Development of an E-Architecture for a Smart City based on LoRa Technology

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Abstract: The proposed e-architecture for a smart city using LoRa Technology is described in this paper. Using LoRa modules and a LoRa gateway, the architecture is created and implemented with two applications. End devices communicate data to the cloud via LoRa gateway; in this procedure, end devices only use LoRa communication to send data. Monitoring environmental indicators such as air quality and carbon monoxide level is the initial use. This is accomplished by building a device that includes the Dragino LoRa module as well as the necessary sensors. Using LoRa connectivity, the device will communicate the values to the LoRa gateway. The data will be uploaded to the cloud via the Gateway, allowing the administration to spot extremely polluted areas and take appropriate action. The second application is concerned with ensuring the protection of women and children. A wearable device with a Dragino LoRa GPS module has been created for this purpose. This gadget can be used to alert the person's whereabouts in an emergency case, as well as if the person has strayed beyond of the set bounds.

***Index Terms* – Architecture, Smart city, LoRa.**

I. INTRODUCTION

Wireless sensor networks are becoming increasingly important in the processing of large amounts of data in today's society. Many wireless sensor networks are deployed in many domains with a variety of applications to achieve the goal of a Smart city, resulting in a tremendous amount of data being produced every day. Successful data administration and analysis are required for new processes and procedures to provide information that can be used to manage resource use wisely and dynamically. Long-range, low-power communication technology is required to connect items, which is why LoRa WAN technology was invented.

Smart City is a standard in the Information and Communication Technology (ICT) age that provides an architecture for society to easily carry out administration in a variety of disciplines and makes it easier for administrators to supervise and control the assets in a city [1]. ICT is being used by smart city authorities to detect, evaluate, and coordinate data in the management of urban populations [2]. Since the population of urban communities grows and the boundaries of urban communities expand, the concept of the smart city is gaining traction among local governments, as it can be seen as a critical plan to transform traditional metropolitan regions. The ultimate goal is to improve financial growth, technological advancement, and environmental advancement.

IoT technology refers to an environment in which data is transferred in real time via the Internet to connect a sensor to an object. Until now, humans had to alter the gadgets connected to the Internet in order for data to be exchanged. However, IoT allows data to be exchanged without modification between humans and objects, as well as between objects connected to the Cloud and big data technology. To efficiently transfer object data, Low Power Wide Area Network (LPWAN) technology was recommended. It's a low-power broadband convergence network for IoT devices and a mobile radio communication network.

If near-field communication technologies like Bluetooth and ZigBee are utilized in a smart application, the administrator must go through a lengthy process to communicate with the gateway and end devices. LPWAN, on the other hand, solves this issue and links users directly. This technique is effective in outdoor applications that demand a large number of devices. As with other ICT technologies, LPWAN technology has gone through the standardization process as it gets more commercialized.

LoRa is an LPWAN protocol that is designed for two categories of devices: battery-powered devices with limited energy and devices that only transmit a small number of bytes at a time [4]. Because of its remarkable qualities of low power and extended range, LoRa has become the most popular choice for many smart sensing applications such as health monitoring, smart metering, environmental monitoring, and even industrial applications.

For low power remote IoT communication, numerous correspondence advances are advanced and carried out. As referenced over, the accessible advances can be sorted out in two classes:

1. Low power LANs with under 1km domain: In this class IEEE 802.15.4, IEEE P802.1ah, Bluetooth/LE, and so on are incorporated. These are important straight forward, in the short-run individual area architectures, in the body district architectures; or on the other hand, whenever figured out in a work geography, moreover in the greater zones.
2. Low-power WANs, with a bigger than 1km range: these square measure essentially low-control forms of cell systems, with each "phone" covering an oversized range of end-gadgets. This class incorporates LoRa WAN, and extra conventions; for instance, Sigfox, DASH7 and so on [5].

II. LORA AND LORAWAN

Long Range Radio Communication (LoRa) is a wireless modulation or physical layer that was designed to create long-distance communication networks. Because it is an incredibly capable balance for obtaining low power, different remote frameworks use frequency shifting keying (FSK) modulation as the physical layer. Chirp spread spectrum is the LoRa's default adjustment; it includes low-power features similar to FSK. It does, however, appear to extend the range of communication [6].

