A Project Report on

Wireless IoT based Solution for Women Safety in Rural Areas

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for the award of the Degree of

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by

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April 2019

Certificate

This is to certify that the Project entitled ”Wireless IoT based Solution for Women Safety in Rural Areas” has been completed to our satisfaction by Mr. Rahul Paknikar, Mr. Shrey Shah and Mr.Shubham Dubey under the guidance of Dr. Prachi Gharpure for the award of Degree of Bachelor of Engineering in Computer Engineering from University of Mumbai.

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Project Approval Certificate

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Statement by the Candidates

We wish to state that the work embodied in this thesis titled "Wireless IoT based Solution for Women Safety in Rural Areas" forms our own contribution to the work carried out under the guidance of Dr. Prachi Gharpure at the Sardar Patel Institute of Technology. We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission.

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List of Abbreviations

BLE	Bluetooth Low Energy
Beacon	Portable device for alerting
UUID	Universally Unique Identifier
AP	Access Point
MANET	Mobile Ad-Hoc Network
GPS	Global Positioning System
ARM	Advanced RISC Machine
LCD	Liquid Crystal Display
GSM	Global System for Mobile communication
IoT	Internet of Things
Wi-Fi	Wireless Fidelity
Tx	Transmission
RSSI	Received Signal Strength Indicator

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Abstract

In today's era, women still feel scared to step out of their homes late nights due to the fear of sexual harassment. This problem is compounded when one shifts the focus from urban to rural sector and interior areas of villages where there is erratic electric supply and poor or no cellular network connectivity. There are many smartphone based solutions, but the availability of smartphone and cellular network in rural areas is unreliable.

Simulation can be an effective approach for analyzing the efficiency of any routing protocol taking into consideration various parameters like response time for hearing the alarm, scalability and efficiency of the system.

Our project aims at proposing a system, by creating a wireless network using IoT technology plus a portable device for alerting the concerned village authorities to prevent any mishap. Women will be provided with a beacon device consisting of a single Help Button. In case of any emergency, the beacon information will reach the central stations and an alarm will be triggered at the prominent places of the village. One can find out the location of the victim based on her proximity to the nearest access point.

Chapter 1

Introduction

IoT is a standard of communication in which everyday objects are equipped with sensors. The IoT could be construed as a cohesive system where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with objects over the Internet, query their state and any information associated with them. IoT is being put into effect in every domain of human concern like traffic navigation, security, smart agriculture, home automation, retail and health care. Beacon Technology is one such aspect of IoT.

We live in the 21st century and have progressed with much technical advancement in all the fields of life. But still a single question lurks in the minds of every women or girl which is about their safety from perpetrators. Women and girl children face the problem of harassment of any form like molestation, eve-teasing, sexual exploitation, domestic violence, workplace bullying etc and get abused physically or mentally leading to depression. To counter such problems, women need to inform the concerned authorities. This issue gets compounded for women living in remote and rural areas. Rural women may not be aware about these crimes and hence these crimes are not reported due to fear of shame. Areas like streets and public spaces have been the territory of such violence. There are many existing applications and devices for women security using smart phones. Though the smart phones have increased rapidly, it is not possible that the smart phones and cellular network will be available all the time in rural areas. Also, many people in the village do not have smart phones which can assist them in contacting the nearest police station authorities. Consequently, the literacy rate of village is low and parents prevent girls from attending the schools due to the fear of sexual harassment or eve-teasing.

The proposed system is based on BLE or Bluetooth Smart beacon. BLE is a wireless technology for short range communication requiring low power consumption. BLE devices find their use in numerous sectors, particularly in security, smart home, health, sport and fitness sectors.
The advantages of BLE devices are:
1) Low power requirements, operating for months or years on a single button cell
2) Small size and low cost
3) Compatible with a large installed base of mobile phones, tablets and computers

1.1 Motivation

In rural areas, if women face sexual harassment it is difficult for them to inform others because most do not have smartphones and even if they have, the network connectivity issue persists.

Electricity supply is also not regulated. After speaking to the village fellows, we came to know that many such events have occurred in the past, but not reported or handled legally. So to provide women a safe environment to live in and promote women empowerment this aspect needs to be solved in a timely manner. We wish to create a wireless network using IoT technology along with a portable device for alerting the concerned village authorities so that legal actions can be carried out there on and accused be punished.

1.2 Objectives

- To build a solution which is cost - effective in terms of designing the wireless local network and the portable device.
- To implement in a manner which is user - friendly and acceptable by the women and the people of village, as they may not be educated.
- To design the system in a way that it will continue to function independent of any electric supply or any network connectivity.
- To design the system such that it will trigger an alarm as soon as the Help Button is pressed. To estimate whether the time to hear alarm lies within the acceptable limit 60 seconds.
- To monitor the effect on routing of distress message packets if multiple communication nodes are dysfunctional. To implement the concept of multi - server system so that message can be routed to other servers if a particular server is down.
- To handle the concurrent requests for emergency, when 2 or more women press the Help Button simultaneously. To implement the concept of multi - server system so that message can be routed to other servers and processing load on single server may be reduced.

1.3 Problem Statement

To design a Digital Wireless Network using IoT and a portable device for alerting the concerned authorities and to facilitate a method of communication between the network and the device which will trigger an alarm at the prominent places of the village.

1.4 Layout of the Project

The organization of this project report is as follows:

Chapter 2: Literature Survey
This chapter emphasizes on the study of existing women safety systems and the demerits of these systems. It describes the research required for this project involving Routing Protocol and Networking concepts.

Chapter 3: Design
The methodology and working model of the proposed system is provided in this chapter. It also gives the description of the hardware components and communication mechanism used in the proposed system.

Chapter 4: Implementation

This chapter provides the implementation details of the proposed system. It also describes the work on running a network simulation for a given worst case scenario.

Chapter 5: Result

This chapter presents and discusses the results obtained from the application and gives a brief description about the results. It also explains the procedure/flow of the simulation.

Chapter 6: Conclusion

The lessons learned as a result of this project are summarized. Conclusions drawn based on the results are also described.

Chapter 7: Future Scope

This chapter suggests various improvements which can be made for providing w safety and the extension of this project to other domains.

Chapter 2

Literature Survey

2.1 Existing Systems

An approach for women and children safety has been suggested Ms. Deepali M. Bhavale et al. [4] provides a unified approach by designing a safety kit for women and school children using Arduino. It consists of handheld device for alerting and a GPS for tracking the location of victim. The input to the system is the user details, the school bus number to be tracked and the button click events. The output of the system is the notification sent to the pre-set contacts, the current location of the user and the user details. The notification is sent to the contacts using GSM Module. The system makes use of 6 fuctions namely:

- F1 (D) - Get User Details
- F2 (D) - Registration
- F3 (D) - Fetch Current Location
- F4 (D) - Send Current Location
- F5 (D) - Send User Details
- F6 (D, E) - Send Notifications

Here D stands for given User Details and E stands for button click events.

Haversine and Trilateration algorithms have been used for determining the exact location of any user on based on the geographical latitude and longitudinal input. Haversine algorithm is used to calculate the great - circle distance between any two points located on a spherical surface as shown in Figure 2.1.1.

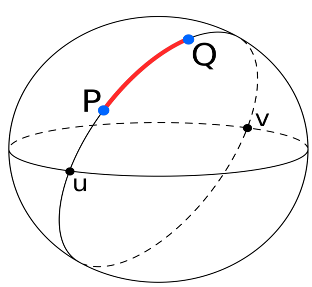


Figure 2.1.1: Great Circle Distance [6]

Trilateration Algorithm is a process of finding absolute or relative locations of points by measurement of distances using the geometry of circles, spheres and triangles. These algorithms require GPS module for accurate tracking on the sphere.

But GPS technology has several demerits:

- GPS is network dependent and cannot be used in areas where there is poor/no network connectivity.
- The GPS chip is power exhaustive and needs periodic power supply or replacement.
- GPS does not provide us with indoor localization as these signals cannot penetrate the building and solid structures.
- The accuracy depends on the strength of the received signal as the signal may suffer attenuation along its transmission path.

Another solution by G. C. Harikiran, Karthik Menasinkai, Suhas Shirol [6] comprises of a wearable Smart band which continuously communicates with smartphone that has access to the GPS and Internet. The Smart Band sends emergency signal to the smartphone through Bluetooth 4.0 BLE which uses GSM messages and Internet to post on social platform provided by the mobile application. However, many remote areas in the country are difficult to be connected using Internet facilities due to latent requirements and location concerns. Also in distributed housing layout of rural areas, the cost of providing broadband connectivity is not justifiable at normal subscription rates and to increase the subscription fee is not viable since this will exceed the affordability of villagers.

