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Real Time Tracking and Security System for Rural Areas Using LoRa Network

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***Abstract*: LoRa (Long range) Network, a promising wire-less technology, is used for communication in isolated areas such as wooded area (forest) with a smaller amount of power consumption. The inspiration of this employment arises from the need of manipulative low-power utilization system allowing Geo positions with using GPS. LoRa plays a very important role because of its appealing features and also, the latest innovative applications that are budding out. A small fare device enabling Geo positions with an elongated battery life span would be helpful for securing winning recovery for those who are in need. LoRaWAN is a set of rules intended for creating large scale public network, the technology allows for sensors to communicate to the internet devoid of 3G/4G/5G, the public crowd sourced projects such as Things Network, aspire to provide access to this technology by deploying gateways globally that others are generously connected to the set of network connections. It is used to recognize the location of the other person in a particular range (30 miles). By setting up LoRa network, the person having the device which is connected to LoRa Network can track the position of the other person and their routes to reach each other. The person's complete health details are sensed by the health sensors, the sensed data will be sent through LoRa network to the other person's device and control room as well. In case of any crisis a person will be secured safely. The temperature and humidity of a particular place details will be known to control room, so that the directing team members may instruct the trekking going people to proceed further on their plans.**

***Keywords*: LoRa, LoRaWAN, GPS, Health sensor.**

1. Introduction

At the present time, outdoor localization is mainly done using Global Navigation Satellite System (GNSS) receiver. The GNSS receivers are also used in many other applications like tracking, pets, undomesticated animals, goods. In attendance, there are reasonably priced GPS receivers are available in the market, but the main problem occurs here is, their battery existence and these batteries need to be re-energized in ever small number of days. The current utilization of a GPS receiver is about 30-50mA, which is significantly more energy required. In LoRa the end point communication chains two ways that is bidirectional communication as well as multicast enabling software upgrades over the air, and other mass allocation messages. LoRa also addresses the need for protection by providing the end-to-end encryption at all the three levels: network level device level and application level.

LoRa spreads the interaction involving the end-devices and gateways across numerous frequency channels and data rates. Here the spread spectrum technology is used, and the spread spectrum uses data rates which are ranging from 0.3 kilobits per second (kbps) to 50 kilobits per second to avoid communications from meddlesome with one another, and provides a set of "effective" channels that increases the capability of the gateways.

To gain the utmost battery existence of the overall network capacity and the end devices, the LoRa network maintain the data rate as well as the Radio Frequency outputs for each and every end-device independently through a method of adaptive data rate (ADR) scheme. LoRa additionally provides the need for security measures by providing end-to-end encryption at the three levels: network level, application level, and device level through the utilization of its only one kind of network key (EUI64), a specific application key (EUI64), and a device-specific-application key (EUI128).

LoRa network is a wireless communication skill, which is providing us the accessibility of utilization of consumption of low-power, low-rate and long-range communication [12]. LoRa uses the open ISM band (industrialized, systematic and medical ratio band systems). A LoRa network consists of four diverse components namely: 1. Network devices, 2. Network gateways, 3. Network servers 4. Application services. The communication networks of LoRa are alike to that of WiFi network, where the network devices make communication through LoRa gateways. Gateways habitually need to scan corresponding spectrum, except LoRa data packets from work station devices and forward the data to corresponding application services in the network server which may process the data packets, where the network server is also used to accumulate the metering data and application server is used for users to look up metering data. Also, every terminal device must have a Lora transceiver chip which is planed and manufacture by the Semtech Corporation. The network server along with the application server both are managed in the power management center. Because, here the LoRa technology uses the open ISM band and its

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communication range can achieve up to 22 kilometers [5].

The impact of the substantial settings such as spreading factor, coding rate and the bandwidth on the data rate and the duration on the air as been investigated [12]. Conclusion of all these information in sequence tells that the LoRaWAN systems should be cautiously configured and dimensioned to achieve an complete a good progress between scalability and efficiency. On the other hand, evaluation of physical layer and link layer performance of LoRa/LoRaWAN have been experimentally tested in the fields. The trial tests are experimental been conducted in various real world environments, ranging from beginning of indoor and urban/suburban to maritime, rural and mountain scenarios. The overall experiment gives us an idea about communication range which ranges from 10-30 kilometers in country side an 2-8 kilometers in inner-city. In addition, the impact of ecological factors such as warmth and vegetation has been investigated [24], [25]. It has been shown that vegetation and higher temperature significantly reduces the communication range. Example in case of indoor operation the result showed that the LoRa can achieve good coverage in entire building of Oulu Campus University.

