NSEMX_Conf2021_016

The Nigerian Society of Engineers
Minna Branch
1st NSE Minna Branch National Conference 2021

Conference theme
Role of Engineering in Sustainable Development Goals

Automatic Radio Selection for Data Transfer in Device to Device

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ABSTRACT

Over the years, as technology evolves in telecommunication, the choice of the kind of radio to be use for data transfer in a multi radio system at a particular time still remains a challenge especially in D2D communications. This is evident in popular user equipment's such as phones where multiple radio systems such as Bluetooth, WiFi and GSM are present. Despite all these radios in place, the selection of these radios has always been done manually by users which often time, is time wasting before instantaneous data transfer and sometimes fail due to unsimilar radio selection which leads to unsimilar channel operation of the two devices. To mitigate this and to have a smarter system, there is need for D2D to be able to automatically select radio for data transfer based on certain yardstick. One of such yardsticks remains area of coverage as different have different rage of coverage area.to this end, this research presents AUTOMATIC RADIO SELECTION FOR DATA TRANSFER FOR D2D DEVICE. This was used via the use of GPS module, Bluetooth device, Lora module and an Arduino Nano. At the end of the research, the radio selection was possible but with error in distance measurement.

KEYWORDS: *Automated radio selection, Bluetooth, Device discovery, device to device communication, LoRa.*

1 INTRODUCTION

Although, the requirements for the next generation of communication systems referred to as 5G, are still debated by the academics and the industry, fairly broad consensus has been reached pertaining few key requirements such as 1 millisecond end to end round trip delay latency, 1000x bandwidth per unit area, 10-100x number of connected devices, up to 10 years battery life for low power/machine-type devices [1]. Apart from the inevitable increase in bit rates, energy efficiency of the system, the excessive increase of multimedia applications such as High definition (HD) movies, mobile gaming, multimedia file sharing, video conferencing, the requirements agreed to has triggered a rapid advancement in cellular communication and its technology. To aid further development, one of the emerging technologies known as Device to device (D2D) communication, has been proposed to bridge the gap between communicating devices [2]. For instance, in isolated regions, the current networks may offer some level of Quality-of-Service (QoS), but they cannot meet the extreme capacity demands on future wireless systems in areas where they have to handle situations where users are located in close proximity to one another, such as residential environment, stadiums, shopping malls, and even open-air-festivals. These environments are crowded with devices that access the Internet often simultaneously; most (if not all) of them could interconnect and exchange data locally, thus assisting in a better offloading. Instead, currently this usage results in large traffic volumes impacting both the network operation, as well as pricing models [3]. This improves cellular coverage, increases resource utilization and reduces latency [4]. This technology allows devices in close proximity to communicate using a direct link rather than having their radio signal traveling through the base station (BS) [5]. The benefit however, is ultra-low latency due to its short signal traversal path. To achieve the implementation of this D2D technology, various short-range wireless technologies like WiFi direct, Bluetooth and LTE (defined by the Third Generation Partnership Project (3GPP) standardization) is often time suggested [5],[6]. However, it is important to note that these D2D supporting technologies differs in device discovery mechanisms, data rates and coverage distance. Bluetooth as observed by [4] supports a maximum data rate of 50Mbps and a coverage range close to 10m. WiFi direct has data rate of 250Mbps and coverage range of 200m, while, LTE direct has data rates of 13,5Mbps and coverage range of 500m [4]. All these mentioned technologies are characterized by short-range and consumes energy. However, this may not be applicable to scenarios with larger coverage area. According to [7] LORA (long range radio is characterized with capability to cover 30km surpassing the already mentioned supporting D2D technologies. Furthermore, it is observed that the D2D already in existence usually employ all these supporting technologies manually. In other words, the operator will have to select the technology he or she wishes to use for communication. To improve device discovery in D2D with scenarios of large coverage area, without expending much energy and having the ability to automatically selects the technology to be used for data transfer based on the area of coverage, this research presents Automatic radio selection for data transfer in D2D.

