LoRaWAN for IoT

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***Abstract*— With the advancement in technology, the number of mobile devices and sensors have increased drastically in the last decade. This increase in implementations has lead to a necessity of devices that can provide reliable long range message transfer at low power consumption. Furthermore the increased adoption of 5G networks has provided with better coverage and higher data rate to connected devices. This paper provides an feasibility study on one such promising technology LoRaWAN as a candidate for this purpose. The paper also covers some scenarios where LoRa devices can be used and provides multi parameter comparisons which can be helpful in deciding a specific sensor given a use case.**

***Index Terms*— Internet of Things; Wireless Networks; Mobile Networks; LoRaWan.**

I. INTRODUCTION

With the expanse of human mobility, the need to extend traditional large scale deployments with next-generation technologies, has arisen. These traditional deployments need to be integrated with the internet to provide enhanced functionality. Mobile and wireless technologies in their assortment of low and ultra power, short and long range technologies continue to drive the progress of communications and connectivity in the IoT. The Internet of Things (IoT) is a fast growing heterogeneous network of connected sensors and actuators attached to a wide variety of everyday objects [1]. The future will foresee smart and low-power networked devices connecting to each other and to the Internet using, mostly, reliable low-power wireless transmissions.

Along with increase in demand of IoT sensors, the need for long range sensors which can provide effective communication at low power has also increased. One such type of low power wireless communication system is LPWAN which is designed to allow communication at low bit rate among IoT devices.

The technology platform for LPWAN can be segmented into two broad components [2]:

1) **LoRa** : The proprietary radio modulation technology used by LoRaWAN for wireless communication between devices and gateways. LoRa is the technology that modulates the data into electromagnetic waves. It uses a transmission method called Chirp Spread Spectrum, encoding data in frequency-modulated chirps. This transmission method has been used in military and space communication for decades. LoRa is a patented spread-spectrum radio modulation which is owned by Semtech currently. LoRa chips operate in the sub-gigahertz spectrum which is an unlicensed band and thus has much less interference unlike gigahertz spectrum. Also this has the added benefits of increased penetration of signals increased a larger coverage area. But as a limitation of this, the bandwidth is very limited so approximately 50 kb of data can be sent through in a packet.

2) **LoRaWAN**: LoRaWAN is (LPWAN) technology standard developed and maintained by the LoRa Alliance, an industry-based association consisting of telecommunication companies, manufacturers, system integrators and others. LPWANs are wireless wide area networks designed to allow long-range communications at a low bit rates, with the aim of enabling end devices to operate for extended periods of time (years) using battery power.

II. ARCHITECTURE OF LORAWAN

There are four major network elements in the LoraWan IoT network :

1) **End Devices**: These are the IoT endpoints that are installed on-site and connected to the sources where the data is generated. They send these data and receive messages over a LoRa wireless network. Some of the examples of these endpoints can be a smart metering device installed in every home, a security card reader on a gate or just an alarm system.
2) **Gateways**: Gateways act as mediators between the LoRa network and the Internet. They are connected to the network server using standard networking protocols like TCP/IP or UDP. They may be connected via an ethernet link, wireless link or via a dial-up. They listen for messages from the connected LoRa chips and assimilate them and send them to the network server.
3) **Network Server**: Sends and receives LoRaWAN messages to and from devices, and communicates with upstream application servers. It acts as a manager

and also manages atomicity by removing duplicate messages.

4) **Application Server**: It is the destination for device application data sent as payload in LoRaWAN messages. It collects the data and process it. Also, it can send commands based on the data to the sensors.

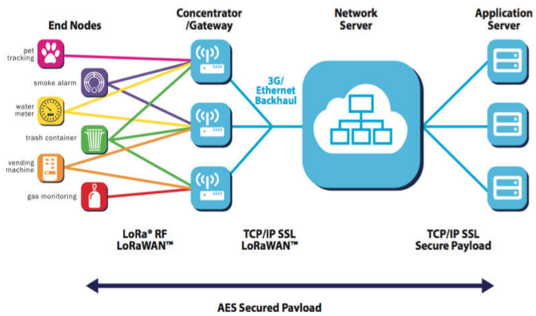

Fig. 1. Architecture of LoRaWan Network

The topology is organized as a ”star of stars”, with the network server connecting to multiple gateways, which in turn connect to multiple devices over a LoRa wireless network. Communication is bidirectional, although upstream communication is the expected predominant IoT traffic type.

