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DEVELOPMENT OF A CLOUD MO[illegible] MECHANISM FOR THE TREATMENT OF DIABE[illegible]TS IN NIGERIA

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MATRIC NO.: 169419002

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May, 2019.

DECLARATION

I hereby declare that this dissertation was written by me. It has not been presented in any previous application for higher degree certificate of this or any other university. All citations and resources used have been duly acknowledged by means of references.

....	....
AWOPETU NIYI GABRIEL (169419002)	**DATE**

CERTIFICATION

This is to certify that this research work titled "DEVELOPMENT OF A CLOUD MOBILE-BASED MECHANISM FOR THE MANAGEMENT OF DIABETES IN NIGERIA" by AWOPETU NIYI GABRIEL (169419002), met the regulations governing the award of Masters of Science, (MSc.) in Adekunle Ajasin University, Akungba Akoko, Ondo State, and it is approved for its contribution to scientific knowledge.

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Dr. A.O. Akingbesote
(Supervisor)

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Date

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Dr. A.O. Akingbesote
(Head, Dept. of Computer Science)

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Date

DEDICATION

This Dissertation is dedicated to God Almighty who guided me throughout the period of this research.

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ABSTRACT

Diabetes is considered as one of the most incurable diseases in the world. Studies have shown that at least fourteen million, four hundred and six thousand Nigerians are currently living with the incurable disease. Several researchers have proposed the use of mobile technology to aid diabetes treatment, but challenges such as time taken for physicians to attend to patients and problems associated with location of hospitals are recurrent. This research approached these challenges by developing a cloud mobile based mechanism that minimizes the time taken for doctors to retrieve patients' information and recommend closest hospitals based on the shortest route.

A cloud mobile based mechanism was developed using Java API to run on Android OS. Each user registers and fills necessary information on this application once. This information is uploaded directly to Alibaba cloud, which serves as the repository. The prototype demonstration of this work was carried out with thirty patients, a total of eighteen physicians across six hospitals designated as A,B,C,D,E and F. Three physicians in each designated hospital attended to 5 patients, and the time taken to attend each patient using our developed model was recorded and compared with existed method. We adopted the Djisktra algorithm to suggest the shortest distance to a hospital within a patient's vicinity, in case the patient requires emergency treatment. The algorithm made use of the six hospitals: A,B,C,D,E and F having 2,4,1,7,3,2,1 and 5 kms as the distances from one location to another on the graph.

Our developed model recorded an average of 17.802, 17.866, 17.868, 18.268, 17.200, and 19.336 minutes across the six hospitals. The existing system was also demonstrated using same conditions, and an overall average time of 39.66 minutes was recorded. Based on the six hospitals used in the experiment, and with the use of relaxation approach of the Djikstra algorithm given by $d[v] = d[u]$ $c[v]$, the result obtained from Source A (Patient) to destination F (Shortest Distance to the patient's location) was 9km.

The developed mechanism has proved to achieve success in tackling issues of late response to patients by physician and getting closest hospital with right physician. In addition, this research also provisioned additional information; like types of food to be taken by diabetes patients, and how to do self test. This research will be of a great help to diabetes patients in Nigeria if the Federal Government can implements the application.

Keywords: cloud, mobile, diabetes, solution.

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1. **Awopetu N.G.** and Akingbesote A.O.: Modeling a Cloud-Mobile Based Mechanism for the Treatment of Diabetes Mellitus in Nigeria. *American Research Journal of Computer Science and Information Technology.*

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Diabetes is considered as one of the most incurable diseases in the world, and once a patient gets infected, it remains forever (Yates and Khunti, 2016). Early research on diabetes mellitus such as (Fajans, 1971), defined the disease as a genetically determined disorder of metabolism which in its fully developed clinical expression, is characterized by fasting hyperglycemia, atherosclerotic vascular disease, and neuropathy. Studies in Anthonia and Chukwuma, (2014) showed that in 180 million Nigerians, the estimated occurrence of diabetes is 1% in rural areas, and ranges from 5% to 7% in urban areas. That is; at least fourteen million, four hundred and six thousand (14,406,000) Nigerians are currently living with the incurable disease. The continuous and organized management of the diabetes is the only way to avoid the impact of such incurable disease.

Although, earlier medication of diabetes was based on paper and pen, pictorial evaluation of patients' healthcare was not possible (Xu & Cao, 2014). Various research works have tried to solve this problem through the use of technology over the physical or one on one treatments, see for example Kumar, (2015), Hanauer, *et al.*, (2015), Mutlu and Sürer, (2016). In Sun & Wang, (2013) the use of web based was introduced. Also, the idea of using mobile health technology for solving diabetes issues was introduce in Konstantas, *et al.*, (2002) and Pavlopoulos, *et al.*, (1998), and these works serve as the foundation on which other mobile health improvement was built. While these ideas have achieved great success in solving diabetes related issues, the issues of mobility and the time taken by physicians to attend to patients still exist. These issues has been great challenges in Africa especially. Since year 2006, there have been over 180,000 recorded deaths of diabetic patients in Africa, because they were unable to connect their doctors from remote areas due to inability to receive treatment as soon as possible, and also the time taken to attend to patients (Alanzi *et al.*, 2018). Solving these challenges is the focus of this research. This research is into the development of a cloud mobile-based mechanism for the treatment of diabetic patients in Nigeria.

1.2 PROBLEM STATEMENT

Living with diabetes is a full-time job. The amount of information people with diabetes need to keep track of the illness can become overwhelming. Patients who want more advice from their healthcare providers are often frustrated with the lack of contact in-between physical office visits. Recent advances in "mobile health" or "mHealth" – the use of mobile technology such as smartphones in healthcare have opened up exciting new ways to keep track and stay connected. Agarwal *et al.*, (2016), Weinstein, *et al.*, (2014), and Jassas, *et al.*, (2015)have proposed the use of Mobile Health (mHealth) systems for managing human health. These devices can be mobile phones, patient monitoring devices, tablets, personal digital assistants, or other wireless devices. However, several limitations such as time taken to attend to patients and mobility issues are associated with mobile health in diabetes treatment, as discussed in (Michalas, 2014). This research aims to tackle these challenges by developing a Cloud Mobile-Based Diabetic Patient Treatment Service Delivery System which will allow patients to upload their diabetes information in cloud, which is accessible to their doctors, thereby reducing the time it takes physicians to attend to diabetic patients, and also recommend closest hospitals to diabetic patients in transit when in need of urgent treatment.

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The aim of this work is to develop a cloud mobile-based diabetic patient treatment service delivery system that can reduce the time taken by physicians to attend to diabetic patients, and also recommend nearby hospitals to patients in transit.

1.3.2 OBJECTIVES

The specific objectives are to:

1. Develop a cloud based mobile application that captures diabetic patients' information and store in cloud,
2. Introduce an optimal routing algorithm in our application, to determine and recommend the closest health care centre to diabetic patients,
3. Evaluate the performance of the developed system with existing healthcare systems.

1.4 EXPECTED CONTRIBUTIONS TO KNOWLEDGE

The contribution of this work to the body of knowledge is in the provisioning of a cloud mobile-based mechanism for the treatment of diabetic patients in Nigeria. The mechanism collects information of diabetic patients, and the directly uploaded to the cloud. This mechanism will aid the minimization of the time taken by physicians to treat diabetic patients. The mechanism will recommend nearby hospitals to diabetic patients in transit. The collected information is used to recommend feeding pattern to the patients and all collected data is stored in cloud. This to the best of the researcher's knowledge is yet to appear in the literature in the context of mobile health in Nigeria.

CHAPTER TWO

LITERATURE REVIEW

Cloud computing is an information technology service model that allows computing services to be provided on-demand to customers over a network in a self-service fashion and independent of devices and location. These services include Software, Infrastructure and a Platform (Buyya, *et al.,* 2008). The main idea of cloud computing is to have rapid and uninterrupted access to various services. Cloud service providers and consumers can interact without necessarily coming into contact With cloud technology (Akingbesote, *et al.,* 2017).

Recently, several services are being deployed in cloud; examples of such services include cloud market, toys, and more importantly health services. The need to deploy health services on the cloud is numerous. Research in (Hossain and Muhammad, 2016) highlighted few of the benefits of deploying health services in cloud as . Furthermore, the author in (Hassanalieragh *et al*., 2015) emphasized on the effects of deploying severe and chronic health related issues in cloud. Example of such severe health issues is Diabetes mellitus.

2.1 DIABETES

Diabetes mellitus is a genetically determined disorder of metabolism which in its fully developed clinical expression is characterized by fasting hyperglycemia, atherosclerotic and micro-angiopathic vascular disease, and neuropathy (Fajans, 1971). Skyler *et al*., (2017) defined Diabetes mellitus (DM) is a glucose metabolism disease characterized by chronic hyperglycemia resulting from defects in insulin secretion, insulin action, or both.

Diabetes happens because the body can't use glucose correctly either the pancreas not producing enough insulin or the cells of the body not reacting rightly to the insulin produced. This disease has three main types; type I, type II and Gestational diabetes (Benali and Asri, 2016).With the evolution of technology, management of diabetes has become easy and uncomplicated. A home blood glucose test was a major leap ahead for diabetics, after the patient tests his blood glucose levels, the management system records and stores the test results and other detailed data like, date and time of tests, the type and dosage of insulin, type of exercise, diet (Benali and Asri, 2016).

DM poses a great threat to human health as well as a huge socioeconomic burden for governments. According to the updated data from the international diabetes federation (IDF), the estimated global prevalence of DM reached 8.8% in 2015 and 12% of global health expenditure was due to DM in the same year (Yates and Khunti, 2016).