Automated radio selection in D2D has been an issue. In the time past people manually select which radio to use for data transfer in their D2D. this manual selection results to waste of time often regarded as latency in the processes of data transfer. Furthermore, the process involved in initiating data transfer may be regarded as unsmart. All these ills are what necessitated this research. The objective of these study is to

1. Design the hardware of the D2D system
2. Implementation of hardware system

The study will look at establishing an Automatic radio selection for data transfer in D2D device with distance as the yard stick.

2 LITERATURE REVIEW

2.1 D2D DISCOVERY AND CONTROLS USING BLUETOOTH

Over the years D2D has been researched into to achieve cheaper means of data transfer. Bluetooth also known as Bluetooth Low-Energy (BLE), because of its short-range characteristics, was one of the earliest supporting technologies used in D2D. The BLE which operates on the spectrum range of 2.4-2.4835 GHz of the ISM band is designed to provide communication at low power [8]. With this understanding, [9] tracked device in a cooperate building using Bluetooth indoor positioning service (BIPS). The concept which involves the collection of Bluetooth devices that can communicate with each other by sharing a common channel called piconet was used. In his presentation, every mobile BIPS user is represented on a handheld device equipped with Bluetooth for interacting with a static device. [10], presented a scheme based on carrier sensing in a self-organized BLE network in an effort to avoid collisions during advertisement. This was done so as to achieve lower latency and low energy consumption during the process of discovery in crowded BLE networks. [11] focused on a Bluetooth based automated home using a cell phone. The model was designed on a standalone Arduino BT board and the home appliances are connected to the input/output ports of this board via relays. The Bluetooth based home automated system is designed to be a low cost but yet scalable, allowing variety of devices to be controlled with minimum changes to its core. [12], presented a voice-controlled wheel chair for the physically challenged person, where the voice command controls the movements of the wheelchair. The voice command is given through a cellular device having Bluetooth and the command is transferred and converted to string by the BT voice control for Arduino and is transferred to the Bluetooth Module SR-04 connected to the Arduino board for the control of the wheelchair. [13] developed an android application used as a remote to control the motion of a RC car. The mobile device harboring the android application acts as the car's remote control. The communication between the android application and the controller is enabled by Bluetooth. Another study presented by [14], focused on Blue-Fi, a system that predicts the availability of Wi-Fi connectivity by using a combination of Bluetooth contact patterns and cell tower information. This allows the device to intelligently switch the Wi-Fi interface on only when there is Wi-Fi connectivity available. Therefore; avoiding the long periods in idle state and significantly reducing the number of scans for discovery. [15], in another study presented a water level monitoring and controlling system using Bluetooth in agriculture. A number of sensors were deployed for detecting the water level from testing the soil, and report the detail to farmer's mobile phone. The water level was calculated in digitally and it was displayed on the mobile application in the smart phone. The electric water pump is controlled by the smart phone via Bluetooth.

