



**ITU Asia-Pacific Centre of Excellence Training
On
“IoT Technologies and Applications for Smart City”**

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Ghaziabad, India



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)



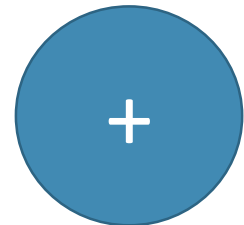
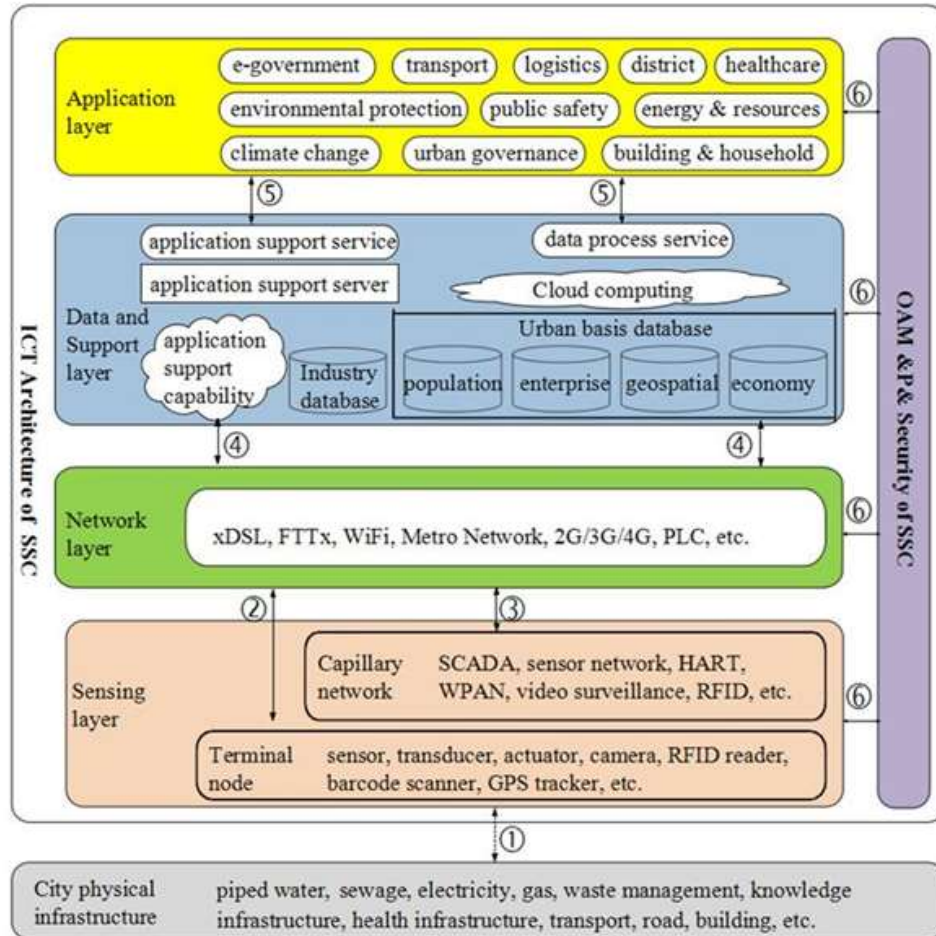
**Digital
Agenda for
Europe**

**Smart Cities
(China)**





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



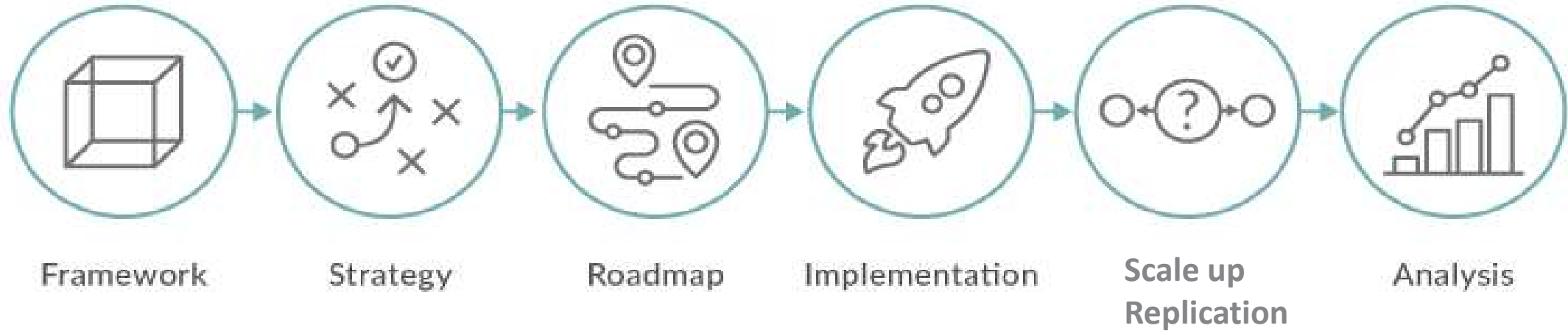
Enabling Environment , Digital Inclusion

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 | -/- |

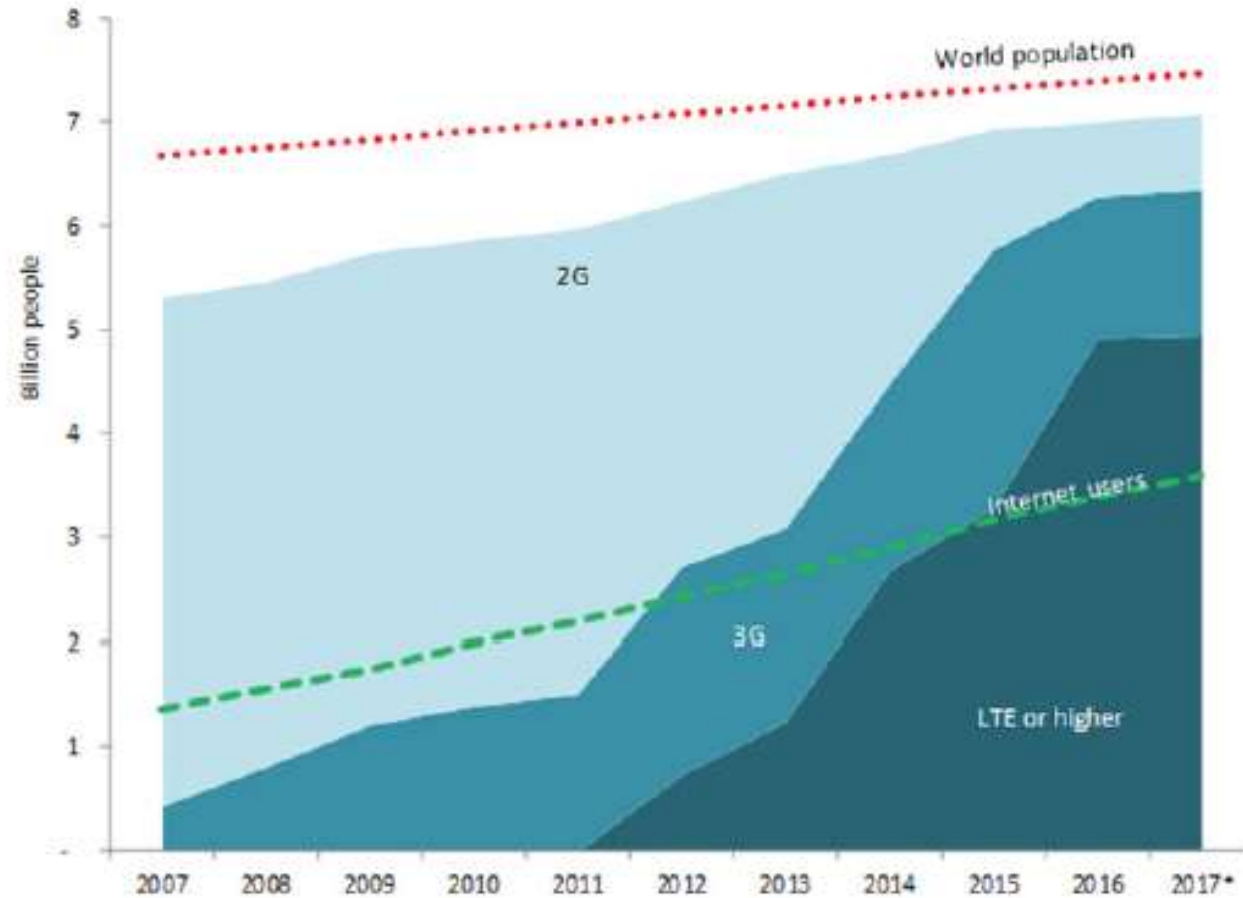
Source: Various. EST = Estimate. BI= Business Intelligence; Del = Deloitte; Facebook, E = Ericsson Mobility Report June 2018 at: <https://www.ericsson.com/assets/local/mobility-report/documents/2018/ericsson-mobility-report-june-2018.pdf> GSMA = GSMA database.

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



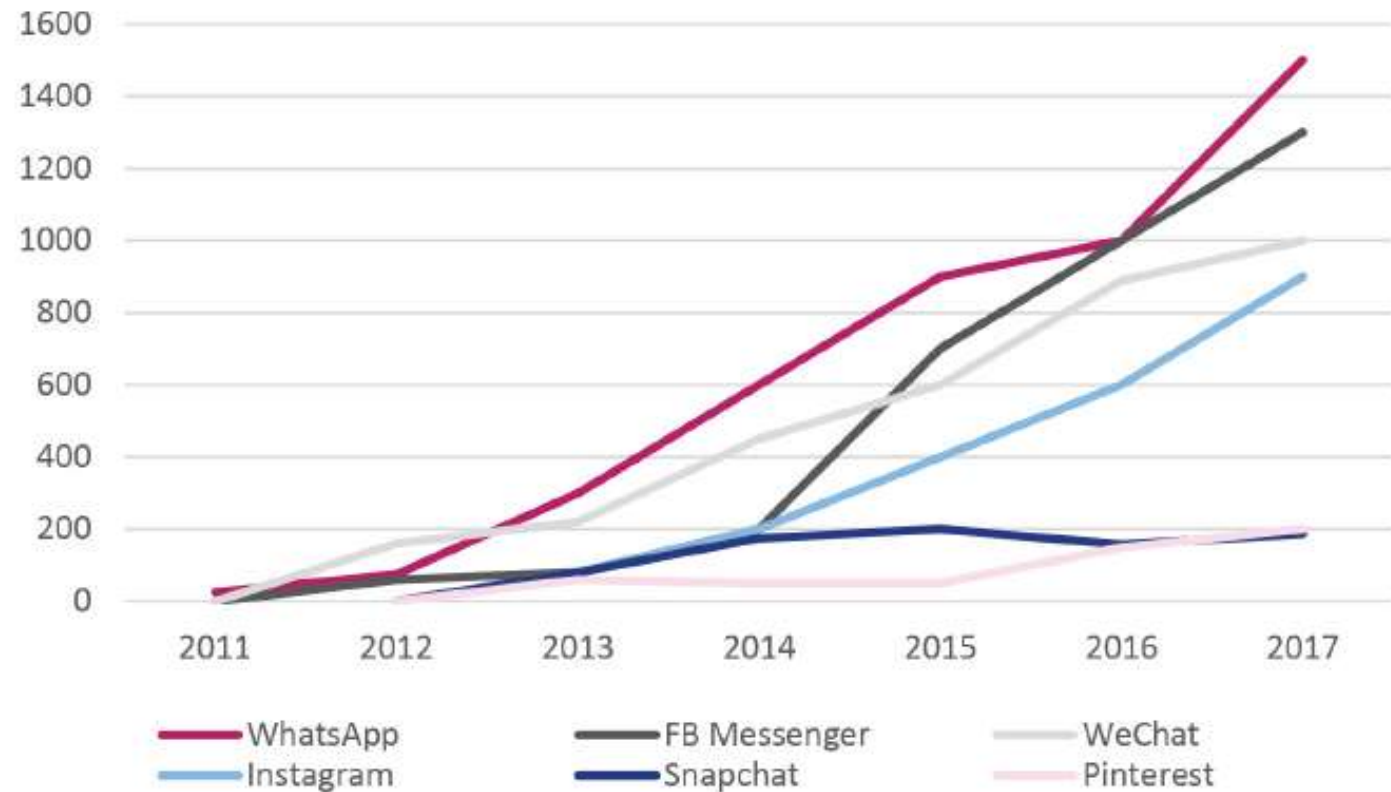
The number of subscriptions per 100 population has grown from 33.9 in 2005 to 76.6 in 2010, 98.2 in 2015 and an estimated 103.5 in 2017.

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

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



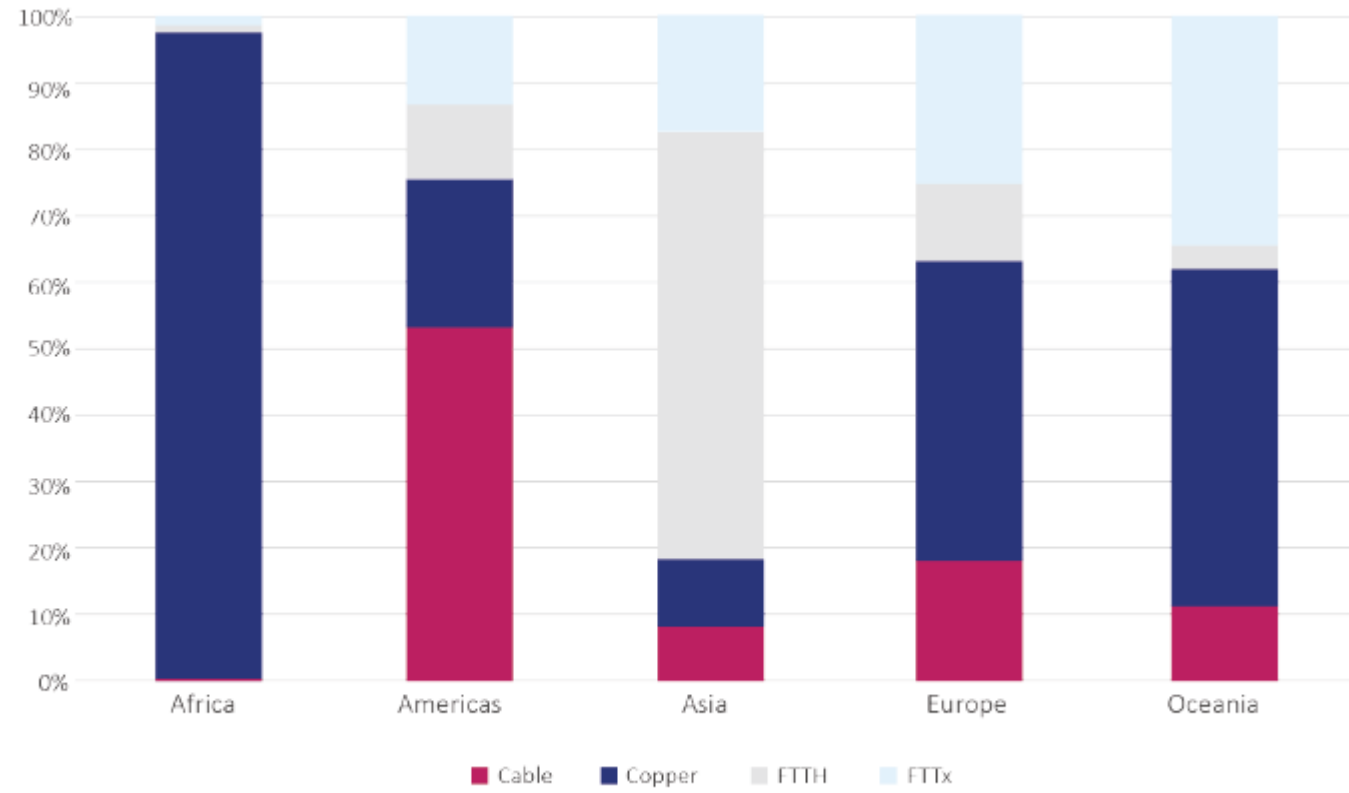
Growth in Number of Users of Messaging and Hybrid Networks, 2011-2017



Source: Various, including Activate.com.



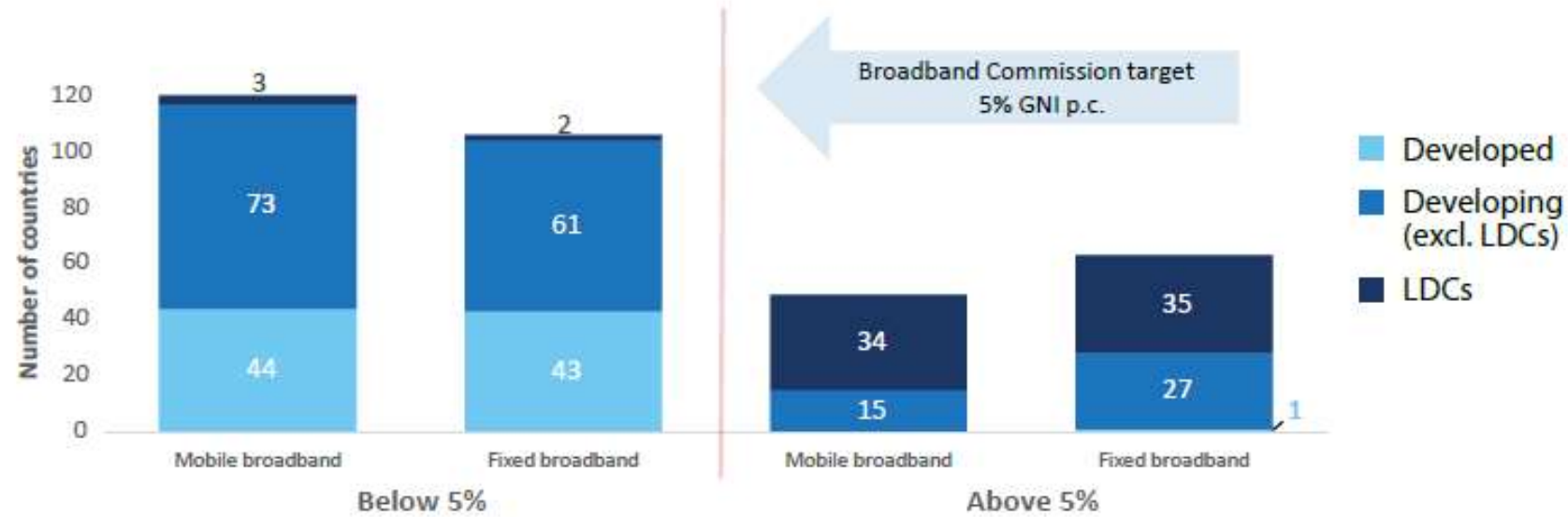
Fixed Network: Technology Market Share by Region, Q4 2017



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.