In LoRaWAN, an application defines how devices are associated with a specific application server back-end, and all devices associated with a particular application share the same security context. The gateways send the LoRaWAN messages received from the wireless interface using the Gateway Message Protocol (GWMP) defined as per the LoRaWAN Gateway to Server Interface specification. The LoRaWAN message and associated control data are sent as a JSON-encoded message over a UDP/IP. Note the gateway can send and receive from one or more network servers.

Like all radio systems, the gateway cannot hear anything when its transmitting. So, when the gateway transmits a message, it shuts down the receivers and is temporarily off the air. Talking to a single node takes the whole receiver out of the picture. For this reason, transmissions and downlinks do not happen often in LoRaWAN. Because of this, LoRaWAN is best suited for uplink-focused networks.

A device can operate according to three different communication profiles - known as Class A, B and C. Each class optimises different aspects of battery life and latency requirements.

1) **Class A**: Battery powered devices, where each end-devices uplink transmission is followed by two short downlink receive windows, minimising time required to listen. Must be supported by all devices. This class of devices have bi-directional transmission capabilities.

2) **Class B**: Latency controlled downlink using slotted time-synchronised communications, allowing for more frequent downlink transmissions. These class of devices support bi-directional transmission but they also have pre-scheduled receive slots in addition to support extra transmissions.

3) **Class C**: Line Powered devices that continuously listen to downlink messages. Such devices will use more power to operate than Class A or Class B but offer the lowest latency for downlink transmission. These class of devices have a bi-directional messaging capability but with nearly continuous open windows for accepting transmissions. Hence it is more suitable for use-cases where large amount of data has to be received and transmission can have comparatively lower data.

Thus, it is observed that depending upon the requirements of data transmission, there are different versions of LoRa chips available which can be used according to the specific use case.

III. COMPARISIONS

The existing wireless communication technologies like cellular connections or WiFi connection cannot provide required support for IoT use cases given the low power and long range constraints. Also with the drastic increase in number of connected IoT devices, they will simply out number, the total capacity of existing gateways. Thus new methods need to be adapted while deciding a networking protocol for the IoT deployment. Currently, there are two standards that are competing for their dominance in this low power wireless communication market, Zigbee and 6LoWPAN. Zigbee and 6LoWPAN protocols are being deployed in factories for monitoring the status of their devices and the environment.

Technology	**Data Rate(dBm)**	**Sensitivity**	**Spectrum Strategy**
WiFi(802.11 b/g)	-95 dBm	1-54 Mb/s	Wide Band
Bluetooth	-97 dBm	1-2 Mb/s	Wide Band
BLE	-95 dBm	1 Mb/s	Wide Band
ZigBee	-100 dBm	250 Kb/s	Wide Band
SigFox	-126 dBm	100 b/s	Ultra Narrow Band
LoRa	-149 dBm	18 b/s - 50 Kb/s	Wide Band
Cellular data(2G,3G)	-104 dBm	Up to 1.4 Mb/s	Narrow Band

TABLE I. Comparison of different communication methods based on transmission parameters

One of the key factors in deciding a protocol is the area that needs to bede2017lorawan covered by the network. This area may be empty or may have multiple obstacles between the node and gateway, as a result the signal gets noisy. If the data rate of a signal is too low then it might not even reach the gateway or be so much distorted that it gets filtered out as noise. Thus to provide a better view of this,

	Parameters	**LoRaWan Devices**	**6LowPan**	**Zigbee**
Quantitative Analysis	Power Consumption	Idle: $20\mu A$ Peak: $110mA$	Idle: $1\mu A$ Peak: $40mA$	Idle: $15.7\mu A$ Peak : $12mA$
	Communication Channel Type	Bi-directional	A mesh topology with a routing algorithm	tree routing protocol through the cluster-tree hierarchy
	Modulation technique	LoRa modulation (CSS modulation) , FSK or GFSK	BPSK modulation. Also uses DSSS technique to convert bits to chips.	BPSK, OQPSK modulation. Also uses DSSS technique to convert bits to chips.
	Network Architecture	A Centralised Gateway Service with multiple devices.	Multiple devices in mesh topology connected to the internet.	Devices connected to multiple gateways connected to zigbee-internet gateway.
	Standard / Alliance	IEEE 802.15.4g, LoRa Alliance	IETF Maintained Community Driven	IEEE 802.15.4 (PHY and MAC layer), Zigbee Alliance (Network, security and Application layers)
	Ipv6 Adaptability	Support Use of Ipv6.	Easily Integrable with Ipv6 networks.	Requires a gateway to translate zigbee to ipv6 and vice-versa.
Qualitative Parameters	Security and Privacy	AES128 Encryption	AES128 Encryption	AES128 Encryption
	Mobility	Urban : 2-3 km Line-of-sight : 10 km		10 - 100 meters
	Availability and Cost-effectiveness	Different sensors are available in market.	Market acceptance is low.	Many commercial devices are found using Zigbee sensors.
	Efficiency	Min 100k devices	Max 100 devices	Max 65536 devices
	Interoperability	Requires a Gateway Server	Connects directly to IP based Services	Requires a connected host node.

