International Journal of Education, Science, Technology and Engineering
p-ISSN: 2685-1458, e-ISSN: 2684-9844

Original Research Paper

Investigation and Implementation of Beacon Technology for Man Tracking in Oil and Gas Industry

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Article History
Received:
15.04.2022

Revised:
28.05.2022

Accepted:
09.06.2022

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Abstract: The oil and gas industry deals with various challenges, and one of it is to comply with frequently changing environmental regulations in monitoring and management system. In this project, the focus will be in the necessity for oil and gas industry to monitor the movement of their employees especially for whom that were conducting tasks in remote areas to wisely optimise the runway resources while simultaneously reaching the needs of delivery schedules. To oversee the workers position, a comprehensive floor mapping system that indicates the real-time status of individuals is required on 24/7 basis. Therefore, the use of beacon system with IOT platform will be applied in this project. The concept is such as the employees are required to carry a customised beacon badge, for this badge will communicate valuable information to the Bluetooth gateway that coordinates the collected information to a cloud-based system for floor mapping process. In other words, an investigation and implementation of a beacon system through a Bluetooth gateway to a cloud-based system in accordance with IEEE 802.15 standard will work out.

Keywords: Beacon Technology, IoT, Tracking in Oil and Gas Industry, WLAN Tracker System.

International Journal of Education, Science, Technology and Engineering, vol. 5, no. 1, pp. 33-42, June 2022. **DOI: 10.36079/lamintang.ijeste-0501.373**

1. Introduction

Oil and gas industry is one of the major sectors in the world. This industry is divided into three areas; upstream, midstream, and downstream. The upstream areas are referring to the search of underwater and underground natural gas fields or crude oil fields and the drilling of exploration wells and drilling into established wells to recover oil and gas. While downstream including the process of refining crude oil and purifying natural gas, as well as marketing and commercial distribution to consumers and end user in various forms. The midstream is also categorised under the downstream category [1]. Figure 1 Shows how pipelines work and to what extensions it used in.

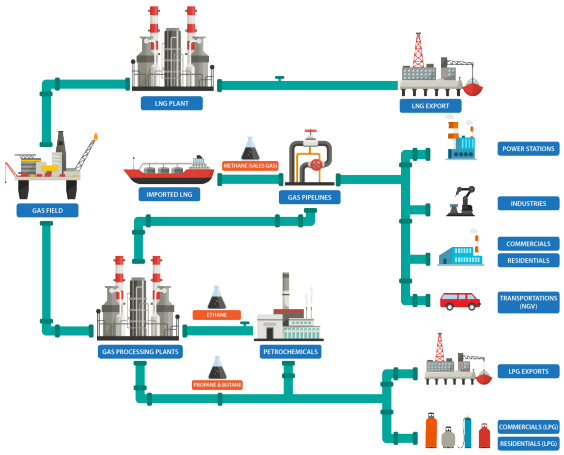

Figure 1. Pipelines Work and To What Extensions It Used in

Transportation of oil and gas are generally by oil tankers, pipelines, barges, or railroad tank cars. Pipelines play a vital role in transporting the oil, they are very long and spread across countries and continents [2]. To compare between pipelines and traditional railroad transportation; the oil and gas pipelines show effective, and a safer transportation method, the oil and gas pipelines show considerably lower reported accidents [3]. However, although it is currently a cost-effective and a safer transportation method, it still faces high risks of dangerous accidents or physical damages. Those threats will affect the integrity, safety, reliability and the security of pipelines.

History recorded the largest accidental oil spill in the world at Gulf Mexico in April 2010 which killed 11 employees and injured another 17 employees. Following the explosion, oil gushed from the broken well beneath the surface of the Gulf for about 85 days. Such accident has a severe impact on the environmental issues as well as the safety issues of employees. Even before the explosion occurs, similar incidents of oil spills have been recorded such on June 3, 1979, at the bay of Campeche off Ciudad del Carmen, Mexico or on July 19, 1979, at the off coast of Trinidad and Tobago and some more [4]. The spilt oil has a severe effect on the environment. For example, it may affect marine life in a way by damaging animals' organs, causing cancer, and immune system suppression and might also lead to reproductive failure [5]. The situation will affect the diversity and the ecosystem of wildlife. Despite the dangerous threats, this industry offers to the environment; they also threaten the safety and life of the employees with possible severe hazard outburst. Some of the risks that they need to take are motor vehicles accidents, contact injuries, fire and explosions, slips, trips and fall, and confined space [6]. Apart than that, they also face health and illnesses hazards like chemical hazards, physical hazards, biological hazards and some more.