The typical vascular and neuropathic manifestations of diabetes may occur in patients with a genetic predisposition to diabetes who have relatively mild carbohydrate intolerance and normal fasting blood glucose levels (Skyler *et al.*, 2017). There are various stages in the natural history of Diabetes Mellitus, this is shown in Figure 2.1.

Table 2.1: Stages in the natural history of Diabetes Mellitus (Source: Fajans, (1971))

	PRE-DIABETES	SUBCLINICAL DIABETES	LATENT DIABETES	OVERT DIABETES
Fasting Blood Sugar	Normal	Normal	Normal or Abnormal	
Glucose Tolerance Test	Normal	Normal; Abnormal during Pregnancy stress		Not Necessary for Diagnosis
Cortisone-glucose tolerance	Normal	Abnormal	Not Necessary	-
Delayed and/or decreased insulin response to glucose	+	++	+++	++++

Diabetes Mellitus (DM) is a huge burden for human health. The authors in Hsu et al., (2016), developed a diabetes treatment satisfaction questionnaire as shown in Table 2.2.

Table 2.2: Diabetes Treatment Satisfaction Questionnaire (Source: Hsu et al., (2016),)

	Control Group (n=20)	Intervention group (n=20)	P Value
Age (Years)	53.8	53.3	0.90
Weight (Pounds)	211.1	203.9	0.64
Height (Inches)	68.7	67.4	0.27
Body Mass (Kg/m^2)	31.7	30.8	0.63
Years from Diagnosis	9.0	9.6	0.79
Questionnaire Score	34.3	31.9	0.41

The study was able to develop a diabetes management program. The program supports the development of self-efficacy in diabetes care through self- tracking tools, shared decision-making interfaces for subjects, and streamlined communications tools (secure text messages and virtual visits).Self-tracking in the program begins with the co-creation of a diabetes care plan between the subjects and HCPs. The plan can include any number of medications a day, which can be scheduled at specific times with flexible adherence windows. The plan is visualized for the patient on the tablet computer application in order to provide daily awareness and to allow self-tracking of medication adherence and blood glucose(Hsu et al., 2016).

Lifestyle factors and blood glucose (BG) management are important in reducing long-term diabetes complications (Nathan et al., 2005).

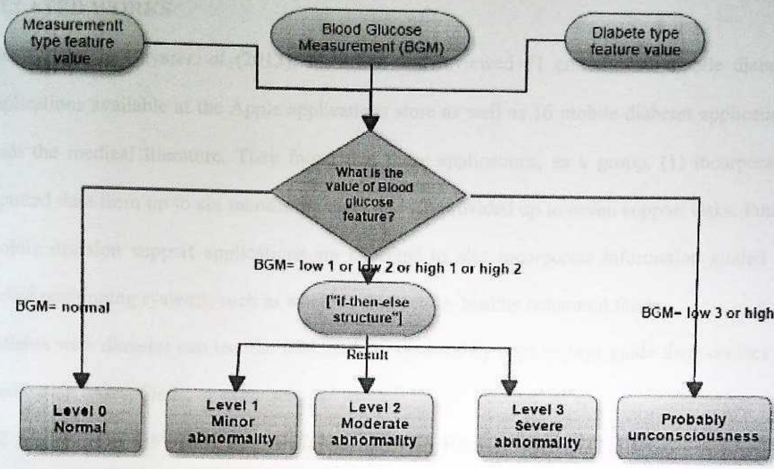

Figure 2.2: Process of Blood Glucose Abnormality (Source: (Benali and Asri, 2016))

Advances in ICT provide a variety of options for developing hardware and software deployment platforms for new test and sensor technologies. However, many of these products have not been optimized for usability or evaluated for their effectiveness in motivating or changing users' self-management behaviors(Suggs, *et al.*, 2012). Several studies such as Suggs *et al.*, (2012), Bourouis and Feham, (2011), (Lv, *et al.*, 2010), exist on the use of mobile technology for diabetes management, However, there are few published studies addressing which specific elements of mobile diabetes applications offers the greatest potential to benefit users effectively. Many mobile decision support software apps for smart phones are now available for diabetes and are intended to assist patients to make decisions in real time without having to contact their HCP. Rao *et al.*,(2010), reported that they had visited the Apple iTunes store on October 9, 2009, and selected the 12 diabetes apps with the highest ratings. They found that these apps contained 22 types of data management features.

RELATED WORKS

The authors in Gayar*et. al.*,(2013), identified and reviewed 71 commercial mobile diabetes applications available at the Apple applications store as well as 16 mobile diabetes applications from the medical literature. They found that these applications, as a group, (1) incorporated inputted data from up to six monitoring tasks and (2) provided up to seven support tasks. Future mobile decision support applications are expected to also incorporate information guided by global positioning systems, such as where to find nearby healthy restaurant foods.

Patients with diabetes can use the information presented by apps to help guide their choices of medication doses, foods, or exercises.

2.2 ADOPTION OF MOBILE TECHNOLOGY IN HEALTH MONITORING

It is certain that ICT has contributed to the positive growth of health care delivery systems in major hospitals in Nigeria. Most healthcare providers believe that improvement in telecommunication within the hospitals is capable of improving the quality of care. They believe that intercommunication between patients and care givers as well as among care givers can be especially improved (Omitola, *et al.,* 2009). For example, up to 68% of post-surgical patients have been effectively followed up using their GSM phone contacts (Mbah, 2007). This observation beams a ray of hope as it appears that with increasing availability of mobile phones and extension of connectivity to the rural areas, the problem of difficult patient follow-up which has been the bane of longitudinal study design in Nigeria may be over soon. The use of telephone to schedule clinic appointments is also emerging, particularly more prominently in University College Hospital, Ibadan (UCH).

The author in (Okuboyejo and Ikuhu-Omoregbe, 2012) emphasized that People saddled with chronic diseases need recommendations or facts regarding disease management. These include dosage adjustment of medication and other general information that highlights correction of life styles, changes in diet and physical exercise. The ubiquity of mobile phones and its current integration in health care has made it a worthy tool to this effect. The need to evolve from regular GSM call monitoring of sick patients led to eHealth.

eHealth, or digital health, is the use of emerging communication and information technologies, especially the internet, to improve health (Burke *et al.*, 2015). mHealth is a subsegment of eHealth, and it is the use of mobile computing and communication technologies (eg, mobile phones, wearable sensors) for health services and information (Akter, *et al.*, 2011). Mobile health technology uses techniques and advanced concepts from an array of disciplines, for example, computer science, electrical and biomedical engineering, medicine and health-related sciences (Dwivedi, *et al.*, 2016).

Recently, mobile phone has become the main sources of information for users. In fact, a huge number of applications were developed in different mobile operating systems to respond to the user's requirements (Benali and Asri, 2016). Several applications have been created to manage diabetes. The authors in (Okuboyejo and Ikuhu-Omoregbe, 2012), designed a Framework for a Mobile-Based Alert System for patient Adherence in Nigeria. The system works by sending mobile medical alerts through SMS to patients, prompting them to take their drugs. However, the real life system wasn't implemented. Hossain and Muhammad, (2016), developed Mobile Based Patient Compliance System for Chronic illness care in Nigeria. The phone based Patient Compliance System (MPCS) works by reducing the time-consuming and error-prone processes of existing self-regulation practice to facilitate self-reporting, non-compliance detection, and compliance reminder among patients in Nigeria. Lester *et al.*, (2010) carried out a study on the effects of Mobile Phone Short Message Service on Antiretroviral Treatment adherence in Kenya.

The study showed that several researchers have applied wireless technology in ensuring patient adherence to antiretroviral treatments. Okuboyejo and Ikuhu-Omoregbe, (2012) designed and implemented a Voice-based Mobile Prescription Application (VBMOPA) to improve health care services. The application can be accessed anyplace anytime, anywhere through a mobile phone by dialing an appropriate number, this connects users to an e-prescription application that is resident on a web server. This system could lead to costs and life savings in healthcare centres across the world especially in developing countries where treatment processes are usually cumbersome and paper based. Wangberg, (2006) developed a system that sends Diabetes Educative materials via Mobile Text Messaging SMS messages are sent to educate parents with Type 1 diabetic children.

In Norway, SMS messages are sent to educate parents with Type 1 diabetic children. Wedjat which is a mobile medication reminder and monitoring system was developed in (Wang, *et al.*, 2009). It is a smart phone application designed to help remind its users to take the correct medicines on time and record the in-take schedules for later review by healthcare professionals. Also, (Slama, *et al.*, 2017)developed a mobile based medicine in-take reminder and monitor system.

Lawal, (2017), developed a Wireless Technology for social change. It works by collecting patient information using mobile phones during home based care visits for HIV/AIDS patients. Also, BGluMon (Blood Glucose Monitor) a mobile application that permits the patient to see clearly his/her blood glucose level on daily basis was developed in (Bglumon, 2016).

All these developed systems have their shortfalls, as they do not take patients' location into consideration and the time taken for physicians to attend to diabetic patients. These limitations led to the development of clinical decision support systems for diabetic patients, which help physicians to administer treatment to patients.