Emergency



Education



Health



Agriculture



Governance



Investment



Applications



Policy & Regulation



Capacity Building



Transport



IoT, Sensor Networks, GIS, Satellites



Universal Broadband



Green ICT & E-Waste



Measurements



Electricity



SMART SOCIETY



Infrastructure Security



Privacy & Security



Water



Standards, Conformity & Interoperability



Spectrum Management



Digital Inclusion



Finance

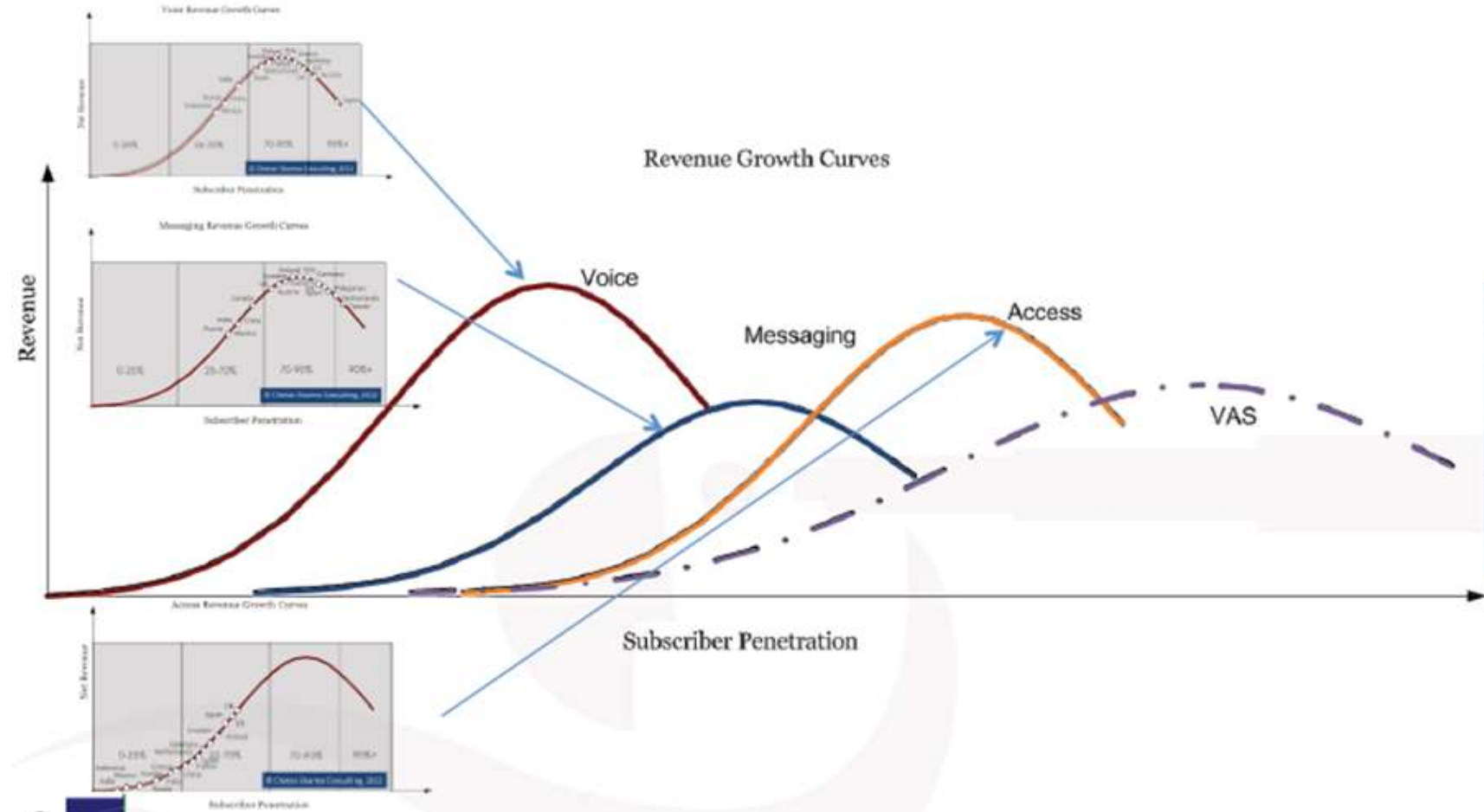
ICTs have become even more multi-sectoral and can be leveraged to achieve SDGs



The 4th Wave: We are about to enter the golden age of mobile



4th Wave



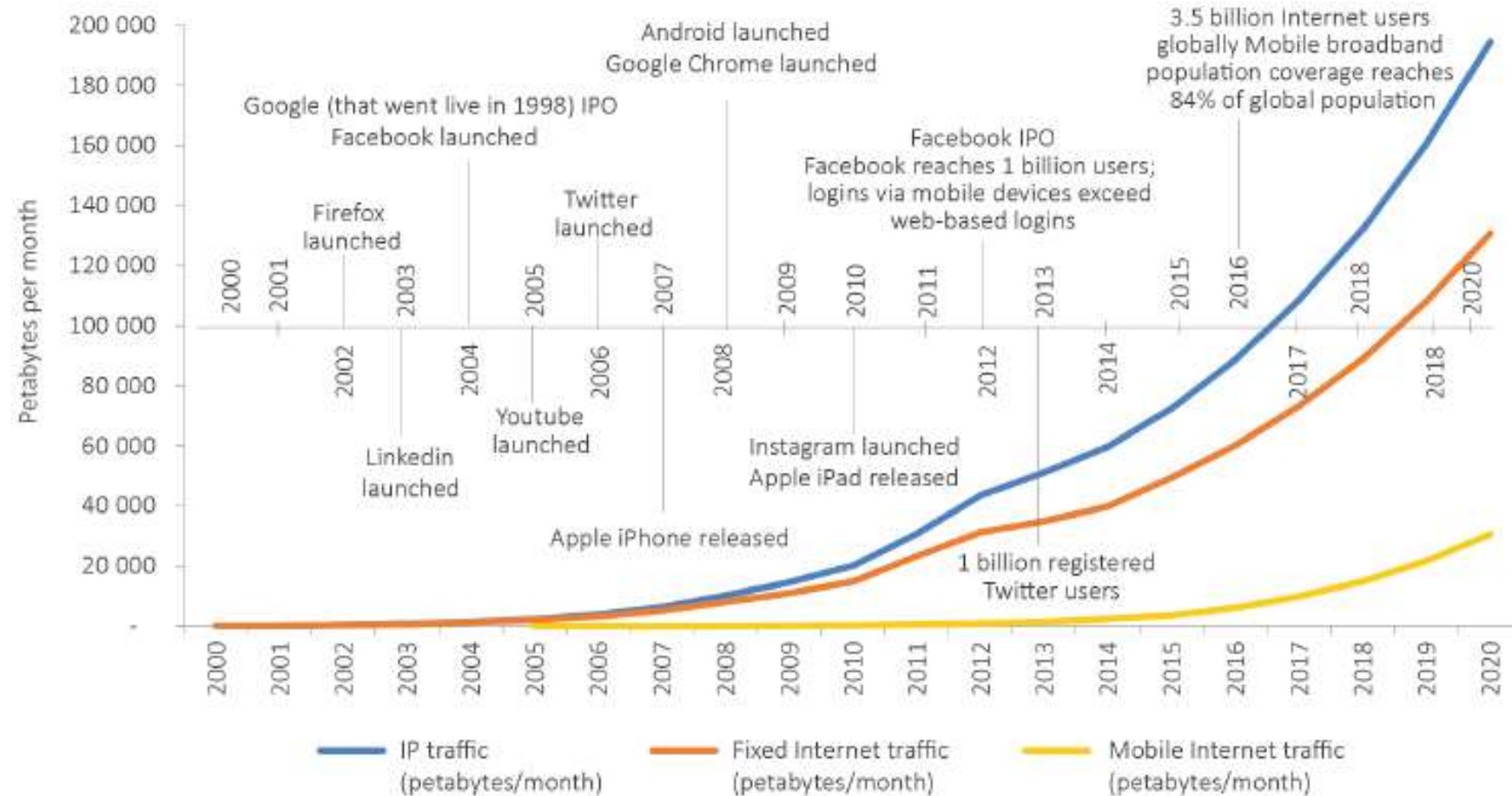
© Chetan Sharma Consulting, 2012

Source: Operator's Dilemma (Opportunity): The Fourth Wave





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



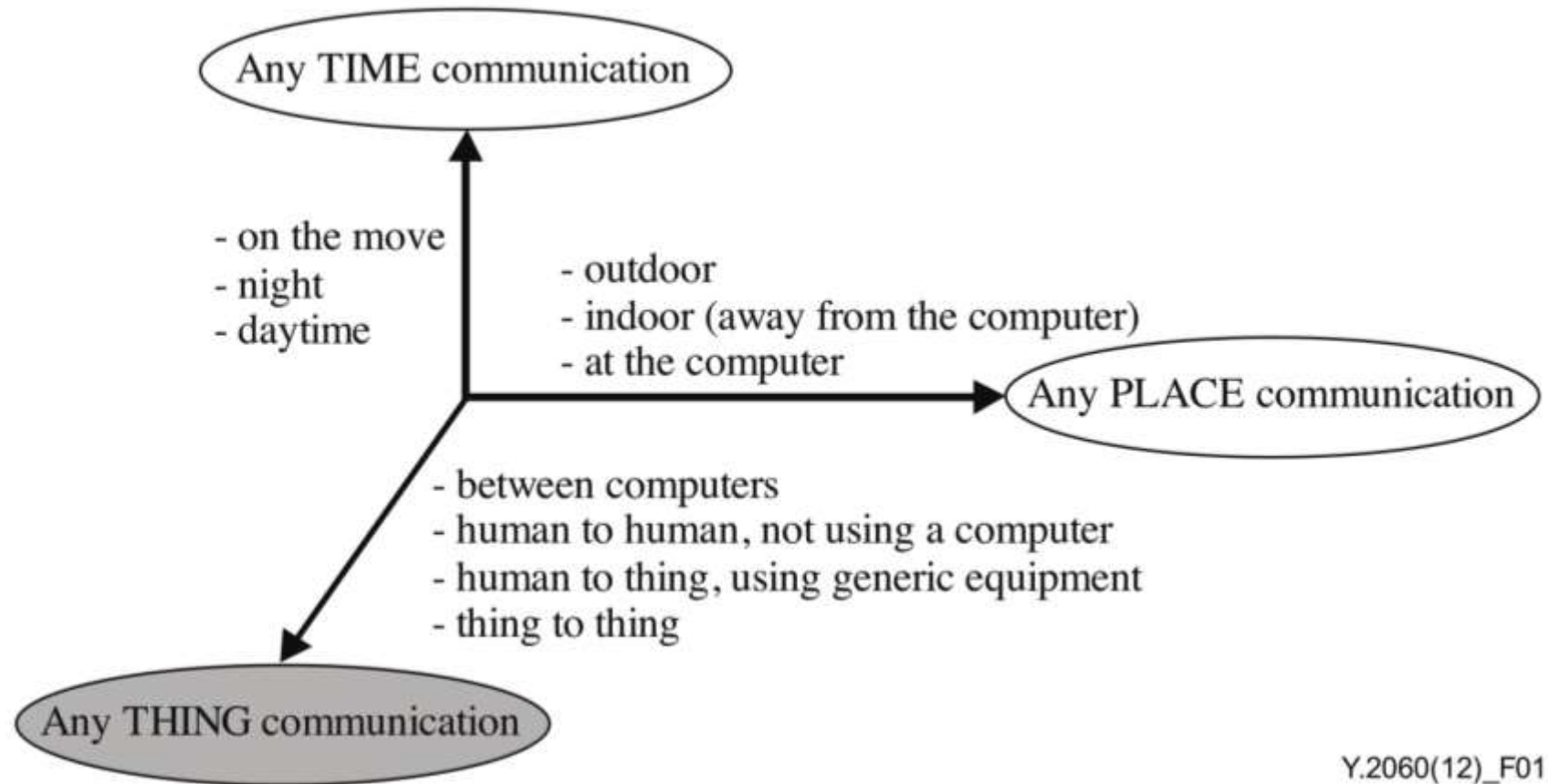
Definition from ITU

- **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.



IoT: A New Dimension

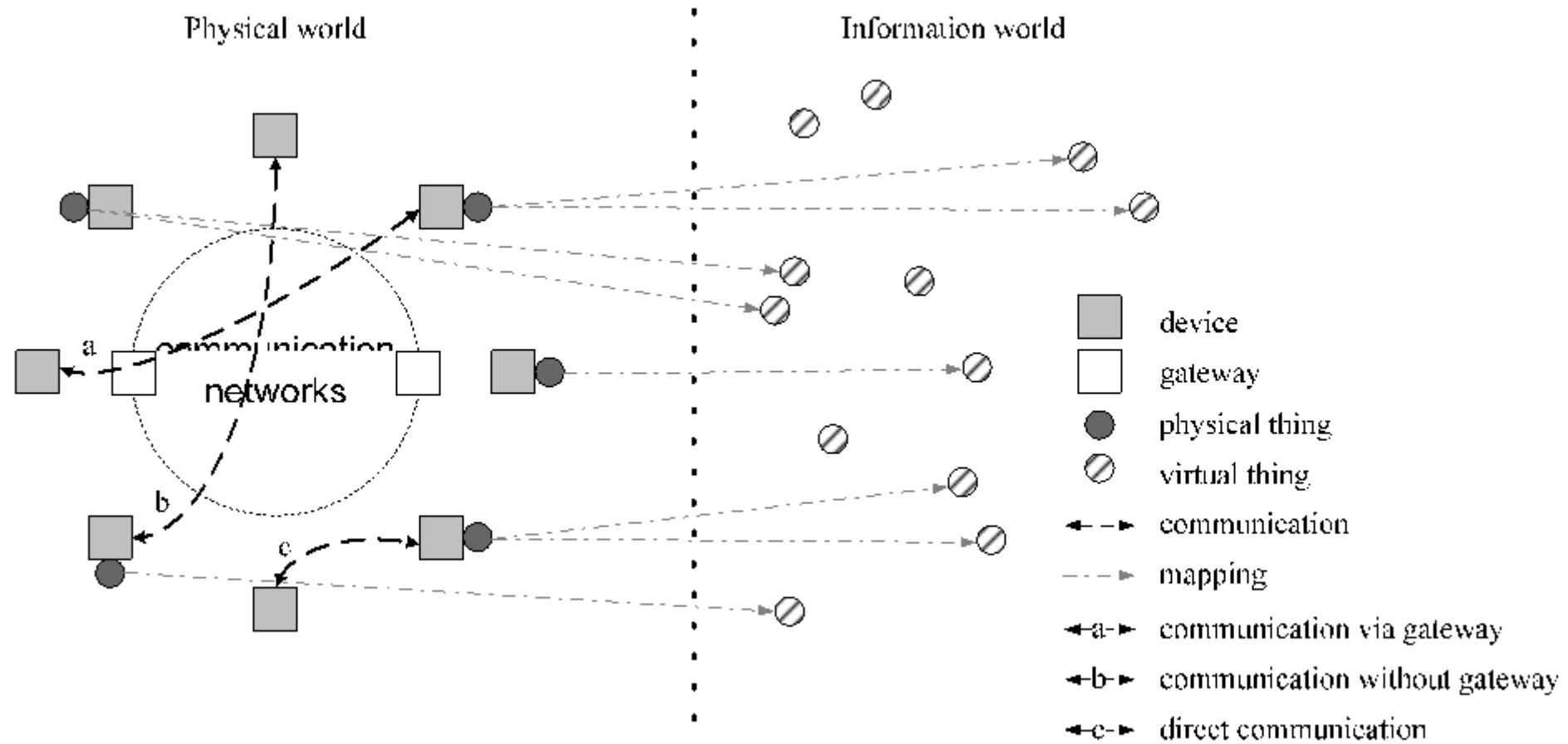
thing: With regard to the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.



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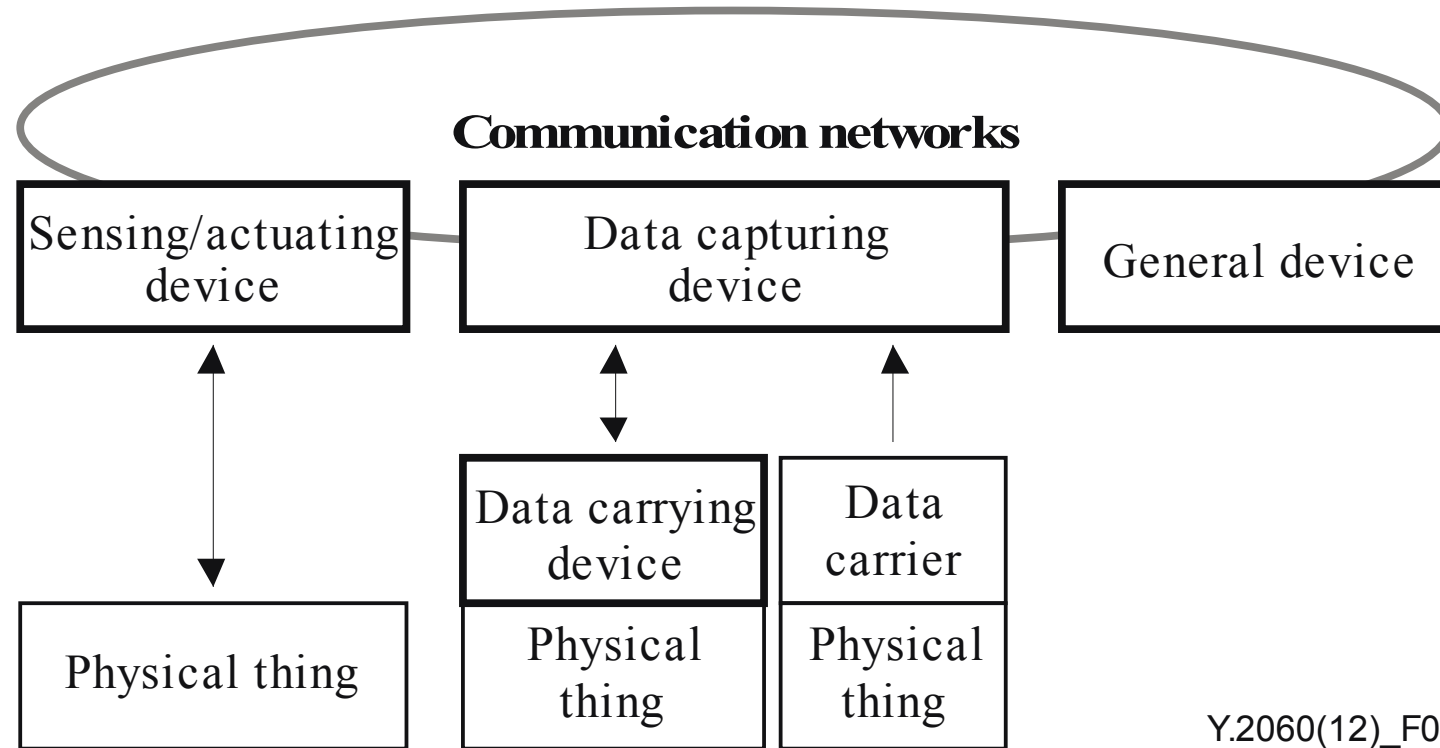


Technical Overview of the IoT





Types of Devices and Their Relationship to Physical Things



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Fundamental Characteristics

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



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.