On the further process, the losses of high packet rates and the connectivity issues are been encountered in the crypt [11], whereas the best coverage is achieved when the receiver is situated on the roof top moderately than in the crypt. Lora has been experimentally tested in different kinds of fields such as, Automobile to grid communications, physical condition monitoring etc. In the current period, there is a new way for selecting the communication technologies named as low-power wide-area (LPWA) networks which has lately been anticipated to specifically address the requirements of Long-range and Low-power Internet of things (IoT) applications. Measuring the difference between the conventional 2.4-GHz standards that suffer from weak saturation capability and heavy in-band interference, LPWAN utilizes the sub-GHz band and is intended to make availability for the coverage of several kilometers in an open-air environment. On the other hand, even with such stretched out transmission range, achieving the wide-ranging enclosed coverage is still not very easy by a single-hop star topology apart from the base stations which are deployed with an adequate amount of density and in appropriate locations [6]. In the infrastructure-free MBAN, a multi-hop relay network is still vital to make sure the trustworthy between any-to-any communications.

2. LoRaWAN Technology

LoRaWAN is an unwrapped typical architecture industrialized by LoRa Alliance to provide us a medium access control mechanism and enable End-Devices (ED) to commune with individual gateway or more gateways. LoRa basically is a physical layer technology which provides long range communication, Long-data rate, and squat power wireless communications. LoRa is an unlicensed band technology that modulates the signals in the sub GHz ISM bands using the spread spectrum method and commercialized Microchip, and others methods. LoRa technology can be used in peer-to-peer communications between the nodes.

A. *Architecture*

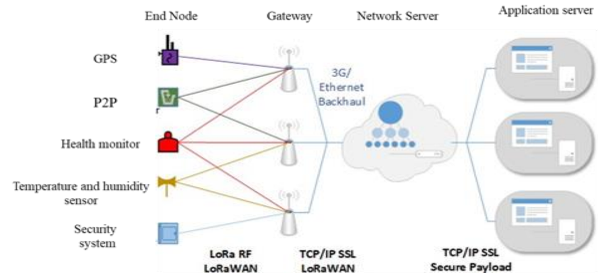

Fig. 1. LoRaWAN system architecture

LoRaWAN Alliance uses a star network topology, in which a gateway seamlessly relays messages linked between a Network Server (NS) and End Device (ED) as shown in Figure 1. End- Devices bring LoRa into play to communicate with Gateways (GW). Gateways use IP network (Ethernet, 3G, WiFi, etc.) to communicate with the server. Communication between the devices and gateways is extended out on different frequency channels, and data rates are determined according to communication range and message period. Selection of data rate and the frequencies can be managed by a LoRaWAN network infrastructure, which will decide on the data rate and channel for each device by means of an Adaptive Data Rate (ADR) scheme.

- End-Device (ED): Their operations are used to send or receive the information in order. End devices can be anything. On particular process, there is no exact explanation of an End-Device. Sensors, actuators, detectors and some sensing and controlling operations takes place are referred to End-devices.
- Gateway (GW): in addition to it, it is named as modem or access positions. Gateway is the second-hand to promote the messages from/to the End-Device and Network-Server. In LoRaWAN, End-Device's are not related with the Gateways. As an alternative, any message from an End-Device received by the Gateways will be delivered to the Network server.
- Network Server (NS): This is the most intellectual and efficient branch of the LoRaWAN network and it is liable for:
    - Monitoring the Gateway and End-Device.
    - Aggregating the inward bound data.
    - Routing/forwarding inward bound messages to the consequent application server.
    - Removing duplicates: remove duplicate information received from one End-Device through several Gateways.
    - In the downlink, the development of selecting one Gateway is based on the superior Received Signal Strength (RSS).

- Buffer downlink messages: is used to stock up downlink messages until the proposed End-Device wakes up.
- Application Server (AS): It represents the function for a developer or producer to parse the messages received from an End-Device. For example, in a cooling system application, if the temperature rises over 25◦ c, it may come to a decision to turn on the A/C to shrink it.

B. LoRaWAN Communications

The LoRaWAN Alliance stipulations describe three classes for an End-Device, as shown in Figure 2. All these three classes have a special capability to cover a wide range of applications. Each one of the classes constitutes a trade-off among battery life-span and the network downlink communication latency. Depending on the necessities, an End Device can change its states among the classes, but as a default class A must be implemented on all devices.

