ANDROID BASED SMART PARKING SYSTEM IN PREPARATION TO NARROWBAND INTERNET-OF–THINGS TECHNOLOGY

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ABSTRACT

Proper parking management plays an important role in society, specifically the cities, due to a lot of establishment present. This paper shows a smart parking system to ease traffic congestion, and help drivers find and/or reserve a specific parking slot in a specific area through the use of today's communications technology, namely, Internet-of-Things. The project aims to incorporate a system of wireless sensor networks that can utilize narrowband internet-of-things technology, to provide a fast data transmission and reception, low cost, and low power, for an efficient smart parking system consisting of a real time parking monitoring and reservation features. The project's smart parking is designed for both gated and not, to benefit both private and public parking areas.

Keywords: *smart parking, internet-of-things, narrowband internet-of-things*

INTRODUCTION

Internet-of-Things (IoT) continues to be a great trend nowadays. IoT makes smart objects form a smart environment for efficient management on its applications. This technology features interoperability, self-configuration, self-adaptive, and self-protection. IoT applications include health-care, environmental, commercial, smart city, industrial, and general aspects [1] [2].

As a smart city has been mentioned, smart parking is one of its parts. A prototype of a Smart Parking by Ericsson suggests that using a traditional broadband network provides an unstable network, which may cause the system to go offline at times, due to increasing attenuation as the coverage area also increases. In comparison, Narrowband IoT (NB-IoT), a 3rd Generation Partnership Project utilizing 200kHz frequency band, can prevent such circumstance by providing a better coverage at low power consumption [3]. In the Philippine setting, telecommunication providers are now eying to have NB-IoT as part of their system.

Smart Parking is not limited to a specific feature and can exist in different classifications. Among the classifications, two are stated in the following. The first one is Electronic Parking (E-Parking) which lets the user identify the vacancy of a parking slot electronically, with reservation and payment even before entering the parking area. The other is called Car Park Occupancy Information System (COINS) wherein the detection of the presence or absence of vehicle depends upon a single source utilizing a digital image analysis, or so called video sensor technique [4].

In 2018, a total of 25,469 illegal-parking incidents were caught via CCTV in Metro Manila [5]. The need of advanced parking technology is due to such circumstances and due to road congestion when drivers want to find and secure their parking slots. The first Smart Parking in the Philippines was led by Oroza Enterprises. Metal structures are the ones to move a car into a vacant parking space [6].

The researchers propose a Smart Parking which demonstrates a system that is a preparation to NB-IoT, to execute real-time parking slot monitoring system, which is accessible to mobile phones and gadgets crafted with android application. NB-IoT is designed for stationary systems, making it more suitable for smart parking. The project aims to reduce manually operated parking management through wireless sensor networks. By implementing the system on different establishment parking areas, the vacancy and occupancy can easily be identified, reservations will be made possible, and the NB-IoT preparation will make the system more efficient in terms of reliability, data reception, data transmission and power consumption [7]. This study will benefit the establishments of both pay-parking and not, for the ease of monitoring of parking reservations and occupancy, and for the ease of drivers finding vacant parking spaces and reservation features given that they have the mobile application and an internet connection.

In addition, the project aims to address the following challenges:

1. How will the components of the parking system be integrated?
2. What platform/s will be utilized by the parking system?
3. How can the reliability and efficiency of the parking system be measured?

In summary, the project focuses on achieving the following specific objectives:

- Design a system that can adapt to NB-IoT technology and compare its possible outcomes with the current available cellular technologies.
- Make parking lots more advanced by providing sensors in the remote area, to give the actual state of a specific slot, such as occupied, vacant and reserved, and to reduce time being consumed in looking for a slot in the parking area.
- Provide information about parking lots through a mobile application to make it easier for the user to reserve and identify the status of a parking space, and to avoid traffic jams due to slowing down of vehicles when drivers are searching for a parking space.

Industries are upgrading to fully automated systems as a replacement to manual operations and human labor. One of the examples to upgrade are the car parking systems. This may lead to efficiently assisting motorists to vacant parking spaces, and at the same time, monitor the safety of their vehicle in the parking slot [8].

The sensors that can be used for smart parking are proximity sensors, which are intended for object detection. A survey suggests that common sensors are infrared, ultrasonic, piezoelectric, inductive loop detectors and more. The sensors can be connected through IoT so that they can exist independently without the use of GSM in identifying the location of vacant slots in a parking area [9].