Semtech has suggested and the LoRa Alliance has endorsed LoRa as one of the most capable wide area IoT technologies. The success of LoRa is due to its adjustable data rate chirp modulation technology, which allows for flexible long-range communication with low power consumption and a low-cost architecture.

The LoRa Alliance has established and standardized the open MAC layer protocol LoRa WAN, which is based on Semtech's LoRa wireless RF IC. It uses unlicensed spectrum, provides long-range bidirectional communication, and is employed in a star-ofstars network topology, in which end nodes are not connected to a single gateway, but instead send data to numerous gateways within their range. Each gateway is capable of supporting tens of thousands of sensor nodes.

The data rates on the LoRa WAN are scalable, and they use an adaptive data rate algorithm to reduce power consumption and increase network capacity [7].

2.1 Sub GHz Advantages

Low-power wireless networks are a vital enabler for IoT devices, but existing networks such as ZigBee, Wi-Fi, Cellular, and Bluetooth do not meet the requirements of long range and battery life; thus, LoRa WAN uses these low-power networks to overcome the new Sub-GHz regulations.

High repetition alternatives achieve high information rates, but they have a limited range at sufficient power levels. For power-constrained plans that require a longer range, low-recurrence operation is the preferred method. When the recurrence is lower, minimal power is required to maintain a precise link budget at the given range.

Lower data rates can be achieved by using lower frequency transmissions, however IoT applications rarely have high throughput needs. Another benefit of adopting lower data rates is that mistake rates are lower, which influences the receiver's sensitivity needs [8].

The requirements for range, power, and information rate necessary by most IoT applications can be addressed by using sub-GHz interchanges. The modulation technique used for information encoding can have an impact on these critical factors.

2.2 Modulation Method

Diversify your spectrum for a long time, modulation techniques have been used to improve noise or interfering signal insusceptibility. Coding sequence is used to modify the phase of the carrier signal in typical Direct Sequence Spread Spectrum (DSSS) systems. The spreading code, also known as the chip sequence, is multiplied by the desired data signal in this operation. Chip sequences occur at a quicker pace than data signals and extend beyond the data signal's original bandwidth.

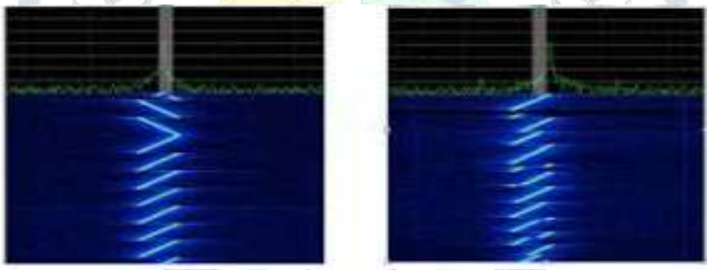
Re-multiplying with a locally generated replica of the spreading sequence generates the needed data signal on the receiver side. The spread signal is successfully compressed back to its original outspread bandwidth in the receiver thanks to this multiplication procedure.

Many data transmission applications make use of the DSSS protocol. Low-cost or power-constrained devices and networks, on the other hand, have some difficulties.

Semtech's LoRa modulation tackles all of the problems of DSSS systems, resulting in a low-cost, low-power, and most importantly, reliable alternative to standard spread-spectrum communication approaches.

LoRa is a particular spread spectrum modulation technique that improves the plan requirements by bringing the benefits of spread spectrum noise immunity. LoRa modulation is based on a frequency modulated "chirp" signal that can be produced using a fractional-N Phase Locked Loop (PLL) [9].

The repeated chirps used in LoRa transmissions (Figure 1a) and the chirps encoding a transmission's payload are seen in this waterfall view (Figure 1b).



(a) Lora transmission (b) Payload of a transmission

Fig.1. Repeated Chirps

A PLL that can be bolted onto the Preamble starts the gathering of a message stream on the collector side. A LoRa modem can detect signals as low as 20 decibels below the noise floor due to the chirp pattern's diversity. With a sensitivity of -148 dBm, LoRa technology enables high availability across great distances. Because it receives several different transmissions, each differing only in chirp rates, the LoRa modem can simultaneously service a large number of IoT devices.

2.3 Features of LoRa Modulation

A. **Scalable Bandwidth:** Both data transfer and repetition are customizable with LoRa modulation. It can be used for narrowband repetition bouncing as well as wideband direct succession. LoRa can be successfully modified for any mode of operation with just a few fundamental configuration enrolment modifications, unlike existing narrowband or wideband regulatory designs.