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.



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.



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.



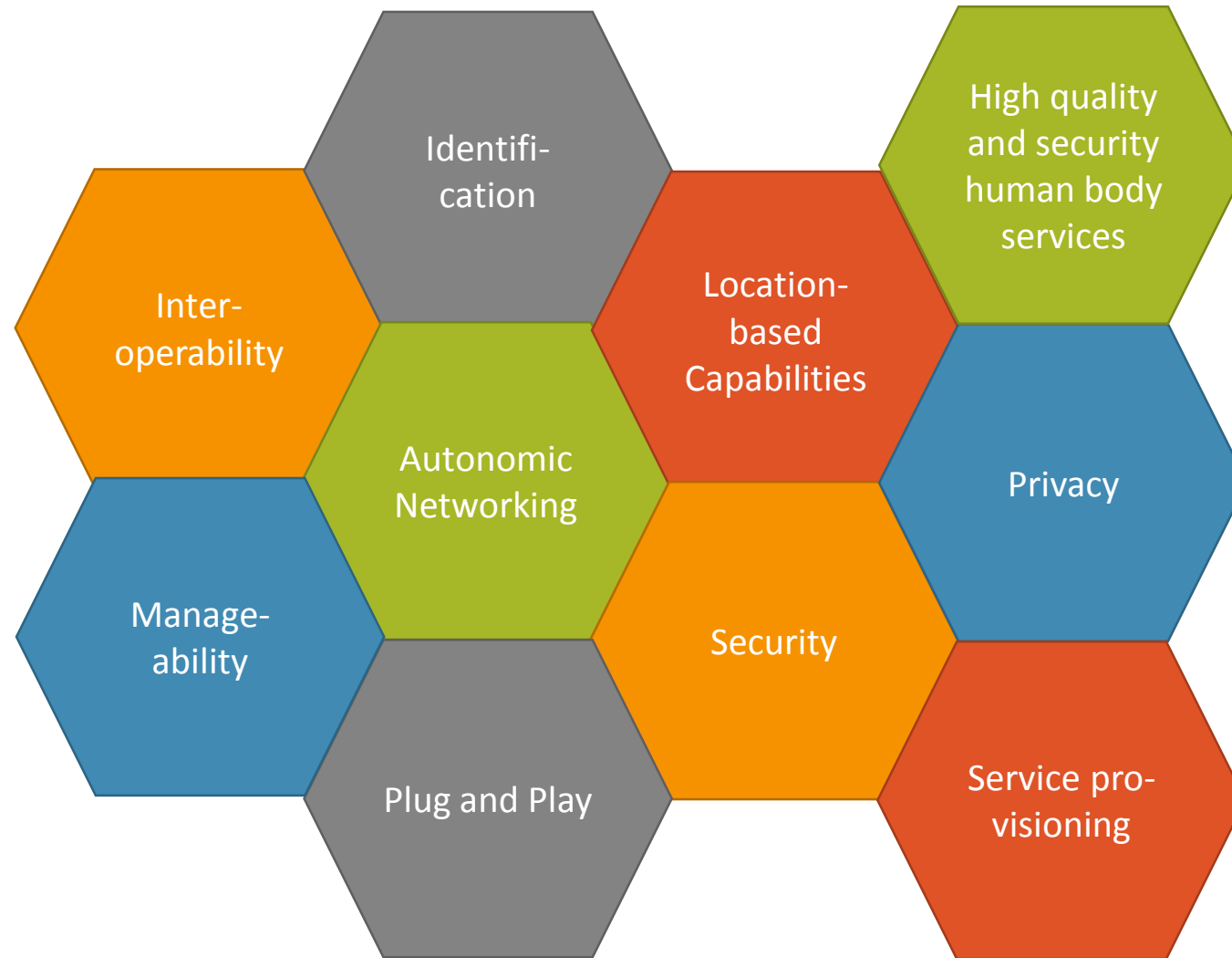
Fundamental Characteristics

- 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.

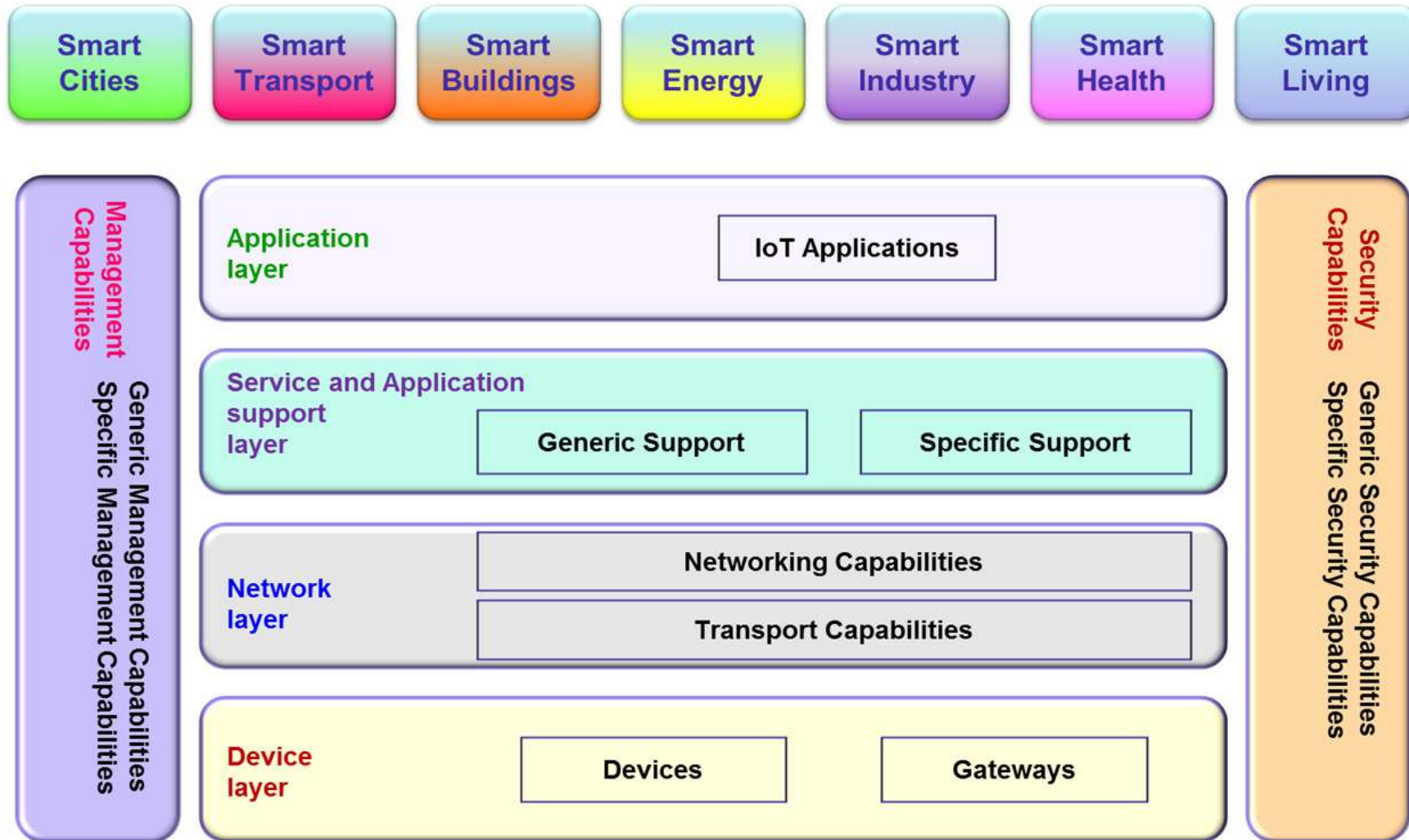


High Level Requirements





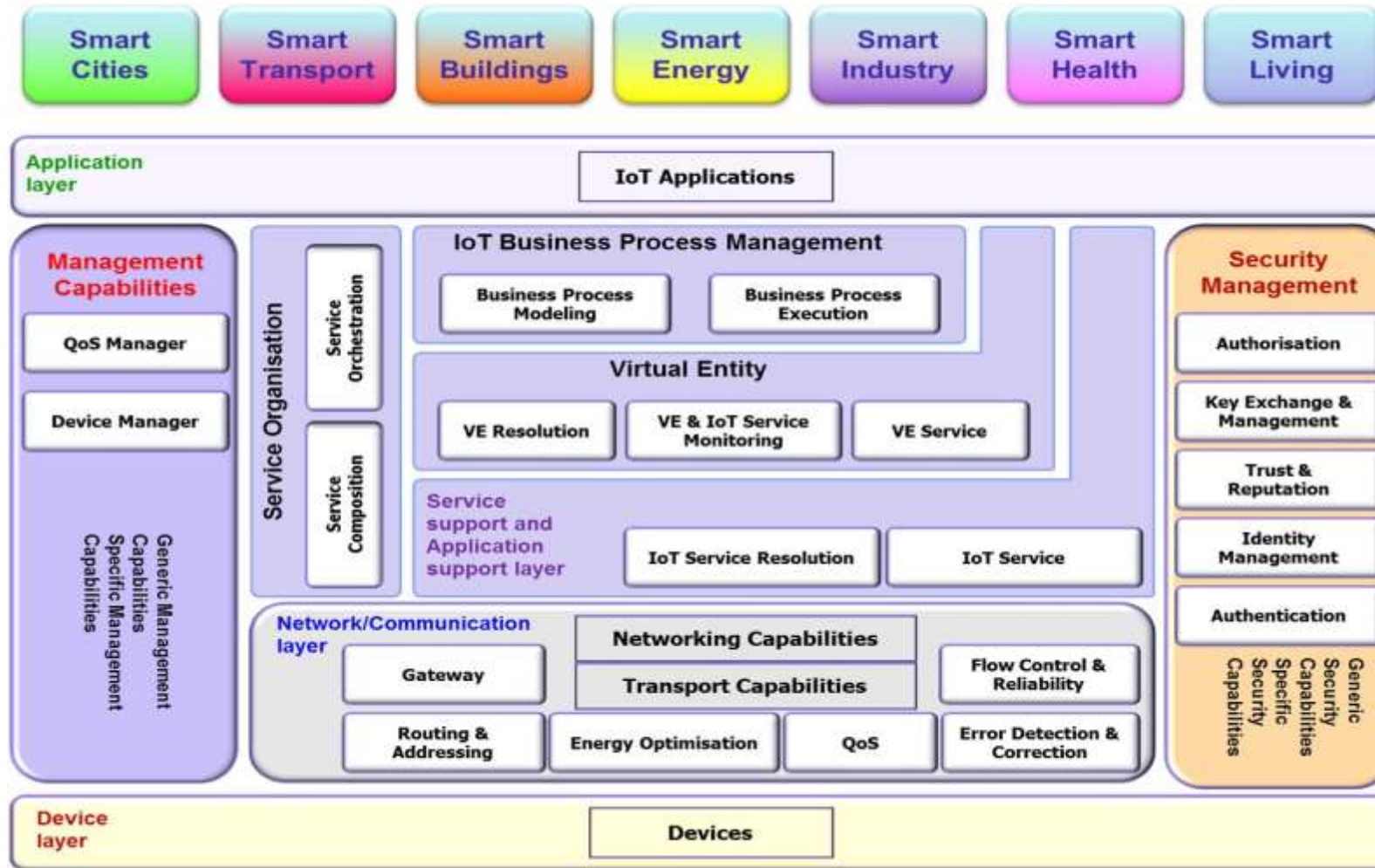
IoT Architecture



IoT Architecture (source: ITU)



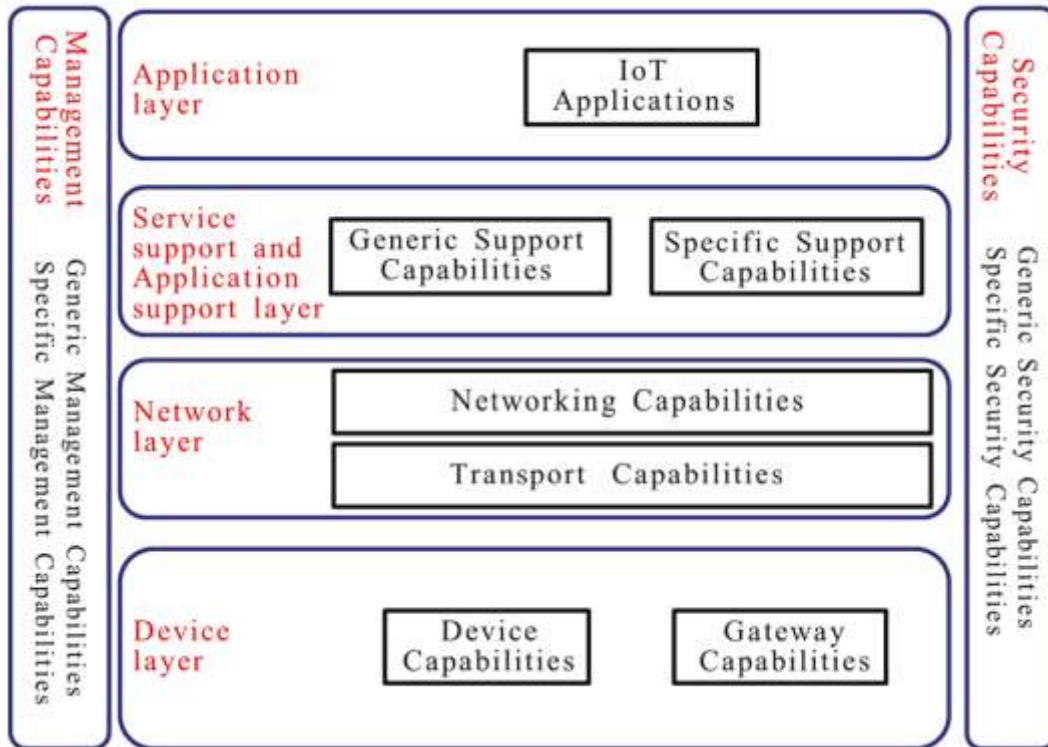
IoT Architecture



Detailed IoT Layered Architecture (Source: IERC)



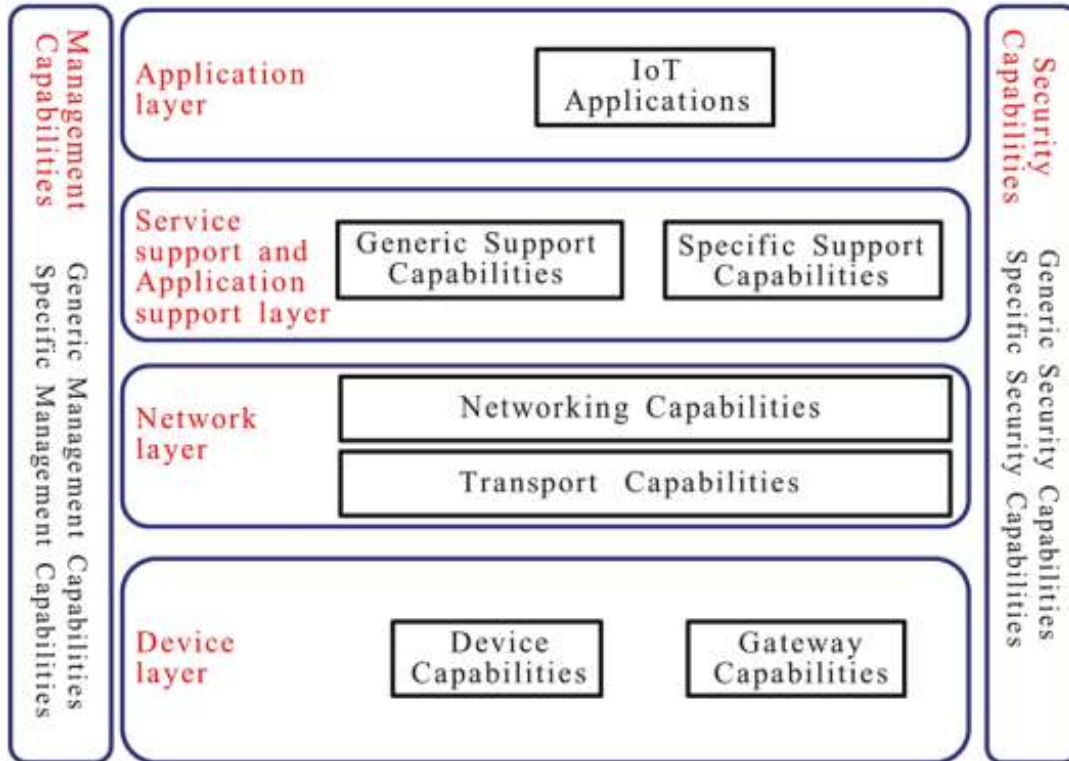
IoT Reference Model



- **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.



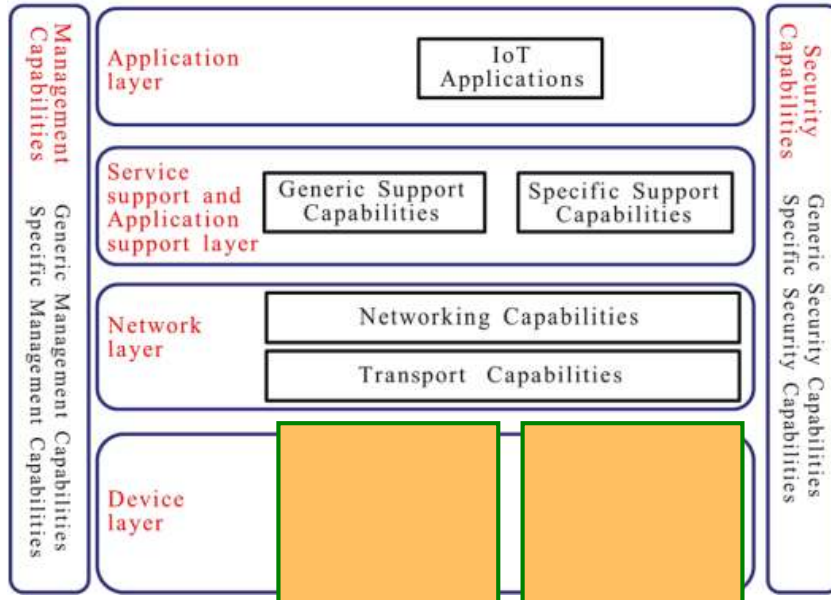
IoT Reference Model



- **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.



