White paper

LoRaWAN™: global standard for Low Power Wide Area IoT networks

Actility
Connecting with intelligence

LoRaWAN™

Executive Summary

This document will provide a high-level technical and business overview of LoRaWAN™ technology and its benefits and applications, including a comparison with other existing technologies:

I. **Why IoT needs LPWAN?:** long-range communications at a low bit rate allow connecting objects at very low power, enabling years of autonomy for sensors operated on a battery, therefore supporting the rise of the Internet of Things.

II. **LoRa® and LoRaWAN™- two sides of the same coin:** LoRa wireless data communication technology includes two parts with LoRa as the physical layer and LoRaWAN the MAC layer.

III. **LoRa Alliance:** the fastest growing tech ecosystem committed to enabling large scale deployment of LPWAN through the deployment of the LoRaWAN™ open standard and ensuring its interoperability.

IV. **How does LoRaWAN™ work?:** the network server has a central role in the management of gateways and the data flow from devices, with a star network architecture and high network capacity allowing incredible energy effectiveness.

V. **LoRaWAN™ key benefits:** long range, low power, and low-cost connectivity fully compatible with unlicensed spectrum. Easy to deploy solution providing energy efficiency and security for both devices and network, supporting both public and private IoT deployment segments

VI. **LoRaWAN™ roaming:** new business opportunities enabled by the first LoRaWAN™ peering hub, providing technical and business enablers for public operators and enterprise networks

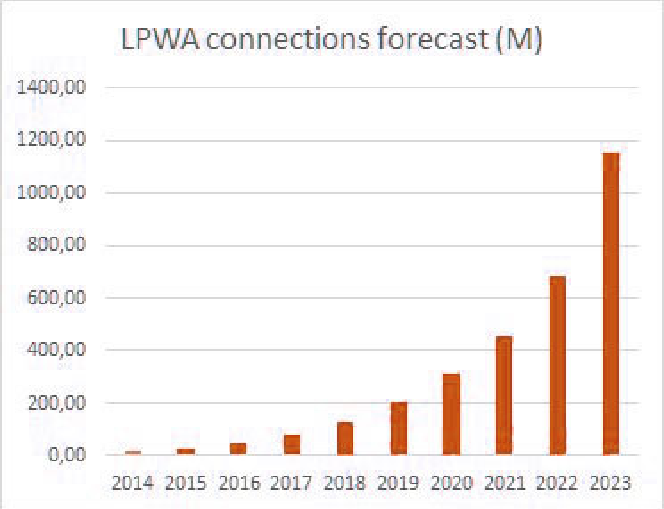
VII. **LoRaWAN™ geolocation:** LoRaWAN unlocks low-cost tracking with its native location capabilities and GPS optimization

VIII. **LoRaWAN™ applications:** LoRaWAN™ networks enable a large variety of vertical solutions allowing enterprises and service providers to use one platform and standard to manage various use cases

IX. **LoRaWAN™ in the IoT space:** IoT presents various complementary and competing network technologies, with LoRaWAN™ standing out by optimizing LPWAN for the battery lifetime, capacity, range, and cost.

I. Why IoT needs LPWAN?

The **Internet of Things** allows millions of devices to be connected, measured and monitored to automate processes and operations and support better decision making. IoT is expected to produce a massive amount of information which will be used to optimize the consumption of all types of resources and improve the efficiencies of increasingly interconnected systems. IoT will also enhance or create new services to bring sustainable value to businesses, consumers and the overall environment. Today, the IoT already impacts the business models of many industries and services such as consumer electronics, automotive, utilities, facility management, smart buildings, connected cities, e-health, supply chains or manufacturing applications.



Scheme: LPWA connections (LoRa, CAT-M, NB-IoT, Sigfox, and others), all regions, all sectors. Data source: ABI Research, 2018.

The soaring of the Internet of Things is supported by the **Low–Power, Wide-Area Networks (LPWAN)** allowing the transfer of information at low cost. LPWAN is a type of wireless telecommunication wide area network, also called low-power wide-area (LPWA) network or low-power network (LPN), designed to allow long-range communications at a low bit rate among connected objects, such as sensors operated on a battery. The low power, low bit rate and intended use distinguish this type of network from a wireless WAN that is designed to connect users or businesses, and carry more data, using more power.

Many technologies and communication protocols co-exist on the IoT market for different applications. There are a number of existing standards in the LPWAN space, including LoRa®, Ultra-narrow band (UNB), NarrowBand IoT (NB-IOT), LTE-M and others. However, the Industrial IoT demands cost-effective, long-range and power-efficient sensors and actuators, and **LoRaWAN™** stands out by optimizing LPWAN for the battery lifetime, capacity, range, and cost.

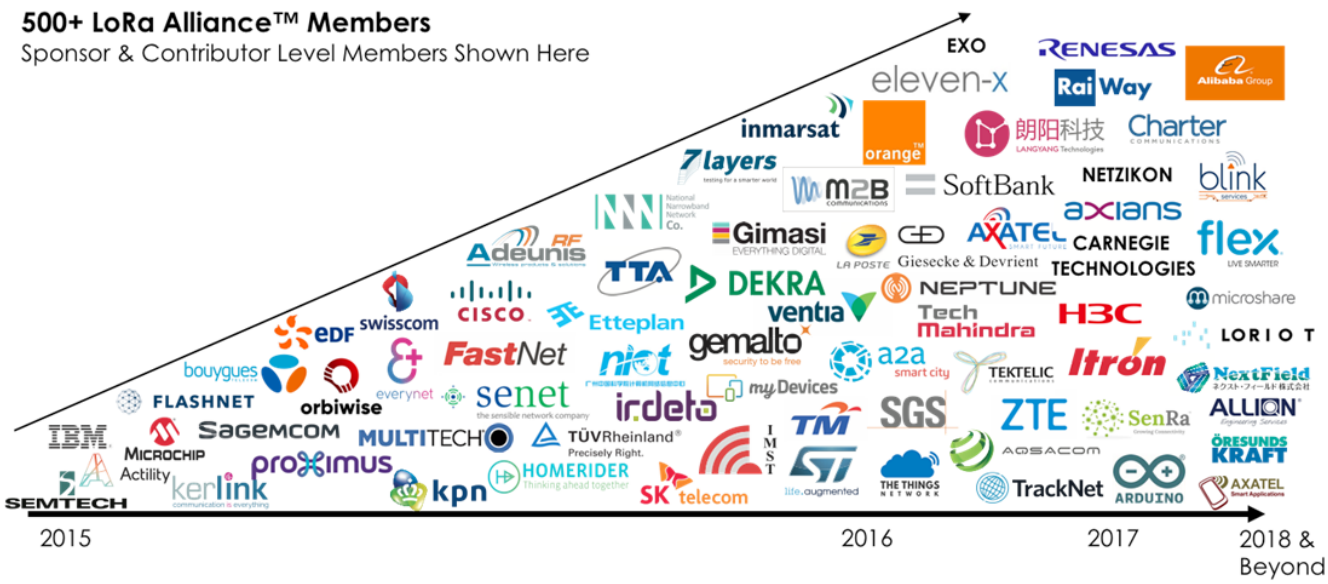
II. LoRa® and LoRaWAN™ What's the difference?