According to Occupational Safety and Health Administration (OSHA), a person needs to tailor their safety management system (SMS) to their specific work operations and work environments. A useful SMS shall consist of 5 elements; (1) Safety culture, (2) Involvement, (3) Wellsite analysis, (4) Hazard prevention and control, (5) Education and training. In a way to achieve a good SMS in oil and gas work environment, it will be better if the oil and gas industry could track their worker position and the number of people in specific areas. The reason for this is that the employees are mostly required to work in remote areas, their state and wellbeing are always left in question. If each of them can be tracked and tracked others, it will help the people in the industry to always check in with each other. This way, if there are incidents occurred which possibly involve a worker, a faster notice, and better

International Journal of Education, Science, Technology and Engineering, vol. 5, no. 1, pp. 33-42, June 2022. **DOI: 10.36079/lamintang.ijeste-0501.373**

moves can be taken into action. Apart than that, if there are leaks or hazardous situation detected in specific areas, nearby employees can take fast action on the situation.

Oil and gas industry faces the exceptional need to monitor the unknown states of remotely located employees in the surroundings of an oil and gas environment. The pipelines for transporting oil and gas extended widely and are mostly located in remote areas. It is hard to monitor the condition of the workers. The system is to make sure their safety is taken care and to avoid or cope with unwanted accidents.

Next, the dangerous threats in safety and the health of employees made it necessary for them to always stay in contact to ensure their well-being. According to Centers for Disease Control (CDC), the fatality rate for people in the oil and gas industry between 2003 and 2010 are seven times higher than the national industry average [7]. That shows the vulnerability of the workers to the threats and fatal accidents that might even cost their lives. If the system detects a suspicious act, it will lead to faster notification regarding the safety of the worker thus may lead to a faster action if there are any accidents occurred.

Other than the safety of workers, oil and gas industry are also threating the environment with possible severe pollution. Environmental pollution that oil and gas had to offer is serious issues, by monitoring the position of workers; this industry can urge them to check any issues detected by the computer system in any particular areas along the pipelines. In case there are leaking, or breakdown of pipelines in specific areas detected by the system, workers that were nearby can take a faster action to prevent more significant issues from rising. Recently CNN news reported an oil leaking accident from the Keystone Pipeline system in the United States. The spills reported as the most massive oil spill to date in South Dakota [8]. Division of task to which employees for monitoring the pipelines upon discovering the irregularity in the system will be faster and easier by knowing the whereabouts of the employees.

2. Literature Review

2.1. WLAN Tracker System

This type of tracker system measures the signal strength from different wireless access points (WAPs) to determine user location. Examples of tracking system that based on WLAN are; (1) RADAR from Microsoft, (2) PhD from Carnegie Melon and (3) Active campus from UCSD. One of the studies in WLAN tracking system is a system that consists of two components that are the server and the clients. The server will perform the location tracking operation as the clients communicate with it and send the necessary data [9]. The WLAN tracker operates in two phases; data collection phase, and execution phase. In the data collection phase, a signal map constructed as the user walks around the map area and takes samples. During the execution phase, the client will detect WAP and send the signal strength and its MAC address to WLAN tracker periodically for it to process the data to estimate the location of the client. Another proposed similar system is by Mike Emery and Mieso K. Denko in which they experiment with their study both indoor and outdoor. In their experiment, they set the observation points in a straight line leading away from the wireless access point in 1-meter intervals. In between the interval, they set the application to estimate the position using both training and propagation based estimates once every second for ten seconds [10].

2.2. Wireless Sensor Network

Wireless sensor networks (WSNs) is currently the new way of gathering data, where constrained resources mostly use its application. WSN can be view as a network of devices that sense the environment and communicate the collected information of monitored field via a wireless link. The devices denoted as nodes in the network topologies. The sensor node in the network processing the information and communicates with other connected in the network. In more straightforward word, WSN is a network that send any value using any protocol to any system. The data sent through multiple hops to a sink for it to use locally or connected to other networks through a gateway. In WSN, the traditional single-sink suffers from the lack of scalability, unlike single-sink, multiple sinks WSN can be scalable [11].