The implementation proposed by D. G. Monisha et al. [8] discusses the project with aim resembling our project aim. But their application is suitable for women in cities who have access to smart phones and strong network connectivity. Our system has been designed in a manner which tackles both the above issues and still delivers a women safety mechanism for rural areas. They have designed a device using ARM Controller along with various components and an Android Application. They have synchronized the smart phone and the controller using Bluetooth. The components include GSM Module, GPS Module, Audio Recorder, Hidden Camera Detector and an LCD as shown in the figure 2.1.2. The GPS (UBLOX) Module gives the precise location of the person. Pressing the Emergency Button activates the device and the way in which button is pressed triggers different activities. If pressed once, it sends the current location and a distress message to police and pre - set numbers using GSM Module. If pressed twice, it does the above activity and also records the audio of incident. If the button is pressed for long time, it initiates a call to the police and pre - set contacts along with message and current location. They have also created an Android Application which consists of simple user interface and guides the user on how to proceed and use the application. There are several icons like distress message,Hidden Camera Detector, Women Safety, Video Recorder. Depending on the severity of the situation the user will choose one option and corresponding action will be taken.

There are components which have various functions:

- <u>SOS Message:</u> It is a distress message which is sent to pre - set contacts and police periodically. The message consists of the geographic location based on GPS and an emergency message. Audio may be recorded and call may be initiated to the police.

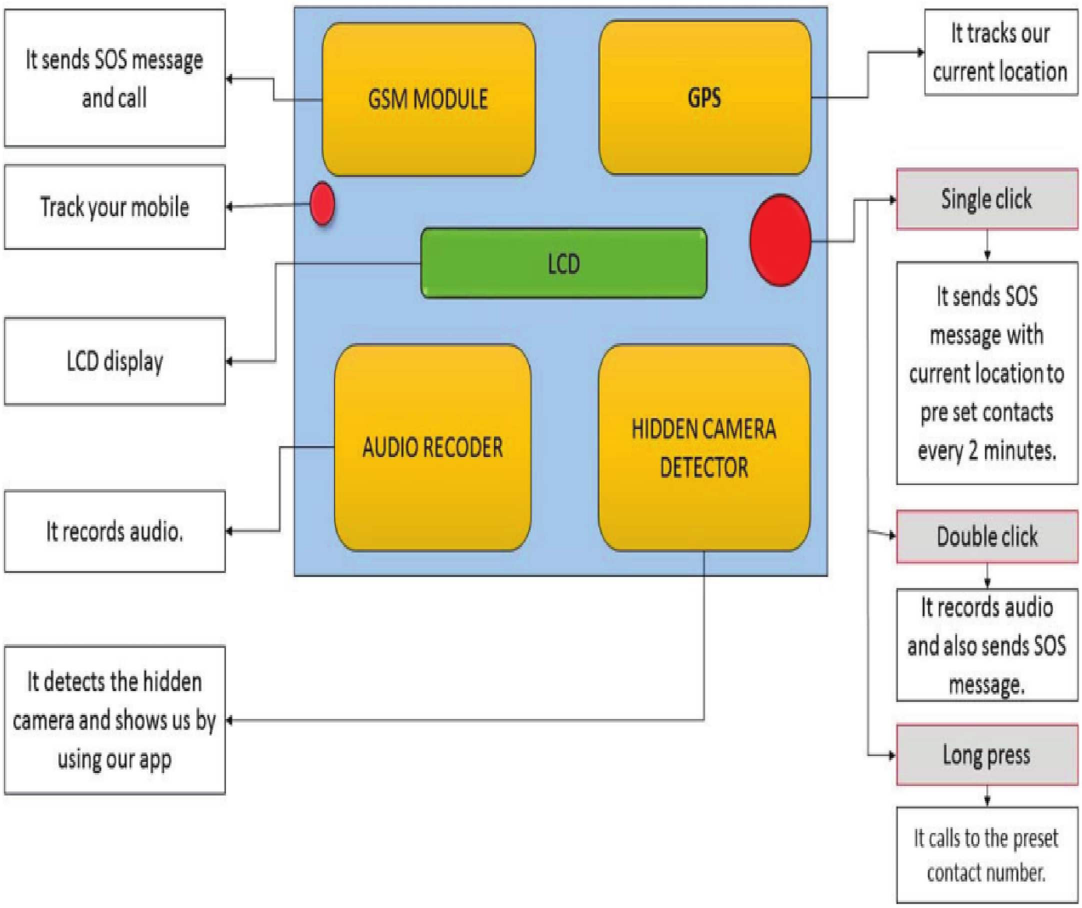


Figure 2.1.2: Schematic diagram of the device [8]

- Hidden Camera Detector: It is used by women to safeguard her own privacy. It receives Radio Frequency and catches electromagnetic signals broadcasted from any hidden camera. In close range, this detector lights up indicating the presence of any hidden camera. This scenario comes into picture basically in trial rooms of malls and showrooms.
- Audio Recorder: This components is present in the hardware device. It starts recording the audio when it is initiated and this recording is sent to police as a proof.
- Video Recorder: This is a part of the Android Application. It starts recording the video of the incident and can be used as a proof for further legal actions to be taken.

Based on the study of the existing systems, we have found out certain issues that we need to solve. All these systems make use of GPS and network based techniques for identifying user location. But in remote rural areas where there is no network connectivity these systems are not useful. To solve these issue our proposed method consists of following 4 components:

- Creation of Local Wireless Network using IoT boards.
- Design of portable device.
- Communication protocol between nodes and beacons.
- Placement of IoT boards on street poles.

A literature review was done [1],[2],[3],[4],[5],[6],[7],[8],[9] to find out the best possible choice of hardware and technology to give the most viable solution to the problem. For designing the composite system, we have also surveyed upon existing systems which have been using tracking systems for estimating the location of the user.

2.2 IoT Boards

To create a local network, we need hardware devices that can work as access points. A wide range of sorts of equipment are being planned keeping in view the necessities of IoT. These incorporate Microcontroller, System-on-Chips and Single Board Computers (SBC). According to survey paper[4], BeagleBoneBlack, Intel Galileo, UDOO x86 and Edison Arduino Kit, Tessel 2 and Raspberry Pi Zero(W) are some of the option that are best considering the application. These boards provide effective and a solid stage for advancement of the wireless module. As per our examination [2], out of these six boards, Raspberry Pi Zero W is the most adaptable and reasonable board. The explanation for this are its less expensive sticker price, numerous alternatives availability, scope of OS support. Because of the ubiquity of the Raspberry Pi Zero W, an assortment of libraries for different equipment applications are as of now accessible in the market.

2.3 Portable Device

Many different types of devices are available which can serve as beacon devices. These are produced by different companies. We have surveyed 4 different types of beacons namely iBeacon by Apple, Eddystone by Google, AltBeacon by Radius Networks and GeoBeacon by TecnoWorld.
As described in [2], when contrasted with above mentioned devices properties along with GPS, Wi-Fi - Access Point based Solutions and RFID, the BLE Beacon [3] based arrangements have favorable position because of their ease, simplicity of organization, availability to the clients and superior interior localization. Bluetooth LE, as the name clues, has low vital necessities. It can last up to 3 years on a single coin cell battery. BLE is 60-80% less expensive than customary Bluetooth and BLE is perfect for straight forward applications requiring little intermittent exchanges of information. Also it indicates information by proximity measurement of an object to an area. So it can used for estimation of the relative distance between any 2 objects: stationary or non - stationary. The paper also suggests that BLE Beacons can also used for sensing the activities of the user by getting accurate location using gesture identification technology.

Beacon consists of 4 parameters which identify it. They are as follows:

1) UUID - It consists of 32 hexadecimal digits which have been divided into 5 groups which are separated by hyphens.
2) Major and Minor - Major and Minor values are numbers assigned to the beacons, in order to identify them with greater accuracy than using UUID alone. Minor and Major are unsigned integer values between 0 and 65535.
3) Transmission Power - It is a factory-calibrated, read-only constant which indicates what's the expected RSSI at a distance of 1 meter to the beacon. Combined with RSSI, it allows to estimate the distance between the device and the beacon.

Reference [3] discusses in detail about the Protocol working, the different profiles and its power consumption characteristics, how the energy can be stored and energy harvesting capabilities of Beacons. It gives us insight into different types of Beacons which are available in the market and they have been categorized on the basis of casing and power source, which we require so that we can model our hardware beacon which is portable and easy to be worn by women and girl children.

2.4 Communication Protocol

Based on the reference of BLE Beacons [2], as compared to GPS, Wi-Fi - Access Point based Solutions and RFID, the BLE based solutions [3] have an advantage due to their low cost, ease of deployment, ease of accessibility to the users and superior interior localization. Bluetooth LE, as the name hints, has low energy requirements. It can last up to 3 years on a single coin cell battery. BLE is 60-80% cheaper than traditional Bluetooth and BLE is ideal for simple applications requiring small periodic transfers of data. BLE protocol is associated with 4 components - UUID, Major, Minor and Transmission Power, which can be used to uniquely identify the user. BLE communication consists primarily of “Advertisements”, or small packets of data, broadcast at a regular interval by Beacons or other BLE enabled devices via radio waves. A node on receiving packets from Beacon will transmit it to the control station of the local network.

