SIMULATION OF 4G NETWORK IN HEALTHCARE

BY

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ABSTRACT

This project is a simulation of 4G network in healthcare project for academic purpose. 4G network is the fourth generation of cellular network standardized by 3rd Generation Partnership Project (3GPP). 4G supports wireless broadband which provides a way for users to get an Internet connection without a fixed wired connection from Internet Service Provider (ISP).

For the research purpose, testing 4G network in real world would be costly. Hence, testing in the simulation environment is the most suitable way. OMNeT++ provides the open-source framework and effective way to test 4G network before implementing in real world. The simulation of 4G network in healthcare are carried out in OMNeT++.

The primary objective behind this paper is to evaluate performance of 4G network in healthcare and propose further improvement can be made in it. The simulator will show the results of performance evaluation obtained.

TABLE OF CONTENTS

TITLE PAGE	**i**
REPORT STATUS DECLARATION FORM	**ii**
FYP THESIS SUBMISSION FORM	**iii**
DECLARATION OF ORIGINALITY	**iv**
ACKNOWLEDGEMENTS	**v**
ABSTRACT	**vi**
TABLE OF CONTENTS	**vii**
LIST OF FIGURES	**x**
LIST OF TABLES	**xi**
LIST OF ABBREVIATIONS	**xii**
CHAPTER 1 INTRODUCTION	**1**
1.1 Problem Statement and Motivation	2
1.2 Objectives	4
1.3 Project Scope and Direction	4
1.4 Contributions	5
1.5 Report Organization	5
CHAPTER 2 LITERATURE REVIEW	**6**
2.1 Ambient Assisted Living (AAL)	7
2.2 Community Healthcare	8
2.3 Mobile H-IoT	9
2.4 Wearable Device Access	9
2.5 Blood Pressure Monitoring	10
2.6 Oxygen Saturation Monitoring	10
2.7 Rehabilitation System	11
2.8 Wheelchair Management	11
2.9 Internet of Health Things and Digital Telehealth	12
2.10 Challenges for IoT in Healthcare	13

CHAPTER 3 SYSTEM MODEL **14**

3.1 System Requirement 14

3.1.1 Hardware 14

3.1.2 Software 14

3.1.2.1 OMNeT++ 15

3.1.2.2 INET Framework 15

3.2 4G Network Architecture 16

3.3 UE 16

3.4 E-UTRAN 17

3.5 EPC 17

3.6 Protocol Architecture 18

3.6.1 PDCP Layer 18

3.6.2 RLC Layer 19

3.6.3 MAC Layer 19

3.6.4 PHY Layer 20

3.6.5 RCC Layer 20

CHAPTER 4 SYSTEM DESIGN AND SIMULATION **21**

4.1 Overall Architecture Design 21

4.2 Simulation Model 21

4.3 Simulation Specification 22

4.4 Simulation Configuration 22

4.5 Additional Modules 27
4.5.1 Configurator 27
4.5.2 LTE Binder 27
4.5.3 LTE Deployer 28

CHAPTER 5 RESULTS AND DISCUSSION 29
5.1 Performance of 4G 29
5.2 Performance Measurement 30
5.3 Connectivity Test 31
5.4 Project Challenges 32
5.5 Objectives Evaluation 33

CHAPTER 6 CONCLUSION 35

REFERENCES 36

APPENDIX A
A.1 Weekly Report A-1
A.2 Poster A-7

PLAGIARISM CHECK RESULT

Place your Turnitin plagiarism checking result here.

CHECK LISTS

Place the check lists here at end of report. Check items using '√' and sign.

LIST OF FIGURES

Figure Number	Title	Page
Figure 1.1	Lack of Connectivity in Healthcare System	3
Figure 2	Roadmap of Development of H-IoT Use Cases	6
Figure 2.1	Graphical Representation of AAL System	7
Figure 2.2	Remote Patient Monitoring	8
Figure 2.3	Different of Wearable Technology	9
Figure 2.9	Remote Medical Examination of Patients by Doctors in IoT	12
Figure 3.2	4G Network Architecture	16
Figure 3.5	4G Network User and Control Plane	18
Figure 4.2	Simulation of Patients to Hospitals Network	21
Figure 5.3.1	Server Request	31
Figure 5.3.2	Jitter of Ping	32

LIST OF TABLES

Table Number	Title	Page
Table 3.1	Specifications of Laptop	14
Table 5.1.1	Performance of 4G	29
Table 5.1.2	Experiment Setting	29
Table 5.2.1	Latency Standard	30
Table 5.2.2	Packet Loss Ratio Standard	30
Table 5.2.3	Jitter Standard	30

LIST OF ABBREVIATIONS

AAL	Ambient Assisted Living
ARQ	Automatic Repeat Request
BCG	Ballistocardiogram
BP	Blood Pressure
CH	Community Healthcare
DPI	Deep Packet Inspection
ECG	Electrocardiogram
EPC	Evolved Packet Core
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
H-IoT	Healthcare Internet of Things
HR	Heart Rate
HSS	Home Subscriber Server
IoHT	Internet of Health Thing
IoT	Internet of Things
MAC	Medium Access Control
M-IoT	Mobile Internet of Things
MME	Mobility Management Entity
MT	Mobile Terminal
NED	Network Description
PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PGW	Packet Data Network Gateway
PHY	Physical Layer
QoS	Quality of Service
RLC	Radio Link Control
RRC	Radio Resource Control
RSRP	Reference Signal Received Power
UE	User Equipment
USIM	Universal Subscriber Identity Module
VOD	Video On Demand

Chapter 1

Introduction

Healthcare heavily relies on the 4G networks and other communication technologies for smart healthcare applications. The Internet of Things (IoT) is a megatrend in the 4th generation of technologies that can provide outstanding interconnection to each identifiable smart object and devices [1] in Internet infrastructure in the past decade. IoT is influencing every aspect of our existence, from how we react to how we act. Everything from air conditioners we can operate with our smartphones, Smart Cars that show us the shortest route, or our Smartwatch that monitors our daily activities. IoT refers to a vast network of connected items [1]. These devices gather and share data about how we are used and the environment in which we are operated. Sensors, which are present in every physical object, are used in every step of the process [2]. It can be our mobile phone, electrical appliances, Pecos barcode sensors, traffic lights and almost everything that we come across in day-to-day life [2].

IoT is now more effective when it comes to healthcare systems. IoT in the healthcare industry specifically integrates sensors, microcontrollers, and many other components to analyze and send sensor data to the cloud, where it is subsequently sent to caregivers [23]. Telemedicine, home diagnostics, wearable health monitor technologies, and even pop-up retail venues are radically altering how and where medical decisions are made and treatment is provided [23]. Healthcare professionals are starting to understand how important remote patient care is. House calls, a growing trend in remote healthcare, are now possible thanks to technology, which has also made it possible to treat patients at home more quickly while also lowering intervention costs and raising the standard of care [22].

The drive for patients to use wearables and other customized technologies to acquire a range of readings that they can immediately compare to a number of benchmarks and determine whether to proceed to a healthcare professional is an alternative to hospital-run healthcare programs [26]. Instead, some patients may choose to use health social networks to share information from their automated readings, engage in Q&A sessions with medical professionals, or even seek out emotional support. Patients may also utilize apps to discover a connection between their disease and drug interactions or harmful habits in order to decide how to improve their health [25]. Patients may also choose to use home testing kits or personalized genomics services, including environmental testing, projected bio-simulation, and testing of blood and other biomarkers.

