Internet of Things: A technical overview of the ecosystem

Regional Workshop for Africa on

"Developing the ICT ecosystem to harness Internet-of-Things (IoT)"

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Summary

I. Characteristics

II. Network architecture

III. Technologies

A. Fixed and short range

B. Long range

i. Non-3GPP standards

ii. 3GPP standards

I. Characteristics

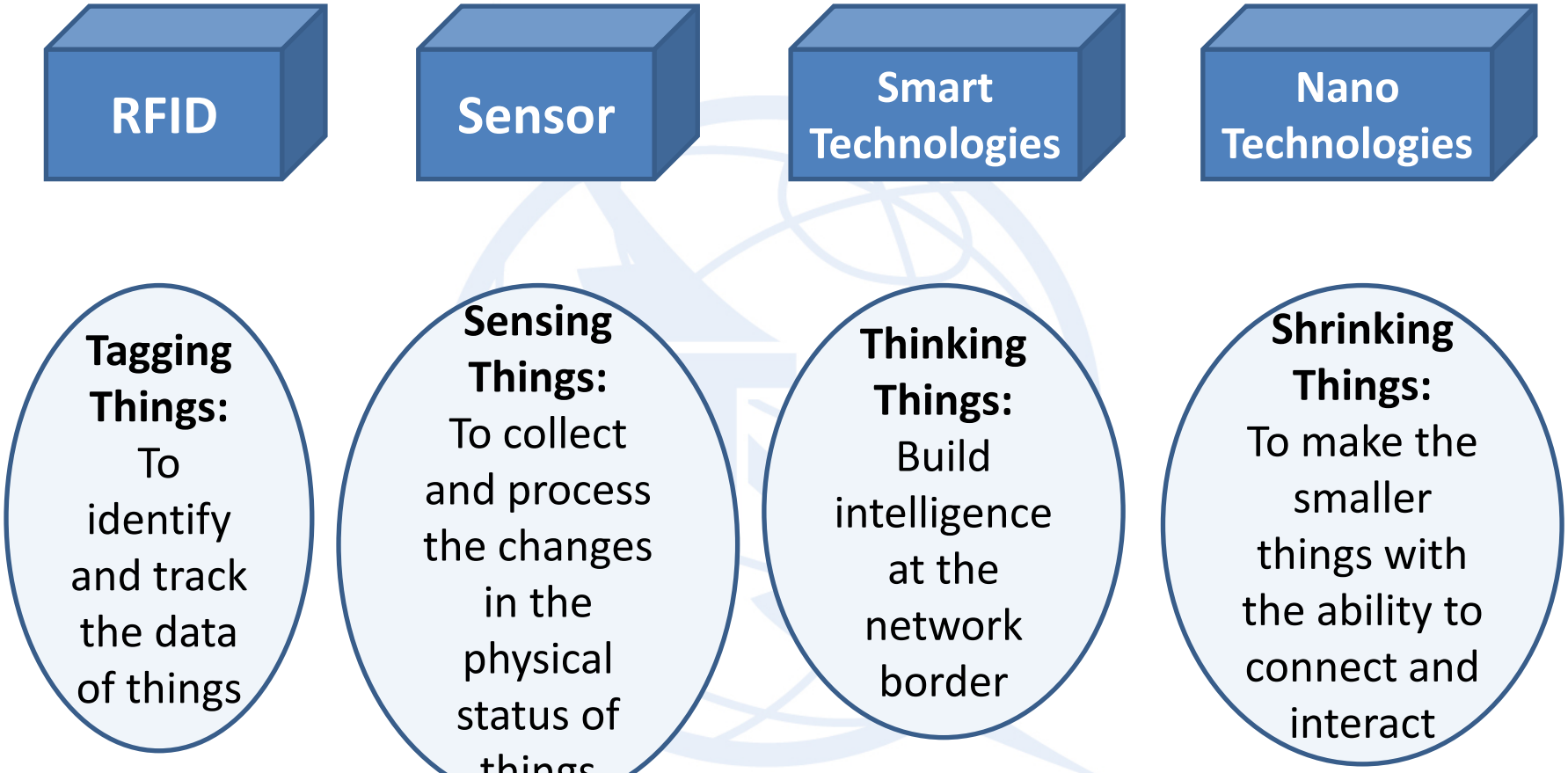
IoT communications are or should be:

- Low **cost**,
- Low **power**,
- Long **battery duration**,
- High **number of connections**,
- Low **bitrate**,
- Long **range**,
- Low **processing capacity**,
- Low **storage capacity**,
- Small **size devices**,
- Simple **network architecture** and **protocols**.

- **Low power**,
- **Low cost** (network and end devices),
- **Short** range (first type of technologies) or **Long** range (second type of technologies),
- **Low bit rate** (≠ broadband!),
- **Long battery** duration (years),
- Located in **any area** (deep indoor, desert, urban areas, moving vehicles …)

- Unique device identity
- Integrated sensors
- Embedded systems
- Big data analytics
- Security
- Reliable networking

Enabling technologies of IoT



II. Network Architecture

IoT 4 layers model

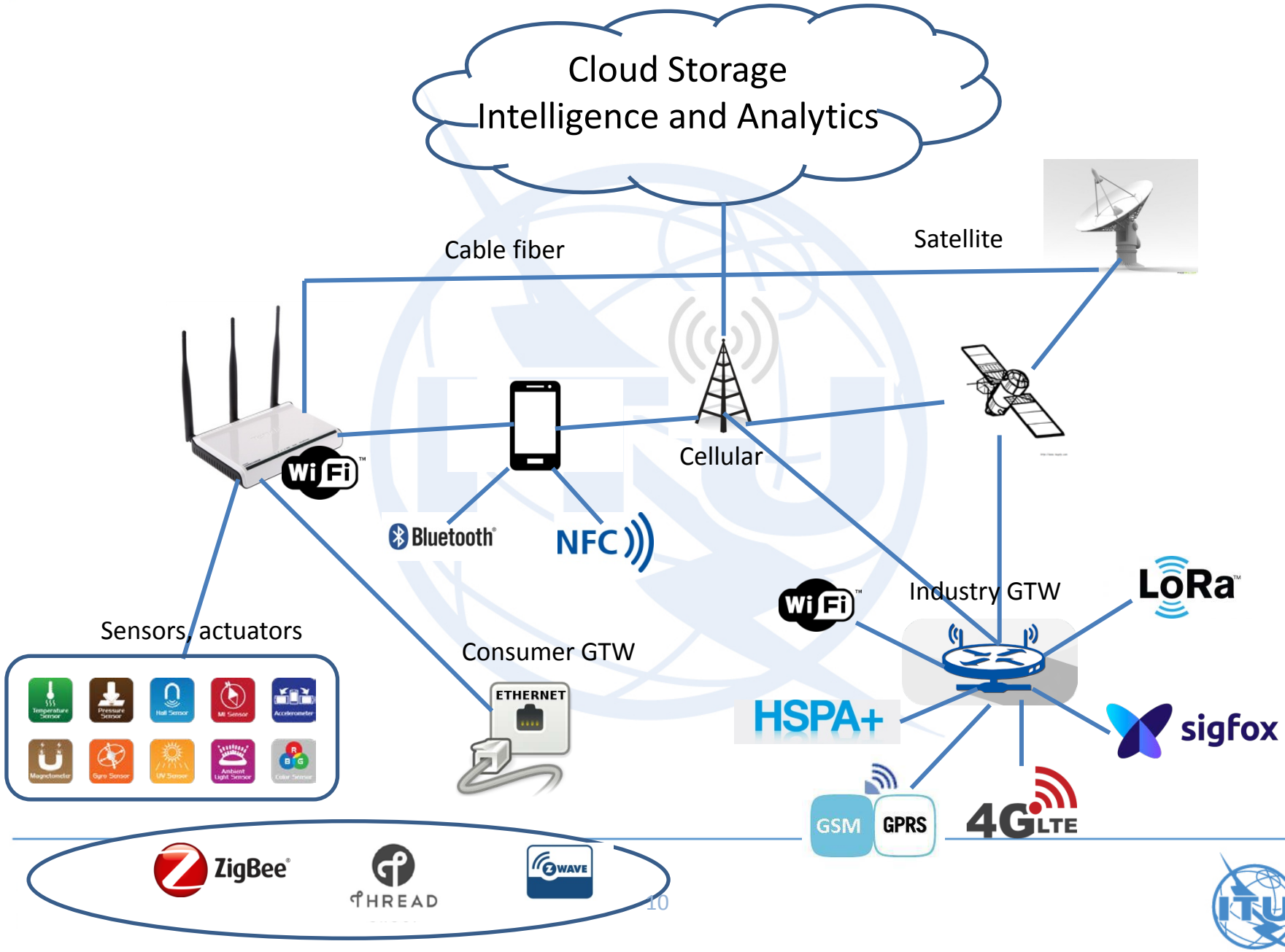
Integrated Applications

Information Processing

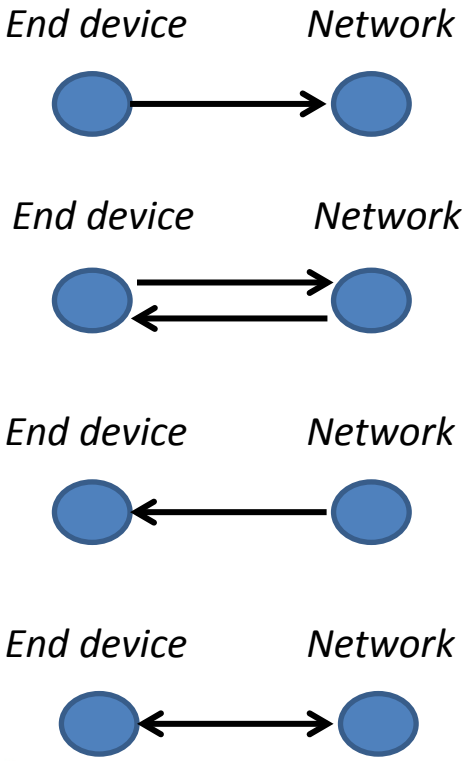
Network Infrastructure

Sensing and Identification

IoT network general architecture



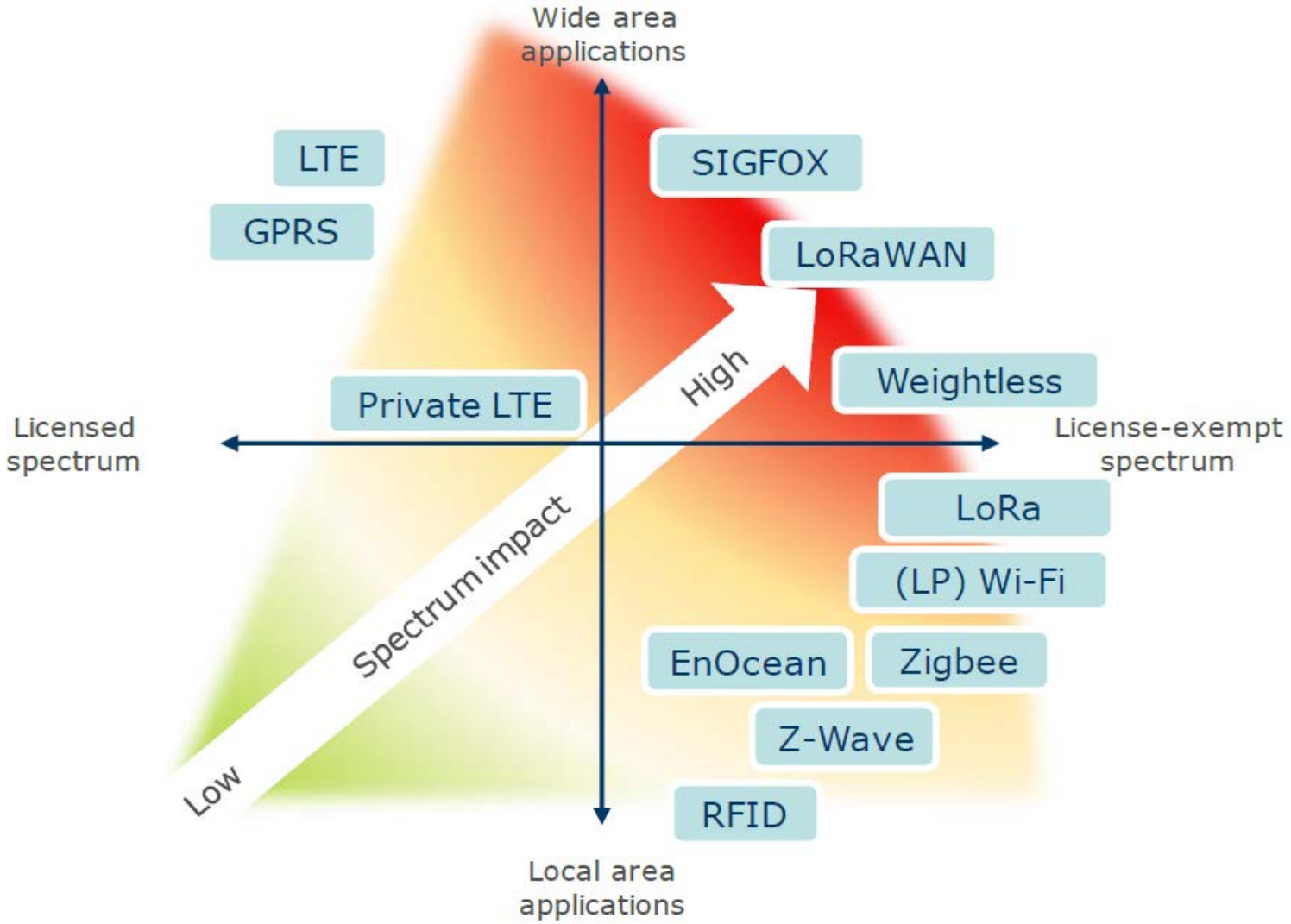
- Things/Objects differentiate according to:
  - The **range** (short, medium, long)
  - The **type of interaction** with the system (i.e., service type):



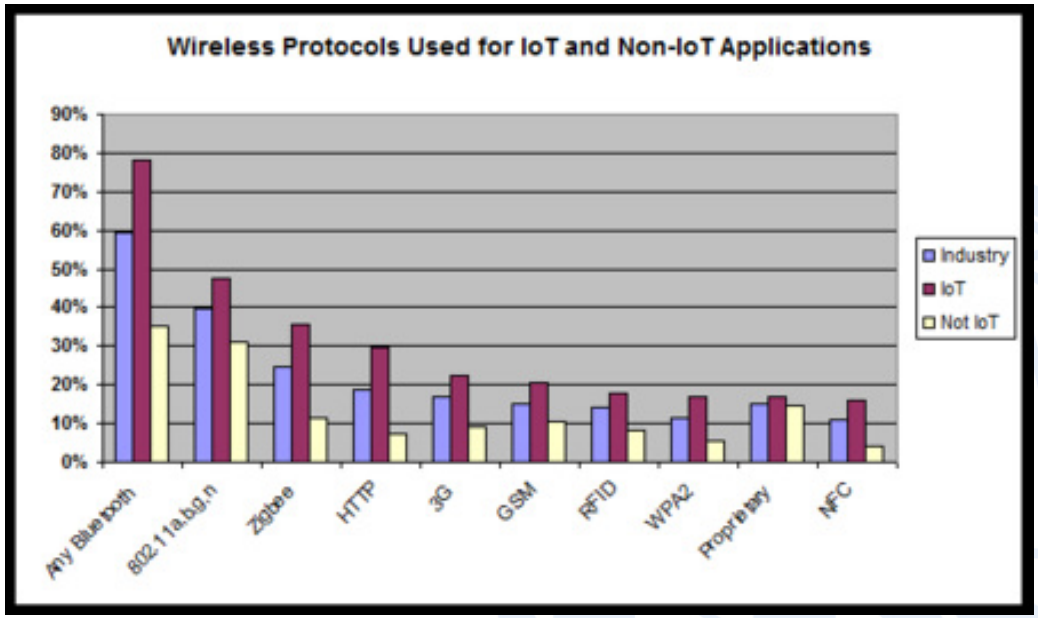
- ***Alarm*** (transmission initiated by the end-device only, according to the events, bursty traffic),
- ***Measurements*** (triggered either by the end-device or by the system),
- ***Control*** (transmissions initiated by the system),
- ***Combination*** of these.

