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LoRaWAN - A Low Power WAN Protocol for Internet of Things: a Review and Opportunities

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Introduction

- > 25 billion devices by 2020

- Bluetooth & Wi-Fi not well suited for many scenarios
  < 100m, high throughput & power consumption

- 3G/4G cellular not well suited as well
  $ hardware, $ SIM's/plans, high battery inefficiency, available spectrum.

- Endpoints costs need to be low
- Must be small for integration into everything
- Conserve wireless spectrum – duty cycle policy
- Conservative power – run on a battery – i.e. mA
- Support really low bandwidth for Bytes not MB of data
- $ network plans

LoRaWAN

The emergence for IoT introduces new challenges that cannot be addressed by the current available connectivity protocol, such as:

- **Bandwidth/Data Rate:** In LoRaWAN, the data rate is selected by a trade-off between the communication range and the duration of the message.

- **Battery Life:** To maximize the life of the final device batteries, the LoRaWAN server controls the RF output and an output rate through an adaptive scheme for each end device.

- **Range:** LoRaWAN obtains about 2-5 km of coverage range in urban perimeters and about 45 km in rural areas.

- **Latency:** There is a trade-off between downlink communication latency versus battery life time that can be resolved through QoS classes in a LoRaWAN device.

- **Throughput:** Data rates between 290 bps and 50 kbps.

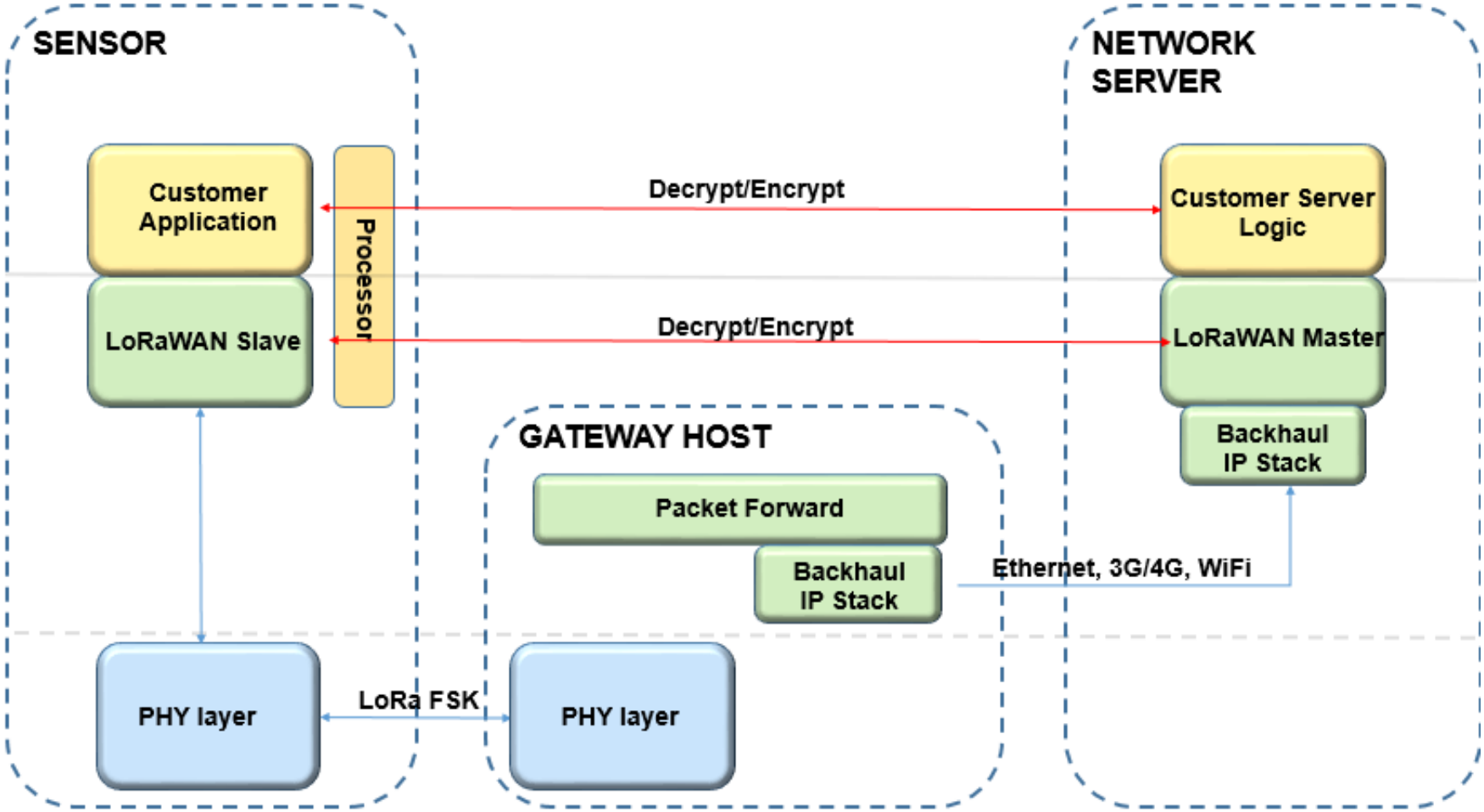
LoRaWAN Protocol

LoRa pursues an approach based on the following two distinct layers:

i) a physical layer (LoRa), which employs a radio modulation technique called CSS (Chirp Spread Spectrum);

ii) a MAC layer protocol (LoRaWAN is an open standard) that provides access to LoRa architecture.

LoRaWAN Protocol



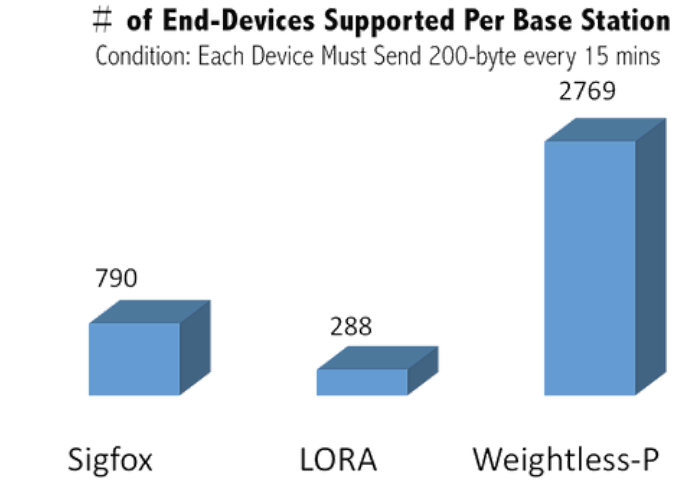
LoRaWAN Entities

End-devices perform the communication gateways using LoRa and LoRaWAN technologies.

Gateways (i.e., base stations) dispatch the LoRaWAN frames from the end devices to a network server using a back-haul interface with higher throughput, usually via Ethernet, 3G/4G, satellite or Wi-Fi.

The **Network Server** decodes the packets sent by the devices, performing security checks and adaptive data rate, thus generating the packets that should be sent back to the devices.

Each **Application** receives data from the network server. It should decode the security packets and uses the information to decide the action in the application.



Source: **Do LoRa Low-Power Wide-Area Networks Scale?**

Critical Factors and Characteristics

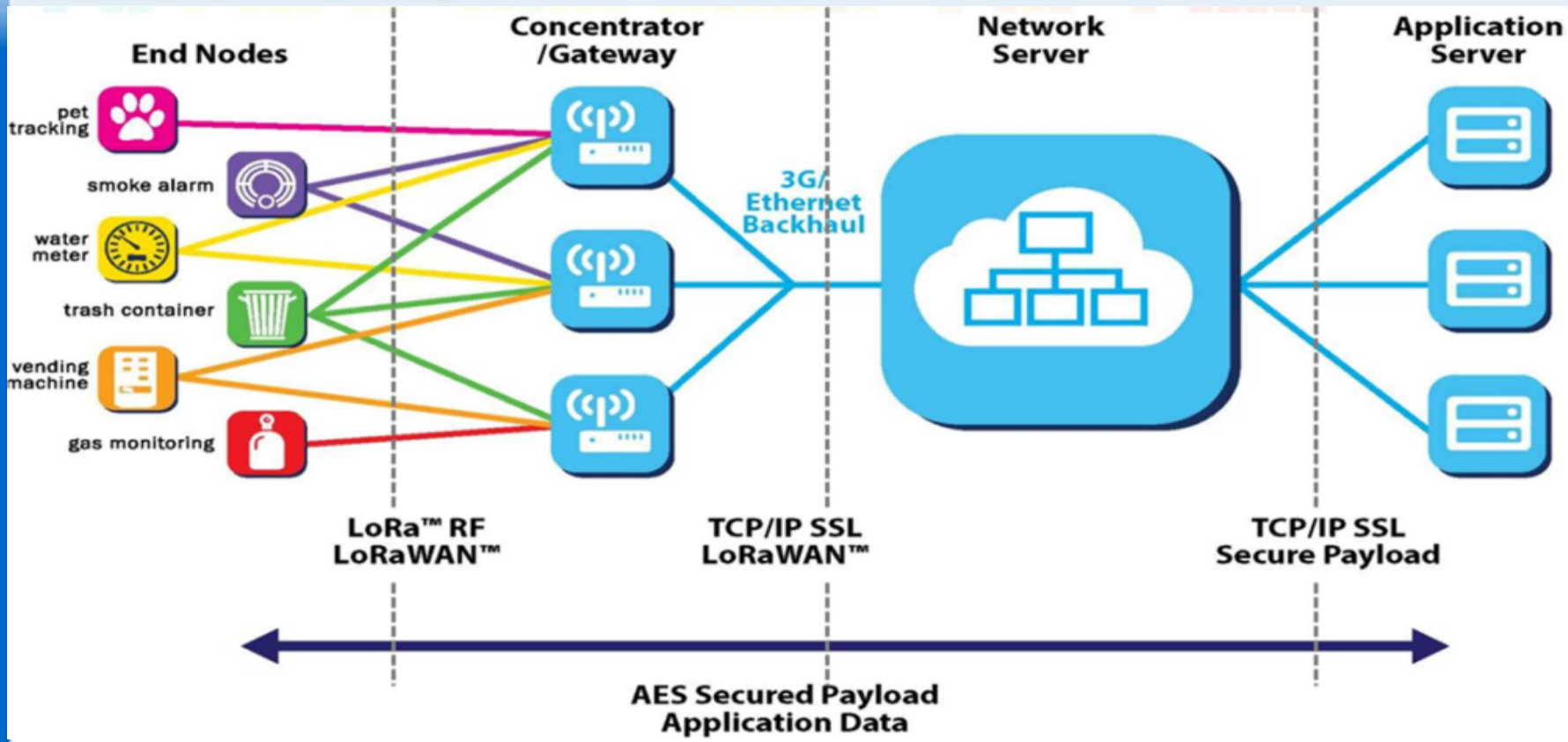
The most **critical factors** in a LPWAN are:

- Network architecture;
- Communication range;
- Battery lifetime (low power);
- Robustness to interference;
- Network capacity (maximum number of nodes in a network);
- Network security;
- One-way *vs* two-way communication;

TABLE I
LoRaWAN Main Characteristics.

Characteristic	LoRaWAN
Topology	Star on Star
Modulation	SS Chirp
Data Rate	290bps - 50kbps
Link Budget	154 dB
Packet Size	20-256 bytes
Battery lifetime	8 ~ 10 years
Power Efficiency	Very High
Security/Authentication	Yes (32 bits)
Range	2-5 km urban 15 km suburban 45 km rural
Interference Immunity	Very High
Scalability	Yes
Mobility/Localization	Yes

LoRaWAN Network



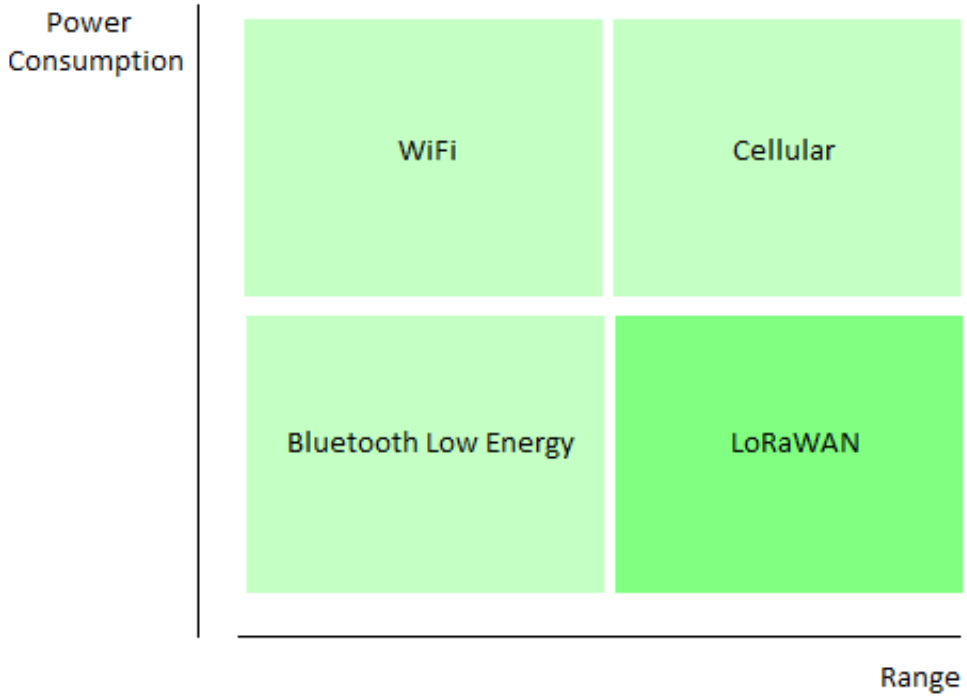
- **Long range star network (same architecture as cellular)**
  - Easy to deploy/maintain, reduces cost of infrastructure, optimizes battery lifetime
- **A professionally, centrally managed multi-tenant network**
  - Enables customers to focus on end-node design/application not in network management
  - Reduces costs and complexity for all segments of the market