2.2 LTE D2D DISCOVERY.

The last decade has experienced growth in both the amount of mobile broadband traffic and the user demand for faster data access [16]. Considering that the current 4G technology cannot satisfy the present communication demand and the forthcoming user demand [14], Third Generation Partnership Project (3GPP) developed an enhanced Long-Term Evolution LTE radio interface called LTE-Advanced [17]. [18] modelled two basic scenarios to achieving device discovery using LTE which the first is the broadcasting mode where the device wishing to be discovered broadcasts a message containing its identification information, while devices that want to discover scan and decode the broadcast message and can determine if the device is in its proximity. The second scenario is the Request-Response mode where the device trying to discover another device sends a message containing its identity information to the target device, after the target device is done decoding the message it allows the device trying to be found to discover the target device by configuration, sends a response message to the originating device revealing the proximity. The results of this modelling give efficiency in energy consumption in the first scenario and better interference management. While the request-response mode consumes large energy on the devices if there is no prior information from the discovering device. [19] used LTE as a proximity base to support the Mobile Crowd Sensing (MCS) feature, the MCS feature is installed into smart devices to achieve device discovery. The MCS platform assigns task to participants who are active and generate sensing data. Each task to be completed may include multiple data gathering actions in a given time span within an area of interest; these actions are performed automatically by the MCS app without human interaction (except for initially accepting the task), or may require some active response by the participant. As observed, to provide a detailed user's feedback about an event. The MCS platforms include an MCS server that assigns tasks and gather participants' information from the MCS client app installed on their devices. The result showed efficient location sharing and energy consumption. Limitations was cost of application development and user acceptance. [20], used Timing Advance (TA) to assist the mobile network to determine the distance between two or more devices and they also proposed a direct approach where each device broadcast their discovery signal to determine the other device's location. The result they achieved apart from discovery was efficiency in energy consumption and spectrum utilization. [5] used the parameters of LTE-Advance by introducing the Full Duplex Amplify and Forward (FDAF) Relay Nodes (RNs) to assist cellular network and D2D communication. The result of this experiment was the increase in the coverage probability for both cellular and D2D communication with the relay nodes. [21] proposed a network science approach for adaptive wakeup schedule based on nodes staying asleep when a contact is unlikely to happen and wakes up only when the possibility of successful contact with another node is relatively high. The result was reduction in energy consumption without degrading the performance of the network. In world news, natural disasters occur frequently. [22] takes advantage of 3GPP and D2D communication to help save lives. D2D can be an alternative communication in natural disaster situation with a total or partial absence of network infrastructure. Proposed that a receiver probes all physical resource blocs in a given spectrum band-based LTE networks in order to be able to detect victims. Spreading technique is used when an SOS is transmitted and correlation is analyzed in the receiver side in order to decide whether a victim is using a Resource Bloc to ask for help or not. As well, to multiply the number of receivers in different location to exploit the user's diversity in order to enhance the detection accuracy based on hard information combining. Hence, receivers will cooperate to derive a reliable decision about an SOS transmission. [23] introduced a technique called ROOMMATE which Used the Proximity Based Service (ProSe) to provide the list of available devices and their colocation information and uses the information to help in peering decision process. This model was proposed for a small number of discovery signals and reduce the collision probability of discovery signals.

2.3 WIFI D2D DISCOVERY

The IEEE 802.11 standard for Wireless Local Area Networks (WLANs), commonly known as Wi-Fi [24], has become a choice for short range communication, due to the cost-effective deployment. Its network is implemented in large scale and available for Wi-Fi devices such as smartphones, consumer electronics and industry sensors [25]. In recent time, Wi-Fi direct was released, it' is built upon the IEEE 802.11

infrastructure mode and offers direct, secure and rapid device to device communication. The Wi-Fi direct has become an interesting and suitable technology for communication in several applications [26]. [27], designed a smart home based on the principles of the Wi-Fi technology, embedded the QCA9531 wireless communication module to a STM32F107VCT processor and provided a 5V power for the Wi-Fi wireless module to control the home system through an android platform. The APP user interface contains the welcome interface, login interface, the main interface. Where a user needs to register an account in the APP, set a password and log into the main interface to ensure the privacy of the user. The main interface contains the settings interface and the home control interface. [28], introduced a handheld indoor directory system built on Wi-Fi based positioning techniques. The system consists of three modules, namely mobile phone module, kiosks module and database module. The mobile phone module is the main frontend module which installed on users' mobile devices, whereas the Kiosks and website are to provide supports and maintenances to the main module. User can download maps and application from the Kiosks or website. On the other hand, administrator uses the website to manage the database. The system provides a new way of providing indoor floor directory, which offers capabilities to retrieve customizable information, to navigate interactively, to enable location-awareness computing and most importantly the portability of the directory system. [29], identified several attacks that challenge Wi-Fi Direct based D2D communications. Since pairwise key establishment lies in the area of securing D2D communications, we introduce a short authentication string (SAS) based key agreement protocol and analyze its security performance. The SAS-based key agreement protocol is integrated into the existing Wi-Fi Direct protocol, and implemented in android smartphones. The Wi-Fi Aware was used by some researchers, which enables low power discovery over Wi-Fi and can light up many proximities based used cases. [30] modelled an architecture based on the cellular networks to accommodate non cellular Internet of Things (IoT) devices by device working as relay devices for IoT devices and internet uses. Wi-Fi Aware was also used as a supporting technology for proximity services to discover relay devices. The result of this model reduces energy consumption of devices in IoT.