2.3 CLINICAL DECISION SUPPORT SYSTEMS FOR DIABETES INTENDED FOR CLINICIANS

The main purpose of the CDSS technology intended for clinicians is to assist clinicians at the point of care. Clinical decision support systems can generate alerts and information with little real-time input from clinicians. For treatment decisions, however, clinician input is necessary. Whereas older CDSSs would make decisions for clinicians, newer CDSSs require clinicians to interact with the system to formulate a decision based on both the clinician's knowledge of that patient and the software's bank of standards and best practices. The use of these two types of input leads to better decisions than either the clinician or computer could make without collaboration. Typically, a CDSS will make suggestions and the clinician selects the best one. The CDSS can be programmed to deliver many alerts but few choices to the clinician, which has been likened to donning a straightjacket. Alternatively, the CDSS can allow more treatment options but make it inconvenient to prescribe the less desirable pathways, which have been likened to driving with guardrails.

The authors in Lv *et al.*, (2010) developed an icare system for elderly, the system has four parts The first one isdevices, including different body-sensors and other medical devices. Then, the second part is smart phone that plays a vital role in our system as an intermediary. It receives physiologicaldata from sensors, processes them andtransmits them to the server. Smart phone will monitor physiological data get from sensors and automatically alert to the emergency centre, family and friends of the elderly when detecting the emergency. In addition, it also designs unique auxiliary functions as a life assistant. The server is the third one that acts as the personal health information system. In the meanwhile, it also plays the role of the medical guidance which can offer the real-time medical guidance for users. The last part contains the emergency centre that will receive alarm messages via GSM protocol and call an ambulance to the location of the subject in the emergency status. This is shown in Figure 2.3

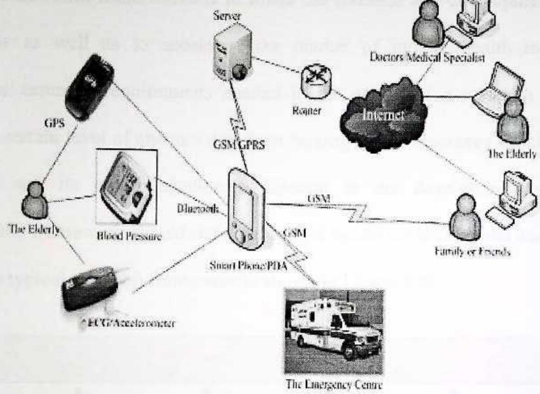

Figure 2.3: Architecture of System Developed in Lv *et al.*, (2010)

Although the icare app was divided into four parts in design section and every part has different framework and platform, they are integrated by the bend of heterogeneous network. The developed application which can not only dynamically monitor the elderly anytime anywhere and automatically alarm to the emergency centre in the emergency situation, but also play a role in acting as a living assistant. It provides auxiliary functions as the living assistant, including e.g. regular reminder, quick alarm. However, the limitation of this work is in the absence of cloud storage.

As numerous as research works on mobile applications for the management of illness and dieseases are, several limitations still exist. The authors in Dwivedi, *et al.*, (2016), compared several works on mobile health, and carried out studies on the motivations behind the adoption of m-health by individuals. The research was able to provide medical professionals as well as ICT and marketing researchers with some excellent practical guidelines in providing service to people.

The main goal of mHealth frameworks is to foster the research and development in health and medical domains as well as to accelerate the market of mobile health technologies and applications. The essential requirements needed in the design of a mHealth framework are outlined next. A certain level of abstrac- tion from heterogeneous resources should be ensured to make hardware and its communication transparent to the developer. For the sake of interoperability, the framework should define a unified model for multimodal health data(Banos *et al.*, 2014). The typical mHealth framework is shown in Figure 2.4

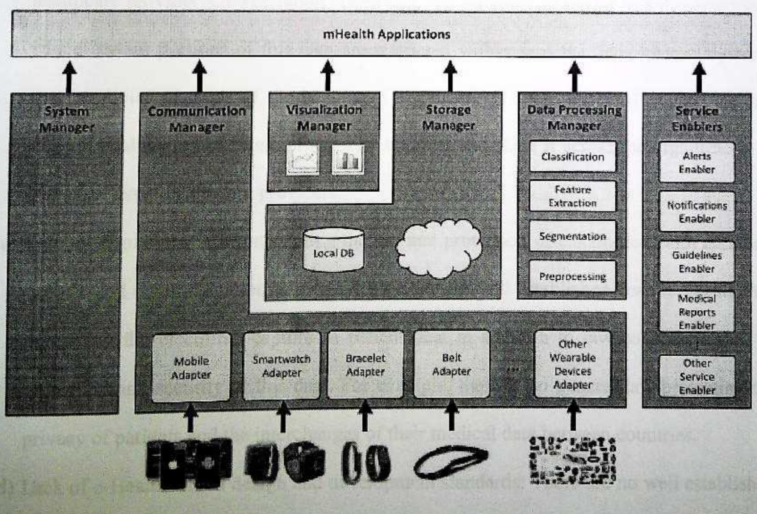

Figure 2.4: A typical mHealth framework (Source: Banos *et al.*, (2014))

2.4 LIMITATIONS OF E-HEALTH

The limitations of e-health was discussed in (AbuKhousa and Najati, 2012)

(a) High cost of implementing and maintaining HIT: the cost of HIT requires investments in software, hardware, technical infrastructure, IT professionals, and training. This can result in a considerable cost to healthcare organizations in particular for the medium and small sized entities. HIT implementations can be time consuming and stressful for the already stressed healthcare organizations due to demands on healthcare professionals who have to share project responsibilities with their patient care duties. Finally, HIT requires dedicated teams and proper funding to handle day to day management and maintenance.

(b) Fragmentation of HIT and insufficient exchange of patient data: HIT in most cases exists as separate small clinical or administrative systems within different departments of the healthcare provider's organization. Therefore, the patients' data exist in a dispersed state where certain portions of this data are restricted within separate departmental systems, certain clinics or areas of the healthcare organization. Such dispersed pockets of data make it challenging to bring information together and share it across the organization or across different healthcare providers.

(c) Lack of regulations/laws mandating the use and protection of electronic health care data capture and communication: currently, there are no well established laws or regulations mandating the electronic capture of patient data in addition to law covering issues of protection and security of this data. For example, there is no general law protecting the privacy of patients and the interchanges of their medical data between countries.

(d) Lack of e-Health Cloud design and development standards: There are no well established standards available for healthcare providers to use to design and build their systems. This would include definitions of data types, forms and at times frequency of data capture in addition to defining how the data is obtained, stored, used and protected.

These limitations can be solved by the introduction of cloud health.

2.5 CLOUD COMPUTING AND CLOUD HEALTH

Cloud computing has various definitions; some of these definitions are shown in Table 2.1. Research on various aspects of cloud computing has increased steadily over the last 5-8 years; workshops and conferences are being established and numerous publications are being produced (Jennings and Stadler, 2014). The basic theory of cloud computing is that IT resources are made available within an environment that enables them to be used, via a communications network as a service (Balco, *et al.,* 2017). Cloud computing has several definitions. Some of these is shown in Table 2.1. There are three main cloud service models according to Mell & Grance, (2011), and they are listed as Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS).The cloud has penetrated into several areas such as cloud e-market, cloud toys, and most importantly, cloud health.

Cloud health provides more efficient and cost effective solutions. In addition to providing independent per-healthcare provider solutions, the e-Health Cloud also has the potential to support collaborative work among different healthcare sectors through connecting healthcare applications and integrating their high volume of dynamic and diverse sources of information. Dispersed healthcare professionals and hospitals will be able to establish networks to coordinate and exchange information more efficiently (Abukhousa, *et al.,* 2018).

Table 2.3: Some Definitions of Cloud Computing

Definition	Reference
A style of computing where massively scalable IT-related capabilities are provided as a service across the Internet to multiple external customers.	(Gartner, 2017)
A pool of abstracted, highly scalable, and managed infrastructure capable of hosting end-customer applications and billed by consumption.	(Staten, 2008)
Cloud computing embraces cyber-infrastructure, and builds on virtualization, distributed computing, grid computing, utility computing, networking, and Web and software services.	(Armbrust, Fox, Griffith, Joseph, & Ranfy, 2009)
A type of parallel and distributed system consisting of a collection ofinterconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers.	(Rajkumar Buyya, Yeo, & Venugopal, 2008)
A large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the infrastructure provider by means of customized SLAs.	(Vaquero, Rodero–Merino, Caceres, & Lindner, 2009)
A model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.	(Mell & Grance, 2011)

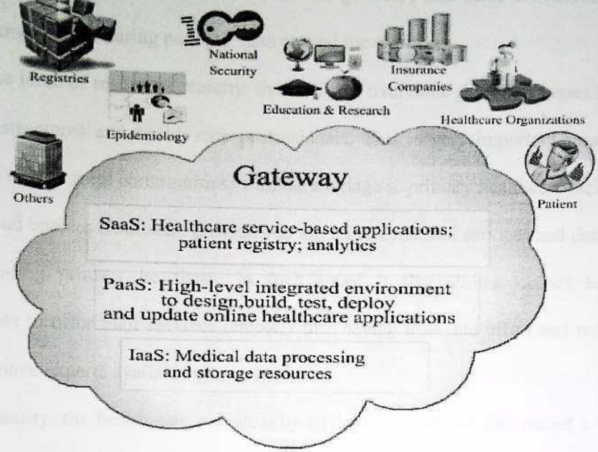

Figure 2.5: Generic Architecture of cloud e-health (Source: (Chomutare *et al.*, 2012)**)**

Collection of patients' information and uploading in cloud has several benefits. Examples of such benefits are discussed in (Chomutare *et al.*, 2012):

a. Better patient care: the ability to offer a unified patient medical record containing patient data from all patient encounters across all operators. These records will be available anywhere and anytime allowing healthcare providers to have a comprehensive view of the patient's history and provide the most suitable treatments accordingly.

