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An Integrated IoT System Pathway for Smart Cities

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ABSTRACT: Internet of Things (IoT) has in recent years witnessed widespread implementation, especially in the area of smart homes, automated factories, monitoring of gas leaks, smart wearable devices used to actively monitor health conditions, and numerous other applications. In this paper, an application of IoT is proposed, more precisely, a system that incorporates various independent systems into a single whole. These systems, function well independently and achieve their intended purposes. However, this paper seeks to improve on these independent systems with the overall objective based on the quote "the whole is greater than individual parts". The proposed system called Smart Patient Health Management System (SPHM), combines smart health, intelligent emergency service, smart parking, and hospital management into a single integrated system. The various components of the SPHM framework and how they interplay with each other as well as the underlining technologies to achieve this system are presented in this paper. In addition, an android software application called CABIFY was developed as a smart transportation means to aid the SPHM for the purpose of quick and efficient healthcare delivery.

Keyword: IoT, Health Management System, Sensors, Smart Parking.

Abbreviations: IoT, Internet of Things; SPHM, Smart Patient Health Management System; Ahmadu Bello University, ABU.

I. INTRODUCTION

Among many others, the Internet of Things (IoT) and sensor networks are among the fastest growing technologies in recent times. IoT is a technological concept that seeks to connect everyday objects to the Internet, thereby making them ubiquitous [1, 2]. Though there are different deployments and use cases of IoT, a standard architecture is yet to be defined [3]. The closest attempt is that shown in Fig. 1 which consists of four layers – sensing or perception layer, network layer, support or middleware layer, and application layer. This architecture has been discussed in [4, 5]. The success of IoT however relies heavily on the underlining sensing layer; which is a network of sensors (Fig. 1) which actively collect information from connected devices or the environment to be relayed across to remote users.

IoT has applications in numerous areas, such as health care [6-9], smart parking [10, 11], smart buildings [12, 13], smart cities [14, 15], and autonomous vehicles [16-20] etc. However, most of these works focus on application silos, with the exception of those applications in the area of smart cities. This paper, focuses on the application of IoT to health care and proposes an integrated system which combines intelligent emergency service, smart parking with smart health care.

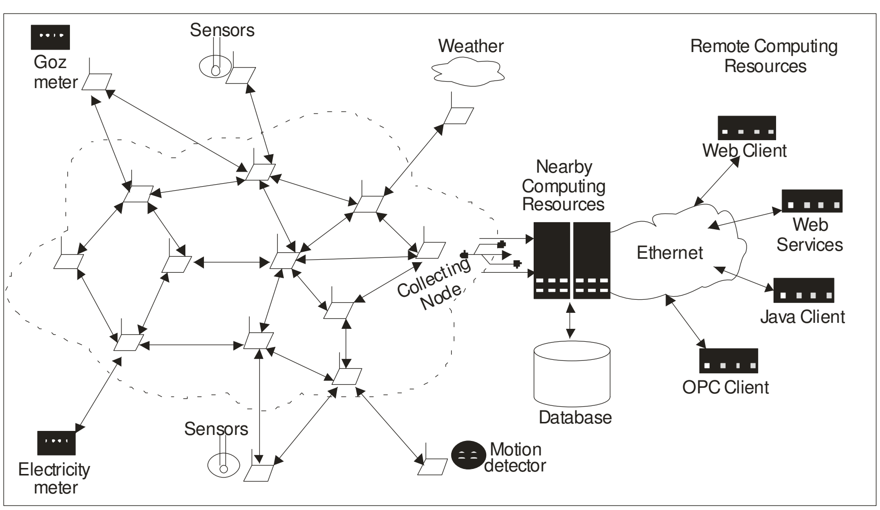


Fig. 1. Sensor Networks.

A smart city can simply be regarded or seen as an instrumented, interconnected, and intelligent city; hence, a smart city uses information and communications technology to enhance its live ability, workability, and sustainability [21-23]. For instance, intelligent transportation or smart transport system applies advanced technologies of electronics, communications, computers, control, sensing and detection techniques in all kinds of transportation systems in order to improve safety, efficiency of service, and traffic situation through transmitting real-time information into the system in order to make the development of the smart city shaped dramatically by changes in internetworking technology [24-29].