2.4 LoRa D2D Discovery

In recent years, Low-Power Wide Area (LPWA) technologies are becoming popular due to the rapid growth in wireless communication. Supporting technology such as Long Range (LoRa) Technology which is a low-power, low bitrate and wireless technology engaged as an infrastructure solution for Internet of Things [31], [32]. The aim of LoRa is to assess the "worst case" coverage of the technology, by having an estimated number of gateways to cover a city [33]. [34], presented a system used on Internet of Things (IoT). A LoRa based technological platform for the tracking and monitoring of patients with mental disorder. The system consists of the LoRa end device (client side) which is a wearable device attached to the patient, and LoRa gateways, installed in the hospital and other public locations. The LoRa gateways are connected to local server and cloud servers by exploiting both mobile cellular and WiFi networks as the communications media. [35], presented a LoRaWAN tracking system, which is capable of exploiting transmitted packages to calculate the current position without using GPS. This is done using LoRa where the geolocation is calculated applying a multiliterate algorithm on the gateways timestamps from received packages. The whole system consisted of an end-node, four gateways, a server and a java application to store the obtained data in a MySQL database. [36], presented an object tracking system using LoRa, which was deployed on bicycles for location tracking and managing system. The structure is composed of an end device, gateway, server, database and user web and application. For the end device Waspmote is used attached with internal acceleration sensor, GPS sensor and SX1272 of LoRa module. For the gateway, Meshlium is used, which is based on Linux OS, has SX1272 of LoRa Module, and offers Bluemix MQTT API. For the server and database, the data provided by IBM Bluemix and database by Mongo DB are used. IBM Bluemix that serves a role of server, the Broker called IoTF receives data and transfer to Bluemix server. Then the data is saved to Mongo DB, in which data is provided in Cloud form in Bluemix. The Waspmote installed on a bicycle saves data in IBM Bluemix by using gateway and offers services to the mobile APP and website to locate the bicycles. Another study presented by [37], used LoRa for industrial applications compared to the traditional industrial wireless system. With light modifications to the upper layer of LoRaWAN communication stack. The result of their study shows the feasibility of the approach, which is compatible with the requirements for soft real-time applications in process industry.

All these contributions done by various researchers made contributions on device discovery on D2D with those supporting technologies, which were manually operated. In other words, the operator will have to select the technology he or she wishes to use for communication. To improve device discovery in D2D with scenarios of large coverage area, without expending much energy by designing a sub unit that automatically selects the technology to be used for data transfer based on the area of coverage, this paper presents an Automatic radio selection for data transfer in D2D.

3 METHOD

The section presents the method adopted for the design of the system. This includes hardware and software designs.

3.1 SOFTWARE REQUIREMENT.

To achieve the design of the system, C++ is written on Arduino IDE. The code developed was burned on the controller. Furthermore, for the purpose of presentation in this study, Fritzing was used to achieve the drawing of the design

3.2 HARDWARE ARCHITECTURE

The hardware of the two devices is designed with the architecture shown in Figure 3.1. The battery powered devices consist of a controller which is interfaced with a LoRa radio, Bluetooth module and a GPRS via a multiplexer. The multiplexer is used to expand the universal asynchronous receiver transmitter (UART) communication protocol. Furthermore, the controller is interfaced with an alphanumeric display and a sensor.