Sensor Network Technology

A sensor network is simply an interconnection of distributed or localized sensors with a central point, and computing resources to handle events. A part of its technology is called Wireless Sensor Networks (WSNs), which may involve signal processing, radio and networking, artificial intelligence, database management, etc. [10]. The WSNs basically consist of a communication device, sensors and actuators, memory and controller, and a power supply.

The advances of WSNs go along with IoT. The concept that can be incorporated with interconnected networks is IoT. All the WSNs enable objects and devices to be active participants of, and communicate with each other for exchange of data, monitor areas, record and understand events and actions, to be able to sense and actuate accordingly [11].

Internet-of-Things Technology

IoT is a technology of putting things together in a network in order to make it function. IoT makes smart objects form a smart environment for efficient management on its applications. IoT refers to the combination of internet and WSNs [1]. An emerging technology of IoT is called Narrowband IoT (NB-IoT). It is a Low Power Wide Area Network (LPWAN), which uses low power, and allows data connection in Wide Area Networks. The technology consumes only 200kHz of bandwidth and it can be deployed at low cost because it is directly related with Global System for Mobile communications (GSM) and Universal Mobile Telecommunications Systems (UMTS). It has an advantage over short range communications such as Bluetooth and Zigbee because of its wide coverage feature and mobile connectivity [12].

Wireless communications technology has an advantage of mobility and cost efficiency over wired networks [13]. Mobile wireless Generation (G) is a part of this technology, which makes difference in speed, frequency and data capacity from 0G up to 5G [14]. Narrowband IoT can co-exist with 2G, 3G and 4G/ LTE. It supports ultra-low complexity devices with a narrow bandwidth. For operators with LTE spectrum available, in-band LTE deployment will be the most suitable in providing an efficient system [15].

These technologies can be incorporated with Smart Parking systems. The demand of vehicular parking spaces has not been properly addressed and parking lots need a demand strategy to be well managed and organized [16]. Car park occupancy detection takes into consideration the two main categories for proximity sensors; intrusive and non-intrusive. Intrusive sensors require mounting on the ground or ceiling such as infrared sensors and weigh-in motion sensors. The other category, non-intrusive sensors, is easy to install and does not affect the surface on process. These include sensors such as microwave radar, RFID and ultrasonic sensors [17]. Proximity sensors are intended for object detection without direct contact. Ultrasonic sensor has been used because this type of sensor is not affected by color transparency, and only depends on sound waves.

The researchers came up preparing for the use of NB-IoT to incorporate the system due to the following advantages:

Low Power Consumption – Sensors are being installed on areas that are not always accessible to the providers, therefore the system needs to avoid often replacement of batteries. Low Power consumption signifies long battery life to avoid often maintenance.

Low Cost – Low cost is being modified by the low data rate since it will only consume the narrow bandwidth. This contributes to low cost because of the low power consideration of the system.

Reliability – NB-IoT binds a strong connection and easily detects devices that are connected in a network system.

Wide Applications – NB-IoT has lower bit rates and better link budgets compared to traditional networks. It doesn't need gateways to provide connectivity. NB-IoT can directly connect sensors to the base station, which will boost flexibility while lowering costs.

ESP8266 microcontroller chip, a highly integrated Wi-Fi solution, is widely used for IoT industries. It has a built in Wi-Fi which makes it a suitable for different applications [18]. A research using ESP8266, focusing on the Quality of Service (QoS) in terms of power consumption and battery life, has shown that battery life span is proportion to the QoS and the IoT network life relies on it. It can also play a significant role of processing the communication activities over Wi-Fi and the data retrieved from the sensors is loaded into flash memory [19].

To make the system applicable in NB-IoT technology, application layer must be taken into consideration for IoT. IoT uses different modules in order to incorporate sensors, actuators, facilities, and buildings. Some of the modules can be Wi-Fi, LTE and Bluetooth, which are used to monitor and control the working status of different devices [20]. The application layer is responsible for providing services and determines a set of protocols for message passing at the application level [21].