III. Technologies

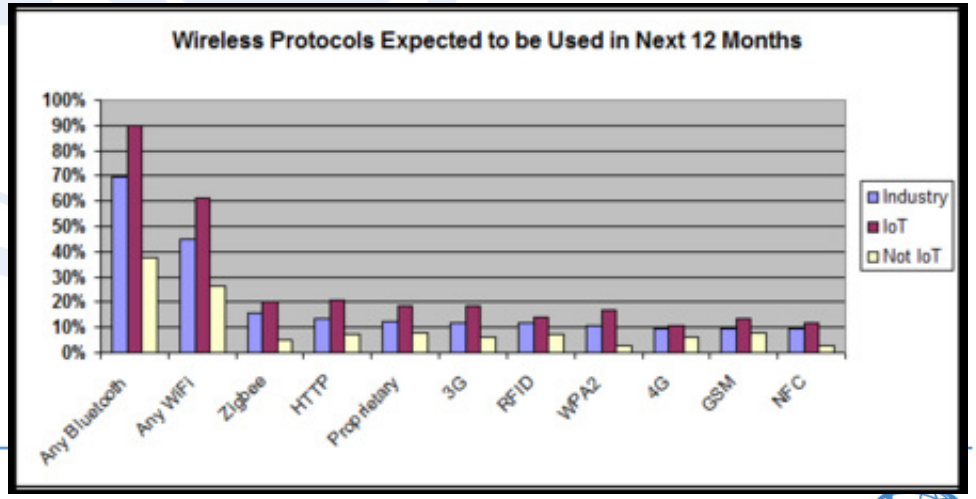
IoT wireless technologies overview



Technologies and Standards Used for IoT



Bluetooth and **WiFi** are the most dominant used technologies for IoT applications in 2016. Their main advantages are power use, range, and data throughput.



A. Fixed & Short Range

B. Long Range technologies

1. Non 3GPP Standards (LPWAN)
2. 3GPP Standards

A. Fixed & Short Range

i. RFID

ii. Bluetooth

iii. Zigbee

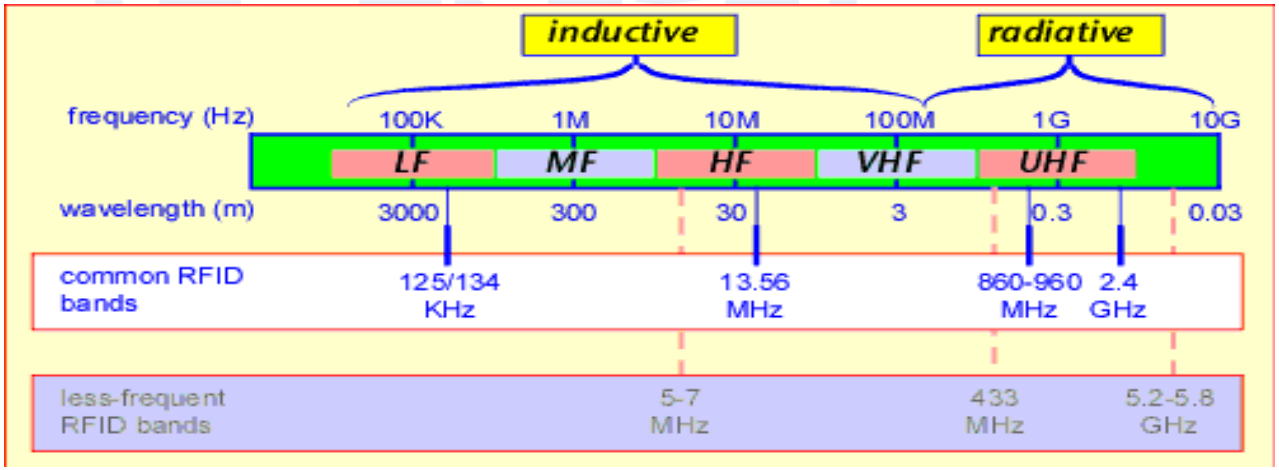
iv. WiFi

i. RFID

RFID (Radio Frequency Identification)

- Appeared first in 1945
- *Features*: Identify objects, record metadata or control individual target
- More complex devices (e.g., readers, interrogators, beacons) usually connected to a host computer or network
- Radio frequencies from 100 kHz to 10 GHz
- *Operating*: reading device called a reader, and one or more tags

RFID Frequencies



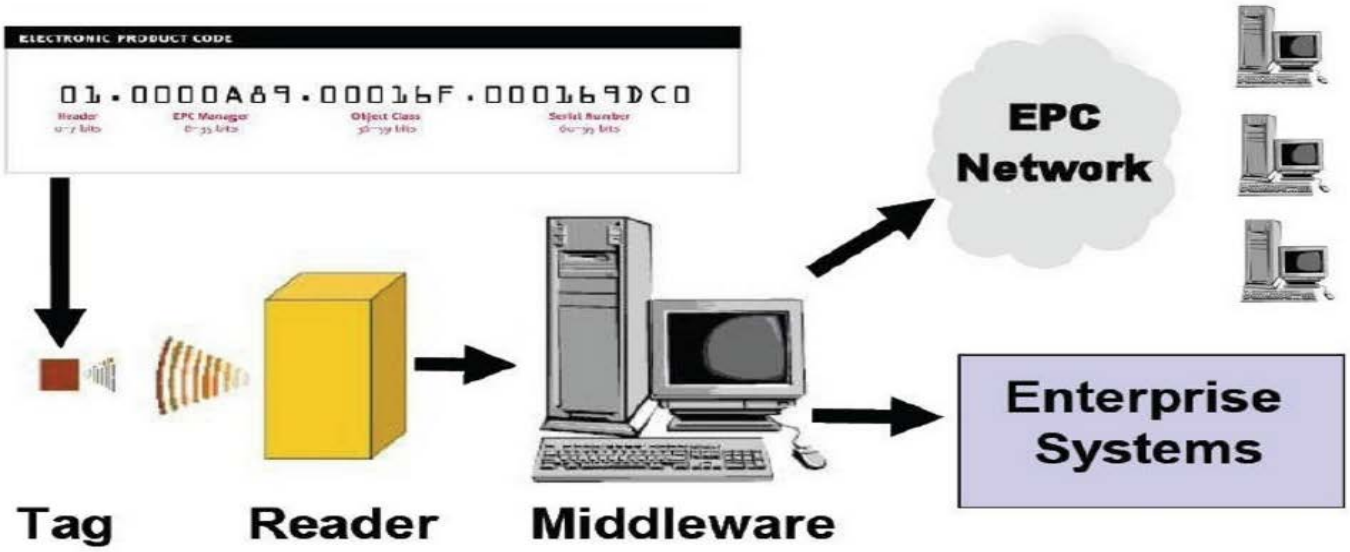
How does it work?

Tag

- Microchip connected to an antenna
- Can be attached to an object as his identifier

Reader

- RFID reader communicating with the **RFID tag** through radio waves



Different Types of TAGs

	Passive Tags	Active Tags
Power	Powering through RF **from Reader**	**Internal** to the Tag
Battery	**No**	**Yes**
Availability	Only in the field of Radar	Continuous
Required Signal Strength to Tag	Very High	Very Low
Range	Up to **3-5m**	Up to **100m**
Multi Tag Reading	Few Hundred within 3 meters from the reader	1000's of tags recognized
Data Storage	128 bytes	128 bytes with search and access

Short or very short range technology, most applications are based on manual involvement and limited to presence detection.

ii. Bluetooth

Bluetooth characteristics

- **Low Power** wireless technology
- **Short range** radio frequency at **2.4 GHz** ISM Band
- Wireless *alternative* to wires
- Creating **PANs** (*Personal area networks*)
- Support Data Rate of 1 Mb/s (data traffic, video traffic)
- Uses frequency-hopping spread spectrum

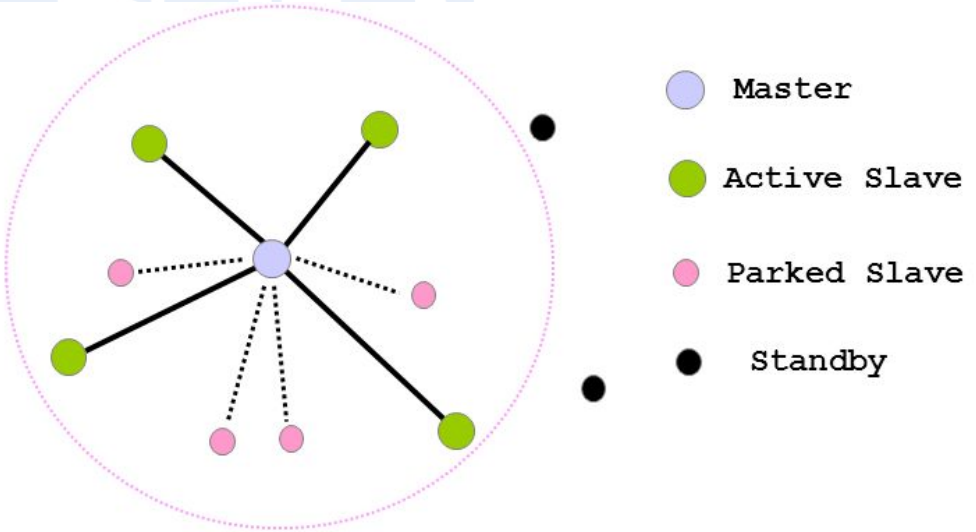
Class	Maximum Power	Range
1	100 mW (20 dBm)	~100 m
2	2,5 mW (4 dBm)	~10 m
3	1 mW (0 dBm)	~1 m

Bluetooth Piconet

- Created instantly and automatically between Bluetooth devices within the same area
- A ***master*** device and others ***slaves***
- Slaves cannot directly send data to each others
- All traffic must go through the ***master***
- Up to 7 active slaves

Bluetooth Scatternets

- Two or more piconets
- Devices that participate in two piconet act as **gateways**



Bluetooth Low Energy

- Enables IoT features
- Lowest cost and Easy to implement
- Improvements for ease of discovery & connection
- Low latency, fast transaction (3 ms from start to finish)
- Data Rate 1 Mb/s: sending just small data packets
- **Bluetooth 5**: 4x range, 2x speed and 8x broadcasting message capacity.

Range	**~ 150 m**
Output Power	~ 10mW(10 dBm)
Max current	15 mA
Modulation	GFSK at 2.4 GHz
Sleep current	~ 1 µA

Low cost, available, ready to go.

iii. ZigBee

ZigBee

Control and **wireless sensor** network

Based on the **IEEE 802.15.4** Standard

Created by the **Zigbee alliance**

Low data rates and low power consumption

Small packet networks

Operates on unlicensed bands:

- ISM 2.4 GHz at 250 Kbps
- 868 MHz at 20 Kbps
- 915 MHz at 40 Kbps

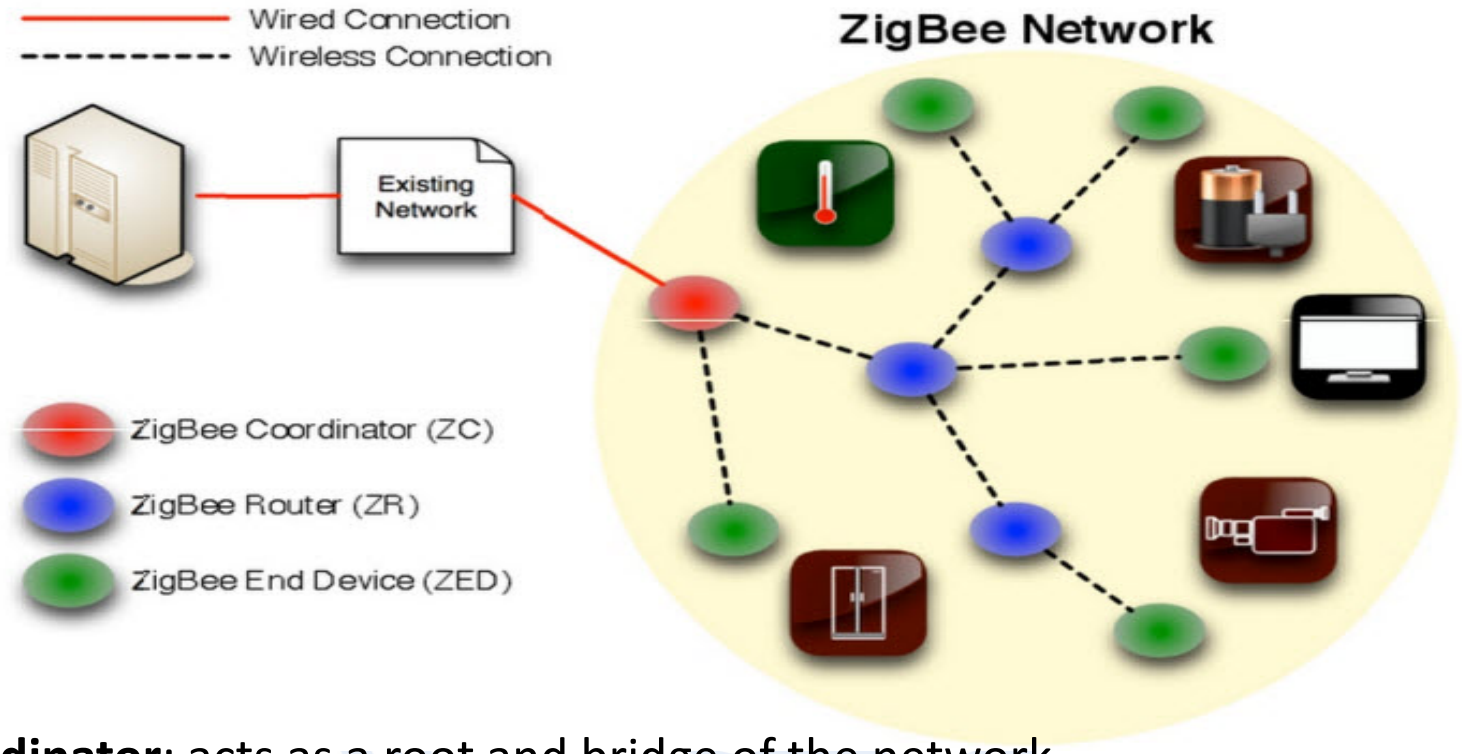
Topology:

Star, Cluster Tree, Mesh

Up to 65 000 nodes on a network

ZigBee™

ZigBee



- **Coordinator**: acts as a root and bridge of the network
- **Router**: intermediary device that permit data to pass to and through them to other devices
- **End Device**: limited functionality to communicate with the parent nodes

Low cost, available, ready to go.

iv. WiFi

- Wireless technology
- Alternative to Wired Technologies
- IEEE 802.11 standard for WLANs

Standard	Frequency bands	Throughput	Range
WiFi a (802.11a)	5 GHz	54 Mbit/s	10 m
WiFi B (802.11b)	2.4 GHz	11 Mbit/s	140 m
WiFi G (802.11g)	2.4 GHz	54 Mbit/s	140 m
WiFi N (802.11n)	2.4 GHz / 5 GHz	450 Mbit/s	250 m
IEEE 802.11ah	900 MHz	8 Mbit/s	100 M

Wi-Fi HaLow

- A new low-power, long-range version of **Wi-Fi** that bolsters **IoT** connections, it will be available in 2018
- Wi-Fi HaLow is based on the pending IEEE 802.11ah specification
- Wi-Fi HaLow will operate in the unlicensed wireless spectrum in the 900MHz band
- It will easily penetrate walls and barriers thanks to the propagation capabilities of low-frequency radio waves.
- Its range will be nearly double today's available Wi-Fi (1 kilometer)

- WiFi is longer range than Bluetooth and ZigBee
- More flexible
- Closer to networks