IoT Reference Model

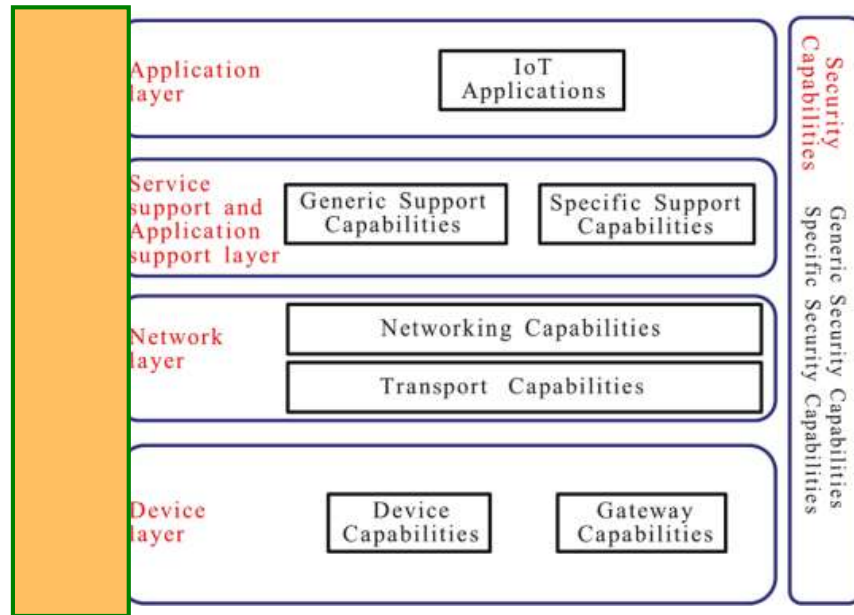


- Multiple interfaces support
- Protocol conversion

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



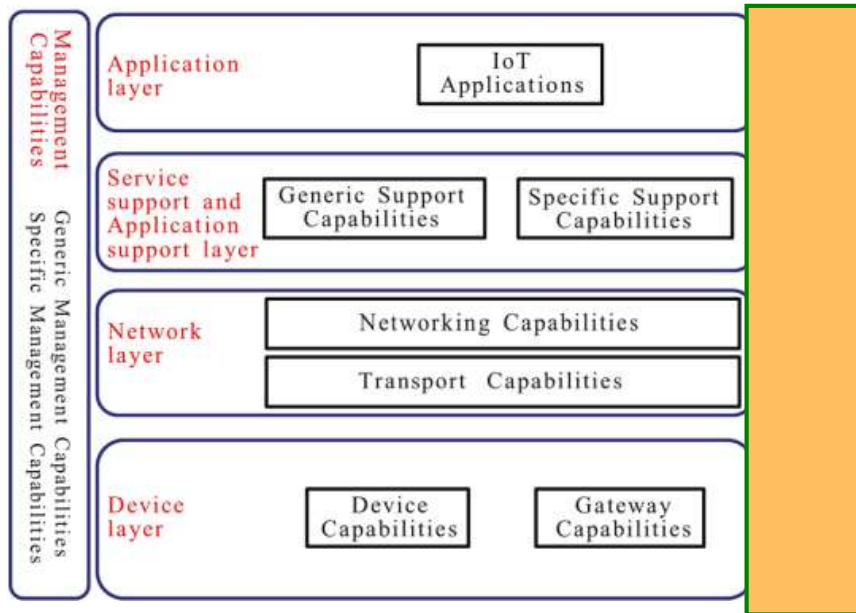
IoT Reference Model



- 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.



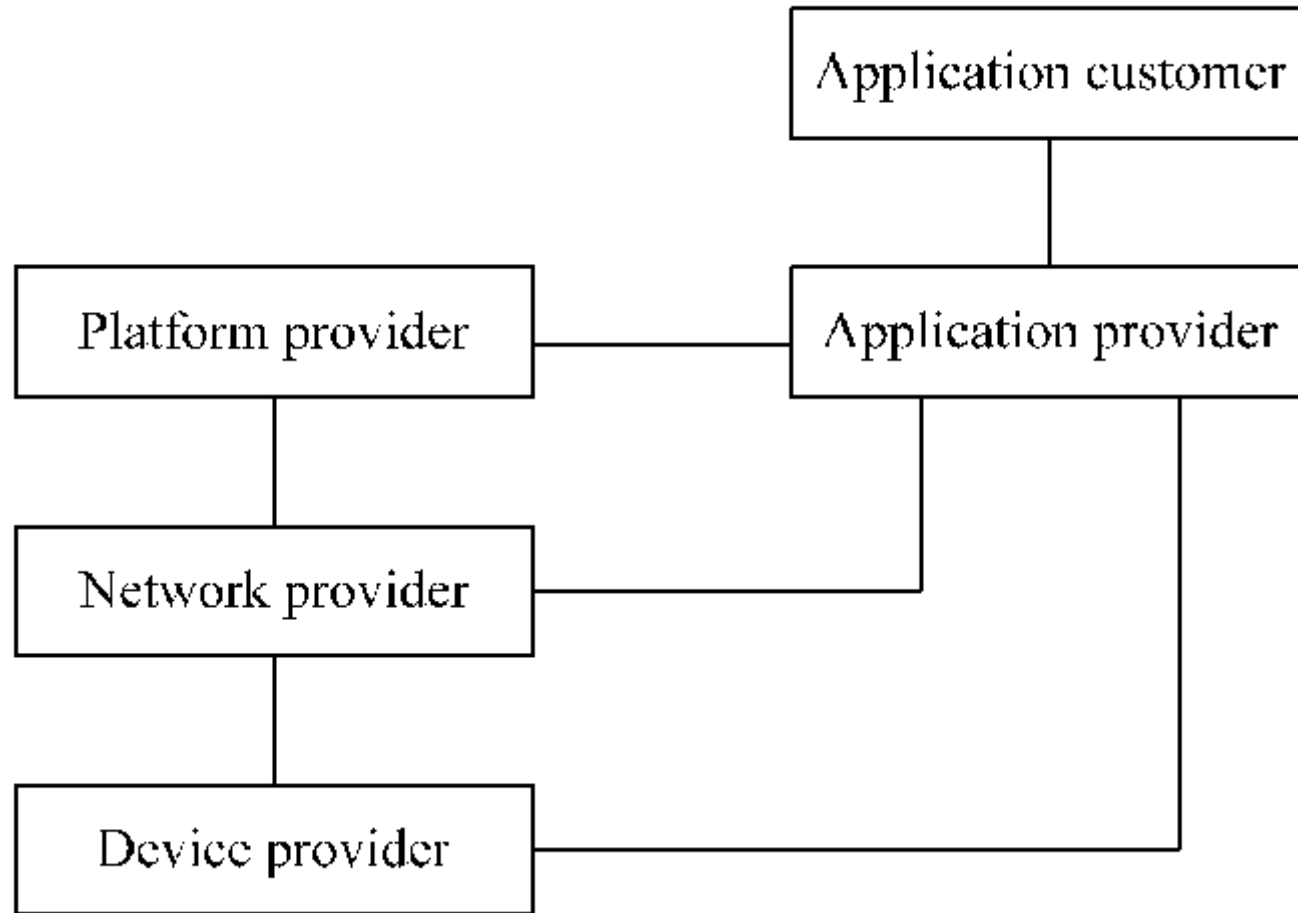
IoT Reference Model



- 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.



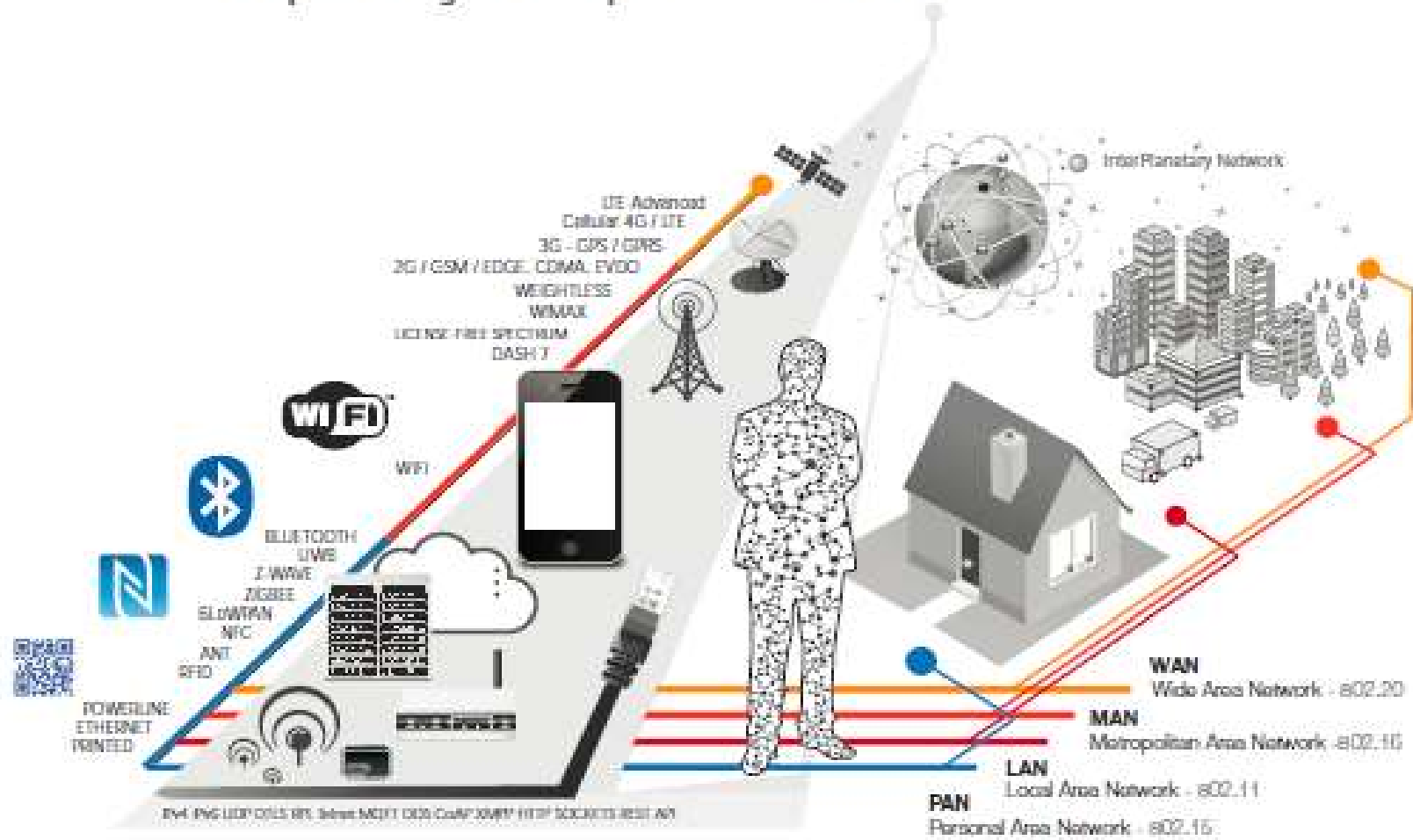
IoT and Business Models





Communication Options

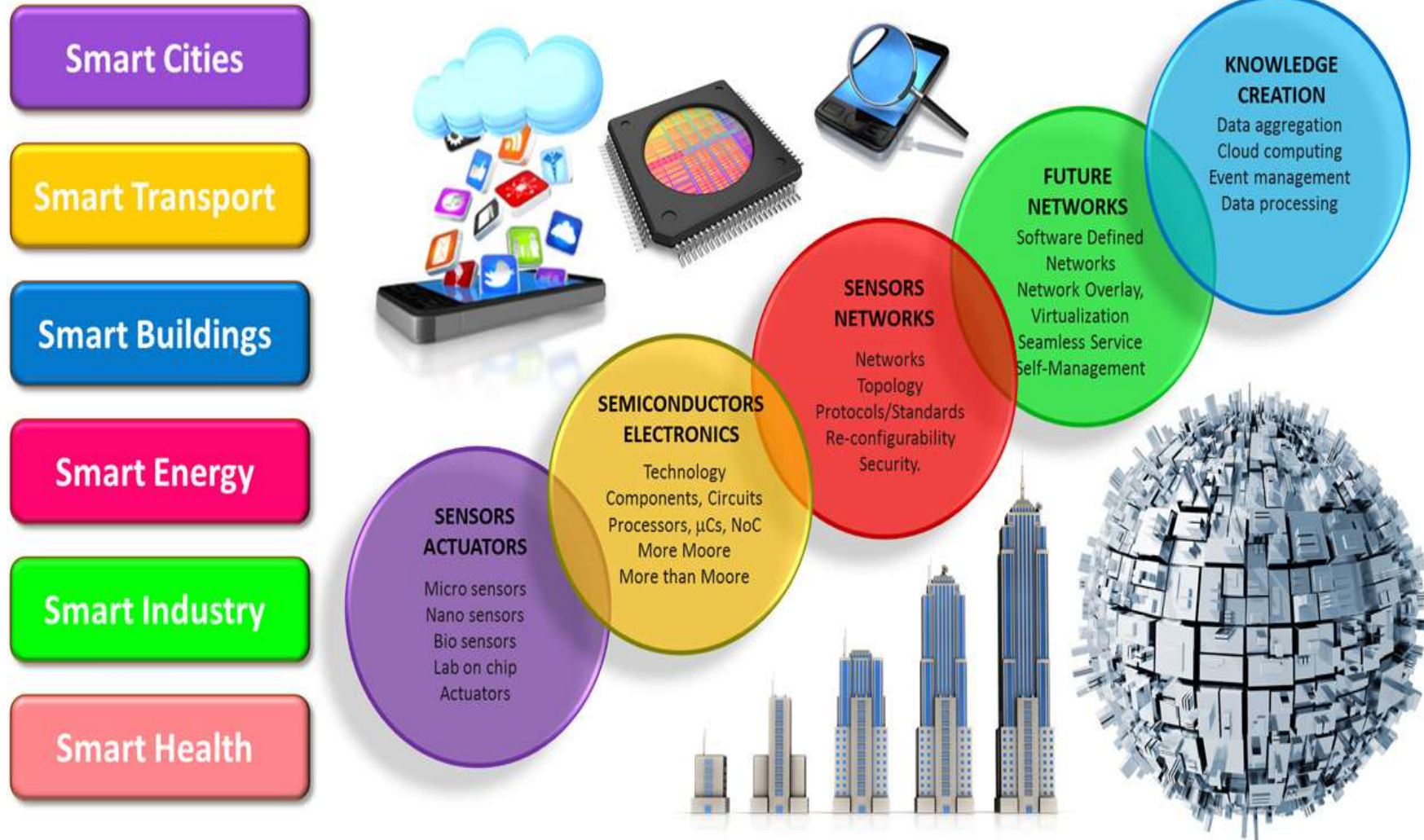
These inputs are digitized and placed onto networks.



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 | low | no | yes | yes |
| Red charging | low | low | low | low | yes | no | yes |
| eCall | low | very high | 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 |

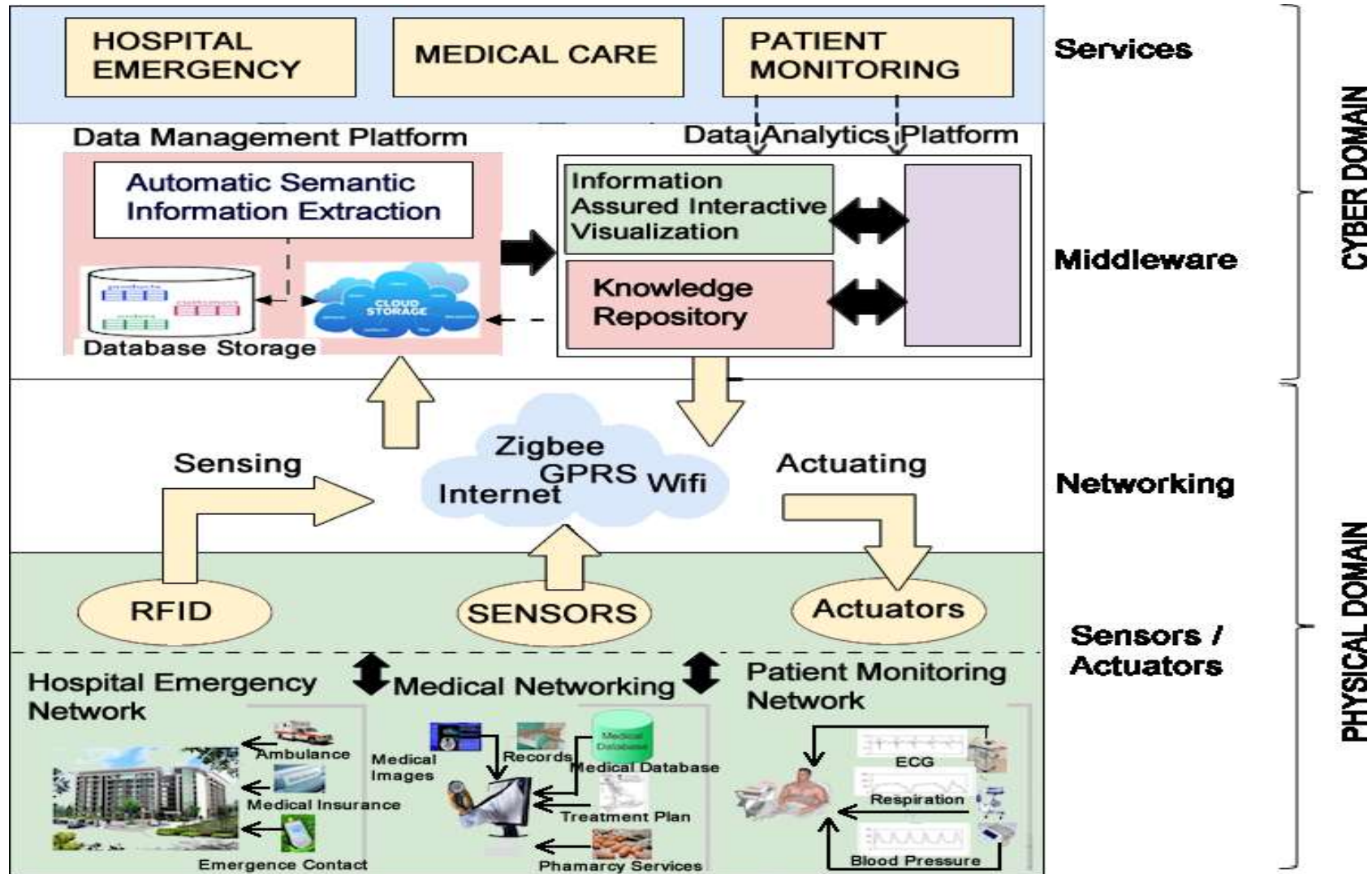
very low low intermediate high very high

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

Example Applications (source: ITU)



Cyber Physical Health System



Cyber Physical Health (CPH) Architecture [2]



Impact on Applications

| | Ex-post | | | Current | | | Future | |
|----------------------|---|--|-----------------------------------|---|-----------------------------------|--------------------------|---|--|
| | Evaluation and Assessment | | | Measurement and Real-time Feedback | | | Prediction and Planning | |
| Financial Services | Mobile money agent placement | | | Algorithmic fraud detection | Social network analysis marketing | Agent network monitoring | Enhanced credit scoring | Algorithmic liquidity needs prediction |
| Economic Development | Income and poverty assessment | Mapping social divides | GDP estimates through mobile data | Migration monitoring | | | Text analysis economic downturn prediction | Text analysis commodity fluctuation prediction |
| Health | Assessment of mobility restrictions | | | Disease containment targeting | Migratory population tracking | | Predicting outbreak spread | |
| Agriculture | Mobile data to track food assistance delivery | | | Geo-targeted links between suppliers/purchasers | Pests, bad harvest alerts | | Agricultural yield/shock predictions | |
| Commercial | Campaign effectiveness | Social network delineated market areas | | | | | Predictive algorithms to anticipate product churn | Social network targeted marketing |
| Other | Post-disaster refugee reunification | Sentiment analysis of public campaigns | Urban planning | Mobile disaster relief targeting | High frequency surveys | Crime detection | Social unrest prediction | |

