URSI AP-RASC 2019, New Delhi, India; 09 - 15 March 2019

LoRa-based Alert System for Public-safety

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Abstract

This paper presents a novel closed loop architecture for citizen security using LoRa based devices. The proposed system comprises of a custom made end-device which can be connected to street light poles in an area and a gateway device which can be connected at a large distance from the end-devices. LoRa physical layer is used as the main communication interface which enables large distance transmission. A data logging server is used for logging the node-id everytime it is pressed. Data is uploaded to the server using a 4G-LTE dongle. An android app is also developed which shows the location of the pressed node and provides navigation routes to the concerned security person to reach that node. We have compared our network operation with commercially avilable security devices. Power consumption and cost are the two metrics chosen for evaluation. Results show that our network is extremely low-cost and low-powered than existing solutions.

1 Introduction

The Internet of Things (IoT) paradigm refers to a network of interconnected things, that is, devices such as sensors and/or actuators, equipped with a communication interface, and processing and storage units [1]

One of the most extensively researched topics under IoT is smart cities. Citizen security, green environment,increased operational efficiency with the help of smart sensors and actuators are considered as some of the primary aspects of smart cities. Wireless sensor networks are fundamental for these services as they offer very low cost of deployment, low power consumption and maintenance cost. Smart innovative cities should provide data about the impact of human activity to the environment and services related to health, transportation, sustainability, economy, law enforcement, community and others affecting the overall wellbeing of the residents.

Ideally smart city should be able to smartly secure its inhabitants. Smartphone based emergency alert system is a good start towards reaching this goal [3, 4]. The system may fare up well in a place where everyone has a smartphone and has ample knowledge of its usage. However, in developing countries and rural areas everyone does not posses a smart phone and even if they do, they are not so proficient in handling it. So, smartphone based approach is futile in such cases.

Thus, there is a need for alternative communication standard that can provide us the range needed in a city-wise concept. This brings us to various surveillance systems like CCTV, WiFi-based monitoring etc. Child observation system using information terminal bus stops is on the rise in developed countries like Japan [5, 6]. In India CCTV surveillance is a fast growing security measure especially in crowded places like bus stops, railway stations and airports [7]. The drawbacks of these methods are – cost of deployment and difficult set-up. Using WiFi for wireless surveillance, limits the range upto less than 50 meters. The probable solution to this is LoRa RF. LoRa physical layer is specially built for use in developing IoT sensor networks [8, 9]. In general LoRa RF can broadcast signal upto around 2km radius, but is shown to acheieve range upto 10km in line of sight(LoS) with receiver using directional antennas [10].

In this paper we propose a novel closed loop security system using LoRa RF as the communication interface. We have designed a custom PCB for making the end device. We have also developed an android application to show real time navigation to alerted node. The proposed network is evaluated in terms of cost estimation and power consumption. The use of LoRa RF enables long range and low power, which is its primary advantage over existing wireless communication standards.

The remainder of this paper is structured as follows: Section 2 describes the proposed system, Section 3 evaluates our proposed network based on certain parameters and finally conclusions are drawn in Section 4.

2 PROPOSED NETWORK

The proposed system architecture as shown in Fig 1. consists of n number of LoRa based transceiver nodes, a gateway device, a data logging server and an android application. LoRa physical layer, developed by Semtech, is based on chirp spread spectrum (CSS) modulation scheme which is immune to interference since information is spread accross several frequency channels and data rates using coded messages [11]. Thus, it enables quick deployment in public places using hardware and software which is bidirectionally secure, interoperable and mobile. LoRa uses unlicensed radio spectrum in the Industrial, Scientific and Medical (ISM) band. LoRa offers three transmitting frequency, $433/866/915\ MHz$ depending on the country it is deployed. LoRa exploits variable error correction technique