LoRa® (**Lo**ng **Ra**nge) is a patented radio modulation technology developed by Cycleo of Grenoble, France, and acquired by Semtech in 2012. It'is the physical layer utilized to create a long-range communication link. LoRa® is based on chirp spread spectrum modulation (CSS), which maintains the same low power characteristics as FSK (frequency shifting keying) used in many legacy wireless systems, but significantly increases the communication range. Chirp spread spectrum has been used in military and space communication for decades due to the long communication distances that can be achieved and robustness to interference, but LoRa® is the first low-cost implementation for commercial usage. LoRa uses license-free sub-gigahertz radio frequency bands like 868 MHz in Europe and 915 MHz in North America. For more information visit http://www.lora-alliance.org

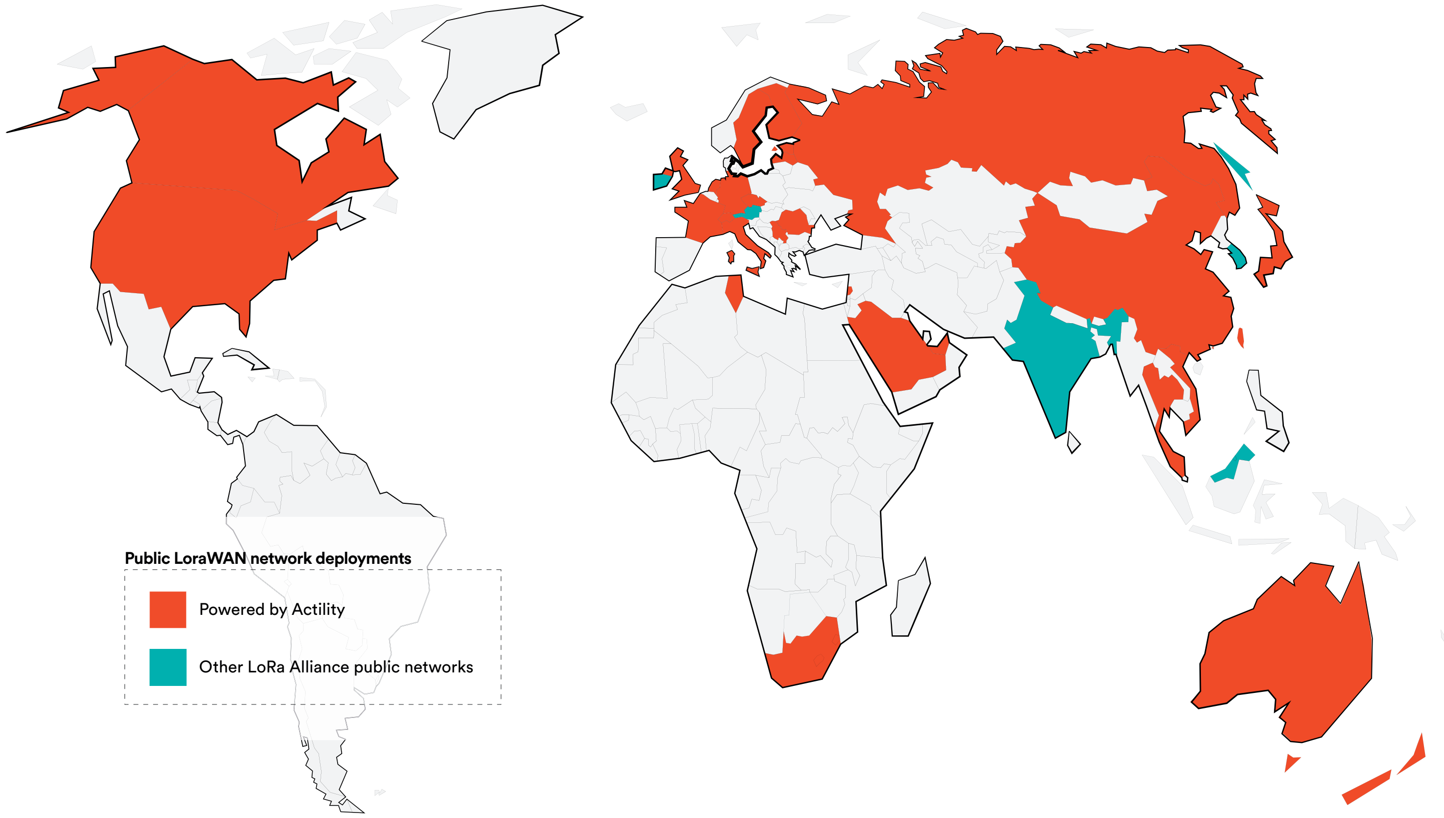
LoRaWAN™ (**Lo**ng **Ra**nge **W**ide **A**rea **N**etworks) specification is a MAC layer that has been added to standardize and extend the LoRa physical communication layer onto internet networks, for managing communication between LPWAN gateways and end-node devices as a routing protocol. To simplify, LoRaWAN™ is the network on which LoRa operates, and can be used by IoT for remote and unconnected industries. The specification is open sourced and supported by the LoRa Alliance. The LoRaWAN™ protocol also includes several key wireless network features such as E2E encryption and security, managing the communication frequencies and adaptive data rate optimization, quality of service, and other advanced communication applications. The LoRaWAN™ specification varies slightly from region to region based on the different regional spectrum allocations and regulatory requirements.