B. **Consistent Envelop/Low Power:** LoRa, like FSK, is a stable envelope modulation technology, which means that the same low-effort, high-effectiveness PA stages can be re-used without any modifications. Furthermore, owing of the processing gain associated with LoRa, the transmitter's output energy can be reduced in comparison to a traditional FSK interface while maintaining or improving link budget.

C. **High Robustness:** A LoRa signal is particularly resistant to both in-band and out-of-band obstruction components because to its high BT item (BT >1) and non-concurrent nature. Because the LoRa image period can be longer than the typical short length burst of quick jumping FHSS architectures, it provides incredible resistance to AM impedance systems; and, typical recipient out-of-channel selectivity figures of 90 dB and co-channel dismissal of better than anything 20 dB can be obtained. For FSK regulation, this equates to a 50 dB co-channel dismissal and a 6 dB neighboring and interchange channel dismissal.

D. **Multipath/Blurring Resistant:** Because the chirp signal is often broadband, LoRa is resistant to multipath and blurring, making it ideal for usage in both urban and rural environments where the two systems are overburdened.

E. **Doppler Resistant:** The Doppler shift creates a minor repetition shift in the LoRa pulse, resulting in a minor shift in the baseband signal's time axis. The need for tight-resistance-reference clock sources is reduced by this recurrence-balance resilience. LoRa is ideal for mobile data communications, such as remote tire-pressure monitoring systems, drive-by applications, toll booths, tag readers, and railroad trackside interchanges.

F. **Long Range Capability:** The LoRa connection expenditure plan outperforms traditional FSK for a given output power and throughput. When combined with the observed proclivity for impedance and blurring instruments, this modification in interface-spending plan can quickly result in an x4 and past improvement in run time.

G. **Upgraded Network Capacity:** Semtech LoRa modulation employs orthogonal spreading factors, allowing several spread indications to be sent simultaneously and on the same channel with minimal RX affectability loss. Regulated indicators at varying spreading factors seem to the target beneficiary as noise and can be dealt with as such.

H. **Ranging/Localization:** The ability to directly isolate recurrence and temporal errors is a distinguishing feature of LoRa. LoRa is the ideal balance for radar applications and, in an ideal world, would also be suitable for range and localization applications, such as in real-time location services.

III.PROPOSED SYSTEM DESIGN

As illustrated in the diagram (Figure 2), our proposed system includes the following modules:

Module 1: Client

Module.2: Gateway

Module 3: Cloud

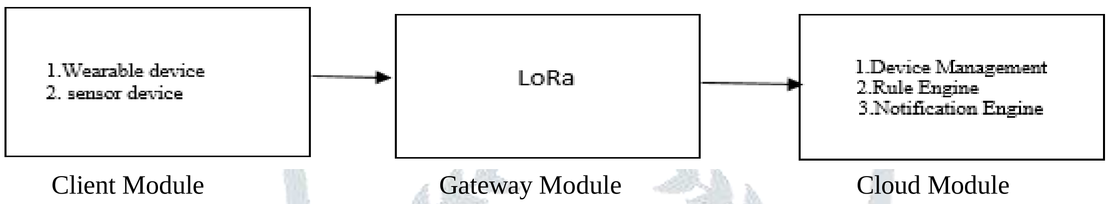


Fig.2. Proposed System Design

Module 1: Client-Two devices for two separate applications are designed in the Client Module. The first is a wearable gadget that ensures the safety of women and children; it is built with a Dragino LoRa GPS shield mounted on an Arduino board and connected to a switch. Using LoRa Communication, this device will relay the end-location user's information to the gateway. The second device is a sensor that is built with a Dragino LoRa shield, mounted on an Arduino board, and connected to two sensors: an air quality sensor MQ135 and a carbon monoxide sensor MQ7. To keep track of environmental characteristics, this gadget will communicate sensor values to a gateway.

Module.2: Gateway-LoPy is utilized as a communication gateway between the Client Module and the Cloud Module in this module. Through the LoRa Gateway, data from the end devices displayed in the Client Module is sent to a web server in the Cloud Module.

LoPy is the main triple conveyor Micro Python, enabled with smaller scale controller available now; it is the ideal enterprise grade IoT stage for connected Things, using LoRa, Wi-Fi, and BLE. The LoPy's latest Espresso chipset provides a great blend of energy, friendliness, and versatility. It connects items from all around the place.