Local convenience store healthcare is the phrase used to describe this kind of care. For those who choose to consult a healthcare expert, several options may arise that redirect the patient's away from a hospital, retail outlets in common city centers and can accept patients in far-off places, look over their records, and determine whether to continue providing them with medical care [24]. Doctors on call are also immediately available to patients wherever to respond to inquiries and give instructions regarding their medical care via video, chat, email, or mobile phones.

1.1 Problem Statement and Motivation

Due to the increase in many health problems in today's world, health support for everyone should be considered as very significant. A perfect healthcare system would provide seamless connectivity, allowing patients and healthcare service providers to work together across organizational and geographical borders [2]. To enable better diagnosis and medical services, it is important to promote the implementation of secure health data sharing services and applications.

However, there are a number of issues, including a lack of patient health histories that are thorough and full and a lack of a secure and reliable platform for sharing health data that can be used to process information gathered from different healthcare systems. Figure 1.1 summarized these issues which act as barriers to delivering personalized healthcare.

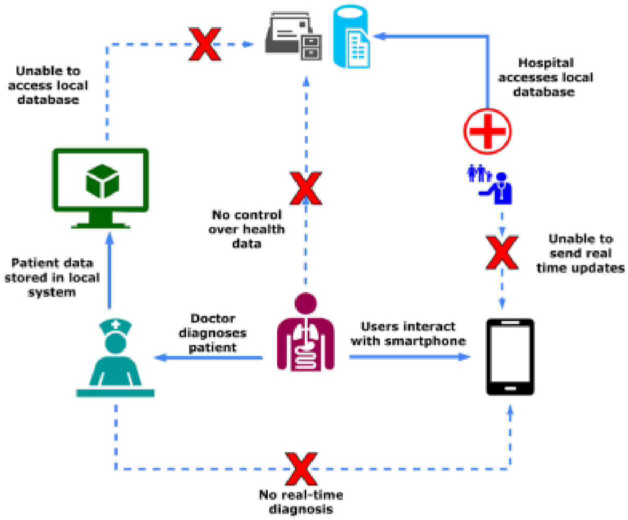

Figure 1.1 Lack of Connectivity in Healthcare System

In an existing healthcare system, doctors who are providing care for the patient make a diagnosis and manually enter the patient's health information into the clinic's or hospital's main database. Real-time diagnostics are impossible because there is no connection between the hospital's system and user's devices. Besides that, the doctors can access to the database of hospital that stored all of the patient's medical information and medical history. On the other hand, patients cannot access over their own medical data. Hence, there is a lack of data confidentiality, integrity, and openness.

IoT technology will be used by 90% of healthcare organizations by 2020. One of the problems facing today's society is the need to increase the effectiveness of healthcare and offer patients high-quality care [3]. The effective healthcare depends on speed and accuracy which are supporting the many people and enormous devices that connected to IoT. Therefore, the primary reason for conducting research in the healthcare industry is to offer a thorough grasp of the technologies that have been applied in recent years.

1.2 Objectives

The healthcare sector has advanced significantly from the manual collection of medical data in physical records to electronic medical records and remote therapy, where doctors can use IoT devices to perform remote real-time health monitoring and diagnosis.

- To study the quantitative approach to discuss issues related to 4G network architecture for real-time applications
- To study literature about healthcare IoT applications and challenges for IoT in healthcare
- To analyze the performance for 4G network by using real-world parameters
- To study the simulation environment in OMNeT++

1.3 Project Scope and Direction

This report will cover some general idea on various research challenges that are faced by many authors. The majority of ongoing studies are effective at keeping monitors on the patient and sending information to the monitoring center. Due to IoT's limited storage capacity for processing some encryption algorithms, privacy is one of the primary concerns. Cloud storage aids in managing enormous amounts of system data, and complexity increases when the IoT is integrated. In terms of scalability and dependability, the current IoT system offers reliable patient monitoring. In order to better understand the services provided by each layer and to explore the general architecture of the H-IoT, this project will attempt to deploy simulation tools.

Besides that, this research would cover issues related to factors that can affect performance evaluation of simulate 4G network. The technical details of 4G network implementation with IoT devices in simulation environment of OMNeT++ will be provided and the results will be critically evaluated.

1.4 Contributions

The contribution of this project is significant to the sector of H-IoT. With this simulation of 4G network in healthcare, developers of healthcare system could be able to learn more information about generic architecture for H-IoT applications. Using simulation modelling, real-world issues in healthcare can be safely and effectively solved. In addition, a comparison of the benefits and drawbacks of implementing various healthcare systems to make a decision. Otherwise, this research might help some people demonstrate a simulation in complex care situations. From cognitive skills perspective, it could improve people’s critical thinking, creative thinking and problem solving.

1.5 Report Organization

This report is organized into 6 chapters: Chapter 1 Introduction, Chapter 2 Literature Review, Chapter 3 System Model, Chapter 4 System Design and Simulation, Chapter 5 Results and Discussion, Chapter 6 Conclusion.

Chapter 1 is the introduction which includes problem statement and motivation, objectives, project scope and direction, contributions and report organization. Chapter 2 is the literature review which is about several existing IoT about healthcare which are the healthcare IoT service stack, healthcare IoT application stack and the internet of health things and digital telehealth in the market to find out the challenges for IoT in healthcare sector. Chapter 3 is discussing the overall system model of simulation. Chapter 4 is the details on how to implement the system design and simulation. Chapter 5 reports the results and discussion. Chapter 6 is the conclusion of the project.

Chapter 2

Literature Review

Medical data is transformed by IoT into insights for better patient care. Modern healthcare is increasingly technologically sophisticated, and everything is connected. IoT is extremely important in healthcare as a result. All the data can be stored in the cloud using gadgets like connected sensors and other wearable technology, which enables caregivers to readily view patients' real-time data.

Healthcare IoT Service Stack

The variety of healthcare services and applications that can be established through integrating IoT with healthcare systems. The development plan for an extensive range of healthcare IoT use cases is illustrated in figure 2. In [4], the authors note that the intended application and required quality of services (QoS) are taken into consideration while developing healthcare systems.

