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Smart Infrastructure Monitoring using LoRaWAN Technology

Priyanka Chaudhari
Dept. of Computer Engineering
Sinhagad Academy of Engineering
Pune, India
c.piyu@outlook.com

Aman Kumar Tiwari
Dept. of Computer Engineering
Sinhagad Academy of Engineering
Pune, India
amankumartiwari7@gmail.com

Shardul Pattewar
Dept. of Computer Engineering
Sinhagad Academy of Engineering
Pune, India
shardulpattewar@gmail.com

S. N. Shelke
Dept. of Computer Engineering
Sinhagad Academy of Engineering
Pune, India
snshelke@sinhagad.edu

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***Abstract*—An online monitoring system for manhole covers in a smart city environment is proposed. We have used LoRa physical layer for wireless transmission and LoRaWAN protocol for cloud connectivity. The system incorporates sensor nodes, LoRaWAN network and application at the backend. LoRaWAN based IoT has an extremely low power requirement for significant distance transmission. We have employed an accelerometer sensor to monitor the position, removal or harm of manhole covers in sewage systems. When these covers are moved or harmed, the LoRa board transmits the signal, cautioning the nearest gateway associated with The Things Network (TTN), a cloud-based open source LoRaWAN platform. The TTN sends an alarm to the support division of the civic authorities to take corrective actions. Such innovative applications can be displayed for monitoring and controlling different parameters in the smart city.**

***Index Terms*—LoRa, LoRaWAN, Smart City, The Things Network, Manhole Cover, Accelerometer, Atom, Micropython, Pymakr**

I. INTRODUCTION

Low Power Wide Area Networks (LPWAN) based Internet of Things (IoT) has many applications in the smart city environment and is getting deployed at an extremely high rate. These technologies are designed to emphasize low cost devices, small-sized data with low bandwidth, longer battery life, a large number of devices, and extended coverage. The advancements in IoT is in all phases of industry and markets. It characterizes the methods of designing, managing and maintaining the networks, data, cloud and connections. IoT applications use low complexity and energy-efficient nodes in different settings on wide area networks [1]. To help such necessities, a low-power IoT, called LoRa (Long Range) [2] based networks, was introduced. LoRa based LPWAN covers larger regions, low data rate and long battery life. Low power utilization and significant distance transmission qualities have great development expectations in the field of IoT [3][4].

Our paper proposes a LoRaWAN based system to monitor manhole covers utilized in sewage systems in smart city environments. In developing nations, checking the wellbeing of a manhole cover is a difficult issue. Frequently, manhole covers are harmed or stolen due to a few mishaps and deaths. Our system detects the manhole cover and its health. In the event of damage or theft, it hints the cloud-based server in real- time, and the server alerts the concerned officers or personnel about the equivalent to make the vital move as quickly as time permits.

II. LORAWAN AND TTN

Since the Semtech organization created the LoRa extraordinary chip [2] in 2013, LoRa has been rapidly advanced in Europe and America. LoRa has been applied to utility meters, transportation, structures, natural checking and different fields. LoRaWAN is a type of wide area network. LoRa is a physical layer technology, whereas LoRaWAN facilitates the network connection through the Internet and hence gets connected to the cloud. From the technical point, it provides low power facility, long-distance for communication, wide range of distribution, a small amount of signal transmission data, economical construction with low data rate, etc. are the key characteristics which are very useful in the monitoring of manhole covers, as compared to current technologies [5]. It also works on free frequency ranges of the ISM band. In India, the frequency range for LoRa technology, or we can say, for LoRaWAN is 865 MHz, and it is again license-free. The block diagram of LoRaWAN network is as shown in Fig. 1. LoRa-based IoT sensor nodes are wirelessly connected to LoRaWAN gateway. The LoRaWAN gateway is also connected to a cloud network server through IP networks. The network server is connected to various application servers.