WiFi-based IoT Devices

Home & Building Automation

- Bringing intelligence, convenience and lifestyle

Smart Energy

- Adding power awareness to products and helping to save energy

Multimedia

- Wireless audio streaming and advanced remote controls

Security and Safety

- Improving remote control and home monitoring

Industrial M2M Communication

- Internet enhanced M2M communication using existing Wi-Fi infrastructure

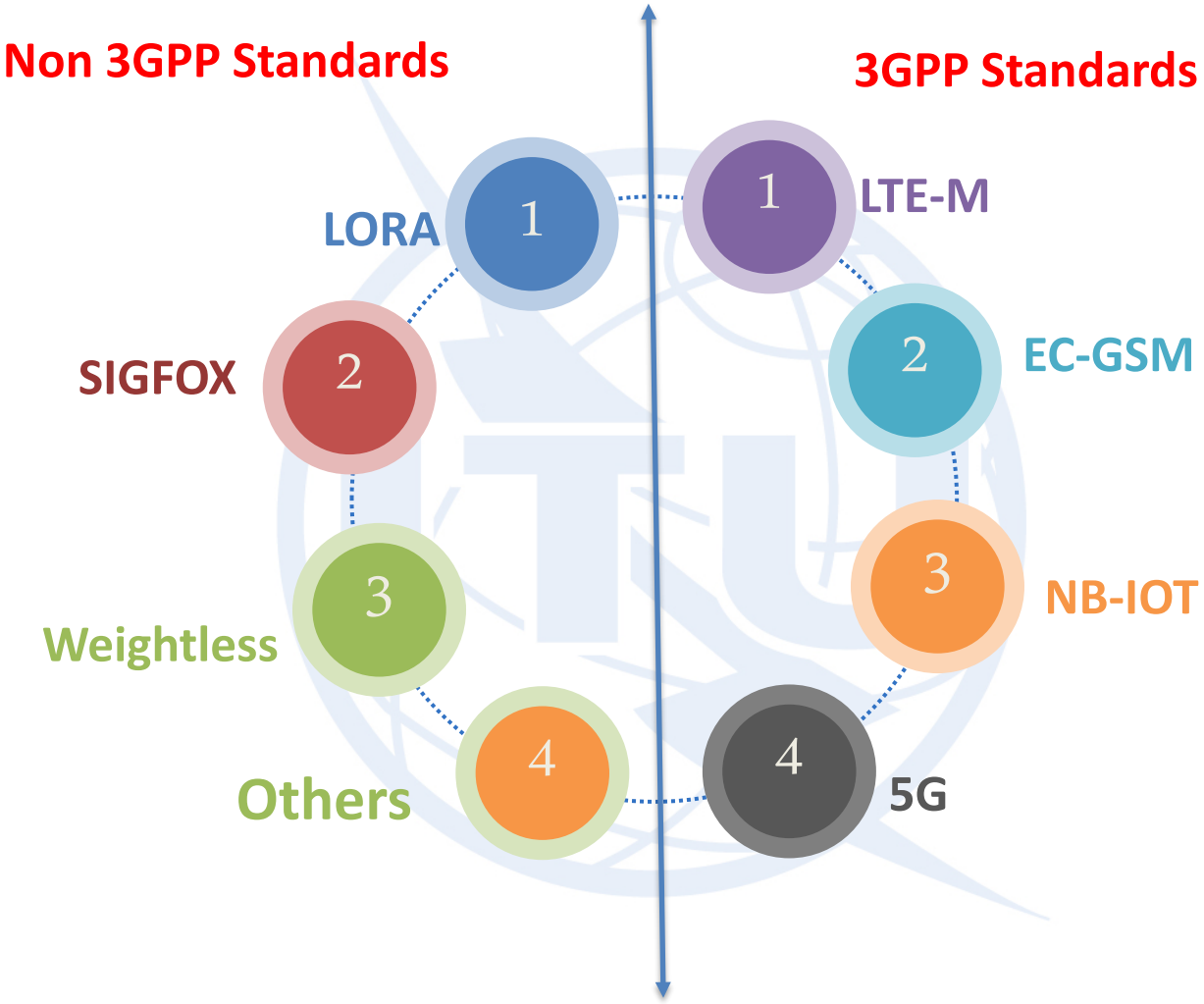
2

A. Fixed & Short Range

B. Long Range technologies

1. Non 3GPP Standards (LPWAN)
2. 3GPP Standards

Long Range Technologies



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

B. Non 3GPP Standards (LPWAN)

i. LoRaWAN

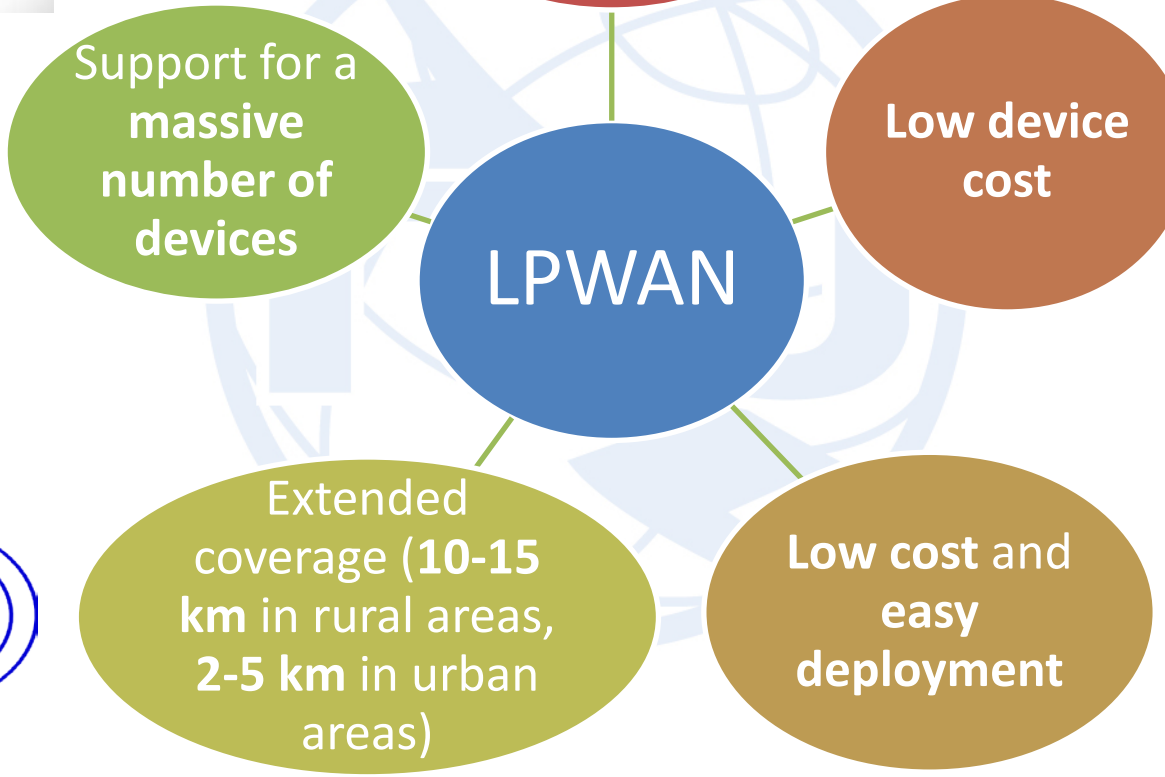
ii. Sigfox

iii. Weightless

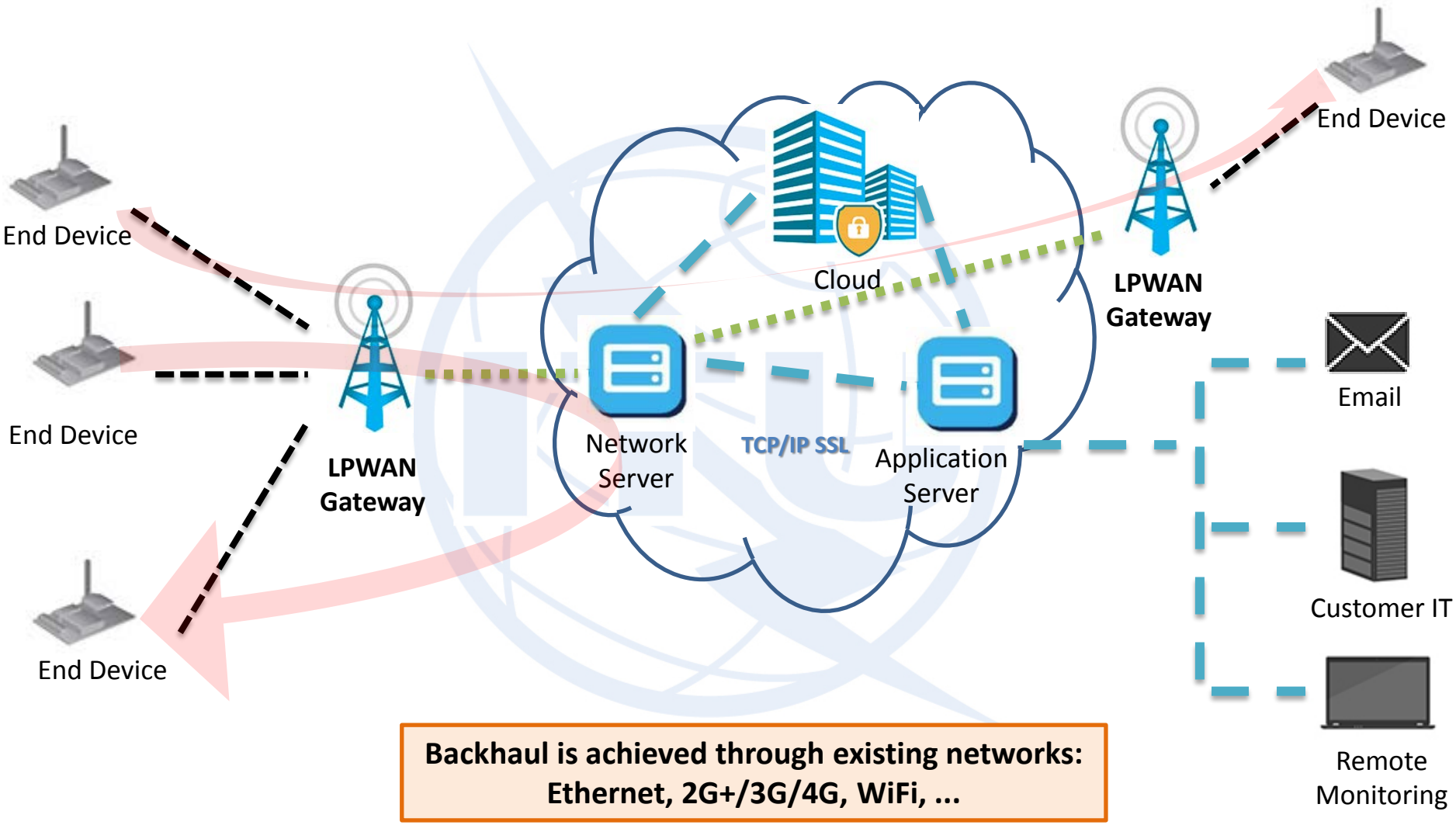
iv. RPMA

v. Others

LPWAN Requirements



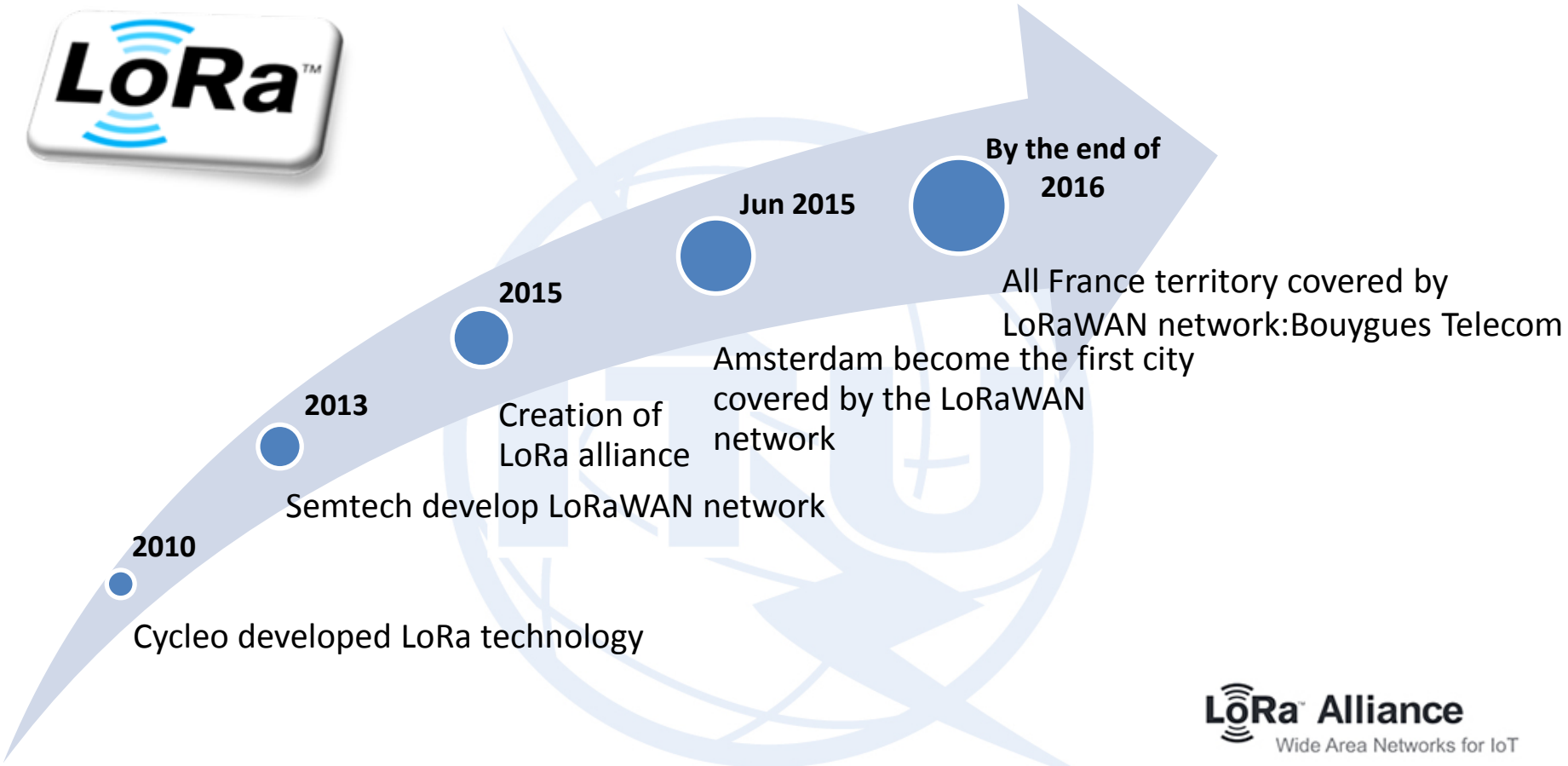
General architecture of LPWAN



Backhaul is achieved through existing networks: Ethernet, 2G+/3G/4G, WiFi, ...

i. LoRaWAN

Roadmap



LoRa Alliance
Wide Area Networks for IoT

LoRa Alliance

International Operators — International development of the solution

Integrators and industrialists — Appropriate technology and maintain it over time

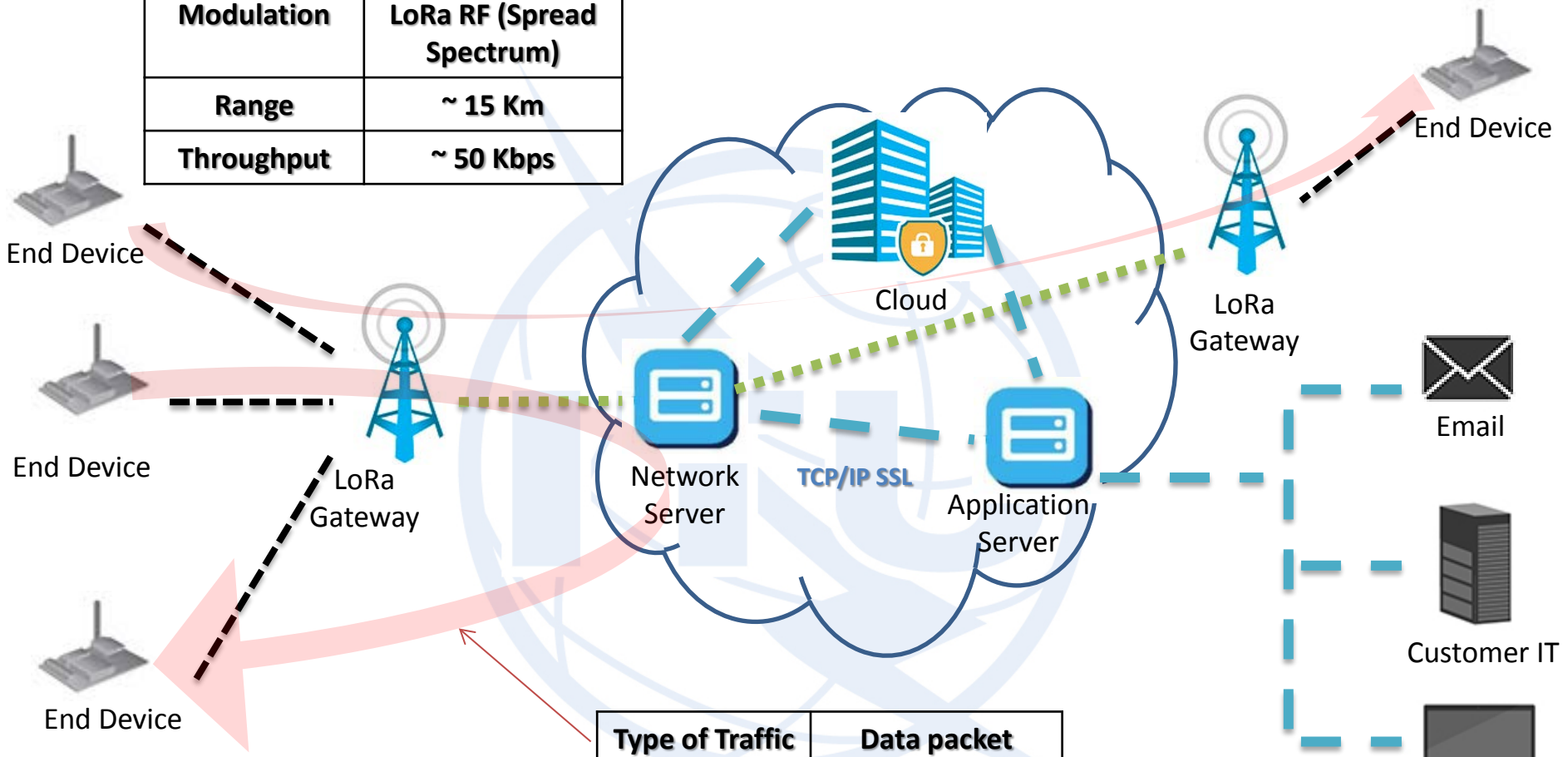
Manufacturers of End-points — Broadcast end devices

Manufacturers of Semiconductors — Integrate LoRa technology

- LoRaWAN is a *Low Power Wide Area Network*
- LoRa modulation: a version of Chirp **Spread Spectrum** (CSS) with a typical channel **bandwidth of 125KHz**
- High **Sensitivity** (End Nodes: Up to **-137 dBm**, Gateways: up to **-142 dBm**)
- Long range communication (up to **15 Km**)
- Strong indoor penetration: With High Spreading Factor, Up to **20dB** penetration (**deep indoor**)
- Occupies the entire bandwidth of the channel to broadcast a signal, making it **robust** to channel noise.
- **Resistant** to Doppler effect, multi-path and signal weakening.