WSN can be emerging technology for remote monitoring in oil and gas industry. In the recent years, there is continuous research ongoing for the development of WSN system. In the example, there are a study conducted to derive delayed acknowledgement time for nodes in a network thru mathematical formulation. The study proposed a dual path delayed acknowledgement (DPD-ACK) model, which formulated for Transmission Control Protocol (TCP) agent in a multi-hop linear topology. TCP used in most IEEE 802.11 based application to achieve high performance and

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congestion collapse avoidance. The reason for the study is that the long-range data transmission in multi-hop WSN has a severe performance degradation issues thus contributing towards inefficient fairness in the network [12].

Other than the stated study, WSN faces an issue in a vast network where its performance was critically influenced by the uniqueness of a multi-hop linear topology [13]. Thus, a group of researcher proposed a Dual Path Delayed Acknowledgement (DPD-ACK) model. The motive of their study is to derive delayed acknowledgement times of nodes. It was found that the unfairness in the network was majorly influenced by the distance between source nodes and the destination node in the multi-hop linear topology. The DPD-ACK, however, can retain the throughput fairness in the variable linear network.

WSN are faced with some limitations in its processing capability, memory size, coverage of distance communication, as well as the energy capabilities [14]. Energy- aware load distribution technique can overcome this problem. This technique is to provide an excellent data transfer of packets through a hop-by-hop basis. WSN is believed to be a good alternative in monitoring oil and gas pipelines despite its limitations in sizeable linear networking as there is a solution provided for it. Through WSN technology, we can centralise monitoring station and able to facilitate real-time data transfer. As pipelines were widely extended areas, increasing the number of nodes in a linear architecture according to the performance of WSN makes it possible to expand the communication range [15]. However, WSN will result in affecting low throughput, high latency, poor delivery ratio, increase in power consumption and network inequality.

2.3. Bluetooth Low Energy

Bluetooth Low Energy (BLE) or sometimes referred to as Bluetooth 4.0 is a wireless personal area network technology used for transmitting data over short distances. This new Bluetooth technology designed for low energy consumption and cost usage while maintaining a communication range similar to the classic Bluetooth. It can run on coin-cell batteries for months or years at a time. The ability makes Bluetooth 4.0 ideal for applications that depend on long battery life without needing a high throughput streaming data.

BLE operates in 2.4 GHz license-free band and typically have a range of around 30 meters with 0dBm power and up to 100 meters with 10 dBm power. In BLE technology, the advertisement is a fundamental operation for devices to broadcast their presence allowing connections to be established. The BLE devices are advertising broadcasts packets on one or multiple advertisement channels in which the remote devices can pick up. Then a scanner will listen for incoming advertisement to discover and connect, or to receive the data broadcast by the advertising devices [16]. Other device roles in BLE including the master, slave and hybrid; in which the slave is referring to a device that was connected to one or multiple masters.

To work with BLE, it is possible to use a platform for BLE to receive input, generate output and to store information. Such platform is usually a processor board to run the required functions. The platform will need an APIs to control the platform through a programming application.

Commonly BLE is used for indoor tracking more than outdoor tracking. One of the studies in BLE that have been conducted is research in analysing the accuracy of BLE for indoor positioning applications. It studies the impact of BLE in their advertising mode. The studies also included the comparison between WiFi and BLE fingerprinting in a large indoor area with a high accuracy of ultrasonic ground truth referencing system [17]. It is stated in the study other than power-hungry WiFi Protocol, the access points of WiFi are rarely deployed with ideal density and geometry for positioning. The BLE can, however, overcome the shortcomings of this issue as it also operates with 2.4 GHz license-free band, similar with indoor propagation characteristics of 2.4 GHz WiFi transceiver.

BLE is not much different from classic Bluetooth in using frequency hopping to communicate. Containing 40 channels, with a width of 2MHz each, it moves between these channels pseudorandomly to transmit data in short chunks [18]. However, only 3 of the channels were used to broadcast its identifier and thus compromises with energy consumption. The BLE scan continuously and reporting any advertisement it received and reporting multiple sightings of a beacon when a scan lasts longer than the beacon interval. Therefore, the research conducted using non-connectable beacons to avoid the issues.