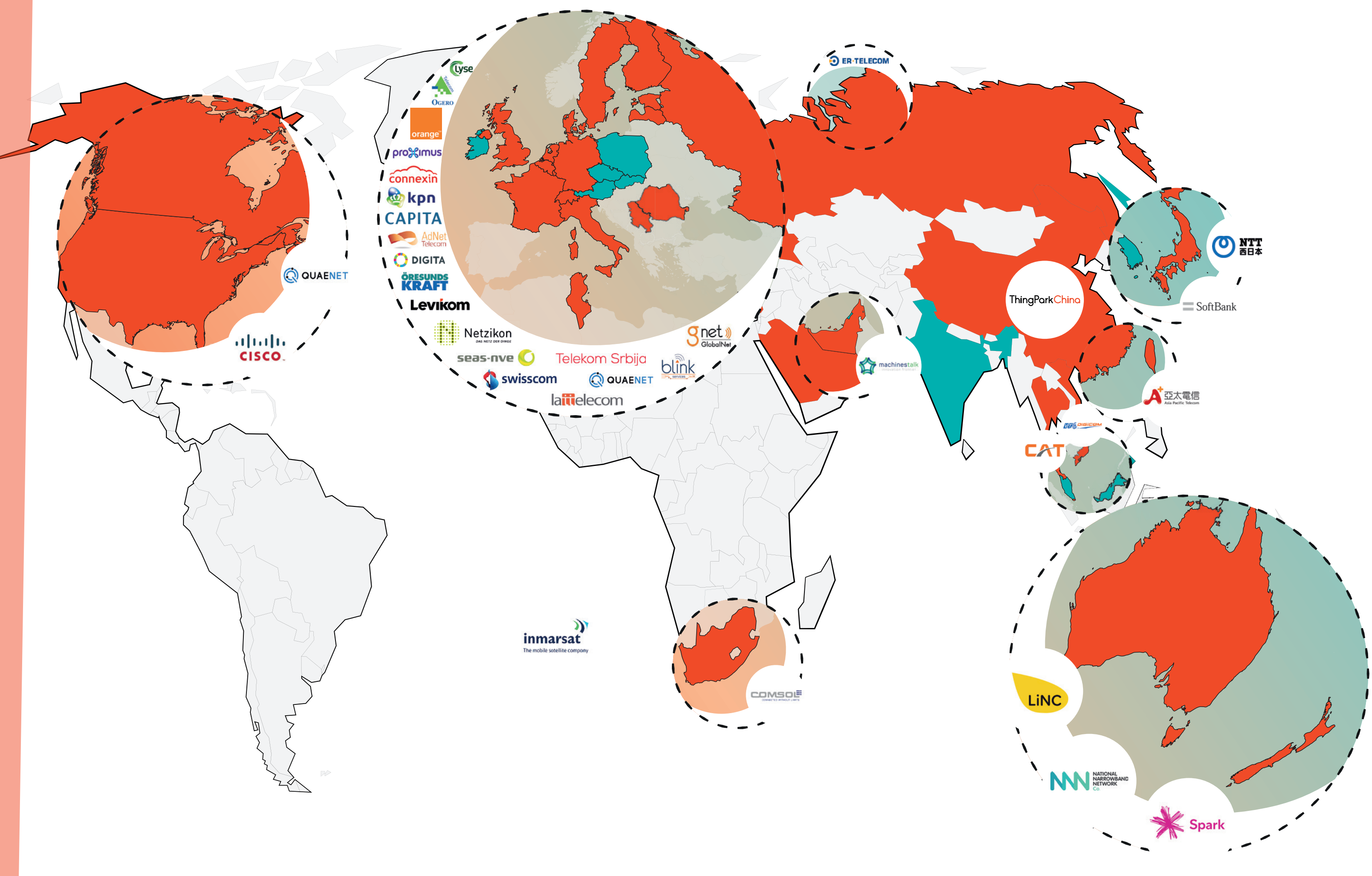
III. LoRa Alliance

Actility is a founding member of the LoRa Alliance™, an **open and non-profit association that maintains the open LoRaWAN standard, supports members in implementing the standard and promotes the adoption of LoRaWAN™ for IoT solutions.** Launched in early 2015 and one of the fastest-growing groups in technology, the Alliance now has over 500 members, ranging from major network operators to the gateway and device manufacturers, software and service vendors, system integrators and end users adopting the technology. For more information visit http://www.lora-alliance.org



Through standardization and the accredited certification scheme, the **LoRa Alliance delivers the interoperability needed for LPWA networks to scale,** making LoRaWAN™ the premier solution for global LPWAN deployments. And over half of all national scale LoRaWAN™ networks globally are powered by the Actility's ThingPark platform, supporting LoRaWAN™ deployments made by major global network operators including Orange, Comcast, NTT, Softbank, Proximus, KPN, Swisscom, Enforta etc.

