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Implementation of Transmission Line Fault Detection System using Long Range Wireless Sensor Networks

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Abstract— This paper proposes a fault detection system designed for transmission lines using Long-Range Wireless Sensor Network (LoRAWSN). The system is designed to detect and locate faults across transmission lines in real-time, which can significantly improve the reliability and efficiency of power transmission systems. A WSN will be built across transmission lines over an area. The faults identified by these sensor nodes is then transmitted to a central control unit, which analyses and displays the data. The LoRaWAN technology enables the WSN to cover long distances while consuming minimal power, making it ideal for monitoring transmission lines. The proposed fault detection system is evaluated through real world experiments, which demonstrate the feasibility and effectiveness of the proposed system. Overall, this paper presents a novel and practical approach for fault detection on transmission lines, which has the potential to improve the reliability and efficiency of power transmission systems.

Keywords-LORAWAN; Internet of Things(IoT); Long-Range Wireless Sensor Networks(LoRaWSN)

I. INTRODUCTION

Knowingly or unknowingly, humans became habituated with small, low-power devices that are distributed throughout an environment to collect and transmit data. The applications of these are limitless, they are used in environmental monitoring, industrial automation, home automation, healthcare, etc. A Wireless Sensor Network is a gathering of sensors, communication protocols and controllers, which together, are capable of sensing and transmitting data wirelessly. WSNs consists of three main components: sensors, wireless network and a base station. The sensors fish environmental data, wireless network is used as a medium between sensors and base station to exchange data, and finally the base station is responsible for receiving and processing the obtained data. These networks have the potential to revolutionize many aspects of world by providing real-time monitoring and data collection capabilities that were previously unavailable.

The key challenges in designing WSN are to minimize power consumption and enable long-range communication. LoRa (short for Long Range) is a wireless communication technology, designed for low power, long-range wireless communication. It is based on a networking protocol that permits long-range communication, consuming very little power. In order to achieve this, LoRa uses Spread Spectrum modulation technique in which the signal is spread across a wide range of frequencies, making it more resilient to interference and noise. This technology stands ideal for applications that require long-term, low-maintenance operation. Additionally, these LoRa networks can be easily deployed and managed, as they do not require complex infrastructure or specialized expertise. Overall, LoRa has the potential to unlock new applications that were limited previously due to range and power constraints. Due to the ability to provide real-time monitoring and quick fault detection, transmission line fault detection systems are gaining popularity among governments and power industries. In this system, the sensors are deployed along the transmission line to monitor voltage and other defects such as short circuit and open circuit. The data collected from these sensors is transmitted wirelessly to a base station for further analysis. This allows power companies to quickly respond to faults and prevent long duration power outages, which can have a significant impact on business and consumers. One challenge faced while implementing this system is the inability of the wireless network to cover a wide area. In our paper, we put forward an implementation of these transmission line fault detection systems using long-range wireless sensor networks. Usage of long-range communication modules such as LoRa reduces the power consumed, decreases cost and increases the coverage area, thereby improving the connectivity of the

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transmission line fault detection system. The proposed method increases the connectivity range of our wireless sensor networks allowing access to data from far away sensor nodes.

A. Wireless Sensor Networks

1) History: Early developments of these Wireless Sensor Networks can be traced back to the 1950s, the period in which many researchers began exploring the usage of sensors in military and surveillance applications. During the Cold War, Sound Surveillance System (SOSUS) aided with detection of Soviet submarines by the use of acoustic sensors [1]. Advanced Research Project (ARPANET) formed by US DARPA in 1969 served as a test bed for novel networking technologies. The sensor nodes were very large limiting the number of applications back then. As time progressed and researchers began to investigate the potential of WSNs for environmental monitoring and industrial automation. The deployment of these networks increased exponentially due to their scalability, mobility, accessibility, affordability and small size [2]. WSNs continued to evolve and become practical for a wide range of applications. Advances in sensor technology, communication protocols, and energy management systems have enabled WSNs to become more reliable, efficient and scalable. Today, these networks are used in wide range of applications, such as environmental monitoring, industrial automation, healthcare, agriculture, and smart cities. These networks continue to drive innovation and are expected to grow over years

2) Wireless Sensor Network Basics: The wireless sensor network is defined by a single equation: Sensing + CPU + Radio = Thousands of possible applications. This infrastructure less network can be deployed anywhere with the help of a tiny sensing device that uses radio technology to transmit observed data and a base station to receive [3]. A typical WSN is shown in figure 1.