The result from their experiment concludes that low bandwidth of BLE makes it susceptible to fast fading and so large RSS fluctuations than WiFi [18]. The RSS measurements will vary across a bigger range than the measurement noise for minimal changes in the signal path length when three

advertising channels are used by BLE beacon. To account for the bandwidth and channel hopping issues, it is required to smooth the BLE RSS measurements by batch filtering multiple beacon measurements per fingerprint. When the number of beacons per fingerprint increases, the positioning accuracy also increases. Active Wi-Fi scanning and Wi-Fi network access can cause errors in BLE signal strength measurements.

Another related work in Bluetooth localisation is Improving Indoor Localization Using Bluetooth Low Energy Beacons. The study suggests that BLE technology can be an excellent alternative supplementing WiFi access points [19]. Due to BLE nature which enables a peripheral device to transmit an advertisement packet without being paged by the master, it is possible to construct an energy-efficient transmitter. As in the previous experiment, the BLE transmit 2.4 GHz band with 40 channels at 20 MHz wide for each; the 37 channels are used to exchange data among paired devices, and three channels are designated for broadcasting advertisements. The three channels are primarily used by beacons and were chosen deliberately to reduce the collision with WiFi channels as little as possible. Batteries power BLE beacons, thus they can be placed in a less accessible area without power sockets or other forms of supply. However, in placing the beacons, the radiation pattern of a given device and the possible attenuation elements in the environment must be taken into consideration. Beacon makes the suitable supplement to an existing WiFi network in a building because of its small size and independence of an external power supply.

The focus of the stated study is evaluating improvement in the localisation using BLE beacons by comparing WiFi based stationary localisation with a stationary localisation using a combination of BLE and WiFi. The method of their study including a learning data acquisition and positioning method. Smartphones with a digitised map of a building were used to acquire the learning dataset. It scans signals of all available networks and beacons around, creating a fingerprint of the given place with the aid of application. The strengths of individual signals are recorded for 10 seconds. To be localised, user is measured a fingerprint of a place where they were standing, and the fingerprints in the database are compared with them to search the fingerprint with the highest similarity. Signal Space method is used to compare the measured fingerprint with the database. The k of the nearest fingerprints from the database is searched by means to obtain the k locations, and then estimate the position of the device for localisation.

2.4. Raspberry Pi

Raspberry Pi is a low-cost computer in a pocket size. It can be plugged into a monitor and use a standard keyboard and a mouse for it to be used. This device can also be programmed via SSH application in windows or mac. The program frequently uses python and scratch for their programming language. Many applications have implemented the use of Raspberry Pi in their project.

One of the projects related to a security system that uses a raspberry pi is “Intelligent image capturing alarm system using Raspberry Pi” [20]. This study was to increase security system by capturing an image of intruders. The study involves the use of IoT platform where the pi will send information via an internet connection. Another project that is known to use Raspberry Pi and IoT are in [21]. The study was evaluating the BLE standard and utilising its sensor with Axis cameras. In their finding, the system they made was successful but unfortunate as it is only reliable in a range of 20 meters.

3. Methodology

3.1. Overview of the Research

Before proceeding to the physical implementation in this study, further understanding in Bluetooth 4.0 is practised. The practice is to enhance the knowledge of how Bluetooth 4.0 can relates to WSN to create a human tracking system. Bluetooth 4.0 or also known as BLE is a wireless personal area network technology. This technology was used for transmitting data in a short distance. The advantages of BLE compared to classic Bluetooth is that consume low energy and cost while maintaining communication range like the classic Bluetooth.

Next, research on the type of microcontroller will be done to find the most suitable and cost-effective microcontroller. Then, the microcontroller will be designed as such to track the ID badge’s carrier. After the designing is successful, the microcontroller will be connected to a respective IoT platform. The IoT platform needed for collecting information sent by each microcontroller in different areas. The platform is also responsible for floor mapping process, in which it will review the areas where each microcontroller was installed. Following the IoT platform, a web-based application is to be made to perform further analysis in the system.