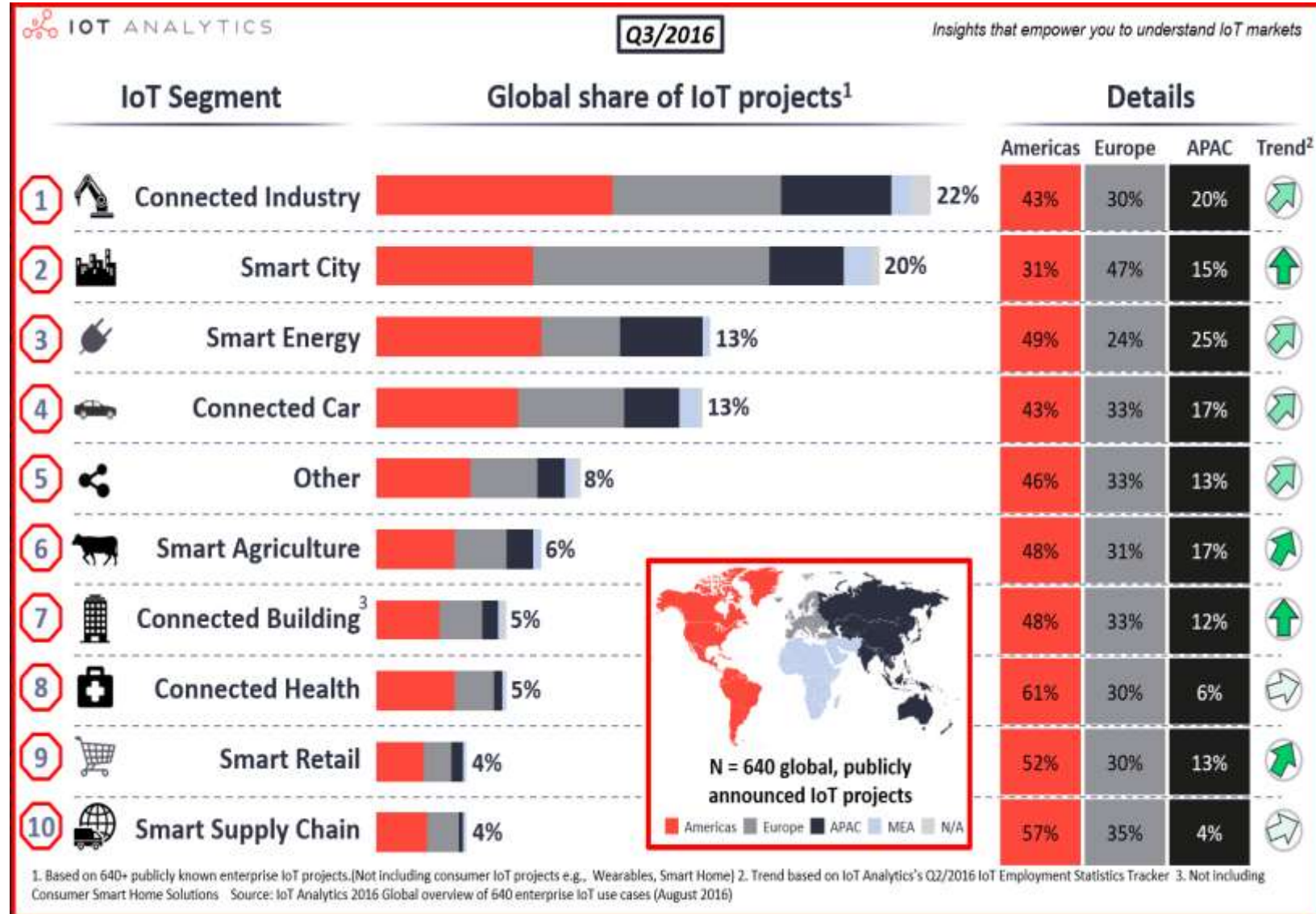
■ High
 ■ Medium
 ■ Low
 Pilot identified

Source: Naef et al. (2014), quoted in the "Measuring the Information Society 2014" report, ITU.

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



Existing and IoT Potential Services





Examples of services per Category

| <i>Smart Utilities</i> | <i>Smart Health</i> | <i>Smart Public Services</i> | <i>Smart Building</i> | <i>Smart Transportation</i> |
|---|---|---|---|--|
| <ul style="list-style-type: none"> • Intelligent Utility Network • Smart Metering • Energy Optimization • Smart Production • Demand Planning • Advanced Distribution Management • Operations Control • River Basin and Smart Water Management • Wastewater Treatment | <ul style="list-style-type: none"> • Smart Care Management • Connected Health • Smart Medicine Supply • Mobile Health • Remote Healthcare Management | <ul style="list-style-type: none"> • Smart Citizen Services • Smart Tax Administration • Smart Customs, Immigration, Border Management • Smart Crime Prevention • Smart Emergency Response • Smart Financial Management | <ul style="list-style-type: none"> • Energy Optimization • Asset Management • Facility Management • Video Surveillance • Recycling and Power Generation • Automatic Fault Detection Diagnosis • Supervisory Control • Audio / Video Distribution Management | <ul style="list-style-type: none"> • Intelligent Transportation • Smart Public Transportation • Integrated Fare Management • Fleet Optimization • Tolling Solutions • Real-time Adaptive Traffic Management • Smart Parking • Traveler Information Systems |
| | <p style="text-align: center;"><i>Smart Education</i></p> <ul style="list-style-type: none"> • Smart Classroom • Performance Man. • Asset Management | | | |

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



Internet of Vehicles

Converging Technologies

Electric Vehicle
Electric Smart Grid
Connected Vehicle
Autonomous Vehicle



Vehicle to Vehicle
V2V

• Communication



Vehicle to Device
V2D

• Telematics



Vehicle to Grid
V2G + G2V

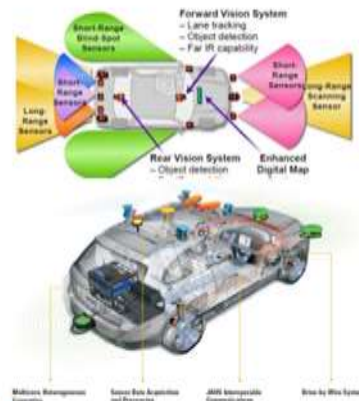
• Charging Stations



Vehicle to Infrastructure
V2I

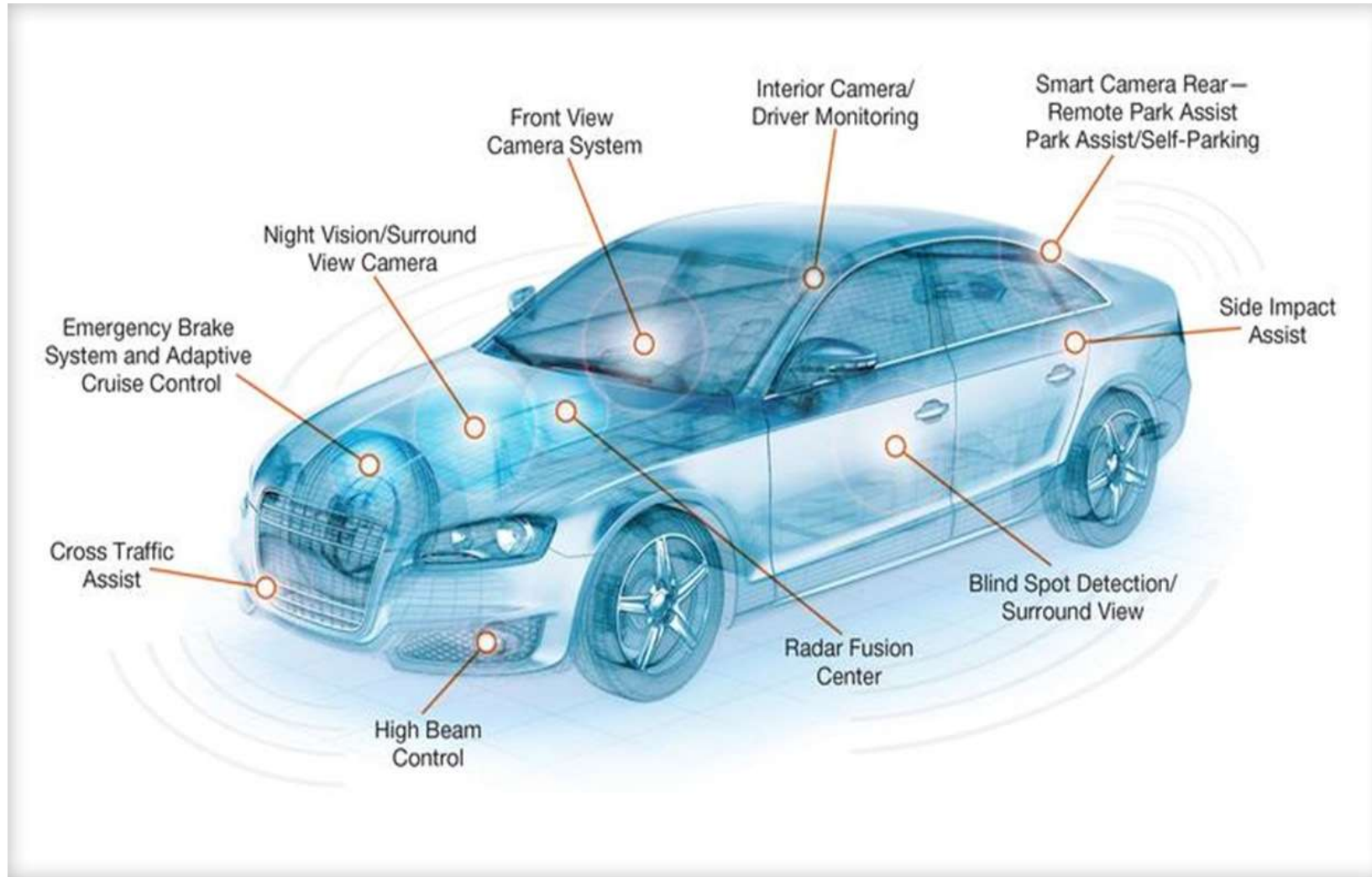
• Communication

Internet of Vehicles
Vehicle to Internet





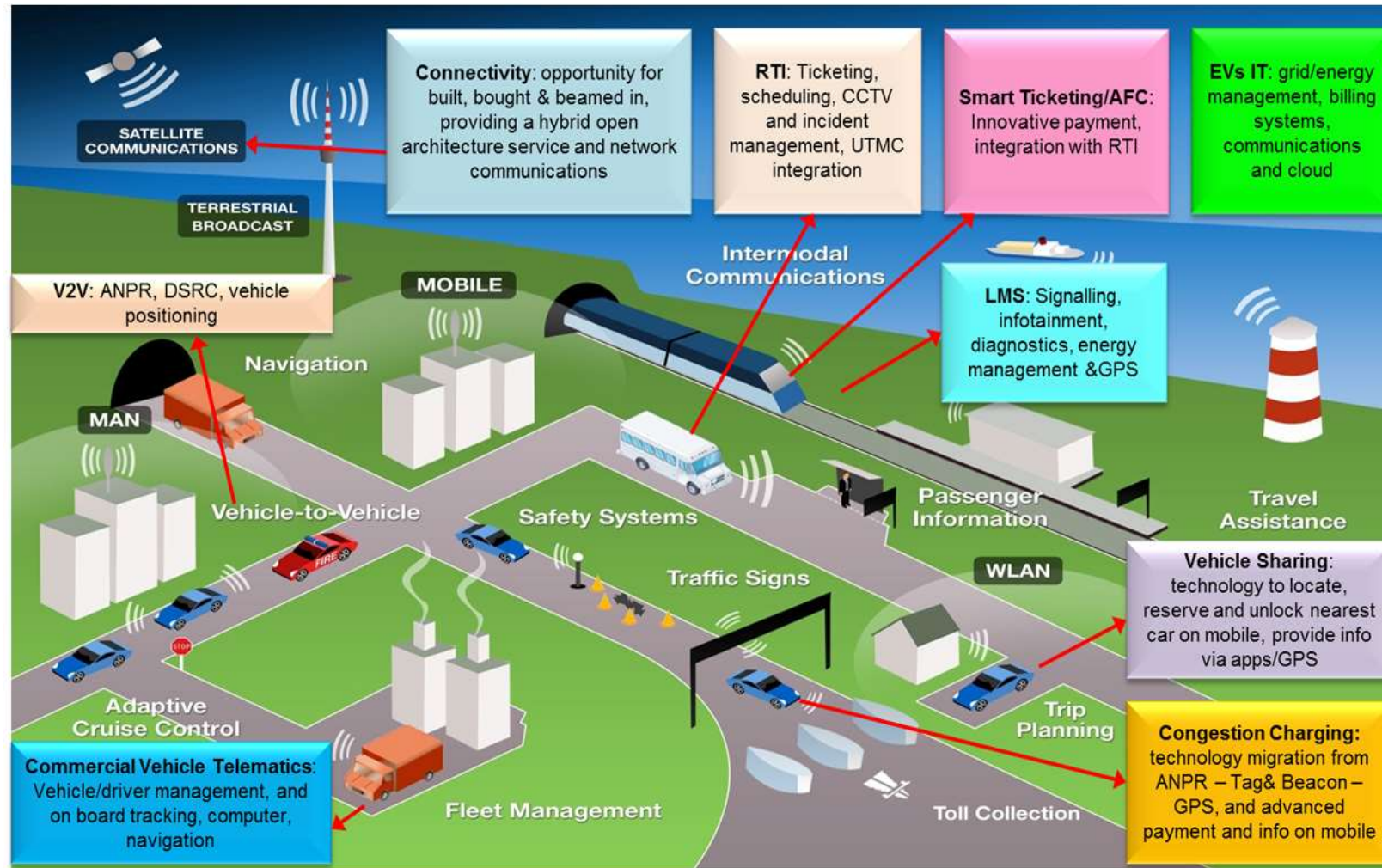
Internet of Vehicles



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



Internet of Vehicles



Source: ETSI

ITS Ecosystem (Source: ETSI)



Internet of Vehicles



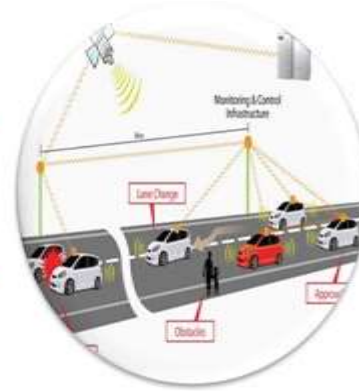
Sensor Fusion Vehicle

*Sensors,
Actuators*



Internet of Vehicles

*Seamless
Integration*



Electronic Vehicle

*Electronics
Computing*



Interconnected Vehicle

*Communication
Gateways*



Software Defined Vehicle

*Software
Algorithms*



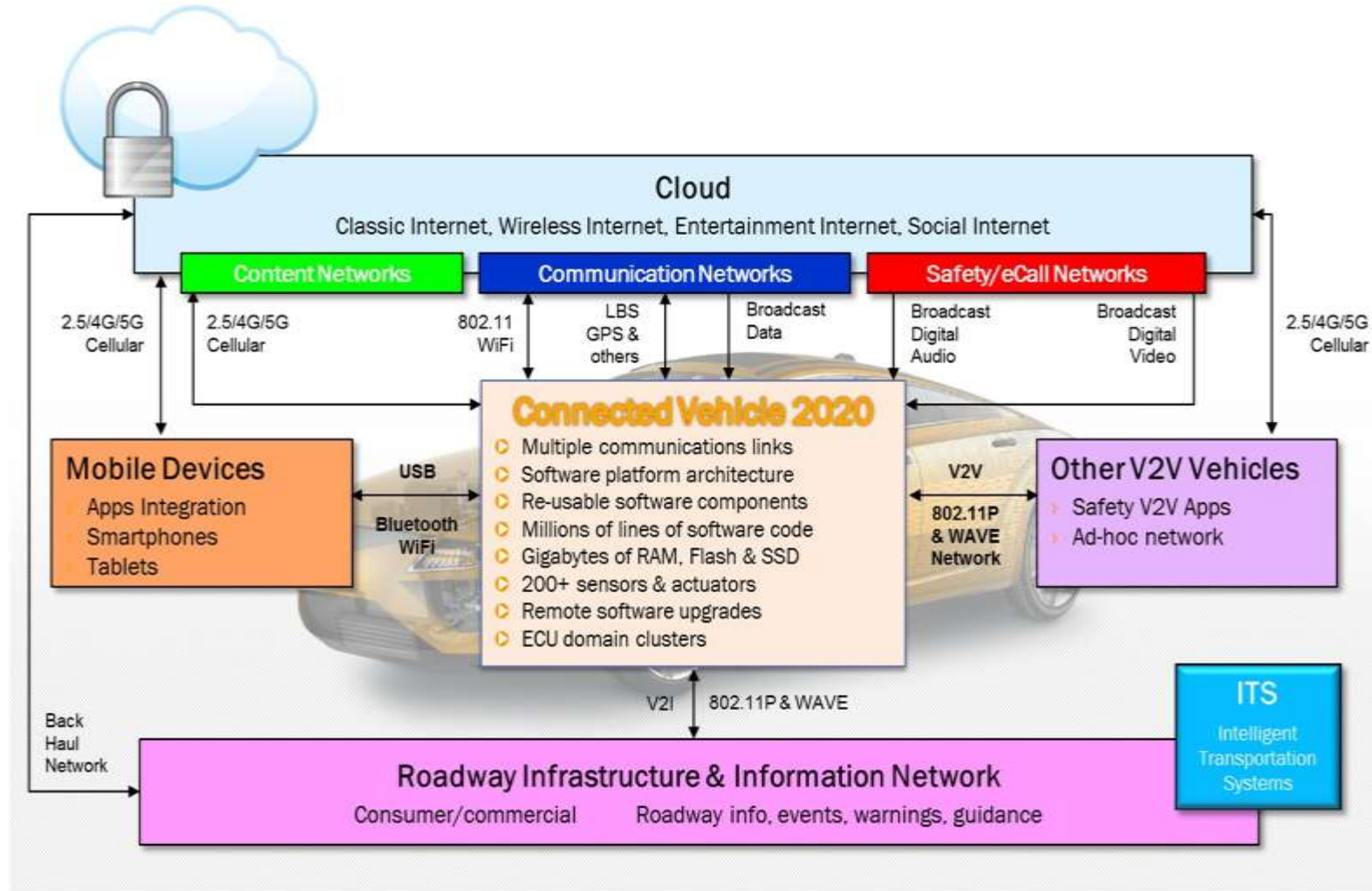
Cyber-Physical Vehicle

*Software
Communication
Interfaces*

ITS Ecosystem (Source: ETSI)