Battery Lifetime

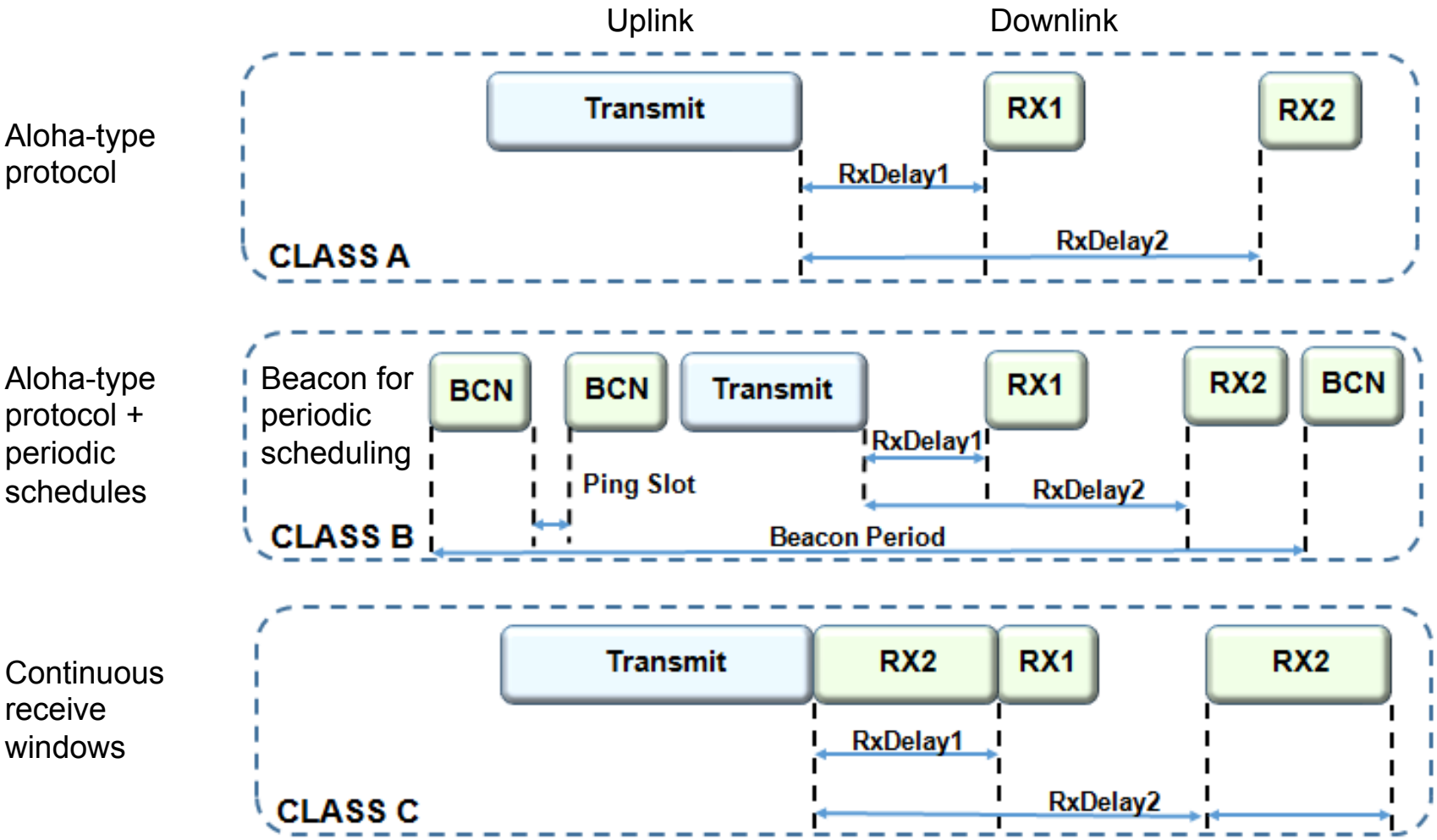
Synchronization network usually **consumes** significant **energy**. In LoRaWAN, nodes are asynchronous and communicate via **events** or in pre-**scheduled** opportunities.

The **ADR** (Adaptive Data Rate) scheme is used for LoRa network infrastructures for manage the individual **data rates** and **maximize** the **battery life** of **each connected device** through RF output.