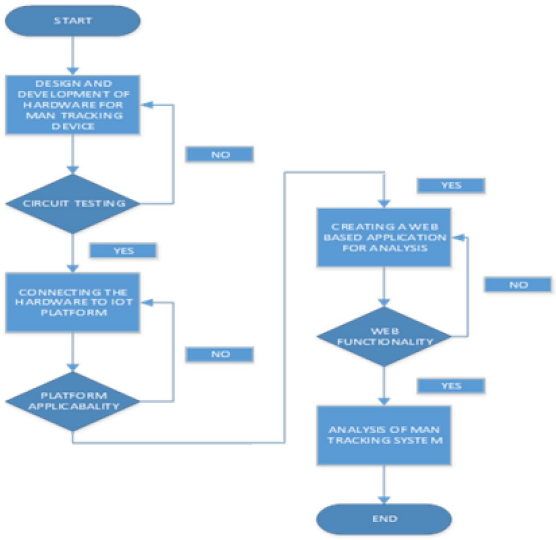

Figure 2. Research Workflow

3.2. Hardware

A Raspberry Pi Zero W was chosen to act as the master in this study. The Pi was an extended version of the Pi Zero family in which it has added functionality consisting of 802.11 b/g/n wireless LAN, Bluetooth 4.1 and a Bluetooth Low Energy (BLE).

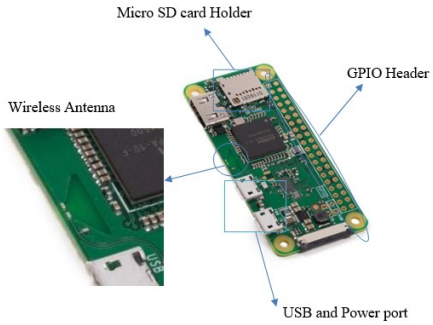

Figure 3. Raspberry Pi zero W

The Raspberry Pi zero W specifications are at the basic to maintain its low cost. Thus it uses a single-core 1GHz ARM and a RAM of 512MB. Another vital part of this Pi is the Micro SD card Holder, as it is required to load the Operating System (OS) use for the Raspberry Pi. The built-in wireless antenna is also a critical component as it is crucial for implementing IoT Platform. Based on figure 3.3, the antenna was printed on board, in which the ground plane that is the triangle recession used to interact with the radio waves.

3.3. Software

The Pi in this study were configured, and an operating system of Raspbian Jessie was installed on an 8GB SD card. The Operating system then loaded into the Pi, and the Pi is powered up by an adapter. After the booting process and an upgrade version of Node-Red were updated in the Pi and a Bluez software was installed. This two software were necessary for programming the Pi into a master device.

This software is flow-based programming, consisting of a wide range of nodes in the palette. The nodes that in use were wired together through a browser-based editor. The latest OS for Raspberry Pi comes with a pre-installed node.js in the system. However, it is still necessary to run for an update as the version that was installed was an outdated version. As Raspberry Pi Zero W runs on armV61, it is

a bit tricky to install the latest version, as the update is not supported in the nodesource. Instead of using the 'apt-get' command, run the *'bash <(curl –sL url)'* script in the Raspberry Pi window to get the latest version of node.js.

To ensure Raspberry Pi could communicate with Bluetooth classics and Bluetooth Low Energy (BLE), BlueZ that is the official Linux Bluetooth protocol stack was installed. The reason is that BlueZ offers support for the core Bluetooth layers and protocols. Use the 'wget' and 'tar xvf' commands to download and extract the BlueZ files. Next, install the dependencies after a change into BlueZ directory on the Raspberry Pi window. Then, run *'./configure.'* first and followed by *'make'* command to compile BlueZ. After compiling the files, run 'sudo make install' to install BlueZ.

4. Finding and Discussion

4.1. Flow of the System

The primary hardware in this study are beacon tags and raspberry pi zero w. 2 raspberry pi zero w was used in this study and located in two different locations. The purpose of that is due to it serves as a master in which they act as a scanner in the one specific area. As there are scanners, the beacon tags serve as the slave in which it advertises its signal continuously. The advertised signal provides information such as its Universal Unique Identifier (UUID), MAC Address and the RSSI value. Such value is the data that will be collected by the master.

