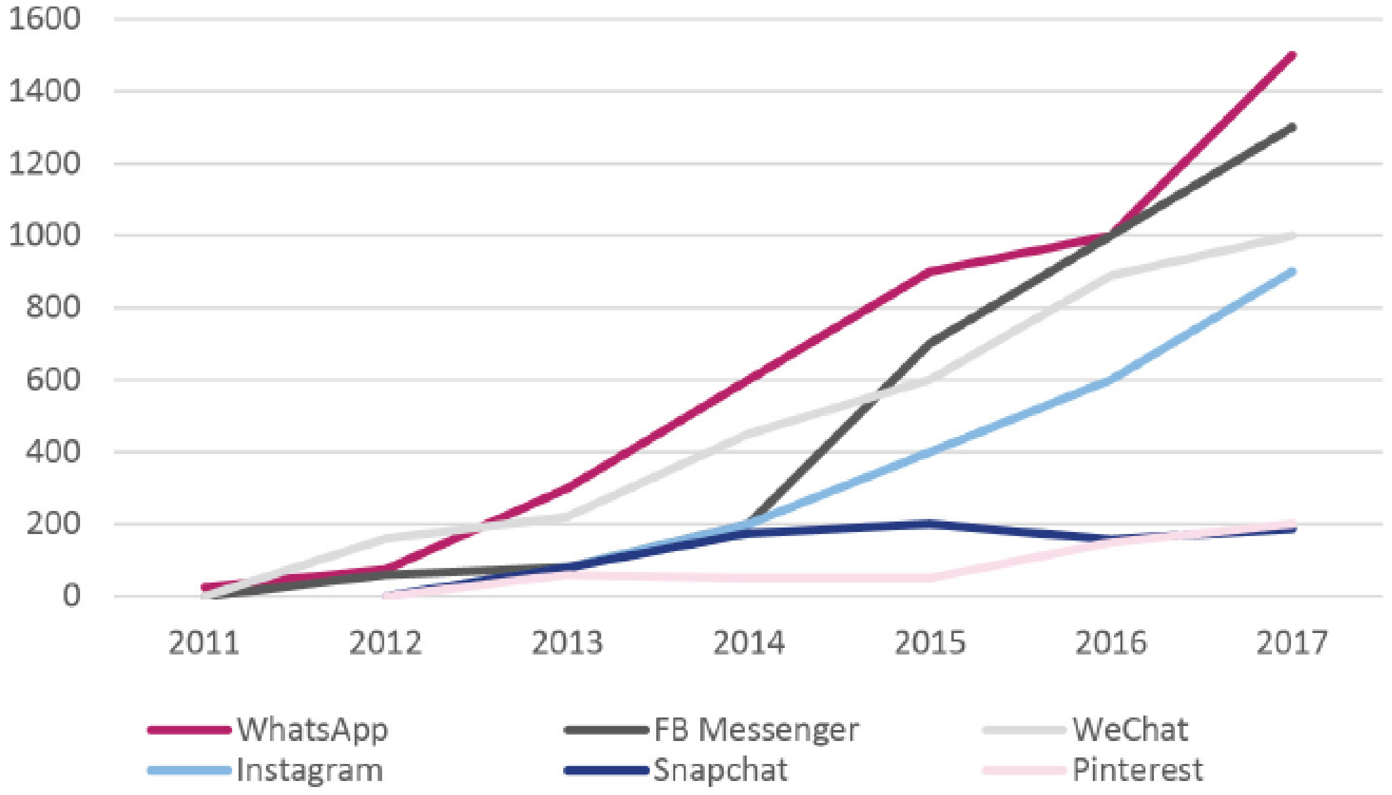


Source: ITU World Telecommunication/ICT Indicators database (* Estimate)

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.

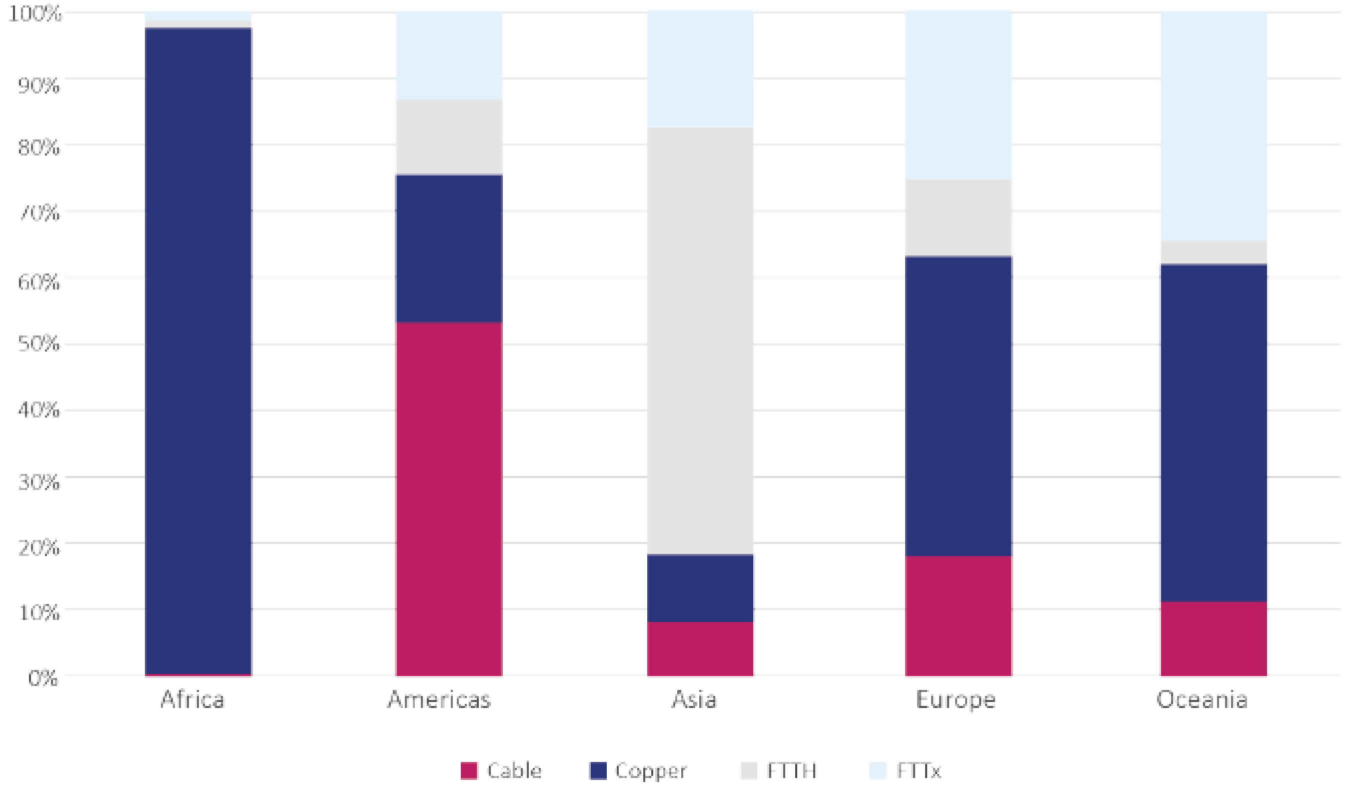
The number of subscriptions worldwide now exceeds the global population, with subscriptions also exceeding population in 112 of the 176 countries included in IDI 2017

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



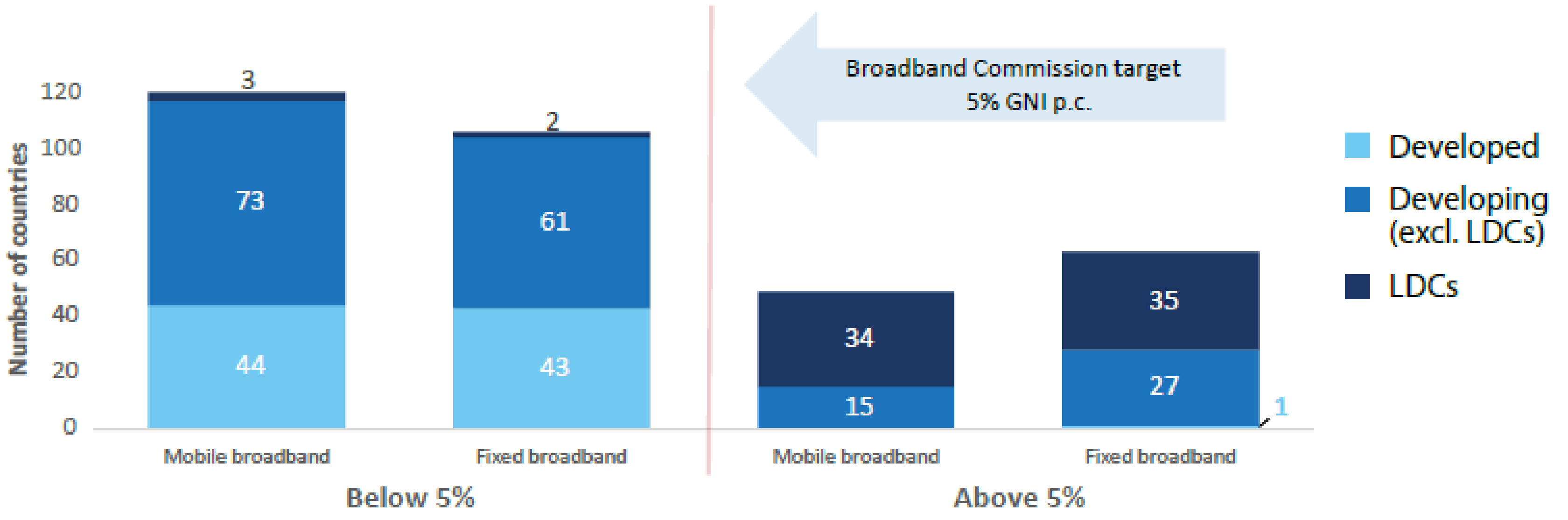
Source: Various, including Activate.com.

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

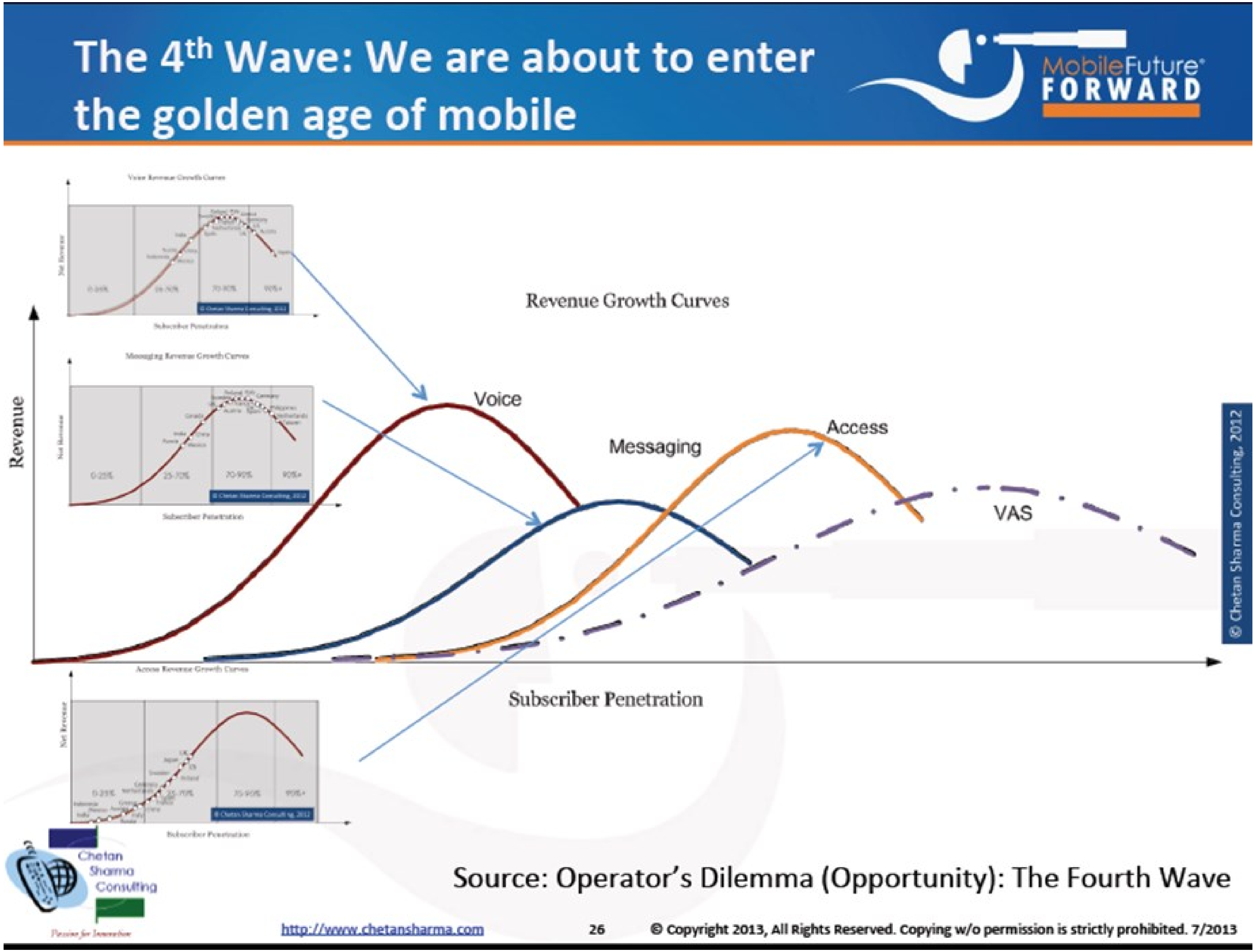


Mobile broadband is more affordable than fixed-broadband services in most developing countries. However, mobile-broadband prices represent more than 5% of GNI per capita in most LDCs and are therefore unaffordable for the large majority of the population.

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.

ICTs have become even more multi-sectoral and can be leveraged to achieve SDGs

4^{th} 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, 2012
Chetan Sharma Consulting
Source: Operator's Dilemma (Opportunity): The Fourth Wave
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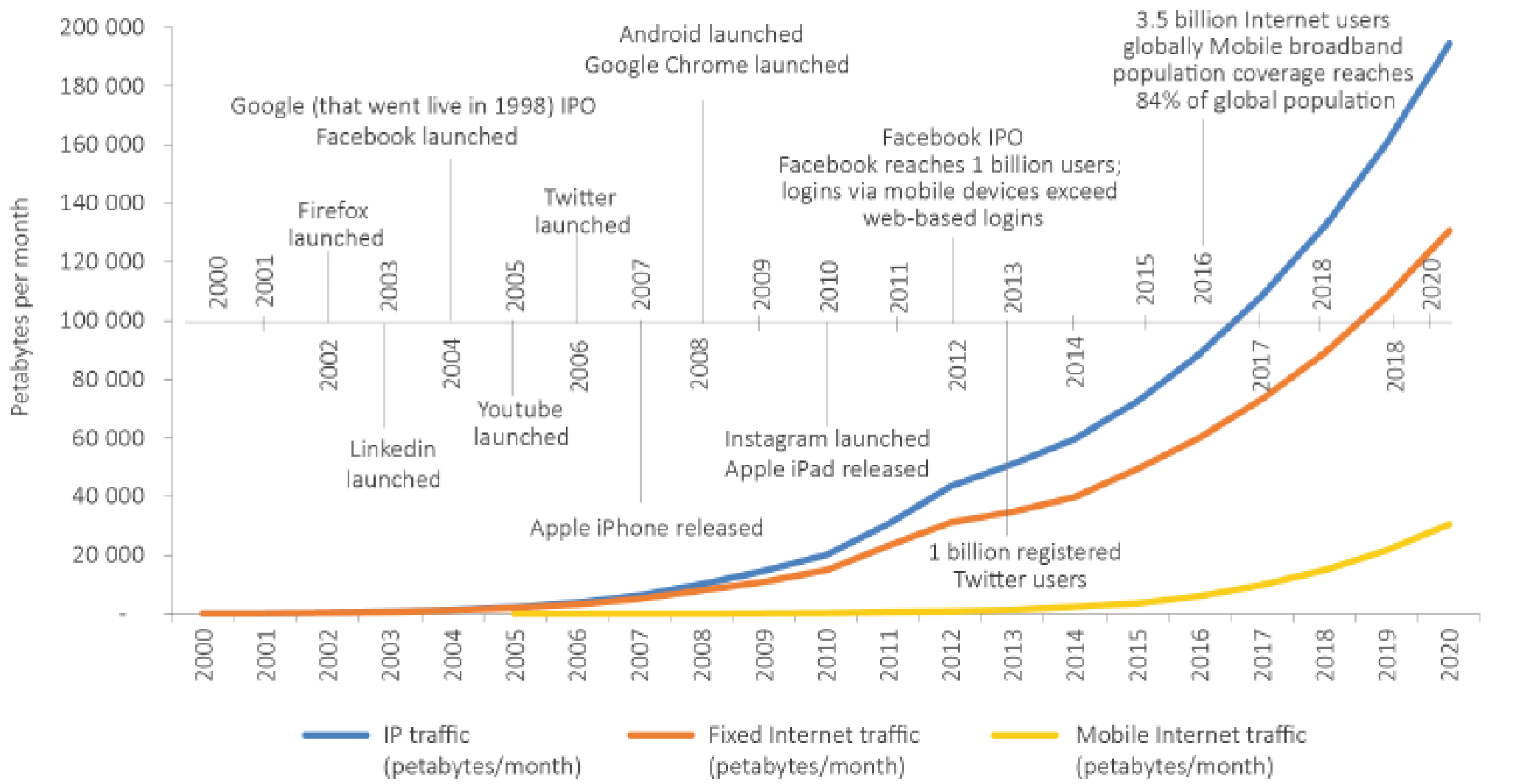
Internet and IP traffic



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.

IOT technologies

Is IoT a new technology?

- No!
- IoT is an ecosystem of existing technologies:
  - Data mining
  - Advanced communications and networking
  - Cloud computing
  - Security and privacy
  - Advanced sensing and actuation

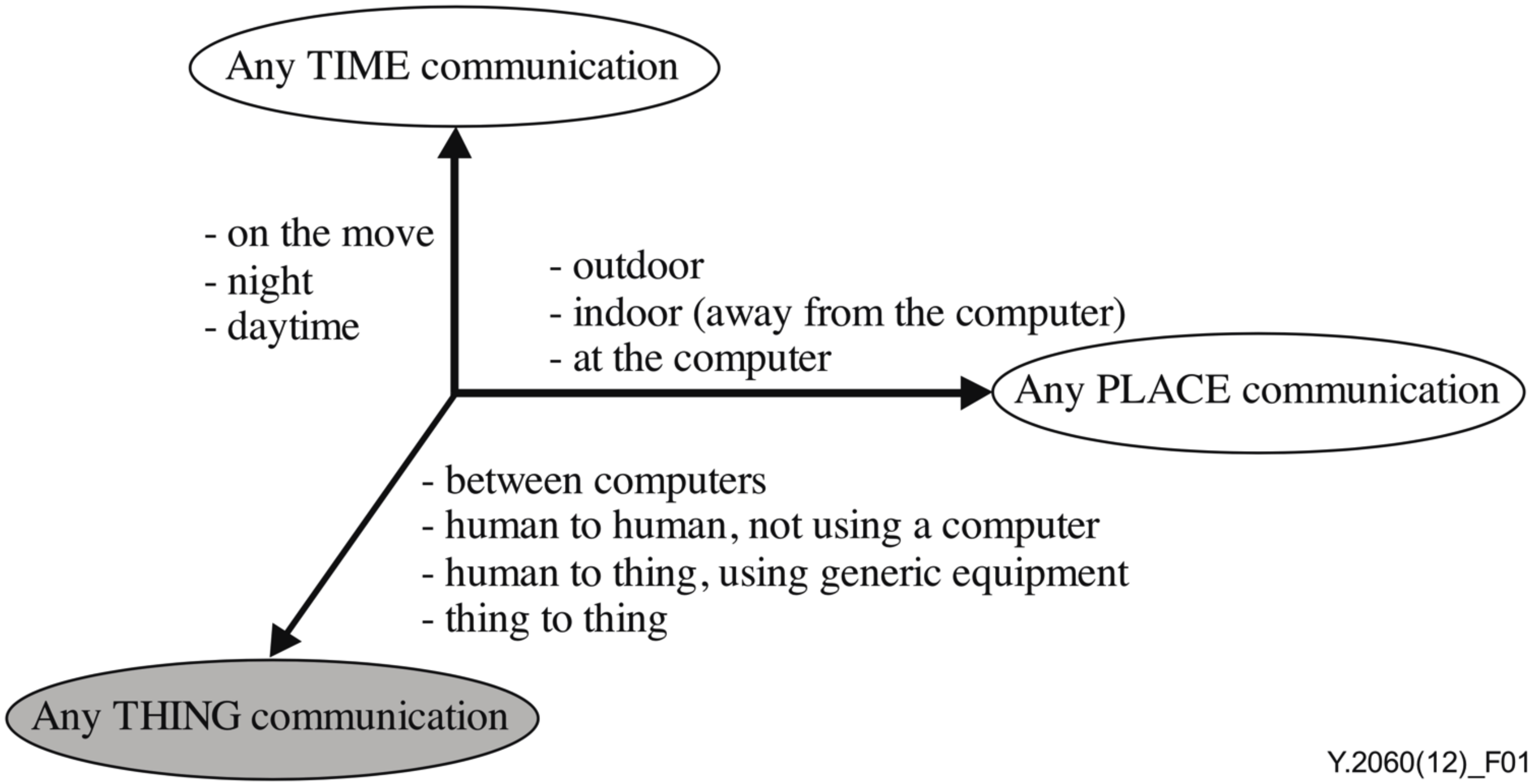
Definition from ITU

- **Internet of things (IoT)**: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.
  - NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.
  - NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