Conceptual Framework

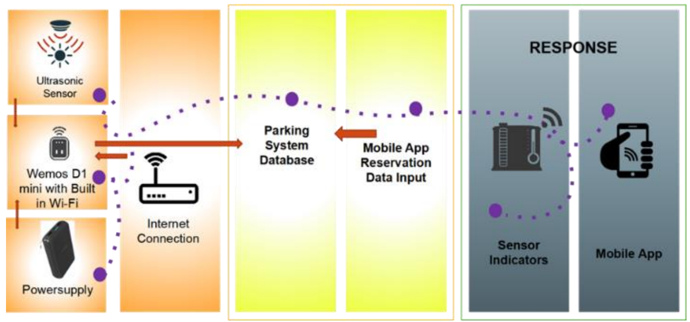

Figure 1. The Input-Process-Output (IPO) of the system, showing the flow of information

The input of the system can either be from the mobile application user or from the sensor itself. The mobile application and the sensor networks are incorporated through Firebase, a real time data base that is suitable for android, IOS and Web applications [22]. For the mobile app, the input will be the reservation, and the output will be the blinking lights. For the sensor, the input will be the occupancy from the ultrasonic sensors, and the outputs are the red light and the occupancy in the mobile app slot. Both the process of the system happens through the program in the microcontroller called Wemos D1 mini and in the Firebase, which incorporates each sensor and the mobile app to each other to form an IoT system.

This study on smart parking involves the use of android mobile application. Through the mobile app, the user will be able to navigate through different parking slots in a specific area. Upon choosing an area, the mobile app will show the availability of parking slots in presence of internet connection. The user can either reserve a parking slot or just monitor its state. For reservations, 10 minutes will be given, this feature can be changed according to the policies of a specific parking area. Unoccupied reserved slots after 10 minutes will be invalid. The parking slot contains indicators for non-app users. Red light for occupied, green for vacant and blinking green and orange for reserved. The system is a real-time monitoring system so that each activity detected by the sensor will reflect on the mobile application and vice versa.

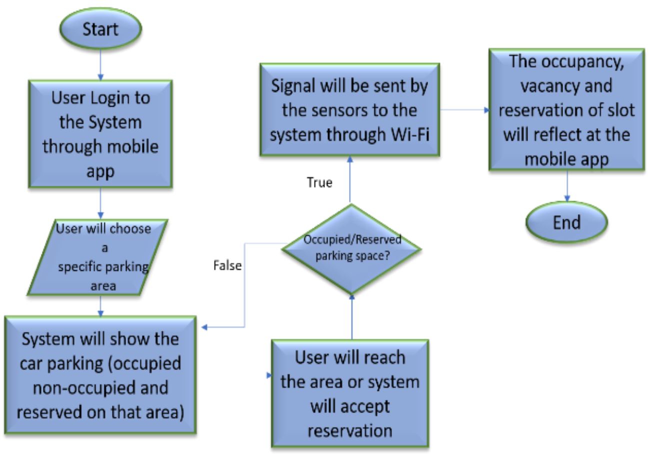

Figure 2. The flow of information in an active system

The researchers proposed designs both for free and for pay parking:

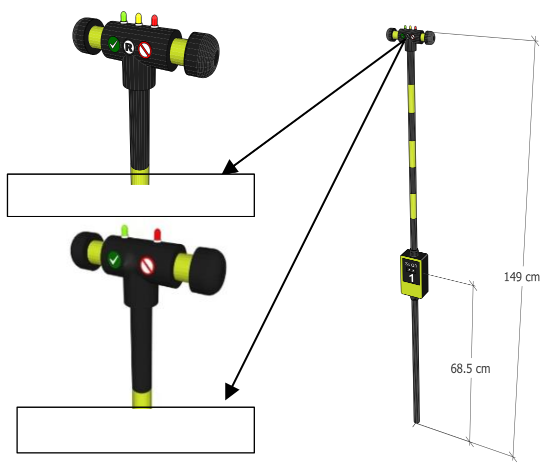

Figure 3. Proposed Design for both Free and pay Parking

A free parking cannot host the system's parking reservation feature since most of the free parking are in a first-come, first-served basis and is open for all. The sensors for free-parking have 2 indicators: Green for 'available' and red for 'occupied'. These indicators are for drivers who do not have the mobile application in finding a parking space. The height of the sensors was designed to be visible to side mirrors of private vehicles of any size.

The model for pay parking systems has a third sensor dedicated for parking reservations. Drivers are limited to reserve one parking slot at a time. Once the driver reserves a slot using the mobile application, the indicator for reservation will light up until the reserved slot is occupied or the reservation is canceled. The reservation feature is intended for gated parking only. This is to ensure the reservation feature of the system. As soon as the driver arrived at the entrance of the parking lot, the drivers should show the proof of reservation before entering the premises to avoid other drivers parking on the reserved slot.