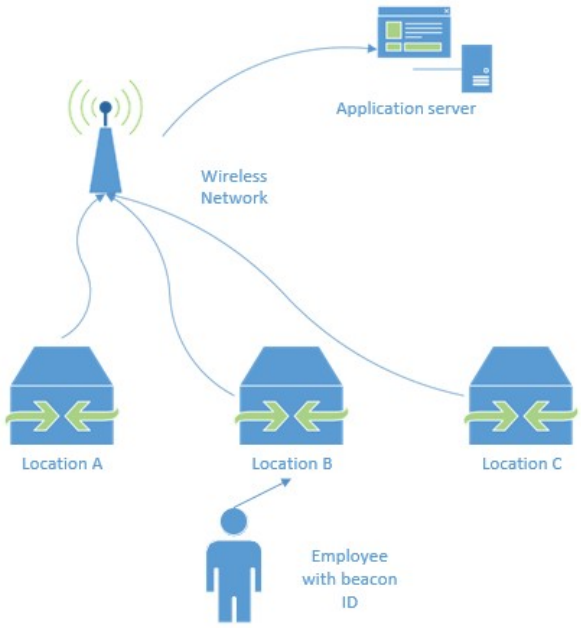

Figure 4. Overview of the Flow of System

As in Figure 4, there are 3 locations, A, B, and C, and each location provided with a raspberry pi zero w. In location B, where we have an employee carrying a beacon ID; the master that serve in that location will detect the advertised signal of the beacon and thus save the data. Through a wireless connection, the raspberry pi zero w will save the data to a cloud and have it accessible to a respected application server.

4.2. Beacon Tags

The beacon tags use in this experiment are the product of Kontakt.io. These beacons were explicitly made only to advertise its data. In this case, the data meant are their MAC address and the Tx Power. It sends out its signal in for a specified interval according to its setting. The tags came in 3 different designs.

International Journal of Education, Science, Technology and Engineering, vol. 5, no. 1, pp. 33-42, June 2022. **DOI: 10.36079/lamintang.ijeste-0501.373**

Table 1. Details of the Beacon Used

Beacon ID	MAC Address	Advertising Interval	Tx Power
OEtG	E2:02:00:0c:48:40	1000	6(0dBm)
iPdH	D2:2F:02:0C:C1:02	350	3(-12 dBm)
RfDl	F4:43:CB:93:B3:B5	625	3(-12 dBm)

3.2. Raspberry Pi Zero W

Raspberry Pi Zero W was provided with a built-in WiFi and Bluetooth adapter. Hence, there is no circuit configuration for this study. However, it was necessary to configure the raspberry pi first. The command 'sudo hciconfig hci0 up' must be run to let Bluetooth function in the raspberry pi to work. Run the command 'bluetoothctl' to enter the Bluetooth service and run 'scan on' to scan nearby advertised signal. The result is obtained as such in Figure 5.