Internet of Vehicles

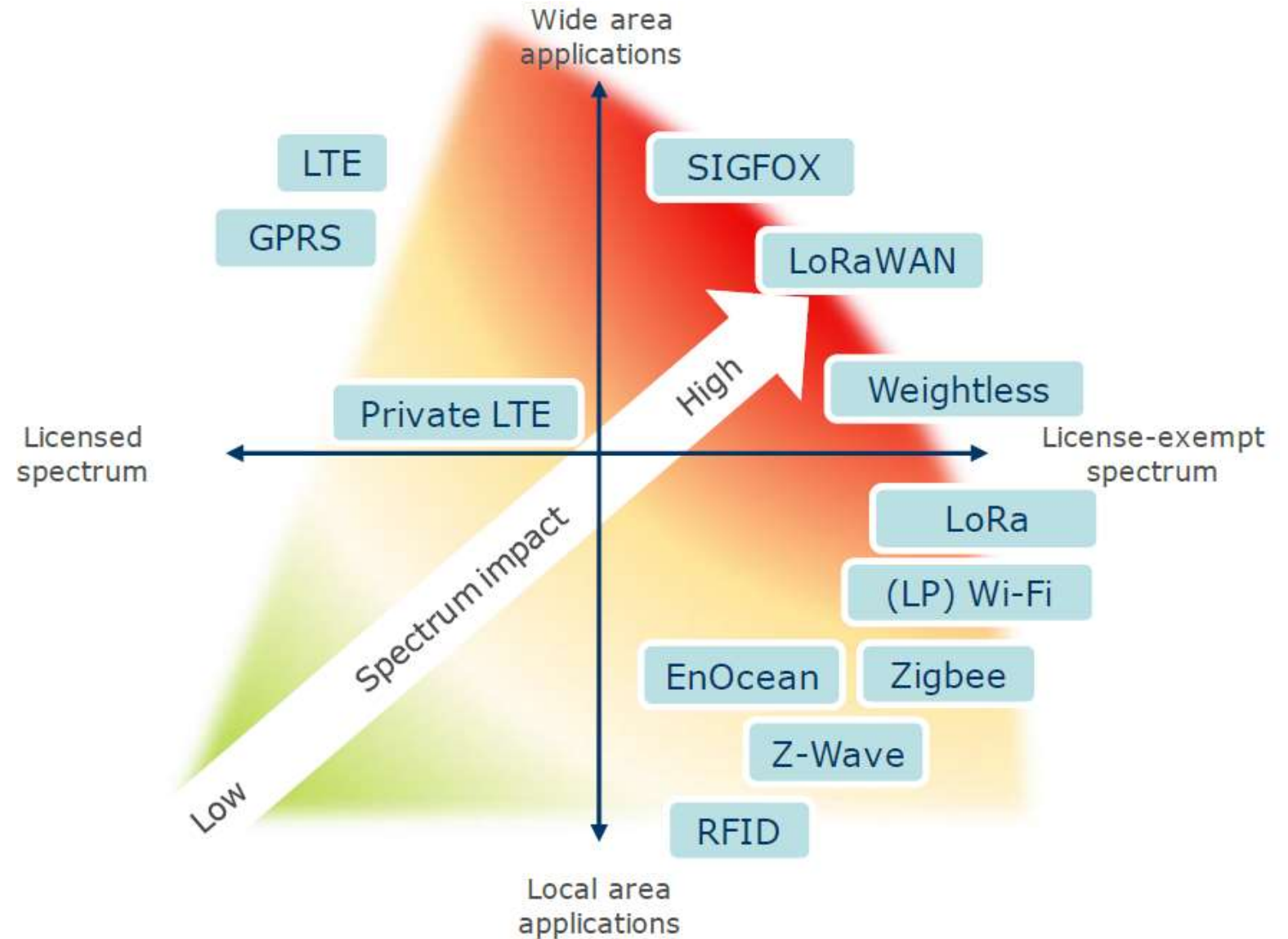


Connected Vehicle 2020-Mobility Ecosystem

(Source: Continental Corporation)



IoT wireless technologies overview



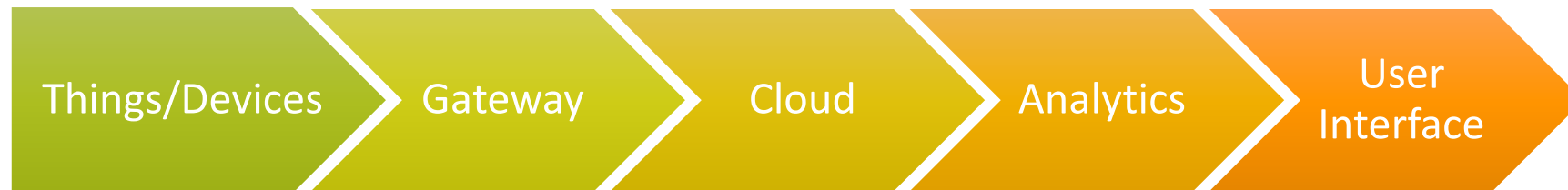


IoT Components

Conceptual overview

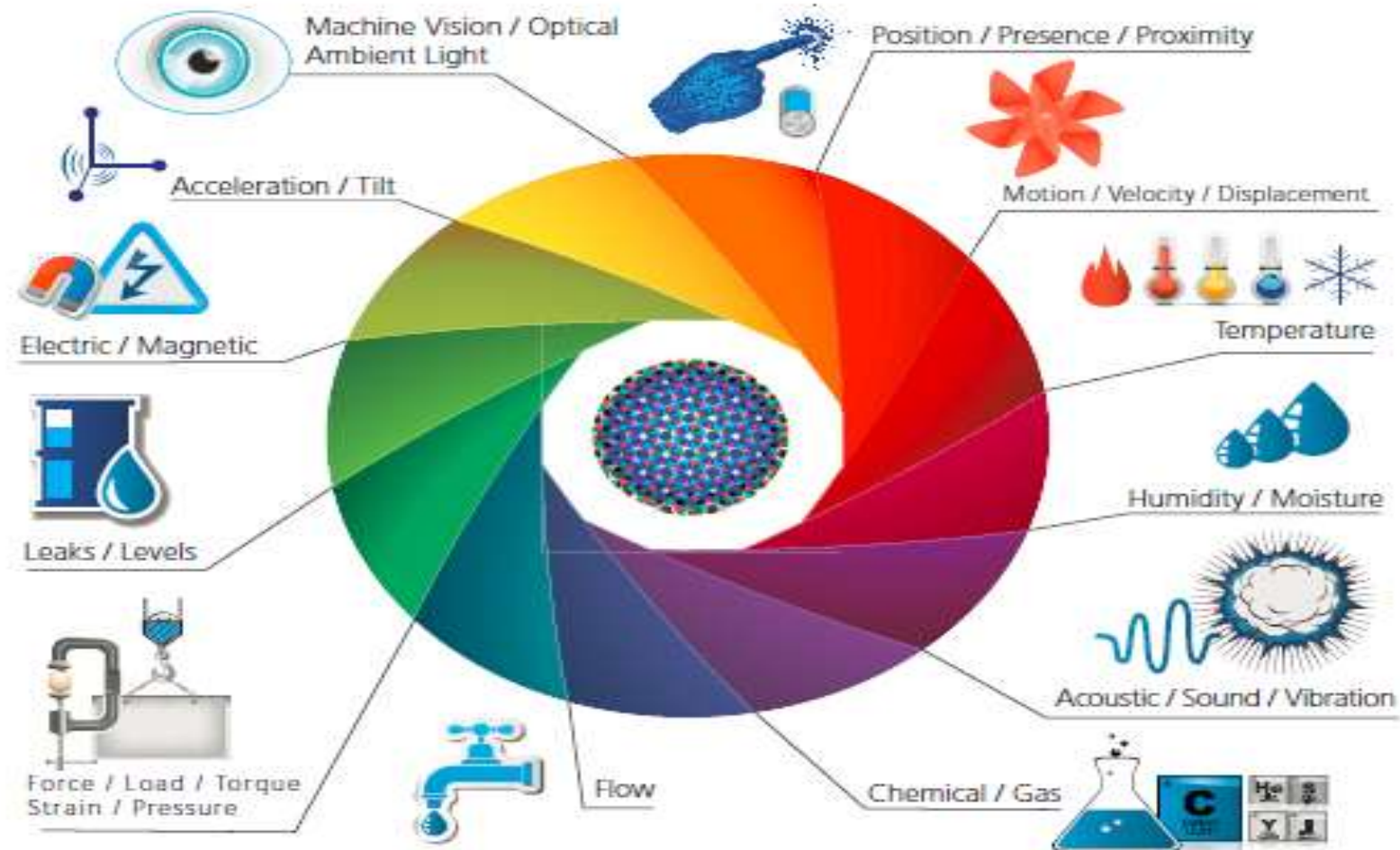


Implementation-driven overview





Sensor Types



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



Sensor Types

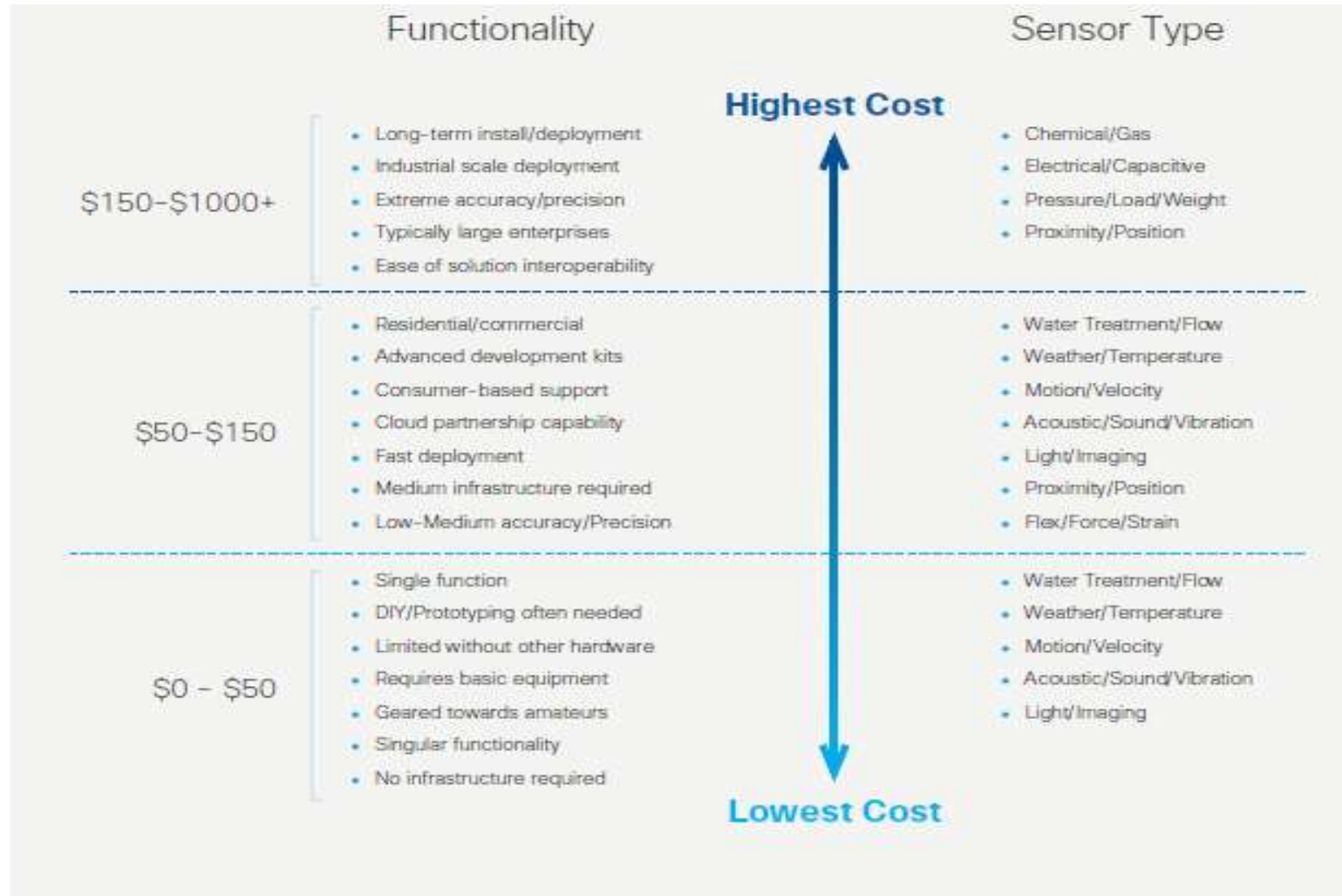


Source: Harbor Insights.

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



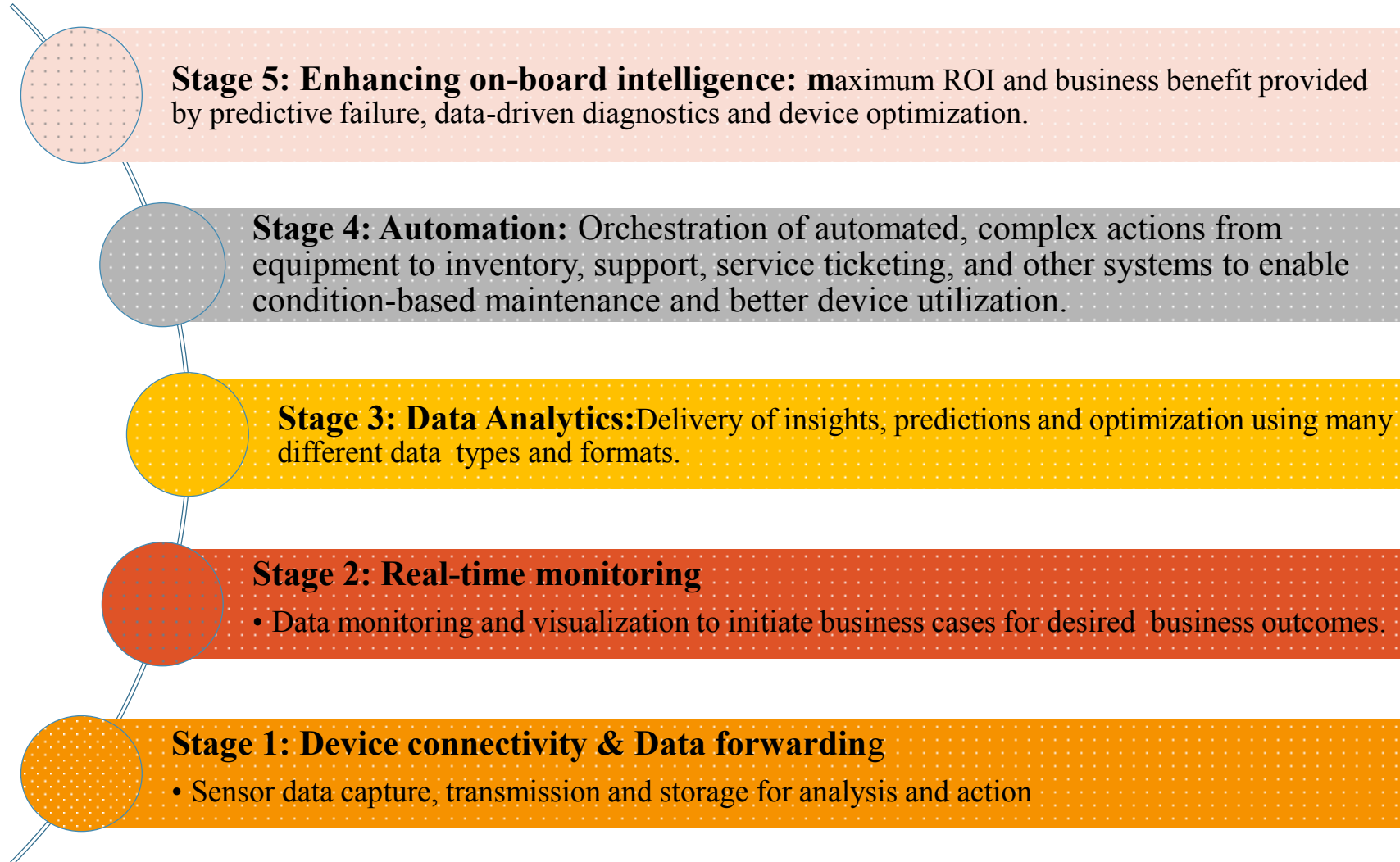
Sensor Types



Sensor Types and Costs (source: ITU)

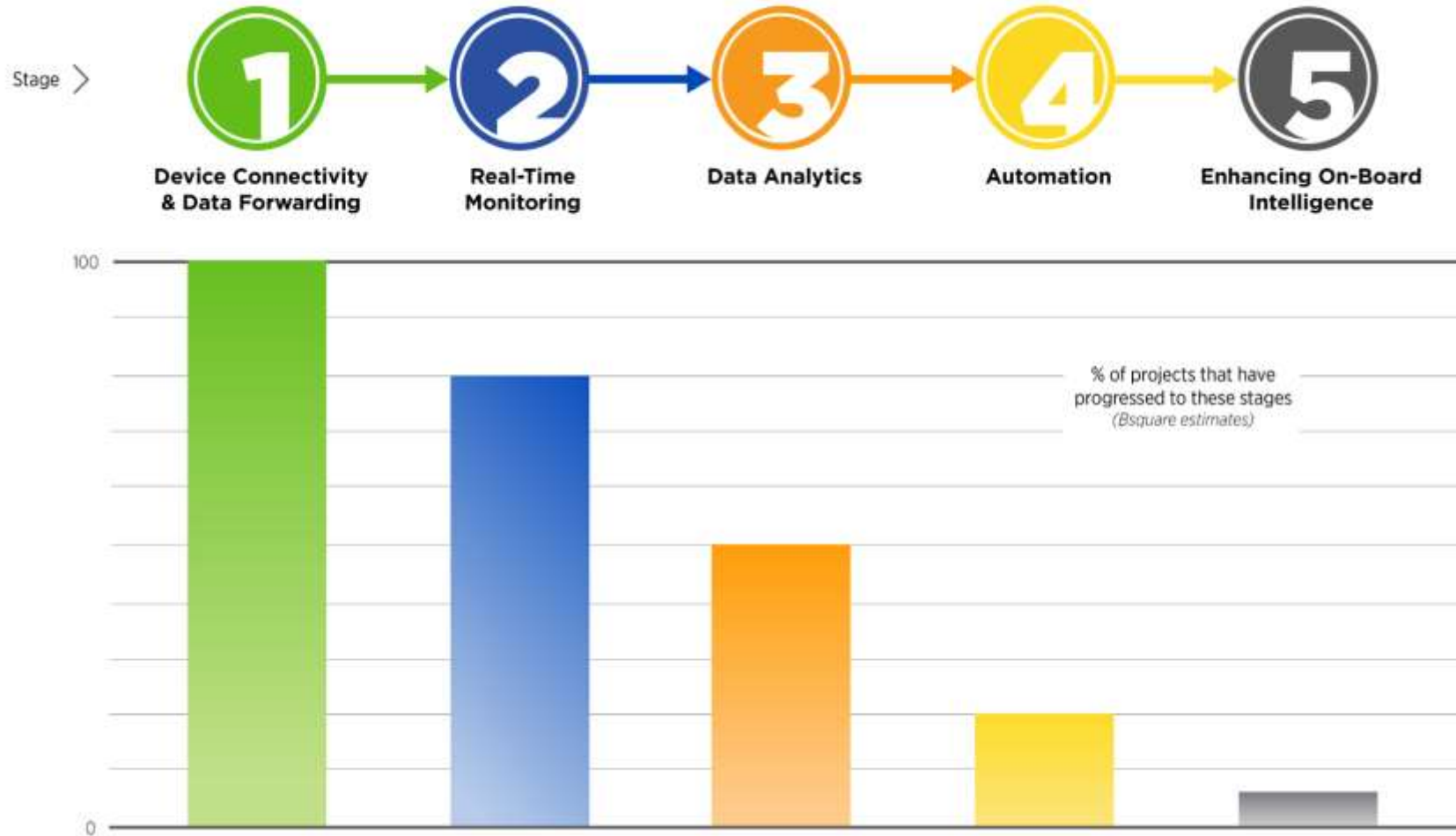


Deployment stages





Deployment Analysis



Deployment Analysis (Source: [3])