TABLE II. Feature wise comparison between LoraWan, 6LowPan and Zigbee Sensors [3],[4],[5]

contending communication protocols are compared based on transmission parameters in Table I.

By comparing the data rate values in the table, it can be deduced that LoRa has almost 1.5 times better penetration power. Thus LoRa can provide better coverage than a cellular network for long range communication given a limited amount of data is to be transferred. While if the quantity of data is more cellular networks should be more preferable.

During the development of IoT solutions, some of the main problems that hinder the process of successful deployments can be

- Connectivity issues like low coverage, very noisy signal
- Insufficient power supply or inefficient energy management
- Security of the data being transmitted
- Availability of the sensors in commercial space

To overcome these challenges for long range communication, a comparison is shown of 3 widely used sensors in IoT devices, based on parameters that address the challenges given in Table II.

From these comparisons, it can be seen that while considering the challenges of power consumption, coverage area or device efficiency, LoRa chips perform relatively better than Zigbee or 6LowPan.

IV. Use Cases

LoRa can be perceived as being relatively recent, there exists scope in many fields, where the existing deployments could benefit from adoption to it. A few of the studied use cases for LoRa devices can be given as follows:

1) **Wireless monitoring of cattle troughs**: In USA, the need of monitoring the water level in troughs is high. To fulfill this need, a system was developed using wireless LoRaWAN technology and IoT sensors to monitor the water levels in cattle troughs for cattlemen. Under testing circumstances, the system was able to sense up to 50 nodes successfully. The study showed that if the number of devices increased in a small coverage area, it adversely impacts the PDR(Packet Delivery Ratio). As a result of the test, it was concluded that smaller the difference between the gateway and the nodes elevation, higher the chances of successful transmission [6].

   The different nodes installed at each of the trough send data to a gateway server in range. Due to high obstacle penetration of LoRa chips, a single gateway can server upto 100k nodes in a 1-2 km area. This data is sent to the network server which send the data to application server where is assimilated. But if the sensors are distributed across different elevation levels then the changes of successful receiving of signals

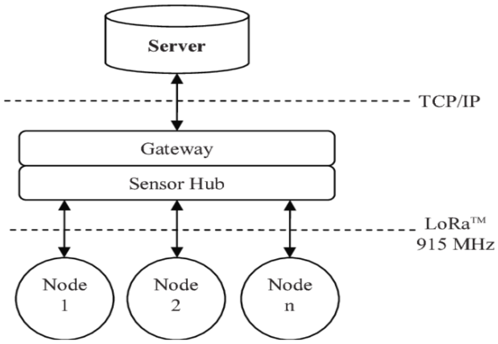

Fig. 2. Monitoring architecture of cattle trough

decrease as the signals collide orthogonally with each other.

2) **Personal Health Monitoring System**: A study was conducted in in the campus of University of Oulu, Finland to test the feasibility of LoRaWAN for short range wireless data communications.A gateway antenna was strung at 24m height from ground level while the node was attached to arm of a researcher and tests were conducted. The researchers of these comparisons, could conclude that lesser distance between the nodes leads to lesser noisy signals. Also it was observed that for transferring the same data using wireless communications, using a Low Power protocol sensor could reduce the power consumed for transmission by 200% over the traditional wireless sensor [7].