As per the reference [7], the well established and standardized Bluetooth protocols cannot be used with BLE for MANET. Also, Bluetooth Specification version 4.0 is not useful as its architecture doesn’t support a single BLE device to act as Master as well as Slave. That is, a BLE device can either be a Master or Slave at a given time, thus can communicate with other devices within the same Piconet which are within its radio range. Hence, Bluetooth Specification version above 4.1 is required so that each device can become Master as well as Slave and participate in multiple Piconets at a given time forming a Scatternet.

Figure 2.4.1 describes three distinct Piconets in Specification 4.0 . Master *M2* has two slaves *d* and *e*, which can communicate with its master on a separate channel. Similarly, Master *M1* and slave *a* forms another Piconet and Master *M3* forms a separate piconet with slaves *g* and *i*. Also, none of the three Piconets can communicate with each other.

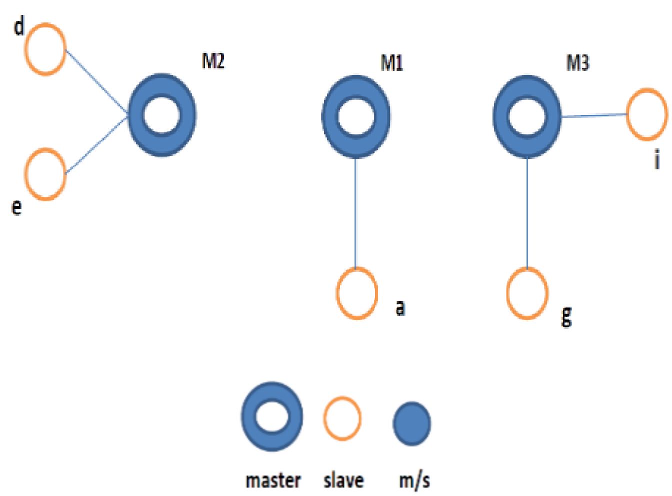


Figure 2.4.1: BLE Topology of specification 4.0 [7]

With Specification 4.1, it is possible for these Piconets to communicate with each other with a relay; thus forming a Scatternet as shown in Figure 2.4.2. Here, Master *M1* acts as relay.

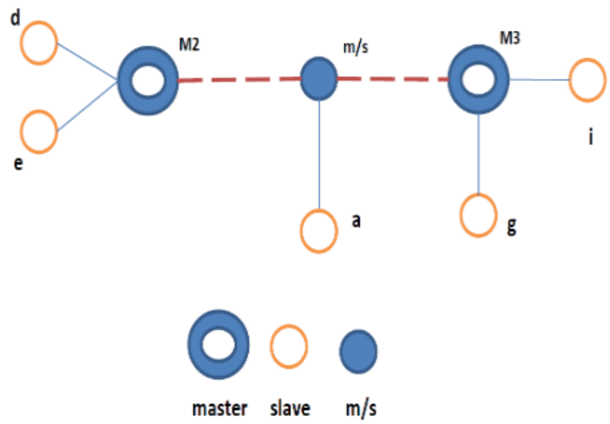


Figure 2.4.2: BLE Topology of specification 4.1 [7]

The suggested protocol described in [7] is shown in the Figure 2.4.3. When a new node comes into the range of a MANET, it will start broadcasting advertisement packets as well as scan to capture the advertisements of other nodes. If this new node gets a response to establish a connection, then it will be added to the network as a Slave. However, if this new node receives an advertisement packet from other node, then it will start establishing a connection with that node and eventually becomes a Master of that node. BLE routing generally assumes the Star topology, reason being very limited work done in the field of BLE Mesh networks as well as the complexity in implementing the same. But the star topology requires the all the nodes (slaves) to be connected to the one Master node, leading to the increased load on one node and also the reduced coverage area, since the master-slave communication is only possible.

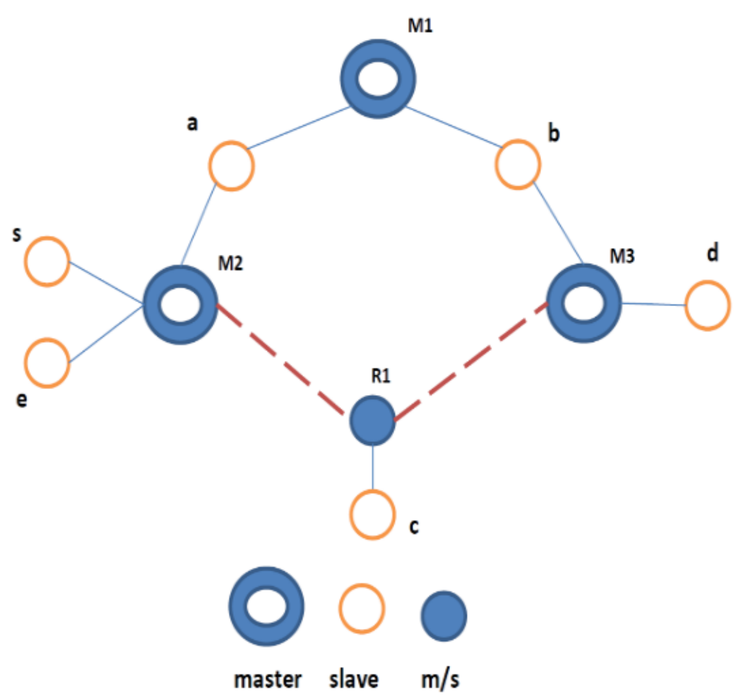


Figure 2.4.3: Scatternet Routing [7]

With the increased demand in IOT and latest Bluetooth specifications 4.1 and 4.2, it has become possible for the single node to switch between master and slave responsibilities and giving a hope for Mesh network to be configured. A theoretical proof [9] of mesh implementation using Dynamic Address Allocation as well as Proactive source routing, with the former being adapted from RSVConf protocol to address auto configuration of BLE is provided. The stages of Mesh network configuration are as follows :

- Dynamic Address Reservation/ Allocation : This stage incorporates the address allocation for new nodes joining or leaving the network. It consist of three main phases : Proxy Selection, Reservation and Configuration.
  - Proxy Selection: It involves the selecting one of the node as a proxy from the network, which is three way handshake involving acknowledgement from the new-joiner.

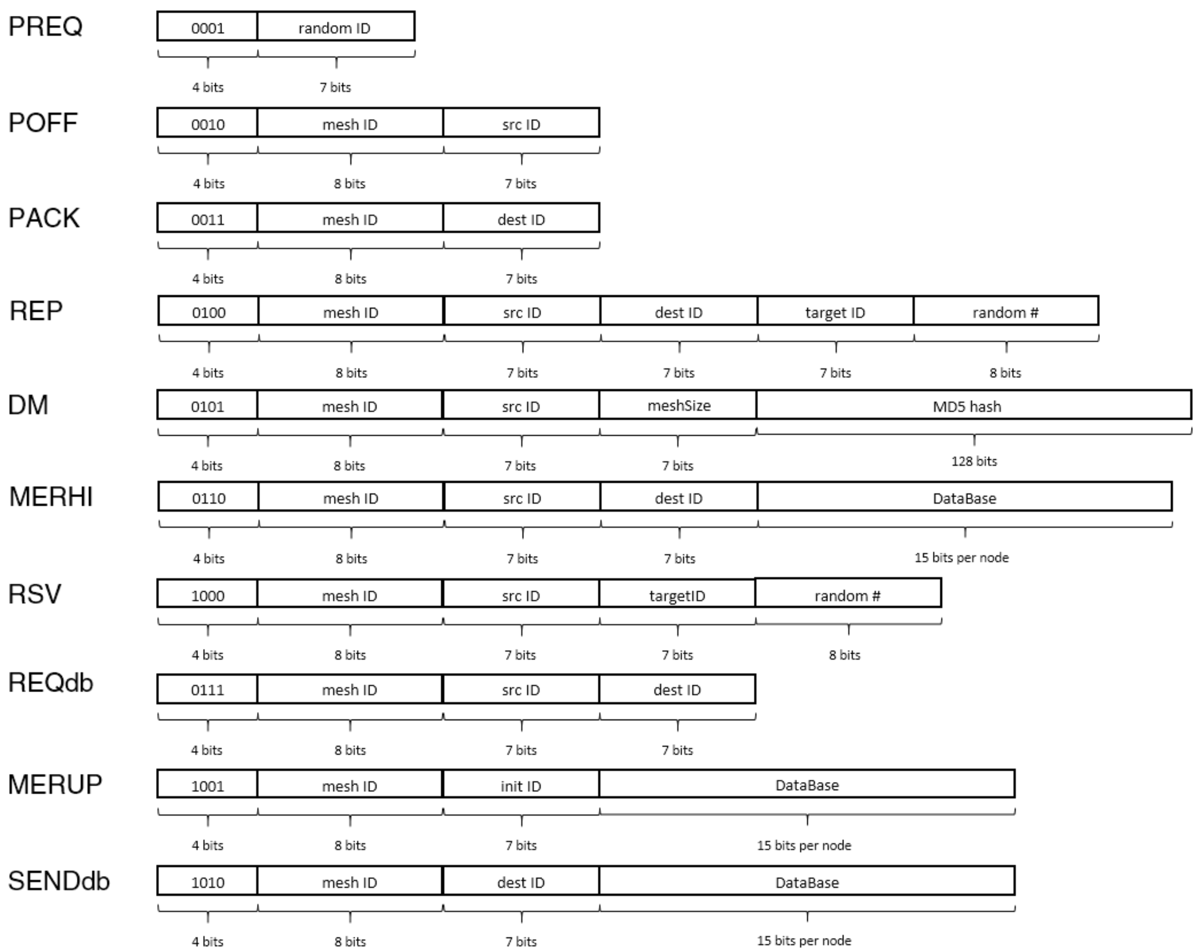


Figure 2.4.4: Reservation Protocol Messages [9]

  - Reservation: Proxy, on checking for the id availability, broadcasts the information about the new node in the network and if alerted as duplicate from one of the member node, the whole address reservation process is restarted.
  - Configuration: Finally, on being granted the address, node asks for the information related to the network topology, so as to generate its own network view.