Over the last three decades, a necessary precursor to smart cities can be found in the IoT technology. The objects within the Internet are generally connected to technology platforms either through the Internet or through local area networks (LANs). This enables these technologies to engage in communication with each other without an immediate need for human intervention to manage these emerging personal media systems [30, 31].

The contributions of this paper are: to review the various application areas of IoT, highlight the limitations of the current health care emergency services and propose a solution that combines numerous IoT driven sub-systems into a single integrated smart health care management system, and to develop a smart transportation model using Ahmadu Bello University, Nigeria as a case study.

To put in context, Ahmadu Bello University (ABU) is a federal government research university in Zaria, Kaduna State. Until the advent of the security issues, the school management had always allowed free interaction of commuting vehicles from outside to freely convey passengers to and from the school campuses. Hence, commuting vehicles that transport commuters within the campus are restricted to operation within the campus for the working hours of 7:00 am to 6:00 pm. This approach, made the school management to have a greater control of its intra-transportation system within the campus, even though it was being managed by the Students Representative council (SRC); hence mitigating security risk to a large extent. On the other hand, worthwhile challenges associated with the transportation system are stated below:

1. Inadequate commuting vehicles: Cases have practically been experienced whereby commuters would be stranded at bus-stops or junctions for appreciable number of minutes without vehicles to convey them to their appropriate destinations. This problem could be associated with insufficient vehicles or even unplanned travel routes by the central transportation management body.

2. Poor management of commuting vehicles: Special cases have also been recorded whereby the transportation management body (SRC) has complained of low financial yield from the commuting vehicles. This problem could be associated with that stated in “1” above.

3. Theft of commuting vehicles: This has also led to the inadequate number of commuting vehicles. Careful observation and preventive measures need to be employed to mitigate against such cases in the nearest future.

The aforementioned challenges are inherent and unanimously constitute an inefficient transportation system within the university campus environment; hence leaving only one solution (i.e. a smart transportation system). In addition to the smart transportation system, a Smart Patient Health Management System (SPHM) is proposed to help ease health related challenges. Both smart solutions are integrated through an IoT framework for an effective smart city architecture.

The rest of this paper is arranged as follows: following the introduction is the discussion of the proposed framework in section II. In section III, underlining technologies for achieving the proposed framework are presented. Section IV presents the developed transportation model for Ahmadu Bello University, Zaria, Nigeria, and section V concludes the paper and highlights possible future directions.

II. PROPOSED FRAMEWORK

To understand the need for the framework proposed in this paper, we would start off by describing a typical health emergency scenario. A hospital is a place where medical care is provided for injured and/or sick people. However, since the hospital is in a fixed location, the sick have to go there to receive treatment. This might not always be possible, hence the need for ambulances. These specialized vehicles convey the sick or injured from where ever they might be to the hospital. This is a typical method of operation for many health care centers or hospitals. This process which has been in use for years has some inherent limitations which can be improved upon. These limitations include:

(a) Limited or zero communication between the ambulance and the hospital: communication between the hospital and the ambulance en route the hospital is often limited to phone or radio conversation between the paramedics in the ambulance and the emergency help desk of the hospital.

(b) Fully occupied parking lot: On arrival at the hospital, the ambulance might not immediately find an idle spot to park. Though most hospitals have dedicated ambulance routes or parking spots; it is not uncommon for these spots to be occupied/blocked by other vehicles – especially those with emergencies.

(c) Asides from the ambulance(s), doctors and medical staff of hospitals might also find it difficult to get spaces to park on arriving the hospital, especially, if the hospital is serving a large community and does not have dedicated parking lots for her staff. This can lead to wasted time, increased agitation, increased fuel consumption, or at worst lead to loss of life if the doctor is unable to get to his duty post on time to attend to the patient.

(d) Lastly, though hospitals these days have a computerized Hospital Management System (HMS), these systems are often stand alone and mostly manually operated.

In a bid to address these limitations, this paper therefore proposes a Smart Patient Health Management System (SPHM).The SPHM combines intelligent emergency service, smart parking, and health care management system as a single system. The proposed SPHM framework is depicted in Fig. 2.

Having described the limitations of the current system, we would now describe the various components of SPHM and how they work together.