1) Classes: The three classes are:

- Class A (Bi-directional End-Devices): class A holds the efficient and majority energy, where an End-device stays in a large amount of the time in the sleeping mode. Following every uplink phase, there are two downlink windows RX1 and RX2 to take delivery of the data with the latency of one second for each approximately.
- Class B (Bi-directional End-Device's with the planned receive slots): class B is identical to class A, but the device pay more attention to the incoming messages on the standard intervals, which are synchronized with a beacon.
- Class C (Bi-directional End-Device's with maximal receive slots): here in this class C, the devices endlessly listen for arriving messages unless transmitting (no latency). Real-Time applications use this class, where power is not constrained.

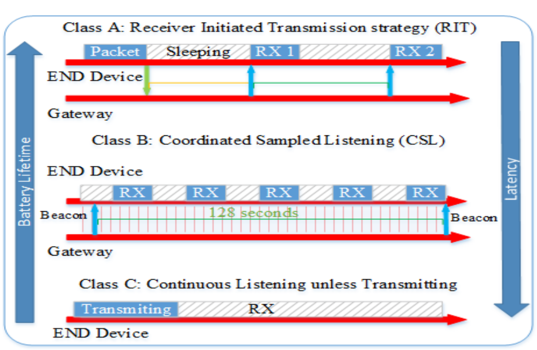

Fig. 2. LoRaWAN End-device classes communication

2) Connection Establishment with the Security

To accomplish protection and reliability of the uplink and downlink messages which involves an End-device and the Gateways to preserve the Network Server time from understanding the messages contents that are appropriate to another network or infrastructure, Mainly LoRaWAN defines two diverse keys which are in use, and LoRaWAN End-device classes communication during the normal message exchange as shown in Figure 3. These are the two keys used by LoRaWAN:

- The Network Session Key (NwkSKey): Encryption of the complete frame is done as shown in the figure 5 it encrypts the headers + payload in case if a MAC-command is sent. When there is a transaction of data's, this input is used to sign in the messages which allow the Network Source to confirm the identity of the correspondent.
- The Application Session Key (AppSKey): In Application Session Key only the payload is encrypted in the whole frame. This Key does not require to be known by the Network Servers. The Application Session key decrypts the data in the same sequence using the same key.

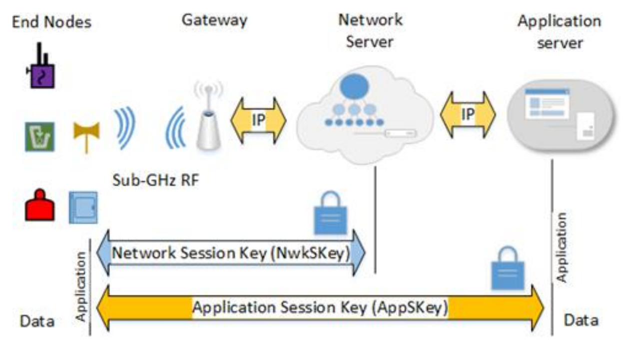

Fig. 3. Communication Exchanging and Security

3. Problem Statement

Development of LoRa Network is to provide wireless peer-to-peer communication and to provide security to people in real time at designated areas with the help of sensors which are connected to LoRa device to track people. And also to design a system which gives the readings of a person's pulse and body temperature.

4. Proposed Work

The purpose of the proposed model is to design a LoRa Device for Real time tracking and security system for rural areas using LoRa network. This device will send a alert to control room which is easily viewed through an android application.

5. Methodologies

The objectives are as follows:

1. Peer-to-peer communication.
2. Tracking of a person.
3. Sensing temperature and humidity of a particular area.
4. Rescuing a person: based on body temperature and pulse rate.

Objective-1:

A Peer-to-Peer (P2P) communication for short network is a consistent overlay network on top of a physical network. Each peer corresponds to a node in the peer-to-peer network and resides in a node (host) in the physical network.

All the peers are of equivalent roles. The links which are linking each peers are logical links, in which both corresponds to the physical pathway which is determined by the routing algorithm and is self-possessed of one or more physical links. Logical links can be additional to the peer-to-peer network arbitrarily as extensive as a equivalent physical path can be found, that is, the physical network is connected. For distributed application the flexibility of the overlay topology and the decentralized control of the peer-to-peer network are appropriate. For example, peer-to-peer network can be used for distributed data sharing or file sharing, where peers announces the data's or the files they have switched over the data or file from each other through a loosely formed peer-to-peer networks, or for mutual Web-caching in which Web pages are cached in collaborative peers to reduce network delay for URL requests, or for application layer multicast in which peers are group members and the peer-to-peer overlay network is a multicast tree. Peer-to-peer network can also be used for distributed computing process which makes use of the idle possessions in the network for a massive computing task. Finally, peer-to-peer can be made available for communication anonymity in which the person who sends the data (sender's) identity is concealed.