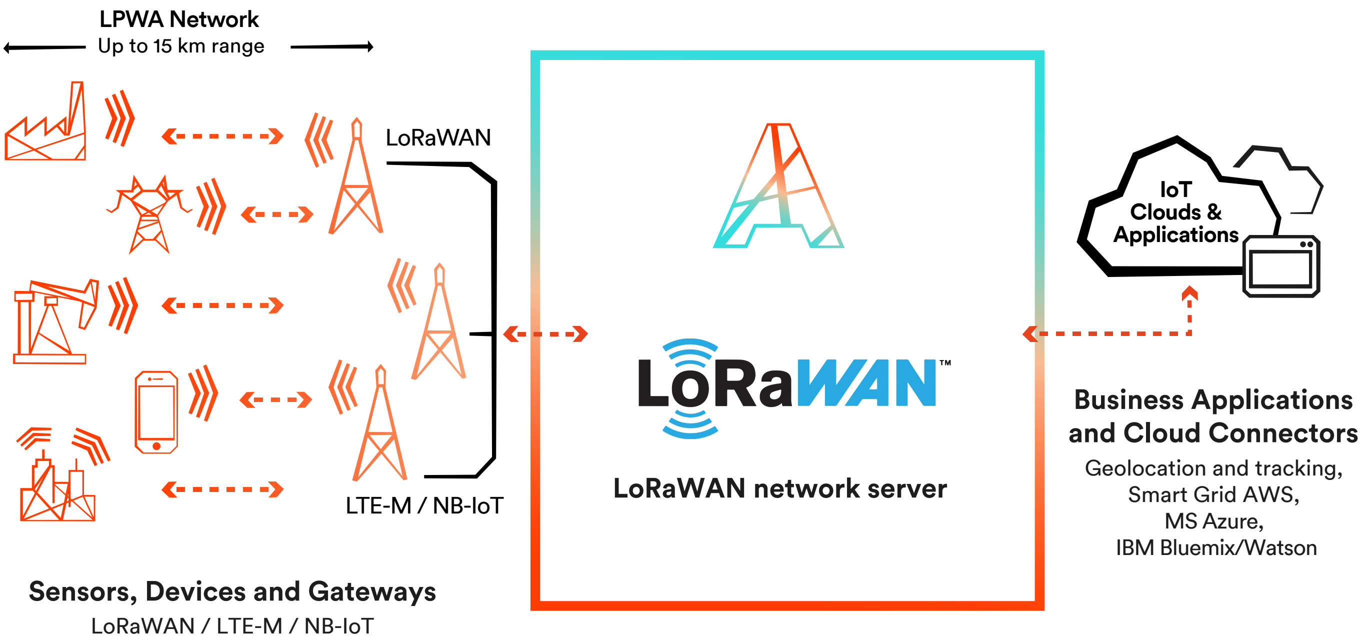

Public LoraWAN network deployments
Powered by Actility
Other LoRa Alliance public networks



IV. How does LoRaWAN™ work?

Network server - the brain of the LoRaWAN network

A centralized **network server,** like ThingPark network server provided by **Actility,** manages the bidirectional data flow with LoRa sensors, filters redundant received packets, perform security checks, schedule downlink frames (including acknowledgments) through the optimal gateway, and perform adaptive data rate, etc. Data is then forwarded to application servers. If a node is mobile or moving there is no handover needed from gateway to gateway, which is a critical feature to enable asset tracking applications–a major target application vertical for IoT. For more information about Actility network server, visit https://actility.com



LoRaWAN gateways - the bridge between connected devices and the network server

Devices use LoRaWAN to connect to the radio Gateway, while the Gateway uses higher bandwidth networks like WiFi, Ethernet or Cellular to connect to the network server. ThingPark Network Server connection is secured using IPSec or TLS tunnels to ensure transport authenticity and integrity. A single gateway can serve thousands of devices. All gateways within reach of a device will receive the device's messages and forward them to the server, which will deduplicate the messages and select the best gateway to forward any messages queued for downlink.

Cisco LoRaWAN Gateway:

Kerlink LoRa IoT Station:

MultiConnect® Conduit™ gateway from MultiTech:

UfiSpace Macro V1-5 Macro Cell Outdoor Gateway:

Connected devices - sources of all data

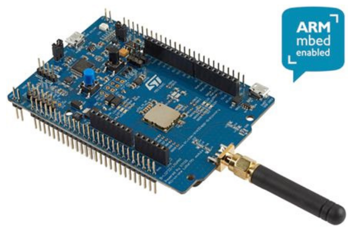
A huge array of devices are available now to fulfill the wide-ranging spectrum of IoT use cases served by LoRaWAN™. Many of them are battery-powered, having up to 10 years of battery life thanks to the low-power capabilities of LoRaWAN™. Among the various device makers for LoRaWAN there are Bosch, Schneider Electric, Yokogawa, STMicroelectronics, Birdz (Veolia) and many more.

BOSCH LoRaWAN Parking Lot Sensor:

YOKOGAWA LoRaWAN "Sushi Sensor" for monitoring of plant equipment vibration and surface temperature:

BIRDZ (Veolia's subsidiary): "G3" LoRaWAN Smart water meter

STMicroelectronics Discovery LoRa Development Kit for CMWX1ZZABZ-091 for LoRaWAN



ABEEWAY (Actility's subsidiary) multi-technology tracking LoRaWAN™ devices for asset management, logistics, and supply chain, safety and security

Simple architecture providing maximum energy efficiency

LoRaWAN™ has a simple **star network,** where nodes are not associated with a specific gateway. Instead, the signal from an individual sensor or device is received by all the gateways within range, which increases reliability and opens up the possibility of location services. **Devices in the network are asynchronous** and transmit when they have data available to send, whether event-driven or scheduled. Each gateway will forward the received packet from the end-node to the cloud-based network server via some backhaul (either cellular, Ethernet, satellite, or Wi-Fi). A star network architecture provides the best compromise between long-range communication, number of antennas (base stations) and devices battery life.

Another unique feature of LoRaWAN networks is that messages in uplink can be received by any gateway (Rx macro-diversity). It's the function of a network server to operate collision mitigation and remove duplicates in uplink and select the best gateway for downlink transmission based on the uplink RSSI estimates. This allows features such as geolocation to be easily built into LoRaWAN deployments. It also enables uplink macro-diversity that significantly improves network capacity, the Quality of Service (QoS) and enhances the battery lifetime of devices. For more information about LoRaWAN capacity, check out our presentation "Designing LoRaWAN for dense IoT deployments".

Over-the-air device updating to patch bugs, maintain security or activate new features

LoRaWAN networks connect thousands of devices deployed in the field supporting customer applications, and many of those devices may be in remote or inaccessible locations. When devices need to be updated with new software features or security patches, it is possible to deliver reliable firmware updates using message fragmentation, multicast, forward error correction, and delta-based functions. All those features are available with the Actility ThingPark Reliable Multicast Server (RMC) supporting FUOTA (Firmware Update Over The Air). For more information, visit https://actility.com

V. LoRaWAN™ key benefits

The LoRaWAN™ protocol is a global standard that offers a long range (up to 15 km suburban environment, even more in rural) bi-directional communications with very low power consumption, allowing operation for up to ten years on the same battery. LoRaWAN™ is used in unlicensed ISM (Industrial, Scientific, Medical) radio bands for cost-efficient network deployments. The use of unlicensed spectrum means that companies can easily roll out networks, and enables private networks for the enterprise. The range highly depends on the environment or obstructions in a given location, but LoRa® and LoRaWAN™ have a link budget greater than any other standardized communication technology. The link budget, typically given in decibels (151 dB), is the primary factor in determining the range in a given environment.

Long Range

LoRaWAN provides long range (up to 15km) communication between sensors and base stations, resulting in networks with 2-3x times fewer base stations compared to cellular.

Battery

LoRaWAN data transmission and reception requires low current (less than 50 mA), dramatically reducing power consumption of the devices and allowing battery life of up to 10 years.

Bidirectional

Fully bidirectional communication enables a wide variety of uses cases requiring uplinks and downlinks: for example, street lighting, smart irrigation, energy optimisation or home automation.

Indoor penetration

The LoRa radio modulation allows deep indoor penetration and adds the ability to reach sensors monitoring water or gas meters located underground.