Architecture

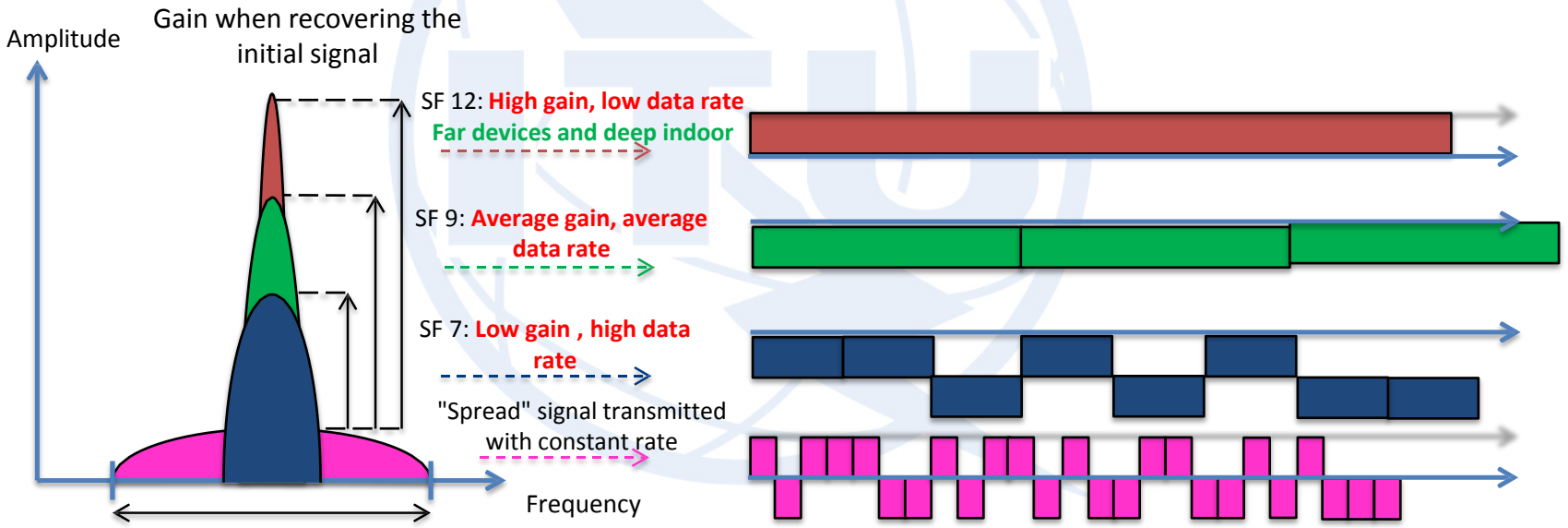
Modulation	LoRa RF (Spread Spectrum)
Range	~ 15 Km
Throughput	~ 50 Kbps



Type of Traffic	Data packet
Payload	~ 243 Bytes
Security	AES Encryption

Spectrum

- Orthogonal sequences: 2 messages, transmitted by 2 different objects, arriving simultaneously on a GW without interference between them (*Code Division Multiple Access* technique: CDMA , used also in 3G).
- **Spread Spectrum**: Make the signal more robust , the more the signal is spread the more robust. Less sensitive to *interference* and *selective frequency fadings* .



Spectrum: unlicensed, i.e. the 915 MHz ISM band in the US, 868 MHz in Europe

LoRaWAN: device classes

Classes	Description	Intended Use	Consumption	Examples of Services
A (« **a**ll »)	**Listens only after end device transmission**	Modules with **no latency constraint**	The **most economic** communication Class energetically.. **Supported by all modules. Adapted to battery powered modules**	• **Fire Detection** • **Earthquake Early Detection**
B (« **b**eacon »)	The module listens at a **regularly adjustable frequency**	Modules with **latency constraints** for the **reception of messages of a few seconds**	**Consumption optimized. Adapted to battery powered modules**	• **Smart metering** • **Temperature rise**
C (« **c**ontinuous »)	Module **always listening**	Modules with a ***strong reception latency constraint*** (less than one second)	Adapted to **modules on the grid** or with **no power constraints**	• **Fleet management** • **Real Time Traffic Management**

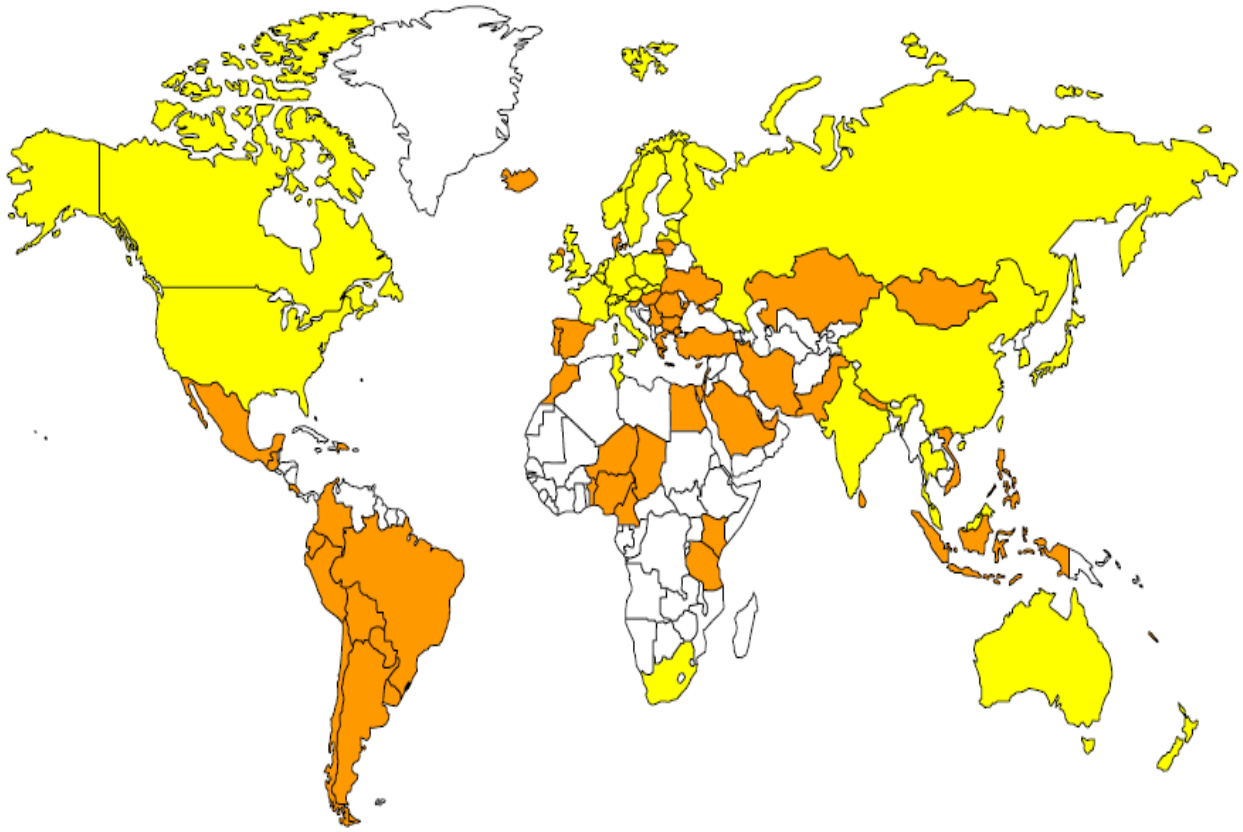
➔ **Any LoRa object can transmit and receive data**

Current state

Amsterdam: was the first city covered by LoRaWAN with only 10 Gateways for the whole city at $ 1200 per unit. Since then, several cities have followed the trend:

Since the end of 2016 , France is covered by LoRa

LoRa coverage map (June 2017)



- 42 Publicly Announced Operators
- 30 Alliance Member Operators
- 250+ on-going trials & city deployments
- 480+ members in the Alliance

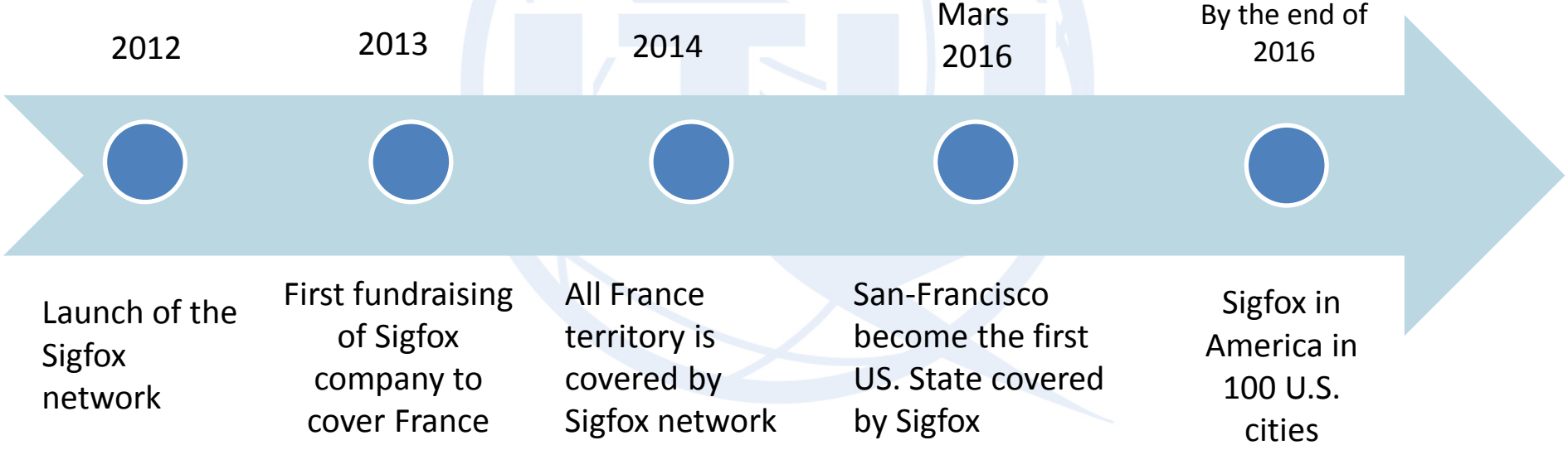
Legend:
- Publicly Announced
- Other Deployments

LoRa Alliance™

June 2017

ii. Sigfox

Roadmap

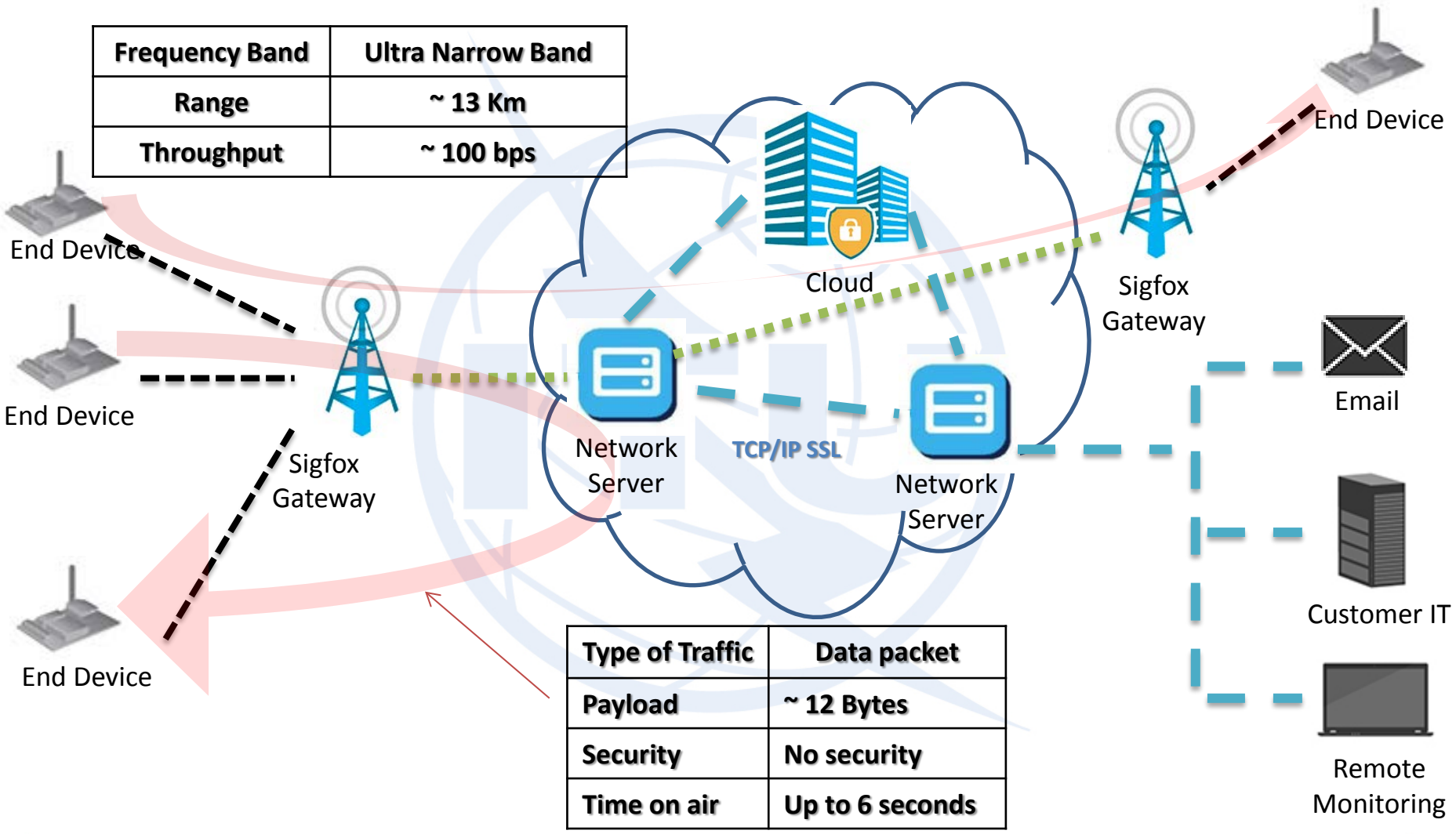

2012
2013
2014
Mars 2016
By the end of 2016
Launch of the Sigfox network
First fundraising of Sigfox company to cover France
All France territory is covered by Sigfox network
San-Francisco become the first US. State covered by Sigfox
Sigfox in America in 100 U.S. cities

Sigfox Overview

- **First LPWAN** Technology
- The physical layer based on an **Ultra-Narrow band wireless** modulation
- **Proprietary** system
- Low throughput (**~100 bps**)
- Low power
- Extended range (**up to 50 km**)
- **140 messages/day/device**
- Subscription-based model
- **Cloud platform** with Sigfox –defined API for server access
- **Roaming capability**