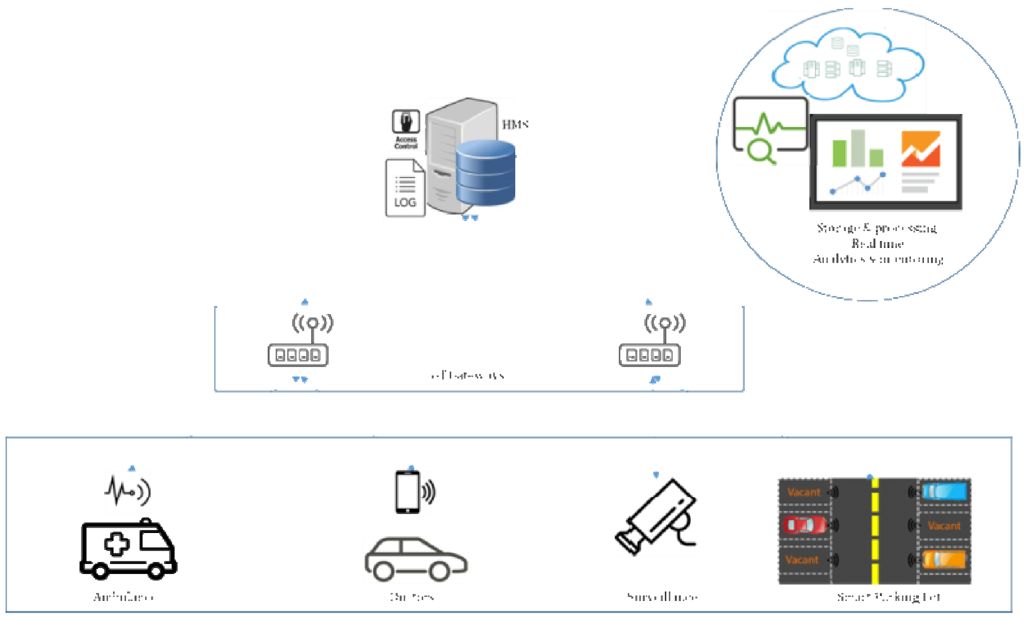


Fig. 2. The SPHM Framework.

Fig. 2 shows the layered SPHM framework. The lowest layer is the sensing or perception layer, from which information is collected. Above this is the network layer, which is responsible for data transportation. In the SPHM framework, the highest layer is the application layer; this layer encompasses both the support and application layers of the IoT architecture shown in Fig. 3.

A. The Sensing Layer

In the SPHM framework, the sensors in the ambulance, the GPS in the doctor/staff's car/phone, the surveillance cameras, and the sensors in the parking lot constitute the sensing layer.

(i) Smart Ambulance: SPHM ambulances are fitted with Internet connected sensors that not only measure the patient's "vitals" - heart rate, blood pressure and primary diagnosis, but also relate these information back to the hospital in real time via the internet. With these information, the hospital is well aware of the condition of the incoming patient and can make necessary arrangements, in terms of preparing a room, surgical theatre or medications. With the two way communication between the hospital and the ambulance, the paramedic can be linked directly with a doctor / specialist who can give more advice on the appropriate medical cause of action to be taken while the patient is en route to the hospital.

(ii) Location Awareness: SPHM passively monitors the locations of hospital staff via GPS sensors installed on their vehicles or on their mobile phones. The monitoring is done passively so as to avoid invasion of privacy. It becomes active in situations where the patient has a smart health monitoring device on and ambulance(s) is/are unavailable or servicing different patients. SPHM can get doctors' locations and with it, intelligently detect which doctor is closest to the patient and then forward the patient's health information and location to the doctor. The doctor can then directly go to the patient to render immediate help.

(iii) Assisted Smart Parking: Upon entering the hospital's premises, the assisted smart parking system informs and directs the driver (via a mobile app) to the available (and possibly best) parking slot. This could save significant amount of time, especially in emergency situations were a few seconds saved could be the difference between life and death. The assisted parking system could also be used by doctors and other staff of the hospital, to help them quickly locate vacant parking spots.