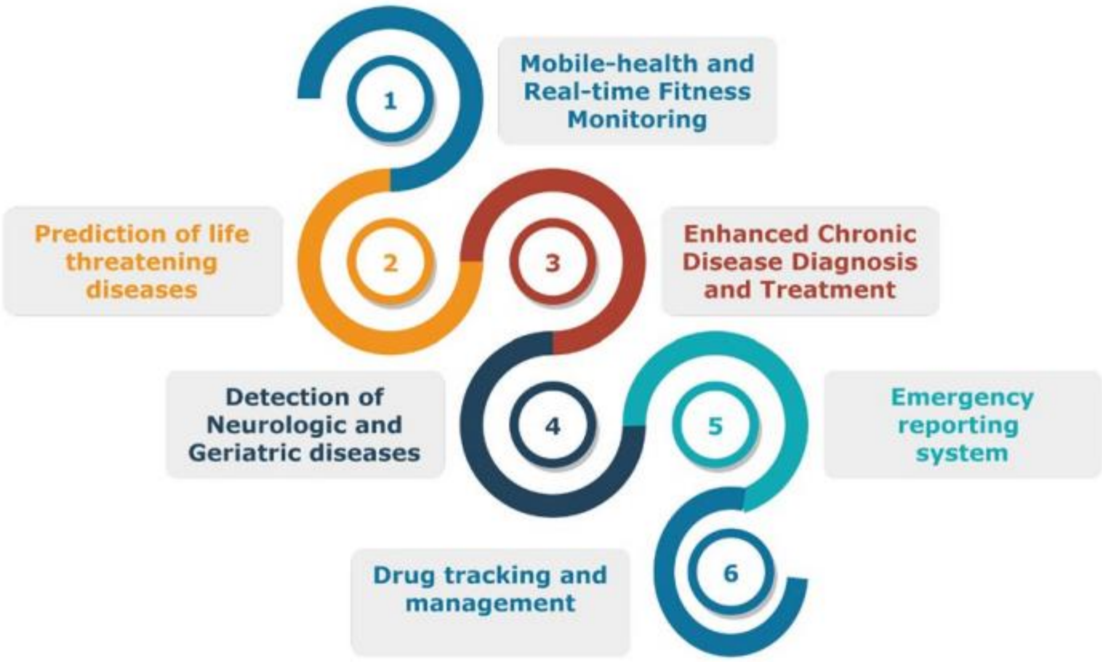

Figure 2 Roadmap of Development of H-IoT Use Cases

2.1 Ambient Assisted Living (AAL)

The concept of AAL is to provide an independent as well as safety and healthy lifestyle at home for elderly people by enabling intelligent environment. This application is quite helpful for elderly people who struggle from some chronic disease due to becoming older. By taking preventive medications before situations worsen, physical data acquired by wearable technology can predict dangerous diseases that affect the elderly and save their lives [5]. AAL offers a number of services that provide a comfortable and safe lifestyle by enabling the environment intelligent, such as ongoing monitoring for chronic diseases, delivering fresh food depending on demand, and connecting with friends and family. Figure 2.1 is presented an AAL overall physical architecture. In [6], by utilizing RFID and NFC-based mechanisms, the authors make the AAL system more secure and make it possible for efficient health monitoring. However, their solution fails to deliver the necessary QoS, and storage constraints prevent it from being implemented in practice.

Figure 2.1 Graphical Representation of AAL system

2.2 Community Healthcare

There are many treatments such as chronic and long-term conditions are available outside the hospital. Community healthcare cover all pharmacy and clinic outside of a hospital. It brings all of care closer to where people live and spend most of their time. Community healthcare moves all of care from the hospital to the community setting. For example, patients who at home can have the treatments in their comfort place where were supported by their family and doctors. For patients, including the elderly and disabled, accessing services locally is more convenient than travelling to hospitals for outpatient appointments or being admitted to hospital. The community healthcare usually will collaborate with local government to cover more audience. There is awareness raised and preventive or health-improving treatments provided to the audience since Community healthcare service is considered essential for monitoring rural healthcare [2] [4]. In [7], a secure Community healthcare that supports authentication and authorisation for a centralized community network has been mentioned by the authors.

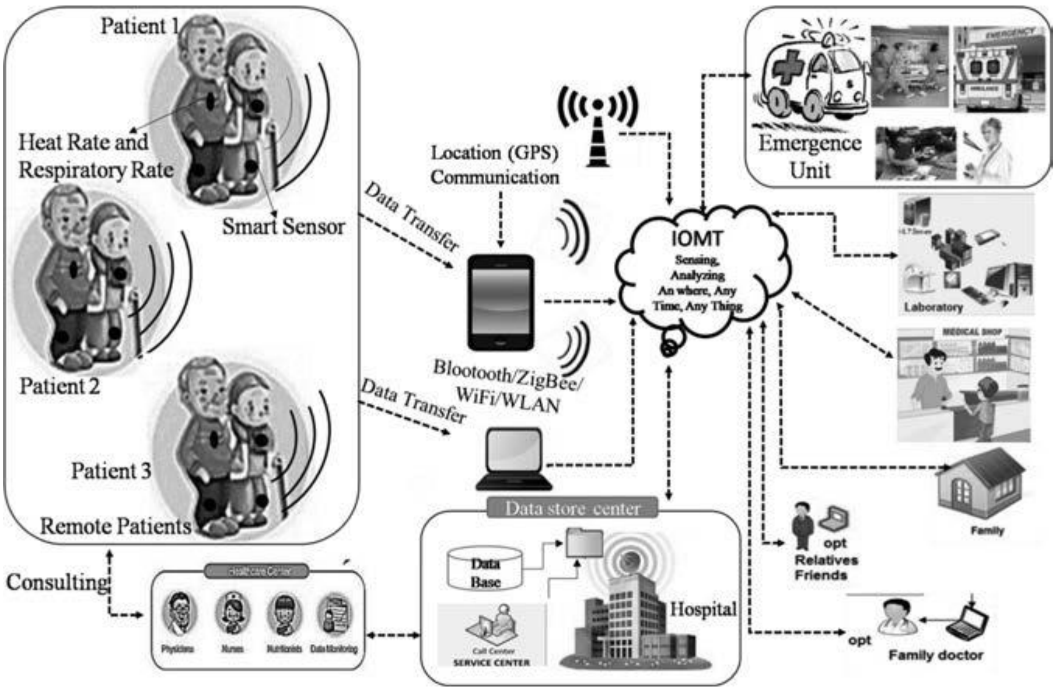

Figure 2.2 Remote Patient Monitoring

2.3 Mobile H-IoT

Mobile devices and sensors are the primary focus of mobile H-IoT in order to collect health-related data. In [11], m-health systems that integrate 4G technology to transmit health information acquired from sensors and smartphones to the cloud have been described by the authors. Context awareness and mobility are the main obstacles to the practical deployment of their system. Their suggested approach has the shortcoming of providing no way to identify whether the network's power consumption is low.

2.4 Wearable Device Access

Wearable health technology enables to track human physical activities and behaviours continuously, as well as physiological and biochemical parameters in daily life [8]. Though the use of electrocardiogram (ECG), ballistocardiogram (BCG) and other equipment, the most examined data include significant signs like heart rate, blood pressure, and body temperature, as well as blood oxygen saturation, posture, and physical exercise. Wearable cameras or video equipment might be capable of providing extra clinical information. Wearable gadgets can be linked to watches, eyeglasses, clothing, gloves, and even shoes as showed in Figure 2.3. Additionally, wearable devices may develop into skin-attachable devices [9]. The user's smartphone or the cloud will receive the data collected by the wearable devices for storing and analysing [10].

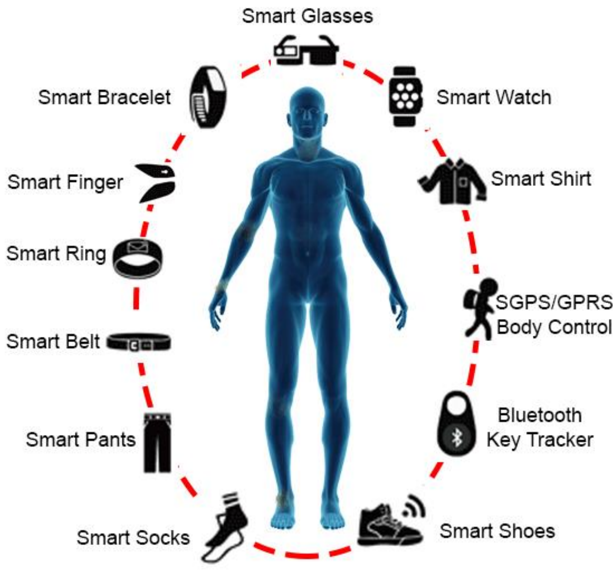

Figure 2.3 Different of Wearable Technology

Healthcare IoT Application Stack

There are various H-IoT applications which are developed to assist people in keeping track of their own health conditions, including heart disease, diabetes, pregnancy, mental health, and more.