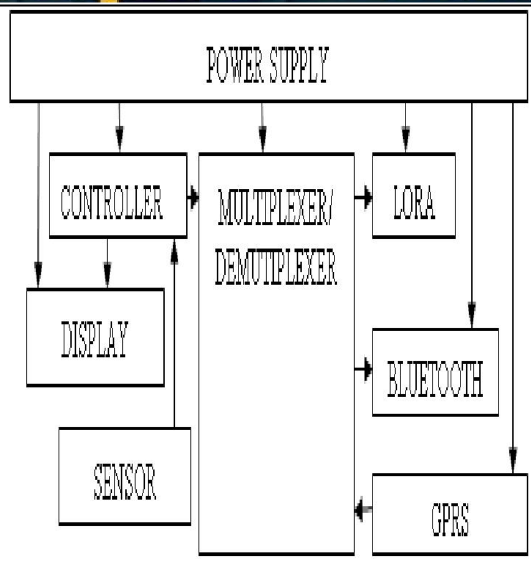

Figure 3.1. Architecture of the system

3.3 POWER SUPPLY

The power supply used in this research consists of two lithium batteries and voltage regulator. The voltage regulators used as shown in Figure 3.2 depends on the voltage requirement of the different devices in the system. According to the data sheet, the controller used needs 3V to 12V to be powered on. Also, the LoRa needs 3.3V which is achieved via the use of LM317 while blue-tooth and the GPRS is powered by 5V regulator. The resistor R1 and RV1 is used to determine the voltage the LM317 outputs. To determine the values of R1 and RV1, the equation (1) is considered

$$V_{out} = 1.25\left[1 + \frac{RV_1}{R_1}\right] \quad (1)$$

From the datasheet, the voltage at the input must be more than the output voltage by a head voltage. The head voltage as prescribed is 2.5V. Also, the minimum current the regulator can deliver is 10mA. Therefore, to maintain constant reference voltage R1 will be given as

$$R_1 = \frac{1.25V}{10mA} = 120ohms$$

According datasheet the value of R1 can range from 120Ω to 1kΩ. let the value of R1 in this design be 240Ω. To calculate for RV1

$$V_{out} = 1.25\left[1 + \frac{RV_1}{R_1}\right]$$

$$3.3V + 2.5V = 1.25\left[1 + \frac{RV_1}{240}\right]$$

$$RV_1 = 840ohms$$

To use a variable resistor one can use 1kΩ which is a little higher than the calculated value.

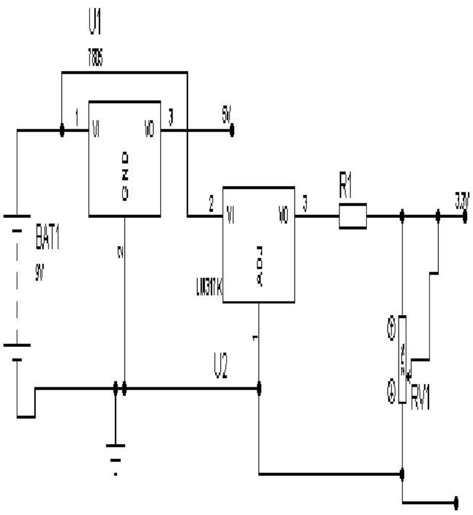

Figure 3.2 Circuit diagram of the power supply

3.4 CONTROLLER:

The controller used in this research is an Arduino Nano. The controller as shown in Figure 3.3 was chosen because of its robust nature as the controller has on board programmer. Furthermore, it is made up of digital input output pins. The controller also has ADC and one UART port which is used to interface the GPS, blue-tooth and the LoRa module.

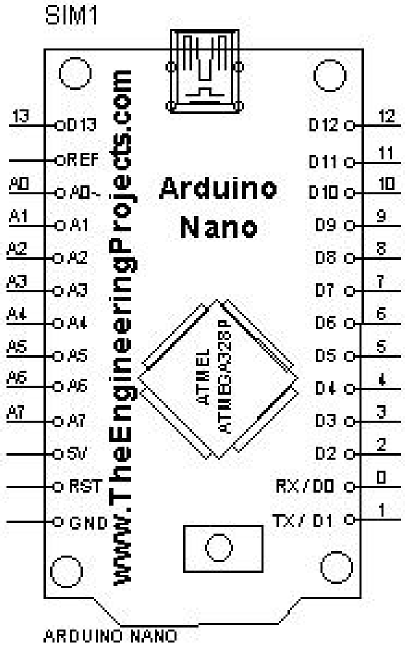

Figure 3.3 schematic representation of the controller

3.5 DISPLAY

The display used in the research is an alpha numeric display. The Liquid crystal display (LCD) 1602 is interfaced with the controller as shown in Figure 3.4 such that the controller communicates with the display via four bits. The number of characters which the LCD displays in total is 32 characters. Sixteen characters are displayed on the upper line and the remaining sixteen on the lower line making 32 characters in total, hence, the name 1602. The display is interfaced to the controller serial port.