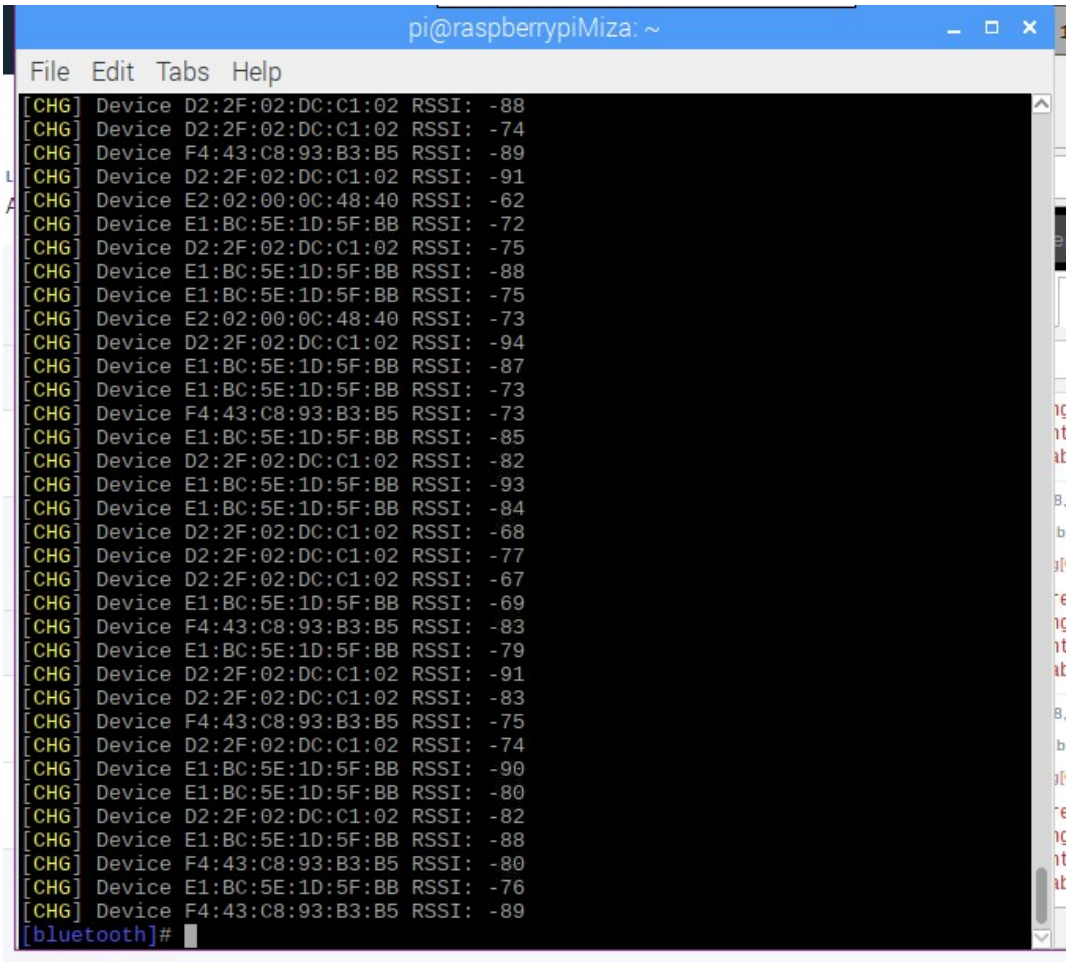

Figure 5. Detected Mac Address and its RSSI Value of Beacon Tags

The RSSI value of the beacons is depending on its transmit power value, surrounding environment condition and distances from the beacon. As the beacon is in the range of fewer than 15 meters from the listener, hence the value of RSSI is quite high. From the result of scanning, it is found that there are four different Bluetooth devices that were detected. The pi captured the MAC Address of each device and as well as its RSSI value.

The scanning of the beacon can be programmed through a programming application such as NODE-Red. This application uses a visual programming approach, by connecting a combination of preferred nodes to create a flow. There are categorised nodes that were used for programming, but the three main types are Input nodes, Output nodes and processing nodes. The input nodes are called as the inject type as it works to send data into the node-red application. The output nodes, on the other hand, have a debug function for it means to send data outside of the node-red flow and to other services as well. Another critical node is the processing nodes; this is the nodes that are required to process data, transform data types, to trigger messages from received data and as well as to write a custom code needed in creating the flow of the application.

Flow is created when nodes are wired together in which the input nodes and output nodes are connected. Some of the input nodes and output nodes have a button that was used in programming to actuate the nodes either to enable and disable it depending on the function.

5. Conclusion

At the end of this research, we manage to configure Raspberry Pi Zero W into a master device that listens to the advertised signal by the beacon. However, the study is not to end only to that level, as the raspberry pi is supposed to also act as a gateway to send the captured data to the IoT platform.

The system shall be able to convert the data into respective file type as it needed to be uploaded to the cloud. The reason for that is to keep a record and track the discovered beacon for further analysis. As there is two raspberry pi used in this study, each of the pis is supposed to come with a longitude, and latitude details which will determine each of their position. Hence, make the location in which the beacon detected are specified.

The IoT platform that is considered in this study is the IBM cloud and ubidots.com. However, the configuration in connecting Node-RED and this two platform were not figured. Other than the website development and the cloud, an algorithm to determine the distance of beacon from the master is best if configured. The reason is so that the specific location of the beacon from the Pi can be determined. The analysis can be achieved by using the RSSI value of each detected beacon.

BLE in man tracking is still a famous study as at the time of this thesis writing. They are not widely implemented as there are many tracking technologies that are competing. However, in the oil and gas environment using a Beacon for tracking can be a promising solution as wireless communication are being implemented. This is related to the strict rules and regulation at working in oil and gas industry. As this industry offers life-threatening dangers, risking in polluting the environment and consuming a high cost for production, the rules and regulation were made to ensure the safety of workers and as well as the environment.

For future work, other than listening to Bluetooth signal that is not only from specific beacon but including all the other Bluetooth devices that are in the covered area, we can program the pi also to differentiate the registered ID and an illegal beacon devices. Through this, we can detect suspicious activities that might go on along the oil and gas working place especially the restricted area. Other than beacon devices that are only transmitting signals, developing another tag that can send a warning or help signal would be a good improvement in the study. This will help workers to discover problems or accidents that might be happening around them faster despite the limitation of communication in the working areas.

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