Open source standard

The LoRaWAN standard is based on an open protocol approach managed by the LoRa Alliance™ which supervises the development of the standard and ensures interoperability between all LoRaWAN networks.

Unlicensed band

LoRaWAN networks are deployed on cost-free ISM bands (EU 868, AS 923, US 915 Mhz) allowing any service provider or company to deploy and operate LoRaWAN networks without having to acquire a license for any frequency.

Cost

The LoRaWAN open standard combined with cost-free operation frequencies and low-cost base stations allows operators to roll out networks in a just few months and with minimum investment.

Network geolocation

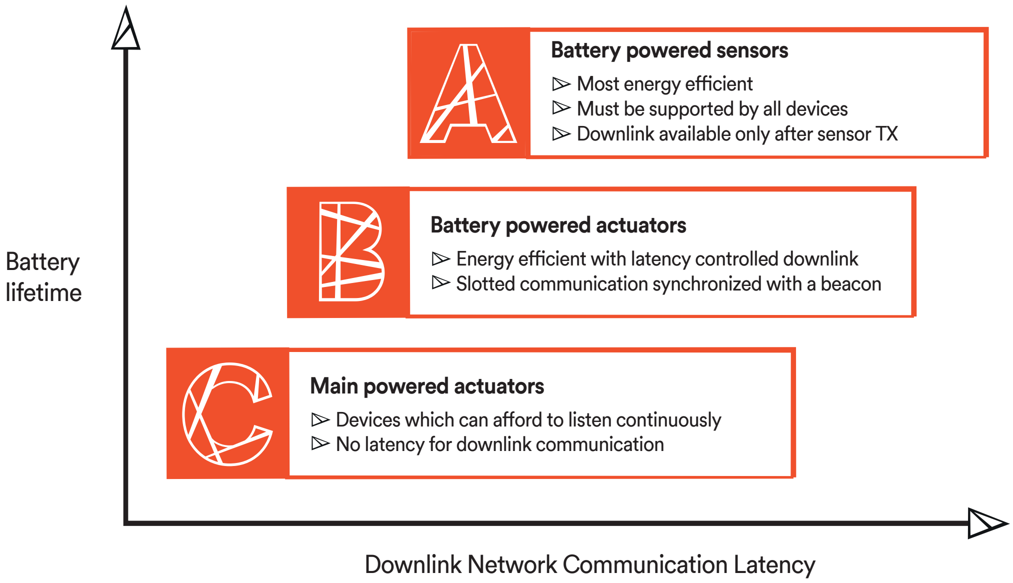
LoRaWAN can use network triangulation to passively locate any LoRa device. This enables new tracking applications, lower cost and battery life optimisation compared to GPS.

Over-the-air device updating to patch bugs, maintain security or activate new features

In order to make a long range star network viable, the gateway must have a very high capacity or capability to receive messages from a very high volume of nodes. High network capacity in a LoRaWAN™ network is achieved by utilizing adaptive data rate and by using a multichannel multi-modem transceiver in the gateway so that simultaneous messages on multiple channels can be received. The network uses this sophisticated adaptive data rate algorithm to fine-tune communication between each device and gateway, to minimize power consumption and maximize reliability. LoRaWAN™networks can be deployed with a minimal amount of infrastructure, and as capacity is needed, more gateways can be added, shifting up the data rates, reducing the amount of overhearing to other gateways, and scaling the capacity.

LoRaWAN™ communication classes

In order to optimize a variety of end application profiles, LoRaWAN™ utilizes different device classes. Each class serves different application needs and has optimized requirements for specific purposes. The key difference between A, B and C profiles is the trade-off made between latency and power consumption.



LoRaWAN™ provides native security

LoRaWAN™ utilizes two layers of security: one for the network and one for the application. The network security ensures the authenticity of the node in the network while the application layer of security ensures the network operator does not have access to the end user's application data. Each sensor has a unique identifier, which is guaranteed by an international organism IEEE. Compared to some other systems which rely on a single key for authentication and encryption, the LoRaWAN™ framework separates authentication and encryption, in order to authenticate packets and provide integrity protection. The LoRaWAN™ core network server solution supports 2 authentication and activation methods described in the LoRaWAN™ specification: Activation by Personalization (ABP) and Over-The-Air Activation (OTAA).

Over-the-air-activation of end-devices is facilitating the activation of end-devices on any network because they are not personalized with any kind of device address (DevAddr) and network key. Instead, whenever an end-device joins a network, a network session key specific for that end-device is derived to encrypt and verify transmissions at the network level. Using both a network session key and an application session key further allows federated network servers in which application data cannot be read or tampered with by the network provider.

LoRaWAN™ deployment flexibility

LoRaWAN offers great flexibility of technical architectures allowing the implementation of both LoRaWAN public and private networks, allowing disruptive models for cost and revenue sharing and densifying the network where it is needed the most, depending on IoT application needs, without limit of size and volume of managed data. LoRaWAN enables Public-Private deployment that. The network has the following types:

▷ **Public Operator Network:** the operator invests in a regional or nation-wide network and sells connectivity services to its customers.

▷ **Private/Enterprise Network:** enterprise customers setup LoRaWAN gateways on private premises, with gateways managed by an operator or using their own LoRaWAN network platform, which is particularly adapted to dense device use cases, as network capacity and enhanced QoS can be provided at marginally increased cost. It becomes possible because LoRaWAN runs in unlicensed spectrum, and gateways are quite inexpensive and easy to deploy.

▷ **Hybrid Network:** an operator provides light country-wide outdoor coverage, but different stakeholders, such as private enterprises or individuals, help in densifying the network further based on their needs on their premises via managed networks. This model enables a win-win private/public partnership in sharing the costs and revenues.

With Actility, to sustain IoT use cases with small and medium scale coverage, local private networks can be deployed following two models: **on-premises or also in SaaS.** For large-scale coverage, the solution is to use a network server in SaaS.