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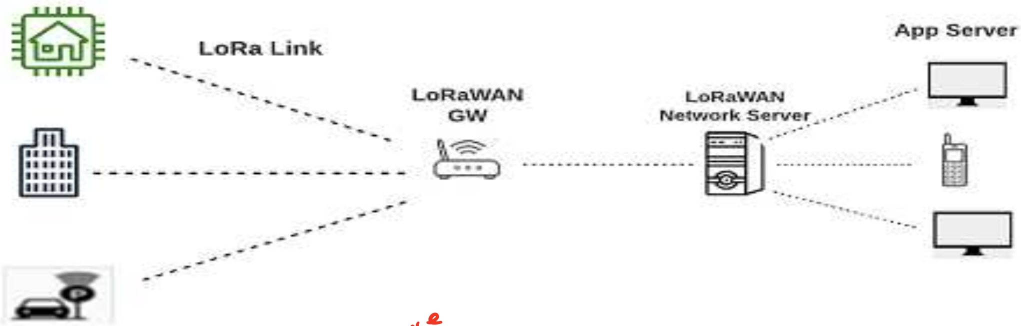

Fig. 1. Block diagram of LoRaWAN network

Other study that suggests end devices are prone to attach

In our case, it is connected to manhole cover applications. There is a gateway to network server security as well as sensor node to application server security. Hence, LoRaWAN based networks are considered as highly secured networks [6].

LoRa-alliance [7] has developed LoRaWAN, a protocol to connect LoRa to the network. The Things Network (TTN) [8], which is a part of the LoRa-alliance, is an open source platform to construct IoT applications and connect to the cloud with minimal price with the greatest security, end-to-end encrypted and secured communication. The TTN is a drive to fabricate an overall open source framework to work with a public IoT and permits sensor nodes to share the data on the cloud. As the measure of traffic produced by nodes is extremely restricted, clients can share the admittance to their routes, which permits the organization to have a more noteworthy inclusion. There are presently over TTN 300 networks around the world. The Things Network provides a feature to create applications, register the device, and connect it to the application server.

III. SYSTEM ARCHITECTURE

In the system, structure of the intelligent manhole cover monitoring system is separated into three steps: the location condition sensor, i.e. accelerometer and other environmental parameter sensors, are liable for the continuous checking of the manhole cover state, gathering data will be sending off to the LoRa gateway. We are using Pycom LoPy boards in our setup, and it is configured as a single channel nano-gateways for demonstration purpose. The nano-gateway sends the received data to the TTN with the goal that the upper layer can measure, dissect and store information and alert the maintenance department. In the system, the nano-gateway goes about as a halfway association, and the uplink is answerable for the data get-together and information transferring of each sensor node. The block schematic of the prosed system is as shown in Fig. 2. TTN application servers can be configured for sending alerts to the maintenance department of civic authorities. The alerts in terms of SMS or emails can be generated periodically or wherever something goes wrong with the manhole cover.

IV.IMPLEMENTATION

The design of proposed LoRaWAN based system to monitor manhole covers used in sewage systems and its hardware setup is as shown in Fig. 3. We have Pycom's LoPy4 Pysense nodes, accelerometer sensors, nano-gateway, and TTN network and application server. Pysense board has an inbuilt accelerometer and many more sensors. Pycom Lopy 4 is a microcontroller that can be fixed on the boards and store all the data. LoRa nodes and gateway are programmed and configured by using microPython. The accelerometer sensors sense the damage and theft of cover using angle algorithms running periodically. When there is movement of the manhole cover, the accelerometer sensor sends the signal to the LoRa node, which transmits RF signals wirelessly in the unlicensed frequency band for long-distance. This signal is received by the nearby LoRa nano-gateway, which is connected to the TTN server [9][10]. The data gets uploaded to the cloud and stored, and it will alert the maintenance department for repairing purposes.