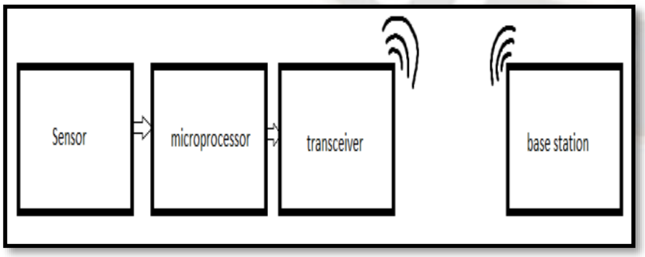

Figure 1. Block diagram of wireless sensor network.

Block diagram of wireless sensor node is shown in figure 2. The small, battery-powered devices are equipped with transducers that observe environmental data such as temperature, humidity, light, sound, etc. Each sensor unit comprises of a CPU for data processing, memory for storing data, and a wireless communication module for transmitting data to other nodes or base station. Wireless Communication Network: This comprises of the communication protocols used for exchanging data between the nodes and the base station. These protocols can be formulated to have a high data rate, or low power consumption, or higher encryption, or long range and are designed keeping in mind the specificity of the applications. Few examples of Wireless communication networks are Zigbee, Bluetooth, WIFI, 6LOWPAN and LoRa. Base Station: It is the central node responsible for receiving information from sensor nodes and forwarding it to a remote server or data processing system. This data can be accessed remotely anywhere from the world by having a constant connection of the base station to the internet.

3) Architecture and Protocol Stack: Architecture of a wireless sensor network is comprised of three main components; this represents the flow of information: Sensor node - responsible for observing and collecting data.

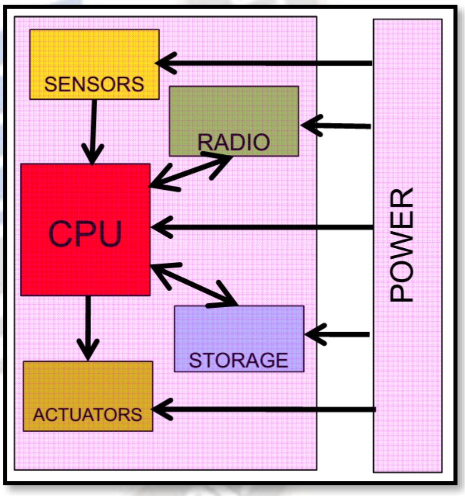

Figure 2. Block diagram of wireless sensor node.

Gateway - it acts as an interface between the sensor nodes and back-end server. Gateway relays data from sensor nodes to the back-end server. Back-end Server is the central component of a network; it receives data from gateway and stores it in database for analysis. Protocol Stack integrates data with networking protocols for an efficient communication mechanism [4]. [5] A protocol stack typically consists of following layers and planes which is shown in Figure 3.

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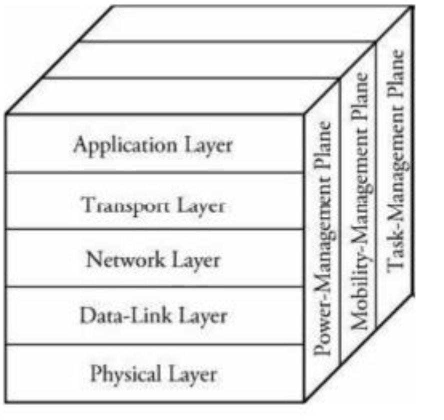

Figure 3. Protocol Stack.

Physical layer is responsible for transmission and reception of data, includes hardware components such as transceivers, antennas which help in wireless transmission in WSNs. Data link layer is designed to provide reliable communication between adjacent nodes by error correction and medium access control (MAC). Network Layer is responsible for routing data across nodes. Performs actions such as address assignment, topology management and routing. Transport layer is responsible for the flow of data is maintained and corrected in this layer with the help of congestion control. Application layer defines the purpose and functionality of the WSN. It includes the specific applications and services that are designed to operate on top of the lower protocol layers, such as data collection, event detection, and data processing. Power management plane manages the power consumed based on different actions performed by the node. Mobility management plane detects the movement in nodes and re-establishes new route accordingly. Task management plane: organizes events based on requirements. Not all areas require sensing at the same time.