b. Reduced cost: the ability to take advantage of the capabilities of CC and create a collaborative economic environment where the overhead costs are shared among the participants; with the flexibility to only pay for actual resource utilization. This feature is very suitable for small and medium sized healthcare providers where they can utilize advanced IT infrastructures and services to support their healthcare operations without facing high initial and operational costs. Another cost reduction aspect is the savings gained from making medical records available globally, thus there are no costs incurred in exchanging and sharing patients' data around the world

c. Solve the issue of resources scarcity: the ability to overcome shortages issues in terms of IT infrastructures and health care professionals. This is very important in some areas (such as remote rural communities) with the shortage in primary healthcare facilities [27]. The Cloud enables healthcare providers to use remote medical services and data that help in providing primary healthcare in such areas. It also allows various health care specialists to offer their services remotely thus saving time and effort and reducing the need to have experts available everywhere.

d. Better quality: the health care operators by having their clinical data stored in the cloud will facilitate supplying concerned entities such as the Ministry of Health or the World Health Organization with information on patient safety and the quality of care provided. The information will be attained by one of two methods; (1) aggregating existing data to arrive at the indicators requested and/or (2) providing on-line ability for health care operators to enter/access data directly. Health care data stored on the Cloud can be aggregated and reported along the lines of generally accepted health care quality indicators such as ones published by the Agency for Healthcare Research and Quality (AHRQ, 2012).

e. Support research: the e-Health Cloud can offer an integrated platform to host a huge information repository about millions of patients' cases which can be uniformly and globally accessed. This integrated platform can be easily utilized to develop data mining models to discover new medical facts and to conduct medical research to enhance medications, treatments and healthcare services

f. Support national security: the e-Health Cloud can increase the ability to monitor the spread of infectious diseases and/or other disease outbreaks. The Cloud can be serviced as an alert system for monitoring the diffusion of any dangerous infectious diseases as well as it can be used to determine the infection areas, the spreading patterns and hopefully the reasons of the outbreak

g. Support strategic planning: decision makers can use the e-Health Cloud data for planning and budgeting for healthcare services. It can also be integrated with other Cloud services to help in forecasting future healthcare services needs. This will help for example in planning the needs for doctors, medical labs and equipments, operating rooms, patient beds, and other medical facilities

h. Support financial operations: the ability to streamline financial operations as the Cloud can act as a broker between healthcare providers and healthcare payers. The billing, settlements, and approval processes can be automated and integrated among both parties.

Even though the benefits of cloud e-health are numerous, some challenges still exist in the literature. Examples of such challenges were discussed in (Chomutare *et al.*, 2012)

a. Data security risks: as in accessing patient data by unauthorized users. Many Cloud services offer some security measures. For example, Today's systems in particular HIPAA compliant health care systems—have the ability to record every access attempt by user names and to include date, time as well as relationship to the patient. However, more work is to be done to enhance security and more importantly increase the users' trust levels of these security measures.

b. The risk of loss of data: Although it is a significant issue, advancements in database management systems such as Oracle, Cache' and SQL have created concepts of hot and cold backups, mirroring and data base restores to provide efficient solutions that minimizes this risk. Not to mention, off site backups and disaster recovery sites.

c. The risk of systems unavailability: losing an e-Health service could be a major issue especially in an emergency situation. However, advancements in the science of business continuity have increased systems reliability and availability.

Another researcher in (Jassas *et al.*, 2015), developed a smart system connecting e-Health sensors and cloud. This model is aimed at preventing delays in the arrival of patients' medical information to the healthcare providers, particularly in accident and emergency situations, to stop manual data entering, and to increase beds capacity in hospitals, especially during public events where a large number of people are meeting in one place. The architecture for this system is based on medical sensors which measure patients' physical parameters by using wireless sensor networks (WSNs). This is shown in Figure 2.6

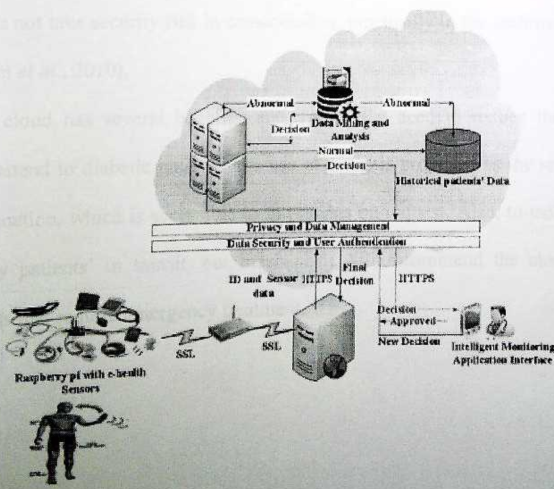

Figure 2.6: System Architecture developed in Jassas *et al.*, (2015)

Sheikholeslami and Nima, (2018), offered a novel design for gathering and accessing a huge amount of data generated by WSNs. The main objective of their architecture is to overcome the challenges of dealing with a huge amount of data and makes sharing of information easier for healthcare professionals. The paper focused on data management in WSNs, specifically sensors' data gathered that have been generated from medical sensors which introduce many challenges for the existing architectures (Lounis, *et al.* 2012). Choi & Lim, (2016), focused on developing patients' data gathering technique. This paper presents a novel framework to solve the problems of taking notes manually which is a slow process. Besides, they cause lateness for accessing real-time data and that restricts the capability of clinical monitoring and diagnostics. Thus, authors proposed a system to automate collecting patients' information process using wireless sensor networks which are connected to medical equipment, and then transferring this data to the healthcare provider centers in the cloud to store, process, and analyze patients' data. However, this paper does not take security risk in consideration, practically in the architecture of proposed solution (Rolim *et al.*, 2010).

The e-Health cloud has several benefits, and due to the need to reduce the time taken by physicians to attend to diabetic patients, the use of cloud is proposed as the repository to store patients' information, which is accessible to physicians on request. Also, to tackle the problems being faced by patients' in transit, our mechanism will recommend the closest hospitals to diabetic patients that require emergency treatment.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The study adopts the use of Object-Oriented Analysis and Design (OOAD) method.

Object-oriented analysis describes an information system by identifying things called objects. An object represents a real person, place, event, or transaction. For example, when a patient makes an appointment to see a doctor, the patient is an object, the doctor is an object, and the appointment itself is an object. Object-oriented analysis is a popular approach that sees a system from the viewpoint of the objects themselves as they function and interact. The end product of object-oriented analysis is an object model, which represents the information system in terms of objects and object-oriented concepts.

The following procedures shall be followed in the execution of the work:

i. Data Collection/Information Gathering: Information was gathered on flow of the method of Diabetes Miletus Diagnosis, Treatment and Management Plan.

ii. Modeling: Well-defined UML diagrams (Data Flow Diagram, Use Case Diagram, Sequence Diagram) were used for the modeling the proposed system.

iii. Design and Implementation: Object-oriented design approach is adopted for the design of the proposed system, which is to be implemented as android-based.

3.1.1 Data Collection/Information Gathering:

Extensive and adequate information were gathered in the field of this study. Some of these include extensive literature review of past research works in this domain of study. Also, experts were consulted in this field of study and information extracted on how the process is been carried out and the needed caution to take into consideration in the design of the system.

Some of the gathered information of the Diabetes Miletus Diagnosis, Treatment and Management includes:

i. The method of diagnosing a patient with Diabetes Miletus
ii. The needed information of symptoms associated with Diabetes Miletus
iii. Also, information pertaining to the treatment and management of Diabetes Miletus Patient.
iv. Feeding Plan and type of food a Diabetes Miletus Patient should eat so as to manage his/her health.

3.1.2 Modeling

Modeling involves graphical methods and nontechnical language that represent the system at various stages of development. The universal modeling language (UML) will be used to model the development and the implementation of this research work.

Various UML Diagrams such as the Use Case Diagram, System Flow Diagram and the Sequence diagram will be deployed to show the various interactions and relationships that exist between objects, entities in the system.

The Use Case Diagram is used to illustrate a unit of functionality provided by the system. The main purpose of the use case diagram is to help visualize the functional requirements of a system, including the relationship of actors (human beings who will interact with the system) to essential processes, as well as the relationships among different use cases. The main actor is the patient while the system is the Diabetes Miletus Diagnosis, Treatment and Management. The use case describes how the user interact with the system such as the diagnosing a patient by responding to some associated symptoms, also getting access to information that will help manage the health of Diabetes Miletus patient which includes, what Diabetes Miletus is, Treatment, Insulin Therapy, Diet and Exercise. While the System Flow Diagram show the flow of interaction of the actors with the system.

3.2 The Developed Model

The following models are deployed as guides to the implementation of this research work. These include the data flow diagram, and the use case diagram.