ITU-T Y.2060 Recommendation, 2012

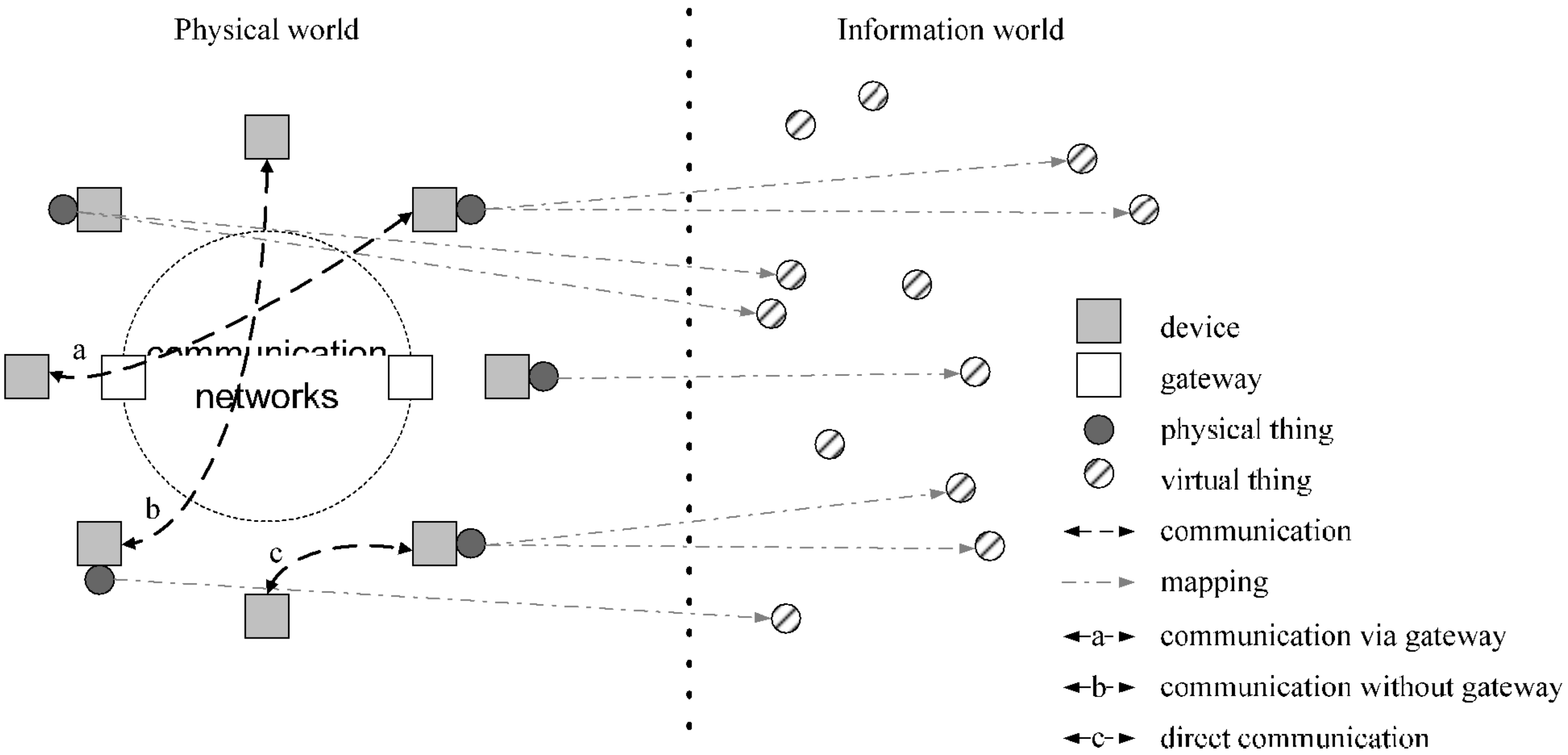
IoT: A New Dimension

thing: With regard to the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.



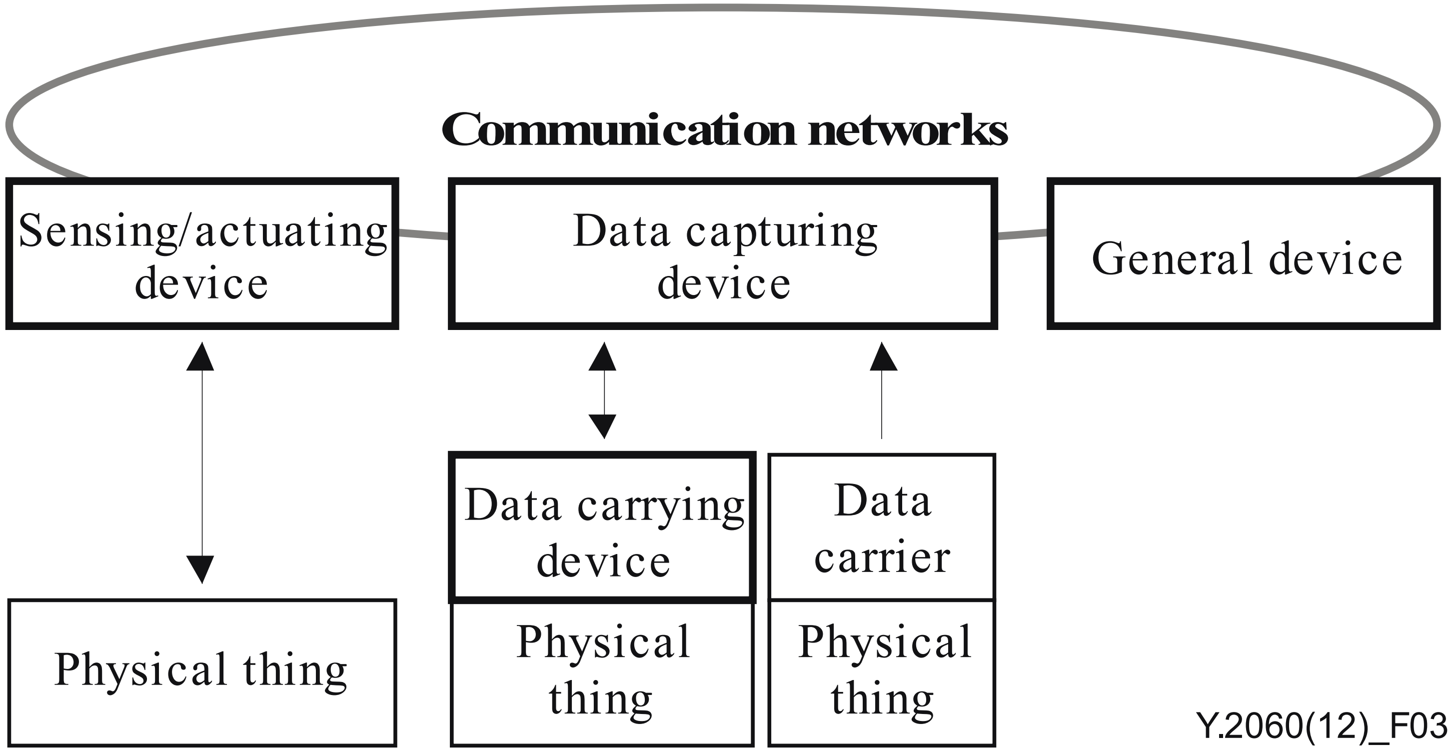
ITU-T Y.2060 Recommendation, 2012

Technical Overview of the IoT



ITU-T Y.2060 Recommendation, 2012

Types of Devices and Their Relationship to Physical Things



ITU-T Y.2060 Recommendation, 2012

Fundamental Characteristics

- Interconnectivity
- Things-related services
- Heterogeneity
- Dynamic changes
- Enormous scale

ITU-T Y.2060 Recommendation, 2012

Fundamental Characteristics

- **Interconnectivity**
- Things-related services
- Heterogeneity
- Dynamic changes
- Enormous scale

With regard to the IoT, anything can be interconnected with the global information and communication infrastructure.

ITU-T Y.2060 Recommendation, 2012

Fundamental Characteristics

- Interconnectivity
- **Things-related services**
- Heterogeneity
- Dynamic changes
- Enormous scale

The IoT is capable of providing thing-related services within the constraints of things, such as privacy protection and semantic consistency between physical things and their associated virtual things. In order to provide thing-related services within the constraints of things, both the technologies in physical world and information world will change.

ITU-T Y.2060 Recommendation, 2012

Fundamental Characteristics

- Interconnectivity
- Things-related services
- **Heterogeneity**
- Dynamic changes
- Enormous scale

The devices in the IoT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.

ITU-T Y.2060 Recommendation, 2012

Fundamental Characteristics

- Interconnectivity
- Things-related services
- Heterogeneity
- **Dynamic changes**
- Enormous scale

The state of devices change dynamically, e.g., sleeping and waking up, connected and/or disconnected as well as the context of devices including location and speed. Moreover, the number of devices can change dynamically.

ITU-T Y.2060 Recommendation, 2012

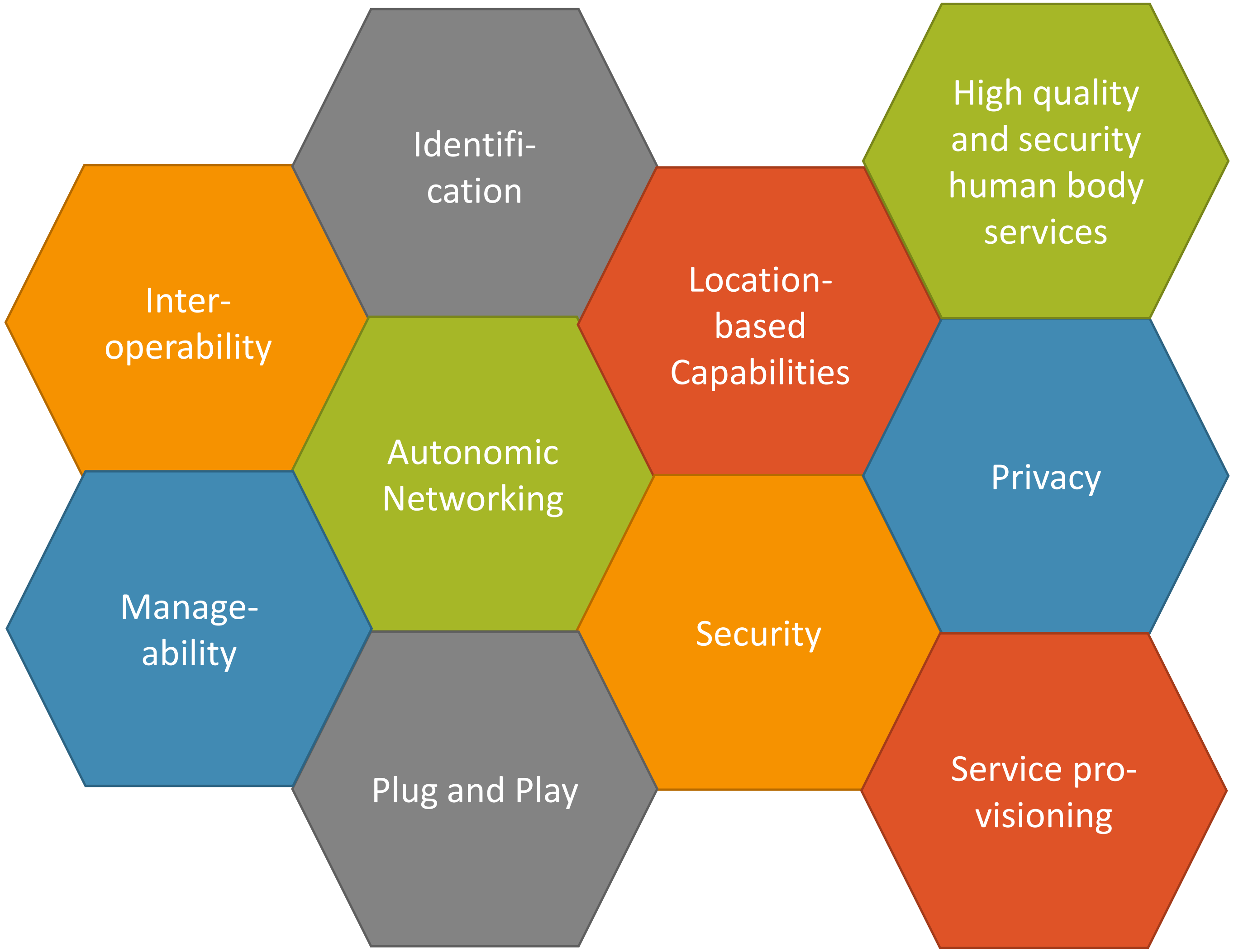
Fundamental Characteristics

- Interconnectivity
- Things-related services
- Heterogeneity
- Dynamic changes
- **Enormous scale**

The number of devices that need to be managed and that communicate with each other will be at least an order of magnitude larger than the devices connected to the current Internet. The ratio of communication triggered by devices as compared to communication triggered by humans will noticeably shift towards device-triggered communication. **Even more critical will be the management of the data generated and their interpretation for application purposes.** This relates to semantics of data, as well as efficient data handling.

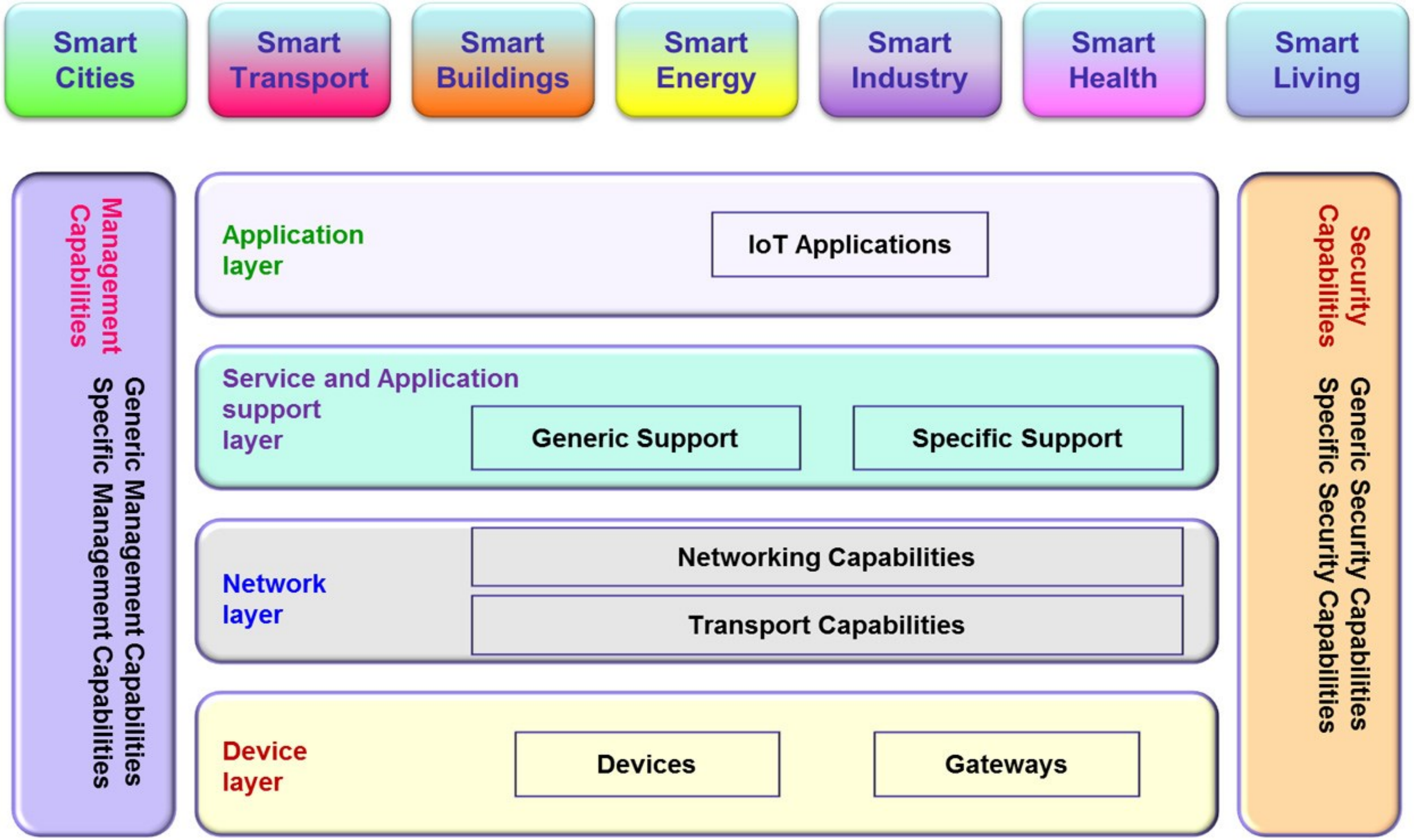
ITU-T Y.2060 Recommendation, 2012

High Level Requirements



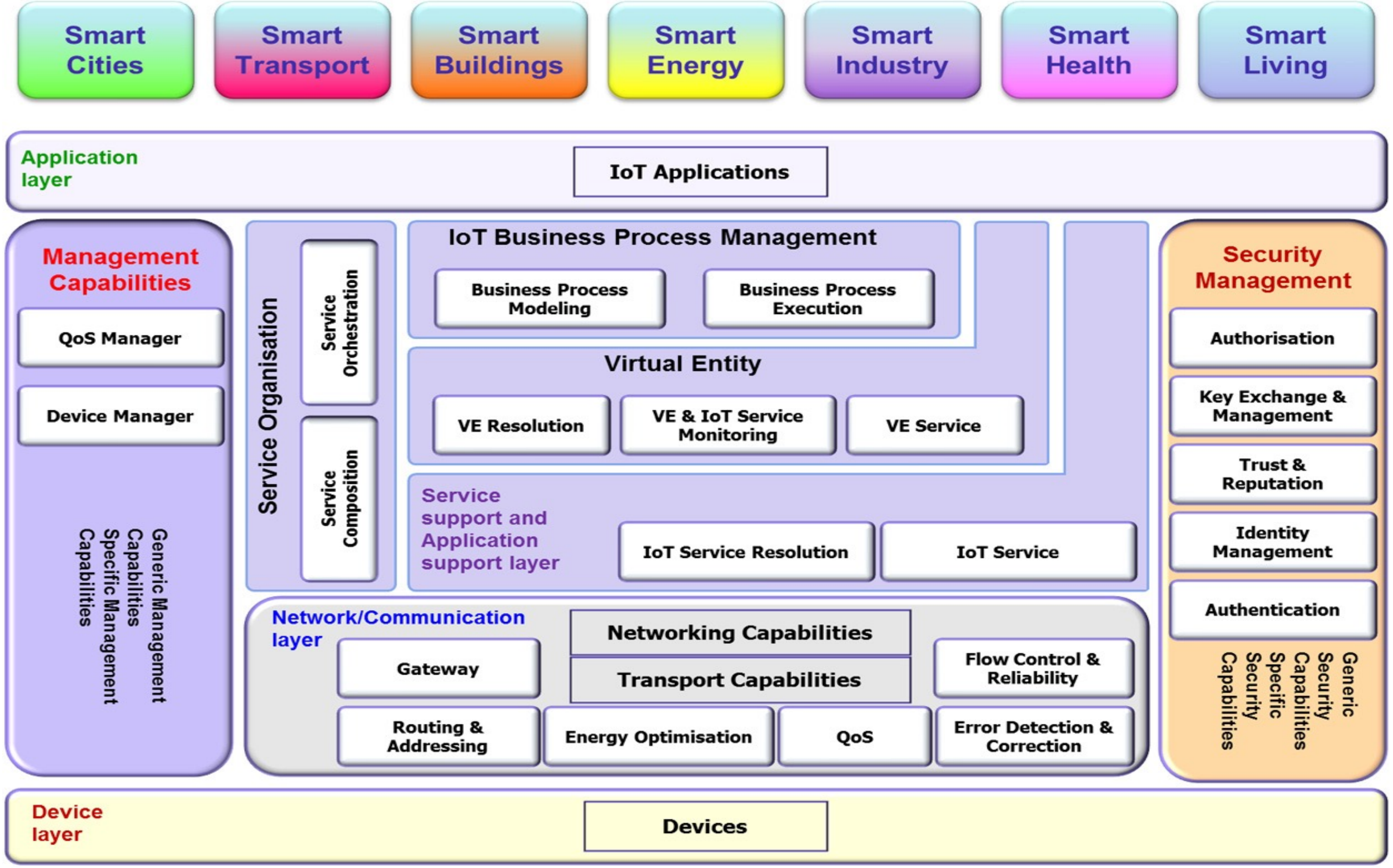
ITU-T Y.2060 Recommendation, 2012

IoT Architecture



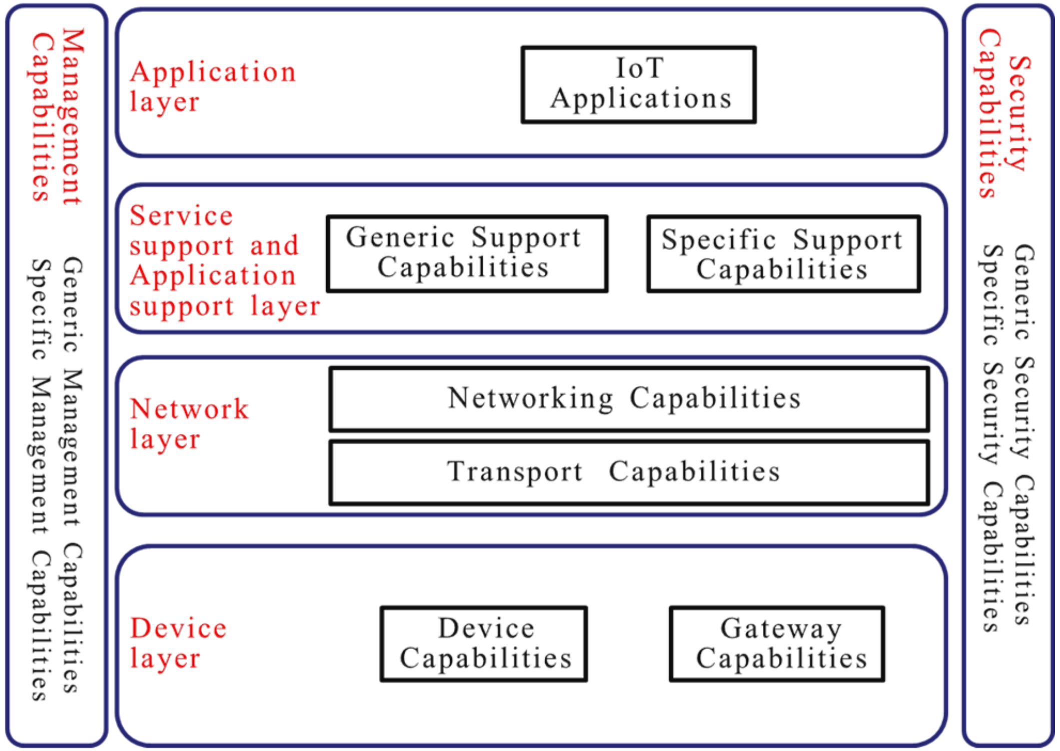
IoT Architecture (source: ITU)