A. System Overview

The new model of Hybrid peer-to-peer network system is composed of two parts: (1.) A core transit network and (2) Many stub networks; each of stub networks is involved with the node in the core transit network level. The core transit level, is called as t-network or hybrid network, is well thought-out peer-to-peer network in which, it organizes peers into a ring similar to a chord ring. We entitle peers in the hybrid-networks or t-network as hybrid-peers or t-peer. Each t-peer or hybrid-peer is given with a peer ID (p id), which is a positive integer. Peers are inserted to the ring in the categorize of their p ids. Each t-peers or hybrid-peers which maintain two pointers in it, in which each pointer corresponds to its successor and predecessor, respectively. A stub network is also as called s-network, is a Gnutella-style unstructured peer-to-peer network. We call the peers in an s-network s-peer apart from for the t-peer attached to this s-network. The topology of an s-network is randomly formed. Each stub-network is connected with a t-peer or hybrid-peer and each of this t-peer belongs to both of the t-network and the stub-network. One thing to be mentioned here is about the stub-network that is the topology of a stub-network is a tree as an alternative to a mesh topology, as shown in the figure 4.

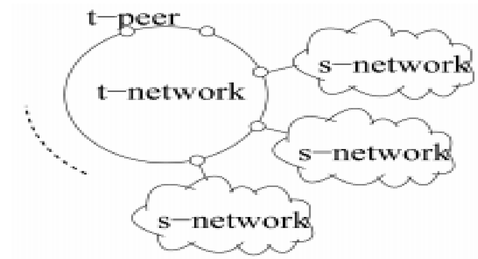

Fig. 4. Over view of hybrid peer-to-peer system

Objective-2:

A tracking system is employed, where the rambling of an individual or an object in process of moving, while supplying timely ordered sequence of location for further processing.

Tracking of a person

Relies on unique identifiers temporally or permanently assigned to the person like personal identifiers, a way to sample their positions, either on short temporal scales as through GPS or for public administration to keep track of the people. The purposes for doing so, is to identify the person or to rescue the person in

Rural areas or forest areas or trekking places etc.

Working:

A Person with the device connected to the LoRa Network is on one side of an area, whereas another person is on the other end of the wide area. When a person needs to track the other person who is present on the different side in the equivalent wide area, he/she uses the communication linking the gateways and the cloud where the transfer Management Center would be worn as the web. We evaluated Low Power WAN (LPWAN) technologies like LoRa (Long range network), Sigfox, Narrow Band IoT(NB-IoT), and Vehicle to the whole thing technologies (V2X) like DSRC (Dedicated Short Range Communication) and C-V2X(Cellular-V2X).

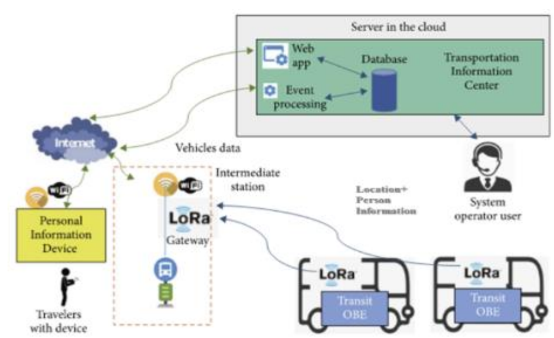

Fig. 5. Network diagram of person tracking service

The network illustration is fashioned as shown in the figure 5, which features the outstanding technological components of the system. The figure 5 shows the network diagram of person tracking services. The device (OBEs and Traveler Support Equipment), communication (LoRa, Wifi and Internet), and application (web-apps and software in the cloud centre sub-system) layers are clearly identified in figure 5. The device is linked to the LoRa network from the beginning to end to the gateways. The network receives data from one device and provides the data to the other device which helps in tracking of the person without any difficulty.

Objective-3:

Temperature is a measure of warmth or coldness and Humidity is a measure of water vapour present in air. The main purpose of detecting the temperature and humidity of a desired place is to rescue a person from any kind of disaster.