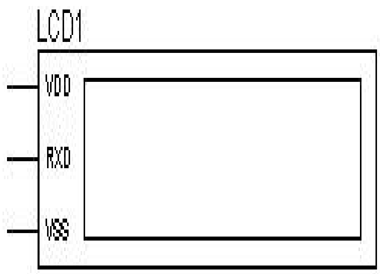

Figure 3.5. circuit description of the display

3.6 SENSOR

The sensor used in this research is a momentary switch (SW). The switch is connected in series with a resistor (R2) as shown in Figure 3.6. This is done to achieve two logics namely logic High which is 5V and logic LOW which is 0V. The LOW logic is achieved when the switch is closed. The reason for the switch in the design is to send a message to the next device.

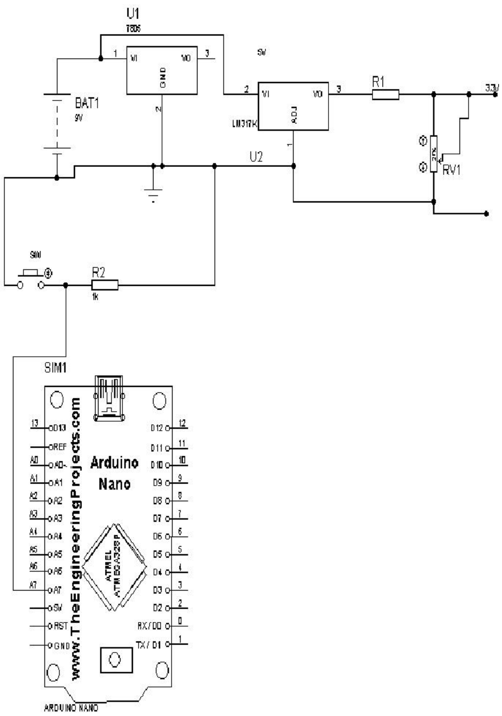

Figure 3.6. circuit diagram of a switch interfaced with the controller

3.7 MULTIPLEXER.

The Multiplexer used is CD4052. The integrated circuit is used to multiplex and de-multiplex signals can be used to select different serial signal channeled to the single serial port of the controller. This is used to interface two devices which are GPS and Bluetooth module which both have Universal Asynchronous Receiver transmitter (UART) port. Figure 3.7 shows the circuit diagram of the multiplexer interfaced with the system.

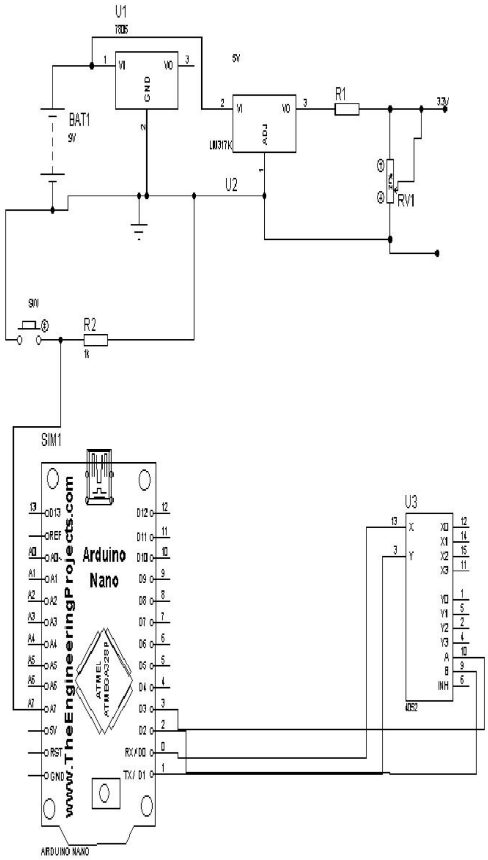

Figure 3.7. Circuit diagram of the multiplexer interfaced with the system

3.8 LORA RADIO

The primary means of communication in this device is the LoRa (long range) module. The module gives the system to communicate in a range of 10km while maintaining low power consumption. The specific LoRa module used is SX1278 which operates at a frequency of 433MHz. Figure 3.8 shows the interface of the of the radio with the system which communicates with the controller via SPI interface