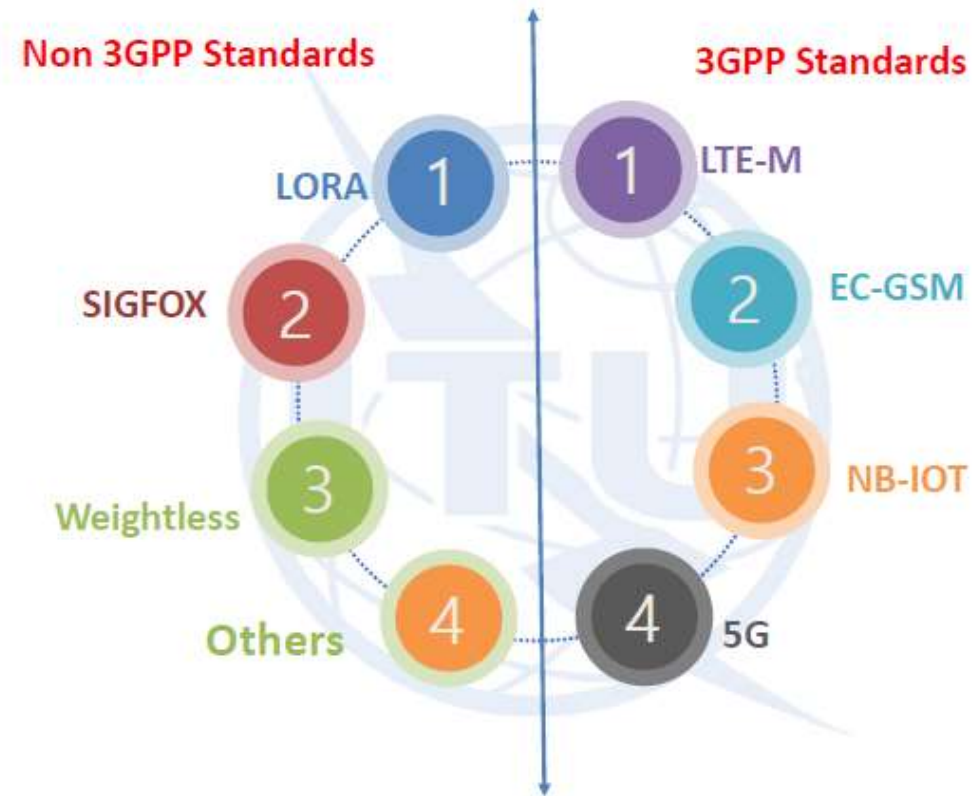


IoT Technologies

Fixed & Short Range

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

Long Range



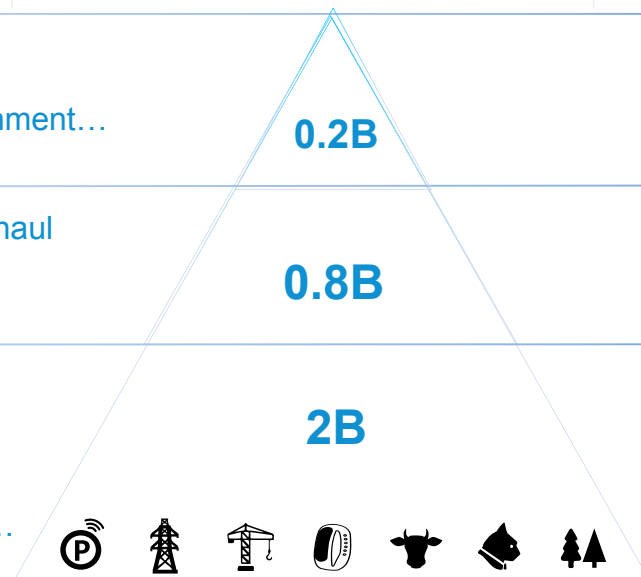


Wide-area M2M technologies and IoT

| 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 |



| Market Segment | Connections in 2020 (Billion) | Requirements | Technology |
|---|----------------------------------|--|---|
| <ul style="list-style-type: none"> ● CCTV(Camera) ● In-vehicle Entertainment... | 0.2B | <ul style="list-style-type: none"> >10Mbps | 3G/4G |
| <ul style="list-style-type: none"> ● IoT Gateway Backhaul ● Wearable ● ... | 0.8B | <ul style="list-style-type: none"> ~1Mbps Low power consumption | 2G/3G/Cat-1 Cat-M1 |
| <ul style="list-style-type: none"> ● Sensors, Meters ● Asset Tracking ● Smart Parking ● Smart agriculture ... | 2B | <ul style="list-style-type: none"> Low Throughput (<100kbps) Deep Coverage (20dB) Low power (10 Years) Low cost (<\$5) | Short Range Tech. Sigfox, LoRa NB-IoT |

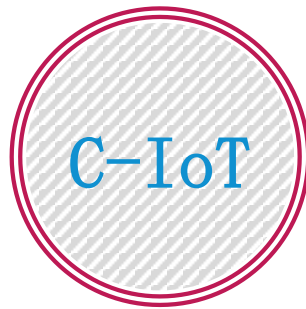


LPWA: Low Power Wide Area

LPWA could account 70% of Cellular IoT Connections in 2020



C-IoT provides wide WAN coverage



Re-use existing Cellular network



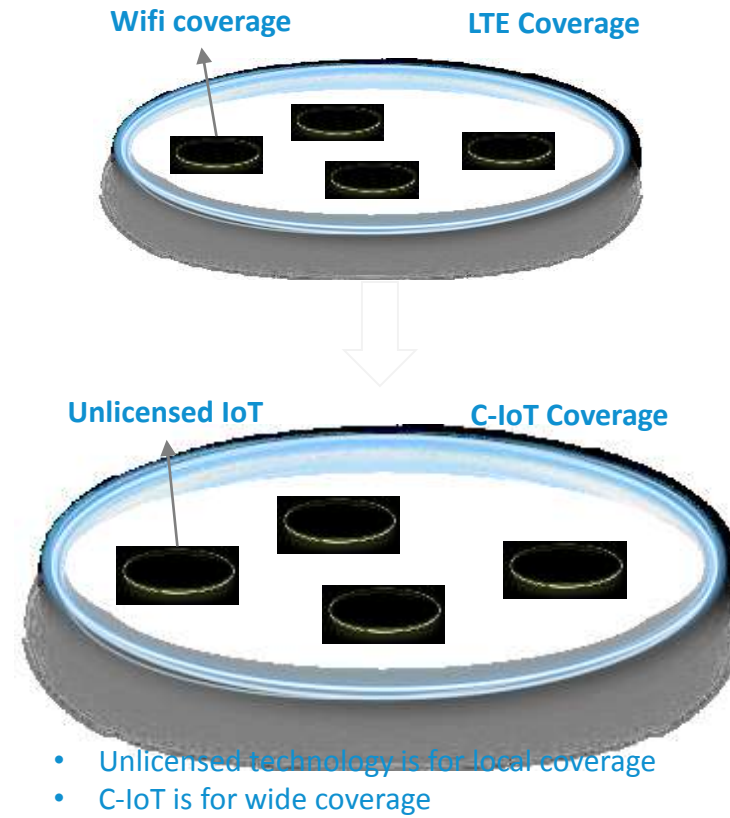
Carrier-grade Reliability



4G-Like Security

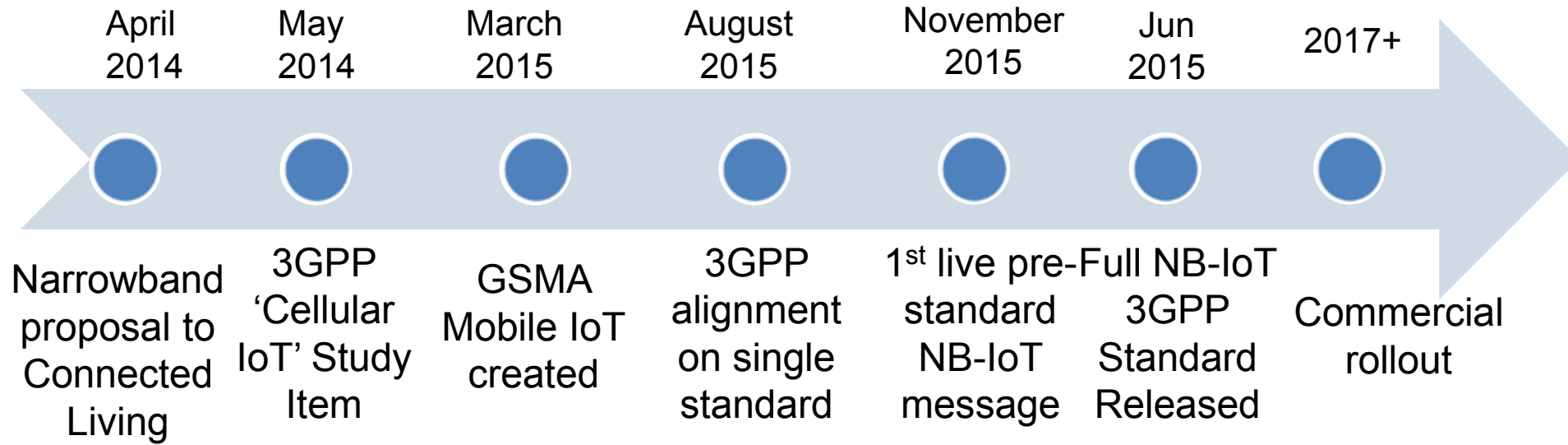


Roaming





Current status



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 Multiple 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™  LoRaWAN™  Certification  News Events  Membership  Resource Hub 

83

Network Operators

57

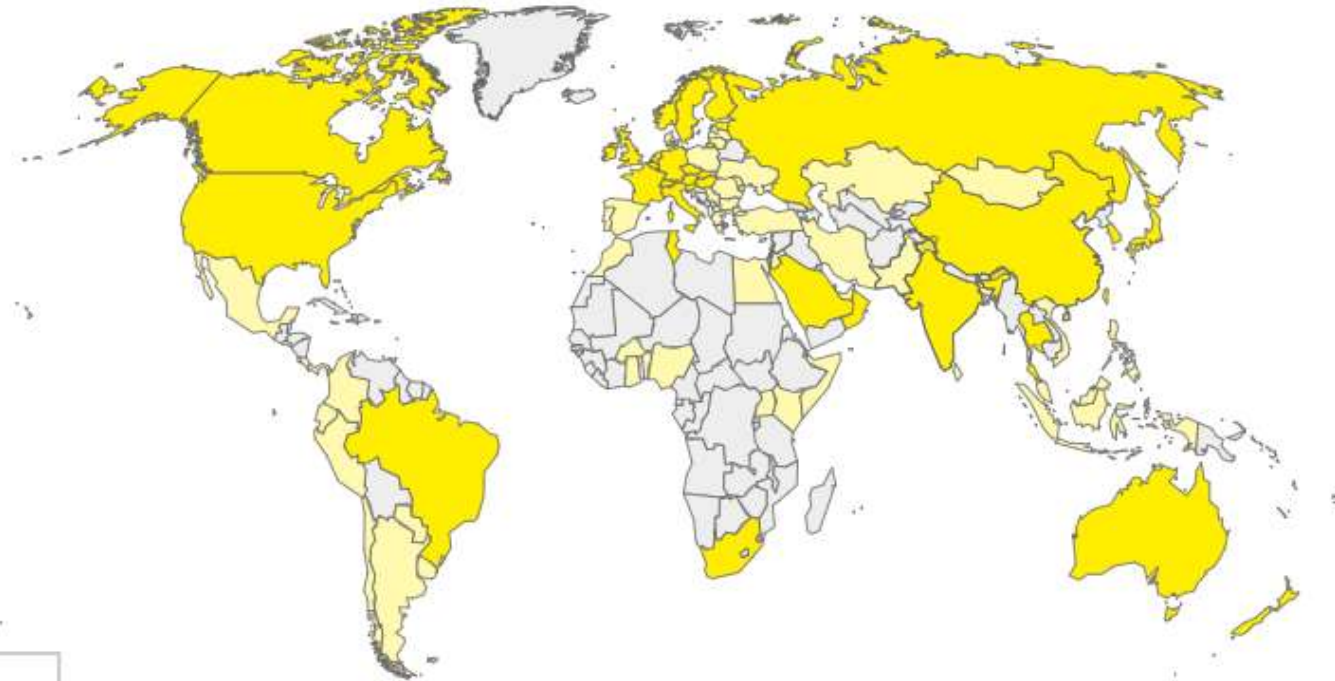
Alliance Member Operators

49

Countries operating in

95

Countries with LoRaWAN Deployments



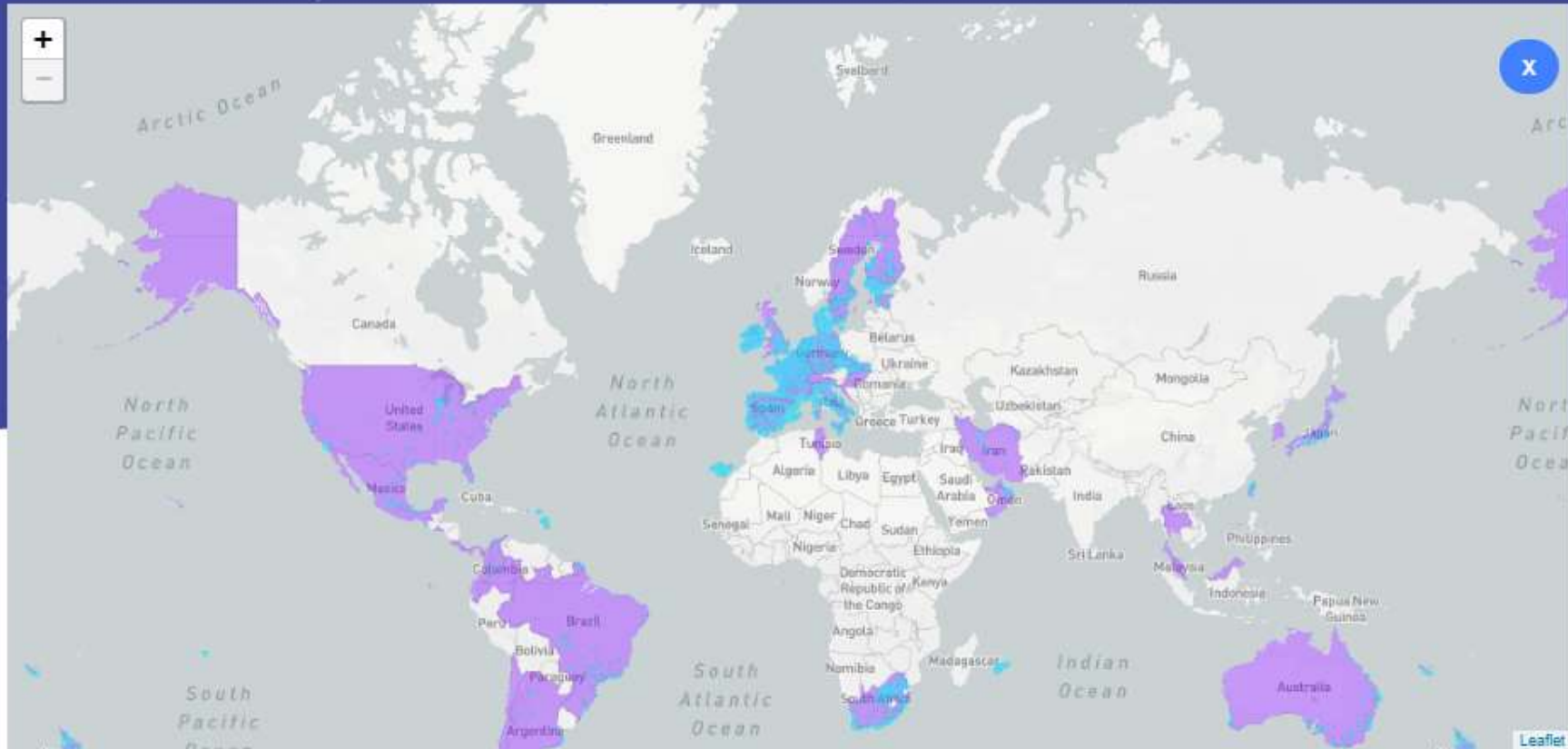
<https://www.lora-alliance.org/>

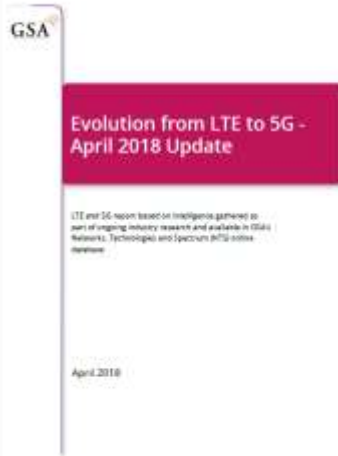


Sigfox



● Live coverage ● Country under roll-out





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.



B. Prices



1. 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.
2. 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

IOT CONNECTIVITY DISRUPTED

10 EUROS
FOR **10** YEARS
FLAT RATE

€ 10
one-off cost per SIM

10 YEARS
lifetime

IOT FLAT RATE
500 MB max – additional
volume bookable

powered by

LIMITED SMB ACCESS PLAN / UNLIMITED ACCESS PLAN

\$20 PER YEAR / YEAR ONE
\$6 per year after year one

\$25 PER YEAR / EVERY YEAR
Unlimited data at 64 kbps

AS LOW AS

50¢ PER MONTH
Includes access to 1 MB of LTE data



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 |
| Band IoT 50 | 500KB | KRW 500 | | |
| Band IoT 70 | 3MB | KRW 700 | Tracking services (e.g. locating tracking | - 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 100 | 10MB | KRW 1,000 | For people/things, asset management, etc.) | |
| 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

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 **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.”