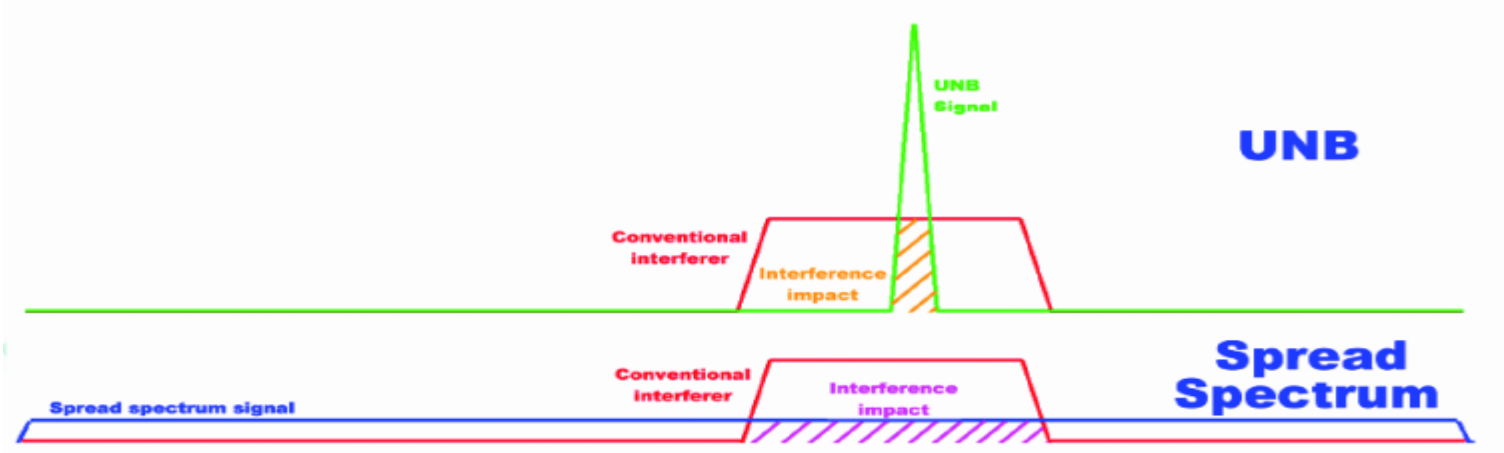
Architecture

Frequency Band	Ultra Narrow Band
Range	~ 13 Km
Throughput	~ 100 bps



Type of Traffic	Data packet
Payload	~ 12 Bytes
Security	No security
Time on air	Up to 6 seconds

- **Narrowband** technology
- Standard radio transmission method: binary phase-shift keying (**BPSK**)
- Takes very narrow parts of spectrum and changes the phase of the carrier radio wave to encode the data

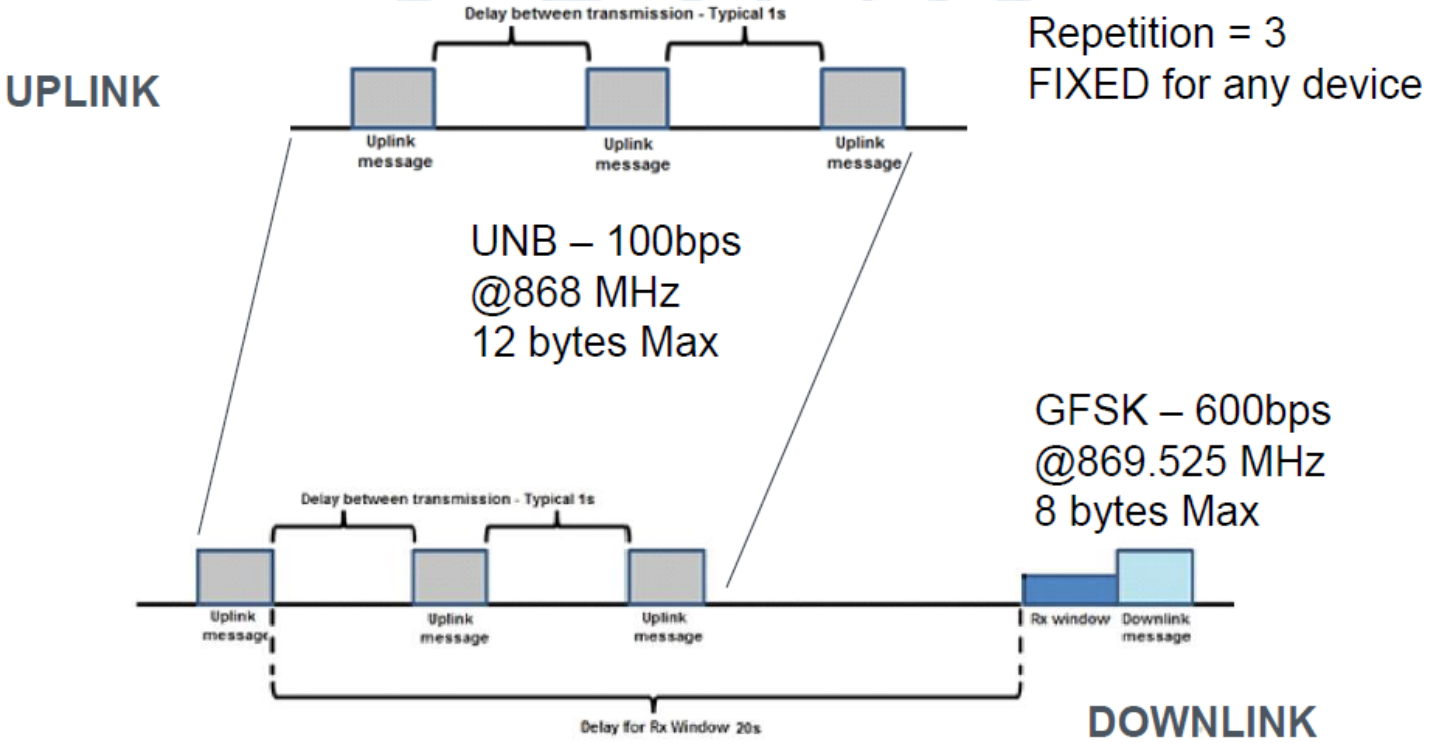


Frequency spectrum:

- 868 MHz in Europe
- 915 MHz in USA

Sigfox transmission

- Starts by an **UL transmission**
- Each message is transmitted 3 times
- A **DL message** can be sent (option)
- Maximum payload of **UL messages** = 12 data bytes
- Maximum payload of **DL messages** = 8 bytes



Current state

Covered countries **Covered areas** **End devices**

- SIGFOX LPWAN deployed in France, Spain, Portugal, Netherlands, Luxembourg, and Ireland , Germany, UK, Belgium, Denmark, Czech Republic, Italy, Mauritius Island, Australia, New Zealand, Oman, Brazil, Finland, Malta, Mexico, Singapore and U.S.

Sigfox company objectives:

- ✓ Cover **China** in 2017
- ✓ 60 countries covered by the end of 2018

SIGFOX
One network A billion dreams

iii. Weightless

WEIGHTLESS Overview

- **Low cost** technology to be readily integrated into machines
- Operates in an unlicensed environment where the interference caused by others cannot be predicted and must be avoided or overcome.
- Ability to operate effectively in unlicensed spectrum and is optimized for M2M.
- Ability to handle large numbers of terminals efficiently.

Roadmap

2012 — Starts specification

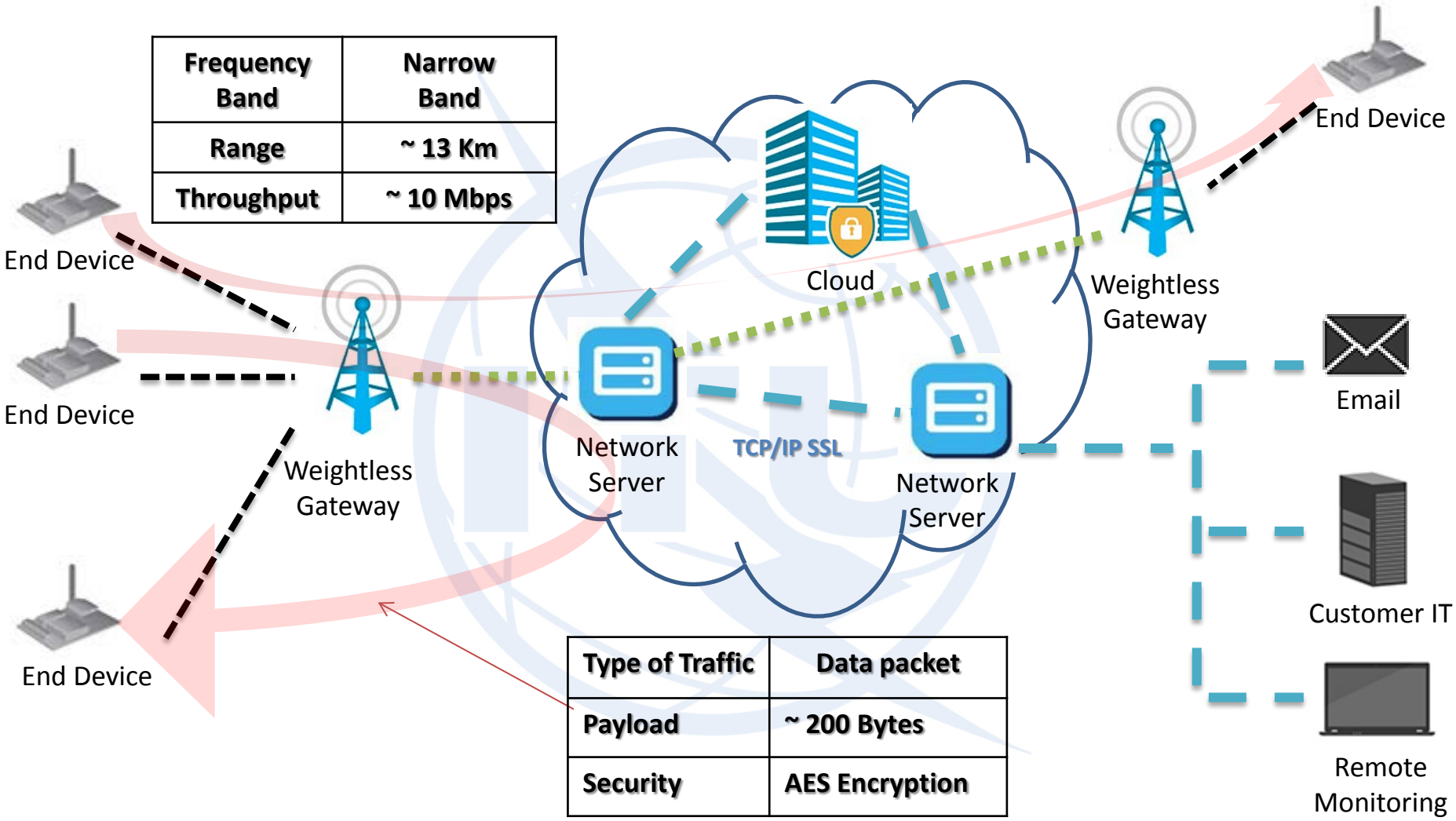
2012 — Creation of ***Weightless Special Interest Group***

2014 — **White Space spectrum** is coming - ratified in USA Q3 2012, UK expected Q2 2014

May 2015 — First version released

Jun 2015 — First Weightless-N network deployed in London

Architecture

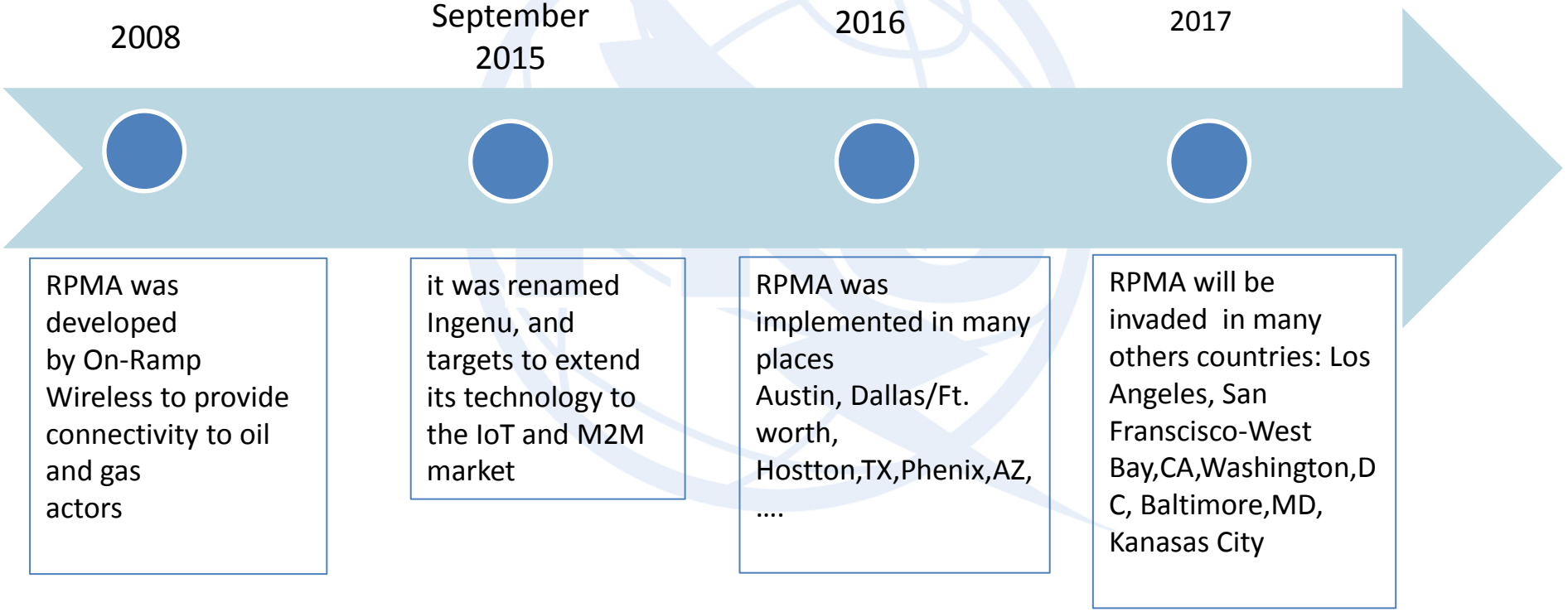


Different Weightless technologies

	Weightless-N	Weightless-P	Weightless-W
Communication	1-way	2-ways	2-ways
Range	5Km+	2Km+	5Km+
Battery life	10 years	3-8 years	3-5 years
Terminal cost	Very low	Low	Low-medium
Network cost	Very low	Medium	Medium
Data Rate	Up to 10 Mbps	Up to 100 Kbps	Up to 200 Kbps

iv. RPMA

Roadmap


2008
September 2015
2016
2017
RPMA was developed by On-Ramp Wireless to provide connectivity to oil and gas actors
it was renamed Ingenu, and targets to extend its technology to the IoT and M2M market
RPMA was implemented in many places Austin, Dallas/Ft. worth, Hostton,TX,Phenix,AZ, ….
RPMA will be invaded in many others countries: Los Angeles, San Franscisco-West Bay,CA,Washington,DC, Baltimore,MD, Kanasas City

INGENU RPMA overview

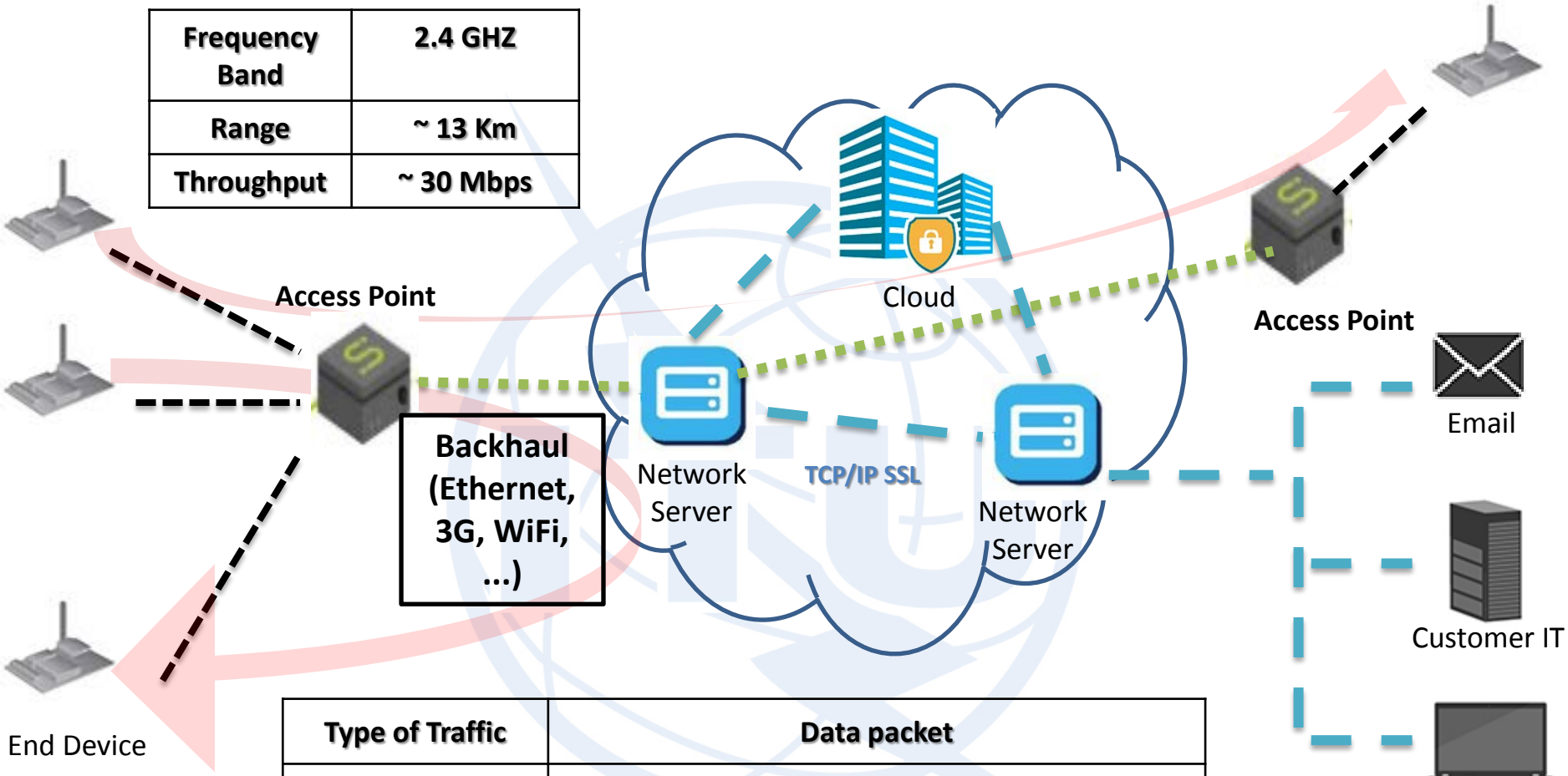
- Random Phase Multiple Access (RPMA) technology is a low-power, wide-area channel access method used exclusively for machine-to-machine (M2M) communication
- RPMA uses the popular 2.4 GHz band
- Offer extreme coverage
- High capacity
- Allow handover (channel change)
- Excellent link capacity