B. The Network Layer

This layer is responsible for data transportation from the sensing layer to the layer(s) above it. The IoT gateways are the key component in this layer and are double ended bridges. On one end, they communicate with the sensors using communication protocols such as Bluetooth, LoRa, ZigBee, and WiFi while on the other, they connect to the traditional IP network (wired or wirelessly). Information obtained are aggregated and optionally filtered before being moved to servers at the application layer.

C. The Application Layer

In the SPHM system, the application layer is a hybrid combination of the supporting and application layers of the IoT architecture shown in Fig. 2. This layer houses edge servers or Fog computing nodes [Cisco, MaKun, IoT8] that perform two functions: (a) receive, process, forward or store the data from the sensing layer, and (b) run the intelligent centralized hospital management system.

(i) **Data Management:** Edge servers or fog computing nodes are defined as decentralized Cloud computers which are closer to the data source for the sole purpose of reducing latency [Fog Everything, IoT5]. For SPHM, the data of interest would include data from ambulances, staff locations, and car parks as gathered in the sensing layer.

(ii) **Automated Hospital Management System:** Hospital Management System (HMS) are not a new concept as they have existed for decades and are commercially available both on premise and in the

Cloud. A review of some of these health care management systems has been done in [6, 8]. Many of these works however considered the various components in silos or only a combination of emergency health services and remote patient monitoring. As earlier stated, SPHM goes beyond these by combining three different application domains into one; this is what makes SPHM unique. The process through which this is achieved is in two phases (patient and staff) and is described as follows:

1. Patient: Prior to the arrival of the patient, the system automatically creates a profile for the patient with basic information such as sex, age, health condition, arrival time, and possible preliminary diagnosis as collected from the ambulance and paramedics. The patient can also be assigned a category based on the severity of his case or other approaches such as those described in [7].

2. Staff:

(a) Upon arriving at the hospital, the cameras and sensors in the parking lot sends the data that is used to automatically "clock in" the member of staff.

(b) With the staff/doctor's profile already in the system, SPHM automatically assigns doctors to incoming patients (in the ambulance) by matching the doctor's preconfigured expertise with the patient's profile earlier created.

The interaction between the various components of SPHM described so far are shown in Fig. 3.

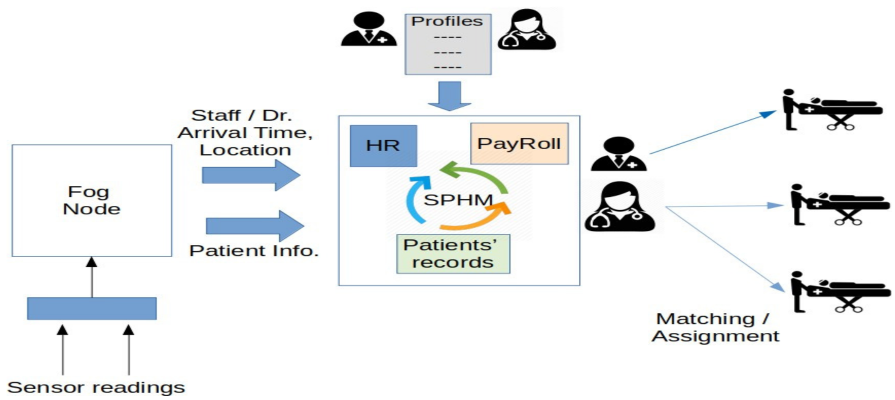


Fig. 3. Interplay between the components of SPHM.

III. IMPLEMENTATION TECHNOLOGIES

The various aspects of SPHM have been well studied as individual sub-systems and published in numerous literatures, hence, the exact workings of each are not discussed in this paper. However, a summary of the underlining technologies used to achieve the whole system is shown in Table 1.

A. Procedure for Developing the Smart Transportation model

This section focuses on the methods employed in developing the smart transportation model using the Ahmadu Bello University, Zaria-Nigeria as a case study. This study probes into its transportation lapses and provides a proficient and suitable solution to the existing lapse being observed in the system. Fig. 4 depicts the transportation bus-stop at the famous Northgate entrance within the school campus.

Table 1: Underlining Technologies for SPHM.