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

1. 1 gigabyte of data valid for up to 1 year and 500 text messages for **\$25**;
2. 3 GB of data valid for up to 1 year and 1,000 text messages for **\$60**;
3. 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
Stack / MAC
Stack implementation
Price

UART
LoRaWAN
Microchip proprietary
\$14.27 @ single unit
\$10.90 @ 1000 units



Interface
Stack / MAC
Stack implementation
Form factor
Price

UART
LoRaWAN
proprietary MultiTech
XBee compatible
~\$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

One world, one global SIM: How ITU-allocated 'global IMSI ranges' support IoT and M2M connectivity

<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 Interference 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:

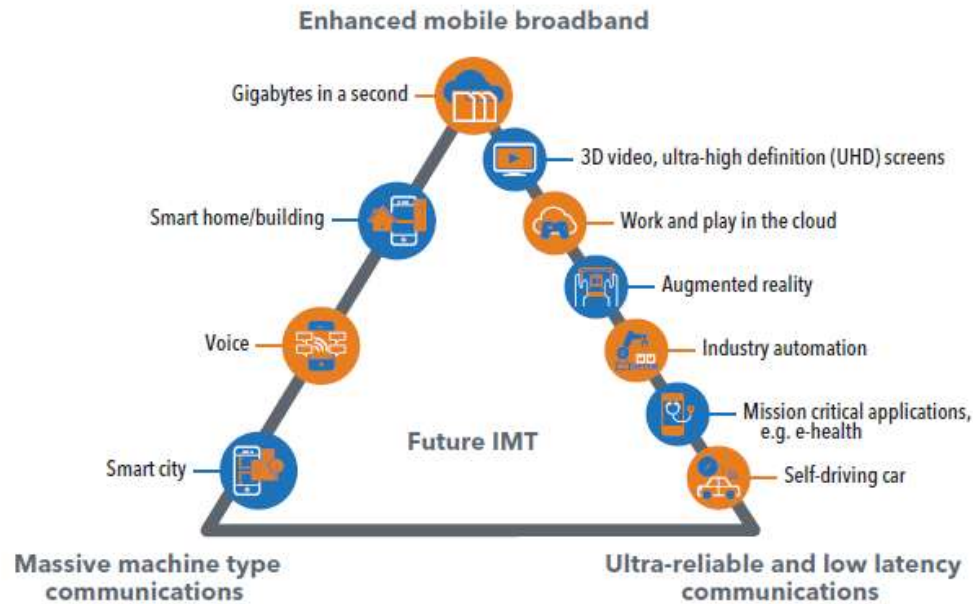
- 5 905 -5 925 MHz for LTE-V2X trials
- 2 x 2.3 MHz in 800MHz can be used for NB-IoT



5G and IOT

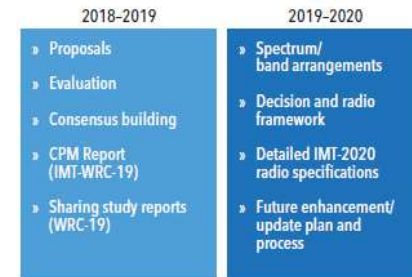


5G usage scenarios from the ITU-R IMT-2020 Vision Recommendation

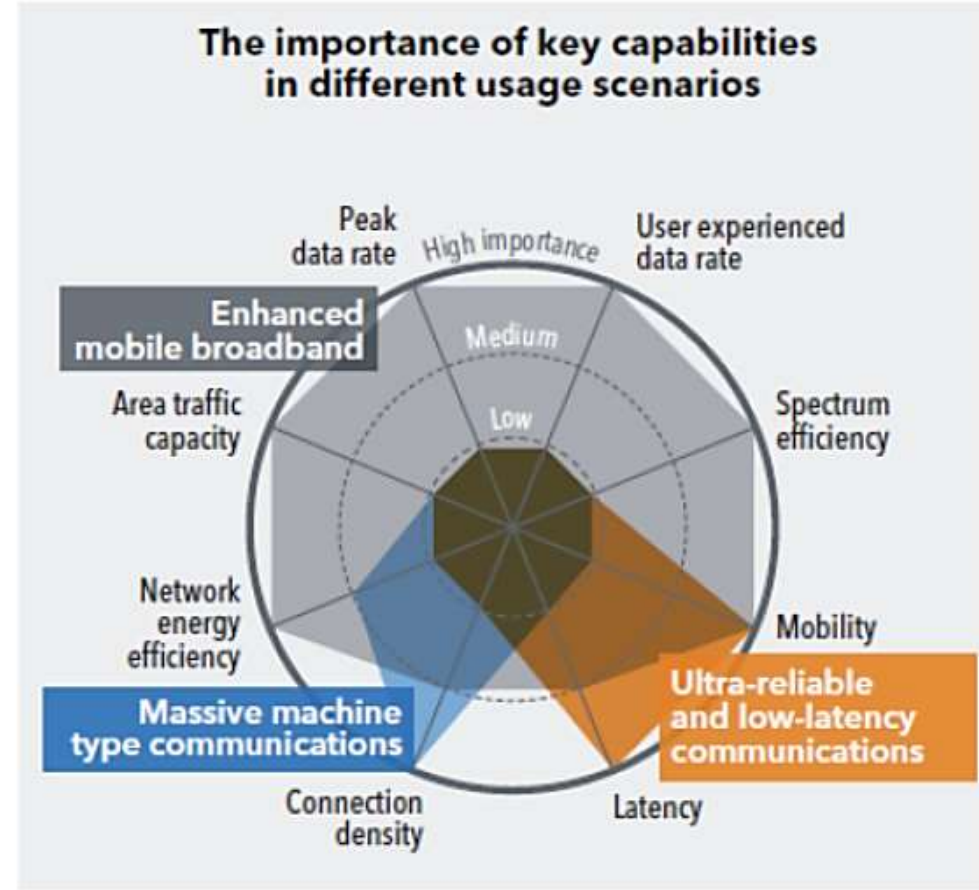
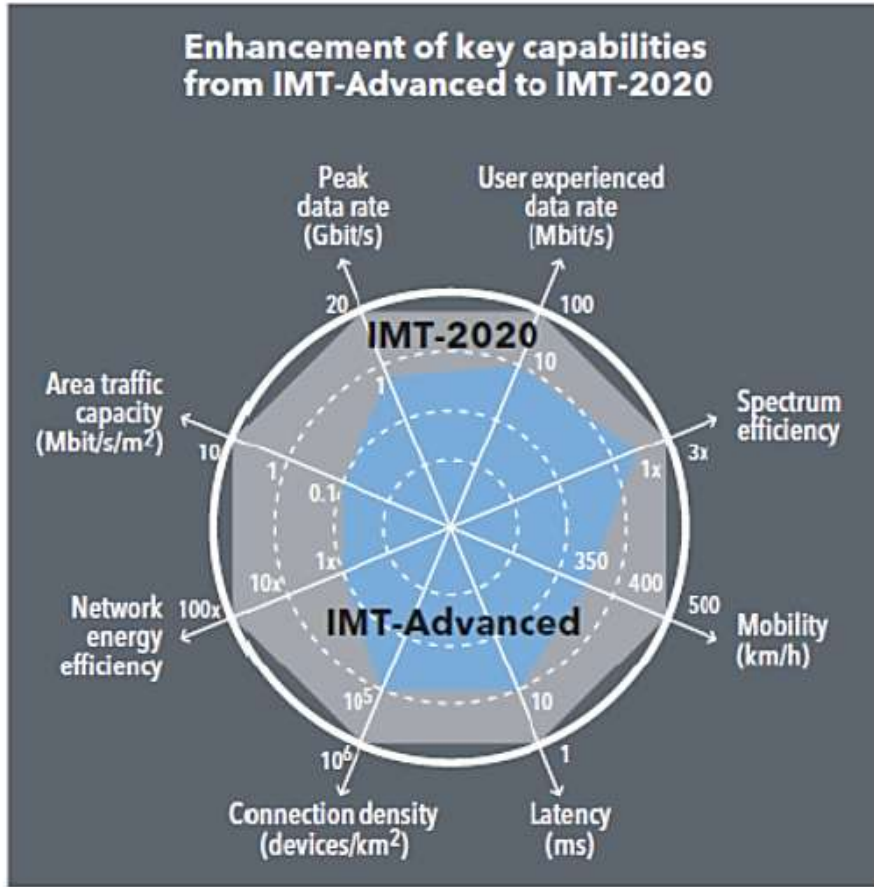


IMT-2020 standardization process

Setting the stage for the future:
vision, spectrum, and
technology views



Defining the technology



*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

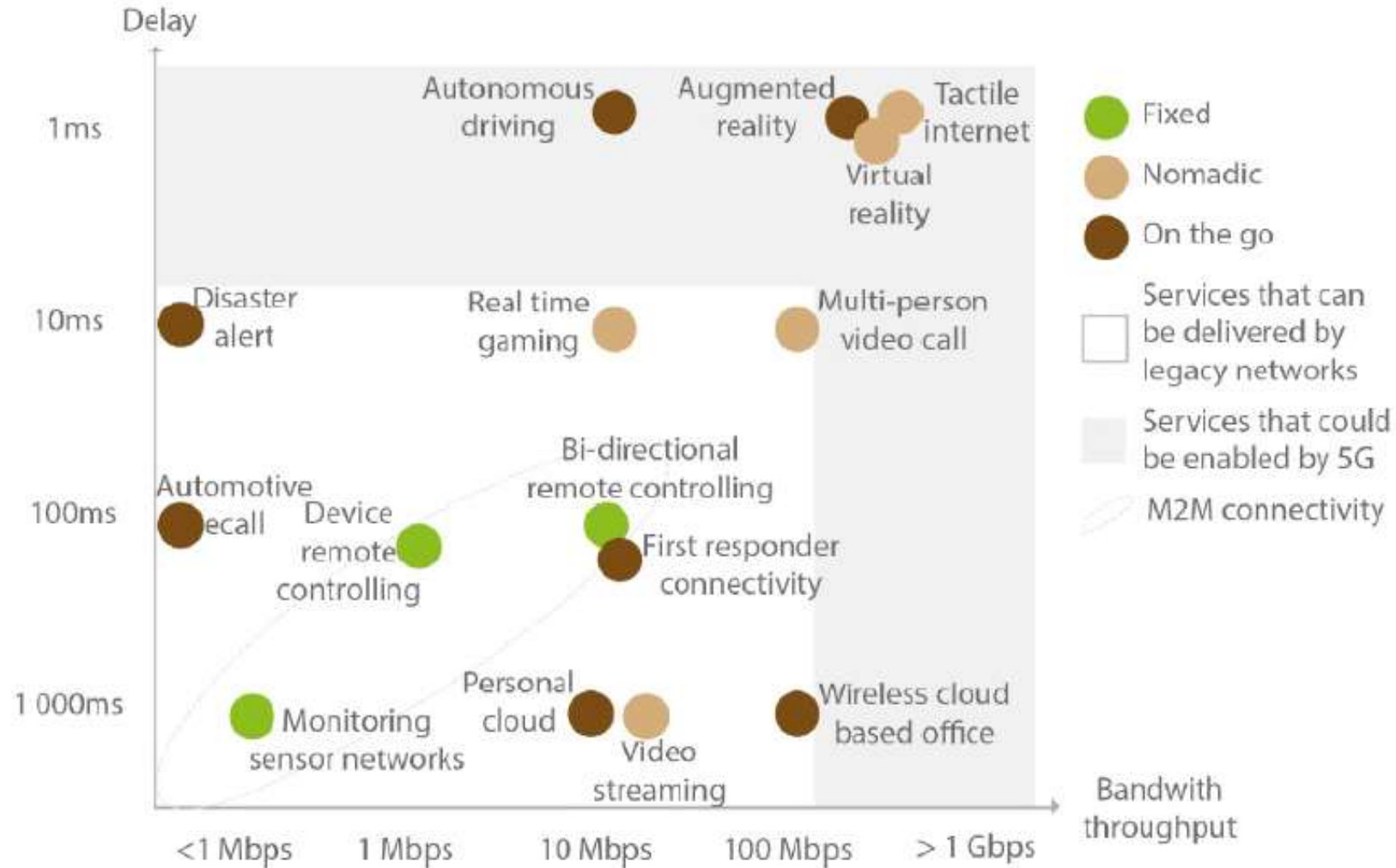
One report estimates that 5G will underwrite USD 12.3 trillion of global economic output by 2035, with the greatest growth in sales activity coming from manufacturing because of an anticipated increase in spending on 5G equipment. This is followed by sales growth in the ICT sector driven by higher expenditure 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

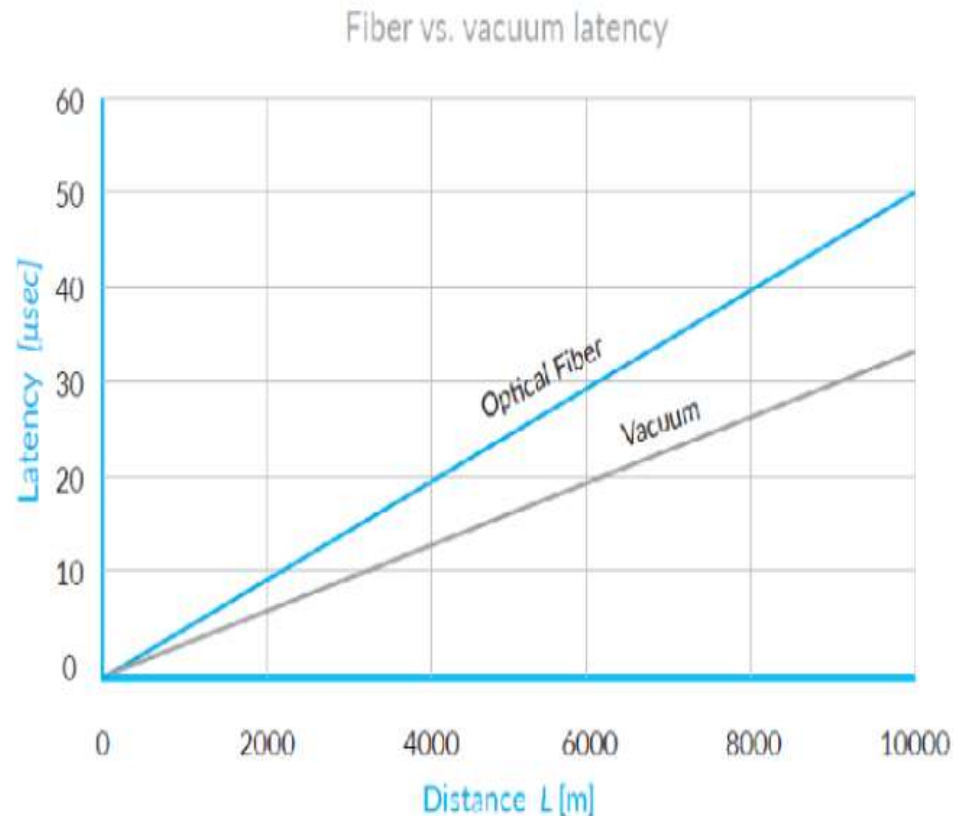


Source: GSMA Intelligence, 2015.



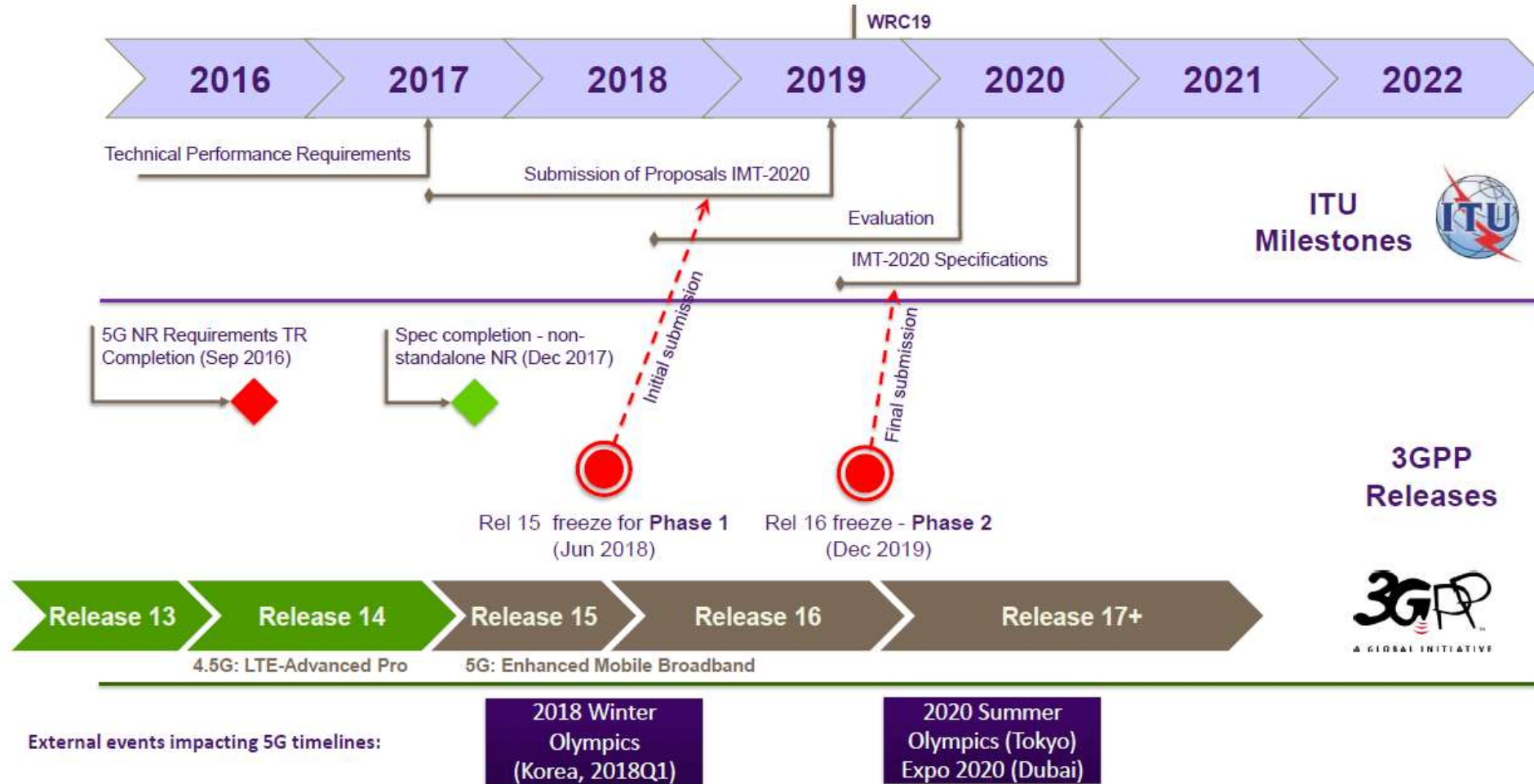
Latency issues

| 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 $2N \times 15$ 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.

Setting the Scene for 5G:
Opportunities & Challenges





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 Tattetelecom 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/iXkYQo> (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

Setting the Scene for 5G: Opportunities & Challenges



| | | |
|----|-----------------------------|---|
| 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 consider holding 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



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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, <u>3.5GHz</u> , 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