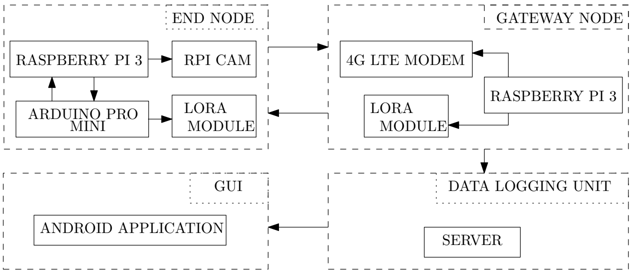
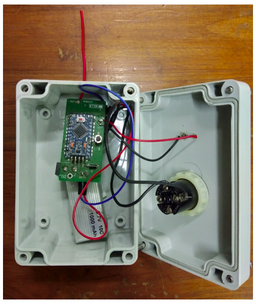


Figure 1. Proposed System Architecture



(a) Inside view

(b) Front view

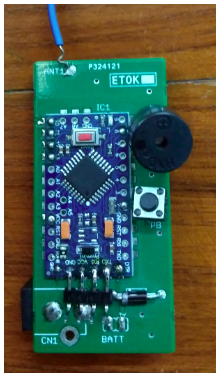
Figure 2. Transceiver end-node

that improves the robustness of the transmitted signal at the expense of redundancy. Primary reason for using LoRa RF is long range and low power.

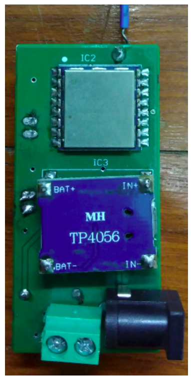
The real-time hardware implementation details has been discussed in the next section.

2.1 Transceiver Nodes

The transceiver node as shown in Fig 2 is our LoRa based end-node. As shown in Fig 3, the custom designed PCB consists of Arduino Pro-mini board using ATMega328p micro-controller, working at $5\,V$ $16\,MHz$, Semtech's SX1276 LoRa IC working at 866 MHz,a charging IC TP4056, a 1N4733A zener diode, a wall connector, a buzzer and a push button. A 1.5 dBi quarter wave monopole antenna is used for signal transmission. The Arduino microcontroller by default remains in sleep state. The push button acts as an interrupt to the arduino and thus on pressing wakes the Pro-mini to send an emergency signal to the gateway using LoRa RF. Arduino and LoRa IC are connected using standard SPI protocol. The components are put in a sturdy weather-proof box to protect from harsh weather conditions since the devices are supposed to be attached to street light poles. A 1000 mAh 3.7 V lithium ion battery is connected to power the node and a charging circuit is used to charge the battery whenever there is power supply at the light poles. The chraging IC used is TP4056 - Micro USB $5\,V$ $1\,A$ Lithium battery charger. For connecting the device to the light poles a $5\,V$ $1\,A$ wall adapter is used. The 1N4733A zener diode is used to ensure unidirectional flow of current from either battery or the adapter.