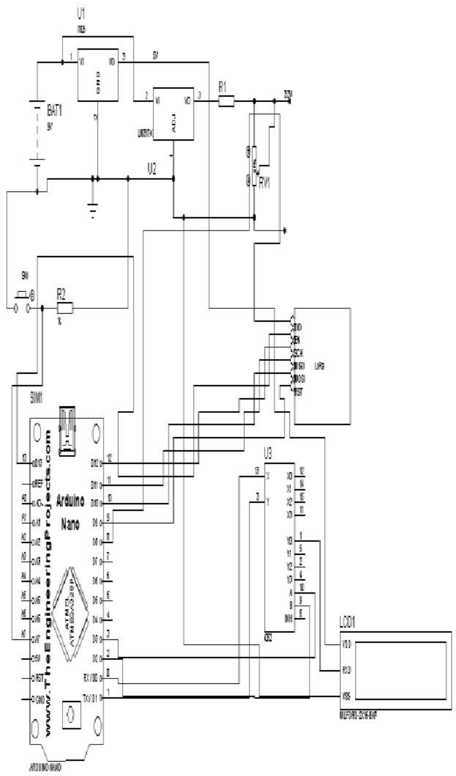

Figure 3.8. Circuit diagram of the system interfaced with LoRa.

3.9 BLUETOOTH

The Bluetooth device used is HC05. This is used in the system so as to aid short distance communication. The blue-tooth which is interface with the controller via UART port is powered with 5V. Figure 3.8 illustrates the interconnection of the device with the system

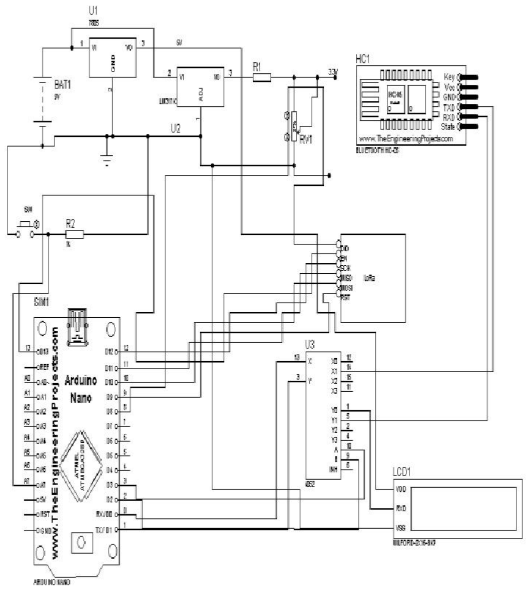

Figure 3.8 Circuit diagram of the system interfaced with the Bluetooth radio.

3.10 DISTANCE MEASUREMENT VIA GPS MODULE

The GPS module used in the system was used to calculate the distance between two devices. This is achieved via the use of the longitude and the latitude of the location where the device is. The transmitting device will take its location and send it to the receiving device with a request to send using the LoRa communication. In the request to send is the location. The receiving device will use this to determine its distance from the transmitter. Then advice the system to transmit using LoRa or any other radio depending on the distance.