B. Low power wide area network

The Cisco Annual Internet Report (2018-2023) [6], predicted an increase in networked devices per capita (the number of devices connected per person). There will be 3.6 networked devices per capita by 2023, raised from 2.4 devices per capita in 2018. This totals to 29.3 billion networked devices by 2023. A mass of these will be connected via short-range technologies such as WIFI, Bluetooth or Zigbee, while a significant proportion will be equipped with Wide Area Networks. These networks, supported with Low Power technologies give rise to a novel communication model, which complements the present traditional cellular and short-range wireless technologies. Practically speaking, non-cellular wireless technologies are not ideal to connect devices that are distributed over large geographical areas because of their high-power consumption and short-range properties. This Low Power Wise Area Network (LPWAN) is gaining significant attention because of its ability to provide cost-effective and energy-efficient connectivity over long distances. Due to this promise, an interest of LPWAN technology in IoT applications is phenomenal.

1) History: Low Power Wide Area Networks (LPWANs) have relatively short history, first LPWANs emerged in the early 2010s. In 2012, Sigfox was founded with a goal of providing a low cost, low power network for IoT by using ultra narrowband modulation and spread spectrum techniques. It was later followed by LoRa in 2013, NB-IoT in 2015 and Weightless SIG in 2016. Since then, LPWAN technology has continued to evolve in research and industrial sector giving rise to unique applications.

2) LPWAN Architecture:

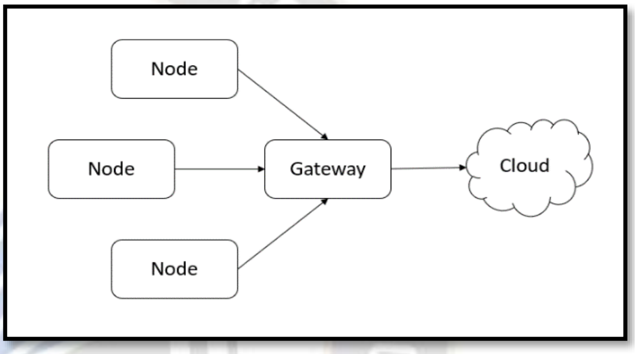

Figure 4. LPWAN Architecture.

Sensor Node transmits the observed environmental data from surroundings. Gateway: The received data from sensor nodes is uploaded to the cloud with the help of gateway. Cloud or Base station: It is the final destination for observed data and later, an analysis is carried out.

3) LPWAN technologies:

The connectivity between devices can be categorized in two ways: short-range communication such as WIFI, Bluetooth, etc and long-range communication known as LPWAN. Several LPWAN technologies have emerged in bandwidth of both licensed (GSM, LTE-M, NB-IoT) and unlicensed frequencies (LoRaWAN, Sigfox) [7]. The LPWAN architecture is similar to that of any wireless sensor network. It consists of three main components:

- NB-IoT: Stands for Narrowband Internet of Things. This technology shares similar characteristics of smaller bandwidth, high scalability, low power consumption like most LPWANs [8]. Being a high-density network, it can support a greater number of nodes. Penetration capabilities of NB-IoT are high, making it easier for the signals to sneak into underground areas. OFDM is used for uplink

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transmission and SC-FDMA is used for downlink transmission. NB-IoT can be deployed easily into cellular systems. Performance parameters of NB-IoT:
Bandwidth: 180 kHz, Peak data rate: 250 kbps, Uplink: 159 kbit/s, Downlink: 127 Kbit/s

- LTE-M: Stands for Long Term Evolution – Machine. Though being similar to LTE, it is used for machine to machine (M2M) communication. Most of the features are similar to other LPWAN technologies. One thing that makes LTE-M stand out from the rest is its higher data rate. LTE-M has higher response and data speed making it suitable for real time communication. It can also tolerate mobility up to a speed of 200 km/hr [9]. Performance parameters of LTE-M: Bandwidth: 1.4 MHz, Peak data rate: 400 kbps, Uplink: 1 Mbps, Downlink: 1 Mbps, Latency: 50 to 100 ns.
- Sigfox: Because of the ultra-narrowband frequency used, Sigfox can be scaled to a billion devices. High efficiency in Sigfox is achieved because of its absence of synchronization which in turn results in low power consumption. Sigfox makes use of DBPSK and GFSK modulation. It covers a long area with minimum number of base stations compromising data rate. It stands resistant to interference due to its adaptation of ultra-narrowband frequency to operate in industrial, scientific and medical band. In addition, there is a safe point-to-point communication interface between the Sigfox gateways; the Sigfox cloud and Sigfox network architecture are following star topology [10]. Performance parameters of Sigfox: Bandwidth: 100 Hz, Peak data rate: 100 bps
- LoRa: A radio modulation technique that works on chirp spread spectrum modulation. It is developed by researchers at university of California Berkely and maintained by LoRa alliance. LoRa achieves long range communication at the cost of data rate. This modulation achieves ultra-low power by utilizing less bandwidth. LoRa signals reach indoors because of its high penetration capability. It does not support real time data. Performance parameters of LoRa: Operates at a frequency of 433MHz, 868MHz, 915MHz. The Bandwidth is 125 kHz. The range varies from 1 km (omnidirectional antenna) to 20 km (directional antenna)