The firmware update of all the used boards was done and then programmed using microPython and Pymakr in Atom IDE. To configure the Pysense node, we have utilized a tilt angle strategy for working of the accelerometer sensor. There can be shift manhole covers from any angle; it is appropriate to utilize a triaxial accelerometer thinking about the accuracy of the measurement. According to the tilt angle method, an index of the state of the manhole cover is our tilt angle. Along with this, the orientation angles are depending upon the order in which we are applying rotations. Different rotation sequence may bring in a similar posture, in similar posture have distinctive pitch and roll, that is the reason we need to characterize a default arrangement: Yaw-Pitch-Roll (ψ-θ-ϕ). The formula for calculation yaw pitch roll is

$$\tan\phi_{xyz} = \left(\frac{G_{py}}{G_{pz}}\right)$$
$$\tan\theta_{xyz} = \left(\frac{-G_{px}}{\sqrt{G_{py}^2 + G_{pz}^2}}\right) \qquad (1)$$

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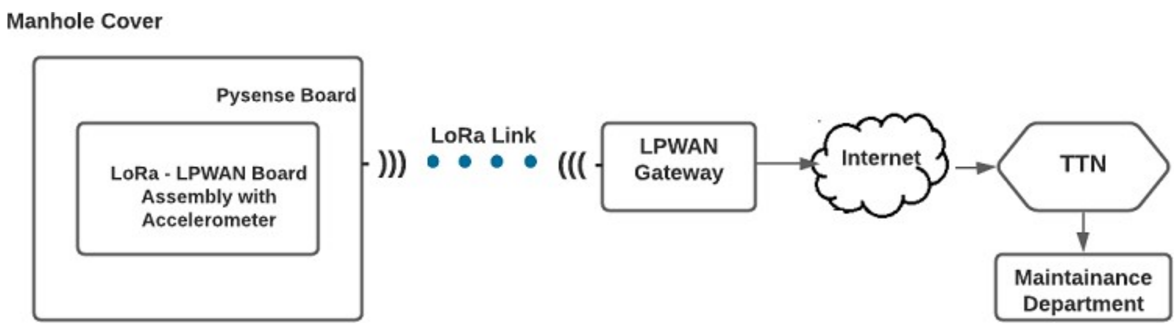

Fig. 2. Block schematic of manhole cover monitoring system

There are two methods to activate the nodes to send data from the nodes to the network: Over The Air Activation (OTAA) and Activation By Personalization (ABP) method. In OTAA, a join request is sent from the node to the network. The network then checks the Application EUI, Device EUI and Application Key provided by the node. If the Application EUI, Device EUI and Application Key are valid, a join accept message is sent back to the node, which triggers an event to be a secured network. In ABP, there is no handshaking between the node and the network. As soon as the node performs a join action, it can start sending data. The Application Session Key and the Network Session Key are set once in both the node and The Things Network server then an event is triggered in a secured network.

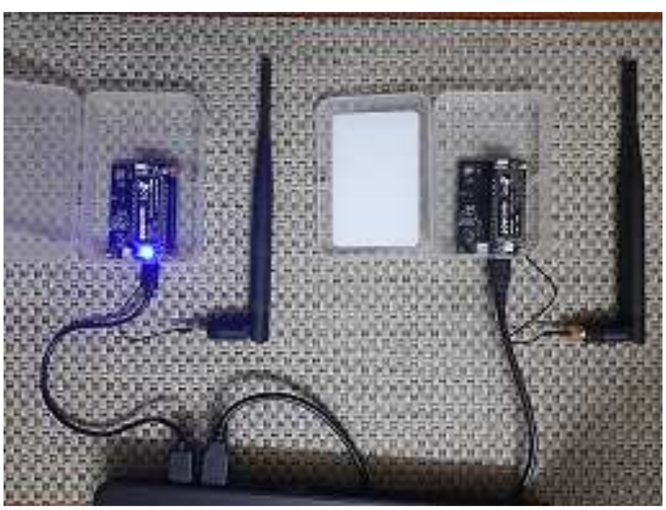

Fig. 3. Hardware setup of the project

V. RESULTS AND DISCUSSION

PyCom nodes can also be configured as single-channel nanogateways for LoRaWAN. We have programmed one of the nodes as a LoRa nanogateway to receive the LoRa signal from sensing LoRa nodes. The nanogateway is connected to the Internet so that it can send data to the TTN server. On the TTN server, we have configured an application to decode the data and is integrated with Webhooks service which is an applet and acts like an API and allows to integrate other services like TTN on IFTTT (If This Then That) with projects via simple web requests which will be transfer to maintenance department in form of email. When the manhole cover is abnormal, it will send out an alarm message to notify the relevant departments to repair and realize the municipal manhole cover's periodical supervision. The proposed placement of the LoRa node on the manhole cover is as shown in Fig. 4