The LoPy gateway can communicate in both directions and operates within a 45-kilometer range. This gateway uses Bluetooth, Wi-Fi, and LoRa to communicate. LoRa and Wi-Fi communication are employed in this system.

Lora communication is used to receive data from the Client Modules and Wi-Fi communication is used to transfer the data to the cloud. Between the gateway and the cloud, the HTTP protocol is utilized to communicate data.

- The LoPy device should be placed where it is needed.
- Data from the Client Modules is received via LoRa Communication.
- HTTP is used to send the data to the cloud.

Module 3: Clouds-The cloud module describes the webpage created for user services and data maintenance. This Cloud Module will have two functions: the first will be a front end application for the webpage, and the second will be a database.

The system takes the user's information from the registration and builds a user profile in the database with a unique user key. It will later build and retain device data based on the user's specifications.

The data received from the gateway is kept in the backend according to the unique user and their devices. In addition, the data is visualized in user profiles under device data.

A. **Device Management:** Authenticated users will be able to design their own devices based on their needs thanks to device management. Users can build as many various types of devices as they want once they've entered into their accounts. A unique device key is generated for each device, which will be important when sending data to the server. The user can build devices by giving each one a unique name and selecting the device type. Depending on the need, each gadget might contain a variety of fields. For each device, data visualization is accessible.

B. **Rules Engine:** The Rules Engine is a service that allows end users to change rules without involving a coder. When a modification is made, the engine calculates the impact on the other rules in the system and notifies the user if there is a difference. On this page, you may set the threshold values for each device field. These values are specified by the end user and can be updated at any moment based on the device's operation. These threshold levels are useful for notifying the user that the device requires action.

C. **Notification Engine:** The Notification Engine is intended to provide notifications to registered users based on their preferences. The user can register any cellphone number here to get device notifications. The user is notified if the device's values exceed the threshold level, allowing them to take appropriate action.

IV.RESULTS AND APPLICATIONS

4.1 Monitoring Environmental Parameters

Air pollution is responsible for a wide range of therapeutic problems. The present air pollution monitoring frameworks are made up of expensive stations that only measure a limited set of data. Due to the high expense of these stations, it is not feasible for metropolitan areas to quantify air quality in detail across the entire region. As a result, the type of measurement architecture needed to implement better air quality initiatives is rarely found in urban settings.

By implementing an air-contamination-checking system that includes sensors and gateways installed with LoRa Technology, as well as a clever low-control and wide-range network in accordance with the Lora WAN convention, urban areas can better quantify the quality and provide the type of information needed to drive change for their citizens.

MQ135 for air quality monitoring and MQ7 for carbon monoxide detection are both employed in this module. This module works in the following way:

- Air-monitoring sensors equipped with LoRa Technology have been installed around the city.
- Sensors provide air quality estimates to a gateway on a regular basis.
- Gateway sends the data to arrange where it is broken down by an application server that can identify the zones of concern and make recommendations.
- The Application Server provides data on air quality levels around the city, including warnings and contamination models, through a PC or portable device. It can also be used to assess the efficacy of air quality projects, with the goal of urban communities replicating programs in other problem areas.

A. **Indoor Air Quality:** The air quality ranges from 300 to 500 ppm when the sensor device is put inside, such as in a room with no gases present. Figure 3 depicts a data graph for this.

Fig.3. Indoor Air Quality Data Graph

B. **Outdoor Air Quality**: Due to the presence of various gases, when the sensor equipment is relocated outside, the air quality values drop to 450 to 700 ppm. Figure 4 illustrates the data graph for outdoor air quality.

Fig.4.Outdoor Air Quality Data Graph

C. **Heavily Polluted Region:** When the sensor is placed in a very polluted region, or when the sensor is purposely exposed to heavy gases such as alcohol, ammonia, or smoke, the air quality deteriorates, and the pollution range is between 650 and 1000 ppm, which is extremely dangerous. Figure 5 depicts the data graph for the air quality in the contaminated region.