C. *Low power wide area network*

LoRaWAN, short for Long-range Wide Area Network, attracted much interest compared to other LPWAN technologies because of its ability to transfer data over long distances saving battery resources, LoRaWAN is an open network protocol innovated by researchers at University of California Berkely and is maintained by LoRa alliance. It is first launched in the year 2015 followed by multiple updates. The price to pay for long range and power efficiency is the reduced available bandwidth, limiting the overall throughput. Cisco predicted that 500 billion devices will be connected with various embedded systems or IoT, where most of them will be for Industrial internet of things (IIoT) or Machine to machine (M2M) communication [11]. The IoT and M2M devices are connected with low power communication technologies wirelessly. They can react, sense and transmit or receive small chunks of data in real time by consuming less power compared to other short range communication protocols, such as WIFI or Bluetooth. LPWANs help massive IoT devices in various applications such as agriculture, mining, fleet management, smart meters, smart buildings [12, 13, 14, 15]. LoRa was designed to be battery efficient and transmitting over a long range because of its adaptation of Chirp Spread Spectrum (CSS) modulation technique. This makes it a potential candidate for massive IoT applications. Each receiver can obtain data from multiple sensor nodes. These qualities of LoRa makes it very much suitable communication protocol in our paper. Transmission line fault detection systems, which were able to identify faults occurring across a region, were proposed with the use of GSM module and had to rely on a cloud service for transmission of data. On the other hand, GSM modules were expensive and consume more battery [16]. A hybrid wireless protocols such as Bluetooth, Zigbee and WiFi used for building evacuation system [17]. The evacuation algorithms are validated with hybrid wireless protocol interfaces [18].The proposed system comprises the implementation of LoRaWAN for line fault detection. The LoRaWAN signal characteristics are analyzed and results are obtained.

II. SYSTEM ARCHITECTURE

The proposed solution is to make use of LoRa modules to construct a Long-Range Wireless Sensor Network across transmission lines. A sensor node placed at each transmission line identifies the type of fault occurred and transmits the data to the receiver present at the nearby electric station. Because of the long range and highly scalable capability of LoRa

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modules, it becomes possible to distribute the network over a city or even a larger area. LoRaWAN properties makes it easier to add or remove new devices in the network. Implementation of this network is affordable and efficient in terms of battery consumption. It also mitigates the use of internet for data exchange between transmitter and receiver. By this method, an independent network is created. At transmitter section, the electric lines, fire sensor and LoRa transceiver are connected to the Arduino UNO. When there is a change in transmission lines, in case of any fault or fire, Arduino senses that due to change in data through the pins and sends it to the LoRa module for transmission which then transmits data over the network. Transmitter section is illustrated in figure 5.

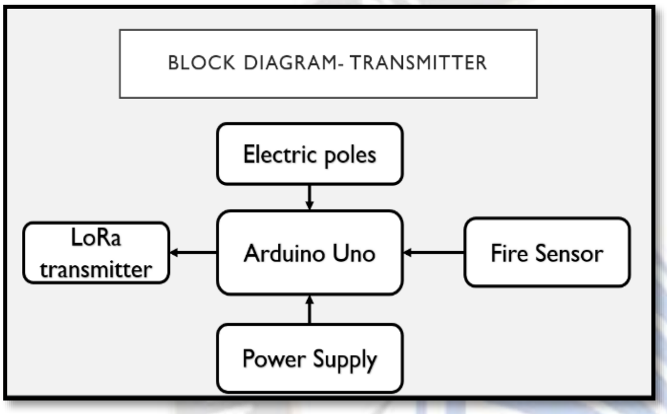

Figure 5. Transmitter section at the poles.