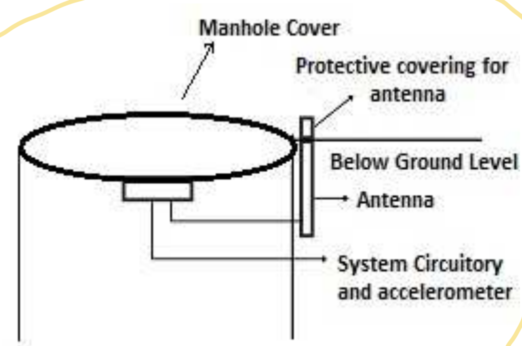

Fig. 4 Manhole cover placement

The captured data is sent to the registered TTN gateway. The screenshot of measured accelerometer readings in terms of roll, pitch and yaw are shown in Fig. 5.

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Fig. 5. Accelerometer readings of the node

Figure 6 shows the activated nano-gateway results in terms of PUSH and PULL acknowledgements.

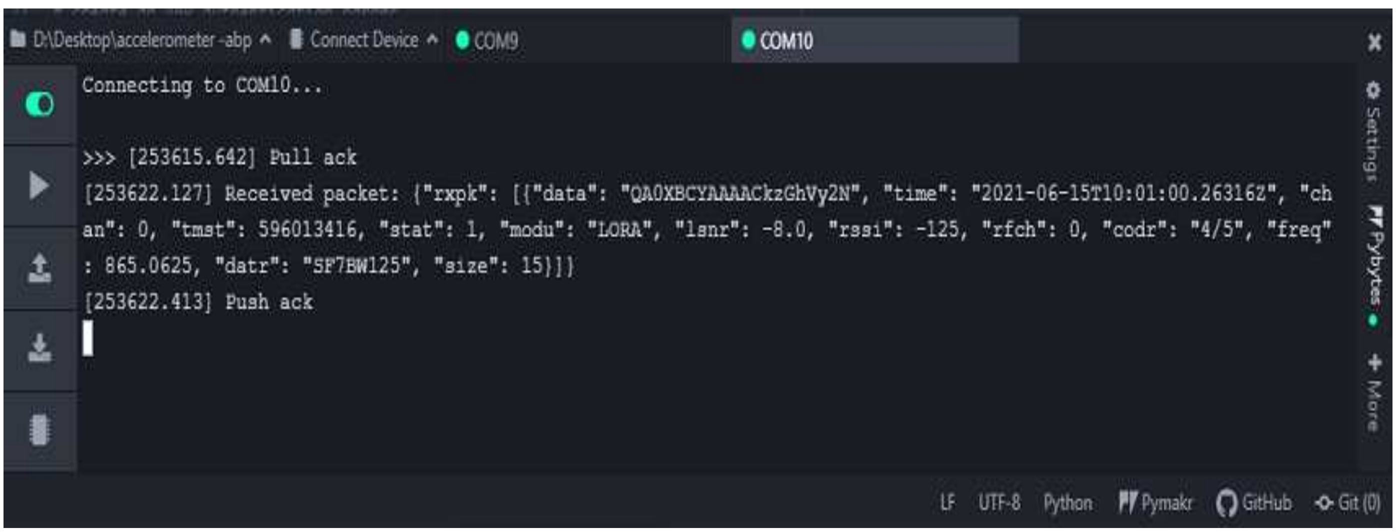

Fig. 6: Nanogateway sending the acknowledgement to the TTN

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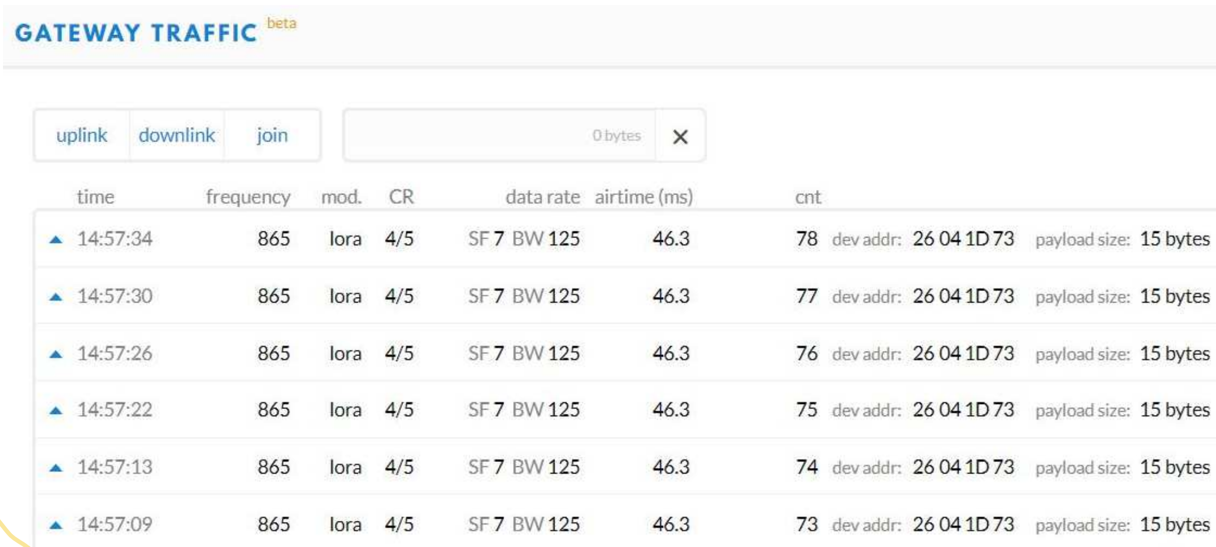
The TTN gateway traffic is as shown in Fig. 7. The received packets can be decoded by using the application server.



GATEWAY TRAFFIC beta

uplink downlink join 0 bytes

time	frequency	mod.	CR	data rate	airtime (ms)	cnt		
14:57:34	865	lora	4/5	SF 7 BW 125	46.3	78	dev addr: 26 04 1D 73	payload size: 15 bytes
14:57:30	865	lora	4/5	SF 7 BW 125	46.3	77	dev addr: 26 04 1D 73	payload size: 15 bytes
14:57:26	865	lora	4/5	SF 7 BW 125	46.3	76	dev addr: 26 04 1D 73	payload size: 15 bytes
14:57:22	865	lora	4/5	SF 7 BW 125	46.3	75	dev addr: 26 04 1D 73	payload size: 15 bytes
14:57:13	865	lora	4/5	SF 7 BW 125	46.3	74	dev addr: 26 04 1D 73	payload size: 15 bytes
14:57:09	865	lora	4/5	SF 7 BW 125	46.3	73	dev addr: 26 04 1D 73	payload size: 15 bytes