- Proactive Source Routing: With the above configuration we can implement BLE Mesh network with the help of broadcast message using flood routing, which is nothing but the sending message to each and every node in the range. But this leads to, as the name says, flooding in the network forcing BLE network to fail due to the amount of traffic. So for that, we require a strong routing protocol, which limits the number of packets in the network at any time and also applicable to BLE.

  Since the intention of this stage is to provide each node with the knowledge of entire network topology with respect to itself [9] they have proposed to use the breadth-first spanning tree(BFST) to store the network information as shown in Figure 2.3.6. The tree is generated by taking the union of all the trees being periodically broadcasted into the network, with current node as the root of the tree.

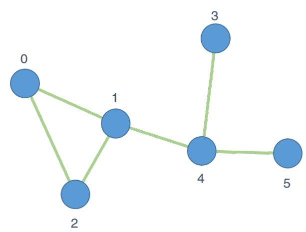


Figure 2.4.5: Undirected Graph (G) [9]

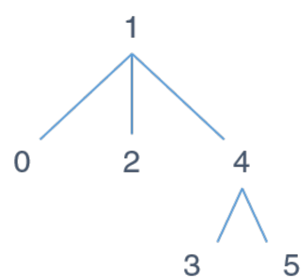


Figure 2.4.6: BFST (rooted at node 1) of G [9]

Also the PSR protocol has the capability to detect and drop the nodes going out of the network range and inform others through periodic broadcasts. This feature combined with the BLE RSV protocol and the keep-alive messages can help to decide if the node has moved out or just changed its position in the network.

2.5 Placement of Access Points (APs)

The placement of the street poles in a given geographical area is an important task to be taken care of, as the installation cost varies exponentially with the number of poles. For that it is required to efficiently place the poles, so as to cover the whole area and avoid any dark spots in the region [5].

The problem of optimization of poles for given geographical area has been solved in an innovative way, as in paper[10]. The problem of Packing is challenging with a wide range of utilization.

They are fascinating NP-hard combinatorial advancement issues; that is, no methodology can precisely tackle them in deterministic polynomial time. They are experienced in an assortment of genuine applications including generation and pressing for the material, attire, maritime, car, aviation, and sustenance enterprises. They are bottleneck issues in PC supported structure where configuration plans are to be created for modern plants, electronic modules, atomic and warm plants, etc. The problem of cylinder palletization comprises in distinguishing the most extreme number of indistinguishable circles (with a known range) that can be stuffed into a square shape of fixed known measurements where the circles ought to be absolutely inside the rectangular box. This issue is delegated a solitary rucksack issue as per the typology of Wascher et al.

Hifi and M'Hallah [10] propose a constructive heuristic and a genetic algorithm. The two calculations scan for a decent request of the pieces and utilize an adjustment of the best neighborhood position methodology to pack the circles. The adjusted positions hovers in the upper left-most accessible position yet exploits the circularity of the pieces to investigate additionally encouraging positions. Adapted methodology is less complex and quicker than existing methodology since a situated circle can't be additionally deciphered, and a circle can be situated in openings created by effectively stuffed ones. The solution aims to solve problem by formulating it as follows :

$$\text{Minimize} \sum_{i<j} \max\left(0, 4\bar{r}^2 - (x_i - x_j)^2 - (y_i - y_j)^2\right)^2$$

$$\text{Subject to}\ \bar{r} \le x_i \le L - \bar{r} \quad i \in I' = \{1, \ldots, k\}$$

$$\bar{r} \le y_i \le W - \bar{r} \quad i \in I'.$$

Figure 2.5.1: Problem Formulation

The above decision problem is feasible only if the value of objective function comes out to be zero, infeasible otherwise.

$$\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} < 2r,$$

$$4r^2 - (x_i - x_j)^2 - (y_i - y_j)^2 > 0,$$

$$\max\{4r^2 - (x_i - x_j)^2 + (y_i - y_j)^2, 0\} > 0.$$

Figure 2.5.2: Objective Function

Chapter 3

Design

3.1 Methodology

Multiple solar powered street light poles are arranged in an optimized formation of triangular geometry such that each pole is within the range of its adjacent poles on either side of it. IoT boards [1] will be positioned on these street poles and will be powered using the solar energy taking into account the unpredictable electric supply to the rural areas. It will act as an AP of the local wireless network through which the communication between the beacon device and the access point will occur.

Women will be provided with the beacons which will consist of the Help Button. Based on the beacon's UUID, the user will be identified uniquely and the Transmission Power parameter will enable us to estimate the location of the victim. The access point which sense the maximum transmission power from the beacon device will give us the location of the victim.

For this, street poles will be identified by a unique identifier and its GPS coordinates in the village area. Beacon communication consists primarily of advertisement broadcast at a regular interval by beacon devices via radio waves. The communication between a Beacon device and an AP, between any two APs and between an AP and a server at central stations is governed by either BLE Multi-Hop routing protocol [7] or BLE Mesh Network Proactive Source routing protocol [8].

3.2 Use Case Specification

The table 3.1 provides us with the most basic use case of the system. This Use Case gives us the details about the primary functionality when the victim presses the help button on the portable device in case she faces any kind of abuse or harassment.

Table 3.1: Use Case Specification

Use Case ID	1
Use Case Name	Victim requesting for help from villagers
Summary	This Use Case describes the sequence of events that take place when any women/girl child is scared of harassment in village due to the presence of any perpetrators and she presses the help button on the portable device.
Level	Primary Task
Primary Actors	Any women/girl child in the village
Secondary Actors	Village authorities
Pre - Conditions	1. The victim must have portable beacon device for alerting. 2. The victim must be in the range of street light on which access points have been mounted.
Trigger	When any women presses the help button on the portable device if she feels threatened.
Description	Use Case 1 is initiated when any women/girl child feels threatened due to and presses the help button on the portable device. 1. The nearest access point will capture the information like beacon ID, location from where the signal was captured, its power etc., and this data will be transmitted to the next access point in the path. 2. Eventually, this information will be stored at a central station situated at concerned locations in the village. An alarm will be heard to alert the concerned village authorities. 3. Location of the victim can be traced on an offline map stored at the central station.
Post - Conditions	1. An alarm must be heard once the harassment information is stored at the central station. 2. The log records of information stored can be viewed and reports be generated.

3.3 Mathematical Model

Whenever we observe the arrangement of street poles on roads or highway, it follows 4-in-a-rectangle placement as seen in Figure 3.2.1 indicating that 2 poles face each other in exact opposite direction. To provide adequate visibility for the same area, we optimize the number of poles by placing them in a 3-in-a-triangle placement with each pole placed at the vertex of a triangle as seen in Figure 3.2.2. This optimizes the number of APs which need to be mounted on these street poles. Further, we place the poles at some viable distance in the transmission range of APs.

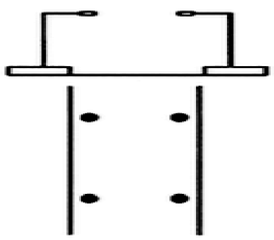


Figure 3.3.1: Rectangular arrangement of poles

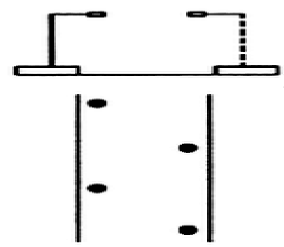


Figure 3.3.2: Triangular arrangement of poles

The maximum transmission range of BLE Protocol is 100 meters. But taking into account the different types of signal strength losses, we have considered the maximum range of transmission as 80 meters. While considering the triangulation, we need to take into account the blind spot, here a centroid, of triangle which is a point outside the normal range of an AP where there is unusually weak reception. The centroid is I as seen in Figure 3.2.3. To cover it within the 3 APs we assume that the distance of the AP to its centroid is 80 meters. Based on a equilateral triangle's property, centroid bisects the median in ratio 2:1. So the height which is GB turns out to be 120 meters upon calculation as per the Figure 3.2.3.