At receiver section, incoming data from LoRa module is passed to the Arduino. If there is any fault, the type of fault is displayed on the LCD display with a beep sound from the buzzer. The data is also sent to PC using Arduino pc connector. Based on the received data, the program running in the PC plots a mark of fault on map with a popup stating the type of fault occurred. The receiver section is depicted in figure 6.

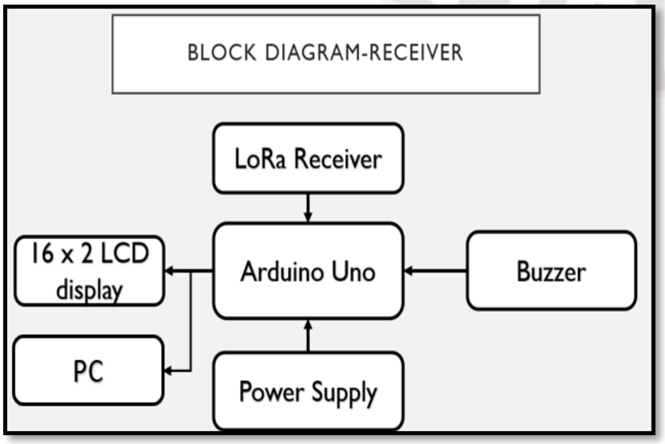

Figure 6. Receiver section at the base station.

III. RESULTS AND DISCUSSIONS

The Arduino at the transmitter section detects the type of fault occurred and sends it along with the device number to identify the location of the fault. The receiver picks up this data and displays the fault on 16 x 2 LCD and on the map. The figure 7 shows the desktop screenshot for showing the open circuit fault detection in the transmission lines. The open circuit fault is displayed in LCD also in receiver section, which is shown in figure 8. The figure 9 shows the location identification of the device, which intimate the faults.

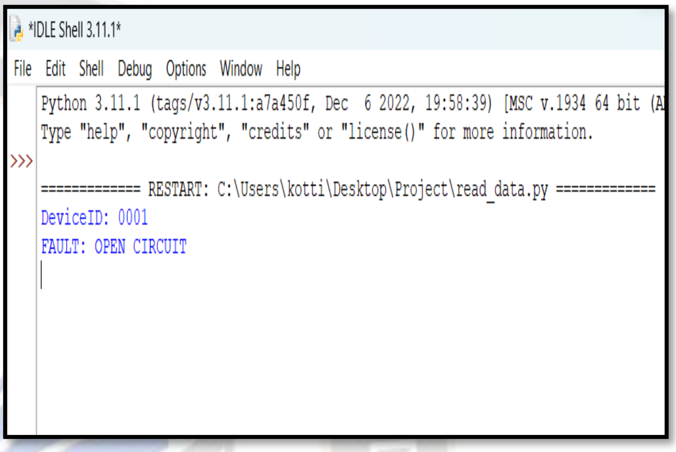

Figure 7. Screen shot of open circuit fault detection

Figure 8. Screen shot of open circuit fault detection at receiver section

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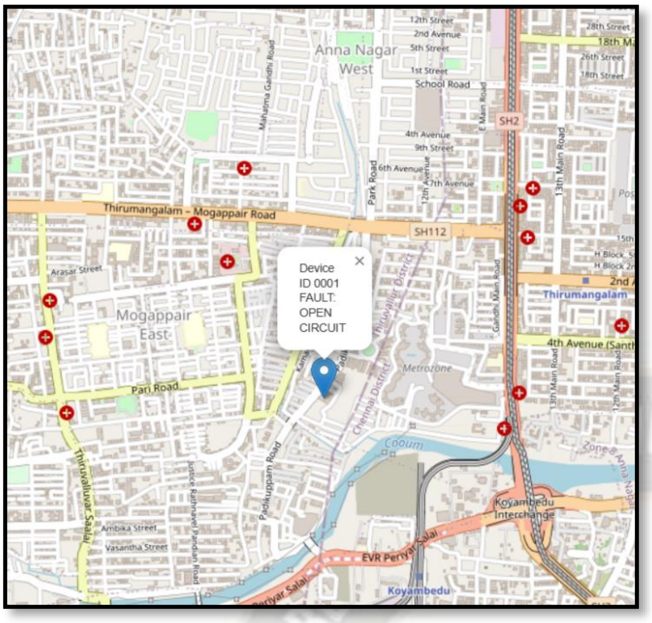

Figure 9. Screen shot of open circuit fault detection with location map

The device ID and the open circuit fault, will be marked by navigation system. The short circuit fault also is detected by the system and the results are illustrated. The figure 10, 11 and 12 shows the short circuit fault detection screenshots, LCD information and location stamping respectively.