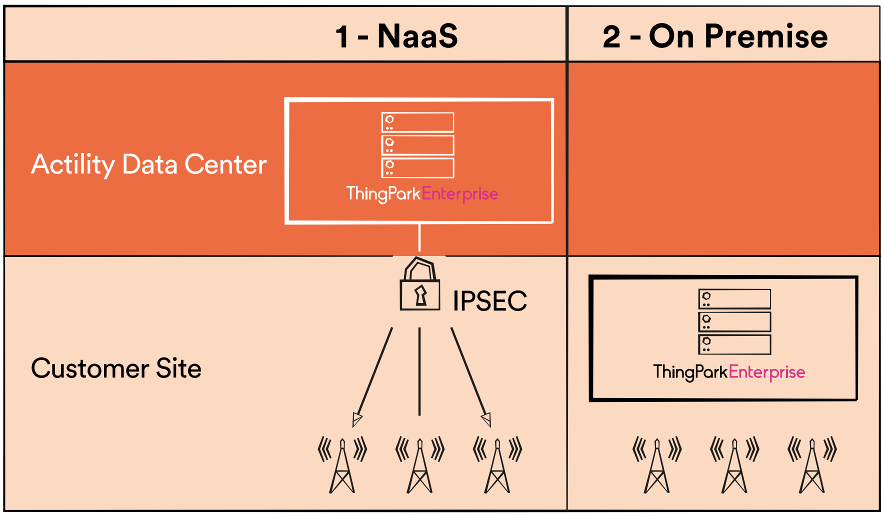
On-premises:

LoRa gateways can be installed on one or multiple sites, with one or multiple network servers. With multiple gateways on one site, a single server can centrally manage all LoRaWAN gateways installed there, or at different remote sites. The main advantage of this architecture lies in the centralized management of all the objects thus making it possible to standardize the data exchanges between the objects and the Enterprise SI. In this context, the core network makes it possible to make the unique interface between the data coming from the connected objects and the business applications.

SaaS (Software as a Service):

This technical architecture offers the benefit of not having to deploy a core network on site. It responds to many use cases and proves to be an excellent way to validate phases of POC. It requires opening the site to the Internet or setting up the native VPN integrated with Actility. This is a popular solution for infrastructure operators or buildings wishing to quickly connect their objects to their business applications.

ThingParkEnterprise Deployment models



Which deployment model?

▷ **“NaaS model”** is the quickest path to your operative LoRaWAN network, ensuring seamless evolution and scalability

▷ **“On premise model”** ensure that you gain full control on your LoRaWAN infrastructure, in line with your operational or security requirements

VI. LoRaWAN™ global roaming

Global roaming between different LoRaWAN networks will enable new multi-country use cases and new business models with simpler deployment models. LoRa Alliance has approved and standardized roaming architecture in "LoRaWAN Backend Interfaces 1.0 Specification" to enable network collaboration between different LoRaWAN operators. There are two types of roaming for LoRaWAN networks: **passive roaming and handover roaming.**

Passive roaming

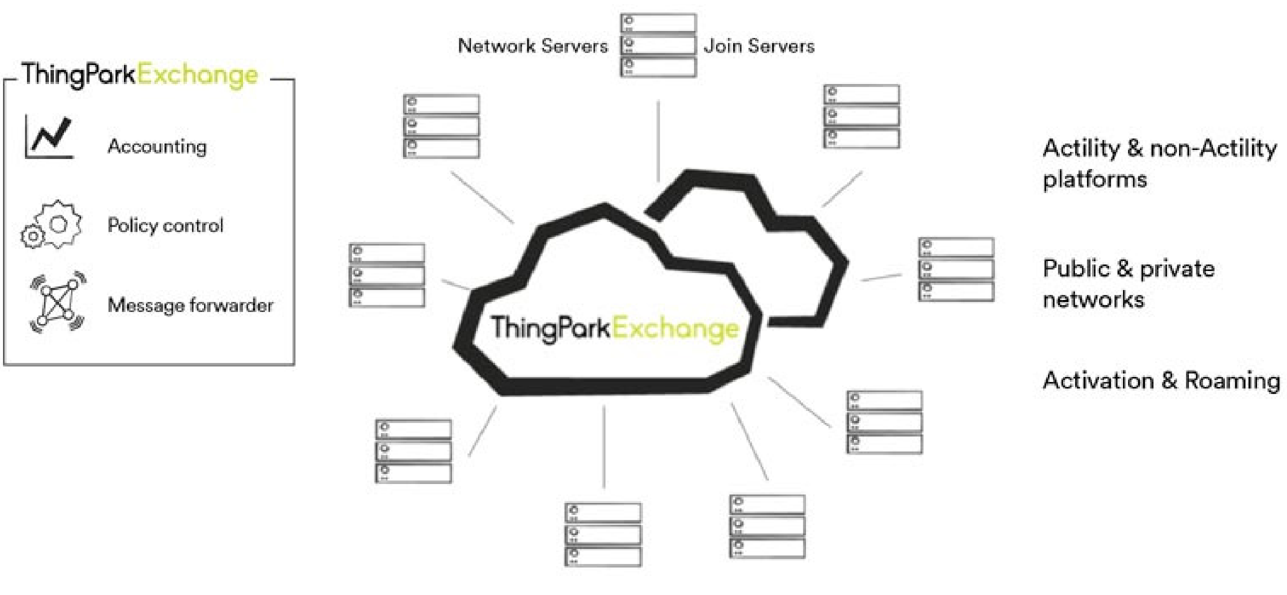
A network using another network's gateways to improve its coverage but without handing over the control of its end-devices. Passive roaming allows flawless packet forwarding between 2 operator networks for optimized network capacities and better device battery management. Besides increasing the coverage, it enabled a reduced Spreading Factor for better network capacity and improved geolocation accuracy.

Handover roaming

With this type of roaming, a home network decides to hand-over the control of an end-device to another network. The device disconnects from the first network and reconnects to the other one. The home network can preemptively regain control of the end-device at any time.

Actility Peering Hub bringing new business opportunities

For the purpose of enabling global roaming, Actility, the industry leader in Low Power Wide Area (LPWA) network connectivity, implemented **ThingPark Exchange,** the first hub for international IoT roaming, allowing LoRaWAN operators around the world to sign up to the service to enable instant packet forwarding between their networks. ThingPark Exchange is the first roaming enablement platform to be fully compliant with the new LoRa Alliance roaming specifications. The Exchange hub enables LoRaWAN service providers to consistently execute and control their roaming agreements. Traffic policy and Service Level Agreements (SLA) can be customized through individual commercial agreements.



By joining ThingPark Exchange, service providers are able to more easily meet their customers' requirements for global roll-outs. For example, companies active in several countries or globally will be able to contract with only one operator for their IoT connectivity, instead of a different operator in every country. The chosen single operator, connected to ThingPark Exchange, is able to make use of other Exchange-connected roaming partners to supply a multi-country connectivity solution for its customer.