Layer	Applicant/ Application area	Sensors	Description	Literature
Sensing Layer	Ambulance	Heart rate monitors such as ECG and Infrared Optical Sensors; ventilation and airway equipment; Temperature sensors; Blood volume and pressure sensors	Used to measure/obtain the patient's health information	[17]
	Staff/Doctor's cars	GPS sensors in phone or in car	Position/location information	[18]
	Parking Lot	Cameras	For recognition of staff faces and vehicle license plate	[19, 20]
		Infra-Red, Ultra-sonic, and RFID	To determine vacant parking slot (s)	[21]
Network Layer	IoT Gateways	Raspberry pi or related platforms	Provides a bridge between the sensing and application layer	[22, 23]
	Connection protocols	LoRa ZigBee, WiFi, and IP	Communication rules between sensors, gateways and upper layers	[24]
Application Layer	Fog Computing	High end computer systems (servers)	Data processing and storage close to the source	[25-28]
	Hospital Management System	Software application developed for health care management	Hospital management software	[6], [8]

Fig. 4. Commuters and Transportation vehicles at the famous Northgate Bus-stop within the Samaru Campus (Photo taken in May, 2018).

B. Cabify Overview

An android software application called 'CABIFY' was built solely for the implementation of the smart transportation solution within the Ahmadu Bello University Campus, Samaru. The software uses an already produced GPS map accompanied with modelled and structured algorithms embedded in the software to facilitate smart transportation. It could be downloaded using the link [32].

IV. DEVELOPING A SMART TRANSPORTATION MODEL: AHMADU BELLO UNIVERSITY AS A CASESTUDY

A. Smart Transportation solution

In an attempt to solve the aforementioned challenges posed by the inherent transportation system of the university campus in Samaru, key areas are targeted and implemented as discussed herein.

1. Dynamic carpooling (car sharing): Carpooling (also known as car sharing) applications will link drivers and passengers in real-time, thus enabling dynamic carpooling. Private drivers wishing to profit from their journeys can find people situated on the same route via a smart phone app and vice versa. Passengers can also directly book their fare through the app, eliminating the need for any money exchange. Optimizing this constraint would eventually reduce not only the costs of travel but also pressure on the roads.

2. GPS-based tracking and route information of public transport: Advanced vehicle tracking solutions will enhance operations and optimize the public transportation and ridership. These solutions offer real-time GPS tracking from mobile devices thus increasing the reliability of public transportation. The administrators can monitor the public transport remotely and take action against any accidents/incidents or even inefficiency. The video footage obtained through monitoring can be used as legal evidence against damage or criminal action on the owner of the public transport.

3. Single fare card: For single fare card for fare payment on the various participating public transportation systems, the cards can be recharged by mobile applications/internet/retail outlets.

In summary, these solutions are targeted at:

(i) Using new sensor technologies, GPS, and satellites to tell motorists about the best routes and parking slots available during rush hours.

(ii) Helping commuters make more informed choices about public transport, telecommuting or driving off-peak periods.

(iii) Developing an integrated public transport system that tracks and adjusts services to meet changing commuter needs.

(iv) Fleets of smaller buses that change route on the fly and go where they're needed most.

Ai. Solution Implementation

The solutions discussed in the earlier sections of this paper have been adequately implemented by performing a rigorous study of the existing transportation models, and then developing an android software application called CABIFY" that would be operated by all arms of the transportation system (i.e. the server (administrators), the commuters, and the vehicle drivers).

1. CABIFY Overview: CABIFY is an android software application which has been developed solely as a means to improve on the existing transportation system in ABU, Samaru Campus. The smart transportation solution (CABIFY software) uses already mapped GPS accompanied with modelled and structured algorithms embedded in the software to facilitate smart transportation. This application can always be downloaded using the link: https://www.suprixtechnology.com/cabify.html.

The users of this application are mainly of three (3) categories; the administrator, the drivers, and the commuters. Fig. 5 shows the first Graphical User Interface (GUI) of the application upon launching.