(a) Front view



(b) Rear view

Figure 3. Custom designed PCB

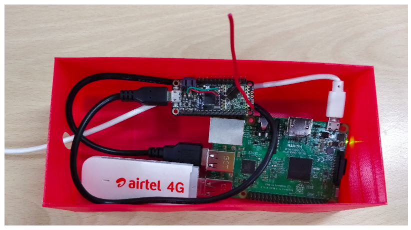


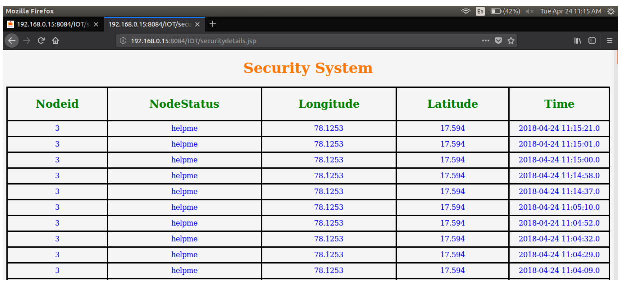
Figure 4. Gateway

2.2 Gateway Device

We have designed a gateway device as shown in Fig 4 which consists of Raspberry-Pi 3 B+ model interfaced with Adafruit 32u4 LoRa module. The Adafruit LoRa model houses a LoRa transceiver based on Semtech SX1276 LoRa RF running in the 866 MHz ISM band. A 1.5 dBi quarter wave monopole antenna is used similar to the end-nodes. A 4G-LTE modem is connected with the RaspberryPi which logs the received node-id to the server and make it available online. Since this device should be continously operating, it is wall powered using a $5\,V$ $1\,A$ power supply. The casing is 3D printed available in-house.

2.3 Graphical User Interface (GUI)

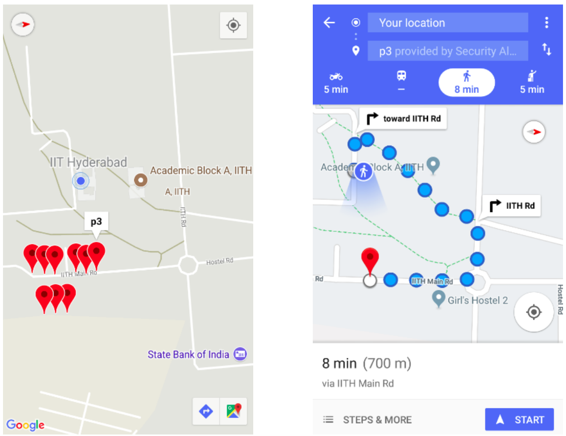
As shown in Fig 6 an android application has also been developed using Android Studio 3.0. The app by default shows markers on the map where the nodes are placed. When someone presses the button on a certain node, it



Security System

Nodeid	NodeStatus	Longitude	Latitude	Time
3	helpme	78.1253	17.594	2018-04-24 11:15:21.0
3	helpme	78.1253	17.594	2018-04-24 11:15:01.0
3	helpme	78.1253	17.594	2018-04-24 11:15:00.0
3	helpme	78.1253	17.594	2018-04-24 11:14:58.0
3	helpme	78.1253	17.594	2018-04-24 11:14:37.0
3	helpme	78.1253	17.594	2018-04-24 11:05:10.0
3	helpme	78.1253	17.594	2018-04-24 11:04:52.0
3	helpme	78.1253	17.594	2018-04-24 11:04:32.0
3	helpme	78.1253	17.594	2018-04-24 11:04:29.0
3	helpme	78.1253	17.594	2018-04-24 11:04:09.0

Figure 5. Webpage of the alert system



(a) Deployed nodes in IITH campus

(b) Navigation from host device to alerted node

Figure 6. Android app

shows a navigation route from the device towards that node for the concerned security personnel to reach there at once and assist the distressed person. This application is intended to be installed on the security person's phone or an android TV to serve the purpose.

2.4 Network Operation

The proposed network comprises of spatially distributed nodes, each operating on LoRa RF. We opted for star topology, since we need the gateway device to be at the centre and able to connect to all nodes in every direction. When the panic button is pressed on the node, the Arduino microcontroller transmits an emergency signal with the node-id contained in it, to the gateway device. The transceiver node is programmed to retransmit the distress signal automatically in case it does not receive an acknowledgement from the gateway within 2 seconds. Thus, ensuring that alert is raised nonetheless. The number of retransmissions can be set by user. The acknowledgement is accounted for by the end-node buzzer buzzing for 10 seconds. The gateway device is programmed to be always in receiving mode. The gateway upon receiving the distress signal, decodes it to find the node-id. All nodes communicate with the gateway using SX1276 LoRa RF transceiver IC using 866 MHz frequency. We have used $125KHz$ bandwidth, spreading factor of 7, and coding rate of 5 which gives us the data rate 3038.1944 bps or 3.038 $kbps$.