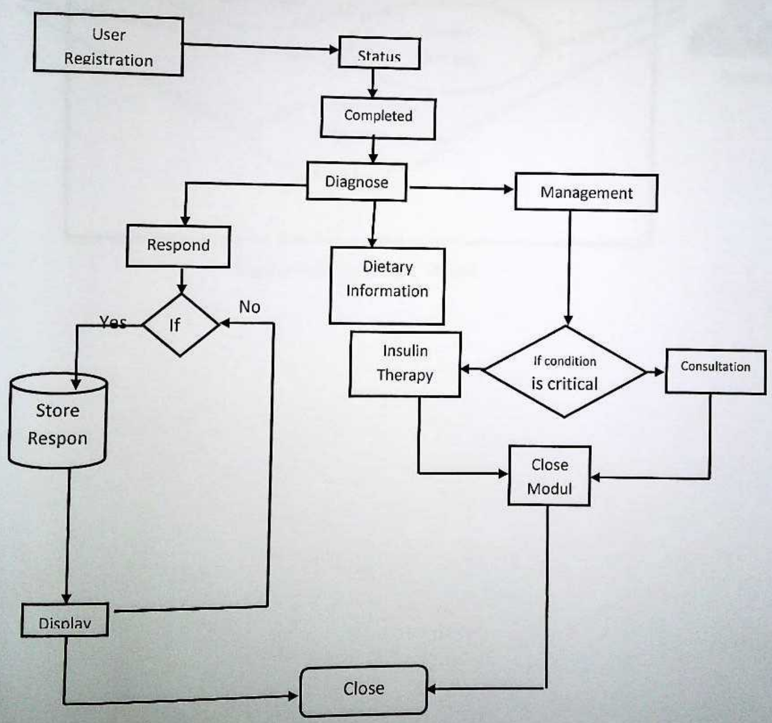

Fig 3.1: System Flow

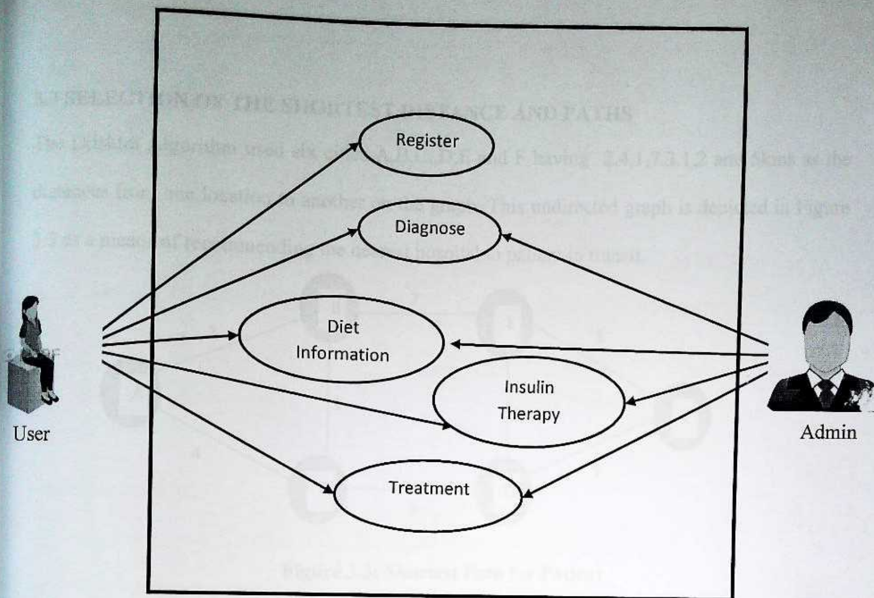

Figure 3.2: Use Case Model

3.3 SELECTION OF THE SHORTEST DISTANCE AND PATHS

The Djisktra Algorithm used six cities A,B,C,,D,E and F having 2,4,1,7.3.1,2 and 5kms as the distances from one location to another on the graph. This undirected graph is depicted in Figure 3.3 as a means of recommending the nearest hospital to patient in transit.

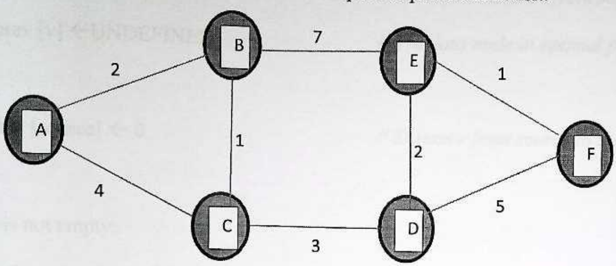

Figure 3.3: Shortest Path for Patient

The use of relaxation approach of the Dijkstra algorithm given by d[v]= d[u]+c[v] was used to get the shortest paths and distance. The full algorithm is in Figure 3.4.

```
function Djiskstra (Graph, source):
create vertex set Q
for each vertex v in Graph:                 // Initialization
    dist [v] ← INFINITY                     // Unknown distance from source to v
    prev [v] ←UNDEFINED                     // Previous node in optimal path from source

    dist [source] ← 0                       // Distance from source to source

while Q is not empty:
    u ← vertex in Q with min dist [u]       // Source node will be selected first
remove u from Q
for each neighbor v of u:                   // Where v is still in Q
    alt ← dist [u] +cost (u, v)
    if alt < dist[v]:                       // A shorter path to v has been found
    dist[v] ← alt
    prev[v] ← u
return dist [], prev []
```

Figure 3.4: Djiskstra algorithm

3.4 EXPERIMENTAL SETUP

A cloud mobile based mechanism was developed using android studio as an IDE (Integrated Development Environment) and JAVA being an object-oriented programming language is used as the choice of language for the design of the frontend and development of the mobile application.Each user registers and fills their necessary information on this application once and this information is uploaded directly to Alibaba cloud, which serves as the repository. The idea is to allow physicians in any available hospital that has connection with Alibaba cloud to access the basic information needed before treatment. We adopted the Djisktra Algorithm in providing the shortest distance to a hospital within a patient's vicinity, in case the patient requires emergency treatment.

CHAPTER FOUR

RESULT AND DISCUSSION

The results obtained from our experiment are in two phases. The first is into the uploading of patient information to the cloud database and time taken the physicians to attend to the patient while the second is into getting the shortest distance and path from source (Patient's position to destination (shortest hospital). Figure 4.1 to Figure 4.11 answers the first phase while Table 4.1 to Table 4.7 attended to the second phase.

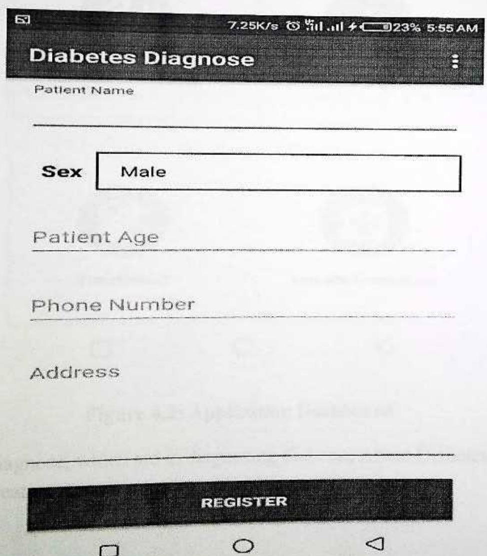

Figure 4.1: Registration Interface

From the figure above patients filled in their information and register as a new user, all the information is uploaded to the cloud mechanism.

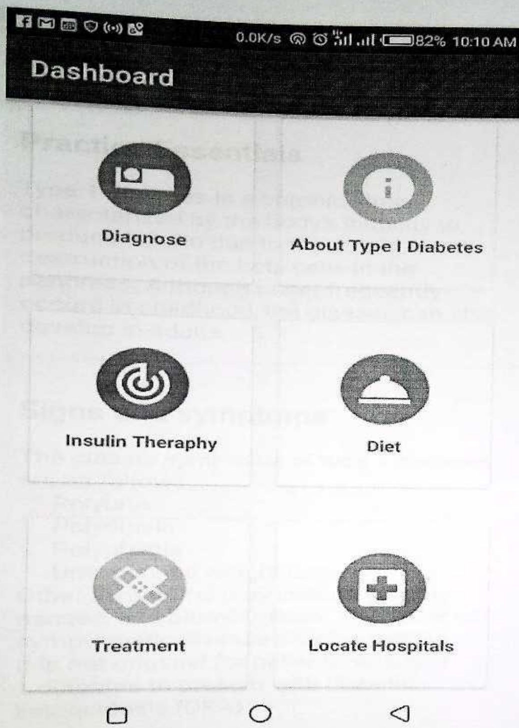

Figure 4.2: Application Dashboard

This figure shows Diagnose, which aid in diagnosing diabetes, About Diabetes, Insulin treatment, diet and treatment.

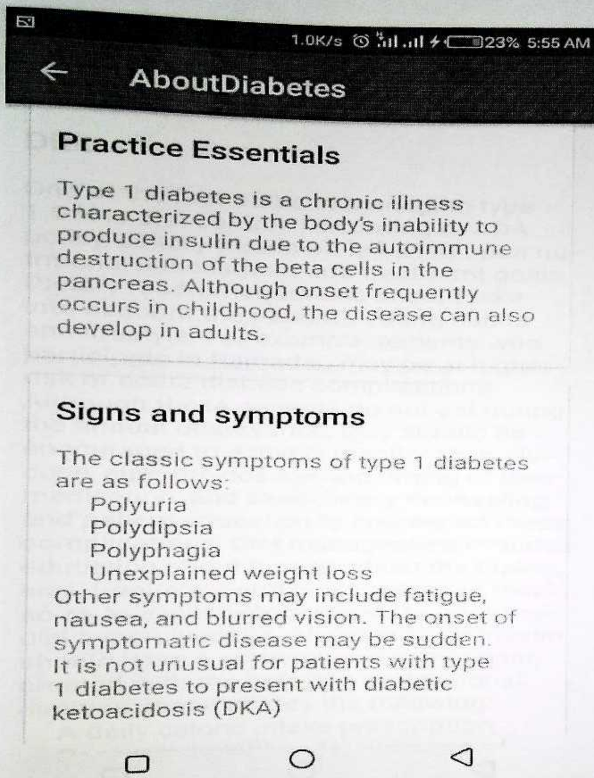

Figure 4.3: Diabetes Information Interface (Sign and Symptoms)