IoT Architecture



Detailed IoT Layered Architecture (Source: IERC)

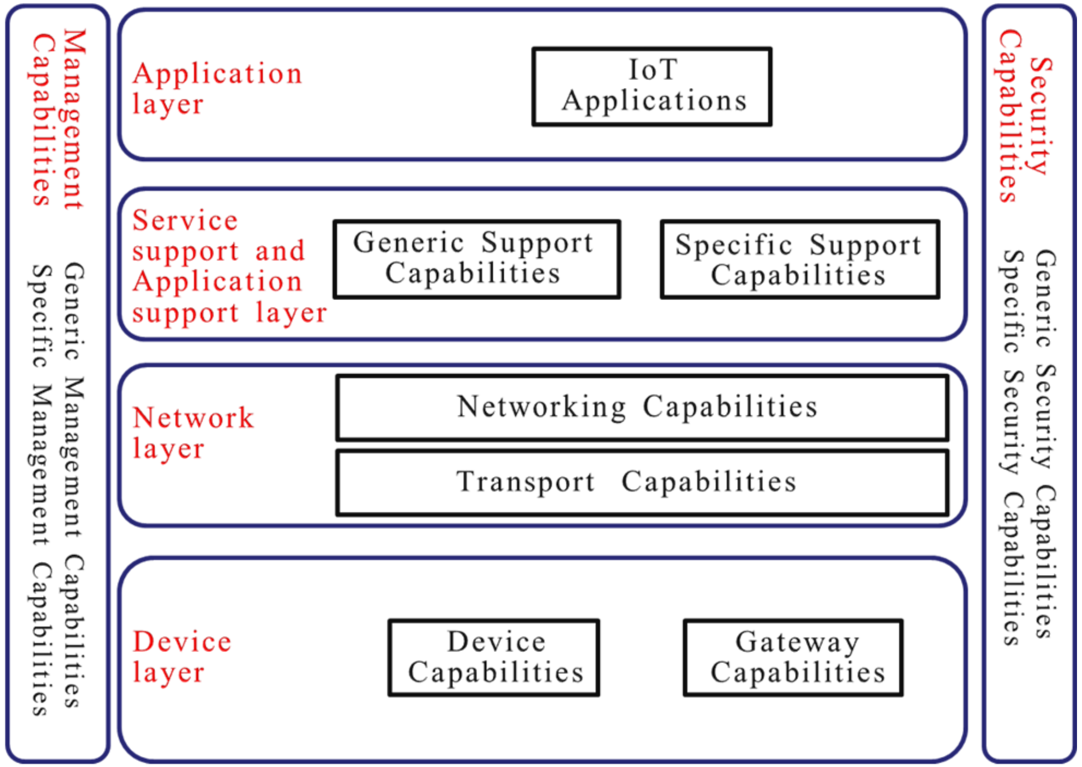
IoT Reference Model



- **Generic support capabilities**: The generic support capabilities are common capabilities which can be used by different IoT applications, such as data processing or data storage.
- **Specific support capabilities**: The specific support capabilities are particular capabilities which cater for the requirements of diversified applications.

ITU-T Y.2060 Recommendation, 2012

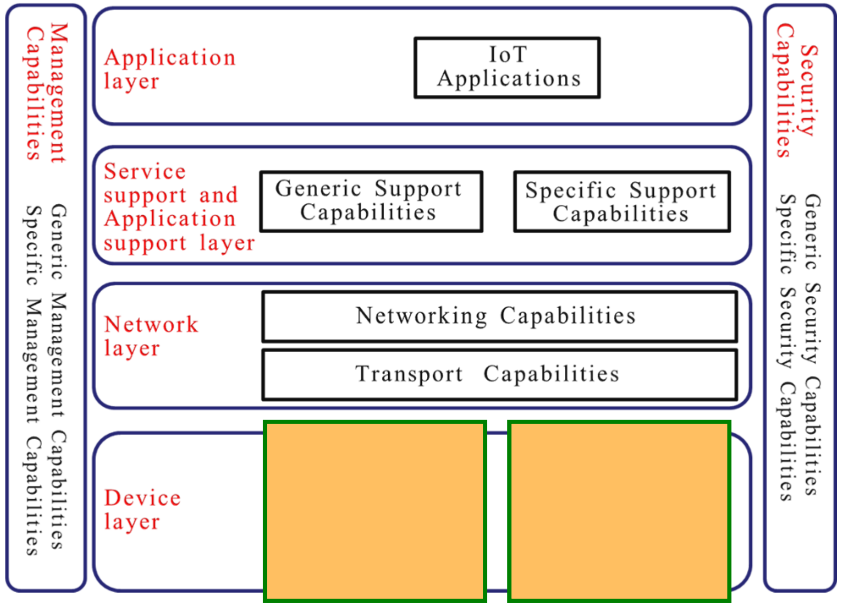
IoT Reference Model



- **Networking capabilities**: provide relevant control functions of network connectivity, such as access and transport resource control functions, mobility management or authentication, authorization and accounting (AAA).
- **Transport capabilities**: focus on providing connectivity for the transport of IoT service and application specific data information, as well as the transport of IoT-related control and management information.

ITU-T Y.2060 Recommendation, 2012

IoT Reference Model

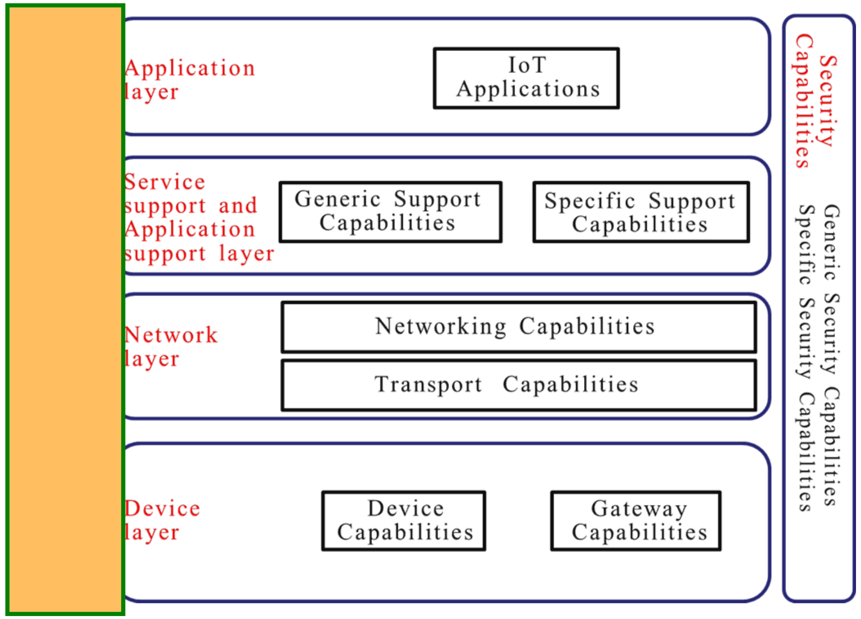


- Multiple interfaces support
- Protocol conversion

- Direct interaction with the communication network (without gateway).
- Indirect interaction with the communication network (with gateway)
- Ad-hoc networking
- Sleeping and waking-up

ITU-T Y.2060 Recommendation, 2012

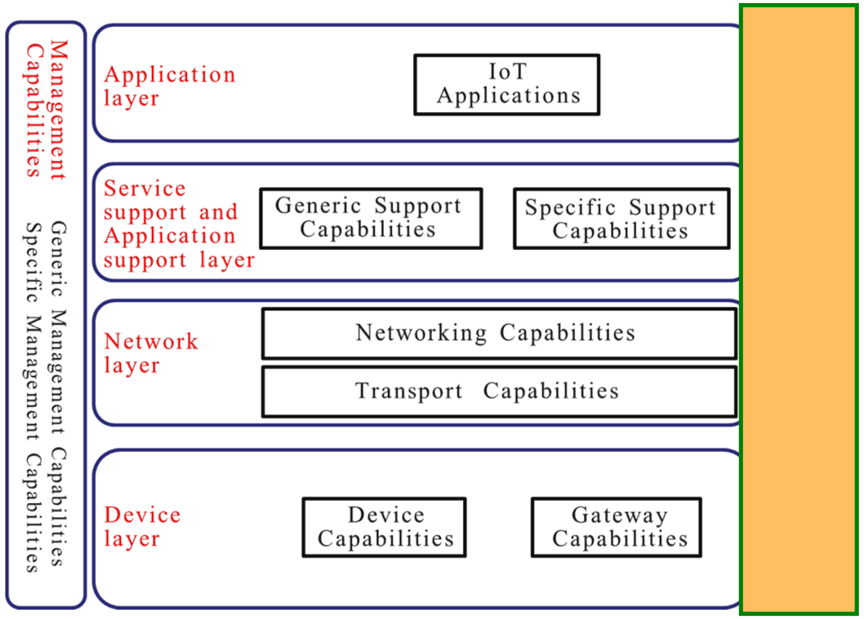
IoT Reference Model



- Device management, such as remote device activation and de-activation, diagnostics, firmware and/or software updating, device working status management;
- Local network topology management;
- Traffic and congestion management, such as the detection of network overflow conditions and the implementation of resource reservation for time-critical and/or life-critical data flows.

ITU-T Y.2060 Recommendation, 2012

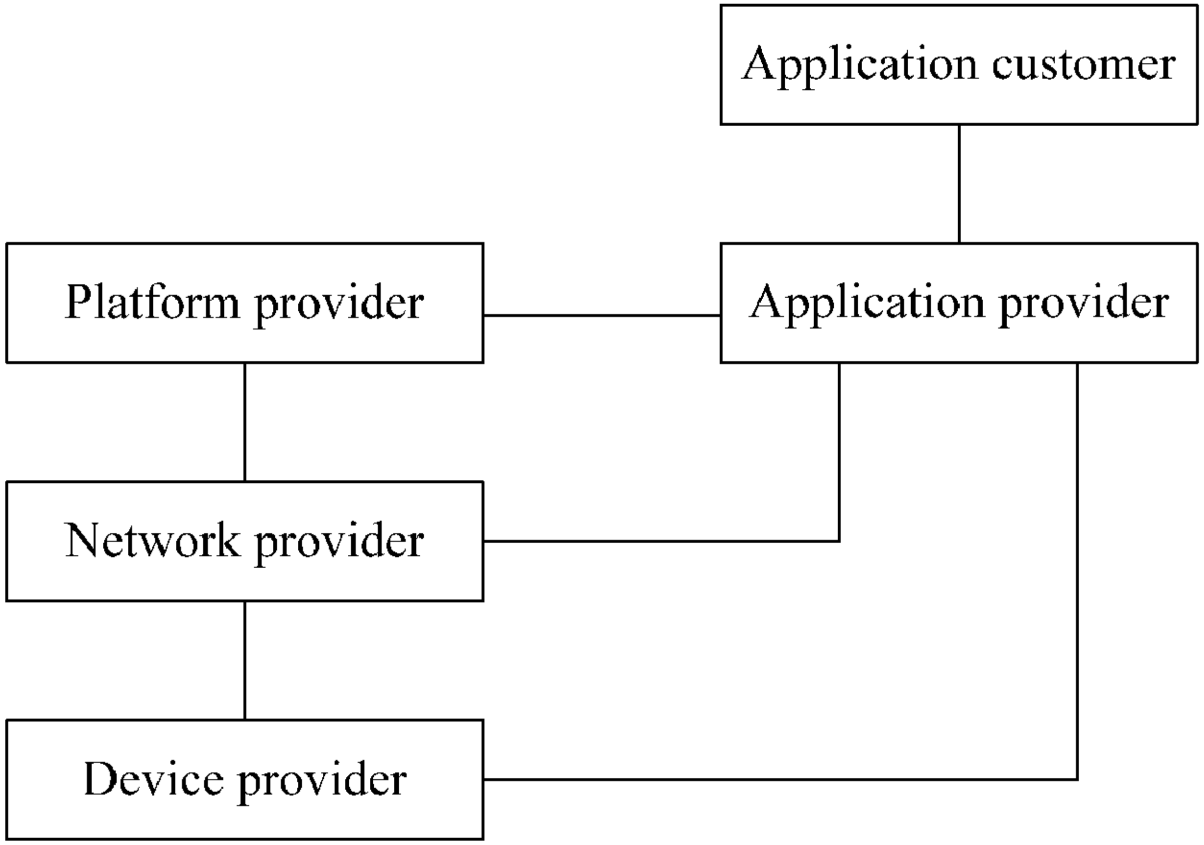
IoT Reference Model



- At the application layer: authorization, authentication, application data confidentiality and integrity protection, privacy protection, security audit and anti-virus;
- At the network layer: authorization, authentication, use data and signalling data confidentiality, and signalling integrity protection;
- At the device layer: authentication, authorization, device integrity validation, access control, data confidentiality and integrity protection.

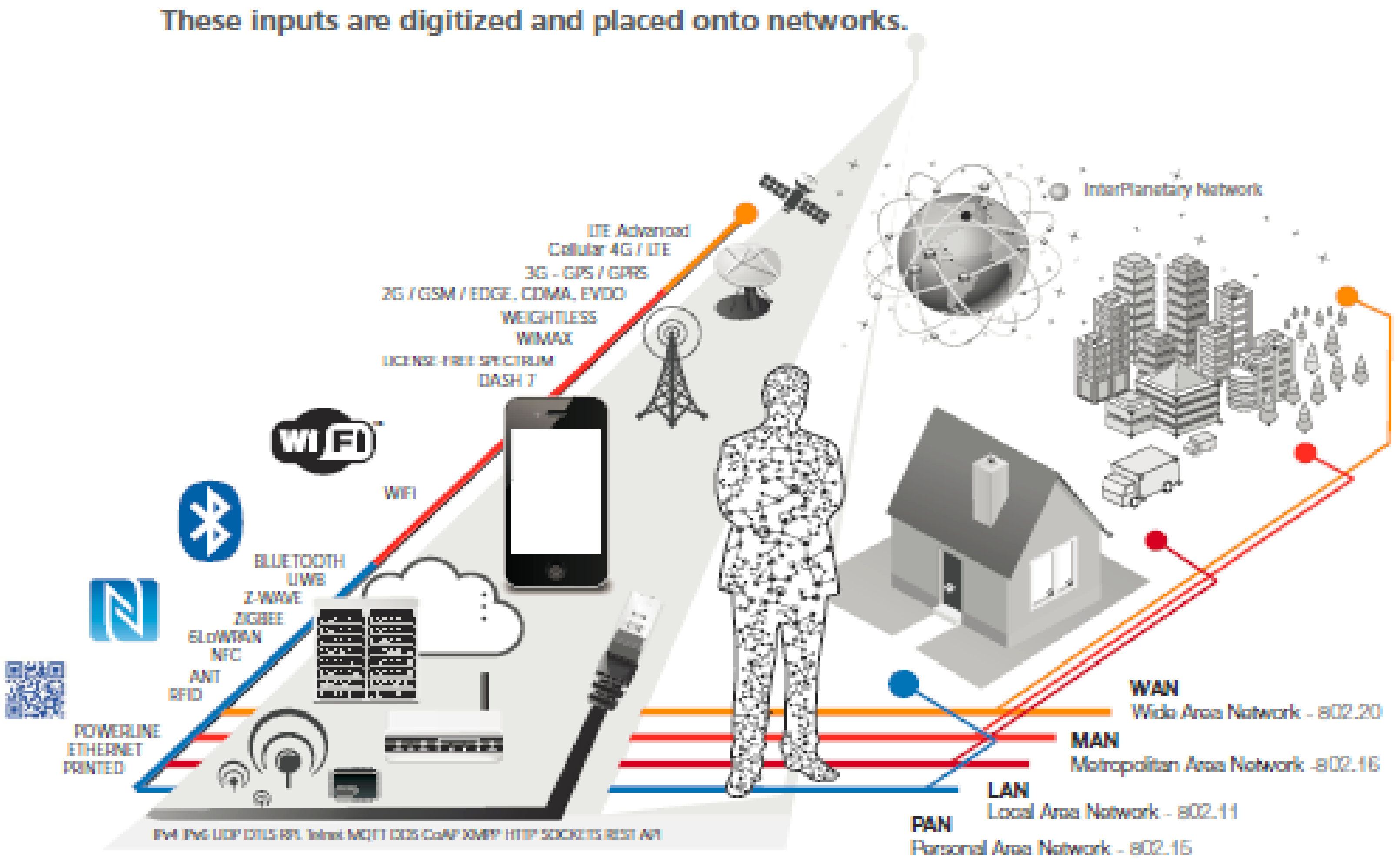
ITU-T Y.2060 Recommendation, 2012

IoT and Business Models



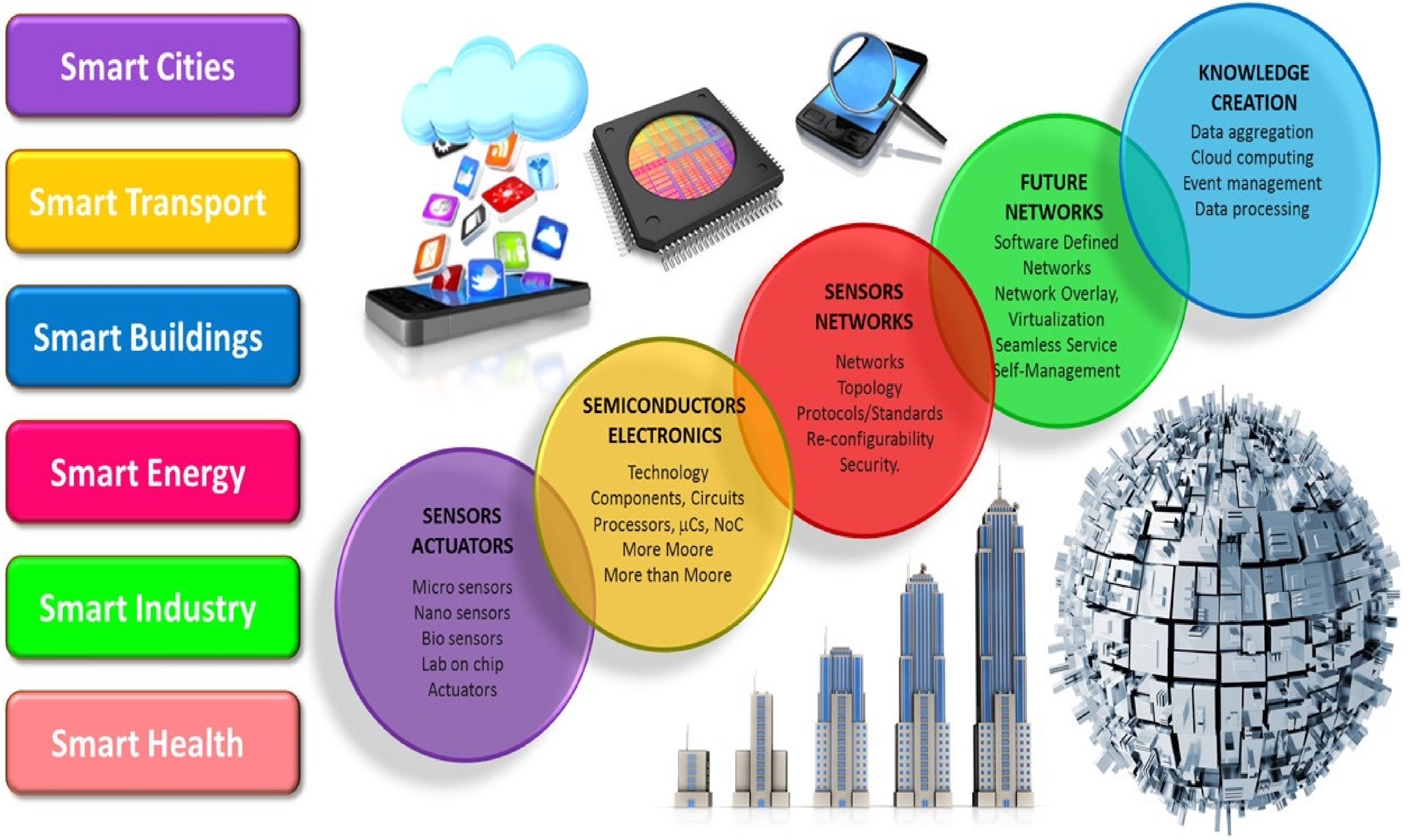
ITU-T Y.2060 Recommendation, 2012

Communication Options



Source: harbor research @ HarborResearch.com

Enabling Technologies



Enabling technologies (source: [1])