ThingPark Exchange also provides access to supplementary services such as ThingPark Activation, which simplifies network provisioning and device activation. This service allows devices manufacturers to provision their devices on a single Join Server and thus a unique AppEUI/JoinEUI, while still being able to activate the devices on multiple home networks connected through ThingPark Exchange.For more information about ThingPark Exchange and ThingPark Activation, visit https://actility.com

VII. LoRaWAN™ for geolocation: easy, cost-effective and long-lasting tracking

LoRaWAN enables new geolocation solutions at unprecedented price levels, making end-to-end digital logistics become a reality. Geolocation can be used to locate connected objects, track them as they move, or create geo-fences: sending an alert if an object moves outside a defined area. Many applications can benefit from geolocation - either GPS-based or LoRaWAN-based, depending on the requirements.

LoRaWAN networks can locate devices without GPS, using only radio communications signals. Three GPS-synchronized base stations with accurate timestamping are able to triangulate any sensor's position. Measuring Time Difference on Arrival (TDoA) translates into the distance between it and three fixed points which allows for an estimated location. Avoiding GPS on a device reduces cost & power consumption.

GPS-based geolocation is not new, but LoRaWAN makes it much more cost effective and versatile. LoRaWAN bidirectional connectivity with an embedded GPS chip offers an exceptionally long battery life (10 times as cellular) enabling sensors to operate for several weeks or months between charges. GPS based trackers applications have been limited by short battery lifetime (or prohibitively high battery costs), and high communication fees. No longer. Using LoRaWAN as the communication technology as opposed to GPRS, or even the newer 3GPP options such as NB-IoT, **cuts the energy budget by over an order of magnitude.**

For more information about LoRaWAN location capabilities, visit https://actility.com

VIII. LoRaWAN™ applications

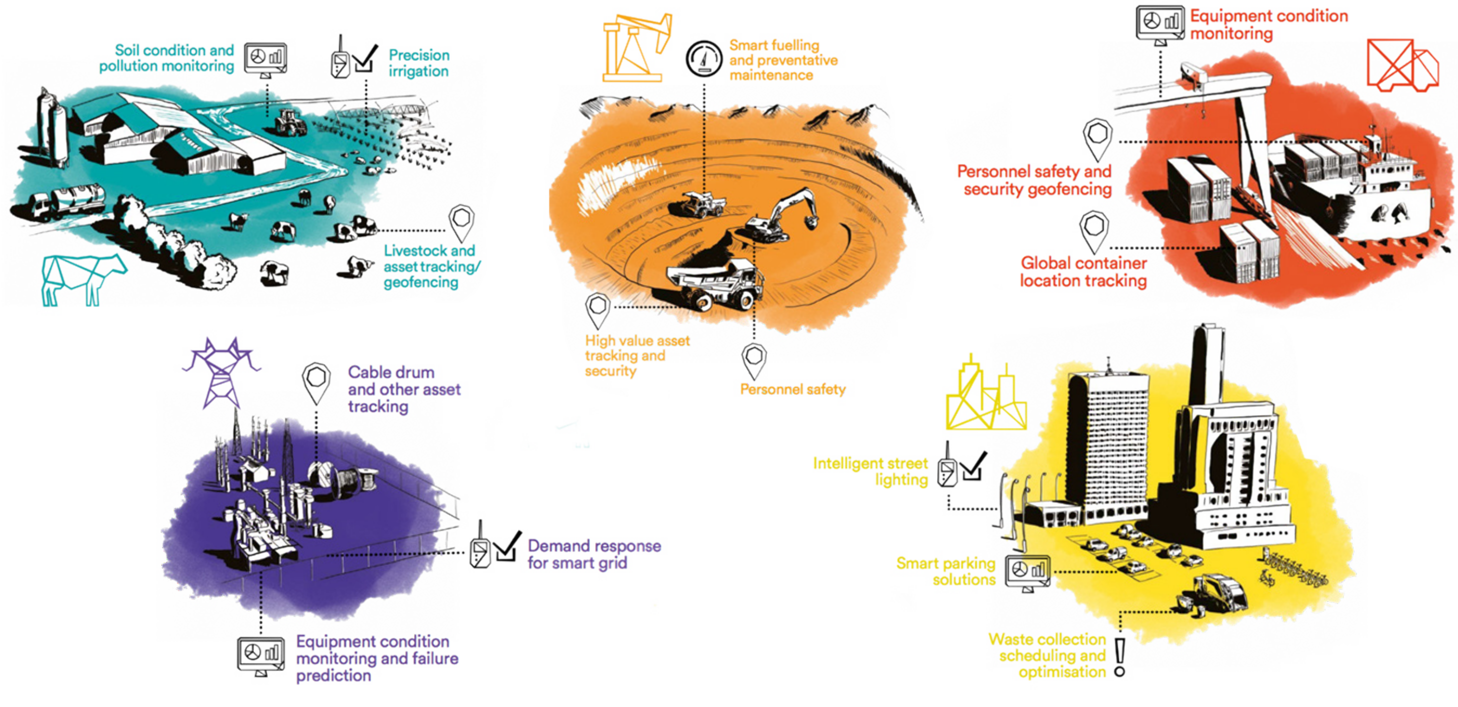
LoRaWAN™ deployment flexibility

The LoRaWAN™ technology has been designed to respond to use cases where a sensor communicates small amounts of data a few times a day. It is well suited for smart meters, trackers, environmental sensors etc. It is not designed to support applications that require high data rates such as audio or video. However, LoRaWAN™ can be used to control other wireless device capabilities; for instance, to remotely instruct a camera to begin a data transmission, and stay in low power mode whenever opening a video stream is not required.