The key features of the software provide the users the ability to:

Commuters

– Create an account
– Make subscriptions for periodic fare payments
– Make orders from their subscriptions
– Board vehicles as passengers

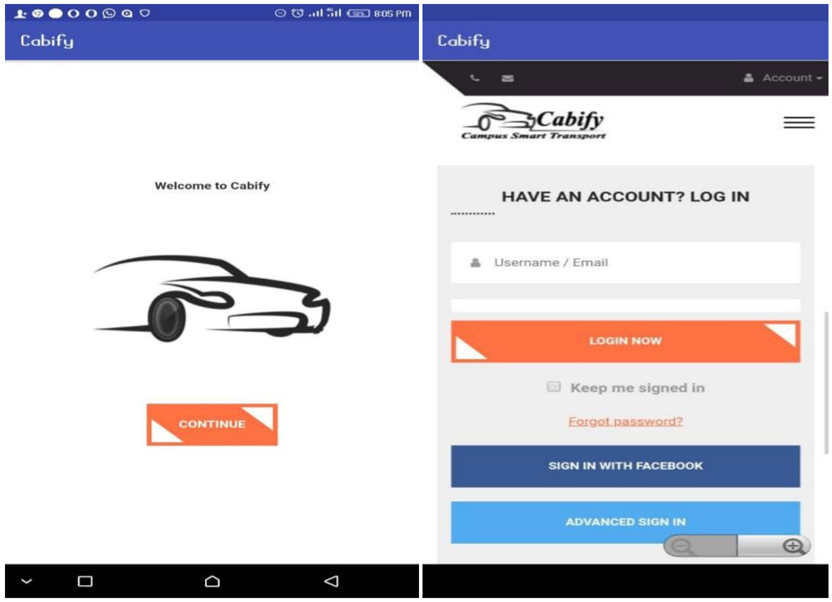


Fig. 5. GUI of CABIFY app upon first launch.

Drivers

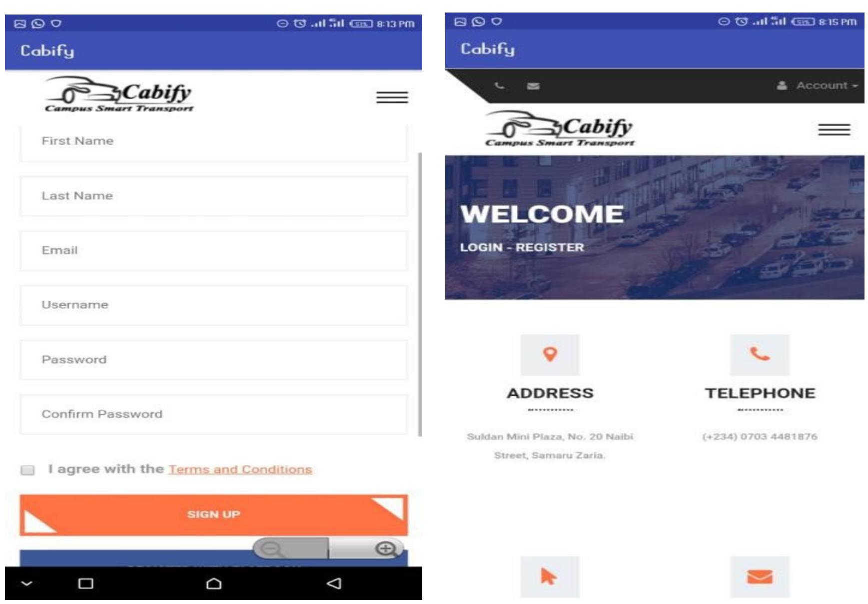
– Create an account
– Register their vehicles
– Track incoming demand by commuters
– Receive directives, payments, and updates directly from the admin

Administrator

–Monitor the transportation system
–Pay the drivers
–Maintain the transportation system

2. Registration Page: The registration page is where the user (both commuters and drivers) are allowed to make registrations. Before registration, certain terms and conditions are then complied with. In the registration page, the users are required to fill in their data (name, email, phone number, and address). Upon completion of the registration, the users are hence directed to their respective user dashboards. Fig. 6 show the user GUIs.

3. Commuter's Dashboard: This dashboard enables commuters to board vehicles (upon adequate registration and periodic subscription payments). In addition, this dashboard enables the commuter to: locate closest vehicles ready for commuting, make payments, and also get an average optimal timing and scheduling for the travel path. The dashboard allows direct and easy communication between the user and the admin, if the need ever arises. Figs. 7-9 show the respective GUIs.



(a) (b)

Fig. 6. GUI of CABIFY showing the registration dashboard (a) during and (b) after registration.