Sensors

Temperature sensor is a device used to measure the temperature through an electrical signal which requires a thermocouple or RTD (resistance temperature detector). The thermocouple is prepared by two dissimilar metals which generates the electrical voltage which is indirectly proportional to change in temperature. Humidity sensors are especially important devices that help in measuring the environmental humidity. The sensors used to measure humidity are called Hygrometer

Working:

The sensor thermo-coupler and Hygrometer are connected to the device which in turn is connected to the LoRa Network. The master network will receive the temperature of the area and the information is stored in the cloud. The details will be displayed on the person's device and the person can forward the received temperature of the place to the control room. This Kind of details will help the people in rural areas, trekking/hiking and for the people who are working in forest departments.

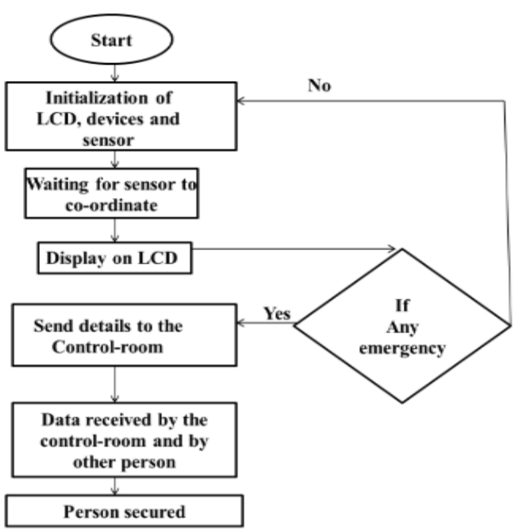

Fig. 6. Flow chart for sensing temperature and humidity

Objective-4

Health refers to the state of complete emotional, physical, mental, and social well-being and as a resource for living a full life.

Detection of the Person's Health using LoRa Network.

Now-a-days, health is a main concern therefore detecting a person's body temperature, pulse rate and sleep is especially important. The device will help in monitoring the health of the person. Monitoring of the person's health will be done by the control room.

Working:

The representation is figure 3 which tells us about the structural design of our LoRaWAN-based Health monitoring systems. LoRa health monitoring system consists of four components: (1) LoRa end node, (2) LoRaWAN Gateway, (3) LoRa Server and (4) Dashboard. Which are described below:

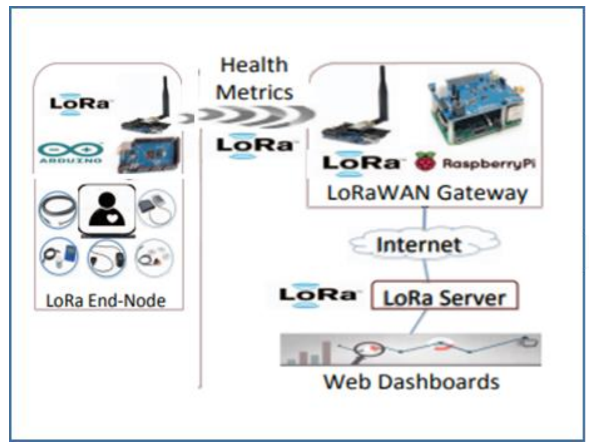

Fig. 7. LoRaWAN based health architecture

1) LoRa end node:

Monitoring module consist of an end node which utilizes the e-health sensors which are associated to a LoRa transceiver. The LoRa End-nodes are used to:

- To get the healthiness information of a person such as glucose level, blood pressure and temperature .
- To-send: According to the LoRaWAN specification the obtained data is sent to the LoRaWAN Gateway.

2) LoRaWAN Gateway:

The LoRaWAN gateway consists of 1. LoRa Concentrator board 2. A Host processor. The IP packets are converted to the LoRa Radio Frequency packets through the LoRaWAN gateways. The Host receives the RF packets by the concentrator. On the concluding process, a packet forwarder is installed to transform the received RF packets from the concentrator to User Datagram Protocol (UDP) packets and sends them to a configured LoRaWAN server by means of the Internet. The LoRa concentrator includes buffers to prevent the data lose if links ruptures down

3) LoRaWAN Server:

The LoRaWAN server is used to get together data packets approaching from LoRa end nodes passing through the gateways. The server checks their integrity, de-encryptions of their contents and stores them is a NoSQL database for future analysis. All the collected data are visualized graphically using real time dashboard.

4) Dashboard:

The Dashboard is a Web-based interface so as to be displayed in both the computers and the mobile devices allowing well-being professional to remotely track the patients.