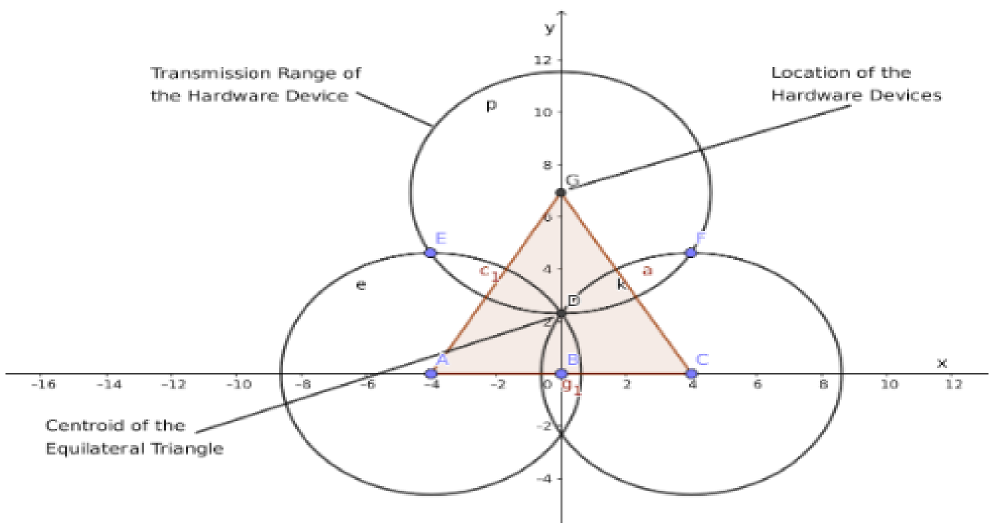


Figure 3.3.3: Calculation of vertical distance between APs

Consider the $\triangle$GAB.
Let us assume that distance AB is r.
Similarly the distance AG will be $2r$.

Using Pythagoras Theorem,
$AG^2 = GB^2 + BA^2$.
$\therefore(2\mathrm{r})^2 = (120)^2 + (r)^2$
$\therefore 4\mathrm{r}^2 = 14400 + r^2$
$\therefore 3\mathrm{r}^2 = 14400$
$\therefore \mathrm{r}^2 = 4800$
$\therefore \mathrm{r} = \sqrt{4800}$
$\therefore \mathrm{r} = 69.28$ meters

Based on this r value = 69.28 meters, any 2 APs can be placed within the range of 130 - 140 meters. Hence, an area of 1 square kilometer require 60 APs to cover the entire region without any blind spot. We can ensure that even if any victim is present at the blind spot and the beacon is pressed the help request will be received by atleast one of the three APs.

3.4 Hardware Components

Our system consists of five hardware components:

- BLE Beacon: It is a wearable and portable device, called as Beacon device or any other BLE enabled device via radio waves [3], for alerting the concerned authorities in the village and is associated with 4 components - UUID (Universally unique identifier), Major, Minor and Transmission Power to uniquely identify the user.

- Access Point: This device forms the basic communication module of the entire system. The distress message packets generated by the Beacon are transmitted to the central station via these Access Points. These devices can be from a set of microcontrollers, processors or any type of routing devices. All of these boards are BLE enabled, have low energy requirements and can be interfaced with the solar panels. They provide smart, efficient and a reliable platform for development of the IoT boards as AP.

- Central Station: At the central station, a server is setup by a computer powered by solar panels. It consists of a database that stores the unique mapping of access point identifiers and its corresponding colloquial village region naming. These identifiers and landmarks is plotted on a preset map stored in the server for faster tracking of victim's location.

- Solar Panel: These panels supply power to both street light poles as well as AP. APs require 5 volts supply and draw 160-300 milli-amperes current on continuous functioning.

- Buzzer: It is an emergency alarm device interfaced with the server in central station. For effective audibility [11], the loudness should be 80-90 decibels with a region coverage of 60 meters.

3.5 Communication Mechanism

3.5.1 Network Creation

For the creation of the wireless local network, the following protocol steps are performed:

- In this step, each individual AP has its routing table.
- An AP keeps track of all the other nodes to which it is connected.
- When a new AP comes into the existing network, it will take turns to advertise itself and listen to the advertisements of other nodes.
- The new AP may receive connection request while it itself is advertising and it may send a response back to establish the connection.
- Or else the AP may listen on the advertisement channel and if it receives advertisement of other node it will initiate the connection process.
- Through this process the APs are able to discover their neighbouring APs and a network is formed. Routing tables get updated.
- The protocol is auto - configuring. So if any node goes down or if any node is added to the system, it is automatically deleted or included in the existing system.

3.5.2 Routing Procedure

Once the local network has been created, the following protocol steps are performed to route the packets:

- After creating the network, the routing tables of all APs get updated.
- When a source AP needs to send data to any other AP, it first sends a route request to the master.
- If the destination AP is in the same network the master forwards the packet. But if not, then the route cache of the AP is checked to search for the frequently used route. Initially the route cache of all APs are empty. So a route discovery process is initiated.
- The process is done on the AP when it needs to find a route to destination AP.
- The above process may be recursively invoked on multiple APs. So this takes two inputs - the route from source AP to the AP on which it is invoked and the destination AP.

3.6 Working Model

Each women is provided with a portable beacon. If any woman feels threatened by any perpetrator, she will press the help button on the Beacon device provided.

Beacon device will send the information about its unique identifier encapsulated in the form of a broadcast message to APs 1, 2, 3, 4 in its range as shown in Figure 3.6.1. Even though AP 4 is down, message will be broadcasted to it but it itself will not be able to forward any messages to other nodes. The access points will route these broadcasted messages amongst themselves until they reach the central station. Multiple routes are possible for the message transmission, which will guarantee the delivery of message even in case of losses.
As per the Fig. 3.6.1 possible paths are as follows:

AP 1 → AP 3 → AP 5 → Central Server
AP 1 → AP 3 → AP 5 → AP 6 → Central Server
AP 3 → AP 5 → Central Server
AP 3 → AP 5 → AP 6 → Central Server

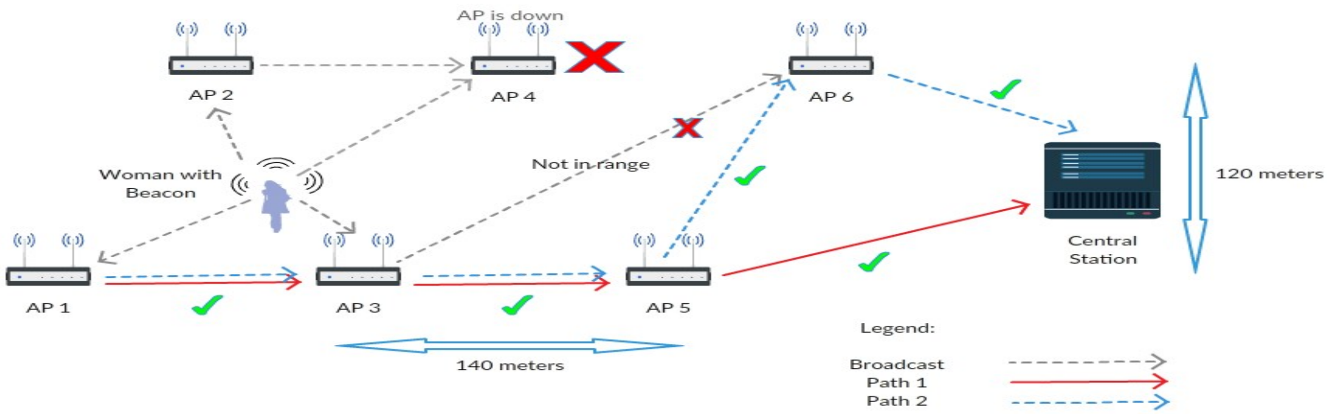


Figure 3.6.1: Working Model of Proposed System

All these paths will route the message to the central station. As soon as the first message reaches the central station, the alarm will be triggered.

3.7 Features of the System

- Independent of Electricity: Rural areas face the problem of frequent power cuts. To power the communication module, our system makes use of solar - powered panels mounted on the village street poles. This provides dual benefit by providing power supply to both the communication module and street poles. So the system will continue to function even in the absence of electricity.

- Independent of real-time GPS: For accurate tracking of the victim's location, we store the GPS coordinates of street poles in a database. Also, an offline map of the entire village is stored on the central stations to accurately track those GPS coordinates on the map along with the landmark.

- Multiple central stations: If multiple help requests are received simultaneously, a single server will not be able to handle and process all the load efficiently. So we have introduced multiple servers so that help requests can be routed to nearest server and alarm be triggered. This also solves the issue if any of the servers breakdown.

- Tracking victim using defined GPS coordinates of APs: Once the victim presses the 'Help' Button on the beacon, the message is transmitted to nearest access point and routed to the central station. Based on the information stored in the central station, the concerned authorities can be sure of the victim's location based on the pre-stored latitudinal and longitudinal details of access points.

- Independent of Smartphones and GSM system:
The system takes care of Internet service issues based on GSM network and on Smartphones which is not possible all the time to make a call or be in range of GSM system.