Impact on Applications

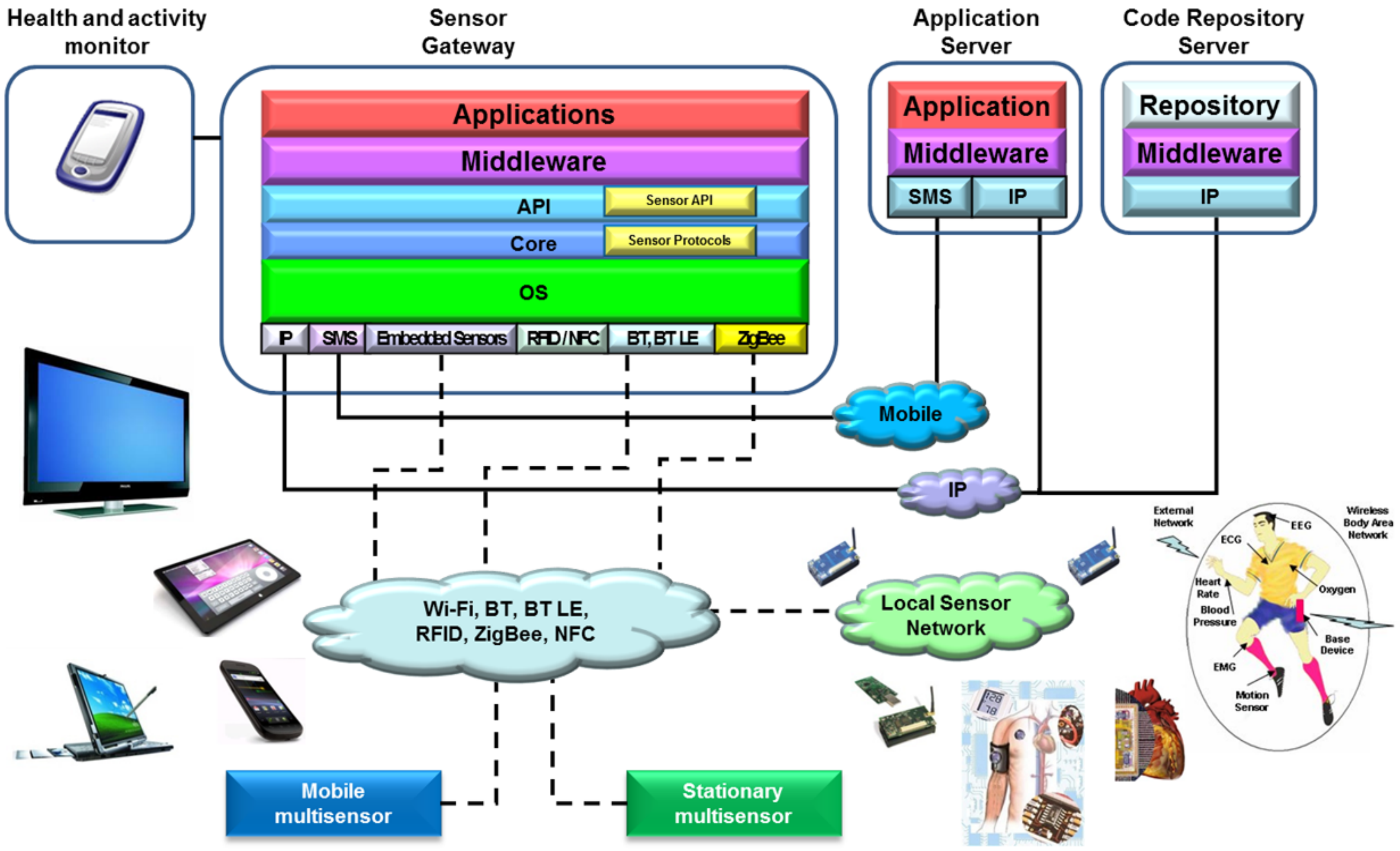
Example Applications	Data volume	Quality of Service	Amount of signaling	Time sensitivity	Mobility	Server initiated Communication	Packet switched only
Smart energy meters	low	low	intermediate	very low	no	yes	yes
Red charging	low	low	low	low	yes	no	yes
eCall	very low	very high	very low	very high	yes	no	no
Remote maintenance	low	low	high	high	no	yes	yes
Fleet management	low	low	very high	intermediate	yes	yes	no
Photo frames	intermediate	low	high	low	no	yes	yes
Assets tracking	low	low	very high	high	yes	yes	no
Mobile payments	intermediate	low	high	very high	yes	no	yes
Media synchronisation	high	low	high	intermediate	yes	yes	yes
Surveillance cameras	very high	very high	low	very high	no	yes	yes
Health monitoring	high	high	high	very high	yes	yes	yes

very low | low | intermediate | high | very high

Source: *Handbook: Impacts of M2M Communications & Non-M2M Mobile Data Applications on Mobile Networks*, page 50. ITU (Geneva, 2012). Available at: www.itu.int/md/T09-SG11-120611-TD-GEN-0844/en.

Example Applications (source: ITU)

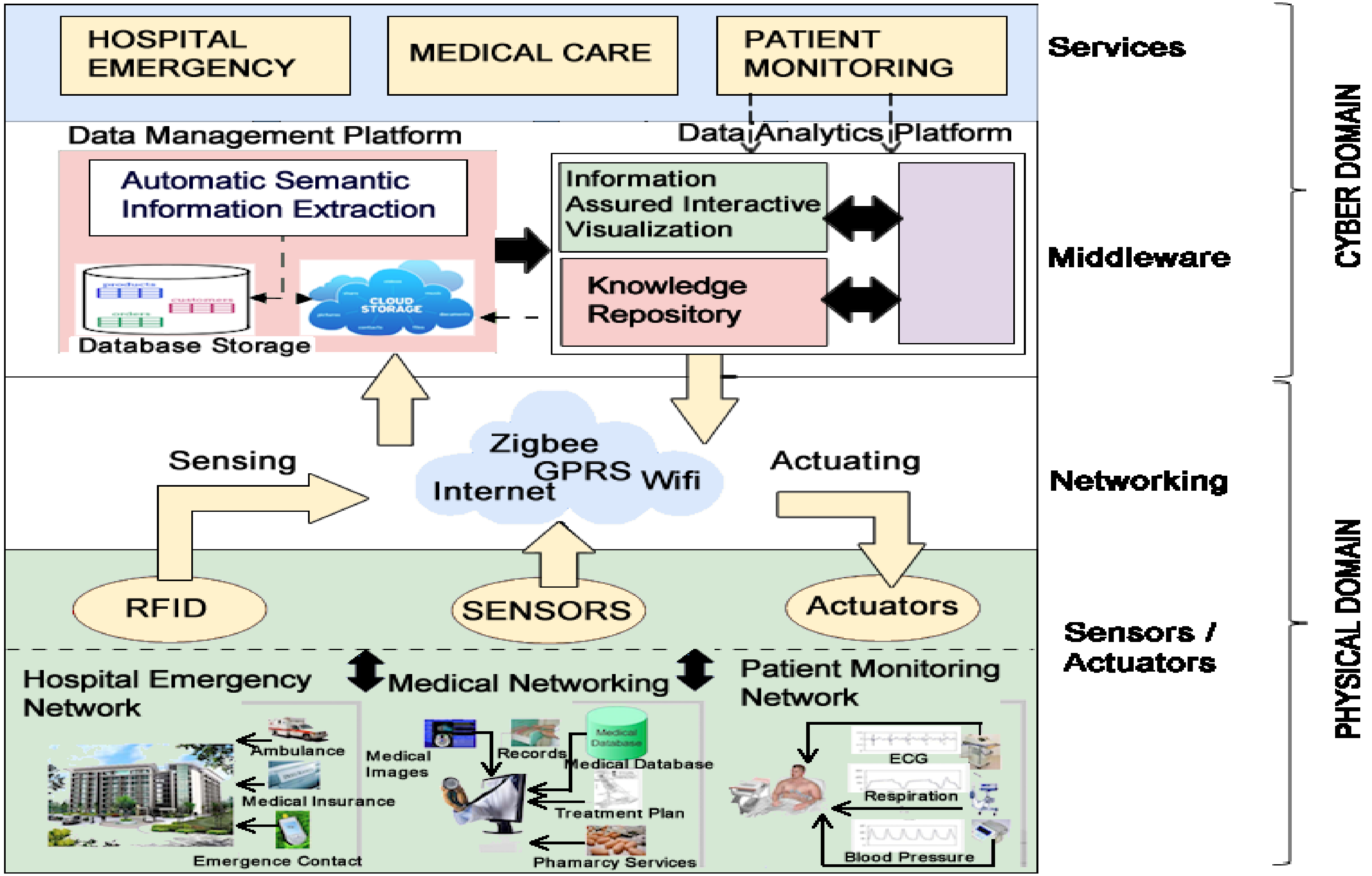
Cyber Physical Health Systems



Smart Health Platform [1]

Ovidiu Vermesan Peter Friess, nternet of Things – *From Research and Innovation to Market Deployment*, ISBN: 978-87-93102-94-1 (Hard copy) 978-87-93102-95-8 (Ebook) , Rivers Publishers, 2014

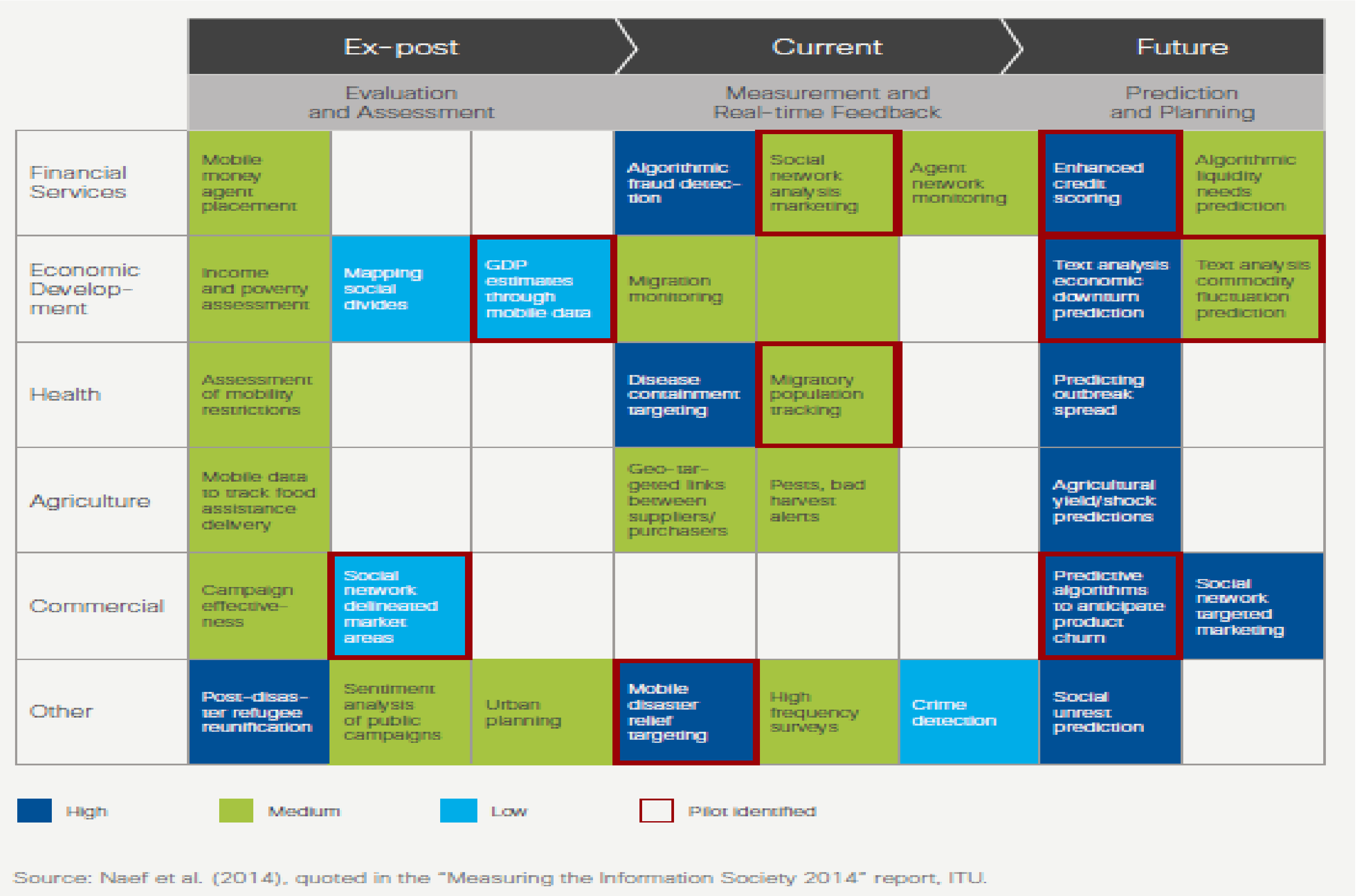
Cyber Physical Health System



Cyber Physical Health (CPH) Architecture [2]

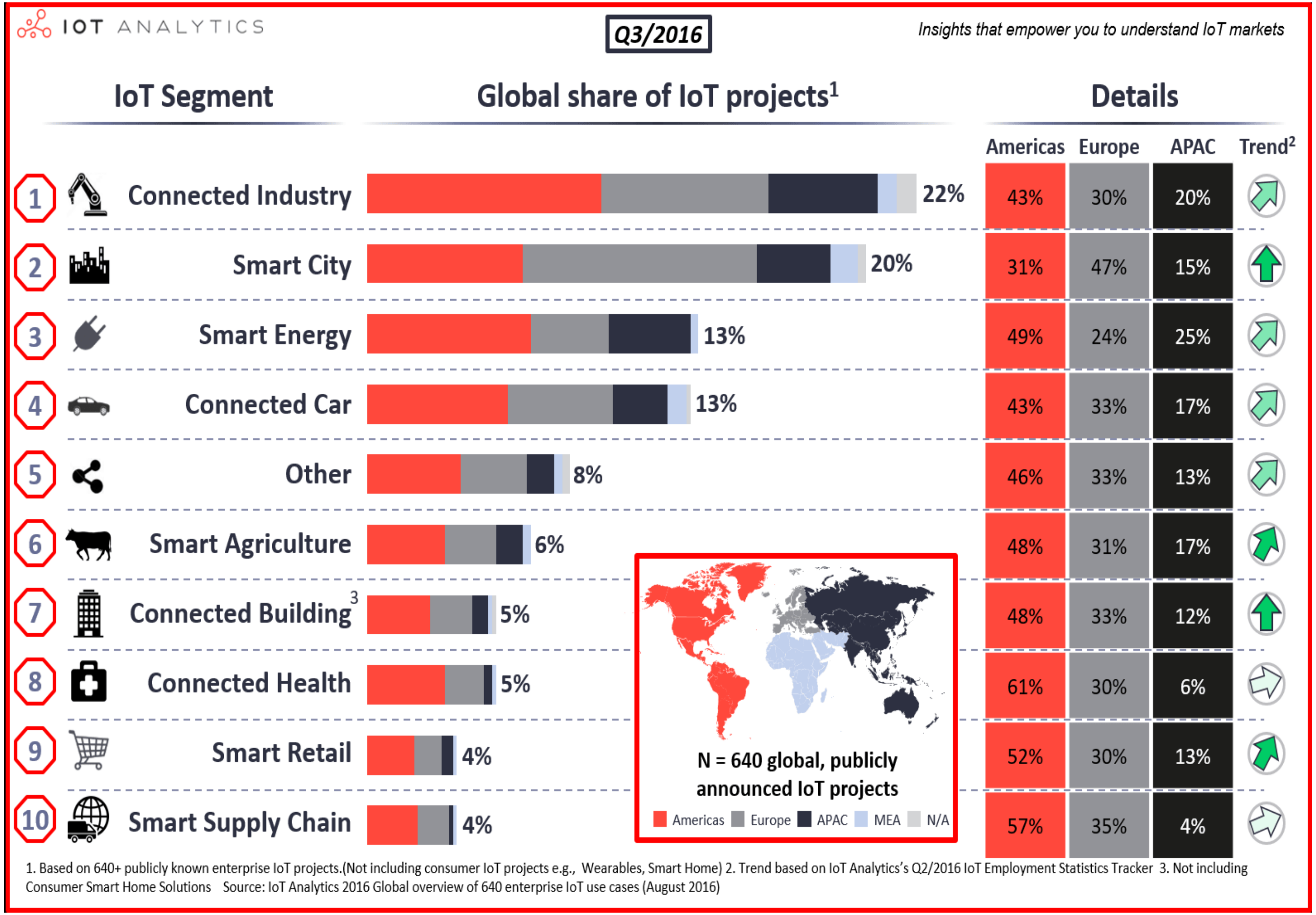
A. Bagula 1, M. Mandava 1 & H. Bagula 2. , *A Framework for Healthcare Support In the Rural and Low Income Areas of the Developing* World, in Elsevier JNCA journal, 2018.

Impact on Applications



Areas of Highest Potential Impact Across Different Sectors (Source: ITU)

Existing and IoT Potential Services



Examples of services per Category

Smart Utilities

- Intelligent Utility Network
- Smart Metering
- Energy Optimization
- Smart Production
- Demand Planning
- Advanced Distribution Management
- Operations Control
- River Basin and Smart Water Management
- Wastewater Treatment

Smart Health

- Smart Care Management
- Connected Health
- Smart Medicine Supply
- Mobile Health
- Remote Healthcare Management

Smart Education

- Smart Classroom
- Performance Man.
- Asset Management

Smart Public Services

- Smart Citizen Services
- Smart Tax Administration
- Smart Customs, Immigration, Border Management
- Smart Crime Prevention
- Smart Emergency Response
- Smart Financial Management

Smart Building

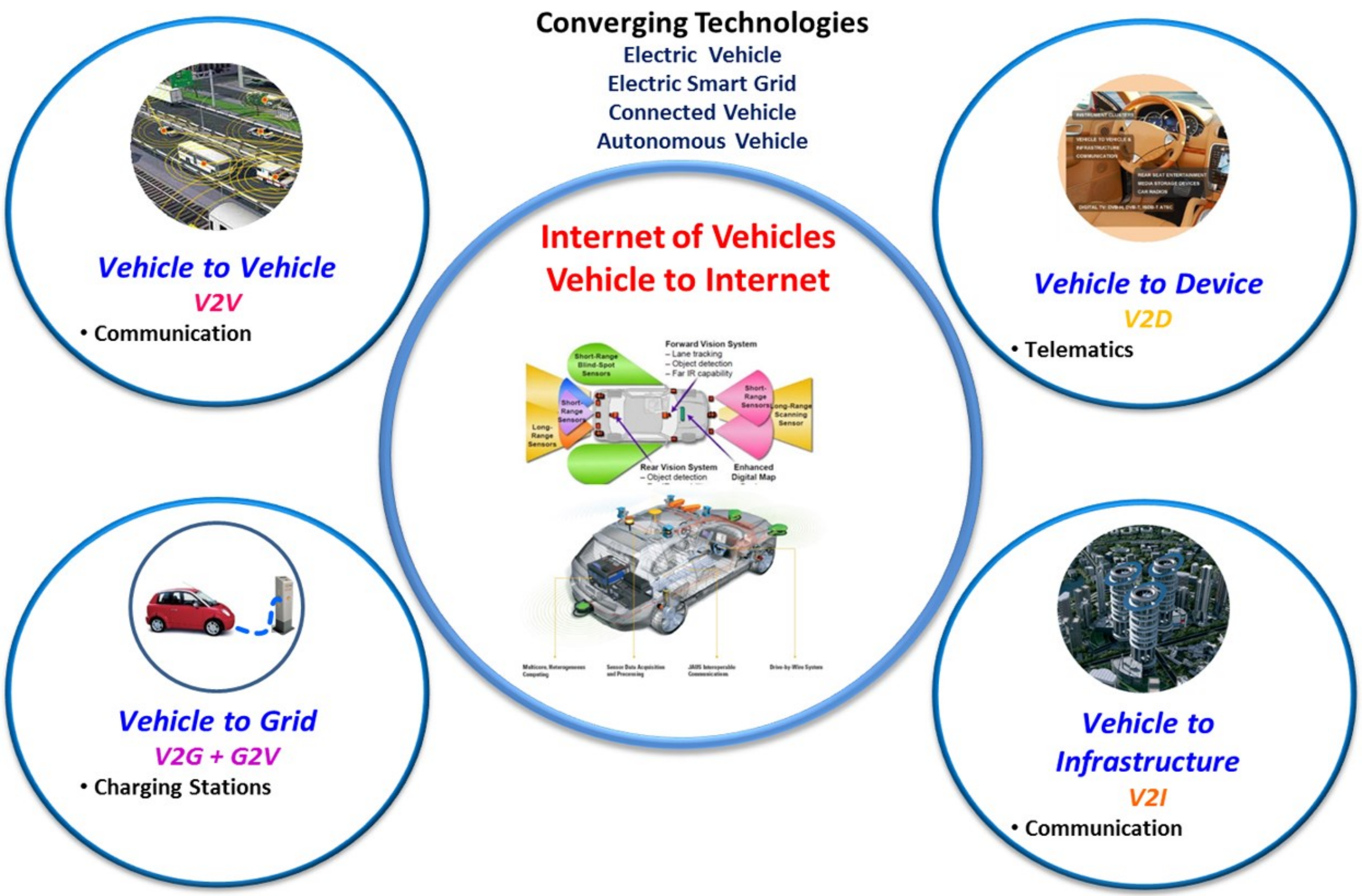
- Energy Optimization
- Asset Management
- Facility Management
- Video Surveillance
- Recycling and Power Generation
- Automatic Fault Detection Diagnosis
- Supervisory Control
- Audio / Video Distribution Management