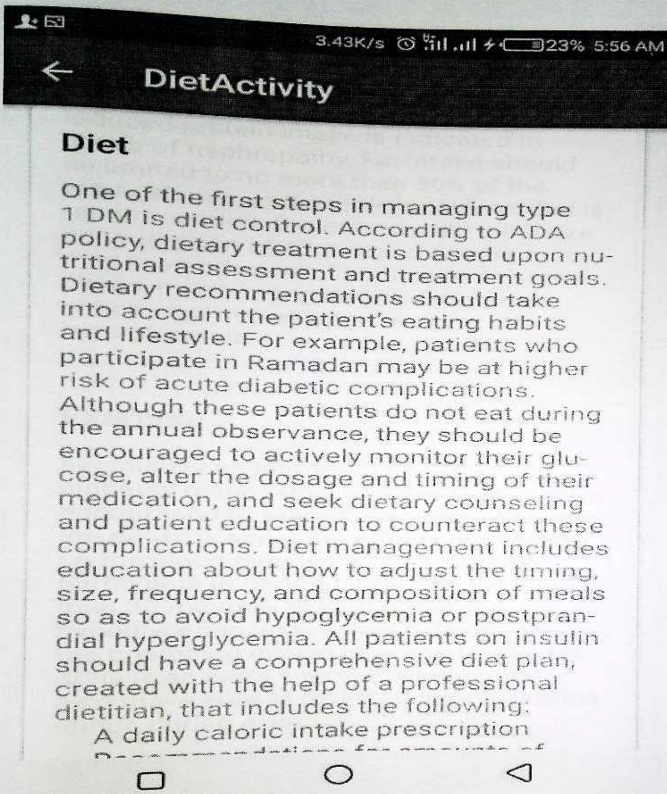

Figure 4.4: Diet Activity Interface (Diet Advice)

Figure 4.4 and Figure 4.5shows the diet activity that is recommended for diabetes patients. and advice on the kind of exercise that diabetes patients should be involved in Treatment activities and treatment information .

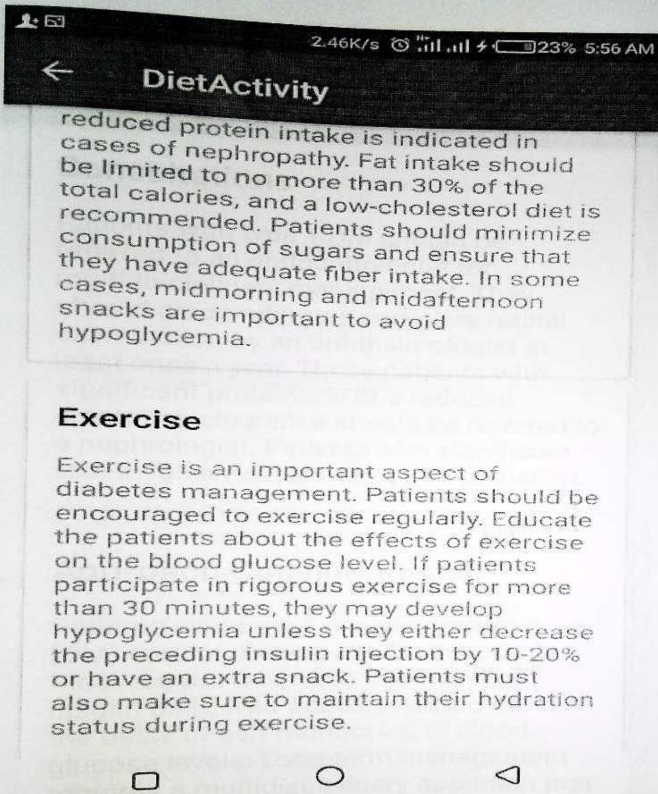

Figure 4.5: Diet Activity interface (Exercise)

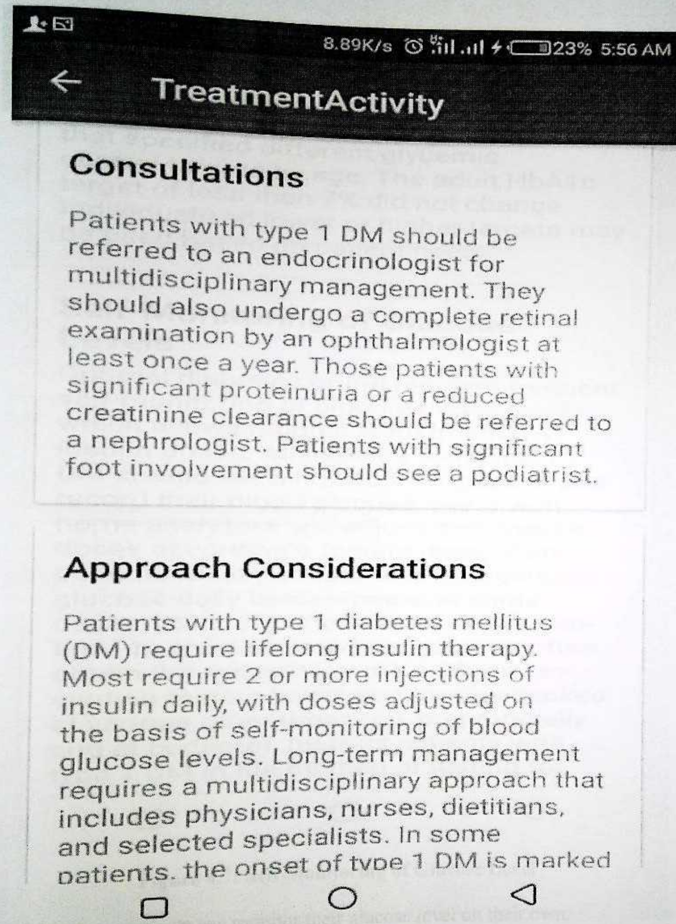

Figure 4.6: Treatment Activity interface

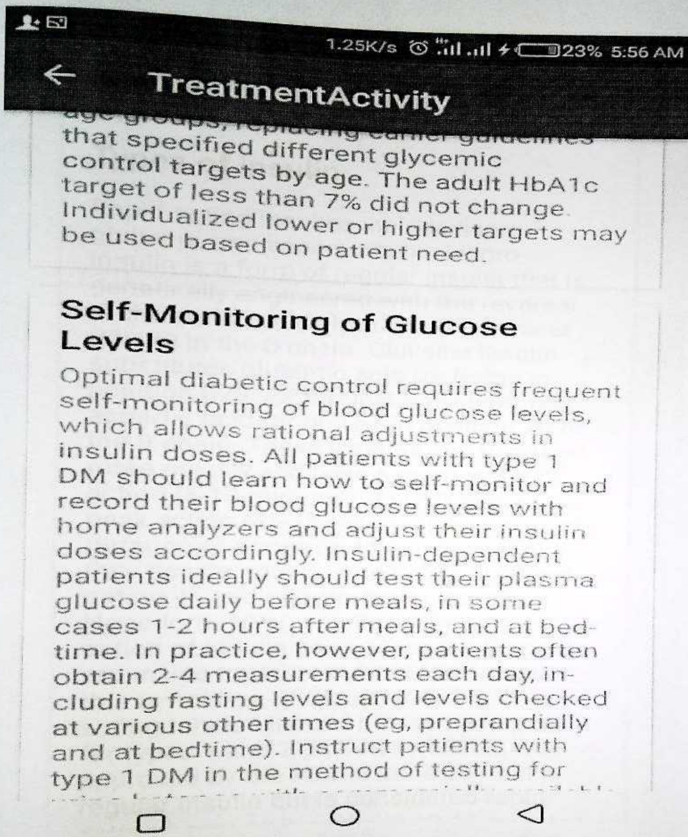

Figure 4.7: Self Monitoring of Glucose Level

This figure shows how patients can monitor their glucose level on their own.

Figure 4.9: Showing Hospitals in a Patient's Environment

Figure 4.9 shows all the hospitals in a patient's environment.

Table 4.1: HOSPITAL A READINGS

PATIENT	PHYSICIAN A_1	PHYSICIAN A_2	PHYSICIAN A_3	AVERAGE
1	20	15	18	17.67
2	15	17	22	18.00
3	17	19	23	19.67
4	16	17	17	16.67
5	15	17	19	17.00
	AVERAGE = 16.60	AVERAGE = 17.00	AVERAGE = 19.8	

Five (5) patients were assigned to hospital A, and Physicians A1 – A3 attended to the patients. Physician A1 spent Twenty (20) minutes, Physician A2 spent fifteen (15) minutes, Physician A3 spent Seventeen (17) minutes, Physician A4 spent Sixteen (16) minutes, and Physician A5 spent fifteen (15) minutes on Patient 1. This is shown in Table 4.1. The average time spent on the patients was calculated and recorded. This is repeated for Patients 2 – 5 in table 4.2 to 4.6 below.

