IoT Devices and Applications Based on LoRa/LoRaWAN

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Abstract: The traditional Internet, which primarily provided services focused on people, has been completely transformed by the Internet of Things (IoT). Through the Internet, it has made it possible for items to connect and interact. Smart water management systems are one of the many uses for IoT. They do, however, need very energy-efficient sensor nodes with long-range communication capabilities. To meet these needs, numerous Low-Power Wide Area Networks (LPWAN) technologies, including LoRa, have been developed. Therefore, to comprehend the current stream of devices being utilized, we study IoT devices and various applications based on LoRa and LoRaWAN in this article. Contributing to the development of LoRa as a workable communication technology for applications requiring long-range connectivity and scattered deployment is the goal. We emphasized the output of every trial we evaluated as well as the device parameter values.

1 INTRODUCTION

The Internet of Things (IoT) is projected to be the next big sensation in the Internet. Its mission is to let anything well, a thing interact over the Internet with, well, you name it: vehicles, animals, plants, you get the idea. IoT has been studied in different types of research and after reshaping, some classifications based on projects have been developed. For illustration, the following smart applications have been defined and are well identified: Smart Cities, Smart Homes, Smart Transportation, Smart Environment, Smart Grid, and Smart Water Systems. In IoT, there is no one deployment model, but that's all dependent on the use cases. A solution deployed in one part of the word using IoT so that it becomes a solution for another part of the word. Thus, it is estimated by researchers that more than 50 billion things will be connected by 2020.

The essential element that unites all of the Internet of Things' components to create a network is communication. The advantages of wireless communication (WC) include portability, reduced cable usage, ease of adding additional devices to the network, and the potential to enable any object to connect to the internet. Furthermore, one of the best technologies for IoT deployments is Wireless Sensor Networks (WSN). Because it facilitates the integration and linking of real items with cyberspace, WSN positions itself as a crucial component of the Internet of Things. Because of the advancements and innovations occurring in WCs, it also lowers the cost of IoT projects and deployments. WSN is made up of wireless sensors with low power consumption that can be used as long-term deployment infrastructure. However, because of the limitations of sensor nodes, including energy capacity, processing capabilities, and communication bandwidth, WSN is linked to numerous inherent difficulties. Security and network management still need more focus.

Various scenarios call for distinct deployment models with various network specifications. For instance, a network deployment that can manage mobility is necessary for smart transportation; a network deployment that can manage long-distance communications is necessary for smart cities; naturally occurring disasters are necessary for smart environments; and so on. Many WC technologies, ranging from short range to long, medium range, have been developed in recent years. LPWANs, or low power wide area networks, will get better IoT applications, both new and old, because of their long-range communication and low power consumption. Both licensed and unlicensed wireless bands are used by LPWANs. The primary LPWAN attributes that ought to direct the development of IoT networks are:

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- Low-cost devices for inexpensive network deployment;
- low power consumption;
- simple nationwide network infrastructure deployment; and security
- Broader coverage

Today, LPWAN infrastructure is going through a period of rapid growth. An all-purpose technology has, however, its limit. As a result, LPWANs are only employed to overcome certain IoT challenges. They are particularly developed for delayed-tolerant, low throughput, low power network, which needs long reach network coverage at an affordable cost. A perfect example use case for LPWAN is system or condition monitoring. In this case, we think LPWANs can be an excellent candidate for Water Distribution Networks (WDN) where small amount of data is collected to monitor different parts of the network. To clarify whether LoRa devices are suitable for monitoring in a distributed water network, this paper investigates into LoRa devices in detail and their performance under different scenarios.

The remainder of the document is structured as follows: An overview of LoRa and LoRaWAN in relation to Internet of Things devices and LoRa-based applications is given in Section II. Comparisons are presented in Section III, and the paper's discussion is covered in Section IV. The paper is concluded in Section V.

2 LoRa AND LoRaWAN OVERVIEW

LoRa stands for long range, which has its roots in low power wireless communication in the industrial, scientific and medical radio band (ISM band) which is based on unlicensed radio spectrum. LoRa aims to achieve things including nothing but shrinking medium range and regional coverage, minimizing the number of costs and complexity, device battery shall have a durability, to enhance the network capacity and service capability is implemented. This distance can be established by the physical layer. Low-power, high modulation-index frequency shift keying (FSK) is used in all wireless technologies. However, the LoRa with a communication range has an issue of the weak power-sensitiveness property due to Chirp-spread-spectrum (CSS) modulation. Here is the launch of CSS in commodity infrastructure. CSS can fend off interference, however, so space agencies and the military have used it for far-flung communication.