2.5 Blood Pressure Monitoring

One of the most significant physiological aspects that affect an individual is their blood pressure (BP). BP monitors that are secure and easy to use are becoming more widespread [12]. As the healthcare system has developed, IoT devices and sensors have been integrated into the healthcare equipment or systems to provide easier communication between patients, doctors and caregivers. IoT sensor that captures real-time data on patient BP levels is connected to an electronic blood pressure monitor. A smartphone kit and blood pressure kit make up blood pressure monitoring system which is IoT-based, as stated in [13]. Based on the IoT network, an intelligent terminal locates the user. The communication module broadcasts sensor data into the network. The system that proposed by the authors has key benefit is that it is effective and secure.

2.6 Oxygen Saturation Monitoring

The pulse oximeter is a tool that continually and painlessly monitors the patient's blood oxygen saturation [12]. Numerous medical procedures use continuous monitoring pulse oximeters to measure both the heart rate (HR) and blood oxygen saturation levels. The IoT sensor that is attached to the patient's body will sense and track the patient's heart rate and oxygen levels, which may restrict their activity [14]. In [15], the scenario of a home respiratory therapy system utilizing the Monere Telecare Platform has been brought up by the authors. In this instance, patients with chronic pulmonary disorders have their blood oxygen saturation continuously monitored using a wearable pulse oximeter. Their system's key benefit is that the sensor is cheap and utilize less power. The data is transmitted from the device to the cloud using Bluetooth communication technology.

2.7 Rehabilitation System

A rehabilitation system can be used to return people with various physical or mental diseases to their regular lifestyles in order to address concerns with the ageing population and when there is a lack of medical experts [12]. There is an efficient treatment available through a community-based smart rehabilitation system. By using an ontology-based automation designing method coupled with an IoT-based smart rehabilitation system, medical resources may be allocated and interacted with in a convenient and adequate manner in accordance with patient needs [16].

2.8 Wheelchair Management

People who are physically disabled or have a physical disease and are unable to walk use wheelchairs. In [17], an automated wheelchair management system based on several sensors has been mentioned by the authors. A pressure cushion (a resistive pressure sensor) will be used to detect whether a person is leaving a wheelchair. Another accelerator sensor included in a smart wheelchair can detect when the wheelchair is about to fall. A variation created by Intel has the wheelchair collecting and storing user essential information for use in location assessments.

2.9 Internet of Health Things and Digital Telehealth

Internet of Health Things (IoHT) is a development of IoT that use communication infrastructure to link patients with healthcare facilities for the purpose of monitoring and controlling important signals of human body [18]. In rural places with limited access to qualified healthcare providers due to a variety of causes, telemedicine is becoming more and more common [19]. Figure 2.9 shows the remote data acquisition using IoHT system. For instance, monitoring of blood pressure, heart rate, oxygen saturation, diabetes, and vital body signs can be monitored remotely. Using a local gateway, the sensors send patient data to the cloud. The doctor analyzes the data using mobile or desktop application before advising the patient or caregivers who taking care of the patient about the results of report generated [20].

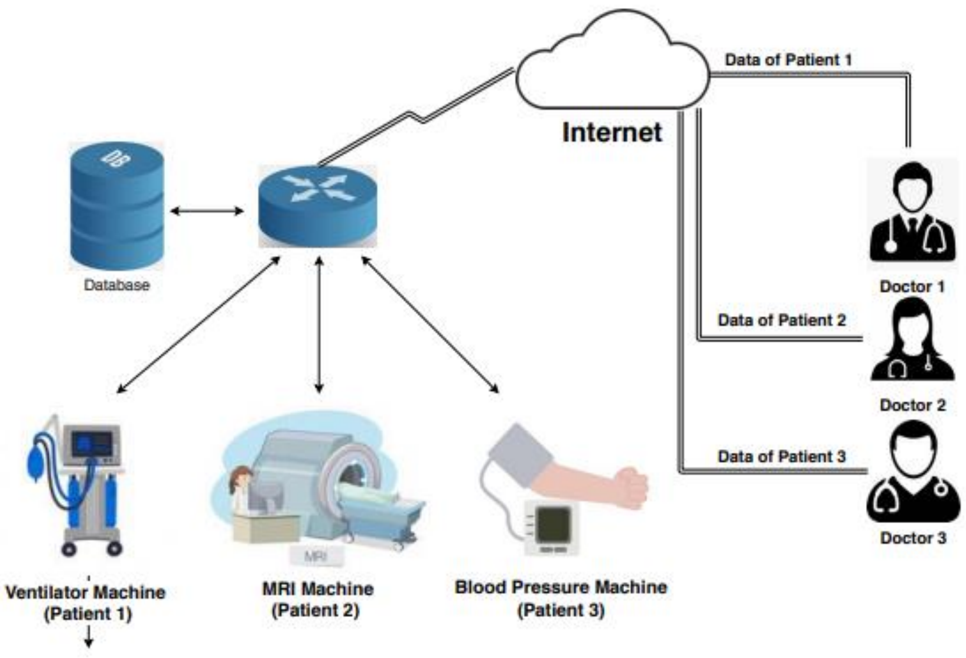

Figure 2.9 Remote Medical Examination of Patients by Doctors in IoT

2.10 Challenges for IoT in Healthcare

From the literatures are reviewed, I was able to identify some important constraints to deploying IoT in the healthcare sector as a consequence of our extensive research. My expectation is that the IoT standard in the healthcare domain can be improved if these difficulties are managed appropriately. The challenges are stated below:

Data Privacy

The main issue in the healthcare system is data privacy. The confidentially of any patient's personal medical record is expected. The patient's health information is, however, frequently stored in cloud storage or shared over the network in IoT-based healthcare systems, which can result in a loss of data privacy.

Managing Device Diversity

In an IoT-based healthcare system, device diversity is a significant challenge. There are many kinds of linked devices that have a diverse range of platforms, operating systems, and services. As a result, implementing IoT-based technologies on these various connected devices can often be challenging.

Integration

Another difficult aspect for successfully using IoT in healthcare is integrating various devices and protocols within the network. There are a large number of smartphones connected to the network that actively collect data. The procedure of gathering the information is made more challenging by the many communication protocols.

Concluding Remark: All of the data which is collected by IoT will be transformed into information for better patients care. The H-IoT applications and systems will assist humans to keep tracking health conditions like blood pressure, oxygen saturation and mental health. The challenges of these H-IoT applications and systems are data privacy, managing device diversity and integration.

Chapter 3

System Model

3.1 System Requirement

3.1.1 Hardware

The project will be needed to use a laptop for the research purpose. In table 3.1, there are the recommended requirements for the use of hardware.

Description	**Specifications**
Model	HP Pavilion Laptop 15-ck0xx
Processor	Intel Core i5-8250U
Operating System	Windows 11
Graphic	NVIDIA GeForce GTX
Memory	4GB DDR4 RAM
Storage	256GB SATA SDD

Table 3.1 Specifications of Laptop

3.1.2 Software

Before developing simulation model, two software needed to be installed and downloaded:

3.1.2.1 OMNeT++

OMNeT++ is an object-oriented modular discrete event network simulation framework. It has generic architecture so that it can be and has been used in various problem domains. Some of the domains that has been used for is modelling of wired and wireless communication, networks protocol modelling, modelling of queuing networks, modelling processors validating hardware architecture, evaluating performance aspects for complex software systems. In general, it is just modelling and simulation of any system where there is a discrete event approach that is suitable and can be conveniently mapped into entities communicating by exchanging messages. OMNeT++ provides infrastructure and tools for writing simulations. It is really not a simulator of any concrete.

