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A Systematic Review on LoRaWAN-based Sewage Monitoring and Alerting System

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Abstract*— This paper reviews one of the LoRaWAN (Low Power Wide Area Network) applications. LoRaWAN offers low-power, secure, low-data rate communication with more than 10km (6.1 mi) coverage. In recent years, LoRa technologies received significant attention from Engineers and Research communities. And many researchers have used LoRaWAN as a solution for many problems, one of which is Sewage Monitoring. Untreated, stagnant, and overflown sewages in civilian neighborhoods attract serious health issues. This paper provides an overview of the methodologies and research work published from 2019 to October 2022, which are accessible through Google Scholar and IEEE Explore. In this paper, we start with a detailed overview of the Technologies used with existing reliability and security mechanisms. In this paper, we reviewed the previous papers by categorizing them into the following topics (i)Physical layer aspects (ii)Network layer aspects (iii)Security and Reliability (iv)CAPEX and OPEX. Finally, concluding with the possible solutions, future scope, and improvements.

***Index Terms*— LoRaWAN, LoRa, IoT, Water level Sensors, Gas Sensors, Cloud Computing**

I. INTRODUCTION

Low Power Wide Area Network (LPWAN or LPWA Network) is designed for long-range radio communication in the unlicensed band at low bit-rates among things in a network mainly operated on battery systems. Examples of this technology are LoRa and LoRaWAN [Alliance 2015].LoRa Alliance is an open and non-profit association to support LPWAN technologies by promoting and supporting the global adaption of the LoRaWAN standard. LoRa is a physical modulation fashion, grounded on Chirp Spread Spectrum(CSS) which is used in nature by batons and dolphins, making it a fashion with good interference rejection capability.

A healthy environment is essential to maintain a healthy lifestyle. Maintaining a proper sewage management system is essential as the overflow of sewage water and the release of harmful sewage gases can lead to numerous diseases like typhoid, campylobacteriosis, hepatitis A, and gastroenteritis. Not clearing the sewage water blockages might cause the streets to get filled with water causing harm to the environment and making the area smelly making it hard to live in. According to the research, if the concentration of sewage gas rises above 0.0005 parts per million then it's harmful and makes daily life difficult. There have been many solution proposals addressing these problems in the past few years. In this systematic review, we intend to highlight the potential of using LoRaWAN technologies as a solution to this problem. And explore the methodologies used by past researchers, and discuss the different aspects of the technology implementation in section 3. Ultimately, we conclude with practical scenarios and deployment options with future scope.

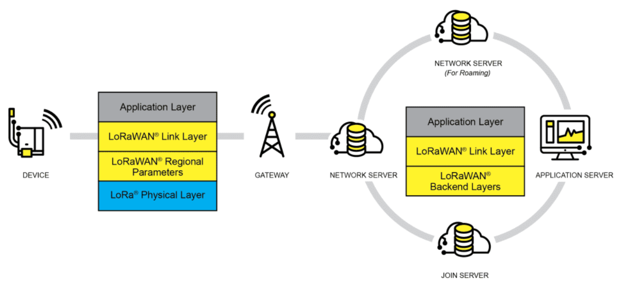
II. LoRa AND LoRaWAN PROTOCOLS

LoRa (from "long-range") is a physical proprietary radio communication technique.[1] It is based on spread spectrum modulation techniques derived from the chirp spread spectrum (CSS) technology.[2] It was developed by Cycleo (patent 9647718-B2), a company in Grenoble, France, later acquired by Semtech.[3][4]

LoRaWAN defines the software communication protocol and system architecture. The continued development of the LoRaWAN protocol is managed by the open, non-profit LoRa Alliance, of which SemTech is a founding member.

Together, LoRa and LoRaWAN define a Low Power, Wide Area (LPWA) networking protocol designed to wirelessly connect battery-operated devices to the internet in regional, national, or global networks, and targets key Internet of things (IoT) requirements such as bi-directional communication, end-to-end security, mobility and localization services. The low power, low bit rate, and IoT 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. The LoRaWAN data rate ranges from 0.3 kbit/s to 50 kbit/s per channel.[5]

LoRaWAN® Network Architecture



III. SYSTEMATIC REVIEW METHODOLOGY

3.1. Physical layer aspects

The physical layer includes aspects like electrical, mechanical, and procedural interfaces to the transmission medium[11]. There are different frequency bands allocated for LoRa protocol throughout the world. Which provides for, 902 - 928 MHz (US), 863 - 870 MHz / 433 - 434MHz (EU), and 470 - 510 MHz / 779 - 787 MHz (CH). In the past, researchers have proposed using different IP protocols like GPS, GSM, and LoRaWAN technology to monitor sewage status. In GSM technology, the Physical layer is composed of Baseband which has FEC(Forward Error Correction), ciphering, burst formation and modulation, and RF. LoRa has a lot of advantages over GSM, few of the list is it uses the ISM band which is available worldwide. And Single LoRa Gateway is designed capable to manage 1000s of end devices or nodes.