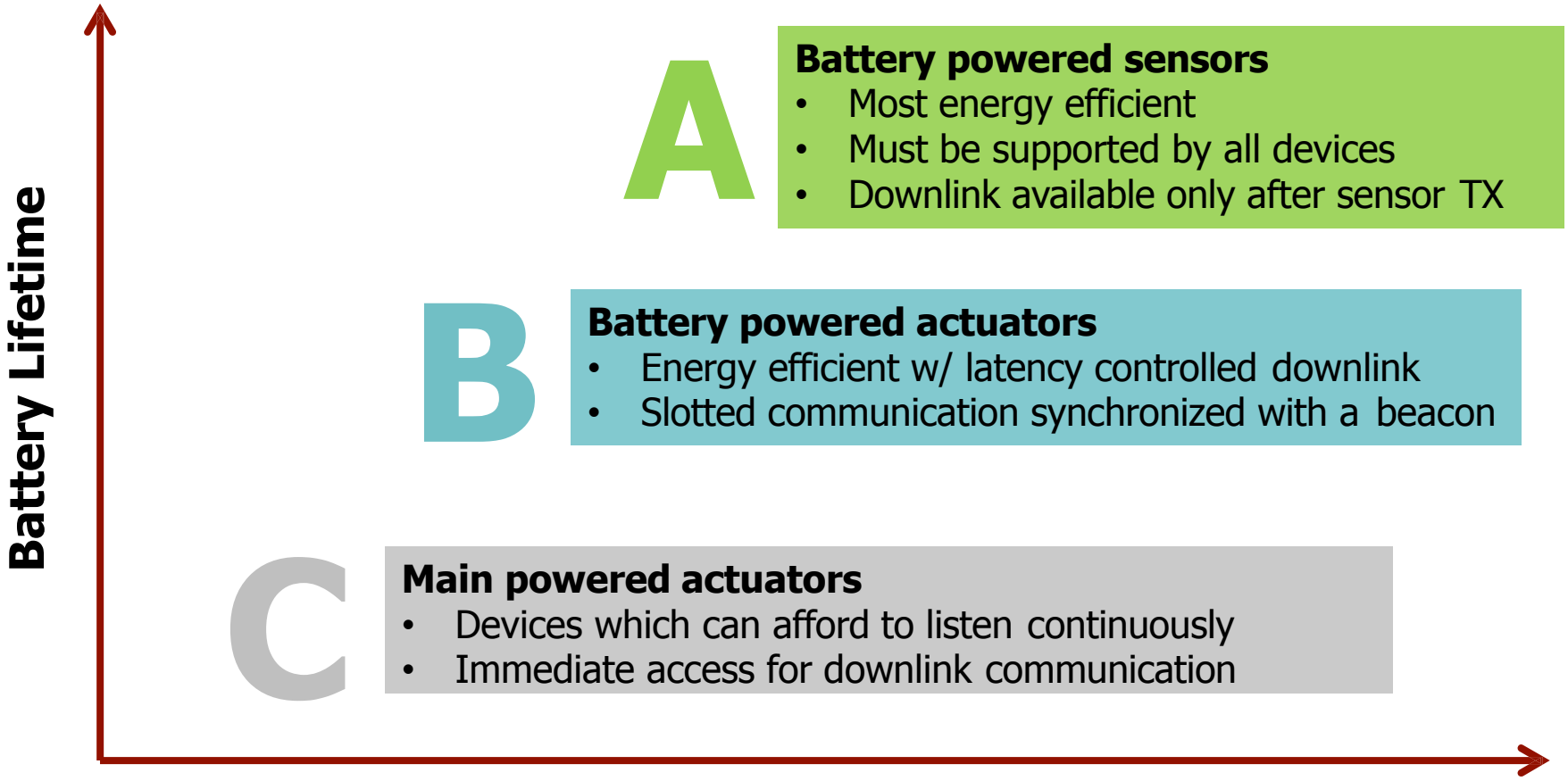
A recent research study performed by **Scientific Research Publishing**, Inc revealed that **LoRaWAN** showed an **advantage of 3 up to 5-fold in the energy economy compared** to all the **others LPWAN** technologies.