- RPMA is a Direct Sequence Spread Spectrum (DSSS) using:
  - Convolutional channel coding, gold codes for spreading
  - 1 MHz bandwidth
  - Using **TDD frame** with power control:
    - **Closed Loop Power Control:** the access point/base station measures the uplink received power and periodically sends a one bit indication for the endpoint to turn up transmit power (1) or turn down power (0).
    - **Open Loop Power Control:** the endpoint measures the downlink received power and uses that to determine the uplink transmit

TDD frame

INGENU RPMA architecture

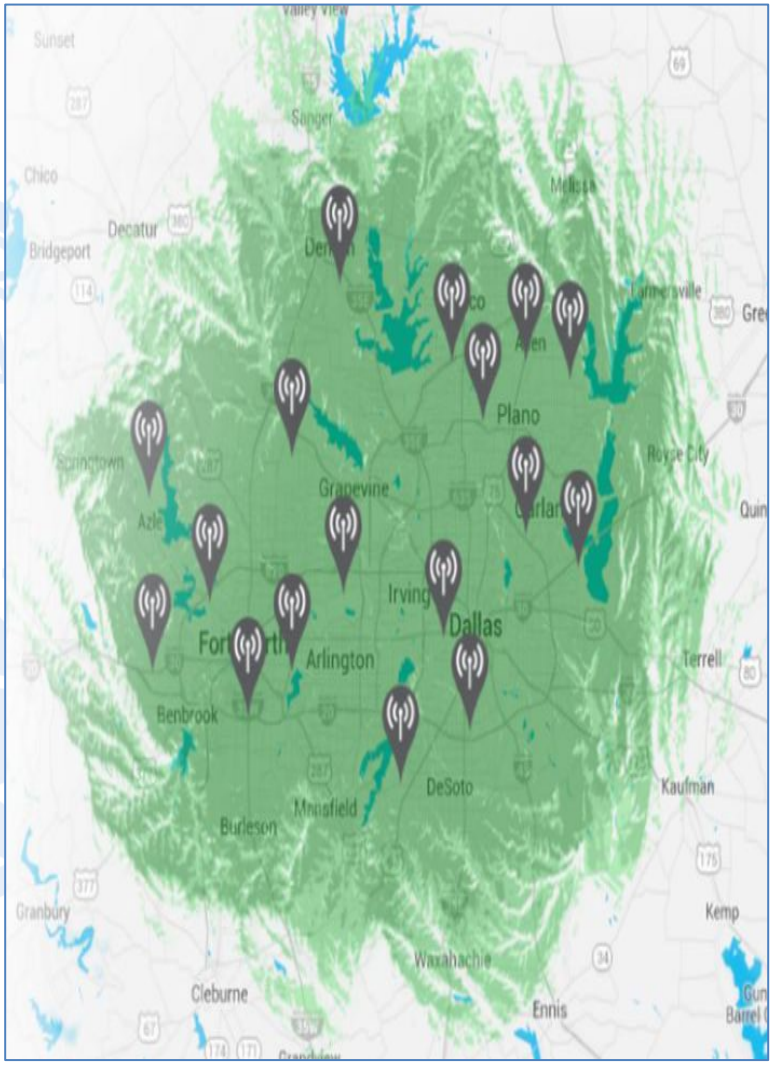
Frequency Band	2.4 GHZ
Range	~ 13 Km
Throughput	~ 30 Mbps



Type of Traffic	Data packet
Payload	~ 16 Bytes (one end point) ~ 1600 Bytes (for 1000 end points
Security	AES Encryption

RPMA's current and future presence

- Heavy presence in Texas, with networks in Dallas, Austin, San Antonio, Houston, and large white space areas.
- Ingenu offer the connectivity to more **50% of the Texas state population**.
- Three densely populated Texas markets are served by only **27 RPMA access points**
- RPMA currently provides **more than 100,000 square miles** of wireless coverage for a host of IoT applications.
- Ingenu will be expanding its coverage to dozens of cities in the next few years.



RPMA's current and future presence

Currently live	Coverage Rollout Q3	Coverage ROLLOUT Q4 2016	Coverage planned 2017
• Austin,TX • Dallas/Ft.worth, TX • Hostton,TX • Phenix,AZ • Riverside,CA • San Antonio,TX • San Diego,CA	• Columbus, OH • Indianapolis,IN	• Atlanta,GA • Jacksonville,FL • Miami,FL • Oriando,FL • New Orleans,LA • Charlotte,NC • Albuquerque • Memphis,TN • Nashville,TN EL paso,TX • Salt Lake City,UT • Richmound, • Virginia beach,VA	• Los Angeles,CA • San Franscisco-West Bay,CA • Washington,DC • Baltimore,MD • Kanasas City • Greeensboro,NC • Las Vegas,NV • Oklahorma City, OK • And many more cities

A. Fixed & Short Range

B. Long Range technologies

1. Non 3GPP Standards (LPWAN)

2. 3GPP Standards

2. 3GPP Standards

i. LTE-M

ii. NB-IOT

iii. EC-GSM

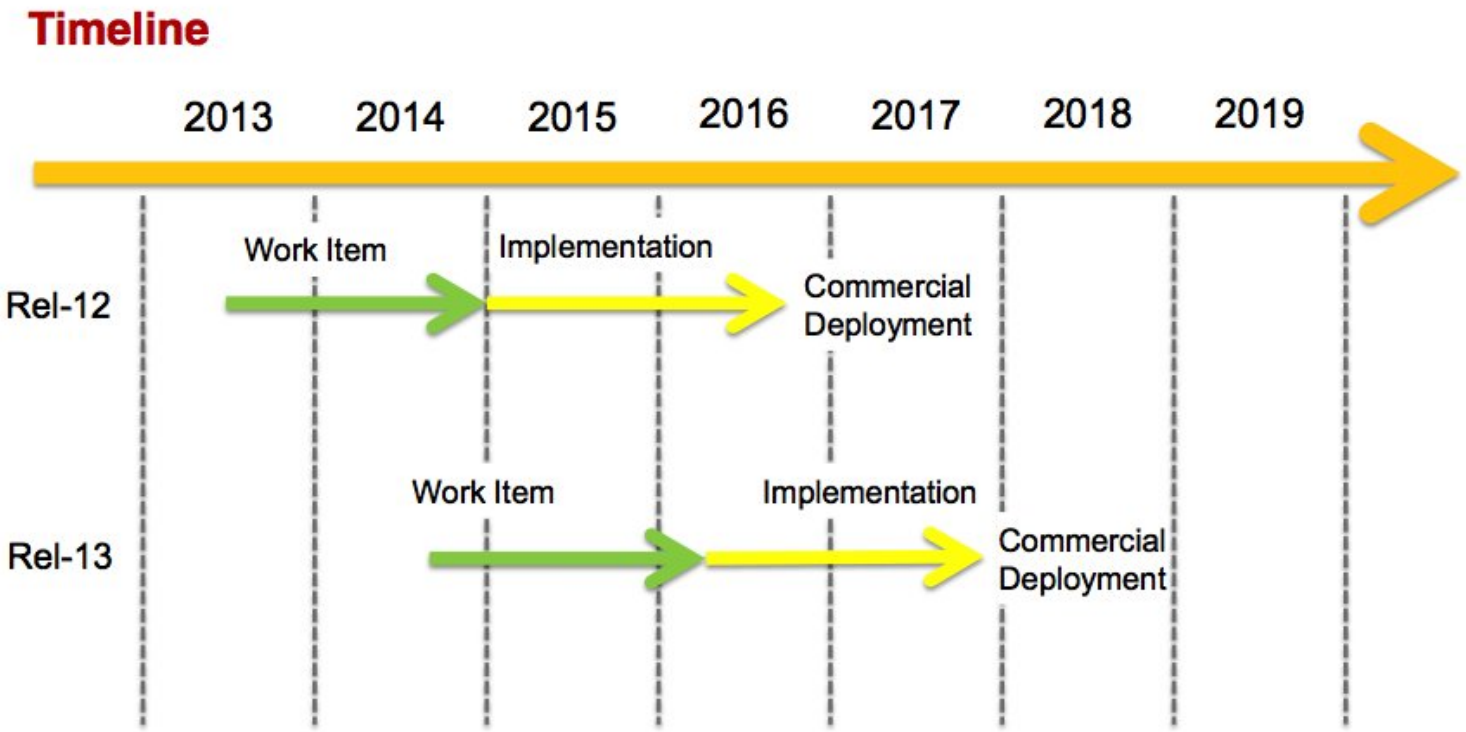
iv. 5G and IoT

i. LTE-M

- **Evolution of LTE** optimized for IoT
- **Low power consumption** and **extended autonomy**
- **Easy deployment**
- **Interoperability** with LTE networks
- Low overall **cost**
- Excellent coverage: up to **11 Km**
- Maximum throughput: ≤ **1 Mbps**

LTE-M

Roadmap



- First released in Rel.1in 2 Q4 2014
- Optimization in Rel.13
- Specifications completed in Q1 2016
- Available in 2017 (?)

LTE to LTE-M

3GPP Releases	8 (Cat.4)	8 (Cat. 1)	12 (Cat.0) LTE-M	13 (Cat. 1,4 MHz) LTE-M
Downlink peak rate (Mbps)	150	10	**1**	**1**
Uplink peak rate (Mbps)	50	5	**1**	**1**
Number of antennas (MIMO)	2	2	**1**	**1**
Duplex Mode	Full	Full	**Half**	**Half**
UE receive bandwidth (MHz)	**20**	**20**	**20**	**1.4**
UE Transmit power (dBm)	**23**	**23**	**23**	**20**

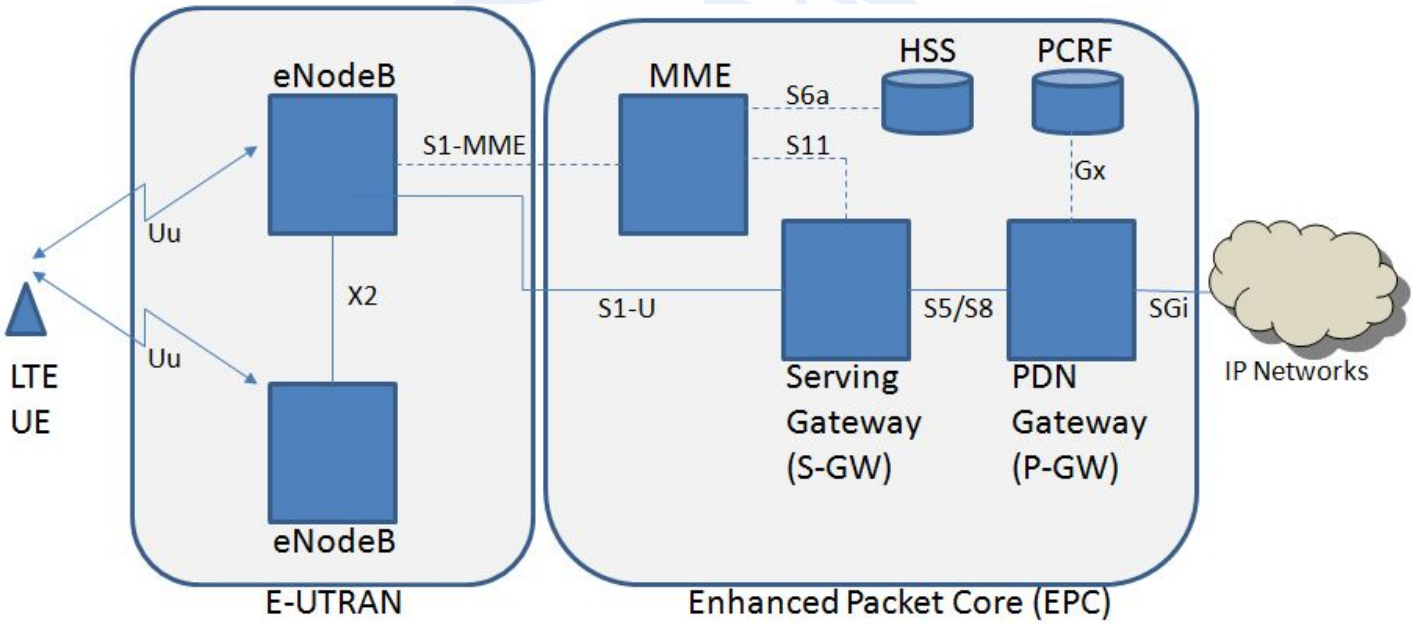
Release 12

- New category of UE ("Cat-0"): **lower complexity** and low cost devices
- **Half duplex FDD** operation allowed
- **Single receiver**
- Lower data rate requirement (Max: 1 Mbps)

Release 13

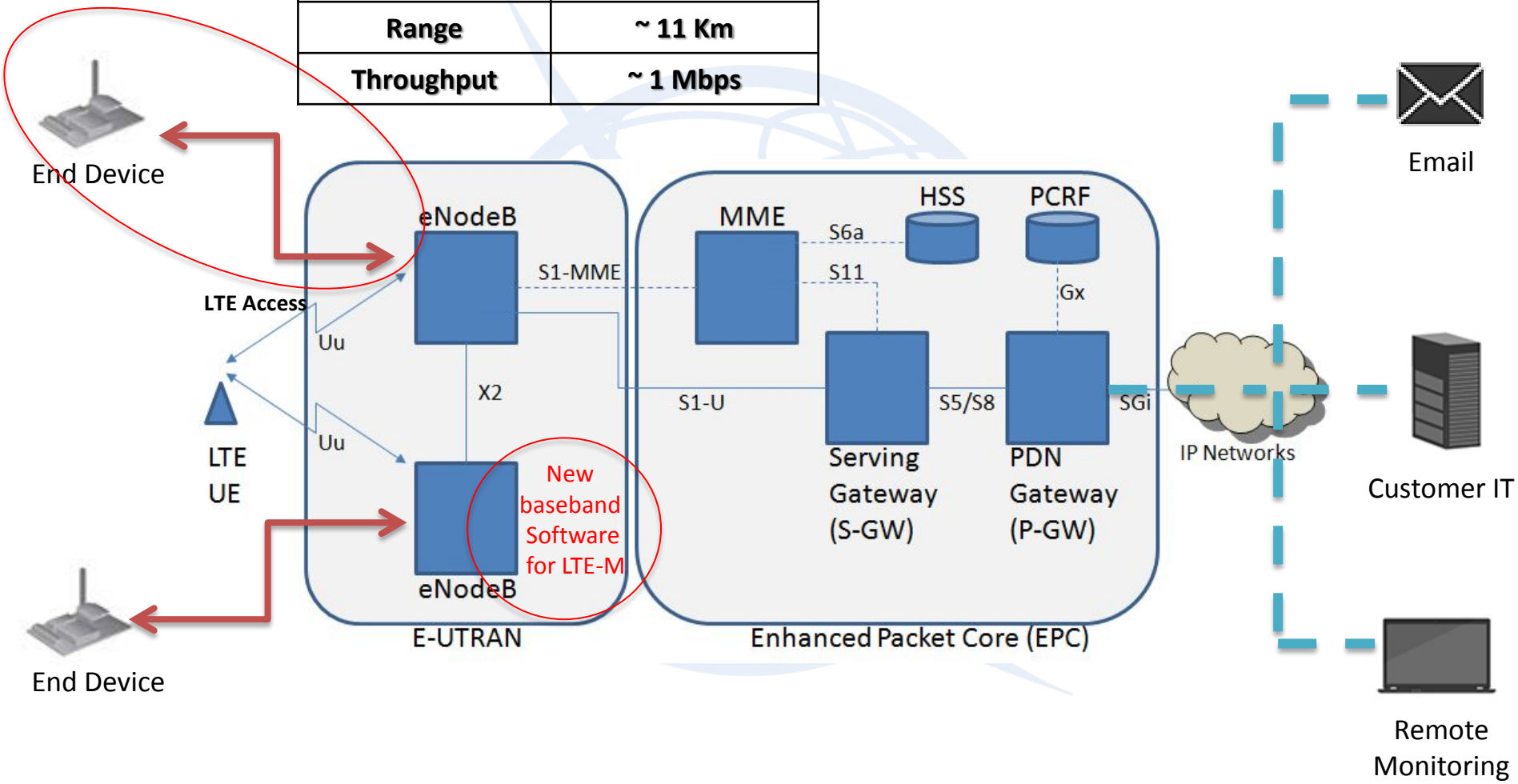
- Reduced receive bandwidth to 1.4 MHz
- **Lower device power** class of 20 dBm
- 15dB additional link budget: **better coverage**
- More **energy efficient** because of its extended discontinuous repetition cycle (eDRX)