The physical layer uses a modulation technique known as CSS (Chirp Spread Spectrum. It uses 6 SF(spreading factors) from SF6 to SF7. which is much more resilient to interference and noise. In the previous approaches for sewage monitoring in the papers [8] [10] GPS module with a GSM module to provide latitude and longitude has been used. Using GSM GPS technology at the end devices can be power-hungry and unreliable due to signal coverage conditions. Using LoRa can be a huge advantage over battery power consumption, and geological footprint. In LoraWAN Class A operation[9] which is the most energy-efficient mode of communication and supports the longest battery life.

The class A end device stays in deep-sleep mode until they sense a change in the variables or environment and an event is triggered waking up the device and going back to deep sleep after the event.

3.2. Network layer aspects

The network layer includes the aspects like packet forwarding, and connectionless communication viz. IP protocols, host address, and message forwarding. In the LoRWAN protocol, the End device is wirelessly connected to the LoRaWAN receiver or to the LoRaWAN network through gateways using LoRa RF modulation.

Each gateway is registered (using configuration settings) to a LoRaWAN network server. A gateway receives LoRa messages from end devices and simply forwards them to the LoRaWAN network server. Gateways are connected to the Network Server using a backhaul like Cellular (3G/4G/5G), WiFi, Ethernet, fiber-optic, or 2.4 GHz radio links.[12].

LoRaWAN server is the most reliable and secure, as it establishes secure 128-bit AES connections for data transfer by providing end-to-end security, checking and verifying the device address for authenticity, and providing acknowledgment of confirmed uplink data transfers.

3.3. Security and Reliability

LoRaWAN uses a modern encryption scheme, i.e. Advanced Encryption Standard (AES), to guarantee its end-to-end security for secure communication which makes it reliable and threat-free. Some basic features include bi-directional authentication, integrity checking, and data encryption. In bi-directional authentication, only authenticated devices can be connected to LoRaWAN between end devices and network servers which means the eavesdropper and invalid devices cannot be successfully authenticated. [7]

Two different network join methods are implemented by the LoRaWAN which is handled by the Join Server to authenticate an end device.

One method is ABP, which specifies that all the information necessary to authenticate a device is previously set up in the end device and the Join Server. This method excludes the need for the end device to exchange authentication messages with the Join Server. The network manager is responsible for managing the join procedure.

Another method called OTAA requires a handshake between the end device and the Join Server. Only end devices can initiate a join procedure, and this happens every time a new device wants to join a network or a device loses connection with the Network Server. Forward Error Correction (FEC) provides high reliability in LoRaWAN even over a bursty channel [13].

3.4. CAPEX and OPEX

When it comes to practical scenarios and deployment CAPEX (Capital Expenditure) and OPEX (Operational Expenditure) plays a very important role.

In recent research works the methods used are NB-IoT and LoRa. the choice between these two is not simple. When we consider deployment NB-IoT network can be deployed inexpensively via the existing LTE network reducing CAPEX, but for the service to be running the client needs to pay the operational expenses i.e $6-10 per each end device annually.

For deployment using LoRa, the operator needs more sites than NB-IoT and they need to design a city-wide grid with RF planning with consideration of the geological footprint in that locale. NB-IoT base stations can be deployed on existing LTE sites but they're expensive. In either case, deploying a network can be pricy.

One needs to consider other factors like reliability and security. On basis of other factors, it is recommended to use LoRa for the sewage monitoring application, as we need a long battery which is promised by the Class A devices of LoRaWAN and not dependable on the LTE network as having a dedicated RF channel is more reliable.

IV. CONCLUSION

This work observed and analyzed the methods used in previous research the technology was satisfactorily applied and the applications were done on basis of experimental environments. No technology has been near practical deployment in the past years. Few have power efficiency issues, few have network security and reliability issues.

Finally, we are working on a more practically deployable technology model of this system using LoRaWAN and low-power node devices with manually configurable geo coordinates and monitoring data with Cloud Computing.

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