LoRaWAN is the best answer to the problem of long-distance networking for the Internet of Things, emerged thanks to LoRa Alliance. Its LoRaWAN based system architecture greatly addresses these long range, low power at low dataspeed issues. "Nonetheless, it is a primary cause impacting the node battery life, network capacity, security, Quality of Service (QOS) and the breadth of applications the network can support.

3 LoRa AND LoRaWAN DEVICES FOR APPLICATIONS

This section covers several LoRa deployment devices, their configurations, and a summary of the applications that employed them. The next section compares the devices and applications that are utilized.

3.1 LoRaSIM

Bor et al. analyzed some LoRaWAN protocol in regard to scalability of a network consisting of LoRa devices. Their smart city application uses a scalable network for configuration. The behavior of the link itself is analyzed with the NetBlocks XRange SX1272 LoRa module. The first identified limitations, through practical experiments, in the device link behaviour comprising of: (i) communication range independence from communication configurations (e.g. bandwidth (BW) and spreading factor (SF)); (ii) the capture effect of LoRa transmissions, depending on the timings and power of the transmissions. The goal of their study was to assist them with the models that would allow them to develop a LoRa simulator, which they called LoRaSIM. The authors say that the simulator enables the assessment of scalable LoRa networks and stores the link's behavior. The smart city experiment was performed using the LoRaSIM. In the normal metropolis, 120 nodes should be electro-assembled every 3.8 hectares, according to the findings. This is made possible using the standard ALOHA protocol. However, with dynamic multiple BS (gateways), the network would scale very well.

3.2 Mobile LoRaWAN

Petäjäjärvi et al. used to analyze the coverage of a LoRa network as the distance between the transmitter (ED) and receiver (BS) increases. conducted a real-world research experiment. The study attempts to find out the theoretical upper bound on communication-range that the network configuration could reach based on its deployment locality. Since LoRaWAN parameters are location specific, their findings are applicable to similar environments. By using the maximum SF they increased the base station's sensitivity. When a moving car stretches the distance between the ED and Kerlink's BS (set at 24 m height on top of the University of Oulu building), the ED could be either LoRaMote (mounted in a mobile car and boat) to measure the packets lost and exchanged. Their experiment focused on the percentages of sent and lost packets. European Union (EU) legislation limited the frequency channels that could be utilized. However, the nodes may choose from among the six communication channels that were available. They found that 80% of 5 km transmissions work, 60% are between 5 km and 10 km, and the node connected to the vehicle suffers decent loss above 10 km. In experiments on the boat, 70% of packets were successfully transmitted up to 15 km and a 30 km communication range was achieved. The results enabled them to develop an attenuation model to approximate the density of base stations.

3.3 LoRaWAN Single Node Throughput

To determine the maximum throughput that a single node may achieve, the authors also carried out a LoRaWAN experiment. They adjusted the SF from 7 to 12 and employed 6 channels with a frequency of 125 kHz. 100 packets with a maximum payload of 51 bytes were sent in each of the numerous tests that were carried out. The findings demonstrated that, for small packet sizes, the ED's inability to transmit packets while the receiver windows are open is the real constraint on throughput, not the channel duty cycle. The authors concluded that the data rate used determines the maximum frame size. Additionally, a transmission should never send a payload larger than 36 bytes since LoRaWAN lacks a means to divide large payloads over numerous frames. This is the biggest payload that LoRaWAN can handle, and sending a lot of data will cause capacity to be lost. Additionally, they recommend that the upcoming LoRaWAN specification revision include a fragmentation mechanism.

3.4 LoRa Indoor Deployment

An indoor LoRaWAN experiment was carried out by Neumann et al. to assess its functionality, identify its drawbacks, and specify its application in 5G networks. They demonstrated that the ISM band control, which has an impact on the daily data transmission volume, was the primary cause of the restrictions. Furthermore, the ED data rate may also be a factor of loss if it is not set correctly at the beginning. To decode and log the sent LoRaWAN frames to the database, they set up a single gateway and a single basic server. The Raspberry Pi 2 and IMST IC880A are connected over an SPI bus to form the base station. The ED is composed of a Raspberry Pi 2 interfaced with a LoRa mote RN2483 via a UART interface, and the packet forwarder code utilized is from Semtech.

3.5 LoRa Indoor Propagation

To assess indoor signal propagation capabilities for long-range coverage of LoRa technology, Gregora et al. carried out a study experiment. In two different circumstances, the transmitter position was changed while measurements were being taken, and the receiver was positioned on the roof of a building and in the basement. Their tools were specially designed for the experiment. A USB serial converter was used to connect the IMST iU880A, which was utilized as an ED transmitter, to a PC. WiMOD LoRAWAN EndNode Studio is used to control the node settings.