OMNeT++ simulations can run under various user interfaces, these user interfaces include graphical user interfaces, animating user interfaces which are useful for demonstrating and debugging purpose and there are command-line user interfaces which are very useful for batch execution [21]. Due to its scalable architecture, it may also be used to simulate complex IT systems, queuing and hardware theories even though it is primarily intended for the modelling of communication networks.

For modelling various designs using a higher-level language (NED), OMNeT++ enables a component-based architecture that can be merged and imported into the project. Additionally, the models may be simply integrated within the applications due to its modular architecture and well-developed Graphical User Interface (GUI) [21].

3.1.2.2 INET Framework

INET framework is one of the external extensions available to be used with OMNeT++ when designing and simulating wireless networks. On top of the OMNeT++, the INET framework should be deployed. It is an open-source model. It can be used to replicate wired and mobile networks in addition to wireless ones. It includes implementations of TCP, UDP, IPv4 and IPv6 protocols as well as various other application models. INET framework makes use of modules that communicate by passing messages same as OMNeT++.

3.2 4G Network Architecture

Without providing internet connectivity, none of the network infrastructure technologies are accessible to users. The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) internet access is made available through Evolved Packet Core (EPC) which provides a gateway to transport packets from the LTE domain. There are two types of gateways: Service gateway (S-GW) and Packet Data Network Gateway (P-GW) are modelled. However, the fundamental operation of sending data via the tunnel in the path of the packet gateway has been modelled.

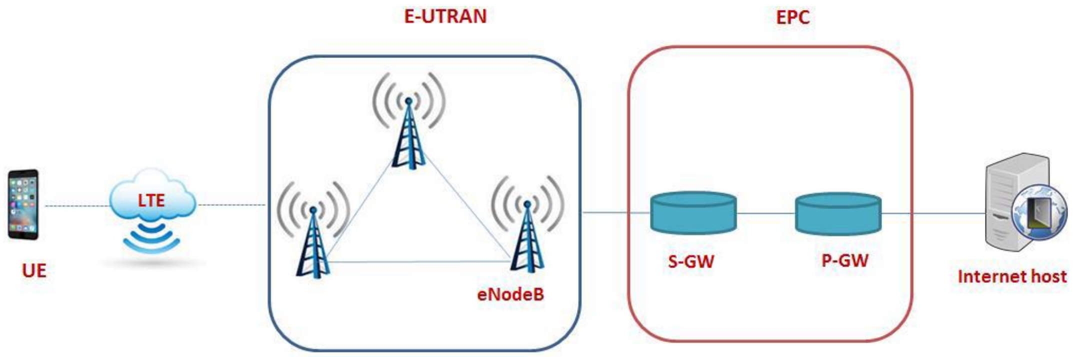

Figure 3.2 4G Network Architecture

3.3 UE

UE primarily consists of variety of the Mobile Terminal's (MT) capabilities, which are accountable for the overall functionality of the call. Besides that, the terminal equipment which is likewise regarded as one of the core UE components, performs data streaming and functions as a Universal Subscriber Identity Module (USIM). User information and network identification are stored in the USIM. The UE such as mobile phone, tablet and laptop has been employed in this simulation of 4G network [21].

3.4 E-UTRAN

In OMNeT++, each protocol is implemented as a stack of nodes that functions as an independent object. The radio communication between UE and EPC was handle via the E-UTRAN. E-UTRAN is made up of one or more eNobeB base stations. The Radio Access Network (RAN) is another name for a component of E-UTRAN. The eNobeB, also known as the eNB, performs the tasks of delivering the E-UTRA user plane ad controlling the plane protocol terminators across the UE [21].

3.5 EPC

EPC is composed of two main components: The S-GW enables communication with other 4G network users and P-GW is in charge of providing connectivity between the UE and external networks like the Internet. It performs the tasks of managing mobility, managing network access and other aspects of network management. All subscriber-related data is stored on the Home Subscriber Server (HSS) that is part of the EPC. The release and configuration of connections between user and the PDN are under the control of the mobility management organization. Additionally, it performs its task by registering the UE authentication location and using valuable data from HSS. The P-GW performs the operations of the GGSN and SGSN, which also denotes the IP network's connectivity. This system is involved with a variety of activities, including IP address assignment, user authentication, QoS, DHCP functions and charging data creation Deep Packet Inspection (DPI) [21].

3.6 Protocol Architecture

The Packet Data Convergence Protocol (PDCP) Layer, the Radio Link Control (RLC) Layer, the Medium Access Control (MAC) Layer and the Physical Layer (PHY) Layer make up the eNobeB protocol architecture under user plane. It contains the Radio Resource Control (RCC) Layer under control plane.

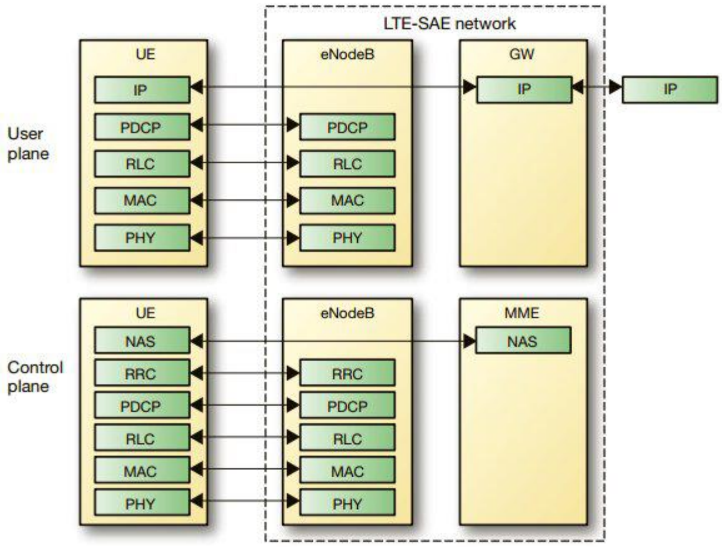

Figure 3.5 4G Network User and Control Plane

3.6.1 PDCP Layer

PDCP layer works in both user and control plane. In control plane, PDCP layer is positioned below the RRC layer and above RLC layer. Data integrity and ciphering are provided to address security-related tasks. It conducts header compression on IP packets, delivering less bytes over the network and enhancing network efficiency. PDCP layer integrates data after obtaining security cues from the RRC layer and then performs ciphering to protect the privacy of message.

3.6.2 RLC Layer

After receiving packets from the PDCP layer, RLC layer resizes them to the MAC layer's recommended size. When a radio resource is assigned to a user, RLC entity is established. It is then eliminated as soon as the resource is released. It stops sending duplicate SDU to the upper layer. RLC entity can be established in different types of reliability modes: transparent mode, acknowledged mode and unacknowledged mode.

Transparent Mode RLC: It serves no purpose since it is a null entity. Transparent Mode RLC is used for RLC layer messages like paging messages that do not require any data protection. The layer above Transparent Mode RLC is RRC layer as these messages avoid the PDCP layer.

Acknowledged Mode RLC: By making it easier to retransmit dropped packets, it enables lossless packet transmission. Acknowledge Mode RLC is used for services like video streaming and file transfer that do not care about delays instead should guarantee no packet loss. It is compatible with radio carries that can transmit and receive in both directions. Lossless transmission is made possible by the usage of ARQ.