Smart Transportation

- Intelligent Transportation
- Smart Public Transportation
- Integrated Fare Management
- Fleet Optimization
- Tolling Solutions
- Real-time Adaptive Traffic Management
- Smart Parking
- Traveler Information Systems

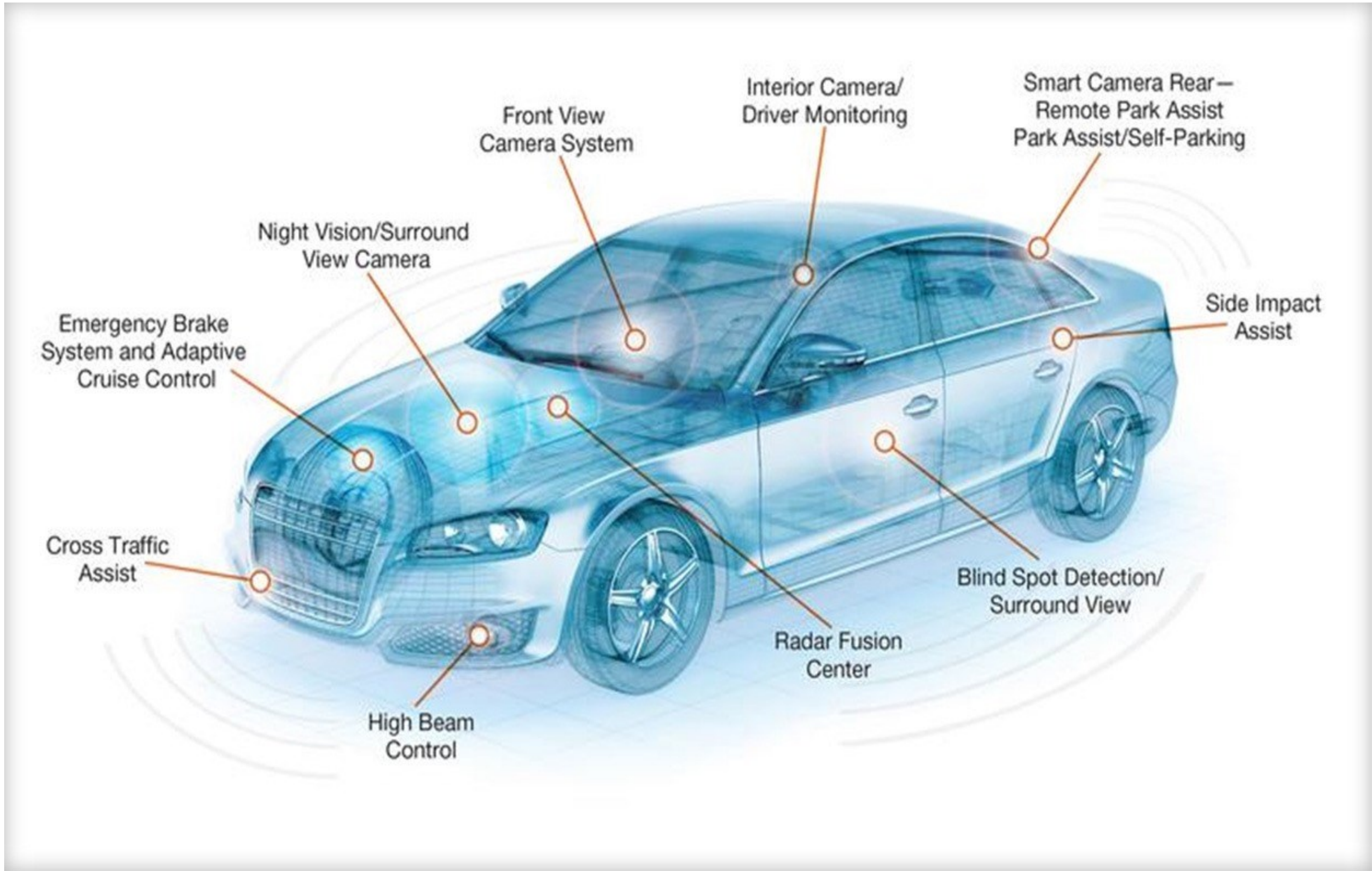
All sectors, All types of Things, All Environments taken into account for network design (**capacity requirements**, **coverage areas**)

Internet of Vehicles



IoV Coverging Technologies [1]

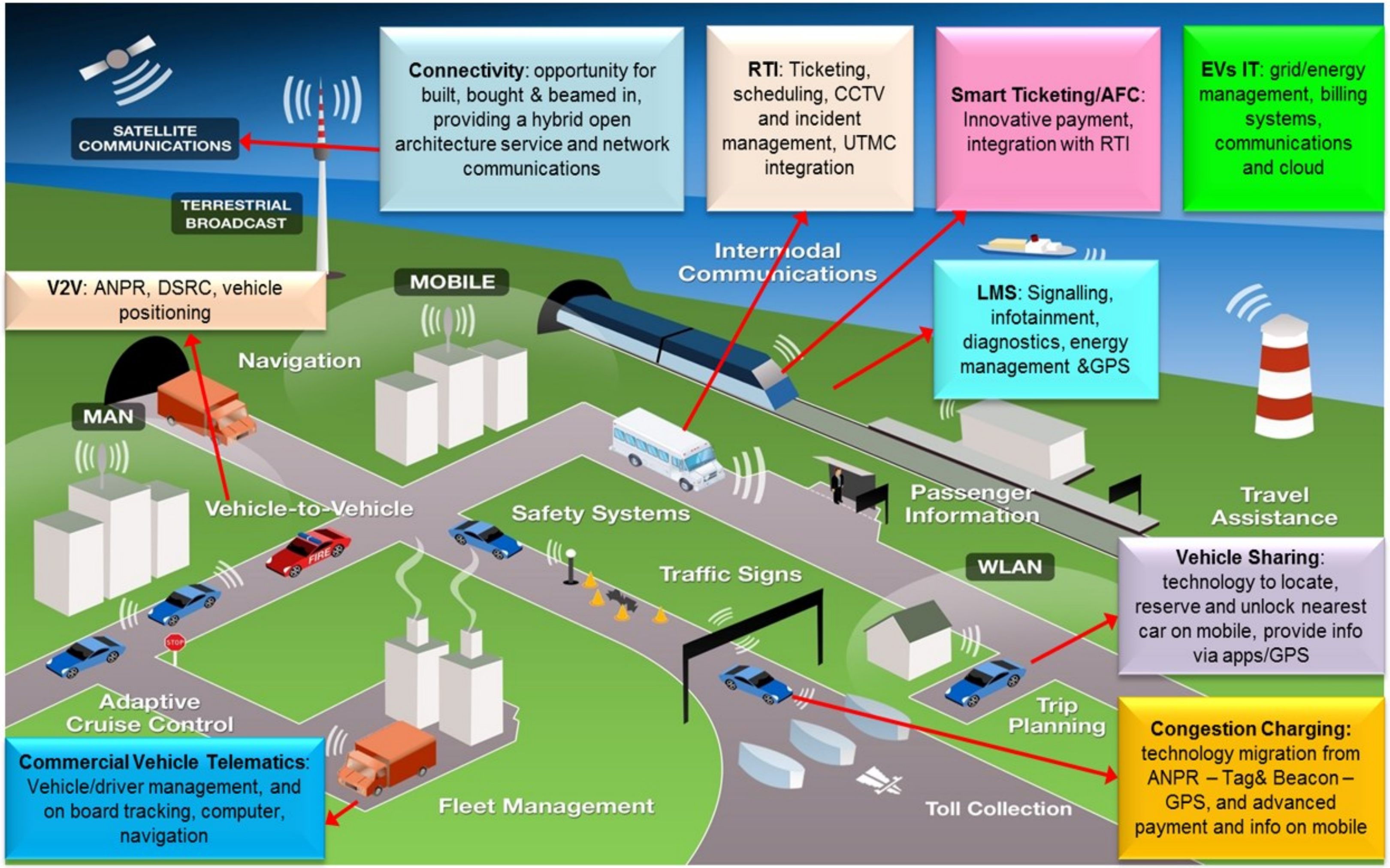
Internet of Vehicles



Communication and computer vision technologies for driver-assistance and V2V/V2I interaction

Ovidiu Vermesan Peter Friess, nternet of Things – *From Research and Innovation to Market Deployment*, ISBN: 978-87-93102-94-1 (Hard copy) 978-87-93102-95-8 (Ebook) , Rivers Publishers, 2014

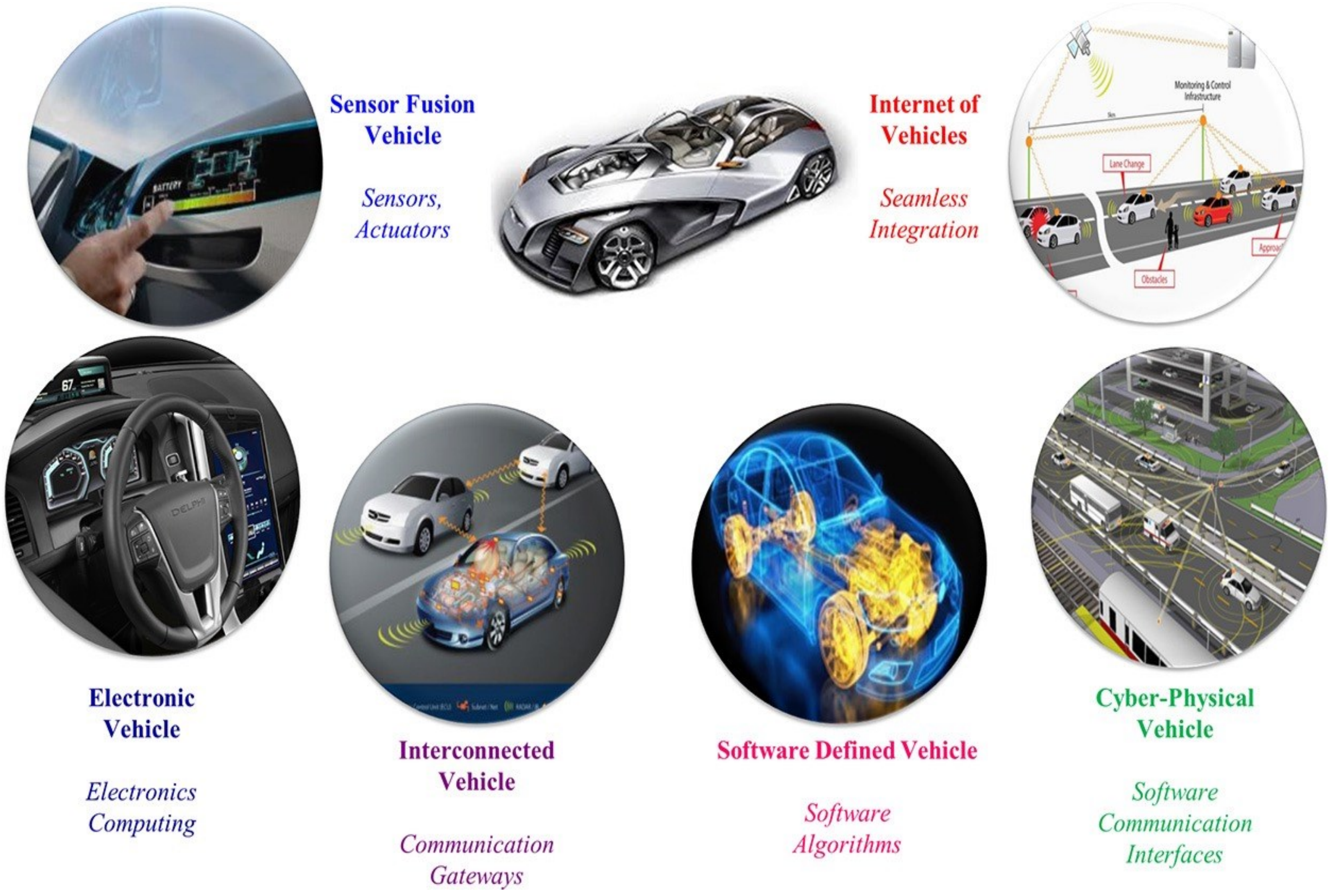
Internet of Vehicles



Source: ETSI

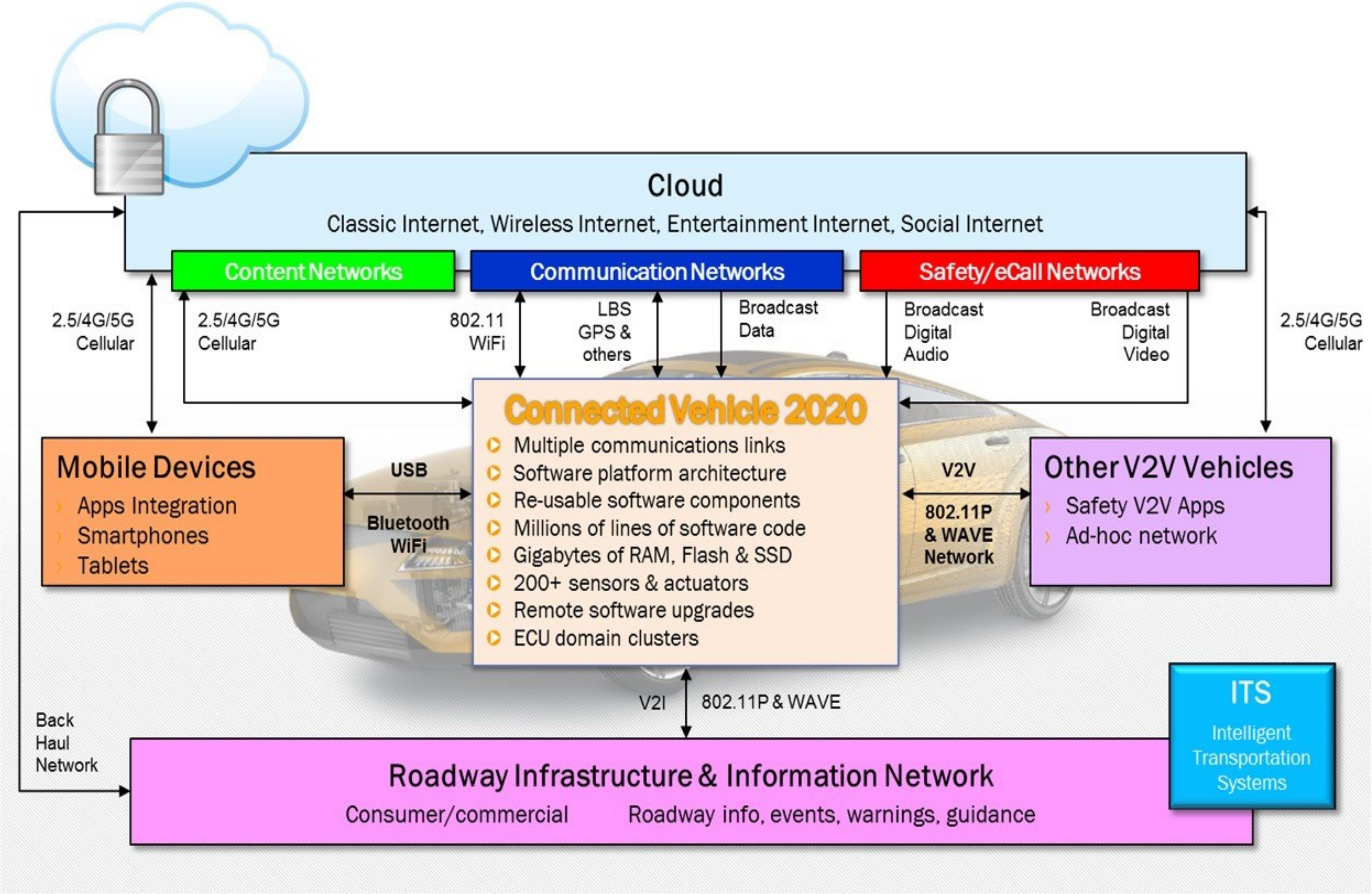
ITS Ecosystem (Source: ETSI)

Internet of Vehicles



ITS Ecosystem (Source: ETSI)

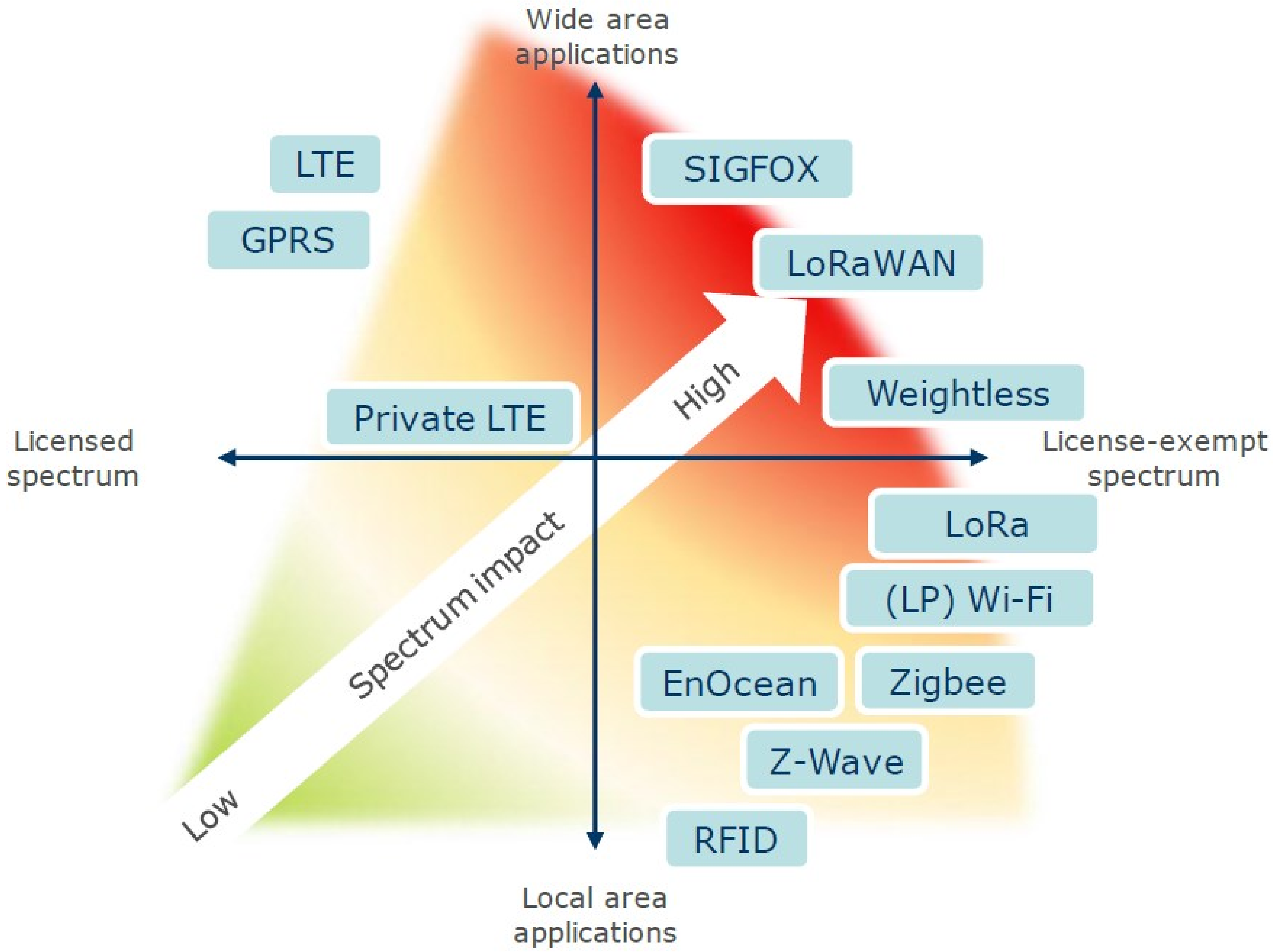
Internet of Vehicles



Connected Vehicle 2020-Mobility Ecosystem

(Source: Continental Corporation)