LoRaWAN Protocol End-Device Classes



LoRaWAN Protocol Device Classes



Security

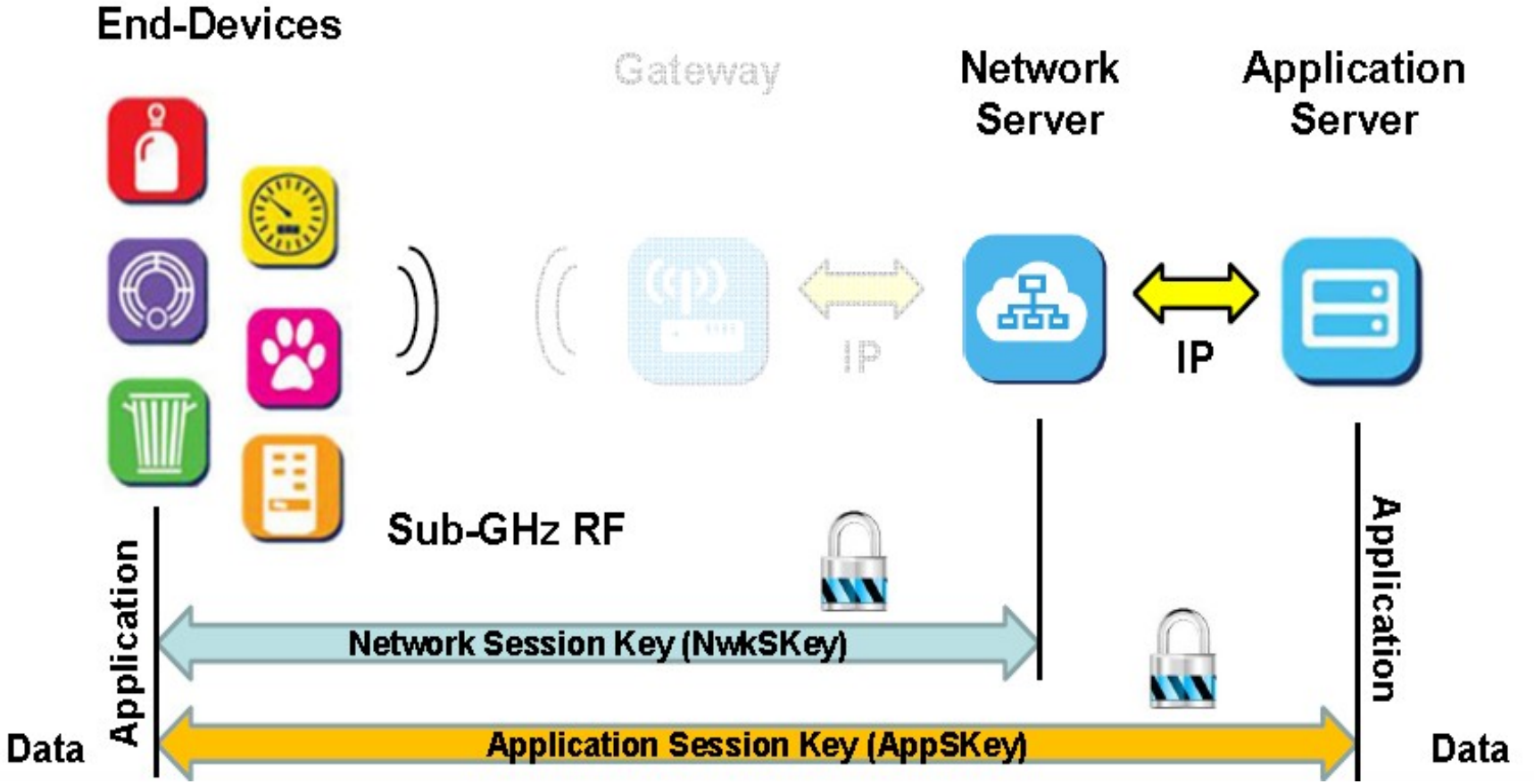
LoRaWAN considers two layers of security, one for the network and another for the applications.

Each end-device has key assignments done by device manufacturers or the application owners. **Other systems use** a **single key** for **encryption** and **authentication**, compared to LoRaWAN.

