# Comparison Of LPWA Technologies And Realizable Use Cases

A Technical Paper Prepared for SCTE•ISBE by

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# Introduction

The evolution of the Internet has opened a wide variety of opportunities for connecting devices remotely. This has resulted in growing demand of remote maintenance and connectivity of devices and has made the Internet of Things evolve at a faster pace than anticipated. The advancement of wireless technologies and data transfer capacities over the same timeframe has resulted in wider usage of internet over wireless. The combination of all of the above factors has led to the development of IoT over wireless communications.

This paper will cover Low Power Wide Area Network (LPWA) technologies which have overcome the challenges of IoT over wireless by reducing power consumption, increasing coverage, tailoring the bandwidth according to the needs, and many other advantages.

There are various LPWA standards developed by GSMA, LoRa(SemTech), Sigfox, NB-Fi(WAVIoT), RPMA(Ingenu) leveraging 2G/3G/4G/5G bands and Industrial-Scientific-Medical (ISM) bands. Currently existing standards are LTE Cat 1, LTE Cat 0, LTE Cat M1 aka LTE-M(eMTC), NB-IoT aka LTE Cat NB1(Narrow Band), EC-GSM-IOT(EDGE), LoRaWAN, Sigfox, NB-Fi. Each of these technologies/standards are discussed and compared in detail in the sections of this paper.

Below are some of the features that are gained with the advancement of above technologies.

- Low power consumption resulting in battery life >10 years.
- Leveraging existing bands and future compatibility.
- Lower device costs of around $5 and lower maintenance costs.
- Improved connectivity – indoor and long range.
- Tailored bandwidth for lower data rates, latency, and mode.
- Network scalability with ease of capacity upgrade.
- Roaming connectivity.
- Security and authorization.

# Content

## 1. Business Forecast

As per market research issued in July 2018, forecast for the Low Power Wide Area (LPWA) global business market is expected to grow at a compound annual growth rate (CAGR) of approximately 72% during the forecast period from 2017-2023.

According to an LPWA forecast from ABI Research, network connections will grow at a 53% CAGR through 2023.

## 2. Architecture

The below architecture diagram shows different layers of LPWA technology. Each of the features per respective layer is explained in sections 6 and 7

 

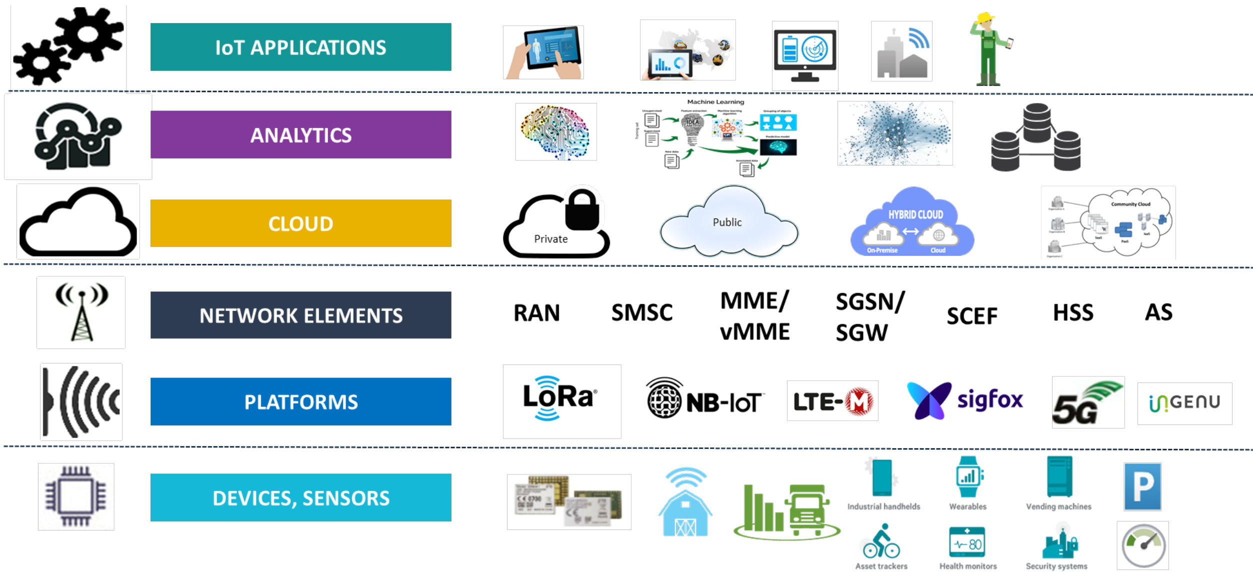


**Figure 1 – Architecture Diagram showing multiple layers**

# 3. Standards/Technologies

## 3.1. LoRaWAN

**LoRaWAN** is a technology developed by the LoRa alliance. LoRaWAN is a media access layer to LoRa, which is the physical layer. LoRa is a patented IoT wireless data communication acquired by SemTech. LoRa uses ISM frequencies and has very long range of transmissions up to 30 miles. LoRa uses less bandwidth, which helps in saving power mode and there by extending battery life of the devices >10 years.