Unacknowledged Mode RLC: It is used for packets that are sensitive to delays, such as real-time data transfer (voice). There are no packets lost or corrupted are retransmitted in this mode of operation. According to the size specified by the MAC layer, Unacknowledged Mode RLC segments the packet data units it receives from the PDCP layer. Each RLC PDU is given a sequence number, allowing the receiver to reorder the packets if they arrive out of order. It is compatible with bearers for unidirectional radio. The creation of two Unacknowledged Mode RLCs, one for transmission and another one for reception, to accommodate bidirectional radio carriers.

3.6.3 MAC Layer

RLC layer and PHY layer are linked by MAC which provides communication between PHY layer transport channels and the logical channels of RLC layer. MAC layer includes multiplexing and demultiplexing entity, HARQ entity, control entity and logical channel prioritization entity.

3.6.4 PHY Layer

After being processed by all of the layers above, data is transferred to PHY layer. Transmission is limited to the smallest time unit of 1ms. The 4G network PHY layer manages time and frequency synchronization in addition to RF processing such as modulation and demodulation. It can use Adaptive Modulation and Coding (AMC) techniques to provide detection against channel defects. It calculates CQI and transmits the report to upper layers.

3.6.5 RCC Layer

It manages UE and eNobeB communications as well as user crossing cell communications. UE can be categorized in two states – RRC connected and RRC idle. In both RRC states, the user is provided with system information via RRC layer such as cell selection and reselection, radio resource configuration, etc.

Concluding Remark: Specification of hardware and software required to build the simulation model has been mentioned. All of the entities that are using in 4G network architecture and protocol architecture has been described in detail.

Chapter 4
System Design and Simulation

4.1 Overall Architecture Design

The overall architecture design consists of three layers between the end users and backend system. The end users could be patients, doctors, or caregivers. The backend system acts as a database for the end users' required data. The middle layer will serve as a connection between frontend and backend system, both of which must be installed on hospital property. For the network's traffic management, the control layer will be in charge. The transport layer will be used for sending and receiving requests from end users.

4.2 Simulation Model

Simulation overview is shown in the diagram below:

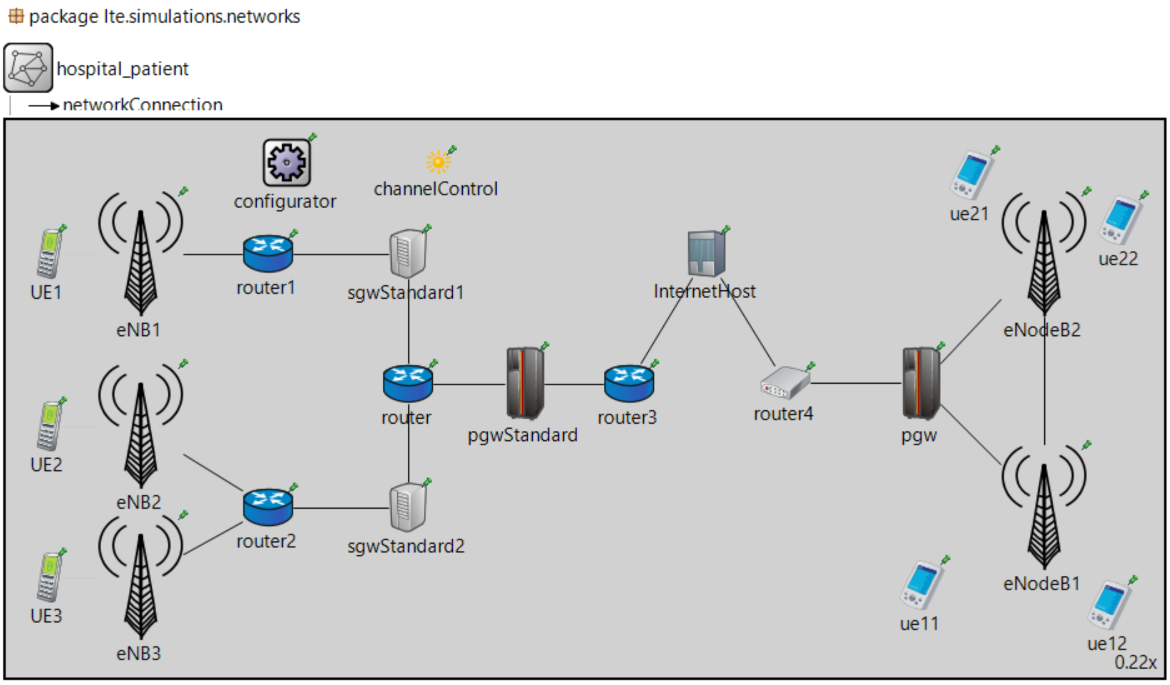

Figure 4.2 Simulation of Patients to Hospitals Network

4.3 Simulation Specifications

In figure 4.2.1, there are five routers in the simulation design; there are four routers in figure 4.2.2 and one router inside the simulation as shown in figure 4.2.3. Each service gateway and packet data network gateway may contain many eNobeBs; in order to direct IP-based traffic to each eNobeB, S-GW and P-GW must be connected via routers. There are five eNobeB in the network in the current simulation, therefore connected routers require some special routing.

Every eNobeB has several users. Only one service type is set up for each user. Linear mobility model is utilized for user mobility in which UE and users move linearly at various speeds.

4.4 Simulation Configurations

All of the general parameters that needed to run the simulation are presented in this section.

- Simulation Time Limit: 20 second
- Record Event Log: True
- Ethernet Link Data Rate: 10 Mbps
- Packet Size: 30 bytes
- Delay: 0.1 us

Omnet++ architecture for the patients to hospitals is illustrated in figure 4.2.1. The simulation network is composed by the following components:

- Seven UE
- Five eNobeB
- Five Routers
- Two S-GW
- Two P-GW
- One Internet Host