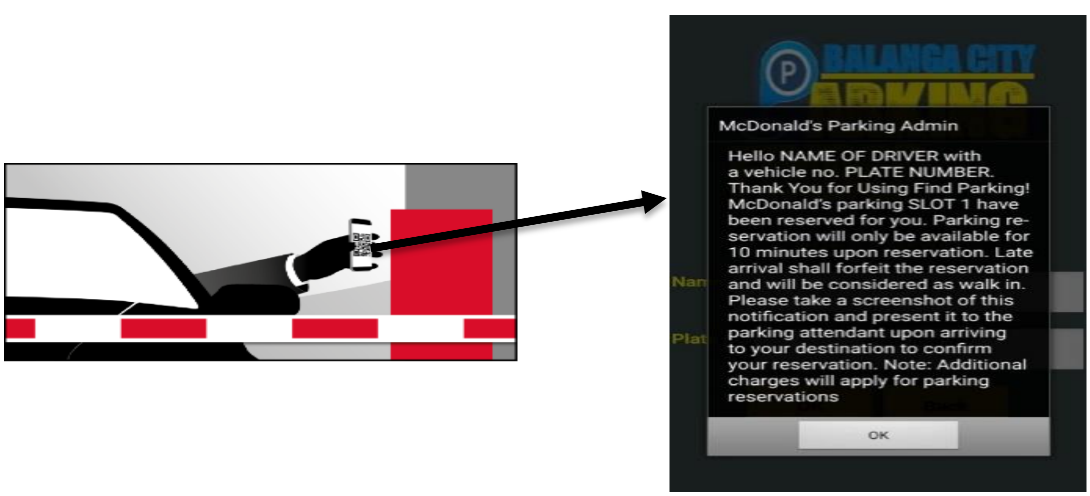

Figure 4. McDonalds Parking Admin

Each sensor contains the following circuit design and schematic design:

Circuit Design

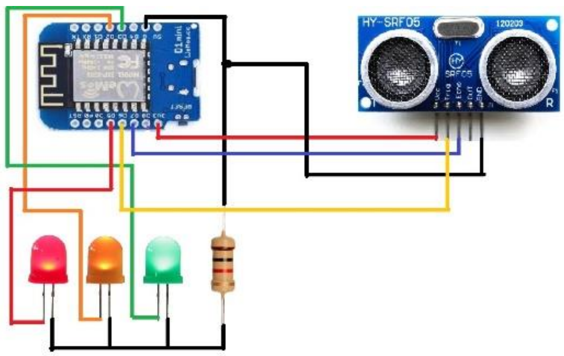

Figure 5 - Connectivity within each parking sensor

Schematic Diagram

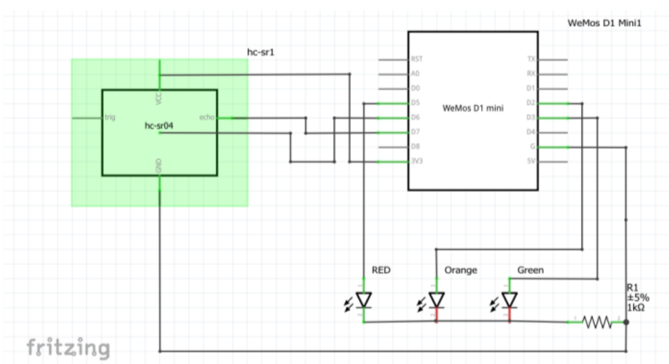

Figure 6 - Schematic Diagram of each parking sensor

The only difference with the schematic diagram of the pay-parking and non-pay parking is the number of LEDs connected to the microcontroller. Furthermore, the programs uploaded on the microcontroller and the specifications of the materials used, are provided in the appendices.

The following table shows the pin assignments:

Table 1. Pin Assignments

Component	Wemos Pin Assignment
Red LED	D5
Orange LED	D2
Green LED	D3
Ultrasonic Ground	Ground
Ultrasonic Sensor Echo	D7
Ultrasonic Sensor Trigger	D6

METHODOLOGY

The researchers gathered data through browsing scholarly sites, finding related studies, reading books, and interviewing experienced professionals regarding the up-to-date technological applications of the concepts mentioned in the study. The researchers end up with a system featuring Ultrasonic Sensors, Wemos D1 mini microcontroller and an android mobile application.

Ultrasonic Sensors

Devices that use sound waves to determine the distance of an object. It senses proximity and detects levels with high reliability. These sensors transmit acoustic waves of frequency between 25kHz and 50kHz which is above human hearing range. Ultrasonic Sensors have an operating voltage of 5V and an operating frequency of 40Hz.