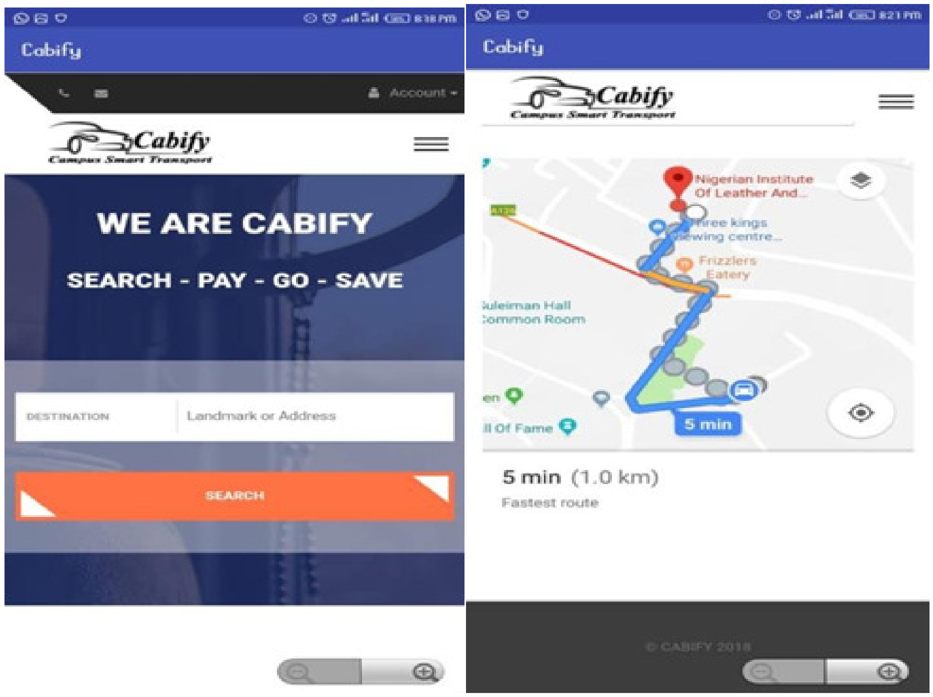


Fig. 7. GUI of CABIFY showing the search/booking process for a vehicle by commuters.