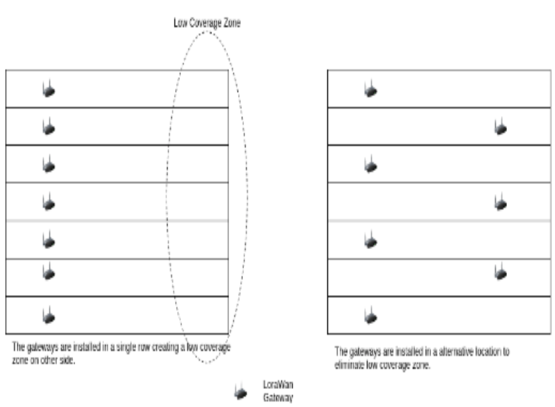

Fig. 3. Smart metering with LoRa chips

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A traditional wireless network would require a lot of repeaters to cover up the whole area and the additional repeaters would also have a bottleneck to the number of devices that can be added to it. Instead a LoRaWAN chip can stay connected to a gateway upto 1 km even across obstacles due to multipath propagation of signals. One feasible solution to implement such a system can be to have gateways installed on opposite ends on alternate floors to cover much more area horizontally and vertically as shown in Figure 3.

3) **Smart Metering System**: A smart metering system is one where the metering device has the capabilities of publishing the reading by itself on regular intervals and the data can be accessible on the internet. It can be used as an example of networks that require only one to two signals to be sent daily. For such system, regular networking technologies like wifi or bluetooth are not suitable as they have low coverage so multiple internet gateways are required. A LoRa chip can be a perfect fit for such use-cases because of the low power, low cost setup and long distance transmission capabilities. Multiple LoRa chips can connect to a single gateway across long distances. Thus only a single gateway can serve to collect data from multiple houses in a community. [8]

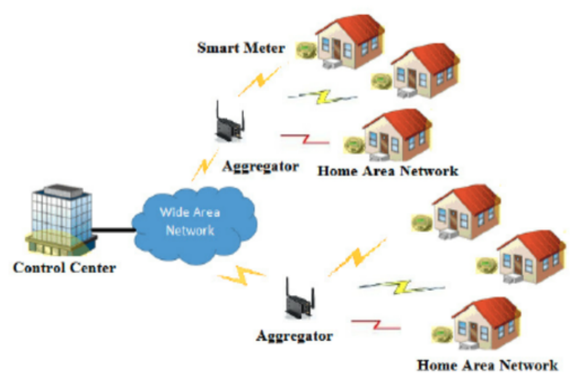

Fig. 4. Smart metering with LoRa chips

Among all evaluated LoRa physical layer settings,SN3, SN4 and SN6 not only scale well with regards to the number of nodes but also scale well with regards to the data generation rate. However, the recommended setting for LoRaWAN, (SN5) and LoRas slowest data rate setting, (SN1) are not useful for any of the evaluated IoT use cases. These settings provide for long distance communication compared to the fastest possible data rate setting (SN3), however their energy consumption is also very high compared to SN3 . However, in a multi-hop scenario nodes near the gateway may become bottlenecks, which may lead to network disconnections.

V. Open Research Challenges

The effect of the duty cycle stated earlier jeopardizes the actual capacity of large scale deployments of LoRaWan. This has been initially addressed by The Things Network [9], an interesting global, open, crowd-sourced initiative to create an IoT data network over LoRaWAN technology. Any researcher interested would have to the research community will have to address the following open research challenges during the next years.

Some of these challenges may be to explore new channel hopping methods to optimally utilise the existing channels in the network, providing TDMA over LoRaWAN infrastructure, densification of LoRaWAN networks, Geolocation of end devices and finding solutions for reduced power usage in multi-hop solutions [10].

VI. Conclusion

LoRaWAN defines both the radio technology and the protocol end to end. LoRaWAN is very well suited for long range, very low power, long-lasting battery operated, low bandwidth use-cases. It is especially fantastic for use-cases where you have more up-link (device sending to cloud or gateway) updates than down link, for example reading Water Meters or getting temperature readings once a day.

Although people refer to LoRa as the radio technology (which was developed by a French company Cycleo and acquired by Semtech) and LoRaWAN as the protocol, it should be noted that originally Semtech was the only manufacturer of chips, and it still owns the patents on the technology. One cannot oversee that developing and deploying a system around LoRa architecture is quite complex as it does not work out-of-the-box like WiFi or Zigbee. The LoRaWAN protocol and network architecture directly influence the battery lifetime of a node, network capacity, quality of service, security, and the variety of applications served by the network.

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