Wemos D1 Mini

A mini development board is based on ESP-8266EX chip and is useful for applications that need wireless data transmission. It is compatible with Arduino IDE and Node MCU firmware and useful when you want to build innovative projects. It has an operating voltage of 3.3V and an operating frequency of 80MHz to 160MHz.

Android Mobile Application

The android mobile application for the project is crafted using MIT app inventor. MIT app inventor is easy to use for its block-based design features and can easily be accessed online. The app was named “Balanga City Parking Finder” and also has a real time feature. Green dot beside the name of the area indicates a parking area with reservation, while red dot indicates a parking area with no reservation. The mobile app has the following interface:

Figure 7 – Balanga City Paking Finder Mobile Application

The researchers intend to apply the system in the City of Balanga, Bataan and chose establishments that are located there. The researchers made a communication with McDonald's Diversion branch owner whom agreed to test the devices in their property, and adapt their parking layout for project demonstration purposes. They conducted several tests on McDonald's Diversion parking area and at a residential area to gather data demonstrating the accuracy, reliability, and efficiency of the prototype using different cellular internet connections, specifically, 2G, 3G, and LTE backhaul. NB-IoT can co-exist with the above-mentioned cellular networks which have been utilized for testing [23].

Since the study requires a prototype, experiments in the form of different testing set ups are considered to support the claim of the study. The reliability of the system is one concern; thus, following testing methods were employed:

Latency Testing

The latency testing focuses on the time required for a system to move one message to another within a network [24]. The system consists of three sets of testing with five trials each, for the whole system's efficiency testing. It includes the time taken for the reservation of the user to reflect on the sensor indicator. The response time taken for occupancy to reflect on the indicators and mobile app has also been recorded. The values will be compared with one another utilizing different internet connections, namely, LTE, 3G, and 2G connection backhaul.

System Functionality Testing

Consist of two users simultaneously using the mobile app and recording the time delay from one user to another upon the reservation of a specific slot.

Sensor Sensitivity

Consist of testing how accurate sensor detection is, and how fast it will respond upon reaching the value provided by the program uploaded in the system. The range set by the researchers is 70 cm and below, and the testing runs from 120 cm up to less than or equal to 30 cm.

Power Consumption Monitoring

Each set of sensor consists of a 10,000mAh power bank to be able to work. The testing monitors if the system will consume 25% of its power supply, with random transmission and reception of data such as occupancy and reservation within 24 hours. Each of the four LED indicators of the power bank indicates 25% of charge. Four LEDs ON, indicate 100% charge, three LEDs ON, indicate 75% charge and so on.

RESULTS and DISCUSSION

The researchers conducted several tests to the prototype using different existing generations of wireless networks such as: 2G, 3G and 4G/LTE Cellular network, to determine the response time between them.

The study testing table shows the over-all average time needed to transmit data from mobile app to sensor (tables 2 and 3). It took an average of 2.23 seconds using LTE backhaul and 3.89 seconds using 3G backhaul. Reservation via 2G backhaul did not reflect on the sensor after two minutes upon being reserved. Thus, reflecting that LTE network provides more reliable system compared to the two other connections.

Table 2. Average time per Trial using LTE Network Backhaul

TRIAL	MOBILE APP TO SENSORS	SENSORS TO MOBILE APP
	Time taken to reflect on sensor upon reservation	Time taken to reflect on app upon occupancy
TRIAL 1	3.13	1.53
TRIAL 2	1.68	2.20
TRIAL 3	2.05	2.77
TRIAL 4	1.87	2.42
TRIAL 5	2.40	2.36
Average:	2.23	2.26

Each trial shows the average time taken for each sensor to reflect the response time (in seconds) from mobile application to sensor, and vice versa using LTE network backhaul.

Table 3. Average Time per Trial using 3G Backhaul

TRIAL	MOBILE APP TO SENSORS	SENSORS TO MOBILE APP
	Time taken to reflect on sensor upon reservation	Time taken to reflect on app upon occupancy
TRIAL 1	4.16	4.07
TRIAL 2	4.28	3.35
TRIAL 3	4.30	3.28
TRIAL 4	3.56	3.66
TRIAL 5	3.15	3.06
Average:	3.89	3.48

Each trial shows the average time taken for each sensor to reflect response time (in seconds) from mobile application to sensor and vice versa using 3G backhaul.

For sensors to mobile app, it took an average of 2.26 seconds using LTE backhaul and 3.48 seconds using 3G backhaul. 2G network has also been tested, but after two minutes upon occupancy, the mobile app did not respond. Thus, also reflecting that LTE connection backhaul provides a more reliable system compared to the two other connections.