6. Block Diagram

The direction of the arrows specifies the stream of data, the component with the arrow top receives data from the other component.

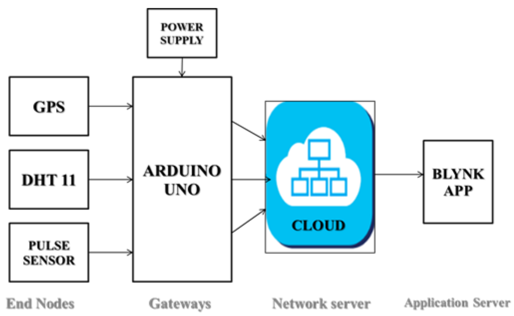

Fig. 8. Block diagram of a system

Networking Devices:

It includes gateways, routers, network bridge, modems, antenna, switches, repeaters and hub.

Gateway:

An interface providing a compatibility between networks by converting transmission speeds, protocol codes, or security purpose.

Modem:

Device which modulates an analog “carrier” signal into an encode digital information, which also demodulates such a carrier signal to decode the transmitted information.

Things Network:

Things network could also be a proud contributor member of the LoRa Alliance. Things Network is about permitting the low power devices to use long range communication. Gateways connects to an open source.

LoRaWAN:

LoRaWAN network, laid out in a hybrid-topology have base stations replying the information between the sensor nodes and the network server. End nodes transmit directly on all the gateways within range, using LoRa.

7. Advantages and Disadvantages

A. Advantages

- Low Powered sensors, and wide coverage area calculated in kilometers.
- Operates on free(unlicensed) frequencies, no upfront licensing cost to use the technology.
- Long battery life devices means, utilization of low power Batteries in sensors can very last for 2–5 years (incolves Class A and Class B)
- The end nodes or the N number of end-devices are designed and taken care by the Single LoRa Gateway.
- Its Structural design is very simple, hence it has easy installation.
- M2M/IoT applications use this in effective way.
- Payload size is Enhanced which is 100 bytes, compared to SigFox size which is 12 bytes
- Open: an open alliance and an open standard. The Open technology compared to competitor SigFox
- There is no limit in Maximum number of daily communication (SigFox has limitation of messages 140/day)
- LoRaWAN has the benefits of being an involvement with an open approach instead of a proprietary one (SigFox).
- LoRa provides Long range solutions to the smart city applications.
- The low-bandwidth in LoRa makes it idyllic for realistic IoT deployments with less data and with data transmissions which are not constant.
- The connectivity costs are comparably less.
- Since the communication is wireless, it is easy to set up the system and it is very quick in its deployment process.
- Security: a layer of security for the network and one for the application with AES encryption.
- The communication is completely Bi-directional.

B. Disadvantages

- LoRa is not appropriate for the large data payloads and they are restricted to 100bytes.
- Here the monitoring process is not continuous (except for the Class C devices).
- LoRa is not a too ideal applicant for the real time applications which requires lower latency and bounded jitter necessities.
- Strengthening the LoRaWAN networks: The propagation of the Low Power Wide Area Network technologies, and particularly the LoRaWAN, which posses the co-existence challenges such as the deployment of gateways which occupy urban areas.
- LoRa’s disadvantage of the Open frequency is that, we may get the interference on the frequency and the data rate might be very low. We may get interference on the frequency and the data rate might be low, (For example the GSM or for permitted frequency), we can broadcast on that frequency without any interference. GSM operates which uses the assured frequencies which pay a large licensing payment to the administration for the use of those kinds of frequencies. LoRa operates on the frequencies that are open and do not need a state authorization or sanction. And open frequencies are different from country to country.

8. Conclusion

LoRaWAN covers long distances, making it ideal for both urban and rural areas. Here, by using LoRa network we are able to track the people movement in rural areas, forest areas, and in trekking places.

Since LoRa consumes less power and has long battery life, it can be used in long tracking purposes. Further to monitor temperature and humidity of an area.

LoRaWAN supports bi-directional communication which is helpful in rescuing the person when in emergency or in any need. Step by step a person's health is noted on a device which helps us to know how well the person is moving on with a work. If any emergency a message will be sent to the control room, which further will help us to rescue a person.

9. Future Scope

The Proposed project can be further used for the estimation of power consumption in a particular area for optimum utilization of power. Using LoRa the further advancement can be made in the field of Smart applications like collection of wastage, smart home, and smart agriculture.

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