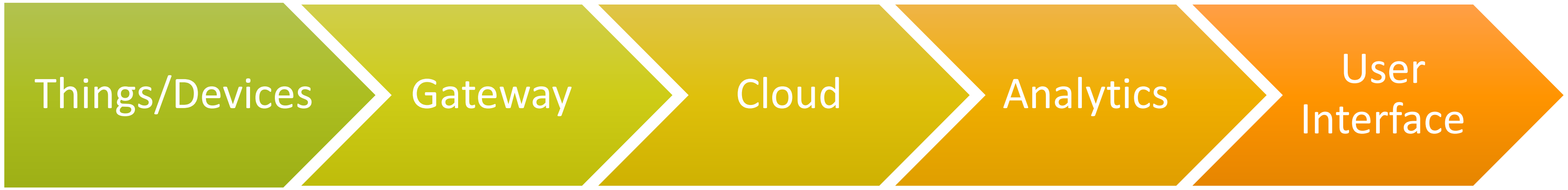
IoT wireless technologies overview



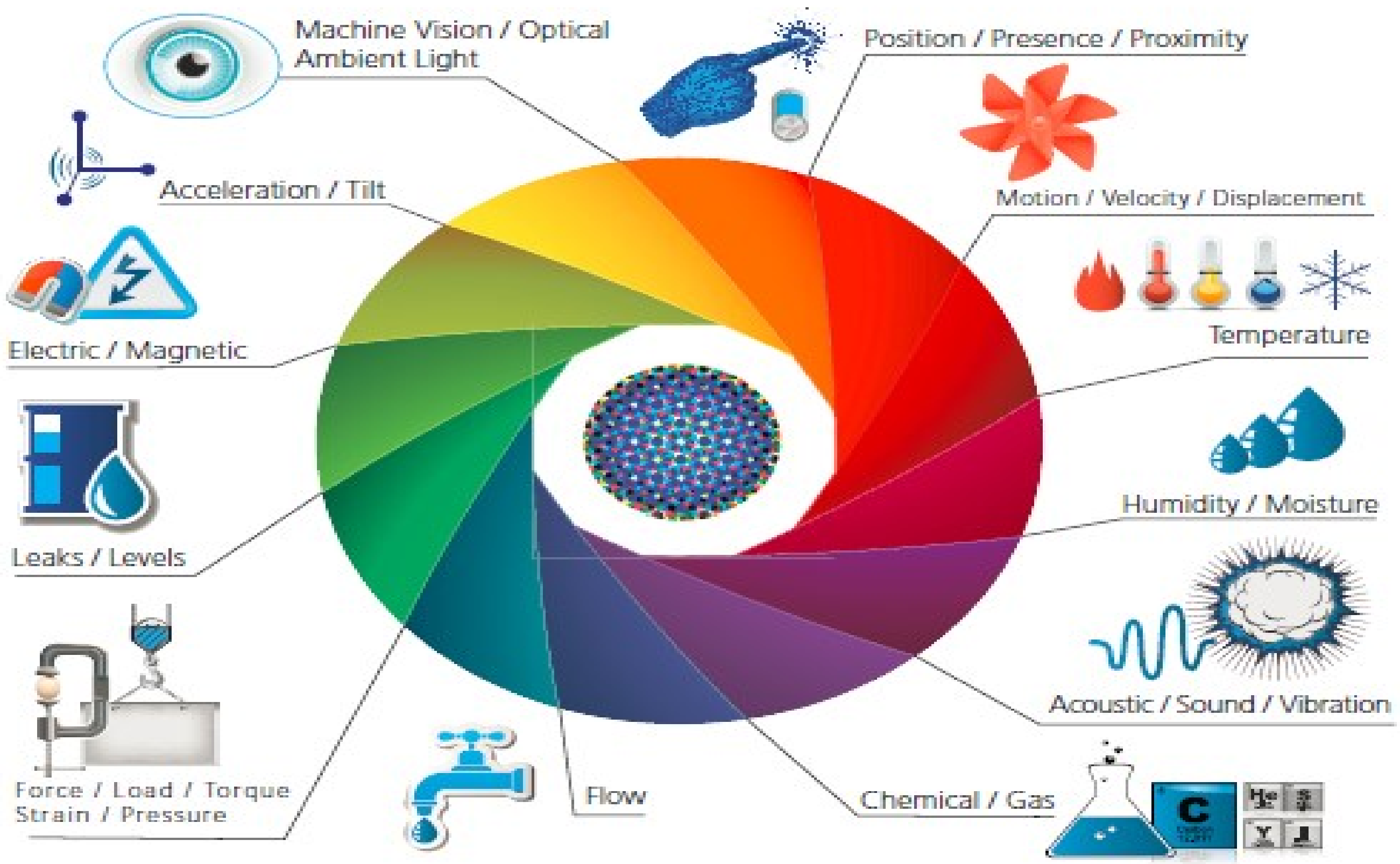
IoT Components

Conceptual overview

Implementation-driven overview

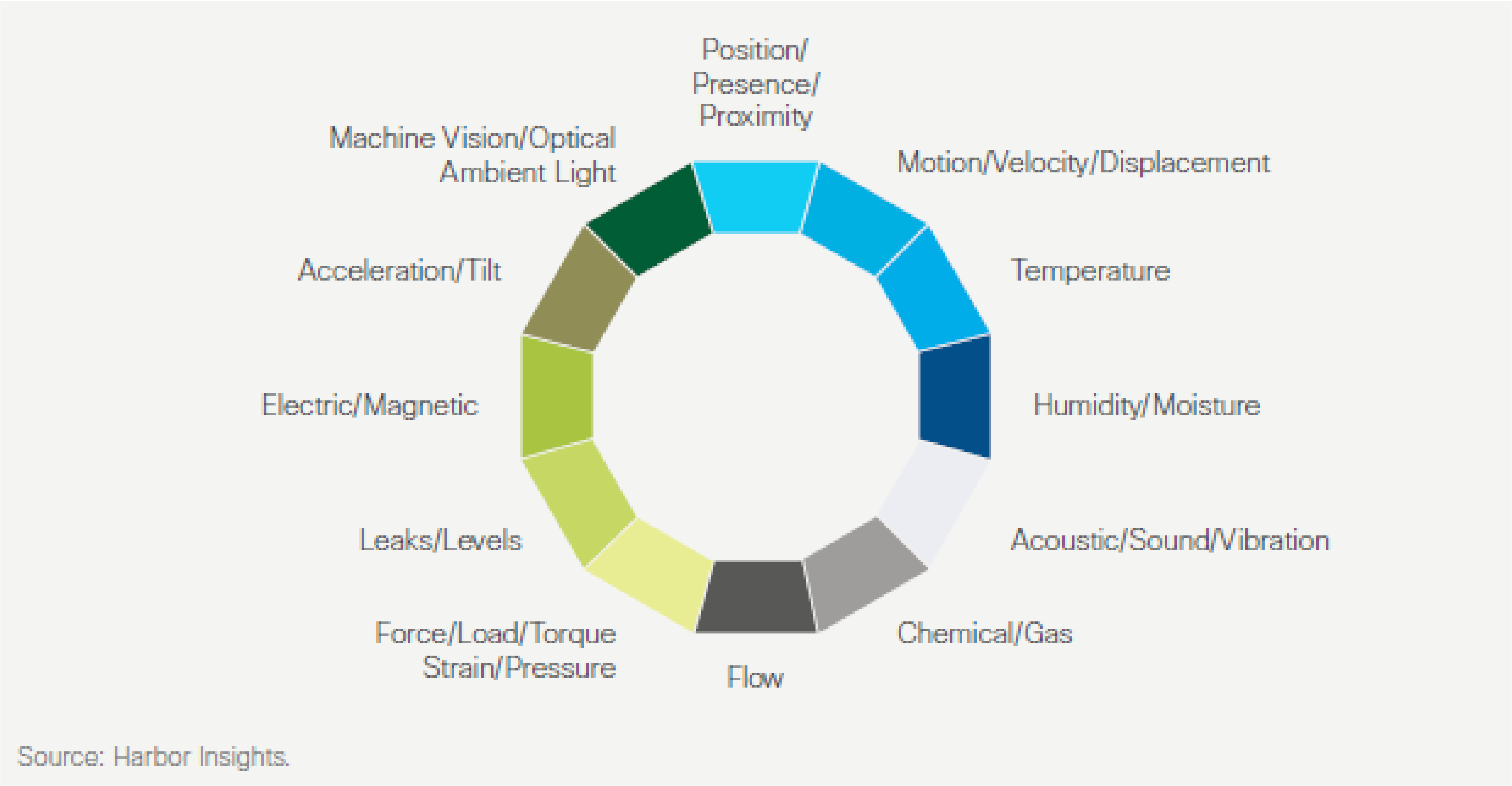


Sensor Types



Sensor Types (source: harbor research @ HarborResearch.com)

Sensor Types



Sensor Types (source: harbor research @ HarborResearch.com)

Sensor Types

Highest Cost ↑ / ↓ Lowest Cost

	Functionality	Sensor Type
$150–$1000+	• Long-term install/deployment • Industrial scale deployment • Extreme accuracy/precision • Typically large enterprises • Ease of solution interoperability	• Chemical/Gas • Electrical/Capacitive • Pressure/Load/Weight • Proximity/Position
$50–$150	• Residential/commercial • Advanced development kits • Consumer-based support • Cloud partnership capability • Fast deployment • Medium infrastructure required • Low-Medium accuracy/Precision	• Water Treatment/Flow • Weather/Temperature • Motion/Velocity • Acoustic/Sound/Vibration • Light/Imaging • Proximity/Position • Flex/Force/Strain
$0 – $50	• Single function • DIY/Prototyping often needed • Limited without other hardware • Requires basic equipment • Geared towards amateurs • Singular functionality • No infrastructure required	• Water Treatment/Flow • Weather/Temperature • Motion/Velocity • Acoustic/Sound/Vibration • Light/Imaging

Sensor Types and Costs (source: ITU)

Deployment stages

Stage 5: Enhancing on-board intelligence: maximum ROI and business benefit provided by predictive failure, data-driven diagnostics and device optimization.

Stage 4: Automation: Orchestration of automated, complex actions from equipment to inventory, support, service ticketing, and other systems to enable condition-based maintenance and better device utilization.

Stage 3: Data Analytics: Delivery of insights, predictions and optimization using many different data types and formats.

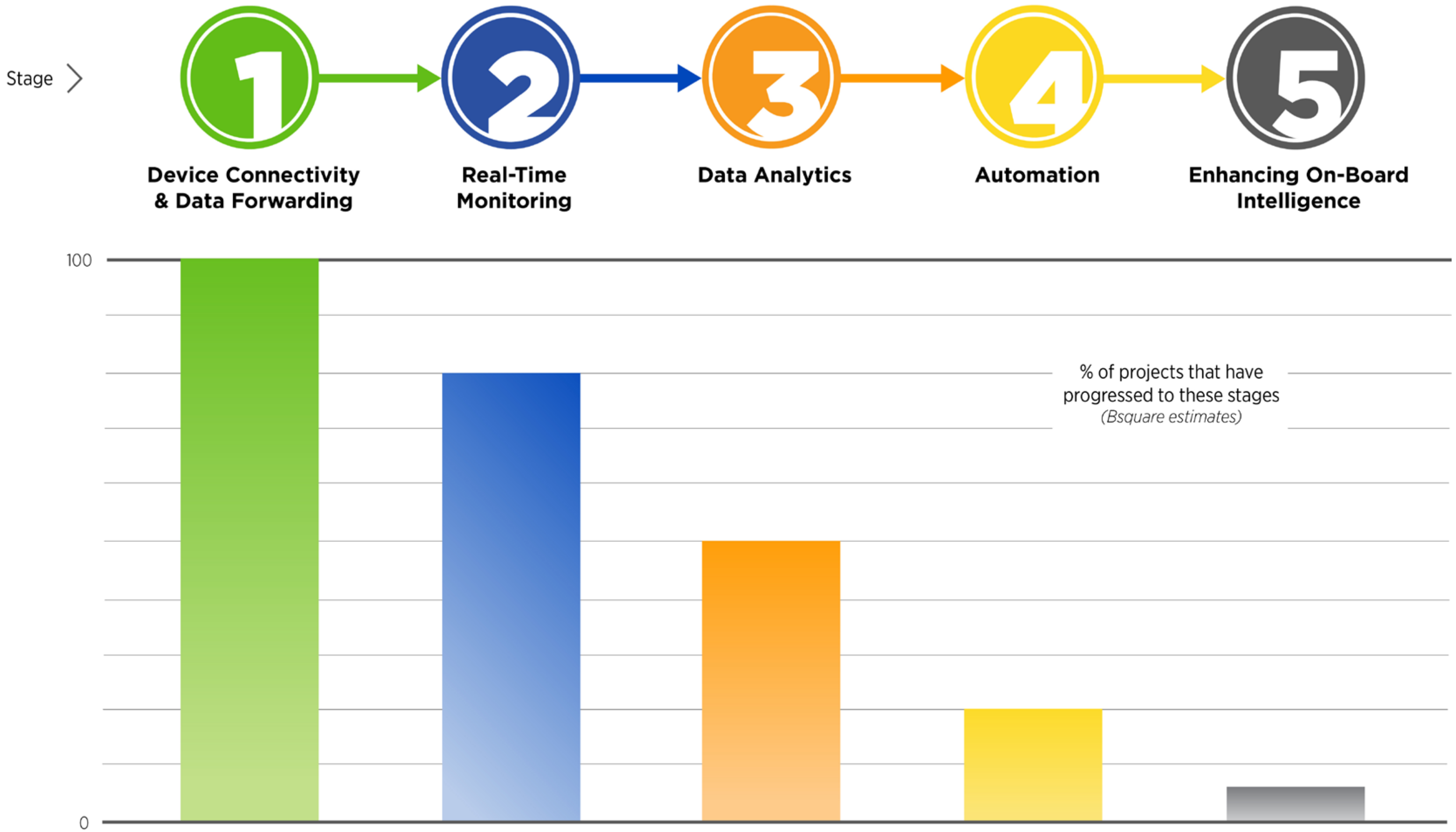
Stage 2: Real-time monitoring

- Data monitoring and visualization to initiate business cases for desired business outcomes.

Stage 1: Device connectivity & Data forwarding

- Sensor data capture, transmission and storage for analysis and action

Deployment Analysis



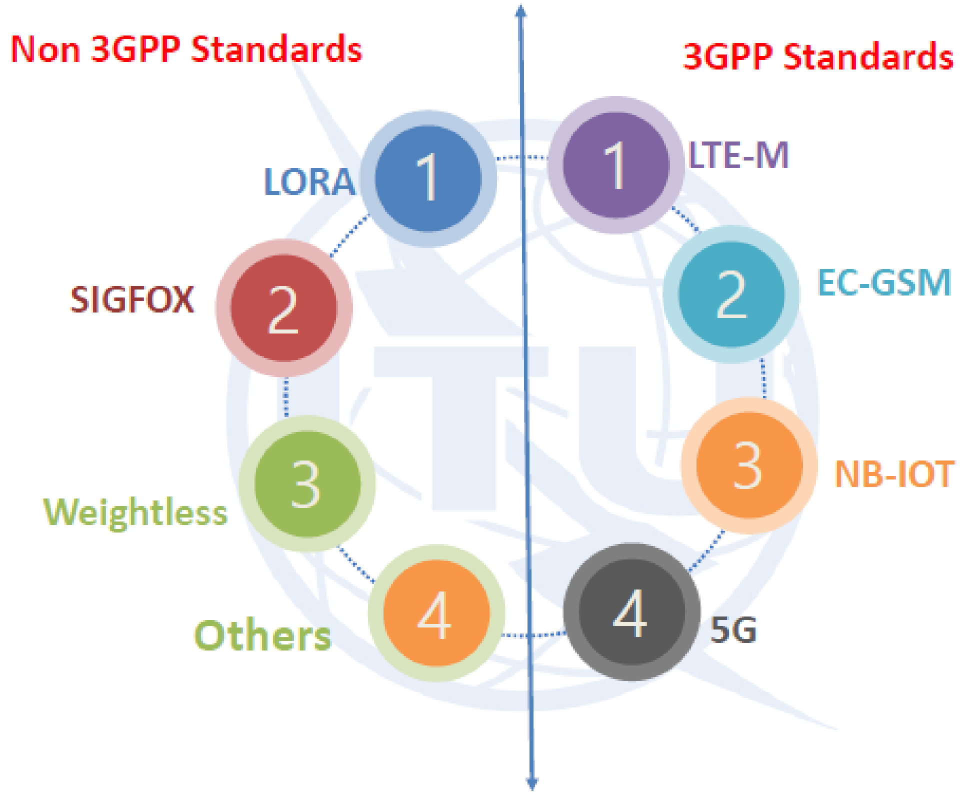
Deployment Analysis (Source: [3])

IoT Technologies

Fixed & Short Range

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

Long Range



Wide-area M2M technologies and IoT

Carrier frequency		Technology	Channel bandwidth	Representative data rate	Link budget target or max. range
Licensed cellular		LTE Cat. 0	20 MHz	DL: 1 Mb/s UL: 1 Mb/s	140 dB
		LTE Cat. M	1.4 MHz	DL: 1 Mb/s UL: 1 Mb/s	155 dB
		NB-IoT	200 kHz	DL: 128 kb/s UL: 64 kb/s	164 dB
		EC-GSM	200 kHz	DL: 74 kb/s UL: 74 kb/s	164 dB
Unlicensed	2.4 GHz	Ingenu RPMA	1 MHz	UL: 624 kb/s DL: 156 kb/s	500 km line of sight
	Sub-1 GHz	LoRa chirp spread spectrum	125 kHz	UL: 100 kb/s DL: 100 kb/s	15 km rural 5 km urban
	Sub-1 GHz	Weightless-N	200 Hz	UL: 100 b/s	3 km urban
	Sub-1 GHz	Sigfox	160 Hz	UL: 100 b/s	50 km rural 10 km urban

H. S. Dhillon et al., "*Wide-Area Wireless Communication Challenges for the Internet of Things*," IEEE Communications Magazine, February 2017

Market Segment	Connections in 2020 (Billion)	Requirements	Technology
• CCTV(Camera) • In-vehicle Entertainment…	0.2B	l >10Mbps	3G/4G
• IoT Gateway Backhaul • Wearable • …	0.8B	l ~1Mbps l Low power consumption	2G/3G/Cat-1 Cat-M1
• Sensors, Meters • Asset Tracking • Smart Parking • Smart agriculture …	2B	l Low Throughput (<100kbps) l Deep Coverage (20dB) l Low power (10 Years) l Low cost (<$5)	Short Range Tech. Sigfox, LoRa NB-IoT

LPWA: Low Power Wide Area

LPWA could account 70% of Cellular IoT Connections in 2020

C-IoT provides wide WAN coverage

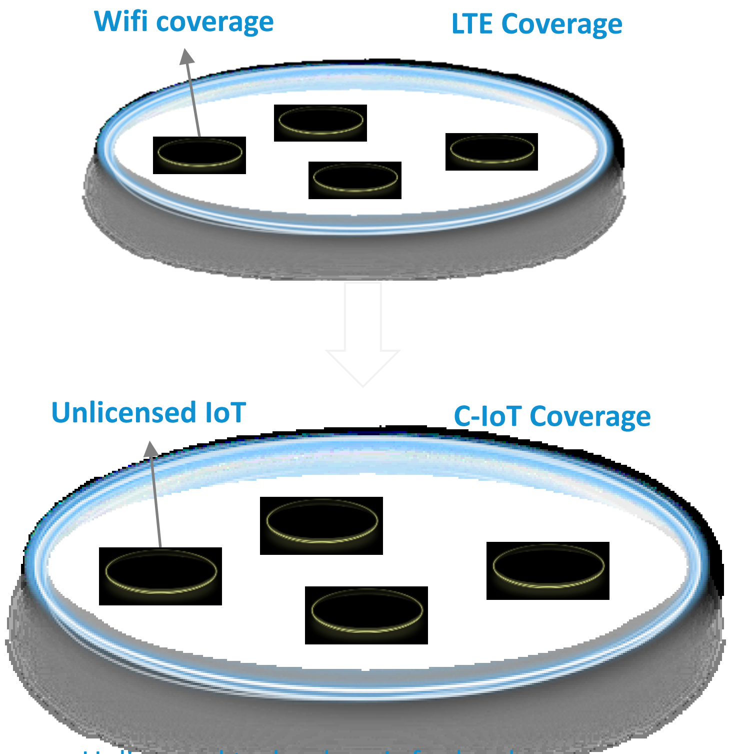
C-IoT

Re-use existing Cellular network

Carrier-grade Reliability

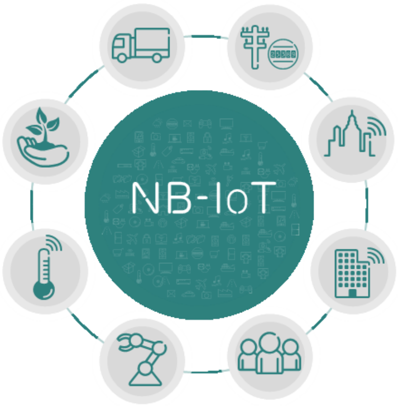
4G-Like Security

Roaming



- Unlicensed technology is for local coverage
- C-IoT is for wide coverage

Current status



April 2014	May 2014	March 2015	August 2015	November 2015	Jun 2015	2017+
Narrowband proposal to Connected Living	3GPP ‘Cellular IoT’ Study Item	GSMA Mobile IoT created	3GPP alignment on single standard	1st live pre-standard NB-IoT message	Full NB-IoT 3GPP Standard Released	Commercial rollout