3.6 LoRa Fabian

FABIAN, a LoRa-based system installed in the city of Renne, was designed and described by Petrić et al. The network topology was a star topology based on the ALOHA protocol. QoS was measured by evaluations. The traffic between the nodes and base stations was the focus of the investigation. They were able to produce traffic that is comparable to what is utilized in sensor monitoring applications. Performance indicators like RSSI and packet error rate (PER) associated with the LoRa physical layer and signal noise ratio (SNR) were observed. An Arduino and a FroggyFactory LoRa Shield running a modified version of Contiki OS made up the nodes that were utilized. The ED is set up with Kerlink as the BS and the LoRaWAN protocol for communication. They provided the results after varying parameters that can impact QoS.

3.7 LoRa Wi-Fi

Kim et al. created a multi-interface module that combines LoRa and Wi-Fi to provide high data transfer, great range, and low battery consumption. This was done in order to give LoRa technology the capacity to send large amounts of data and deliver a variety of services using a range of sensors. The Raspberry Pi, Arduino, and Waspmote and Semtech SX-1272 chipsets made up the Elix board, which offered Wi-Fi and LoRa functionality. Through the Wi-Fi and LoRa modules, respectively, the Wi-Fi handler and LoRa handler transmit data. To control power utilization, the system is integrated with a power and data scheduler that prioritizes sensed data and decides between Wi-Fi and LoRa. Measurements of RSSI and SNR from a communication range of 6 km to a maximum of 20 km were the focus of the studies.

3.8 LoRaWAN Channel Access

As the most critical one for machine type communication (MTC), Bankov et al. examined the performance of LoRaWAN over channel access. Their investigation also sought to evaluate the shortcomings of LoRaWAN and propose a solution. Simulation-based evaluation does not provide the full potential of LoRaWAN. Their analytical approach was thus grounded in a more pragmatic framework. From channel access evaluations, it is known that transmission collisions occur when two transmissions sharing the same data rate temporal overlap. Motes are connected to a gateway as a part of their network configuration. It makes use of three primary uplink channels, each 125 KHz wide, and one downlink channel. The data rates devices are configured to use are between 0 and 5, or an SF of 7 to 12. We have every mote sending a 64-byte payload, of which 51 bytes are frame payload. They also studied PLR (packet loss ratio) and PER (packet error rate) with loads lower than 0.1 per second. There is some loss of packets on the network, when the traffic increases more packets will get lost due to collisions. One packet can be sent each 20 minutes with 100 motes. They are then proposed to be fixed with the densification of LoRaWAN gateways.

3.9 PHY and Data Link Testbed

Based on modeling and field-testing, Augustin et al. Some developed a testbed to evaluate performance for the lower layers heavily. Their work deserves attention as they conducted an extensive study on the LoRa components. As with the authors, we placed the gateway in an indoor environment and the end-device node in an outdoor environment to determine the coverage distances of the LoRa coverage region. When they checked the packet delivery ratio, they changed the distance and SF. Despite lower SF, they found, they achieved higher coverages and packets on the highest SF, which is 12. They inferred that the delivery ratio of a LoRaWAN network could reach a higher one.

3.10 LoRaWAN Nordic Cities

Ahlers et al. employed a LoRaWAN as part of their extensive research to quantify urban greenhouse gas emissions in Nordic cities. It is a low-cost automated system to measure greenhouse gas emissions in the city. Their approach also addresses the issue in Norway where there is no system that provides gas emission statistics and that makes the information available to all its citizens via a municipality platform. Two sensor technologies were used, namely Sodaqs Autonomo (SA) and Libeliums Plug & Sense Smart Environment Pro (PSSEP). LoRaWAN is the communication method used to cover their minimal gateways spread through the city. They added a solar panel beside their node to recharge the power supply and increase the batteries' life. Nodes were equipped with different sensors to measure different characteristics of gas. For six months they monitored CO2 levels, keeping a stable level of battery power. They found that this kind of network is feasible for industrial sensing.

3.11 uPnP-WAN Temperature Monitor

In, Ramachandran etal proposed the uPnP-WAN device in order to give embedded IoT devices plug-and-play capabilities. The system has an ad hoc suburban range of 3.5 km. The team first solved for a system to track temperatures within blood refrigerators in the Democratic Republic of Congo. In practical applications, their battery-powered device is plug-and-play and has a battery life of six years. The antenna height geolocation affects the performance of the range. For class A LoRaWAN, uPnP-WAN utilises Microchip's RN2483 LoRa chip. The uPnP Contiki OS with Erbium CoAP stack runs onAtMega1284p microcontroller with a 10 MHz MCU, 16 kB RAM and 128 kB flash. The uPnP and RN2483 are connected in a UART fashion. Battery life and range testing were carried out. The single-hop LoRa deployment enabled the system to reach 3.5 km. Also, and this is less of a gut feeling, the battery is currently projected to last 10 years (contrast that with their old mesh uPnP-WAN system). Sensor reads were transmitted to the gateway every fifteen minutes through the uPnP-WAN.