The longitude-latitude values of the respective nodes are obtained by differential GPS module and are stored in the gateway Raspberry Pi. Differnetial GPS is used to get end-node location as it gives more accuracy than nominal GPS. Upon receiving the node-id, it compares the latitude and longitude values of the location where the button is pressed with the stored ones. The Raspberry Pi reads the node-id and sends an acknowledgement signal to the concerned node. It then uploads the node-id to the MySQL server using a 4G LTE dongle which makes it available online as shown in Fig 5. The server is responsible for sending the alerted node-id to the concerned security personnel's device using Android popup notification. In case sever is busy or malfunctioning the gateway Raspberry Pi will send a SMS notification to the concerned number using the 4G dongle.

By default, the android app displays a map of the place where the nodes are deployed as shown in Fig 6. In our case we have deployed one node named $(p3)$ physically in one of the light poles in our IITH campus and other location markers are taken for understanding the working of the system. The app on first launch shows the campus map with red markers of the nodes where they are placed. The server is connected to the android app using a back-end PHP script. When the server receives a certain node-id, it compares it with the stored node-ids and retrieve the latitude and longitude values of that node so as to get the exact location on the map. Then the app shows that particular node with a navigation route to reach it from the host device where the app is installed as shown in Fig 6.

3 EVALUATION OF THE PROPOSED NETWORK

We have evaluated our proposed low-power, low-cost IoT Network by measuring power consumption, operating range and cost. In the following section, we have compared the power consumption, range and cost of our proposed network with the already proposed networks in the literature.

Device	**days**
Safer smart jewellery	14
Athena device 3	14
Nimb device	14
Our end-node	**365**

Table 1. Battery life analysis of proposed network

3.1 Power Analysis

For evaluating power consumption we have considered the current consumption of the end-node during transmission and sleep instant. As mentioned before, the end-node is programmed to be in sleep mode when not using and the push button upon pressing activates the arduino. So we measure current consumption at sleep I_{sleep} and transmission instant $I_{transmission}$.

The end-node has I_{sleep} of $0.2\mu A$ and $I_{transmission}$ of $17mA$. We were able to achieve such a low current conspumtion by removing the on-board LED and the power regulator of the Arduino pro-mini. We also programmed to turn off the brown-out detector and watchdog-timer while in sleep mode. A comparison of our end-node battery life expectancy with some of the commercially available devices has been shown in table 1. Thus, it consumes significally less power than available wearable devices. .

3.2 Cost Estimation

We can calculate the cost of the end-node and gateway device as shown in Table 2 and Table 3

Components	Price
Arduino Pro mini	3.5$
Sx1276 LoRa IC and Antenna	7.56$
Charging IC TP4056	0.56$
1000mAh Li Ion Battery	1.6$
Weather-proof box	2$
Total	15.22$

Table 2. Cost estimation of end-node

Components	Price
Adafruit32u4 LoRa module	30$
RaspberryPi 3	34$
Airtel 4G LTE modem	30$
3D Printed box	1.5$
Total	95.5$

Table 3. Cost Estimation of gateway device

It is observed from Table 2 that our end-node costs mere 15$ which is substantially lower than commercially available security wearable devices like Athena, Nimb [12, 13]. Our gateway device costs around 95$ which is pretty less considering we need only one gateway for covering a large area. So, we can conclude that our proposed network can be deployed at an optimum price on a large scale.

4 CONCLUSION

We have proposed and implemented a long-range IoT network for citizen security using LoRa RF. We have designed a custom PCB with Arduino and LoRa IC which acts as our end-node and a Raspberry-Pi based 4G gateway. A data logging server is created which logs all incoming node-ids from the gateway and is made available online. We have also developed an android application which shows alerted node-id in real time and navigates concerned security person to that node. The proposed architecture iks evaluated based on power consumption and cost estimation. Our evaluation results conclude that our network is extremely low powered and heavily cost optimised. This shows that our proposed system is a step towards solidifying the smart city concept.

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