## 3.2. LTE-Cat0/LTE-Cat1/LTE-Cat M1 (eMTC)

**LTE-Cat0/LTE-Cat1/LTE-Cat M1** (eMTC) technologies are based on the mobile networks developed using 3GPP Release 8 to Release 13 specifications. These technologies will co-exist with the existing 4G networks. Each of the technologies are deferred based on the bandwidth. For the applications which require higher data usage utilizes Cat0 & Cat1 which has the highest bandwidth. For less data consumption or sporadic data consumption Cat M1 is being used to extend the battery life with proper sleep modes.

## 3.3. NB-IoT

**NB-IoT** (Narrow Band) technology is also developed based on the 3GPP Release 13 specifications using a subset of LTE standard but with a much narrower band. This can be deployed over the existing 2G/3G/4G spectrums as well. Due to its narrow band, the data uplink/downlink is less than the other LTE technologies thus increasing the battery life. Currently development of NB-IoT Roaming and NB-IoT over 5G network is in progress.

 

### 3.4. EC-GSM-IoT

**EC-GSM-IoT** (Extended Coverage GSM) technology is also developed based on the 3GPP Release 13 specifications based on eGPRS designed for extended coverage with high capacity, long range, low power and lower complexity by leveraging the existing 2G/3G technologies.

### 3.5. Sigfox

**Sigfox** technology is a proprietary technology developed by the company with the same name. This technology utilizes an ultra-narrowband within the ISM radio band, thus enabling the low power requirement. This technology is being used for devices which need a limited amount of data. Due to these factors the cost of Sigfox devices is less than $3 and their battery life is 10+ years.

## 4. Technology Comparision

Table 1 shows the differences between the key features for the technologies discussed above.

**Table 1 – Comparision of Technologies**

| Technology/ Feature | LTE Cat1 | LTE Cat 0 | LTE Cat M1 (eMTC) | LTE Cat NB1 (NB-IoT) | EC-GSM-IoT | LoRaWAN | Sigfox |
|---|---|---|---|---|---|---|---|
| Bandwidth | 1.4 – 20 MHz | 1.4 – 20 MHz | 1.4 MHz | 180 kHz | 200 kHz | 125kHz | 200Hz |
| Spectrum | Licensed | Licensed | Licensed | Licensed | Licensed | ISM | ISM |
| Frequency Bands | 700-2100MHz | 700-2100MHz | 700-2100MHz | 700-2100MHz | 700-2100MHz | 915MHz | 915MHz |
| Standardization | 3gpp Release 8 | 3gpp Release 12 | 3gpp Release 13 | 3gpp Release 13 | 3gpp Release 13 | LoRa Alliance | ETSI |
| Uplink | 5 Mbit/s | 1 Mbit/s | 1 Mbit/s | 250 kbit/s, 20 kbit/s | 474 kbit/s, 2 Mbit/s | 50kbit/s | 100bps |
| Downlink | 10 Mbit/s | 1 Mbit/s | 1 Mbit/s | 250 kbit/s | 474 kbit/s , 2 Mbit/s | 50kbit/s | 600bps |
| Latency | 50–100ms | na | 10ms–15ms | 1.6s–10s | 700ms–2s | 1-10s | 1-30s |
| Duplex Mode | Full Duplex | Full or Half Duplex | Full or Half Duplex | Half Duplex | Half Duplex | Full or Half Duplex | Half Duplex |
| Coupling Loss | 144dB | 144dB | 156dB | 164dB | 164dB | 157dB | 153dB |
| Cost (in $) | > 10$ | > 10$ | < 10$ | < 5$ | < 7$ | < 7$ | < 3$ |
| Batter Life (in years) | 5 | 5 | 10 | 10+ | 10 | 10+ | 10+ |

## 5. Three dimensional view of Parameters vs Technology

Bandwidth, Battery Life, and Range are the three key main features which play a major role in deciding the technology type.

The below picture shows the three dimensional view of WiFi, LTE, LPWA, considering the above three factors.