LoRaWAN™ networks enable a large variety of vertical solutions allowing service providers to use one platform and standard to manage various use cases such as dedicated verticals such as:

- Energy & Utilities: automated meter reading for water, gas, and electricity,
- Smart Cities: smart parking, lighting and waste management applications
- Smart Industries: equipment monitoring in factories, railway safety applications, indoor environment monitoring in airports, liquid level and flow monitoring for Oil & Gas, etc.)
- Building and Facility Management: energy efficiency and water leakage detection
- Logistics and Supply Chain: global asset tracking and goods monitoring
- Precision Agriculture: smart irrigation, crop management, and cattle monitoring
- Consumer IoT: wearables, home monitoring, and consumer tracking

For more information about LoRaWAN use cases, visit https://actility.com

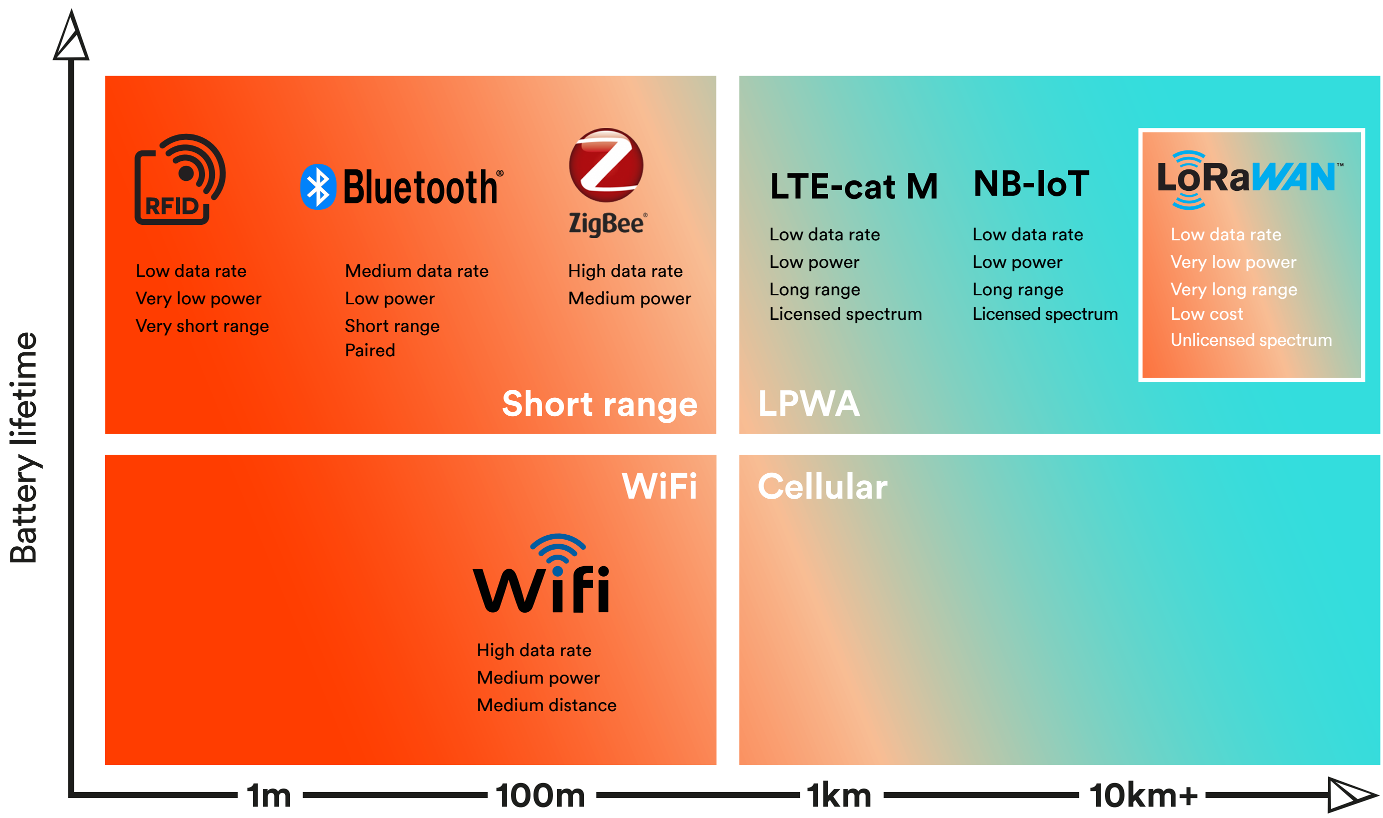


IX. LoRaWAN™ in the IoT space

There is a lot of activity in the IoT sector comparing LPWAN options both from a technical comparison but also from a business model perspective. LPWAN networks are being deployed now because there is a strong business case to support immediate deployment, and the cost to deploy the network in unlicensed bands requires much less capital than even a 3G software upgrade.

A large part of connections is coming from **fixed and short-range connections** such as **Wifi, Bluetooth, Zigbee, Z-Wave** etc. These technologies are well suited for short range applications where power consumption and battery life is not a major issue. The new wireless IoT connectivity family named 'LPWA' networks is well suited to support services and use cases which need **long-range communication** (dozens of km) to reach devices which must have a low power consumption budget in order to operate several years remotely on a single battery pack. **LoRaWAN™** is the LPWA network solution currently gaining the most traction to support IoT applications and services, but there are also **Sigfox** using Ultra-Narrowband (UNB) modulation technology, and the **3GPP standards (Cellular Networks)** such as **LTE-M** and **NB-IoT.**

Although Actility is a co-creator and pioneer of LoRaWAN™, we believe that 3GPP technologies are complementary, and our products are currently supporting all forms of LPWA networking (LoRaWAN, NB-IoT, and LTE-M) to ensure the optimum solution for a specific requirement.



LoRaWAN stands out, though complements 3GPP technologies

For many requirements, LPWAN demands the lowest cost and lowest power. In real-world use cases (around 20 messages/day), the power consumption of LoRAWAN is 5 times better than LTE Cat NB1). The peak current needed is 10 times lower – translating into an order of magnitude reduction in battery size and cost for a ten-year lifespan.

LoRaWAN and Mobile IoT represent different market segments with LoRa serving a large number of devices with low cost, low power and lowest data rate followed by NB-IoT and then LTE-M, which are more adapted to applications like connected cars, telematics which have medium requirements for the data rate. Combining LoRaWAN and Mobile IoT (LTE Cat-NB1, LTE Cat-M1) solves the needs of all the IoT Use Cases, making it complementary.

Another major difference between LoRaWAN and 3GPP is the use of unlicensed spectrum. LoRaWAN allows the easy deployment of “campus” networks with thousands of devices in a small area (smart city, smart building, smart airport, smart factory). Enterprise networks can be entirely under the control of the customer, and data remains encrypted end-to-end.

Why choosing LoRaWAN?

- LoRaWAN allows better time-on-air and better battery life and it’s an easily scalable network due to the Adaptive Data Rate
- Communication is natively bidirectional and unlimited native payload encryption (which is not the case with Sigfox proprietary system)
- Native location (TDoA) unlocks low power tracking use cases
- LoRaWAN enjoys a wide offer in gateways (macro-gateways, indoor gateways, pico-gateways for in-home use) and devices (sensors and trackers), with the possibility to create public and/or private networks