There have snippets of the omnetpp.ini file is reported below:

```
result-dir = ResultLteCoreNetwork
record-eventlog = true
sim-time-limit = 20s

network = lte.simulations.networks.lteCoreNetwork
*.configurator.config = xmldoc("lteCoreConfigFiles/lteIpAddresses.xml")


#============ TFT and TEID tables configuration ============
**.pgwStandard.trafficFlowFilter.filterFileName = "lteCoreConfigFiles/pgw.xml"
**.pgwStandard.gtp_user.teidFileName = "lteCoreConfigFiles/pgw.xml"
**.pgwStandard.gtp_user.tftFileName =  "lteCoreConfigFiles/pgw.xml"

**.eNB1.trafficFlowFilter.filterFileName = "lteCoreConfigFiles/enb1.xml"
**.eNB1.gtp_user.teidFileName = "lteCoreConfigFiles/enb1.xml"
**.eNB1.gtp_user.tftFileName = "lteCoreConfigFiles/enb1.xml"

**.eNB2.trafficFlowFilter.filterFileName = "lteCoreConfigFiles/enb2.xml"
**.eNB2.gtp_user.teidFileName = "lteCoreConfigFiles/enb2.xml"
**.eNB2.gtp_user.tftFileName = "lteCoreConfigFiles/enb2.xml"

**.eNB3.trafficFlowFilter.filterFileName = "lteCoreConfigFiles/enb3.xml"
**.eNB3.gtp_user.teidFileName = "lteCoreConfigFiles/enb3.xml"
**.eNB3.gtp_user.tftFileName = "lteCoreConfigFiles/enb3.xml"

**.sgwStandard1.gtp_user.teidFileName = "lteCoreConfigFiles/sgw1.xml"
**.sgwStandard2.gtp_user.teidFileName = "lteCoreConfigFiles/sgw2.xml"
#===========================================================


[Config LTE-LTE]
#UE1 Pings UE2 and UE3 and vice-versa
#==================== PING Apps Configuration =============
**.UE1.numApps = 2
**.UE2.numApps = 1
**.UE3.numApps = 1
**.UE*.app[*].typename = "PingApp"
**.UE*.app[*].stopTime = 8s

**.UE1.app[0].destAddr = "UE2"
**.UE1.app[0].startTime = 1s

**.UE1.app[1].destAddr = "UE3"
**.UE1.app[1].startTime = 1.2s

**.UE2.app[0].destAddr = "UE1"
**.UE2.app[0].startTime = 1.4s

**.UE3.app[0].destAddr = "UE1"
**.UE3.app[0].startTime = 1.6s
#===========================================================
```

```
[Config Internet-LTE]
# The InternetHost pings every UE
#==================== PING Apps Configuration ==============
*.visualizer.*.interfaceTableVisualizer.displayInterfaceTables = true
**.InternetHost.numApps = 3
**.InternetHost.app[*].typename = "PingApp"
**.InternetHost.app[*].stopTime = 8s

**.InternetHost.app[0].destAddr = "UE1"
**.InternetHost.app[0].startTime = 1s

**.InternetHost.app[1].destAddr = "UE2"
**.InternetHost.app[1].startTime = 1.2s

**.InternetHost.app[2].destAddr = "UE3"
**.InternetHost.app[2].startTime = 1.4s

#==========================================================



network = lte.simulations.networks.GtpNetwork
record-eventlog = true
result-dir = ResultGtpNetwork
sim-time-limit = 10s

*.configurator.config = xmldoc("ipAddresses.xml")

**.Host1.numApps = 3
**.Host1.app[*].typename = "PingApp"
**.Host1.app[*].stopTime = 9s

**.Host1.app[0].destAddr = "Host4"
**.Host1.app[0].startTime = 1s

**.Host1.app[1].destAddr = "Host3"
**.Host1.app[1].startTime = 1.5s

**.pgwStandard1.gtp_user.teidFileName = "s1.xml"
**.pgwStandard1.gtp_user.tftFileName =  "s1.xml"
**.pgwStandard1.trafficFlowFilter.filterFileName = "s1.xml"

**.pgwStandard2.gtp_user.teidFileName = "s2.xml"
**.pgwStandard2.gtp_user.tftFileName =  "s2.xml"
**.pgwStandard2.trafficFlowFilter.filterFileName = "s2.xml"

**.pgwStandard3.gtp_user.teidFileName = "s3.xml"
**.pgwStandard3.gtp_user.tftFileName =  "s3.xml"
**.pgwStandard3.trafficFlowFilter.filterFileName = "s3.xml"
```

```
image-path=../../images
output-scalar-file-append = false
sim-time-limit=20s
**.routingRecorder.enabled = false
**.vector-recording = false
seed-set = ${repetition}

network = lte.simulations.networks.MultiCell
*.configurator.config = xmldoc("demo.xml")

**.lteNic.channelModel.downlink_interference = true

################ Mobility parameters #####################
# *
**.mobility.constraintAreaMinZ = 0m
**.mobility.constraintAreaMaxZ = 0m
**.mobility.initFromDisplayString = true

############### Number of Resource Blocks ################
**.numRbDl = 6
**.numRbUl = 6
**.binder.numBands = 6 # this value should be kept equal to the number of RBs

############### Transmission Power ##################
**.ueTxPower = 26
**.eNodeBTxPower = 40


[Config VoIP]
# Schedulers
**.mac.schedulingDisciplineDl = "MAXCI"
**.mac.schedulingDisciplineUl = "MAXCI"

# one UDP application for each user
*.ue*.numApps = 1

# the amount of UDP applications on server should be equal to (numUEs)*(ue[*].numApps)
*.server.numApps = 1

# connect each UE to the eNB
**.ue1*.macCellId = 1
**.ue1*.masterId = 1
**.ue2*.macCellId = 2
**.ue2*.masterId = 2

# positioning and mobility
*.ue*.mobility.initialMovementHeading = uniform(0deg, 360deg)
*.ue*.mobility.constraintAreaMaxX = 1000m
*.ue*.mobility.constraintAreaMaxY = 1000m
*.ue*.mobility.constraintAreaMinX = 0m
*.ue*.mobility.constraintAreaMinY = 0m
*.ue*.mobility.initFromDisplayString = false
*.ue*.mobility.initialX = uniform(0m,300m)
*.ue*.mobility.initialY = uniform(0m,300m)
*.ue*.mobility.initialZ = 0m
*.ue*.mobility.speed = 0mps
*.ue*.mobilityType = "LinearMobility"
```

```
#============= Application Setup =============
*.ue*.app[*].typename = "VoIPReceiver"
*.ue*.app[0].localPort = 3000

*.server.app[*].PacketSize = 40
*.server.app[0].destAddress = "ue11"
*.server.app[1].destAddress = "ue12"
*.server.app[2].destAddress = "ue21"
*.server.app[3].destAddress = "ue22"
*.server.app[*].destPort = 3000
*.server.app[*].localPort = 3088+ancestorIndex(0)
*.server.app[*].typename = "VoIPSender"
*.server.app[*].startTime = uniform(0s,0.02s)
#------------------------------------#


#------------------------------------#
# This configurations tests three types of well-known schedulers, namely DRR,
# MAXCI and PF, in a scenario with VoIP like traffic.
# The load of the system is varied by means of packet size and amount of UEs
# Inter-cell interference is added by means of External cells, allocating resources according to various policies
[Config InterferenceTest]
output-scalar-file = ${resultdir}/${configname}-${iterationvars}-${repetition}.sca
output-vector-file = ${resultdir}/${configname}-${iterationvars}-${repetition}.vec

extends = VoIP
sim-time-limit = 10s
repeat = 1



*.eNodeB*.mobility.initFromDisplayString = false
*.eNodeB1.mobility.initialX = 100m
*.eNodeB1.mobility.initialY = 100m
*.eNodeB2.mobility.initialX = 600m
*.eNodeB2.mobility.initialY = 100m

*.eNodeB*.lteNic.phy.txDirection = "ANISOTROPIC"
*.eNodeB1.lteNic.phy.txAngle = 45
*.eNodeB2.lteNic.phy.txAngle = 135

*.numExtCells = 2

*.extCell[*].txPower = 20
*.extCell[*].txDirection = "ANISOTROPIC"
*.extCell[*].bandAllocationType = ${extAllocType="FULL_ALLOC","RANDOM_ALLOC","CONTIGUOUS_ALLOC"}
*.extCell[*].bandUtilization = 0.5

*.extCell[0].position_x = 100m
*.extCell[0].position_y = 600m
*.extCell[0].txAngle = 315

*.extCell[1].position_x = 600m
*.extCell[1].position_y = 600m
*.extCell[1].txAngle = 225
```

```
*.extCell[1].position_x = 600m
*.extCell[1].position_y = 600m
*.extCell[1].txAngle = 225

*.ue11.mobility.initialX = 150m
*.ue11.mobility.initialY = 150m
*.ue12.mobility.initialX = 250m
*.ue12.mobility.initialY = 250m
*.ue21.mobility.initialX = 550m
*.ue21.mobility.initialY = 150m
*.ue22.mobility.initialX = 450m
*.ue22.mobility.initialY = 250m
*.ue*.mobilityType = "StationaryMobility"

*.server.numApps = 4
#-----------------------------------#
```

4.5 Additional Modules

4.5.1 Configurator

LTE is an entirely IP-based technology and the IPv4 Network Configurator module, which is necessary in an 4G network, is used in OMNeT++ to assign IPv4 addresses. Additionally, it looks for duplicate network addresses. Users provide an IP address to the network by providing this module with parameters (in the form of xml files)

4.5.2 LTE Binder

In order for the sender to find the ID of the destination node during communication, it links the IP address of the node to its ID and maintains it in a database.