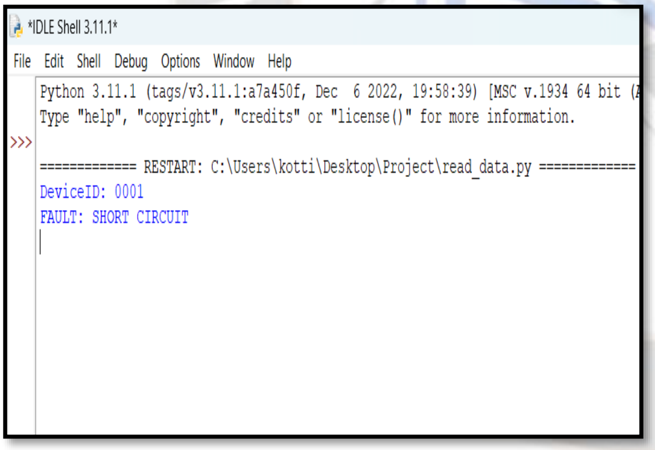

Figure 10. Screen shot of short circuit fault detection

Figure 11. Screen shot of short circuit fault detection at receiver section

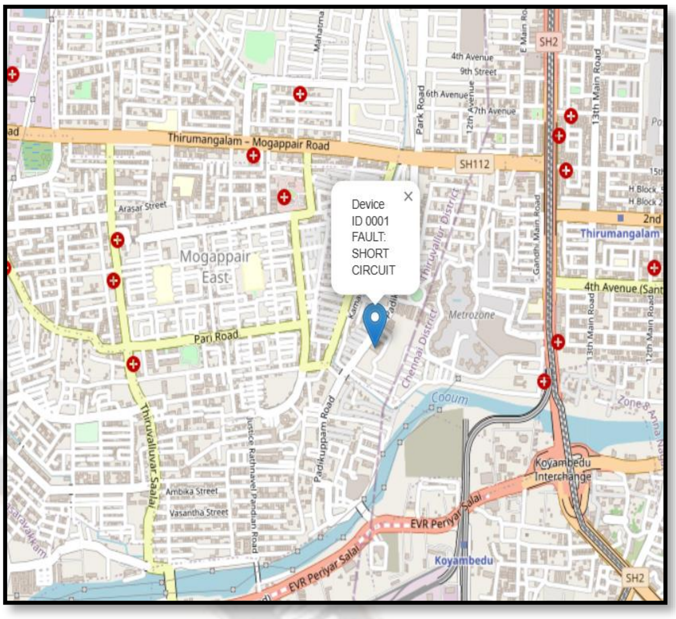

Figure 12. Screen shot of short circuit fault detection with location map

The figure 13, 14 and 15 shows the fire detection scenarios. In order to test the credibility of LoRa modules, we have carried out experiments that help determine the range and packet delivery ratio.