 

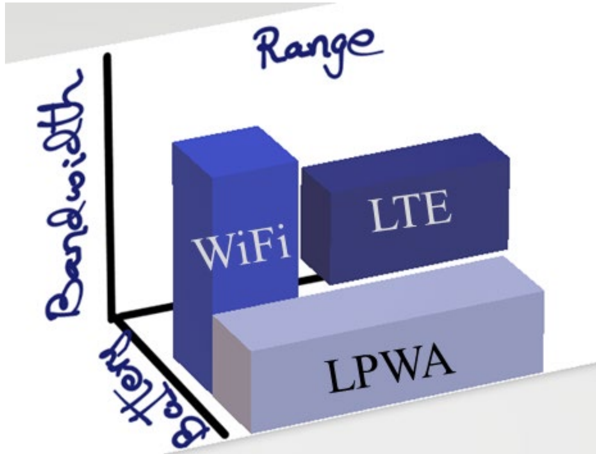


**Figure 2 – 3D view of key parameters vs technology**

# 6. Radio Features

## 6.1. Bandwidth

Based on the usage, bandwidth plays a crucial role. Bandwidth also plays a major role in power, penetration, range, and latency. Bandwidths vary from 20MHz to 200Hz. Machines which need a limited amount of data utilize less bandwidth.

## 6.2. Spectrum

Spectrum requirements vary based on the industry and technology. Technologies using Mobile/Cellular communication are based on license based spectrum. LoRaWAN, Sigfox, RMPA, NB-fi are based on the ISM spectrum.

## 6.3. Frequency Bands

Licensed spectrum bands vary from 700Mhz to 2100Mhz across the globe. 2G/3G/4G technologies fall in these frequency bands. LoRaWAN, SigFox, RMPA, NB-Fi are based on the ISM spectrum, which is centered around 915Mhz.

## 6.4. Standardization

Standardization provides guidelines for features like security, payload, transmission, inter-operability. LTE-Cat0/LTE-Cat1/LTE-Cat M1 (eMTC), NB-IoT and EC-GSM-IoT are developed based on the 3GPP standards from Release 12 to Release 13. LoRaWAN uses the standards developed by LoRa alliance. Sigfox is developing based on the standards/regulations set by ETSI 300-220 and FCC part 15.

## 6.5. Uplink & Downlink

Uplink & Downlink play a major role in determining bandwidth, low power utilization, data formats, protocols and security features. Due to power restrictions, devices will not be continuously transmitting and receiving. Time for on-the-air and continuous burst is restricted. The higher the bandwidth, the higher the data rate and higher the power utilization. LTE-Cat0/LTE-Cat1/LTE-Cat M1 (eMTC) technologies have higher bandwidth, which support higher data transmission rates, and with less battery life. NB-IoT, EC-GSM-IoT and LoRaWAN have intermediate bandwidth, supporting kbps transmission rates. Sigfox utilizes ultra-narrow bandwidth, which supports only hundreds of bps rates.

### 6.6. Latency

Latency is effected by many other features like bandwidth, range, and power saving mode. It supports extended buffering of the downlink data packets when the user equipment is in “sleep” or power-saving mode, and will start re-transmitting when the UE becomes reachable again.

### 6.7. Coupling Loss

Coupling loss is calculated based on device transmit power, occupied channel bandwidth, receiver noise figure and signal-to-noise ratio.

## 7. Non Radio Features

### 7.1. Power Saving Mode

This feature is supported by some user equipment, enabling the device to reduce power consumption by sending the device into deep sleep mode. This mode is intended for devices with infrequent data transmission and which can accept latency at the termination end/user equipment. Devices use timers to listen to the paging channel and only “wake up” when they hear that network traffic is intended for that device.

### 7.2. Extended Idle Discontinuous reception Mode

eDRX stands for extended idle discontinuous reception. Unlike power saving mode, this device mode doesn’t listen to paging and downlink channels, and also turns off part of the circuitry to save power. In this case, the network should support the same frequency as the device when it turns back on.

### 7.3. Cloud Compatibility

To save processing and reduce power consumption, all non-critical data from multiple device types will be sent to the cloud over the network to perform computing, calculations and processing of the data. This will also help in accessing data remotely for any further data analytics.

### 7.4. Artificial Intelligence & Machine Learning

Artificial intelligence and machine learning are applied to the data that is cloud processed for further analysis. By applying smart algorithms, issues are identified and machine learning is used to identify patterns and anomalies.

### 7.5. Analytics and Big Data

Data from multiple sensor types is collected and used to identify the patterns. This can also help in identifying possible information gaps and white space areas.

### 7.6. Low Cost

Considering the above factors would ultimately help in reducing device cost, network utilization, power savings and increasing processing and performance. They also help in reducing the maintenance costs over the device lifespan.