For the system latency measurement, monitoring of response time started when the car reached the 70cm distance range, which is the standard distance uploaded in the microcontroller, to trigger the sensor. Sensor detection and sensitivity have been proven accurate in terms of distance response and delay (See tables 4, 5 and 6). Small data consumption makes the system still function in 3G, making it reliable. The 3.3V power supply needed for the system leads to an efficient, long battery life (See table 7).

Table 4 indicates the response delay (in seconds) for user A mobile application upon reservation from user B.

Table 4. User A App Response Delay

TRIALS	User A App Response Delay
1	1.05
2	1.23
3	1.18
4	1.10
5	0.98
6	0.72
7	1.06
8	1.30
9	1.15
10	0.89

Table 5 indicates the response delay (in seconds) for user B mobile application upon reservation from user A.

Table 5. User B App Response Delay

TRIALS	User B App Response Delay
1	1.51
2	1.32
3	1.16
4	0.80
5	1.72
6	1.06
7	1.54
8	1.12
9	1.47
10	0.96

Table 6 shows the average result from 10 trials if the sensor will respond at a given range, from 120cm to below 30 cm. The distance requirement for the sensor to respond is 70cm and below, which is uploaded in the microcontoller program.

Table 6. Average Result for 10 Trials

	MCDONALD's								VISTA MALL			
Distance	SLOT 1		SLOT 2		SLOT 3		SLOT 4		SLOT 1		SLOT 2	
	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
120cm		/		/		/		/		/		/
110cm		/		/		/		/		/		/
100cm		/		/		/		/		/		/
90cm		/		/		/		/		/		/
80cm		/		/		/		/		/		/
70cm	/		/		/		/		/		/	
60cm	/		/		/		/		/		/	
50cm	/		/		/		/		/		/	
40cm	/		/		/		/		/		/	
>=30cm	/		/		/		/		/		/	

Table 7 shows the results of power source monitoring for 24 hours depending upon the LED indicators of the power bank.

Table 7. Power Consumption Monitoring for 24 hrs.

Operating Hours	Do the power bank loss 25% of its charge?
6:00-9:00	NO
9:00-12:00	NO
12:00-15:00	NO
15:00-18:00	NO
18:00-21:00	NO
21:00-00:00	NO
00:00-3:00	NO
3:00-6:00	NO

The gathered data have shown that the network used as the medium of connection for the system greatly affects the latency of the relationship between the mobile application and sensors. The capability of the system to work in both connections implied that the system transmits small amount of data, and consumes small amount of power.

CONCLUSION

In conclusion, IoT technology is a significant element of this generation's advancement. Future NB-IoT technology can be applied using an NB-IoT module instead of a Wi-Fi module through the same access layer. In this project, the researchers used a built-in Wi-Fi module to utilize cellular IoT technology, and a database to be able to achieve a system with connected sensors, microcontroller, and a mobile application. NB-IoT technology can make the system more efficient, given that 5G cellular technology will be used for it in the future. Based on several tests that the researchers conducted, close average values for the system's response time have been observed using 3G and LTE backhaul. Since 3G network is unstable, delay in response from user to sensor and sensor to user occur at times. LTE connection on the other hand provided more stable values which means that it is suitable for the system. Fully upgrading it to NB-IoT technology will result in a more efficient system, because according to a study by Ericsson, NB-IoT is designed with a good multiplexing and adaptable data rates, leading to a great system capacity and wider coverage. This system is therefore proven to be effective for Smart Parking application and can ease the traffic congestion by providing drivers with an easy way to locate and reserve a parking slot.

RECOMMENDATIONS

This study has the limitation on the Wi-Fi range for the inter-connectivity of the devices within an area. The mobile application is intended for android smart phone users only. The sensors used are not waterproof, with a maximum detection range of 1 meter. The system has been tested on a free parking area, but the testing done is with reservation feature, for demonstration purposes only.

To suppress the above-mentioned limitations, the researchers recommend the use of NB-IoT modules as a replacement for Wi-Fi modules so that the system will be able to connect directly in the base stations and can be implemented for wide range applications. The mobile application can still further be developed, specifically for pay-parking at longer time range, and waterproof ultrasonic sensor can be implemented for other sensor placements. The parking's LED indicators can still be improved in terms of color and indication. For further studies, a Quick Response (QR) code can be used for gated parking to eliminate manual operations, and for easy payment process.

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