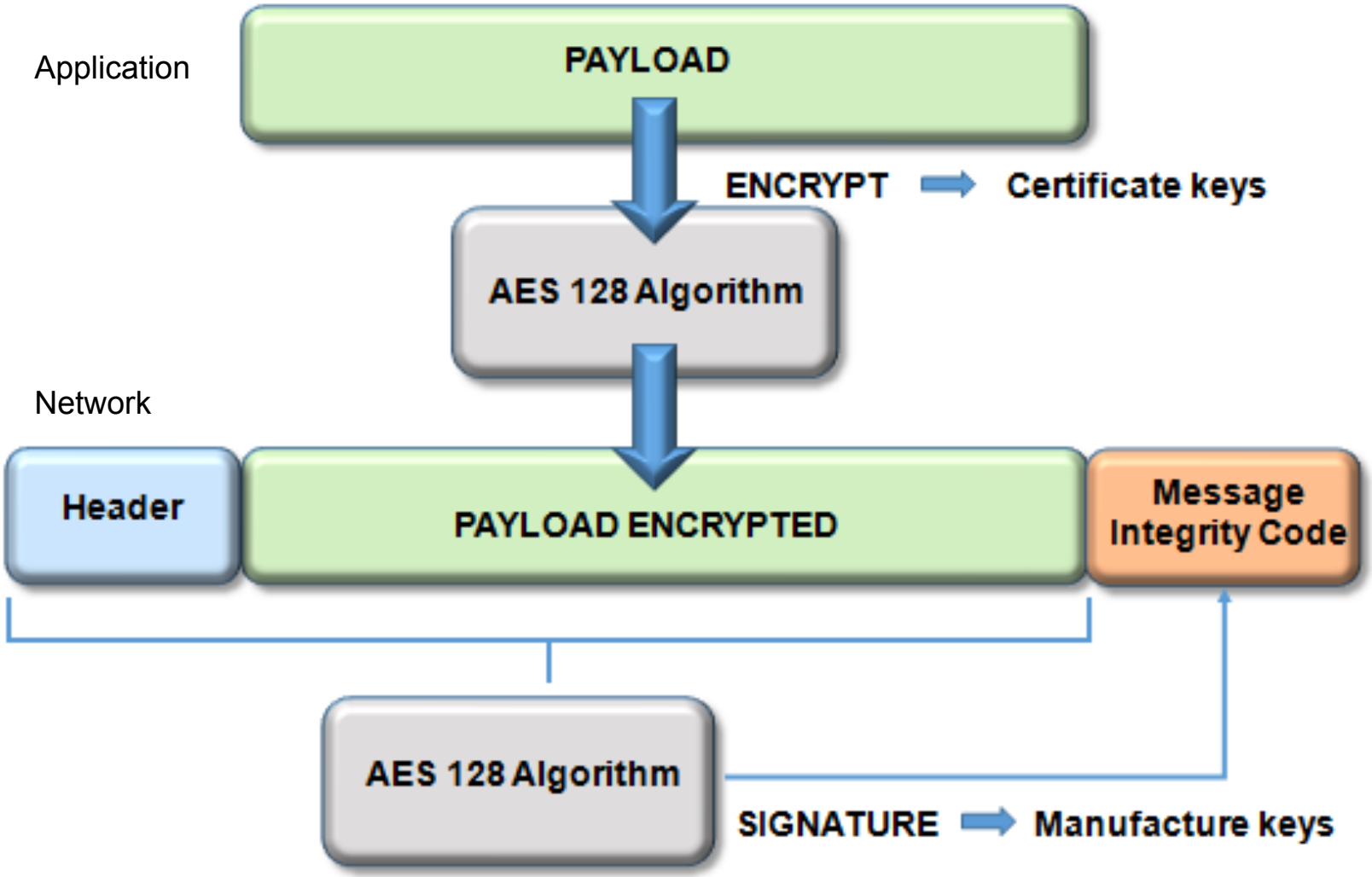
Authentication and encryption are separate, so it is **possible** to **authenticate packets** and **provide integrity protection**.

Security

Logical Data Flow (Programmer's Model)



Security


Application
PAYLOAD
ENCRYPT
Certificate keys
AES 128 Algorithm
Network
Header
PAYLOAD ENCRYPTED
Message Integrity Code
AES 128 Algorithm
SIGNATURE
Manufacture keys

Comparison to other LPWANs

Feature	LoRaWAN	Sigfox	NB-IoT	LTE-M
Modulation	SS Chirp	GFSK/ DBPSK	UNB/GFSK/ BPSK	OFDMA
Data Rate	290bps - 50kbps	100bps 12/8bytes Max	100bps 12/8bytes Max	200kbps - 1Mbps
Link Budget	154 dB	146 dB	151 dB	146 dB
Battery life-time	8 ∼ 10 years	7 ∼ 8 years	7 ∼ 8 years	1 ∼ 2 years
Power Effi-ciency	Very High	Very High	Very High	Medium
Security/ Authentication	Yes(32 bits)	Yes(16 bits)	No	Yes(32 bits)
Range	2-5km ur-ban 15km sub-urban 45km rural	3-10km ur-ban - 30-50km rural	1.5km ur-ban - 20-40km rural	35km - 2G 200km - 3G 200km - 4G
Interference Immunity	Very High	Low	Low	Medium
Scalability	Yes	Yes	Yes	Yes
Mobility/ Localization	Yes	No	Limited, No Loc	Only Mobility