Fig. 7. TTN nano-gateway traffic

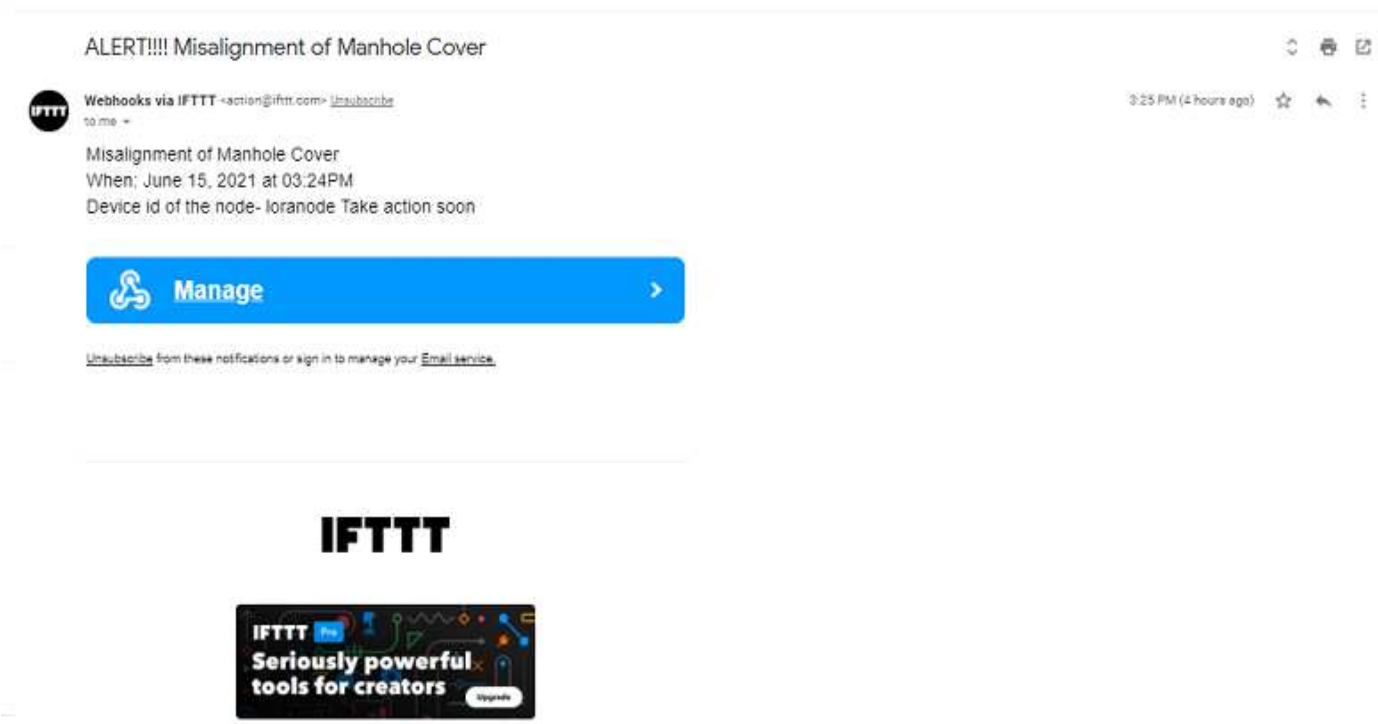


Fig. 8. Alert received to maintenance department using IFTTT integration

VI. FUTURE SCOPE

LoRa and the LoRaWAN protocols provide secured end-to-end encryption connections between nodes and end users. However, using LoRaWAN will not guarantee the trust of network operators. In future, we can have a Blockchain-based solution for LoRaWAN network servers and exploiting the advantages of both of these technologies. Blockchain technology provides an open, decentralized, trusted and tamper-proof system, with an indisputable mechanism to verify that the data of a transaction has existed at a specific time in the network using a consensus algorithm known as proof of work. In the future, we also can use smart contract script technology to define the automated trading model in the IoT network. Further, we would work to build LoRaWAN blockchain networks to link customer's gateways and application servers.

VII. CONCLUSION

LoRaWAN technology is one of the promising technologies for low power and long-range IoT solutions. In the smart city, LoRa WAN can play a crucial role in the deployment of various applications, such as manhole cover monitoring, utility meters, air pollution monitoring, street light controls and many others. We developed a low cost system for monitor manhole covers used in sewage systems. Our systems give instant real-time alerts to the maintenance department of civic bodies wherever there is damage and movement of the cover. It reduces accidents and makes for ease of maintenance. The proposed solution is low cost and can be scaled to monitor a large number of covers.

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