Here is the formula for calculating the distance:

The mean circumference of the earth is

$$2 \times 6{,}371{,}000\text{m} \times \pi = 40{,}030{,}170\text{m}$$

$$\Delta d\ (lat) = 40{,}030{,}170 \times \Delta\Theta\ (lat) / 360$$

(assuming $\Delta\Theta$ is small)

$$\Delta d(long) = 40{,}030{,}170 \times \Delta\Theta(long) \times \cos\Theta m / 360$$

(Θm: mean latitude between two positions)

Now, the distance is $\sqrt{[\Delta d\ (lat)^2\ \Delta d\ (long)^2]}$

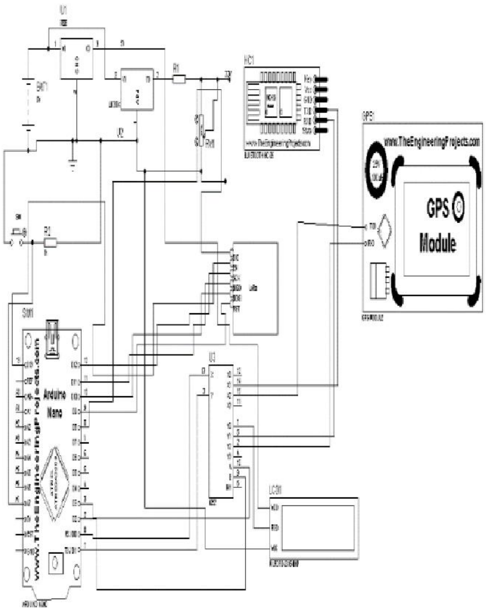

Figure 3.9 complete circuit diagram of the device

4. RESULTS

As stated earlier we designed an Automated radio selection for data transfer in D2D and tested the distance and which radio it selects automatically for connectivity. Table 4.1 shows us the distance we measured, actual distance measured and the error in distance. Also showed which radio is selected at a certain distance. The result shows us an 87.5% accuracy in radio selection.

Table 4.1 Error in Distance and Error in selection.

S/N	Distance Measured (m)	Actual Distance (m)	Error in Distance (m)	Radio Selected	error in selection
1	1.3	1.28	0.08	BT	Nil
2	3.6	3.54	0.14	BT	Nil
3	5.4	5.5	-0.1	BT	Nil
4	7.7	7.65	0.15	BT	Nil
5	9.9	9.87	0.17	BT	Nil
6	10.13	10	0.13	BT	Error
7	11	10.95	0.05	LoRa	nil
8	12.4	12.2	0.2	LoRa	nil

4.1. CONNECTIVITY

We used an Android smart phone to estimate the time taken to for a device to connect with another from point blank (when the user selects the radio on the device) to when Bluetooth connectivity is achieved. Table 4.2 shows us the time of operation establish connectivity by Bluetooth.

Table 4.2 time of operation on a manually controlled smart phone.

DEVICE SPECIFICATION: RAM – 1GB		
S/N	Trial	Time of operation
1	1	8sec
2	2	5.5sec
3	3	7sec
4	4	6sec
5	5	5.5sec

Table 4.3 shows us the time of operation of our D2D system. We estimated the time taken for our D2D to establish connection from the moment it requests to send till the connection has been established. This active D2D system will initiate a connection via the use of LoRa, then determines the longitude and latitude of the receiving device whose initial reception state is also on LoRa. The receiving device receives the packet, it then takes its longitude and latitude and determine the distance between its device and the Device 1. After that, it sends an acknowledgement to connect and then based on the distance, the radio to be used for communication. Device 1 getting the information will turn off the LoRa (if the distance between the two devices is less than 10m, and if the distance between the devices is more than 10m the Bluetooth will stay off) and use the suggested radio. Note that receiving device has already switch to the radio it advised. Table 4.3 in comparison to Table 4.2 shows that the time taken for connectivity is less in the automated D2D.

Table 4.3 time of operation on the automated device.

DEVICE SPECIFICATION: Our D2D		
S/N	Trial	Time of operation
1	1	6sec
2	2	4sec
3	3	4.5sec
4	4	5sec
5	5	4sec

5. CONCLUSION

In conclusion, the Automated D2D system discovered and established communication automatically between devices in respect to the distance and which radio is best for such communication, i.e. If the device is within the Bluetooth range (0-10m) it connects or as far as the LoRa (10km) range as well, and with lesser time taken compared to a manually controlled smart device.

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