Present LTE Architecture

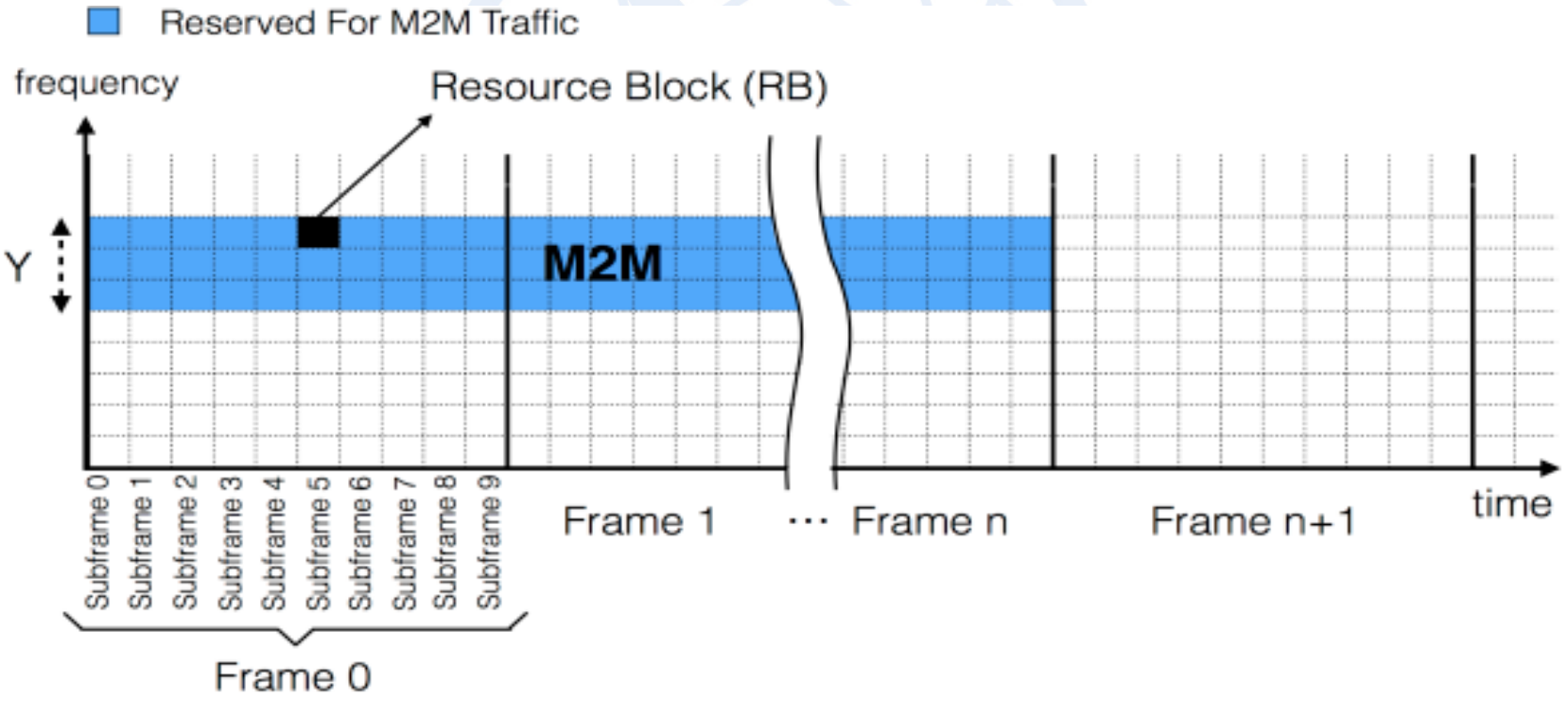


Architecture

Frequency Band	Narrow Band
Access	LTE-M
Range	~ 11 Km
Throughput	~ 1 Mbps



- **Licensed Spectrum**
- **Bandwidth: 700-900 MHz for LTE**
- **Some resource blocks allocated for IoT on LTE bands**



ii. NB-IOT

Current state

A GLOBAL INITIATIVE

April 2014	May 2014	Mars 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

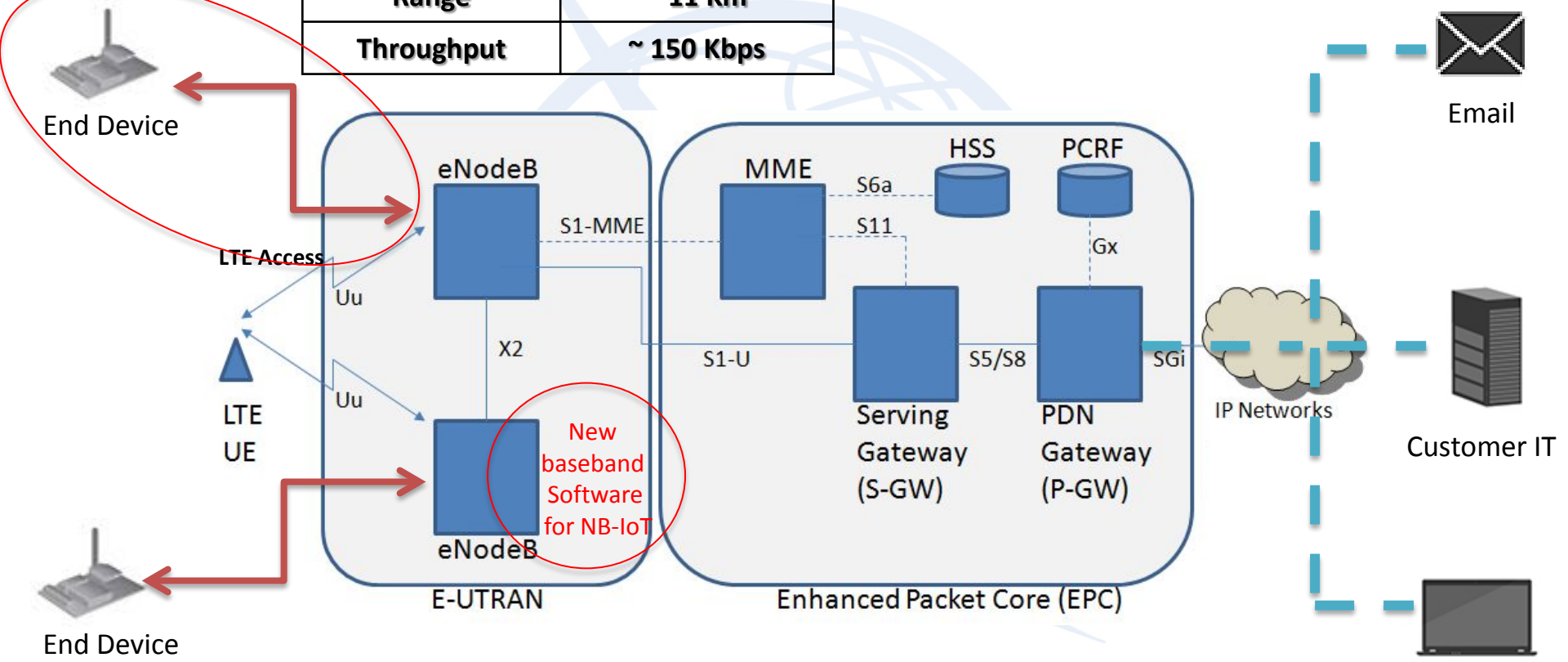
Evolution of LTE-M

- **Narrowband** radio interface
- Part of RAN **Rel. 13**
- Standardization started in Q4 2015 and specifications completed Q2 2016
- **Improvements over LTE-M**
- Reduced device **bandwidth of 200 kHz** in downlink and uplink
- Reduced throughput based on **single PRB operation**
- Provide **LTE coverage improvement** corresponding to 20 dB.

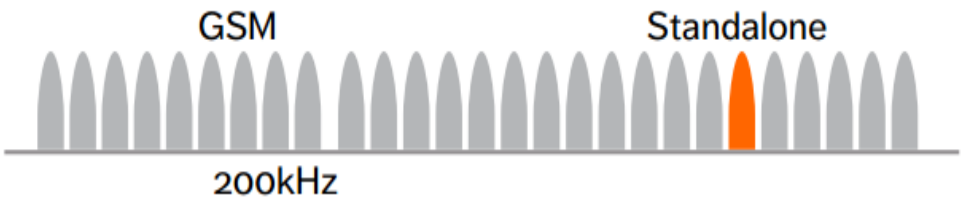
NB-IoT

Architecture

Frequency Band	Ultra Narrow Band
Range	~ 11 Km
Throughput	~ 150 Kbps



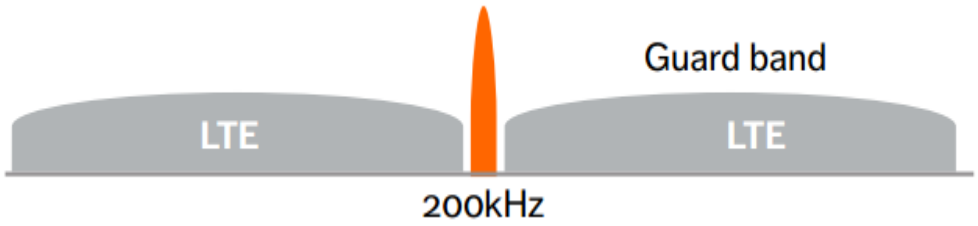
- Designed with a number of deployment options for **GSM , WCDMA** or **LTE** spectrum to achieve spectrum efficiency.
- Use **licensed spectrum**.



Stand-alone operation

Dedicated spectrum.

Ex.: By **re-farming GSM channels**



Guard band operation

Based on the unused RB within a LTE carrier's **guard-band**

In-band operation

Using **resource blocks** within a normal LTE carrier

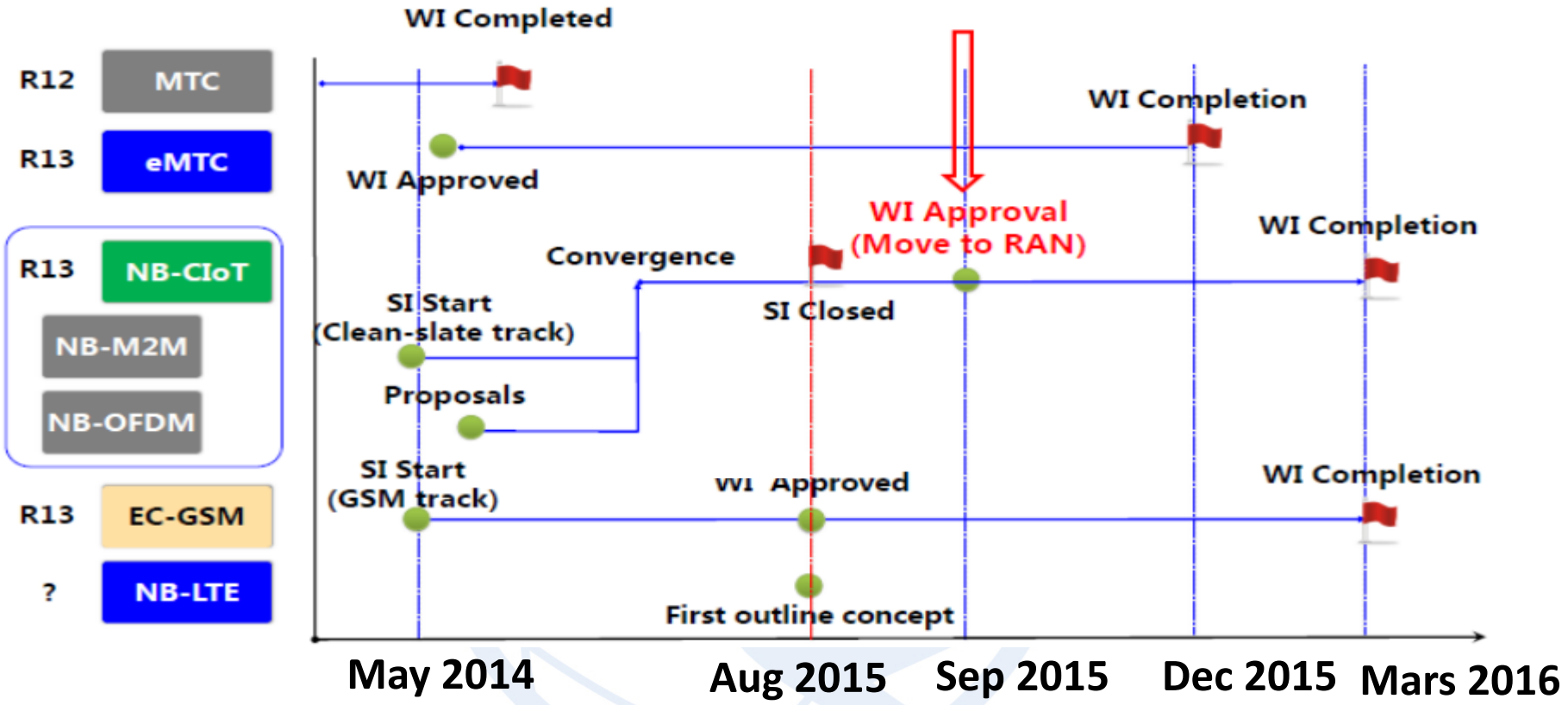
LTE-M to NB-IoT

3GPP Release	12 (Cat.0) LTE-M	13(Cat. 1,4 MHz) LTE-M	13(Cat. 200 KHz) NB-IoT
Downlink peak rate	1 Mbps	1 Mbps	**200 kbps**
Uplink peak rate	1 Mbps	1 Mbps	**144 kbps**
Number of antennas	1	1	1
Duplex Mode	Half	Half	Half
UE receive bandwidth	20 MHz	1.4 MHz	**200 kHz**
UE Transmit power (dBm)	23	20	**23**

- **Reduced throughput** based on single PRB operation
- Enables **lower processing and less memory** on the modules
- 20dB additional link budget ➔ **better area coverage**

iii. EC-GSM

Roadmap



2020: 15% connections excluding cellular IoT will still be on 2G in Europe and 5% in the US (*GSMA predictions*).
GPRS is responsible for most of today's M2M communications

EC-GSM

EC-GSM-IoT Objectives: Adapt and leverage existing 2G infrastructure to provide efficient and reliable IoT connectivity over an extended GSM Coverage

- **Long battery life**: ~10 years of operation with 5 Wh battery (depending on traffic pattern and coverage extension)
- **Low device cost** compared to GPRS/GSM device
- **Variable data rates:**
  - GMSK: ~350bps to 70kbps depending on coverage extension
  - 8PSK: up to 240 kbps
- Support for massive number of devices: ~50.000 devices per cell
- Improved security adapted to IoT constraint.
- Leverage on the GSM/GPRS maturity to allow fast time to market and low cost

❑ Deployment

- ➢ To be deployed in existing GSM spectrum without any impact on network planning.
- ➢ EC-GSM-IoT and legacy GSM/GPRS traffic are dynamically multiplexed.
- ➢ Reuse existing GSM/GPRS base stations thanks to software upgrade.