Chapter 4

Implementation

The proposed system consists of 3 aspects of implementation which are as follows:

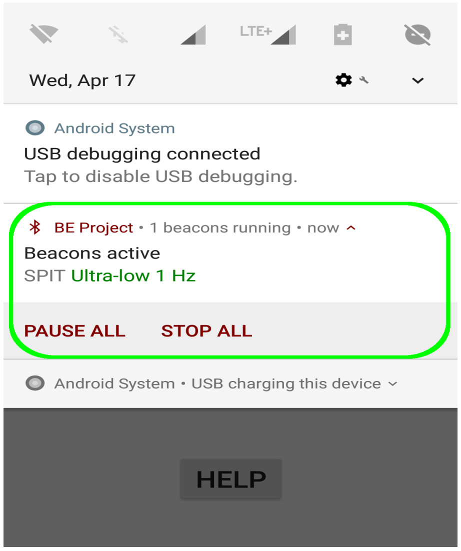
- Beacon - AP Communication
- AP - AP Communication and Routing
- Optimization of APs

4.1 Beacon - AP Communication

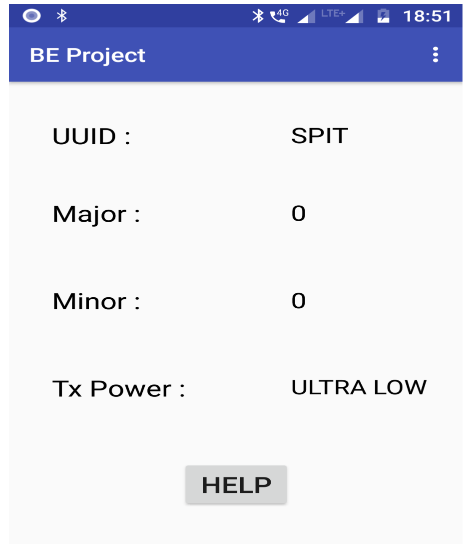
Communication between the Beacon device and an AP was tested by simulating the beacon device as an Android App and an AP device with Raspberry Pi 3, a single-board computer.

Figure 4.1.1 depicts a simulation of portable Beacon device for a regular use-case that is carried by the user. Figure 4.1.1 (a) shows the specification of beacon device where it is continuously broadcasting BLE packets at Ultra-low frequency as supported by the Android architecture. These packets are usual/normal broadcast packets that contain 4 parameters in its header frame as shown in Figure 4.1.1 (b). The UUID name "SPIT" is set at application layer, but at physical level this parameter will be converted into 16 byte universally unique identifier along with Major as 0, Minor as 0 and Tx Power as integer indicating the advertisement mode. Figure 4.1.1 (c) shows the regular broadcast packet captured by the AP device in the range of BLE Beacon device. Since the frequency is Ultra-low, RSSI value and Tx Power are too low for the AP to capture these packets from farther distances. Hence the calculated distance [15] is limited to a certain broadcast range and these packets need to be filtered out. This benefits the system as such packets are regular broadcasts and not emergency broadcast; thus saving energy, increasing lifetime of beacons, reducing load and traffic on APs.

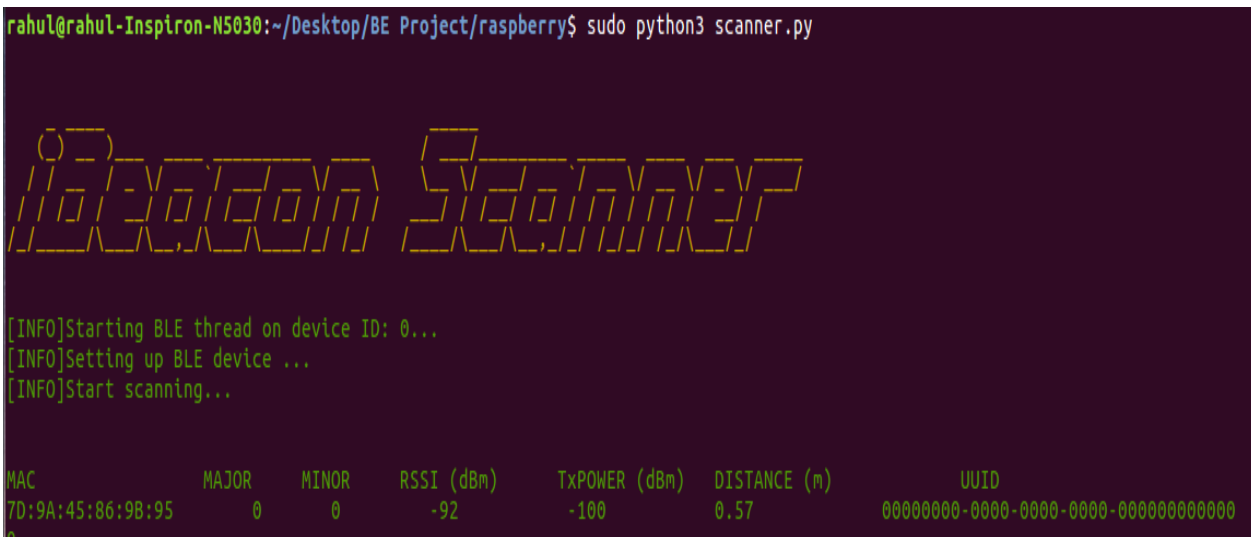
Figure 4.1.2 depicts a scenario for an emergency broadcast by the portable Beacon device that is triggered by the user. Figure 4.1.2 (a) shows the specification of beacon device where it is broadcasting an emergency BLE packet at High frequency as supported by the Android architecture. When user clicks on "Help" Button, the Beacon increases its frequency to transmit the emergency broadcast at a larger distance.



(a) Beacon Configuration



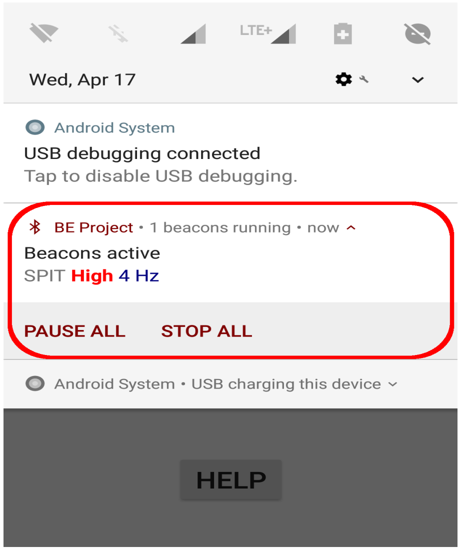
(b) Interface at Beacon device - send regular broadcast



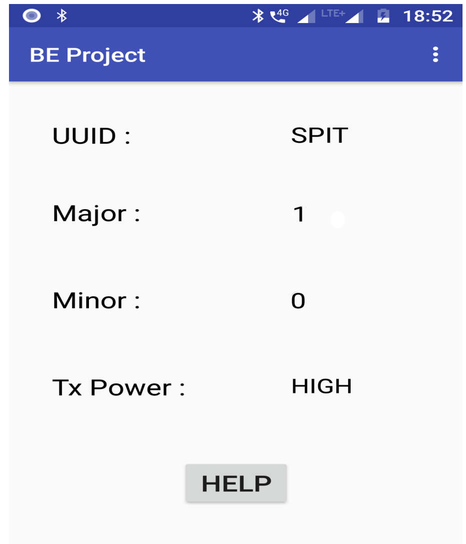
(c) Interface at AP - captured regular broadcast

Figure 4.1.1: Beacon with regular broadcast

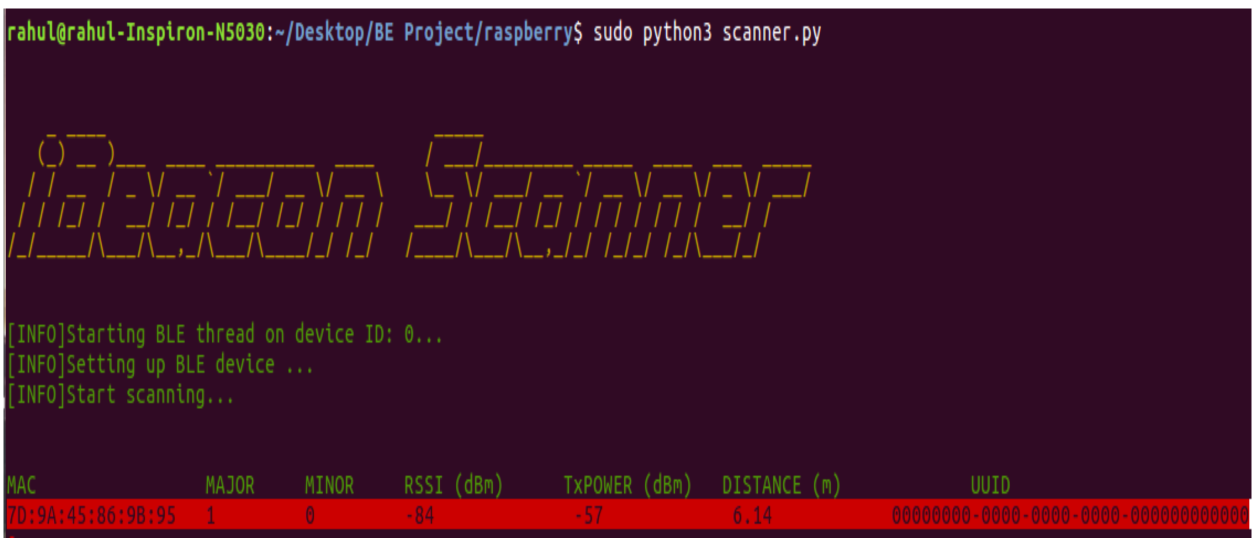
To differentiate between regular and emergency broadcast, a flag or an additional data is required in the packet. As shown in Figure 4.1.2 (b), the parameter ”Major” serves this purpose without increasing the size of the packet. The information from the packet is extracted in a readable format with extra parameters of RSSI and Distance between the beacon device and this AP. The broadcast at High frequency facilitates AP to capture the packet with accurate reading of Tx Power and RSSI value, determining the distance with high accuracy. These information from the received packet will then be routed to the central station for further processing.