### 7.7. Security Considerations

Proper security considerations need to be considered as device-network mutual network authentication and encryption/ciphering of device-network data consume processing power and bandwidth. It is assumed that 10% of the power and bandwidth is being consumed for security. LTE-Cat0/LTE-Cat1/LTE-Cat M1 (eMTC), NB-IoT and EC-GSM-IoT use almost the same security features as mentioned for 3GPP.

## 8. Application Use Cases

### 8.1. Agriculture

Agricultural monitoring sensors can help farmers in measuring soil moisture, growth of crops, humidity, temperature, livestock tracking, remote harvesting, automatic and remote watering, efficient water usage. These features can help farmers in the automation of agriculture.

The above cases don't need the data to be sent continuously. Data can be sent periodically or when a particular condition is met. These devices can send data in intervals and in smaller bandwidths back to the farmers.

### 8.2. Smart Wearables

This application is mainly for users who require health monitoring, including the elderly and healthcare patients. Smart wearables are able to capture all the vitals of the person wearing them. This can help in remotely tracking a person's health and triggering alarms automatically, as soon as the vital metric drops as opposed to pressing a button which may not be possible in some cases. Hypothermia is a use case where the heart beat drops instantly and causes the person to become confused.

The above applications need devices to send data periodically or with an event trigger with less latency. Also these devices need ultra-narrow bandwidth thereby resulting in less data consumption and less power consumption, as well as excellent indoor coverage.

### 8.3. City Management and Metering

Smart metering, smart remote monitoring of electricity grid, smart waste management, and smart parking can enable cities, municipalities, and private corporations to collect data remotely. These events can be triggered periodically. Two event trigger examples are a sudden uptick in grid consumption, or when waste bins are full and require pickup.

All of the above applications require smaller and non-continuous bandwidth.

### 8.4. Vending Machines

Vending machines need to be monitored for these reasons: credit card payments (including proper authentication, privacy and verification of data), vending stock tracking, device diagnostic reports, and raising burglary alarm.

For the above conditions a channel with less latency and more security needs to be chosen.

### 8.5. Industries

Remotely monitoring of temperatures, humidity, safety monitoring, machinery control and propane tank monitoring are some examples which can be monitored remotely.

### 8.6. Environmental Monitoring

Illegal logging of trees or illegal poaching of rare and endangered species can be monitored by using sensors to trigger whenever a particular noise is generated or by tracking the species.

### 8.7. Car Auto-Piloting – Original Idea

Most Car Auto-Piloting failures are happening whenever a static object is placed in the roadway, due to the auto-pilot being unable to instantly reduce speed. A new idea is to place sensors whenever there is a road block or maintenance activity underway. These sensors can send the updates to the navigation systems like Google maps or Waze, thereby there-by alerting the auto-pilot vehicles of possible hazards.

## 9. NB-IoT Roaming

On June 4th, 2018 Deutsche Telekom and Vodafone group successfully completed the first international roaming trial for NB-IoT. These service will be helpful in cases when devices need to exceed geographic boundaries and move from one place to another. For example, the tracking of shipping containers which cross international boundaries from one country to another.

## 10. NB-IoT 5G

3GPP already has standards for 5G LPWA use cases by evolving NB-IoT and LTE-M as a part of the 5G specifications and co-existing with other 5G components.

# Conclusion

LPWA has evolved into many technologies based on many key parameters such as bandwidth, performance, power consumption, latency, spectrum, security. IoT devices/sensors connectivity often require less data consumption, with more battery life, and with co-existing/leveraging of existing networks. Based on these needs, different technologies can be chosen. Evolving and emerging technologies are constantly being researched.

# Abbreviations

| | |
|---|---|
| LoRa | Long Range |
| GSMA | Global System Mobile association |
| NB-Fi | Narrow Band Fidelity |
| Wi-Fi | Wireless Fidelity |
| RPMA | Random Phase Multiple access. |
| ISM | Industrial Scientific Medical |
| NB-IoT | Narrow Band Internet of Things |
| eMTC | enhanced Machine Type Communications |
| Cat | Category |
| LoRaWAN | Long Range Wide Area Network |
| EC-GSM-IoT | Extended Coverage Global System Mobile Internet of Things |
| EDGE | Enhanced Data Rates for GSM evolution. |
| CAGR | compound annual growth rate |
| RAN | Radio access Network |
| SMSC | Short Message Servicing Center |
| MME | Mobility Management Entity |
| SGSN | Serving GPRS support Node |
| SGW | Serving Gateway |
| SCEF | Service Capability Exposure Function |
| HSS | Home Subscriber Server |
| AS | Application Server. |
| 3GPP | Third Generation Partnership Project |
| AP | access point |
| bps | bits per second |
| Hz | Hertz |
| ISBE | International Society of Broadband Experts |
| SCTE | Society of Cable Telecommunications Engineers |

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