❑ Main PHY features:

- ➢ New “EC” logical channels designed for extended coverage
- ➢ Repetitions to provide necessary robustness to support up to 164 dB MCL
- ➢ Fully compatible with existing GSM hardware design (Base station and UE)
- ➢ IoT and regular mobile traffic are share GSM time slot.

❑ **Coverage Extension:** 4 different coverage class

	Channels	CC1	CC2	CC3	CC4
DL	MCL(dB)	149	157	161	164
	EC-CCCH	1	8	16	32
	EC-PACCH	1	4	8	16
	EC-PDTCH	1	4	8	16
UL	MCL(dB)	152	157	161	164
	EC-CCCH	1	4	16	48
	EC-PACCH	1	4	8	16
	EC-PDTCH	1	4	8	16

➢ Beacon and Synchronization channel don't use coverage class

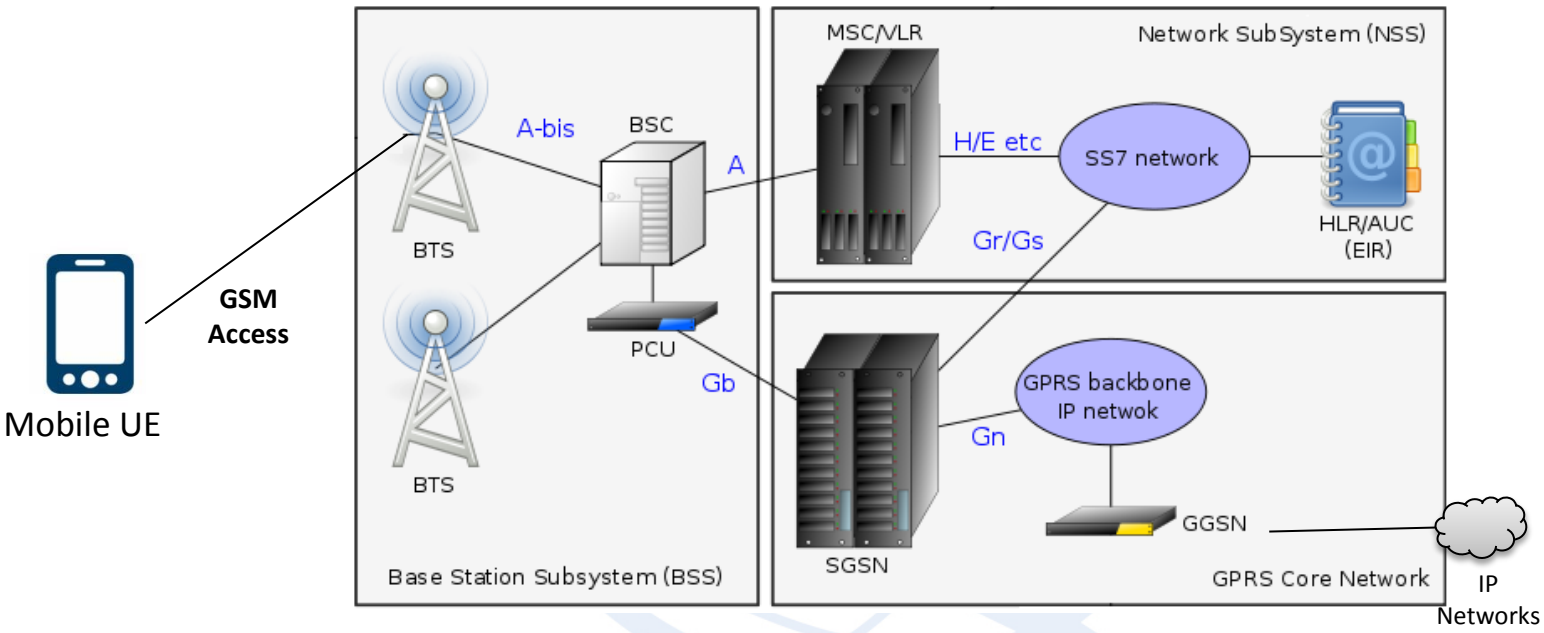
- EC-BCCH: always repeated 16 times
- EC-SCH: always repeated 28 times
- FCCH: legacy FCCH is used.

Mapped on TS 1

❑ Other features:

- Support of SMS and Data, but no voice
- Extended DRX (up to ~52min) [GSM DRX ~11 min]
- Optimized system information (i.e. no inter-RAT support)
- Relaxed idle mode behavior (e.g. reduced monitoring of neighbor cells)
- 2G security enhancements (integrity protection, mutual authentication, mandate stronger ciphering algorithms)
- NAS timer extensions to cater for very low data rate in extended coverage
- Storing and usage of coverage level in SGSN to avoid unnecessary repetitions over the air
- Optional mobility between GSM and EC-GSM

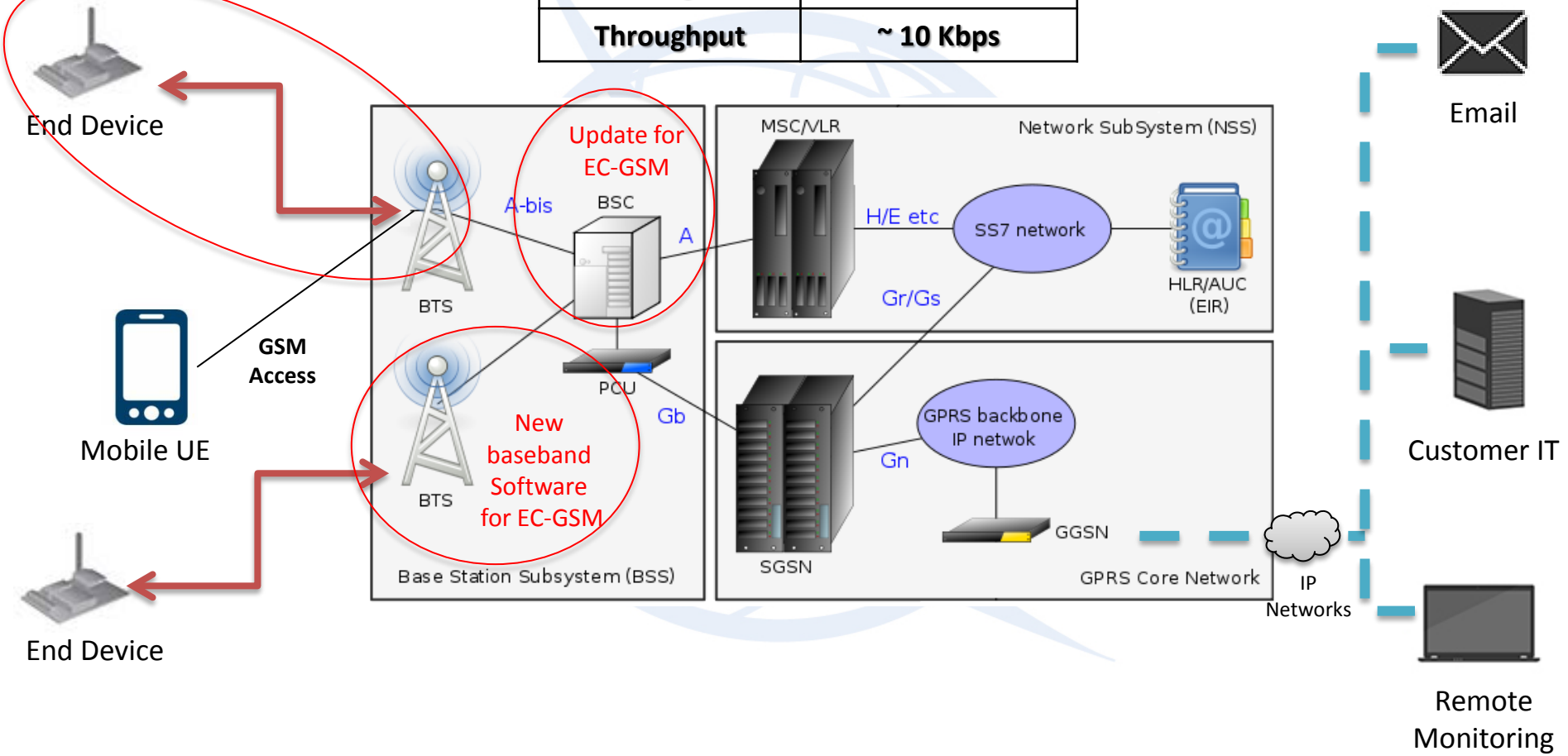
Actual GSM/GPRS Architecture



2G-based NB-IoT networks should come at the end of 2017, with LTE following around 12 months later

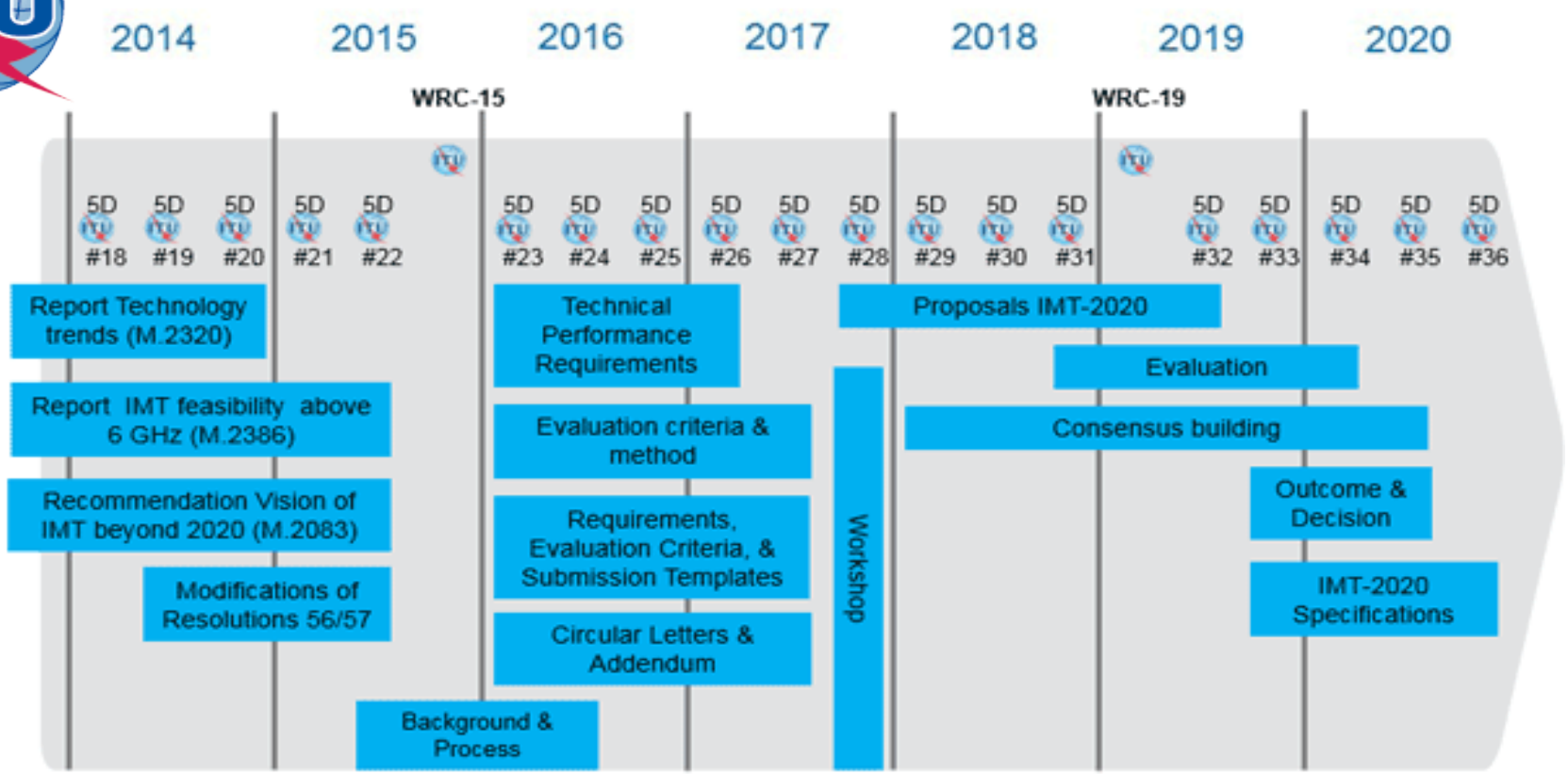
Architecture

Access	EC-GSM
Frequency Band	Narrow Band
Range	~ 15 Km
Throughput	~ 10 Kbps



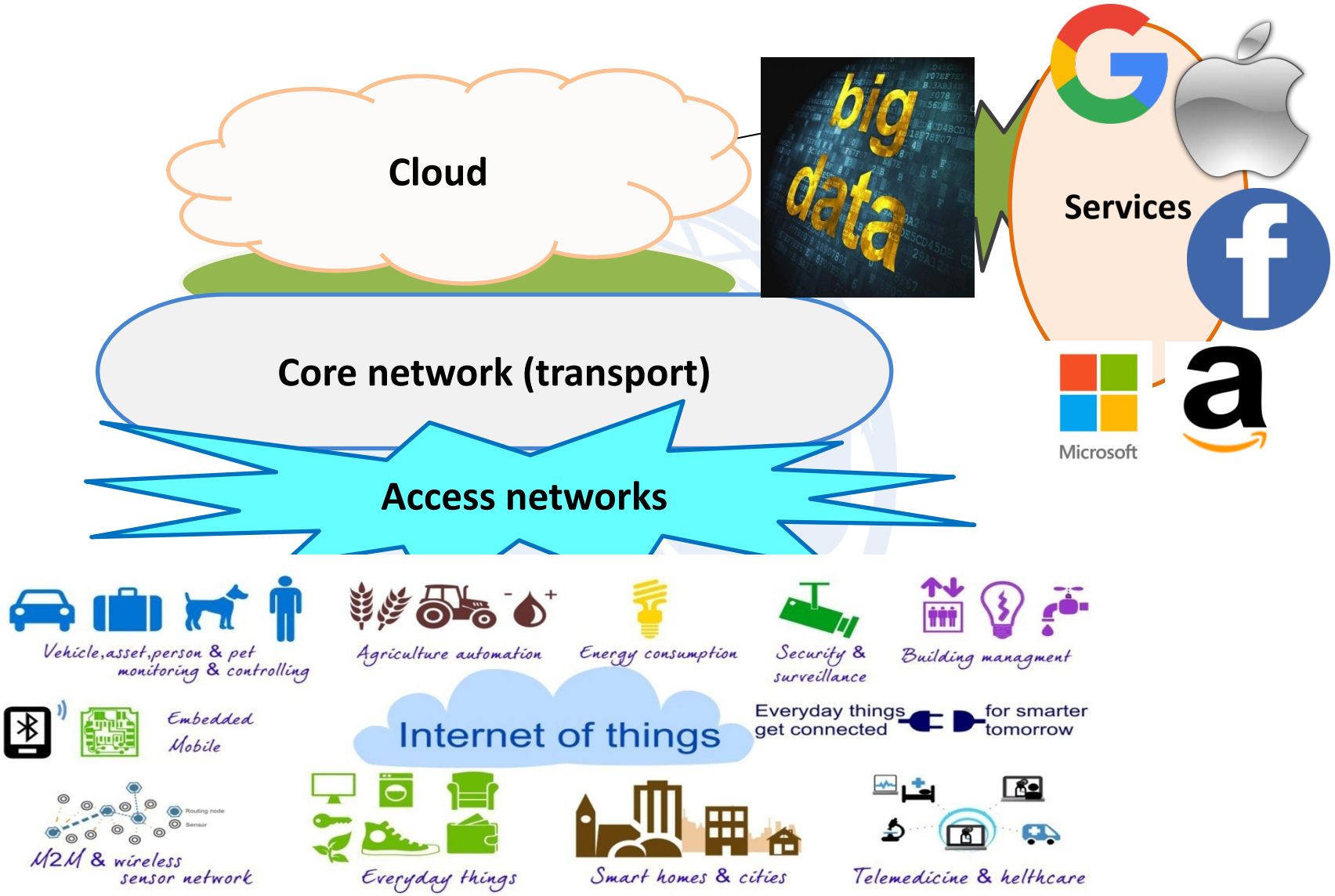
iv. 5G and IoT

ITU-R WP5D



- **Initial technology submission: Meeting 32 (June 2019)**
- **Detailed specification submission: Meeting 36 (October 2020)**

Vision of 5G


Cloud
big data
Services
Core network (transport)
Access networks
Microsoft
Vehicle,asset,person & pet monitoring & controlling
Agriculture automation
Energy consumption
Security & surveillance
Building managment
Embedded Mobile
Internet of things
Everyday things get connected for smarter tomorrow
M2M & wireless sensor network
Routing node
Sensor
Everyday things
Smart homes & cities
Telemedicine & helthcare

Thank You