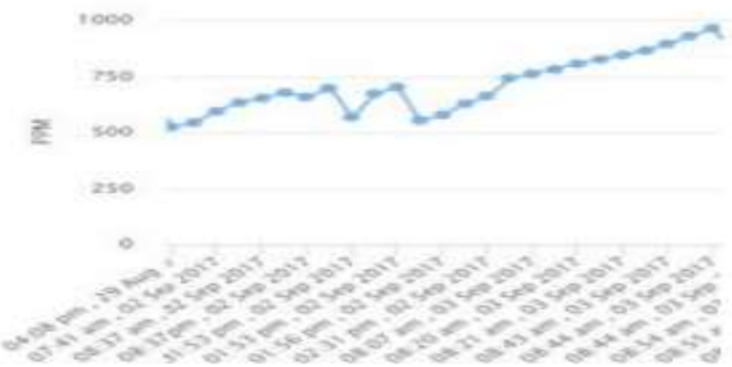


Fig.5.Contaminated Region's Air Quality Data Graph

All of the graphs above have a time period on the x axis and ppm values of air quality on the y axis. We can see from the graphs above that the quality of the air is deteriorating over time.

D. **Detection of CO:** The MQ7 sensor is used to detect the presence of carbon monoxide in the air. All gas sensors operate on the same principle and provide results in PPMs. Carbon monoxide levels in the air should be between 0 and 10 parts per million (ppm). CO levels in natural fresh air are 0.1 parts per million; in the house, they vary from 0.5 to 5 parts per million; and in automobile emissions, they range from 5 to 15 parts per million.

The application for identifying the presence of carbon monoxide in two aspects has been verified. To begin, the sensor is put in a room with normal air; the amount of carbon monoxide present in this space is shown by the data graph in Figure 6.

Fig.6. Carbon Monoxide Content Data Graph

The sensor is transferred to an area with heavy vehicular emissions to detect the higher levels of carbon monoxide. Carbon monoxide levels in this area range from 5 to 10 parts per million. Figure 7 depicts this.

Fig. 7. High Carbon Monoxide Content Data Graph

4.2 Woman and Child Safety

Because safety is such an important component in our daily lives, those who lack the strength and ability to defend themselves can be given the strength and option to do so by using a wearable gadget.

Dragino Lora module with GPS and a push button make up the wearable device. A device boundary can be specified; when the person using the device leaves the boundary, the server sends an alarm notice with the position. If the button is hit in an emergency scenario within the boundary, it will also be notified. Figure 8 depicts the notifications.

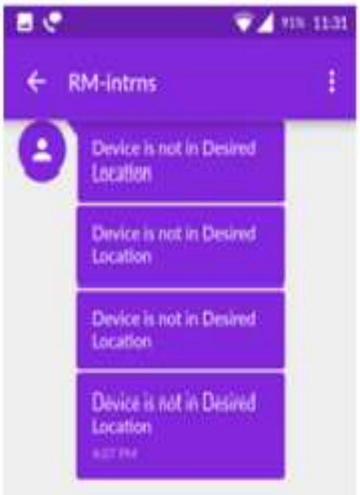


Fig. 8. Mobile Notifications

The Dragino LoRa GPS shield is installed on an Arduino board and wired to the switch button in this module. LoRa GPS shield detects and transmits location information such as latitude and longitude to the LoRa gateway.

A switch button is given for emergency scenarios; if a user of the gadget encounters an emergency situation, he or she can hit the switch to alert the appropriate person.

VI. CONCLUSION

For the benefit of society, a framework has been developed to be used by emerging smart cities in order to make them the safest and most progressive in every way. Two applications have been developed using LoRa technology in this project, making it unique in terms of its particular advantages such as low power, long range, extended battery lifetime, ease of setup, and low cost.

The quality of the air we breathe is a critical aspect in our ability to live a healthy life. As a result, a prototype for monitoring pollution levels in a city utilizing LoRa technology has been developed. End-user devices are equipped with LoRa modules and sensors in this system, allowing them to relay data to the gateway via Lora communication. This information will be uploaded to the cloud for further analysis and action. Two sensors were utilized to assess air quality and carbon monoxide content; by monitoring these sensor readings, users might be warned of pollution levels, alerting them to be cautious and strive toward reducing pollution levels.

A wearable device has been devised to provide protection to women, children, and the elderly, taking into account the work environment and busy schedules of residents' lives. A switch button and a LoRa GPS module were used to make the device. When the device is moved outside of the set border or when the switch button is pressed in an emergency circumstance, the device's functionality is to notify the user. This device allows you to keep track of people in need of assistance and ensure their safety without exerting too much effort.

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