Table 4.2: HOSPITAL B READINGS

PATIENT	PHYSICIAN B_1	PHYSICIAN B_2	PHYSICIAN B_3	AVERAGE
1	24	12	15	17.00
2	22	17	21	20.00
3	18	24	18	20.00
4	17	18	19	18.00
5	14	13	16	14.33
	AVERAGE = 19.00	AVERAGE = 16.80	AVERAGE = 17.80	

Table 4.3: HOSPITAL C READINGS

PATIENT	PHYSICIAN C_1	PHYSICIAN C_2	PHYSICIAN C_3	AVERAGE
1	19	15	23	19.00
2	17	17	22	18.67
3	19	15	25	19.67
4	18	17	16	17.00
5	16	15	14	15.00
	AVERAGE = 17.80	AVERAGE = 15.80	AVERAGE = 20.00	

Table 4.4: HOSPITAL D Readings

PATIENT	PHYSICIAN D_1	PHYSICIAN D _2	PHYSICIAN D_3	AVERAGE
1	20	15	18	17.67
2	15	17	22	18.00
3	17	19	23	19.67
4	15	19	25	19.67
5	17	16	16	16.33
	AVERAGE = 16.80	**AVERAGE = 17.20**	**AVERAGE = 20.80**	

Table 4.5: HOSPITAL E Readings

PATIENT	PHYSICIAN E_1	PHYSICIAN E_2	PHYSICIAN E_3	AVERAGE
1	20	15	18	17.67
2	15	17	22	18.00
3	17	19	20	18.67
4	13	15	18	15.33
5	15	17	17	16.33
	AVERAGE = 16.00	AVERAGE = 16.60	AVERAGE = 19.00	

able 4.6: HOSPITAL F READINGS

PATIENT	PHYSICIAN F_1	PHYSICIAN F_2	PHYSICIAN F_3	AVERAGE
1	20	15	18	17.67
2	15	17	22	18.00
3	17	19	23	19.67
4	16	22	24	20.67
5	18	23	21	20.67
	AVERAGE = 17.2	AVERAGE = 19.20	AVERAGE =21.60	

Table 4.7:OVERALL COMPARISON OF HOSPITALS

	PHYSICIAN 1	PHYSICIAN 2	PHYSICIAN 3
HOSPITAL A	16.60	17.00	19.80
HOSPITAL B	19.00	16.80	17.80
HOSPITAL C	17.80	15.80	20.00
HOSPITAL D	16.80	17.20	20.80
HOSPITAL E	16.00	16.60	19.00
HOSPITAL F	17.20	19.20	21.60

A total average time of **18.05** Minutes

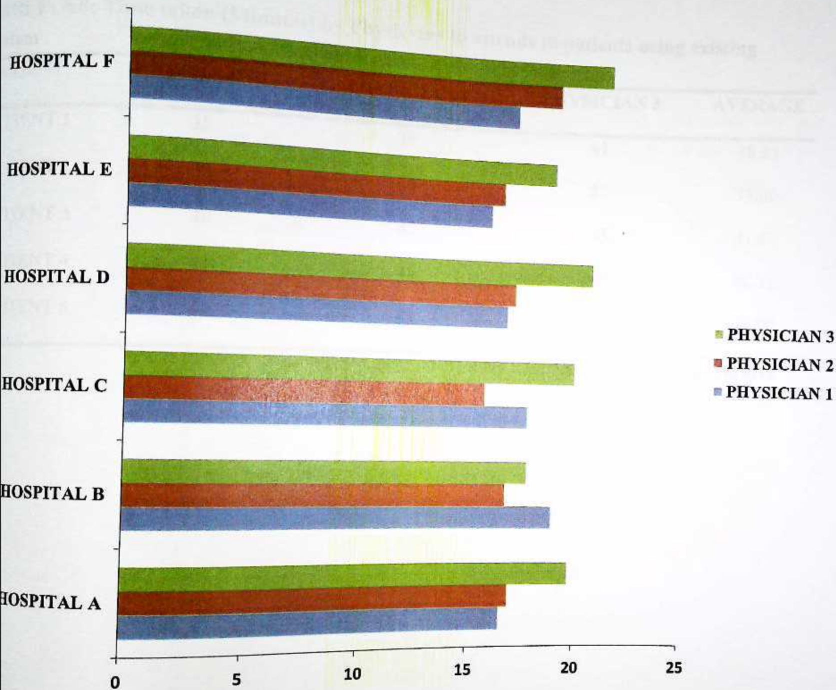

Figure 4.10: Overall Reading of Developed Model

ABLE: 4.8: Time taken (Minutes) by Physicians to attends to patients using existing stem

TIENT	PHYSICIAN 1	PHYSICIAN 2	PHYSICIAN 3	AVERAGE
TIENT 1	35	39	41	38.33
TIENT 2	32	36	37	35.00
TIENT 3	40	42	43	41.67
TIENT 4	41	45	41	42.33
TIENT 5	42	43	38	41.00

Average = 39.66 Minutes

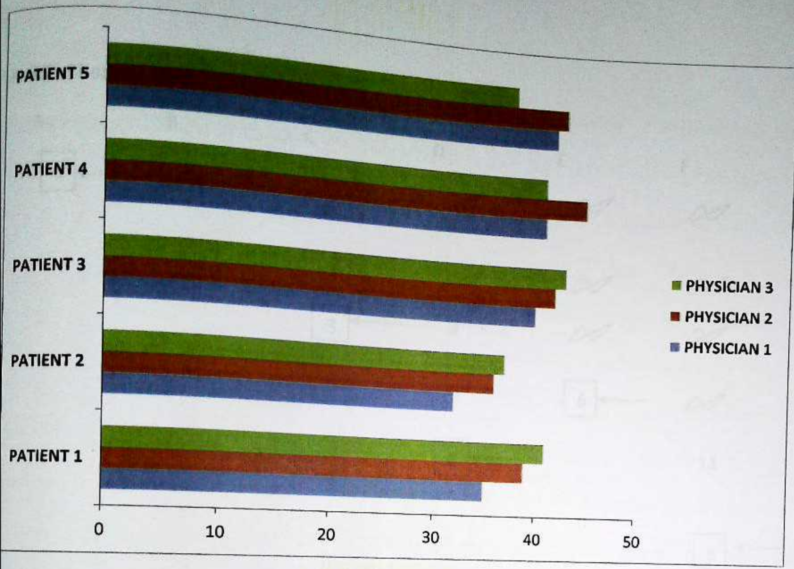

Figure 4.11: Readings of Existing Model

le 4.9: Shortest Path of Hospitals (A,B,C,D,E and F)

A	B	C	D	E	F
[0] ←	∞	∞	∞	∞	∞
	[2] ←	4	∞	∞	∞
		[3] ←	9	∞	∞
			9	[6] ←	∞
			[8] ←		11
					[9] ←

Figure 3.3, the initial location was A= 0 and all other locations is = ∞. Now the direct to A are B and C with C(u,v) to be 2 and 4 respectively. But 2 is less than ∞ and less than erefore the new d(v) = 2 and is selected. Ones it has been selected the next direct paths to B and E with C(u,v) to be 1 and 7 respectively. This gives 3 as the minimum distance as t the former 4 in location C and 9 in E. The minimum out of 4 in C and 9 is selected. The inimum (d(v) = 4). Once a location has been selected it will not be selected again. This s continues until it reaches F. Based on the Dikjstra Algorithm of Table 4.9 the minimum ce obtained was 9kms. The shortest path to location F is indicated by the arrow in Table his is given as F(9)→(8) →(6) →(3) →(2) →(0) in reserve order. This becomes
→C→E→D→F.

DISCUSSION

The mobile application has a lot of interfaces to aid diabetic patients in their treatment. The Registration page is shown in Figure 4.1, patients filled in their information and register as a new user, all the information is uploaded to the cloud mechanism. The mobile application dashboard in Figure 4.2 shows Diagnose, which aid in diagnosing diabetes, About Diabetes, Insulin treatment, diet and treatment. The practice essentials with the sign and symptoms of diabetes is depicted in Figure 4.3, and we listed polyuria, polydipsia, polyphagia and unexplained weight loss as some symptoms. Figure 4.4 shows the diet activity that is recommended for diabetes patients. Figure 4.4 also shows advice on the kind of exercise that diabetes patients should be involved in. Treatment activities and treatment information is shown in Figure 4.5, and several approaches to treatment is adviced. The updated treatment activity is also uploaded to Alibaba Cloud for easy access by physicians. Figure 4.7 shows how patients can monitor their glucose level on their own, Figure 4.8 shows the insulin activity interface which advices patients on how their insulin should be administered, Figure 4.9 shows all the hospitals in a patient's environment.

Our developed model was tested with thirty (30) patients, and we made use of six (6) hospitals designated by A,B,C,D,E and F and eighteen (18) physicians. Five (5) patients were assigned to hospital A, and Physicians A1 – A3 attended to the patients. Physician A1 spent Twenty (20) minutes, Physician A2 spent fifteen (15) minutes, Physician A3 spent Seventeen (17) minutes, Physician A4 spent Sixteen (16) minutes, and Physician A5 spent fifteen (15) minutes on Patient 1. This is shown in Table 4.1. The average time spent on the patients was calculated and recorded. This is repeated for Patients 2 – 5.

The entire process was repeated in the other hospitals B, C, D, E and F, and the average time taken to attend to patients in each hospital is calculated and recorded. This is shown in Figure 4.2- 4.6. The overall reading of the developed model is shown in Table 4.7. It shows the average response time recorded in the six (6) hospitals.

The existing method was also tested with five (5) patients and three (3) physicians, and the time taken by physicians to attend to the patients is recorded, and the average was calculated. This is shown in Table 4.8. A patient around Ado Ekiti made use of the Locate Hospitals feature in Figure 4.2, and the result of hospitals close to the patient is shown in Figure 4.9. The comparison of the time taken by physician in each hospital to attend to their patients using our developed mechanism is represented in Figure 4.10, and we recorded an average time of 18.05 minutes. The time taken by physicians to attend to their patients using the existing method is also shown in Figure 4.11, and this method recorded an average time of 39.66 minutes.