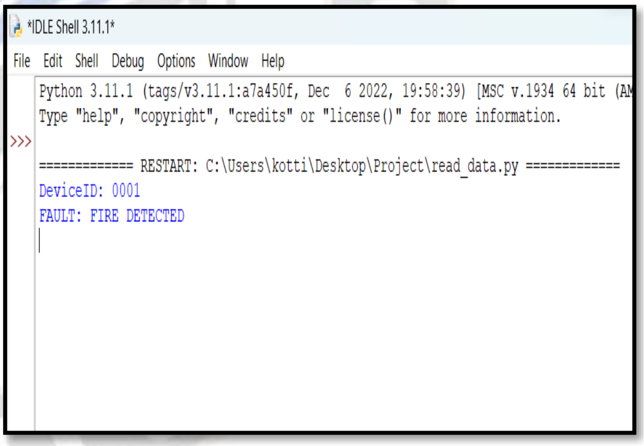

Figure 13. Screen shot of fault detection caused by fire

Figure 14. Screen shot of fault detection caused by fire at reciver section

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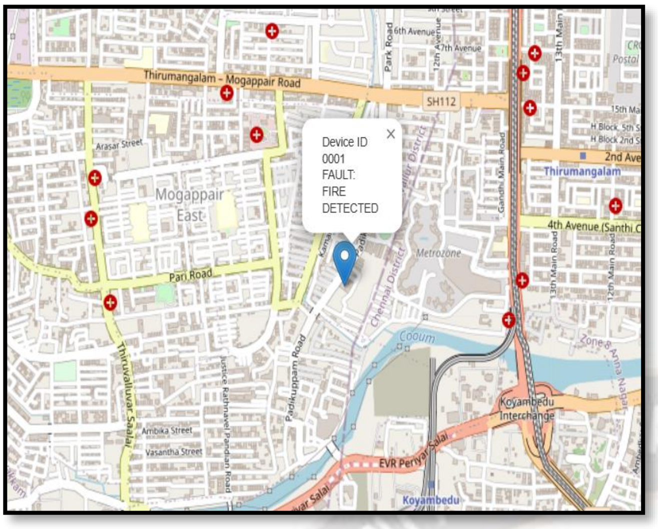

Figure 15. Screen shot of fire detection with location map

In order to test the credibility of LoRa modules, we have carried out experiments that help determine the range and packet delivery ratio.

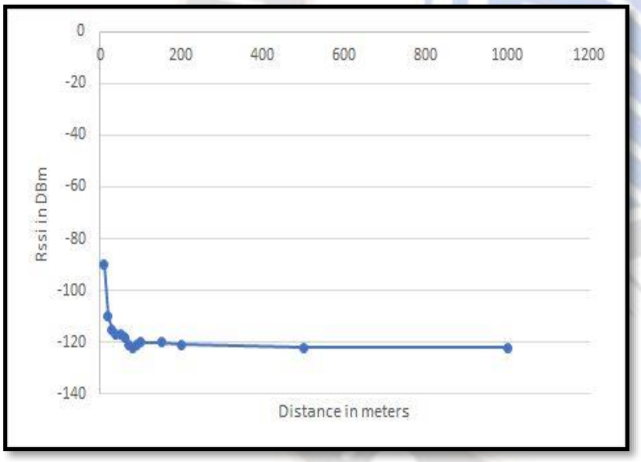

Figure 16. RSSI versus distance

Figure 16 shows that the LoRa module makes it possible to transmit data over a varied range extending from 10 meters to 1000 meters/1km. The Received signal strength (RSSI) varies from -90 DBm at close range to -122 DBm long distance apart. As distance increased, the value of RSSI diminished. The value of RSSI remained the maximum within 20 meteres, and between 20 meters and 200 meters, it averaged on to -118.9 DBm. In addition, beyond 200 meters it remained constant i.e., at -122 DBm.

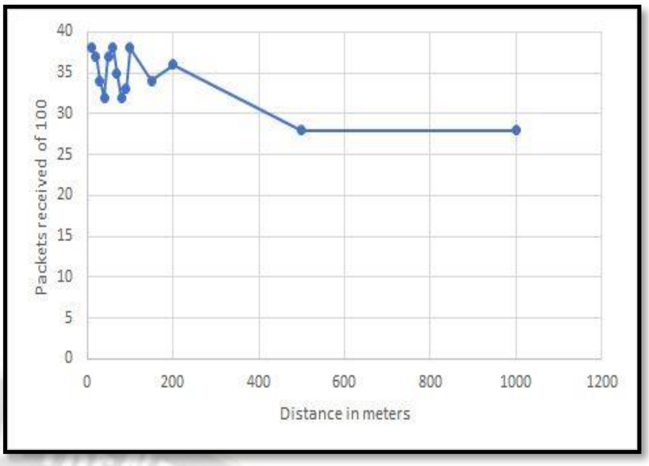

Figure 17. Packet delivery ratio versus distance

The packet delivery ratio graph which is shown in figure 17. It is measured the number of packets received over different distances, the number of packets received between distances 10 meters to 200 meters varied from 32 to 38, having an average packet delivery ratio (PDR) of 0.35. In addition, beyond 200 meters, the packets received has decreased to 28, leaving the average PDR to 0.28. As the above experiments have been carried out in open world, the values might have varied due to presence of environmental interferences such as vehicle radios.