3.12 Troughs Water Level Monitoring System

With WSN, Tanumihardja and E. Gunawan developed a system to monitor the water level in troughs utilizing LoRa and LoRaWAN as its physical layer and communication protocol. They devised a way for cattlemen to monitor their trough ubiquity (or ubiquitous troughs) by repurposing their own gadgets. Raspberry Pi is used as the Gateway to send the sensed data to the server. Since the system is designed for cattlemen with very little, if any, engineering background, it is assumed to do self-configuration. The sensor used to read the water state is the float switch GE-1307, and the deployed nodes in the farm itself use ATMega low power requirement meets for the remote. Since the nodes were placed this low and the gateway was placed on the top of a house that could be eight meters high, the bandwidth in the study was calculated with the distance between the gateway and node kept variable. They conclude that horizontal polarization of the antenna is suitable for this setup.

4 COMPARISON AND DISCUSSION

Summarizes the parameters of different examined device settings in terms of their various LoRa and LoRaWAN applications it is worth noticing that the studies made interestingly diverse standalone deployments using full stack plug and sense devices, and standard single board computers linked to LoRa modules from separate providers that can be performed diverging accordingly. But devices that use LoRa operate differently based on geographical limitations, which include the United States, Asia, and the European Union. Moreover, some of these are built specifically for regions. According to the usage of the device, the LoRa device needs to be reconfigured. As observed, where a large majority of the scrutinized devices worked with the common 125 kHz wideband all supported SF 7-12 (dSF) in full-duplex (dBi) mode, it is observed that static bandwidth does not vary by its position on the spectrum, which is one of the common features of a bandwidth channel. They employed three different BWs: 125 kHz by default, 250 kHz when between DR3 and DR4, and 500 kHz for both upstream and downstream purposes. DR4 upstream 64-71 eight channels and DR10~DR13 downstream 0-7 eight channels. Moreover, 14 dBm was used in 8 dBm (11-12 SF transmit power for optimal performance). Transmission power used of the transmission power of is considered good since it enables the system to lessen noise interference and enhance signal propagation. This source power is mainly used in the 2.4 GHz ISM-band for relatively large channels. The results show typical parameter values for all applications. This could be further refined for LoRa with additional experimentation with different parameters, but this was out of the scope of this research.

The foundation of LoRa devices is range. In one of these investigations, the shortest range measured was 50 cm. To minimize network congestion and enable adjacent devices to transfer at a low TOA, LoRa constantly prioritizes nearby nodes. As one of the upcoming IoT technologies, LoRa technology is now being researched primarily to verify its capabilities and provide long-range communication with minimal power consumption. Furthermore, investigations conducted by the authors have shown positive outcomes, reaching a 30-kilometer link between the gateway and the ED.

According to the publications examined in this work, many scenarios, including interior deployment by and and outdoor deployment by and, have been used to test the feasibility of LoRa technology. Because they perform well with current networks and technologies and fit into most network configurations, LoRa devices offer flexibility. For example, a system that combines Wi-Fi and LoRa was intended to provide long range and maximum throughput. The most noteworthy use was carried out by Raza and Kulkarni, who created a battery-free LoRa device that uses the vibrations of the bridge as vehicles pass it to generate energy. Their ideas demonstrate that, depending on the application type and deployment area, LoRa technology offers innovative opportunities.

5 CONCLUSIONS

The Internet of Things is all about devices that can connect to each other over long distances and with minimal energy use. This is where LPWAN was born or created. Based on new developments, it is no surprise that many cutting-edge advancements are being done in regards with LPWAN networks and technologies such as LoRa. In this study, we focused on IoT devices and applications based on LoRa/LoRaWAN, its current deployments and what it can be used for. The results from the evaluation and study are listed. We found that devices used in all applications are the same, and also that recent LoRa work is comparable. In most deployments of LoRa communication, single board PCs connected to LoRa modules were used. Moreover, several applications used radio station and modular plug-and-sense devices, which are full-stack for deployment of LoRa, but cost can sometimes be a limiting factor for large deployment. In addition, the current deployments can be categorized as simulations, testbeds, and real implementations. However, most popular applications are still related to monitoring. Also, to increase the future use of LoRa, a cross-platform LoRa-based monitoring and control device should be developed.

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