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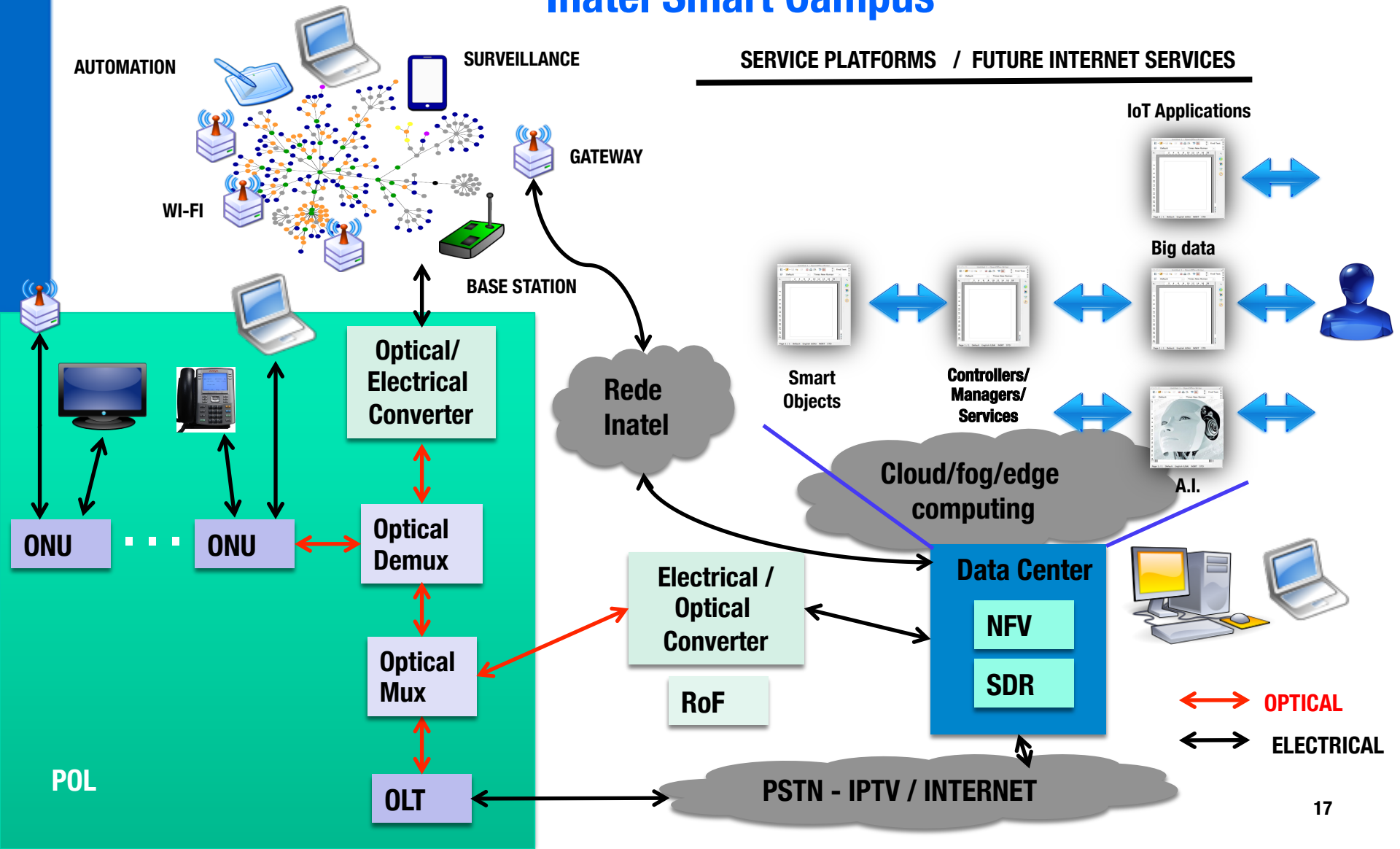

Discussion and Open Research Issues

Open Issues

- Estimation of the collision rate;
- Total capacity per gateway and network;
- Channel load;
- MTU (Maximum Transmission Unit);
- Scaling networks to a massive number of devices;
- Mobility/roaming;
- Single device maximum throughput;
- Other approaches for performance enhancement.
- Application on smart cities verticals.
- Experimental comparison to other LPWANs.
- Security and trust evaluation against attacks.
- Evaluation with novel architectures, such as CCN, RINA, XIA, NovaGenesis.

Conclusion

• Our paper elaborated an analysis about LoRaWAN protocol based on its architecture, battery lifetime, network capacity, device classes and security.

• According to references, this protocol showed an advantage of about **3 to 5-fold** when compared with other LPWAN technologies regarding power consumption for long range communications.

• Moreover, LoRaWAN networks can be deployed with a minimal amount of infrastructure and with the achieved capacity. Latter, more gateways can be added to reduce the amount of overhearing to other gateways and subdivide the data rate.