Evolution of LTE-M

Comparison with LTE-M

Attribute	CAT-1	LTE-M		NB-IOT	
		Rel 13	Rel 14	Rel 13	Rel 14
Spectrum	LTE bands	LTE bands Stand Alone (1.4MHz)		LTE Bands Stand Alone (200KHz)	
Typical MNO	LTE Coverage	Good LTE Coverage		Mix LTE and 2G	
Bandwidth	20 MHz	1.08MHz (CAT-M1)	5 MHz (CAT-M2)	180kHz	
Number of DL Antennas	2	1		1	
Duplex Modes	FD-FDD/TDD	HD-FDD, FD-FDD,TDD		HD-FDD	
UL Modulation	QPSK, 16QAM	QPSK, 16QAM		Pi/2 BPSK, Pi/4 QPSK	
DL Modulation	QPSK, 16QAM	QPSK, 16QAM		QPSK	
Spectral Efficiency	V.Good	Good		OK	
Power Class	Class 3 (23dBm)	Class 3 (23 dBm) Class 5 (20 dBm)		Class 3 and 5	* 14 dBm
UL Multple Access	LTE SC-FDMA	LTE SC-FDMA		LTE SC-FDMA + Single tone transmission with 3.75kHz and 15kHz bandwidths	

Main eMTC, NB-IoT and EC-GSM-IoT features

	eMTC (LTE Cat M1)	NB-IOT	EC-GSM-IoT
Deployment	In-band LTE	In-band & Guard-band LTE, standalone	In-band GSM
Coverage*	155.7 dB	164 dB for standalone, FFS others	164 dB, with 33dBm power class 154 dB, with 23dBm power class
Downlink	OFDMA, 15 KHz tone spacing, Turbo Code, 16 QAM, 1 Rx	OFDMA, 15 KHz tone spacing, 1 Rx	TDMA/FDMA, GMSK and 8PSK (optional), 1 Rx
Uplink	SC-FDMA, 15 KHz tone spacing Turbo code, 16 QAM	Single tone, 15 KHz and 3.75 KHz spacing SC-FDMA, 15 KHz tone spacing, Turbo code	TDMA/FDMA, GMSK and 8PSK (optional)
Bandwidth	1.08 MHz	180 KHz	200kHz per channel. Typical system bandwidth of 2.4MHz [smaller bandwidth down to 600 kHz being studied within Rel-13]
Peak rate (DL/UL)	1 Mbps for DL and UL	DL: ~50 kbps UL: ~50 for multi-tone, ~20 kbps for single tone	For DL and UL (using 4 timeslots): ~70 kbps (GMSK), ~240kbps (8PSK)
Duplexing	FD & HD (type B), FDD & TDD	HD (type B), FDD	HD, FDD
Power saving	PSM, ext. I-DRX, C-DRX	PSM, ext. I-DRX, C-DRX	PSM, ext. I-DRX
Power class	23 dBm, 20 dBm	23 dBm, others TBD	33 dBm, 23 dBm

LoRaWAN

Member's Login Contact

LoRa Alliance™

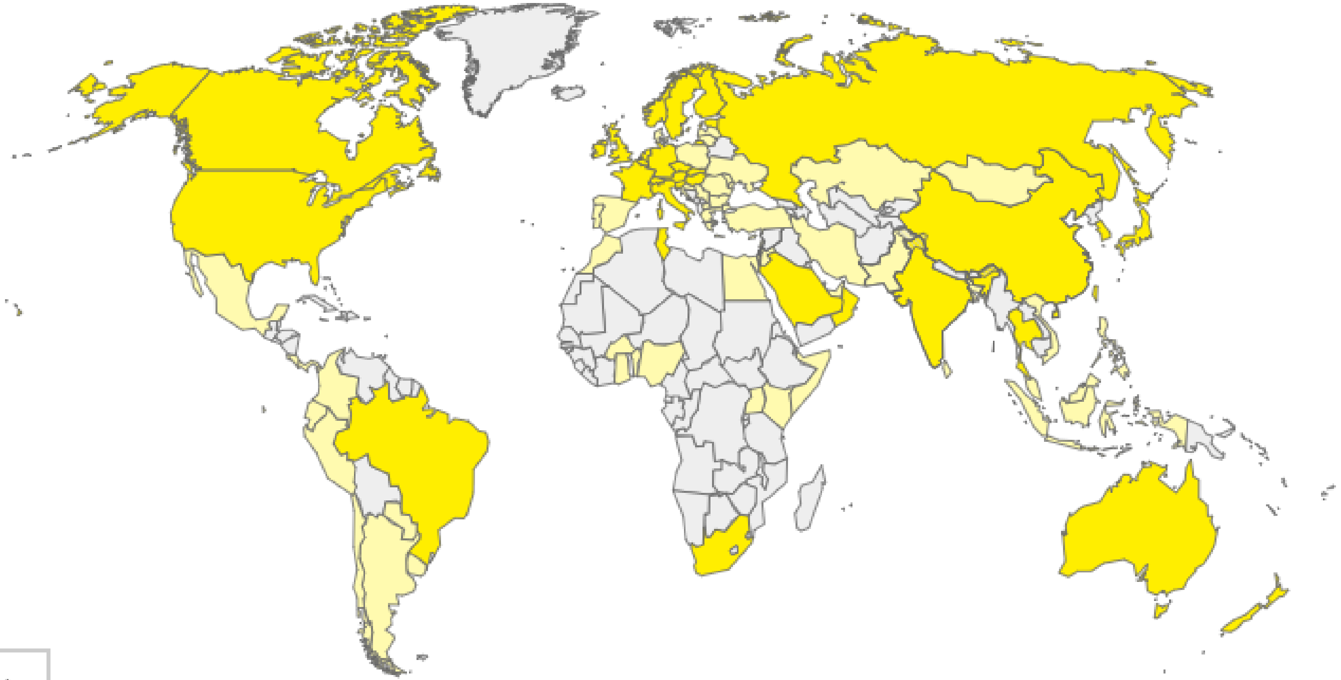
LoRa Alliance™ LoRaWAN™ Certification News Events Membership Resource Hub

83
Network Operators

57
Alliance Member Operators

49
Countries operating in

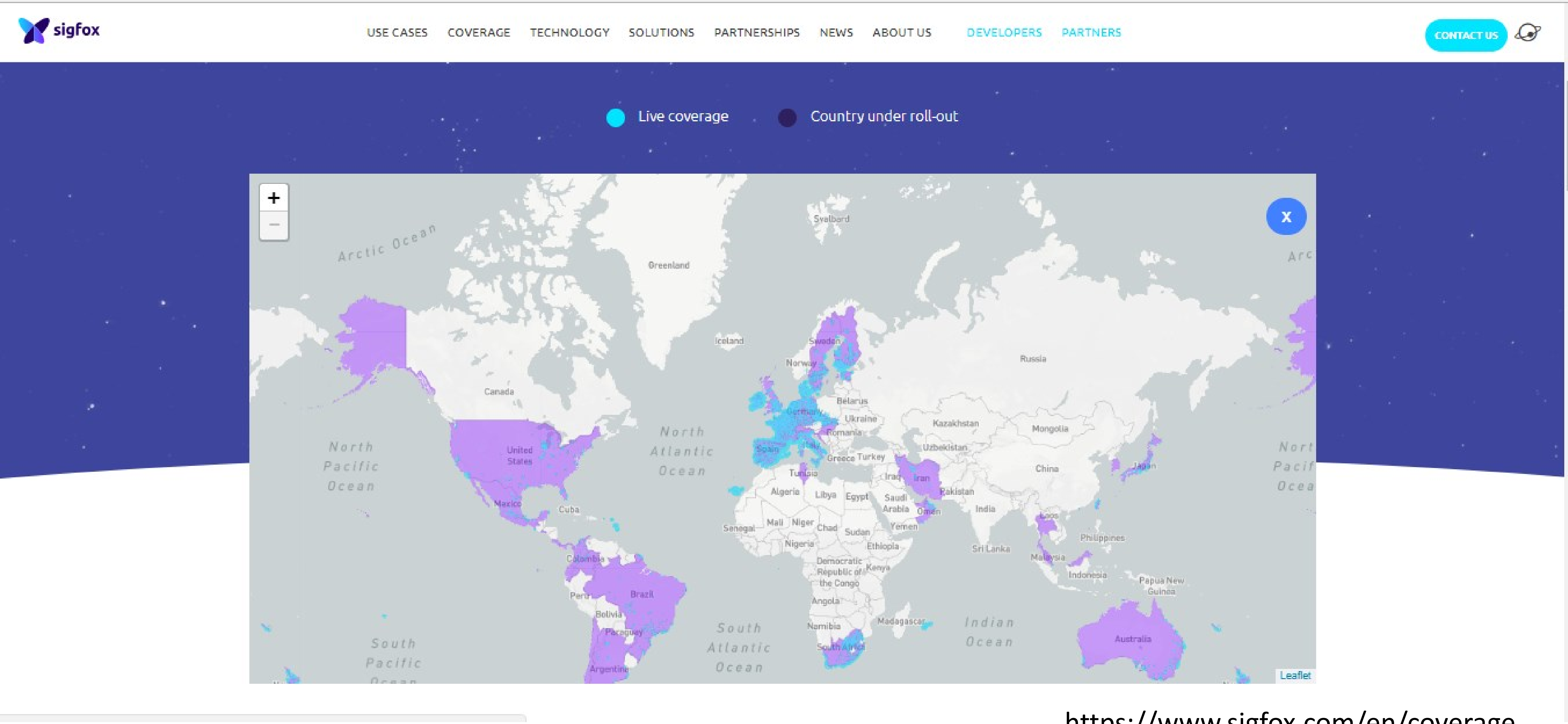
95
Countries with LoRaWAN Deployments



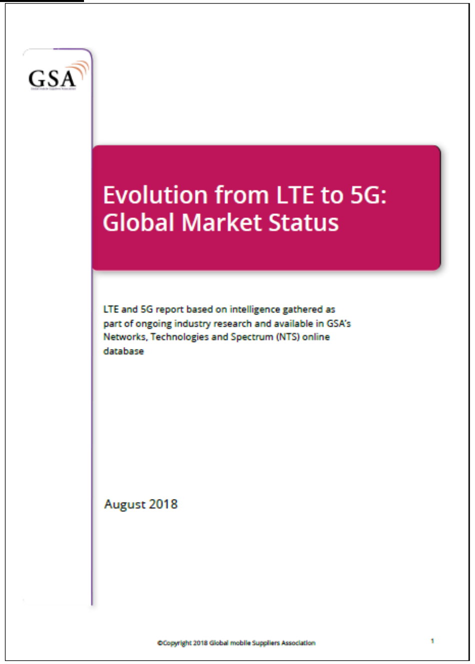
Alliance Member Public Networks
Other LoRaWAN Deployment

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

Sigfox



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


GSA

Evolution from LTE to 5G: Global Market Status

LTE and 5G report based on intelligence gathered as part of ongoing industry research and available in GSA's Networks, Technologies and Spectrum (NTS) online database

August 2018

©Copyright 2018 Global mobile Suppliers Association

1

Report: Evolution from LTE to 5G, GSA

https://gsacom.com/

- 865 operators investing in LTE, including pre-commitment trials.
- 681 commercially launched LTE or LTE-Advanced networks in 208 countries, including those using LTE for FWA services, as well as 114 LTE-TDD (TD-LTE) networks launched in 60 countries.
- 156 commercial VoLTE networks in 76 countries and 229 operators investing in VoLTE in 107 countries.
- 261 launched networks that are LTE-Advanced in 119 countries.
- Four launched networks that are capable of supporting user equipment (UE) at Cat-18 DL speeds (within limited geographic areas).
- 690–700 anticipated commercially launched LTE networks by end-2018 (GSA forecast).
- 60 NB-IoT and 18 LTE-M/Cat-M1 networks commercially launched with 57 other operators investing in NB-IoT and 26 other operators investing in LTE-M/Cat-M1 in the form of tests, trials or planned deployments.
- 154 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.
- 67 telecom operators in 39 countries have announced intentions of making 5G available to their customers between 2018 and 2022

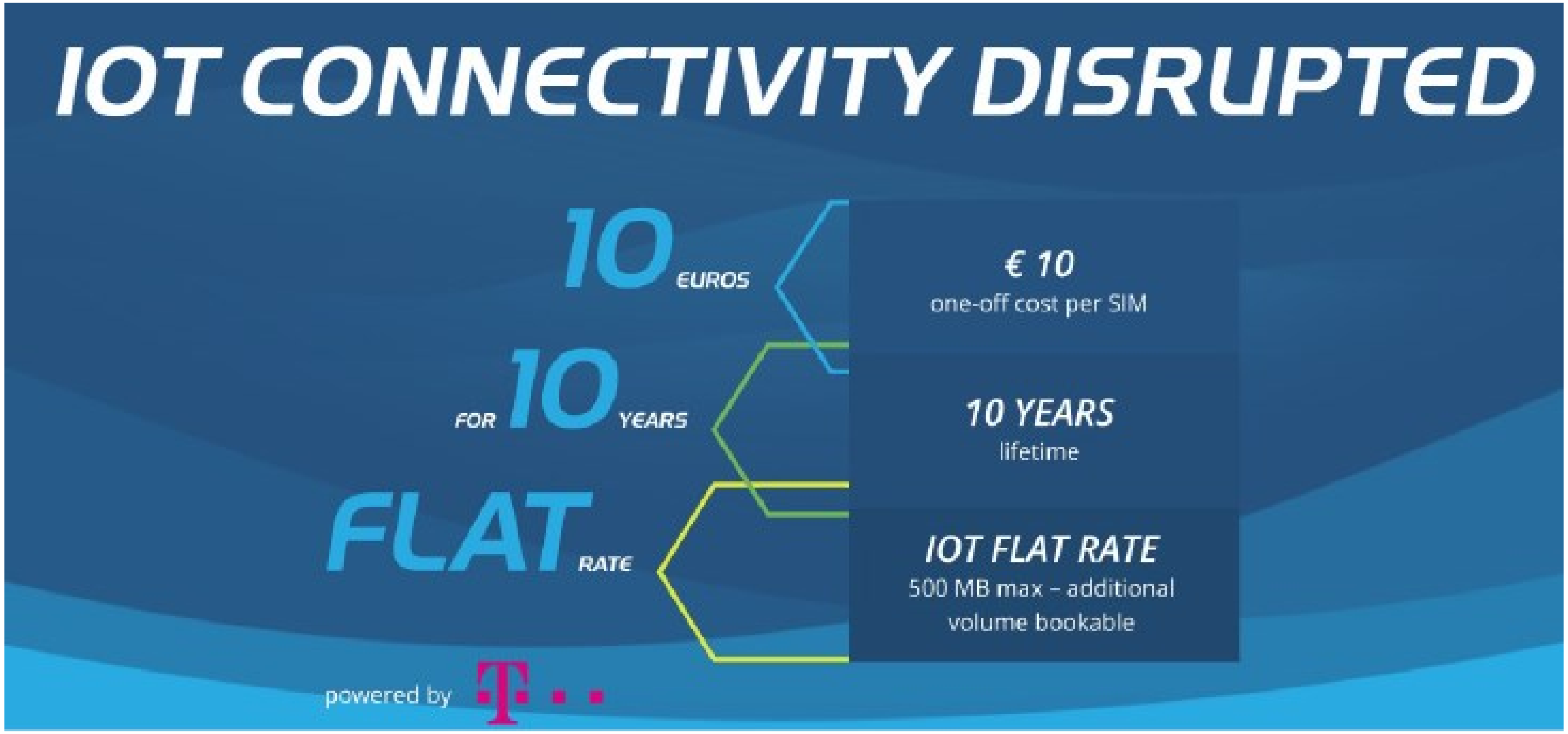
Prices

NB-IoT pricing in Deutsche Telekom

Deutsche Telekom

- The **NB-IoT Access** entry package is available from **EUR 199** and includes a **6-month activation of up to 25 SIM-cards with 500 KB per SIM** pooled in Germany's NB-IoT network. As a further optional add-on – a private APN with IPsec-key encryption is available.
- The **NB-IoT Access & Cloud of Things** entry package is available from **EUR 299** and additionally includes direct access to Deutsche Telekom's Cloud of Things platform for device and data management.

T-Mobile NB-IoT Offer



SK Telecom (South Korea) LoRaWan prices

SK Telecom completed a nationwide LTE-M rollout in March 2017 but only LoRaWAN services are available.

Price plans for LoRaWAN-based IoT services:

1. 350 won (**$0.30**) per month per device for a 100kb allocation
2. 2,000 won (**$1.77**) for a 100MB allocation.

Discounts available for multiple lines, ranging from 2% for those using 500 lines for 10% for those using 10,000 lines. Excess data will be charged at 0.005 won per 0.5KB.

LoRa plans cost just a tenth of the price of its LTE-based IoT services.

Price Plan	Data Allowance* (Frequency of communication)	Monthly Flat Rate (VAT Excluded)	Examples of Services	Note
Band IoT 35	100KB	KRW 350	Metering and monitoring services (e.g. Advanced Metering Infrastructure (AMI), environmental monitoring, water leakage monitoring, etc.)	- Discount benefits for long-term contracts: Ranging from a 5% discount for two-year contracts to a 20% discount for 5 year-contracts - Multi-line discount: Ranging from a 2% discount for those using 500 lines to a 10% discount to those who use 10,000 lines
Band IoT 50	500KB	KRW 500		
Band IoT 70	3MB	KRW 700	Tracking services (e.g. locating tracking For people/things, asset management, etc.)	
Band IoT 100	10MB	KRW 1,000		
Band IoT 150	50MB	KRW 1,500	Control service (e.g. safety management, lighting control, shared parking, etc.)	
Band IoT 200	100MB	KRW 2,000		

**Data usage exceeding the data allotment provided will be charged at KRW 0.005 per 0.5KB.*

UnaBiz (Singapore) Sigfox prices

Network subscription charges: **US$0.75 per device per month**, which comes with a data plan for up to 140 messages per day.

Qualified channel partners who **commit to volume** can ultimately enjoy subscription charges from as low as **US$0.75 per device per year**.

Jonathan Tan, Vice President Business Development & Sales, UnaBiz said, *"Sigfox's technology is built for massive deployment and we are offering ultra-low cost connectivity to grow exponentially the base of devices that can access the network. Compared to existing local networks, businesses on our global network can generate savings of at least 90% off data plan subscription charges."*

AT&T LTE-M services pricing

The new prepaid plans, which target developers and businesses, include three tiers of data and text messages:

1 gigabyte of data valid for up to 1 year and 500 text messages for **$25**;

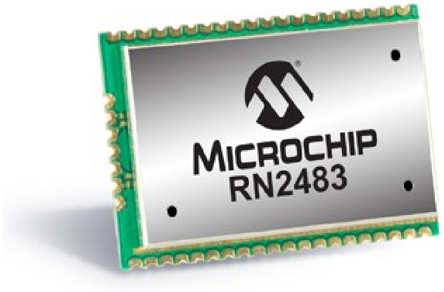
3 GB of data valid for up to 1 year and 1,000 text messages for **$60**;

5 GB of data valid for up to 2 years and 1,500 text messages for **$100**.

Synthesis

Country	Operator	Technology	Price/End-device/month	Conditions (/end-device/month)
Germany	DT	NB-IoT	US$ 1.60	85 KB
			US$ 2.40	" + Cloud
South Korea	SK Telecom	LoRaWAN	US$ 0.30	100 KB
			US$ 1.77	100 MB
Singapore	UnaBiz	Sigfox	US$ 0.75	140 messages
USA	AT&T	LTE-M	US$ 2.08	83 MB and 42 messages
			US$ 5	250 MB and 84 messages
			US$ 4,2	210 MB and 63 messages

LoRaWAN end-devices prices



Interface	UART
Stack / MAC	LoRaWAN
Stack implementation	Microchip proprietary
Price	$14.27 @ single unit $10.90 @ 1000 units

Interface	UART
Stack / MAC	LoRaWAN
Stack implementation	proprietary MultiTech
Form factor	XBee compatible
Price	~$30.00 @ single unit

NB-IoT end-devices prices

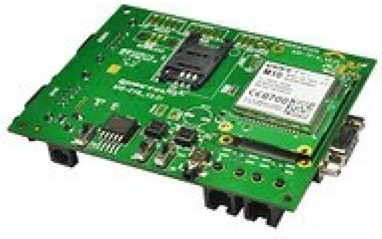
NB-IoT Quectel BC95

AT Commands

3GPP Rel-13

Interfaces SIM/USIM 1 Transmission 100bps

€ 35,00



Quectel GSM/GPRS/UMTS/HSPA/NB-IoT Module

€ 60,00

Digi XBee Cellular NB-IOT

Solution Highlights: Up to ~60Kbps Downlink, 25Kbps Uplink

4-7x better range - strong building penetration

Simple 1 antenna design

200 mW (23 dBm)

Band 20 (800MHz)

Band 8 (900MHz

LTE-M end-devices prices

Digi XBee Cellular LTE-M

Solution Highlights: Up to ~350Kbps Down/Uplink

PSM (Power Saving Mode) and eDRX supported for ultra-low power consumption

Simple 1 antenna design

200 mW (23 dBm)

Verizon: Band 13 (700MHz) Band 4 (1700MHz)

AT&T: Band 2 (1900MHz) Band 4 (1700MHz) Band 12 (700MHz)

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.