IV. Conclusion & Future Scope

The implementation of a transmission line fault detection system using long-range wireless sensor networks is an affordable and significant step towards ensuring the reliability of power systems. The system uses wireless sensor networks to detect faults in transmission lines, which are responsible for most of the problems in the power system network. The system is designed keeping the battery consumption to a minimum and identify faulty power lines by analyzing whether the lines are in open circuit or short circuit. The system is also equipped with fire detection system so that safety of the transmission system is enhanced greatly. The system is essential in ensuring that faults in transmission lines are detected and corrected promptly, minimizing power outages and ensuring the reliability of power systems for users and industries. In future the transmission line fault detection system could be integrated into smart electricity grid management systems to optimize the power grid and reduce losses and power outages that affect people and industries alike. The data collected by the sensors in the field could be stored and analysed by Artificial Intelligence and Machine learning algorithms, which could potentially identify bottlenecks in the transmission system and predict failures in advance so they could be fixed. The system could also be used to detect power theft which is prevalent in rural areas and prevent losses for power companies. The integration of LoRa technology with other emerging technologies such as 5G, Artificial Intelligence, block chain and edge computing can enhance the capabilities of the fault detection system and enable more efficient and secure data transmission.

REFERENCES

[1] M. Kocakulak and I. Butun, "An overview of Wireless Sensor Networks towards internet of things," 2017 IEEE 7th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 2017, pp. 1-6

[2] Jindal, Vandana. "History and architecture of Wireless sensor networks for ubiquitous computing." International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) 7.2 (2018): 214-217.

[3] Maraiya, Kiran, Kamal Kant, and Nitin Gupta. "Application based study on wireless sensor network." International Journal of Computer Applications 21.8 (2011): 9-15.

[4] Kocakulak, Mustafa, and Ismail Butun. "An overview of Wireless Sensor Networks towards internet of things." In 2017 IEEE 7th annual computing and communication workshop and conference (CCWC), pp. 1-6. Ieee, 2017.

[5] Ramesh, Siddharth. "A protocol architecture for wireless sensor networks." Proceedings of the 1st ACM international workshop on wireless sensor networks and applications (WSNA). 2008.

[6] Cisco. "Cisco Annual Internet Report-Cisco Annual Internet Report (2018–2023) White Paper." (2020).

[7] Mekki, Kais, et al. "A comparative study of LPWAN technologies for large-scale IoT deployment." ICT express 5.1 (2019): 1-7.

[8] Beyene, Yihenew Dagne, et al. "NB-IoT technology overview and experience from cloud-RAN implementation." IEEE wireless communications 24.3 (2017): 26-32

[9] Raza, Usman, Parag Kulkarni, and Mahesh Sooriyabandara. "Low power wide area networks: An overview." ieee communications surveys & tutorials 19.2 (2017): 855-873.

[10] Lavric, Alexandru, Adrian I. Petrariu, and Valentin Popa. "Long range sigfox communication protocol scalability analysis under large-scale, high-density conditions." IEEE Access 7 (2019): 35816-35825.

[11] Almuhaya, Mukarram AM, et al. "A survey on Lorawan technology: Recent trends, opportunities, simulation tools and future directions." Electronics 11.1 (2022): 164.

[12] Siddique, Ayesha, et al. "A review on intelligent agriculture service platform with lora based wireless sensor network." Life 100 (2019): 7000.

[13] Suganthi, S. U., et al. "Coal mine safety system for mining workers using LORA and WUSN." Materials Today: Proceedings 46 (2021): 3803-3808.

[14] Kumari, Preti, et al. "An energy efficient smart metering system using edge computing in LoRa network." IEEE Transactions on Sustainable Computing 7.4 (2021): 786-798.

[15] Jabbar, Waheb A., et al. "Design and fabrication of smart home with internet of things enabled automation system." IEEE access 7 (2019): 144059-144074.

[16] Doshi, D. A., et al. "Real time fault failure detection in power distribution line using power line communication." International Journal of Engineering Science 4834 (2016).

[17] Raja, Dinesh Anton P., C. Arunachalaperumal, and Balaji A. Ganesh. "Hybrid cooperative network coding communication wireless protocol interfaces for real-time monitoring of environmental parameters using cozir sensor." Sensor Letters 17, no. 2 (2019): 160-176.

[18] Raja, P. Dinesh Anton, C. Arunachalaperumal, and M. Divya. "Smart building evacuation system with hybrid network based CNC-C architecture." Journal of Ambient Intelligence and Smart Environments 14, no. 4 (2022): 335-347.