(a) Beacon Configuration



(b) Interface at Beacon device - send emergency broadcast



(c) Interface at AP - captured emergency broadcast

Figure 4.1.2: Beacon with emergency broadcast

4.2 AP - AP Communication and Routing

For testing the efficiency and scalability of our proposed system, we designed a network simulation using ns3 Network Simulator [11], [12] for the scenario stated in section as described in Working Model of the Design chapter.

4.2.1 Initial Configuration

Taking into consideration the attenuation in signals that is caused normally due to interference or fading phenomenon, we have assumed the horizontal distances between 2 APs of 80 meters and vertical distance as 65 meters [2], [10]. As seen in Figure 4.2.1, it depicts the initial state of the system simulating a scenario of 12 APs (red) of which 2 constitute the central stations (black) at prominent places in the region, 3 beacon users (blue) distributed in an approximate area of 0.1225 square kilometers.

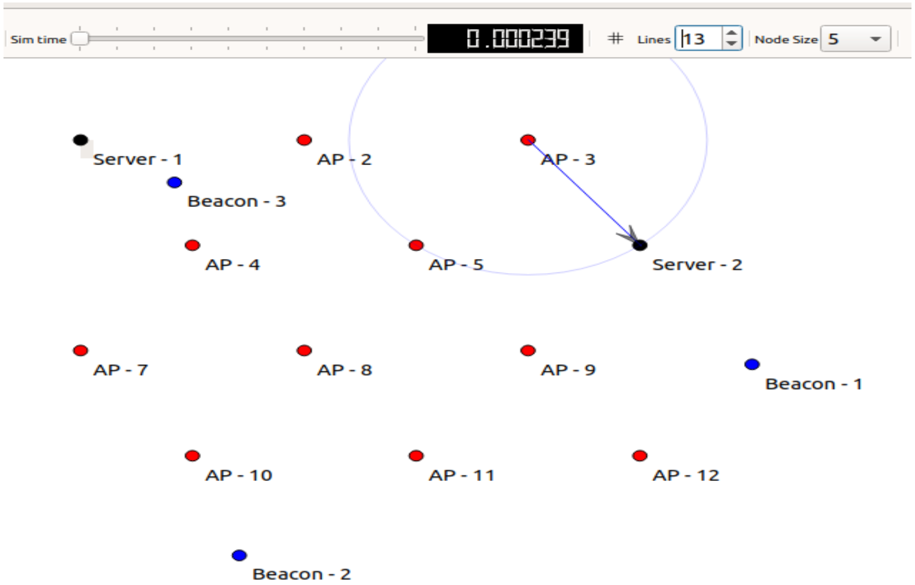


Figure 4.2.1: Initial Configuration of Access Points and Beacons

Communication between the APs and beacons is simulated based on the underlying Multi-Hop routing protocol [7].

4.2.2 Simulation of Dysfunctional AP

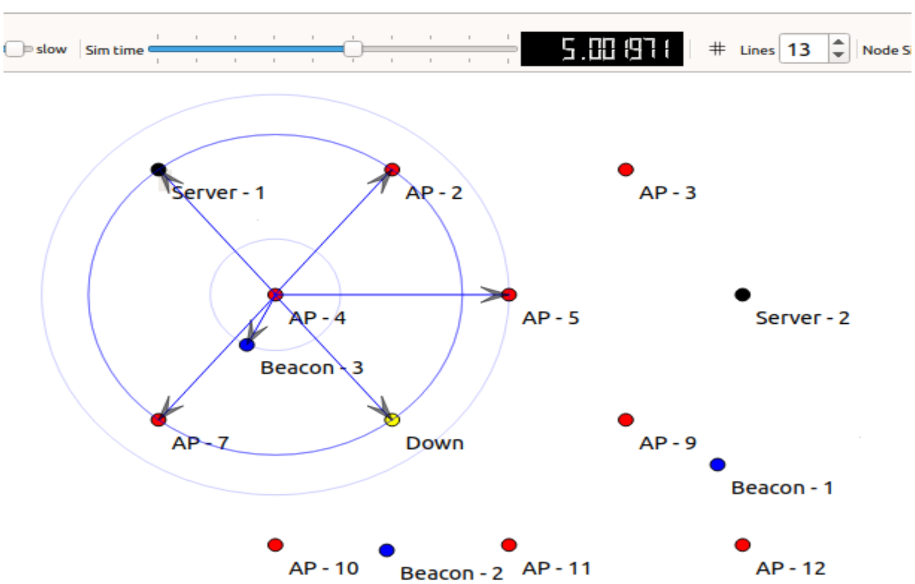


Figure 4.2.2: Considering any random AP as dysfunctional

If certain APs become dysfunctional the system is able to route packets to the central station. To reduce the response time for triggering the alarm multiple servers have been incorporated so that if packets are unable to reach a particular central server, they are routed to some another central server. As per the Figure 4.2.2 we can see that the AP - 8 is labelled as 'Down' indicating that it is not in proper working condition. So packets from beacons will be broadcasted to

AP - 8 but it itself will not forward any message packets. Figure 4.2.3 shows that message from all 3 beacons is received indicating that system efficiently routes packets even in case of AP failure.

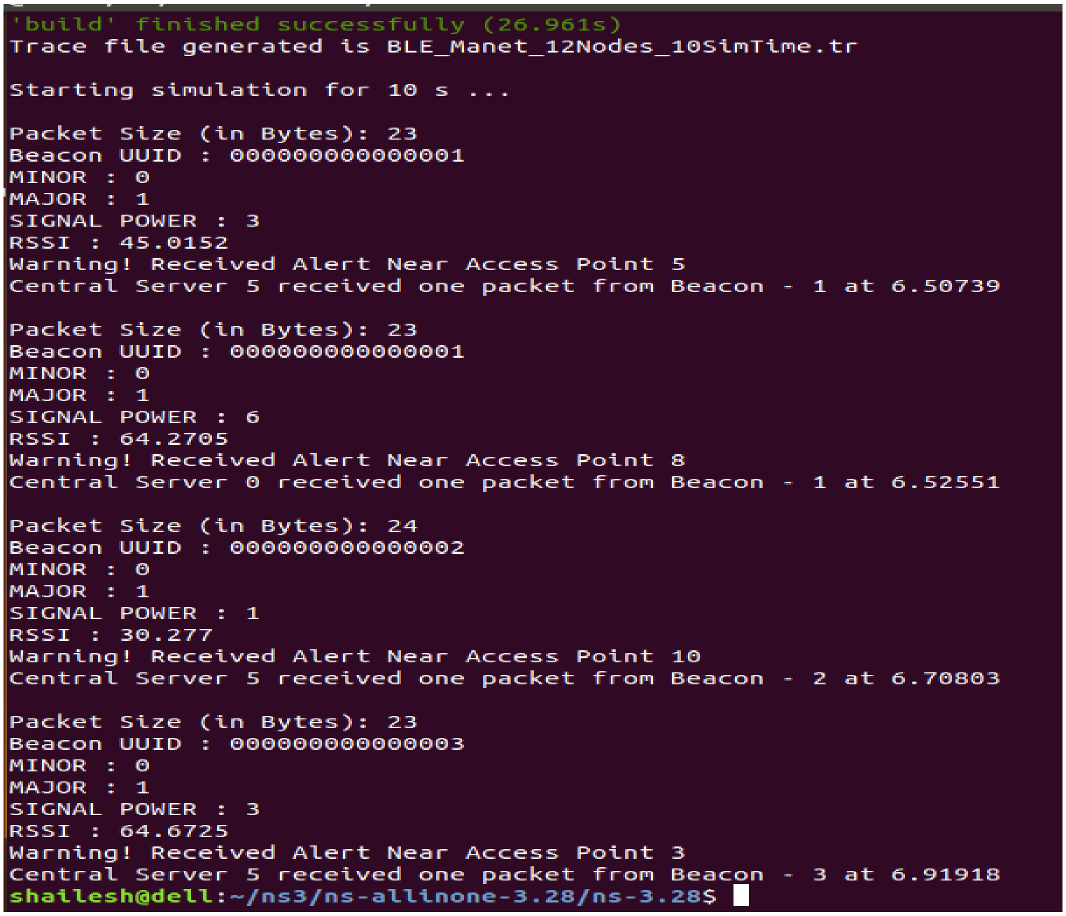


Figure 4.2.3: Information collected at Central Station

Transmission Power helps to estimate the victim location using RSSI. Figure 4.2.3 shows each distress message packet reaching the central station and each parameter of beacon with its value. It also shows the warning alert - the beacon from which it originated and the central station where it is captured along with the time at which the message is received.