On the issue of the shortest distance and paths, the source of patient was chosen from location A and the best hospital for the treatment is location F via different paths as depicted in Figure 4.9 in chapter three. The result is shown in Table 4.9, where the initial location was A= 0 and all other locations is = ∞. Now the direct paths to A are B and C with C(u,v) to be 2 and 4 respectively. But 2 is than ∞ and less than 4. Therefore the new d(v) = 2 and is selected. Ones it has been selected the next direct paths to B are C and E with C(u,v) to be 1 and 7 respectively. This gives 3 as the minimum distance as against the former 4 in location C and 9 in E. The minimum out of 4 in C and 9 is selected. The new minimum (d(v) = 4). Once a location has been selected it will not be selected again. This process continues until it reaches F. Based on the Dikjstra Algorithm of Table 4.9 the minimum distance obtained was 9kms. The shortest path to location F is indicated by the arrow in Table 4.9. This is given as F(9)→(8) →(6) →(3) →(2) →(0) in reserve order. This becomes A→B→C→E→D→F.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

Diabetes is one of the killer diseases in the world. Although this cannot be cured but can be manage has reveal by scholars. The management of this disease is a function of early retrieval of patient Information when the sugar level rises. It is also a function of getting the good hospital that will handle the involved patient. In addition, getting the shortest distance from the source (Patient location) to the available hospital is also needs to be addressed. This work has addressed these challenges by designing a cloud mobile based mechanism that minimizes the time taken for doctors to retrieve patients' information and recommend closest hospitals based on the shortest path. To achieve this, JAVA API was used the used application where the prototype demonstration was carried out with thirty patients with a total of eighteen physicians across six hospitals. Three physicians in each designated hospital attended to 5 patients, and the time taken to attend to each patient using our developed model was recorded and compared with existing method. The Djisktra algorithm was adopted as the solution to achieve the optimal path problem. The reason for the adoption of this algorithm is based on the fact that it is a one source shortest path algorithm. The algorithm made use of six hospitals; A,B,C,D,E and F having 2,4,1,7,3,2,1 and 5 kms as the distances from one location to another on the graph.

The prototype demonstration recorded an average of 17.802, 17.866, 17.868, 18.268, 17.200, and 19.336 Minutes across the six hospitals, the existing system was also demonstrated using same conditions, and an overall average time of 39.66 Minutes was recorded. Based on the six hospitals used in the experiment, and with the use of relaxation approach of the Djikstra algorithm given by $d[v] = d[u] + c[v]$, the result obtained from Source A (Patient) to destination F (Shortest Distance to the patient's location) was 9km.

5.2 CONCLUSION

Late retrieval of Patients' Information by Doctors may lead to death of such patient. The developed mechanism has proved to achieve success in tackling issues of late response and also getting the shortest path to hospital with right physician. In addition, this research also provided a user friendly additional information; like types of food to be taken by diabetes patients, and how to do self test.

Comparison tests were done between the existing system and the developed system based on response time as the major parameter. The developed mechanism showed a great reduction in the time taken by physicians to attend to diabetic patients due to the fast access to Information by Doctors. The average time taken was recorded at 18.05 minutes, while the existing method recorded an average of 39.66 minutes. The issue of shortest path was also addressed based on the used Djisktra Algorithm. The introduction of this mechanism was able to save an average of 21.61 minutes. This research has been able to tackle the recurrent issue of the time, which has contributed to numerous deaths of diabetic patients in Nigeria.

5.3 RECOMMENDATION

The number of deaths recorded due to the increased time taken by physicians in attending to patients has caused several deaths. This research has been able to reduce the time taken to attend to diabetic patients, and also recommend nearby hospitals to diabetic patients in transit.

This research will be of a great help to diabetes patients in Nigeria if the Federal Government can implement the application.

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APPENDIX

```
package com.ssaurel.dijsktra;

public class Edge {

private int fromNodeIndex;

private int toNodeIndex;

private int length;

public Edge(int fromNodeIndex, int toNodeIndex, int length) {

this.fromNodeIndex = fromNodeIndex;

this.toNodeIndex = toNodeIndex;

  this.length = length;

 }

 public int getFromNodeIndex() {

  return fromNodeIndex;

 }

 public int getToNodeIndex() {

  return toNodeIndex;

 }

 public int getLength() {

  return length;

 }
```

```
//determines the neighbouring node of a supplied node, based on the two nodes connected by
this edge
public int getNeighbourIndex(int nodeIndex) {
if(this.fromNodeIndex == nodeIndex) {
return this.toNodeIndex;
} else {
return this.fromNodeIndex;
}
}
}
```

```
package com.ssaurel.dijsktra;

import java.util.ArrayList;

public class Node {
private int distanceFromSource = Integer.MAX_VALUE;
private boolean visited;
private ArrayList<Edge> edges = new ArrayList<Edge>(); // now we must create edges

public int getDistanceFromSource() {
  return distanceFromSource;
}
```

```
public void setDistanceFromSource(int distanceFromSource) {
this.distanceFromSource = distanceFromSource;
}
public boolean isVisited() {
return visited;
}
public void setVisited(boolean visited) {
this.visited = visited;
}
public ArrayList<Edge> getEdges() {
return edges;
}
public void setEdges(ArrayList<Edge> edges) {
this.edges = edges;
}
}
package com.ssaurel.dijsktra;
import java.util.ArrayList;
// now we must create graph object and implement dijkstra algorithm
public class Graph {
```

```
private Node[] nodes;

private int noOfNodes;

private Edge[] edges;

private int noOfEdges;

public Graph(Edge[] edges) {

 this.edges = edges;

 // create all nodes ready to be updated with the edges

 this.noOfNodes = calculateNoOfNodes(edges);

 this.nodes = new Node[this.noOfNodes];

 for (int n = 0; n < this.noOfNodes; n++) {

  this.nodes[n] = new Node();

 }

 // add all the edges to the nodes, each edge added to two nodes (to and from)

 this.noOfEdges = edges.length;

 for (int edgeToAdd = 0; edgeToAdd < this.noOfEdges; edgeToAdd++) {

  this.nodes[edges[edgeToAdd].getFromNodeIndex()].getEdges().add(edges[edgeToAdd]);

  this.nodes[edges[edgeToAdd].getToNodeIndex()].getEdges().add(edges[edgeToAdd]);

 }

}
```

```
private int calculateNoOfNodes(Edge[] edges) {
 int noOfNodes = 0;

 for (Edge e : edges) {
  if (e.getToNodeIndex() > noOfNodes)
   noOfNodes = e.getToNodeIndex();
  if (e.getFromNodeIndex() > noOfNodes)
   noOfNodes = e.getFromNodeIndex();
 }

 noOfNodes++;

 return noOfNodes;
}

// next video to implement the Dijkstra algorithm !!!
public void calculateShortestDistances() {
 // node 0 as source
 this.nodes[0].setDistanceFromSource(0);
 int nextNode = 0;

 // visit every node
 for (int i = 0; i < this.nodes.length; i++) {
  // loop around the edges of current node
  ArrayList<Edge> currentNodeEdges = this.nodes[nextNode].getEdges();
```

```
for (int joinedEdge = 0; joinedEdge < currentNodeEdges.size(); joinedEdge++) {
int neighbourIndex = currentNodeEdges.get(joinedEdge).getNeighbourIndex(nextNode);

// only if not visited
if (!this.nodes[neighbourIndex].isVisited()) {
 int tentative = this.nodes[nextNode].getDistanceFromSource() +
currentNodeEdges.get(joinedEdge).getLength();

  if (tentative < nodes[neighbourIndex].getDistanceFromSource()) {
   nodes[neighbourIndex].setDistanceFromSource(tentative);
  }
 }
}

// all neighbours checked so node visited
nodes[nextNode].setVisited(true);

// next node must be with shortest distance
nextNode = getNodeShortestDistanced();
}
}

// now we're going to implement this method in next part !
private int getNodeShortestDistanced() {
 int storedNodeIndex = 0;
 int storedDist = Integer.MAX_VALUE;
```

```java
for (int i = 0; i < this.nodes.length; i++) {

int currentDist = this.nodes[i].getDistanceFromSource();

if (!this.nodes[i].isVisited() && currentDist < storedDist) {

storedDist = currentDist;

storedNodeIndex = i;

}

}

return storedNodeIndex;

}

// display result

public void printResult() {

String output = "Number of nodes = " + this.noOfNodes;

output += "\nNumber of edges = " + this.noOfEdges;

for (int i = 0; i < this.nodes.length; i++) {

output += ("\nThe shortest distance from node 0 to node " + i + " is " +
nodes[i].getDistanceFromSource());

}

System.out.println(output);

}
```

```
public Node[] getNodes() {
return nodes;
}

public int getNoOfNodes() {
return noOfNodes;
}

public Edge[] getEdges() {
return edges;
}

public int getNoOfEdges() {
return noOfEdges;
}

}
```

```
package com.ssaurel.dijsktra;

public class Main {

public static void main(String[] args) {
Edge[] edges = {
new Edge(0, 2, 1), new Edge(0, 3, 4), new Edge(0, 4, 2),
new Edge(0, 1, 3), new Edge(1, 3, 2), new Edge(1, 4, 3),
```

```
        new Edge(1, 5, 1), new Edge(2, 4, 1), new Edge(3, 5, 4),
        new Edge(4, 5, 2), new Edge(4, 6, 7), new Edge(4, 7, 2),
        new Edge(5, 6, 4), new Edge(6, 7, 5)
    };

    Graph g = new Graph(edges);
    g.calculateShortestDistances();
    g.printResult(); // let's try it !
  }
}
```