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,

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

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

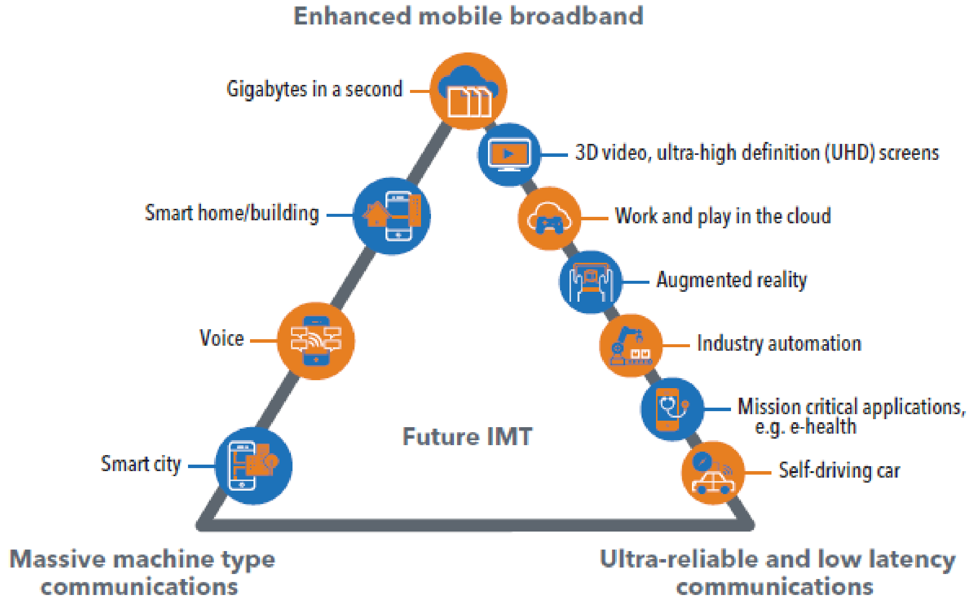
Private network customized for specific M2M/IoT apps.

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

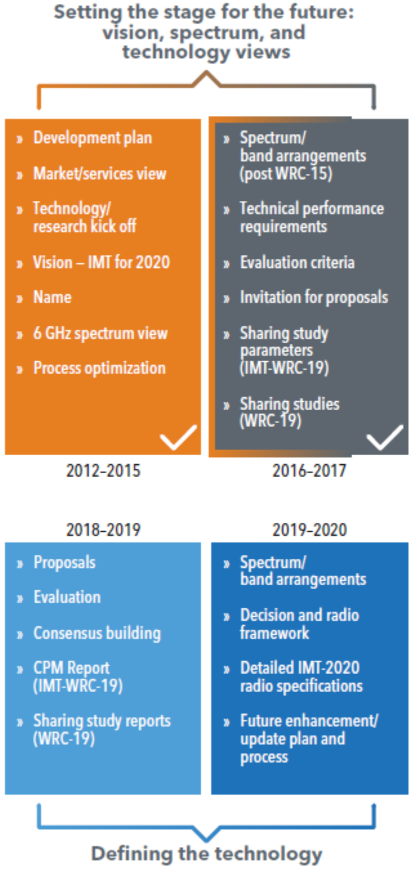
- 5 905 -5 925 MHz for LTE-V2X trials
- 2 x 2.3 MHz in 800MHz can be used for NB-IoT

5G and IOT

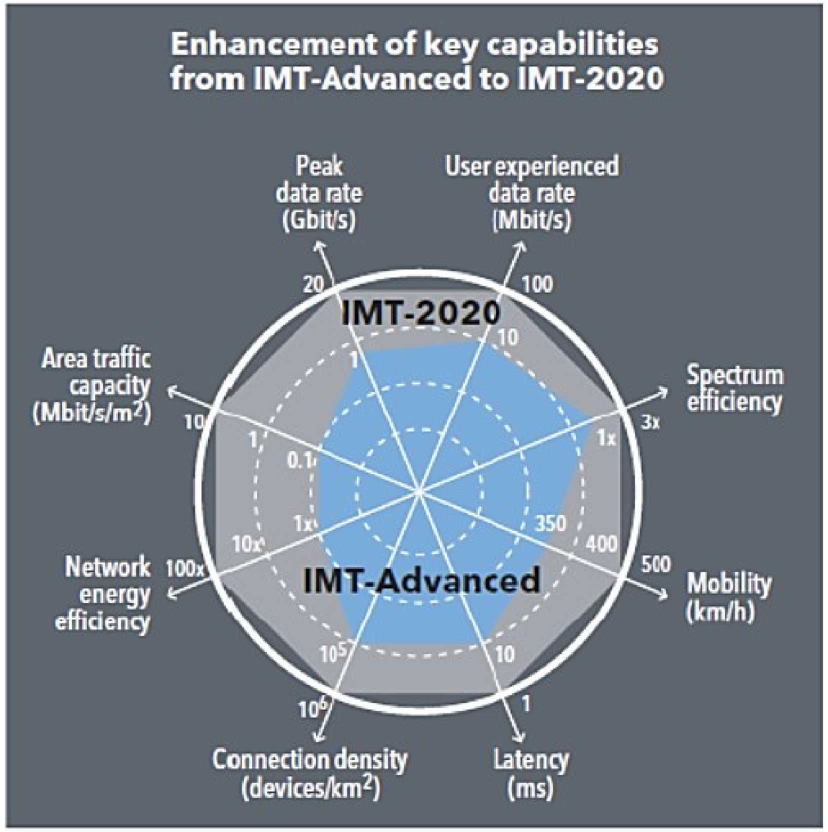
5G usage scenarios from the ITU-R IMT-2020 Vision Recommendation

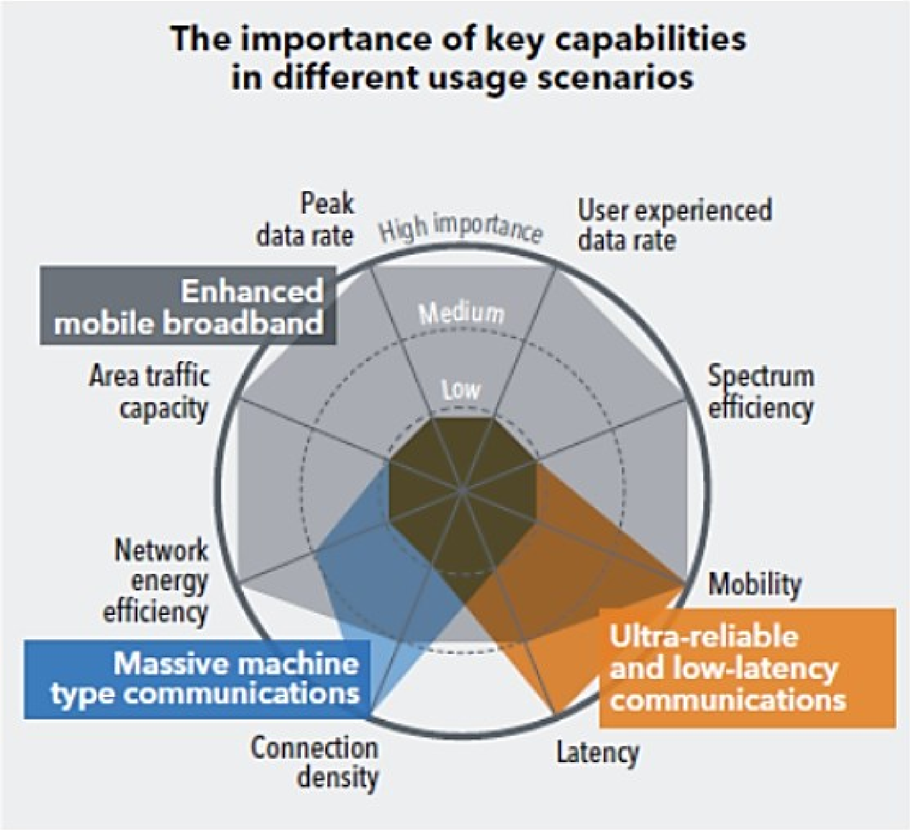


IMT-2020 standardization process



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)***

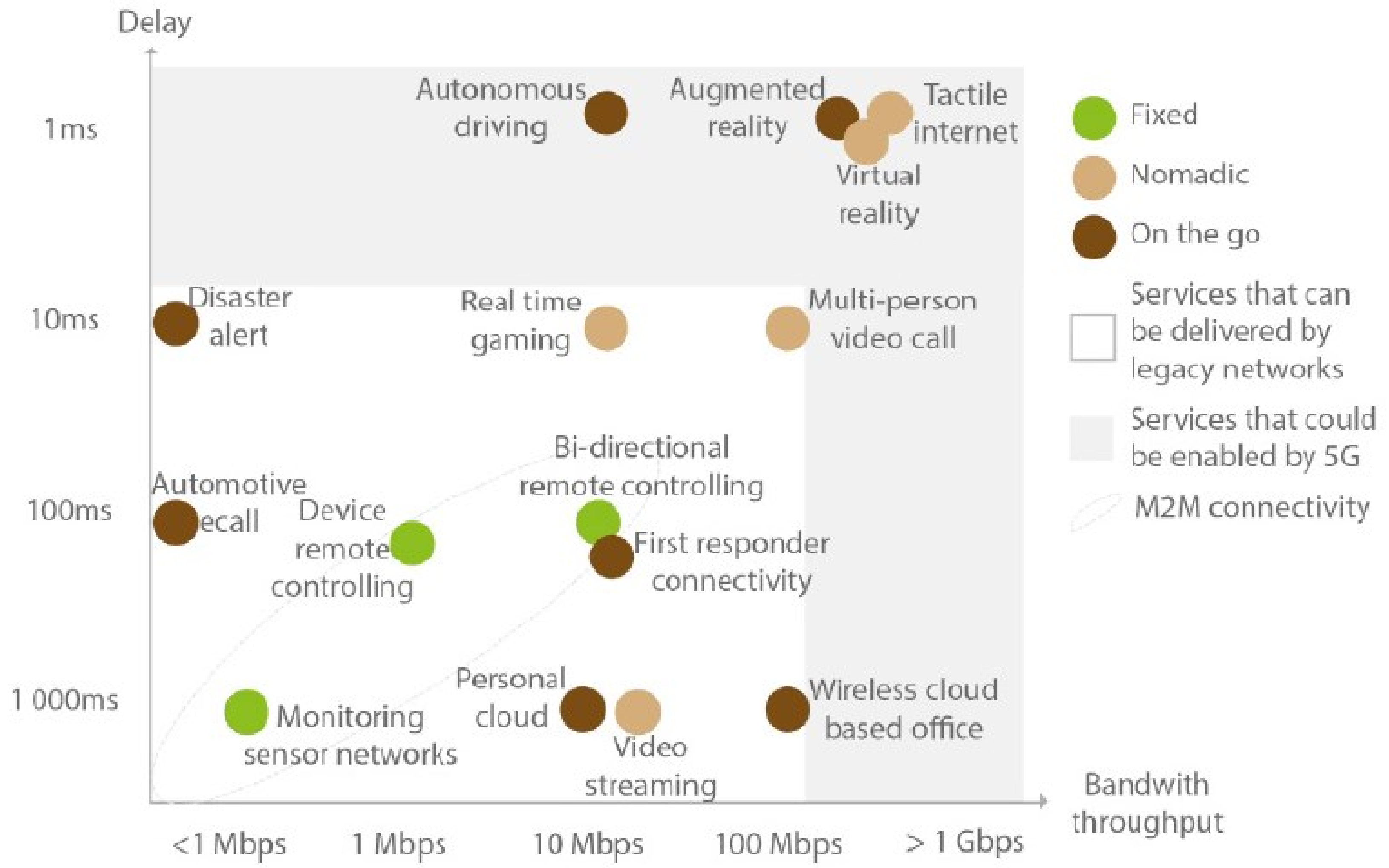
5G and Socio-Economic Benefits

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.

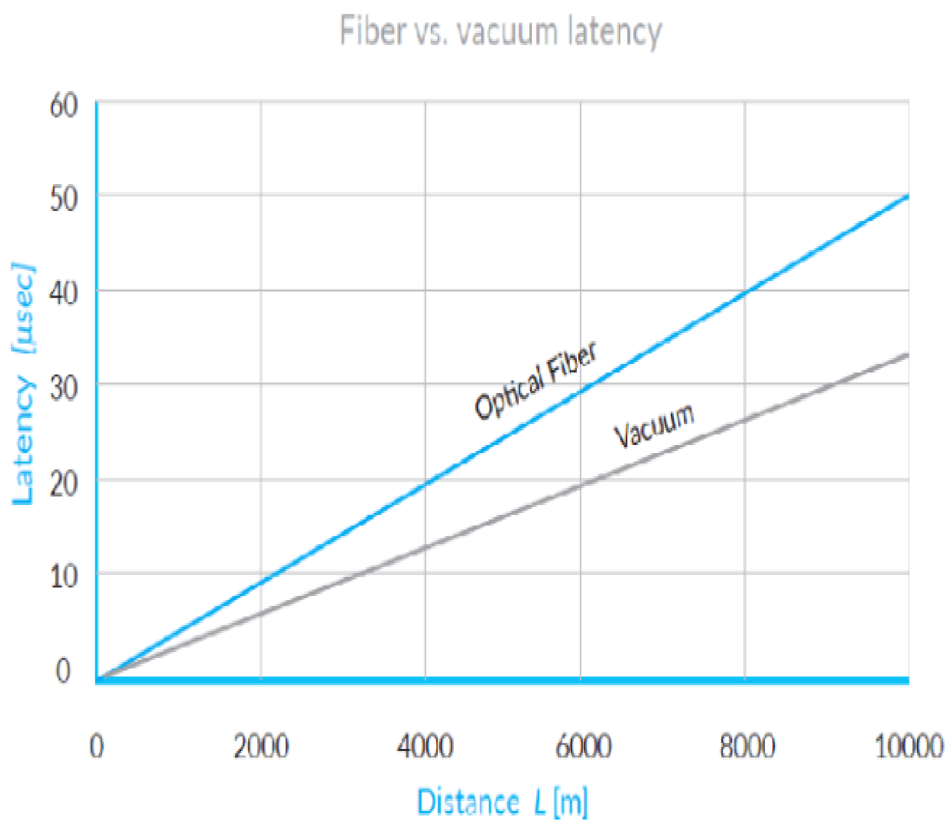
Services that 5G would enable



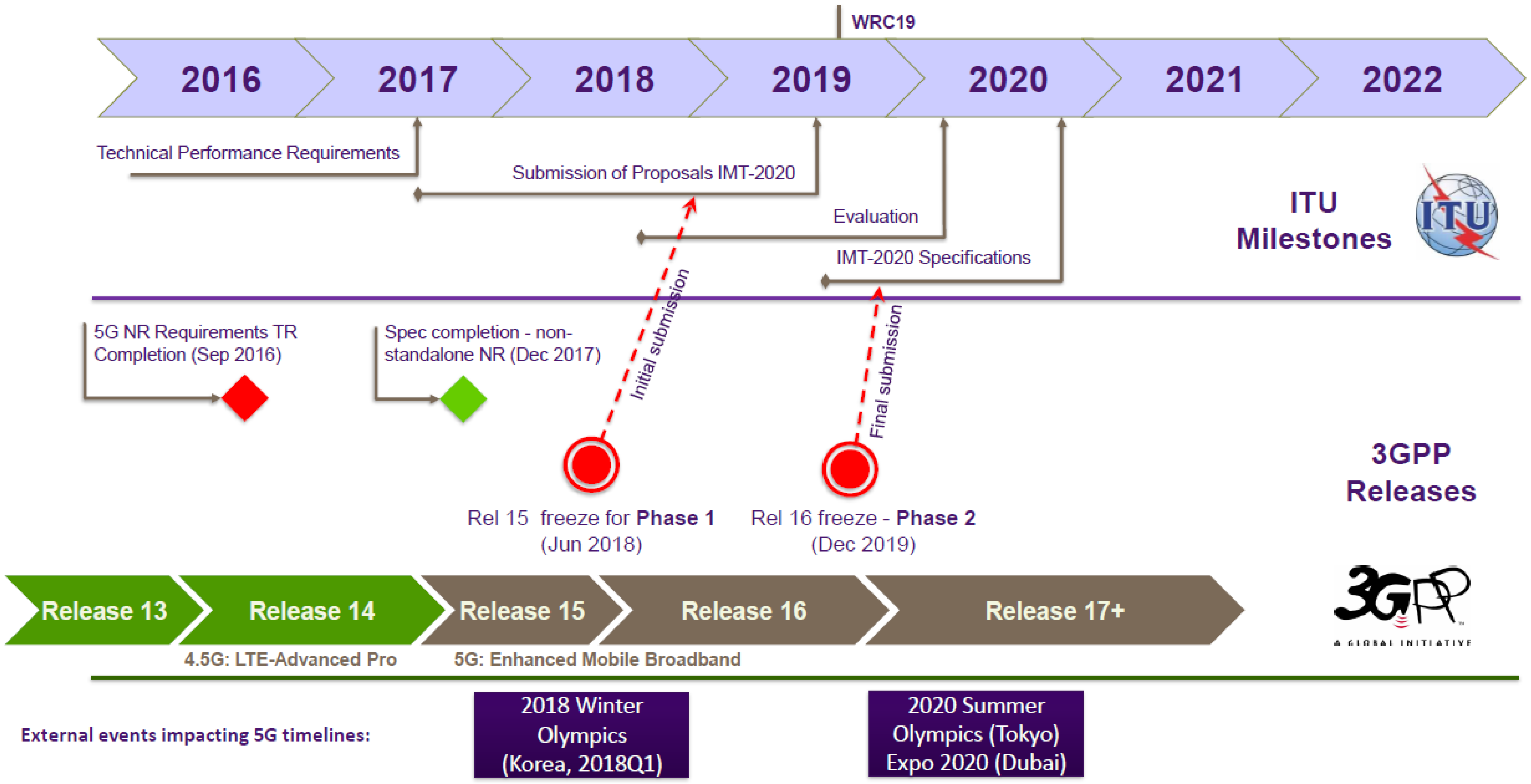
Source: GSMA Intelligence, 2015.

Latency issues

Use case	Latency (ms)
Factory automation	0.25 to 10
Manufacturing cell	5
Machine tools	0,25
Printing machines	1
Packaging machines	2,5
Process automation	50 to 100
Smart grids	3 to 20
Road safety urban	10 to 100
Urban intersection	< 100
Traffic efficiency	< 100
Professional audio	2
Optical fiber (10 000 km)	0,05



5G Timelines: ITU-R and 3GPP



5G Phase One (Release 15)

- **5 Gbps peak downlink** throughput in initial releases, increasing to **50 Gbps** in subsequent versions.
- **OFDMA in downlink and uplink**, with optional Single Carrier Frequency Division Multiple Access (SC-FDMA) for uplink. Radio approach for URLLC to be defined in Release 16, but Release 15 will provide physical layer frame structure and numerology support.
- **Massive MIMO and beamforming**. Data, control and broadcast channels are all beamformed.
- Ability to support either **FDD or TDD modes** for 5G radio bands.
- Numerologies of 2N X 15 kHz for subcarrier spacing up to 120 kHz or 240 kHz.
- **Carrier aggregation** for up to **16 NR carriers**.
- Aggregation up to approximately **1 GHz** of bandwidth.
- **Network slicing**.

5G Phase Two (Release 16)

- **URLLC**.
- **Unlicensed spectrum operation** below 7 GHz, likely based on current LTE approaches such as LAA.
- NR for **non-terrestrial networks**, including satellites.
- Support for radio bands above **52.6 GHz**.
- **Dual-carrier, carrier-aggregation**, and mobility enhancements.
- UE power consumption reduction.
- **Non-orthogonal multiple access**.

Core Network – Network Softwarization

- **NFV** – replaces network functions on dedicated appliances – such as routers, load balancers, and firewalls, with virtualized instances running on commercial off-the-shelf hardware, reducing the cost of network changes and upgrades.
- **SDN** – allows the dynamic reconfiguration of network elements in real-time, enabling 5G networks to be controlled by software rather than hardware, improving network resilience, performance and quality of service.
- **Network slicing** – permits a physical network to be separated into multiple virtual networks (logical segments) that can support different RANs or several types of services for certain customer segments, greatly reducing network construction costs by using communication channels more efficiently.
- **C-RAN** – is presented as a key disruptive technology, vital to the realization of 5G networks. It is a cloud-based radio network architecture that uses virtualization techniques combined with centralized processing units, replacing the distributed signal processing units at mobile base stations and reducing the cost of deploying dense mobile networks based on small cells.

Backhaul

A portfolio of wireless technologies may be considered in addition to fibre, including point-to-multipoint (PMP) microwave, millimeter wave (mmWave), HAPS and satellites.

Fronthaul

Recommendation ITU-T Y.3100 defines fronthaul as “a network path between centralized radio controllers and remote radio units (RRU) of a base station function”. This architecture allows for the centralization of all high layer processing functions at the expense of the most stringent fronthaul latency and bandwidth requirements. The increase in data rates in 5G makes it impractical to continue with the conventional Common Public Radio Interface (CPRI) fronthaul implementation.

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

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 permitting 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 – 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)

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

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Thank You