Chapter 5

Results and Discussions

For any system to be deployed at a large scale, there is always a need to evaluate the performance of the system based on certain criteria.

For our system we have certain metrics which we need to check so that we can conclude on the proper working of our system. They are described as follows:

- Response Time: It is defined as the time elapsed between the victim pressing the help button on the beacon till the first alarm sound is heard at any central station.
- Scalability: It is defined as the ability of a system to handle a growing amount of work by adding more resources to the system and ensuring that the performance of the system does not deteriorate.
- Fault - Tolerance: It is defined as the ability of the system to maintain its normal functioning even if certain components of the system are dysfunctional.

We have tested the system for response time to trigger the alarm, scalability of the system as described in Table 5.1. Following are the observations.

5.1 Response Time

Table 5.1: Variation of Response Time with APs to trigger the alarm

Number of APs	12	50	150	450
Number of Users	3	6	15	30
Number of Central Stations	2	3	7	15
Response Time (in milliseconds)	702	743	1784	8854

The Table 5.1 gives us the results of the simulation depicting the number of APs, number of users having the beacon, number of central stations and the response time to trigger the alarm. We have tested the same algorithm for varying number of nodes like 12, 50, 150 and 450. The information regarding the packets is stored at central station. Based on the difference between the time of pressing the beacon and data received at central station, we calculate the elapsed time.

This is the response time. We take an average of all these values to get the average Response Time.

5.2 Scalability

As seen in Table 5.1 we know that if we want to expand the system covering larger areas, we require more hardware components to be deployed. So we have simulated the algorithm taking into considerations large areas requiring more APs in the range of 50, 150 and 450. Scalability guarantees that even if the work of the system increases the performance should not be compromised. We observe from the Figure 5.2.1 that with increase in number of APs the Response Time grows in a linear fashion. This indicates that the system performance has not dropped down significantly.

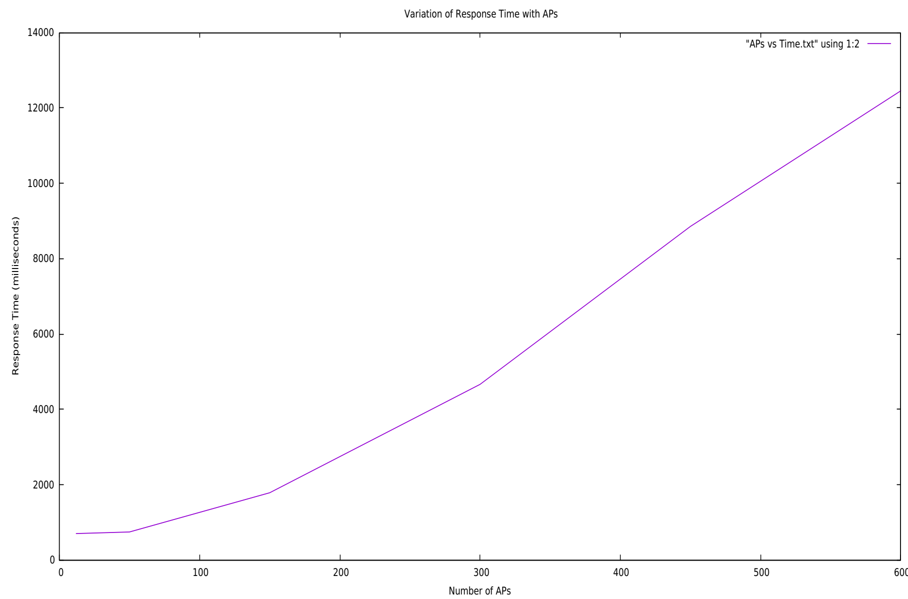


Figure 5.2.1: Graphical representation of variation of response time (in milliseconds) versus the number of APs in the system

As seen in Figure 5.2.1, we infer that the response time, being a critical parameter, is within the acceptable range of 700 - 15000 milliseconds with the increase in number of APs as described in [14] indicating that first minute during an ongoing violence is the most critical and hence the response time should be within 60 seconds. It may be due to the losses and buffer limitations that the time to hear alarm increases due to queuing and processing of packets at central station.

5.3 Fault - Tolerance

As per the Figure 4.4.2 even though certain APs of the simulation were dysfunctional, still all the help requests from all the beacons were registered at the central station. This shows that in spite of certain failure of components, the system functioned normally and produced appropriate result. Introduction of multiple stations is able to handle the load and packet losses by routing packets to all the stations and alarm be heard. If a station is down, still packets are broadcasted to other stations and alarm is heard. The routing algorithm is able to handle the routing of packets even if multiple beacon devices call are triggered simultaneously.

Chapter 6

Conclusion

We have proposed a wireless IoT based solution for women safety in rural areas by taking into account two critical issues of erratic electricity supply and unreliable cellular network which are highly common in remote and underdeveloped areas. To achieve this, solar panels on the street poles power the APs and and an independent local network is created based on BLE routing protocol. Based on the beacon signal received by an access point, location of the victim is traced out through the RSSI value and supported with a plot on preset map of the village. We introduced multiple central stations so that even if a station fails, the distress message can reach other stations to prevent any mishap.

We have developed a network simulation for the above problem statement taking into consideration different scenarios for testing the efficiency of our system. We have tested our system for its scalability, fault - tolerance capacity and the response time for triggering alarm. From the obtained results, we can conclude that our proposed system is able to handle the women safety issues and function independent of electricity supply and poor network connectivity.

Chapter 7

Future Scope

As for future work to be done, the proposed system can be integrated with Machine Learning to identify vulnerable and unsafe regions in the village. Thus, security in such regions can be increased by making the local network coverage more stringent. However such computations need to be done when the system remains idle for long enough, without compromising the safety of women or else can be done at remote systems.

APs can be combined with a surveillance system comprising of atleast one of the audio recorder, video recorder and image capturing device such as camera. This surveillance system can become a medium of providing a record of the harassment incident to serve as an evidence and also can be used to determine if there are any false accusations made by the user.

The portable beacon device can be designed in such a way that it can communicate with the AP as well as capable of producing a loud audible sound as a means of first hand security / safety giving the users some time to escape or causing the perpetrators to flee or alert nearby people.

The proposed system may be extended to various emergency situations like fire breakdown, human accident, child abuse, robbery and senior citizen harassment.

Appendix A

Technical Specification of Hardware

A.1 Raspberry Pi 3 Model B for Access Point

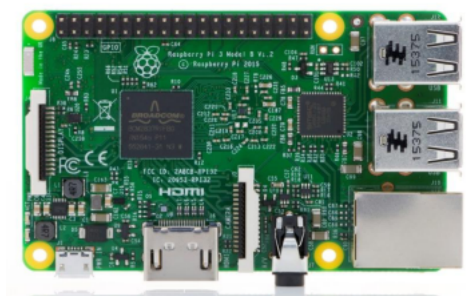


Figure A.1.1: Raspberry Pi 3 Model B Hardware

- Broadcom BCM2837 64bit ARMv7 Quad Core Processor powered Single Board Computer running at 1.2GHz
- 1GB RAM
- BCM43143 WiFi on board
- Bluetooth Low Energy (BLE) on board
- 40pin extended GPIO
- 4 x USB 2 ports
- 4 pole Stereo output and Composite video port
- Full size HDMI
- CSI camera port for connecting the Raspberry Pi camera
- DSI display port for connecting the Raspberry Pi touch screen display
- Micro SD port for loading your operating system and storing data
- Upgraded switched Micro USB power source (now supports up to 2.4 Amps)
- Expected to have the same form factor has the Pi 2 Model B, however the LEDs will change position

A.2 BLE Beacon

Figure A.2.1: A type of BLE Beacon with button

- Microcontroller Unit: ARM Cortex-M4 32-bit processor with FPU, 64 MHz Core speed, 512 kB Flash memory, 64 kB RAM memory
- Bluetooth 4.2 LE standard
- Range: up to 70 meters (230 feet)
- Output Power: -20 to +4 dBm in 4 dB steps, “Whisper mode” -40 dBm
- Sensitivity: -96 dBm
- Frequency range: 2400 MHz to 2483.5 MHz
- Number of channels: 40
- Radio: 2.4 GHz transceiver
- Adjacent channel separation: 2 MHz
- Modulation: Gaussian Frequency Shift Keying (Frequency Hopping Spread Spectrum)
- Antenna: IFA PCB
- Antenna Gain: 0 dBi
- Over-the-air data rate: 1 Mbps (2 Mbps supported)

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