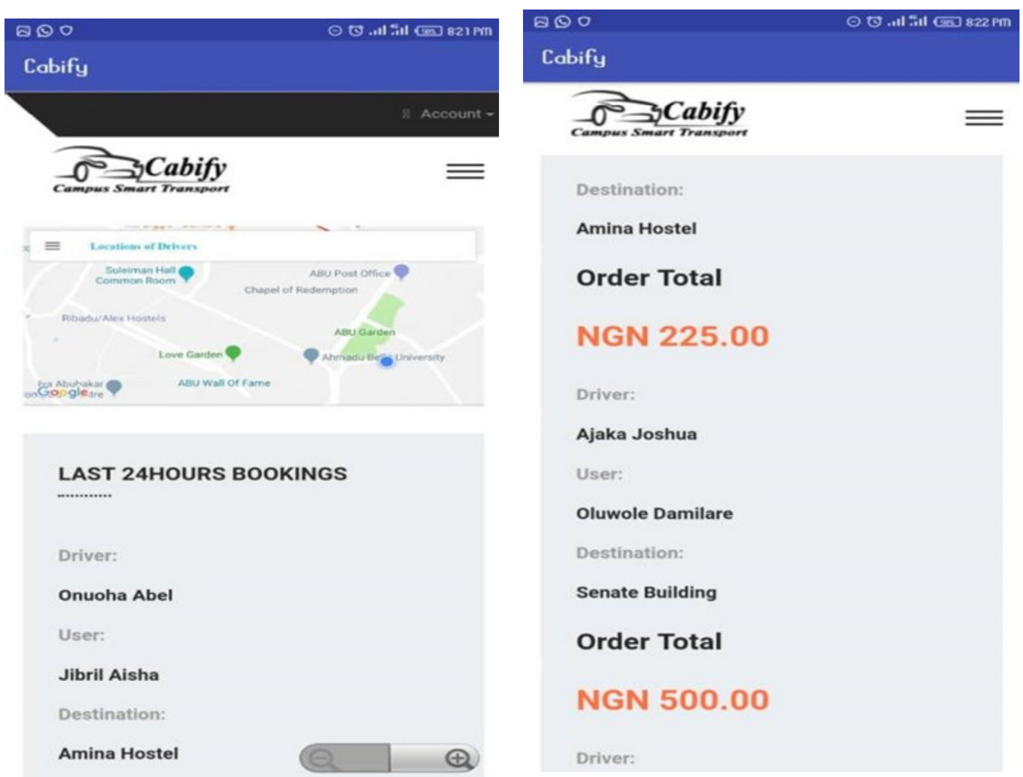


Fig. 8. GUI of CABIFY showing the payment process by commuters.

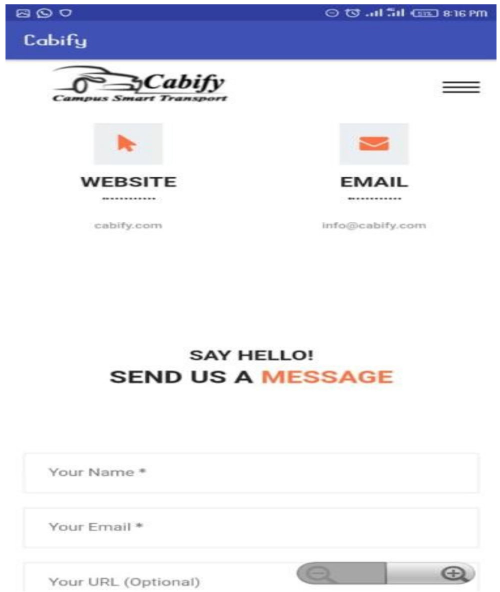


Fig. 9. GUI of CABIFY showing the interaction process between commuters and admin.

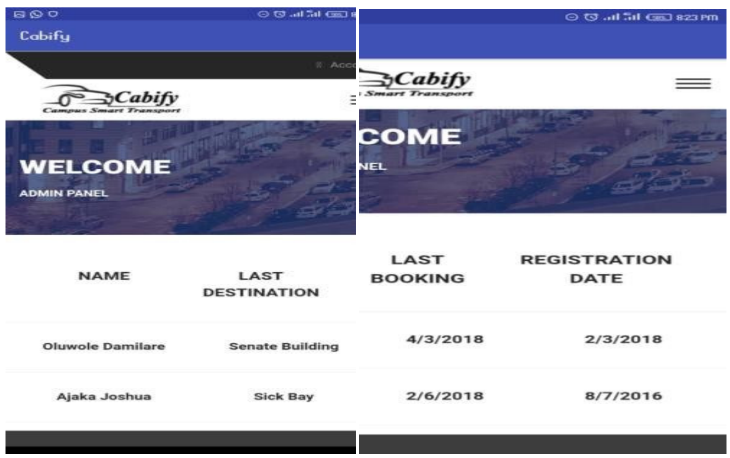


Fig. 10. GUI of CABIFY showing a brief of transactions monitored by the system admin.

4. Driver's Dashboard and Admin Dashboards: Herein the driver's dashboard (Fig. 10), the driver receives necessary notifications including demands for ride, admin personal messages, and payments (as the case may be). In this dashboard, the admin monitors the transportation in real-time.

Although suitable and feasible solutions have been provided and implemented as discussed in previous sections of this paper, few recommendations could be made to better the smart transportation system within the campus for instance: the use of geospatial-enabled efficient transportation system, road user charging, smart parking, and smart toll systems.

V. CONCLUSION

The Internet of Things (IoT) has in recent years enjoyed widespread application. It has been used in vehicles, homes, buildings, cities, and health care. In this paper, the authors presented an IoT based integrated health care management system that combines smart emergency services, smart parking, and health management system. A framework for the system was presented alongside the interplay between the various components of the system. Though the system itself has not been developed, various aspects of it are shown. Future work would focus on the actual implementation of the system as well as the performance and user acceptance tests. This work did not consider smart wearable, which are now a common place in smart health. This could be included as an extension of the SPHM system, whereby in emergency situations, the hospital will be automatically notified by the system. This can be particularly useful for aged or unconscious patients.

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Conflict of Interest. The authors declare no conflict of interest associated with this work.

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