4.5.3 LTE Deployer

This module is used to modify the LTE access network's radio settings. Channel numbers per band, OFDMA symbols per slot, and signaling symbols per channel are all variables that can be changed to test how LTE networks behave under various conditions.

Concluding Remark: All of the details of simulation model are describing in the overall architecture design, simulation specifications and simulation configurations. Additional modules used in simulation of 4G network in healthcare are configurator, LTE Binder and LTE Deployer.

Chapter 5

Results and Discussion

5.1 Performance of 4G

Table 5.1 shows the characteristics and performance of 4G.

- Peak data rates can exceed 1 Gbps is anticipated in a variety of circumstances.
- Low latency demand can be implemented.
- Mobility (up to 350 km/h) can be supported by the network.

Characteristics	Performance
Data Rate	0.01 – 1 Gbps
Latency (Control plane)	100 ms
Latency (User plane)	10 ms
Mobility	Up to 350 km/h

Table 5.1.1 Performance of 4G

As seen the network design in figure 4.2.1, the simulator environment is set up which shown in table 5.1.2. According to the research, the UE speed set as 39 km/h [4]. Two eNobeBs will be selected randomly and set up with 200 m distance.

Specifications	Values
Number of LTE to EPC network	2
Number of eNobeB	3
eNobeB Transmission Power	43 dBm
Distance between eNobeB	200 m
UE Transmission Power	23 dBm
UE Speed	39km/h (10.8 m/s)

Table 5.1.2 Experiment Setting

5.2 Performance Measurement

- ***Latency*** refers to the delay that data transfer from source to destination in network communication. The following table 5.2.1 will show the average and the best quality values for the latency.
- ***Packet loss ratio*** is the average number of packets lost during network transmission from source to destination. The following table 5.2.2 will show the average and the best quality values for the packet loss.
- ***Jitter*** refers to the variance in the measurements. The following table 5.2.3 will show the average and the best quality values for the jitter.

Latency	Quality
<50 ms	Best
<100 ms	Average

Table 5.2.1 Latency Standard

Packet Loss Ratio	Quality
<1%	Best
<5%	Average

Table 5.2.2 Packet Loss Ratio Standard

Jitter	Quality
<20 ms	Best
<50 ms	Average

Table 5.2.3 Jitter Standard

5.3 Connectivity Test

Latency and response time will be examined in straightforward ping.

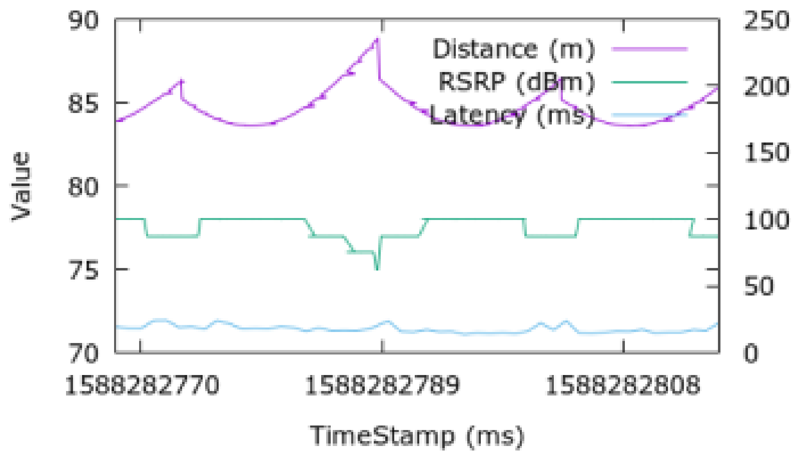

Figure 5.3.1 Server Request

The model with request in figure 5.3.1, the x-axis display the current timestamp which receive values as current distance which mapped to purple color line in y-axis, RSRP and the latency of response in both green color line and blue color line y-axis. For the server request, the average value is around 18 ms and the maximum value is 24 ms. There is not acceptable for live streaming video as it has a bit lag. Furthermore, the propagation delay is estimated by distance/speed, it will only be noticeable as the distance between S-GW from visiting network and P-GW from home network is sufficient. Hence, the average value of latency is 18 ms which meets the standard below 50 ms.

Packet loss does not happen in this simulation. However, even though ping is stable the simulation may still have packet loss issues. This is because some data might not be getting correctly in destination although the data sent and ultimately received. Hence, it is best for ping no packet loss.

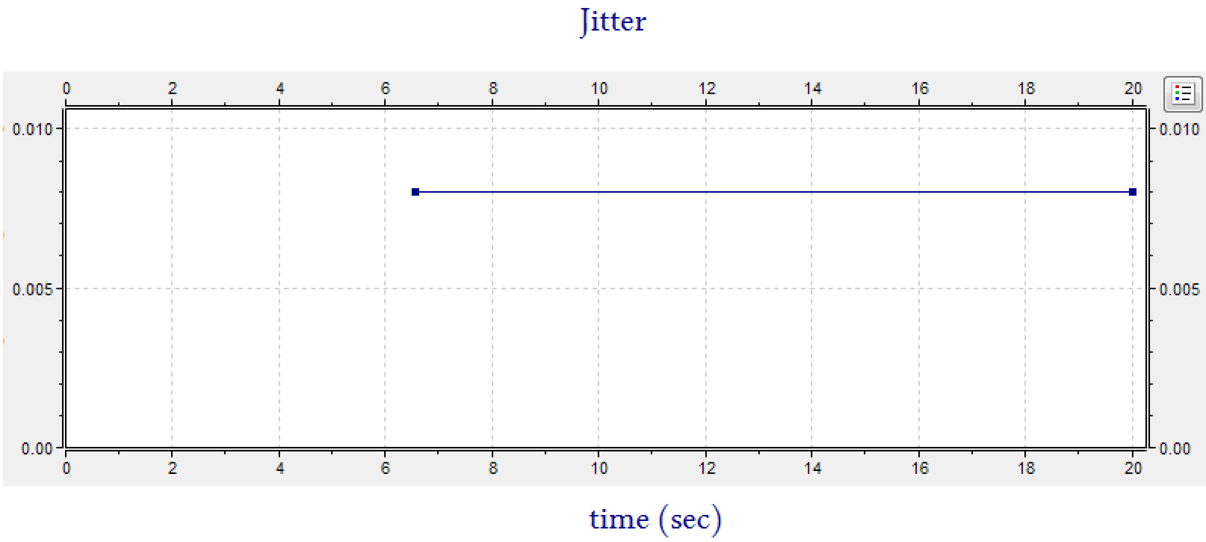

Figure 5.3.2 Jitter of Ping

The jitter as illustrated in figure 5.3.2 remain static and does not change over time. It remained at the 8 ms until the end. Therefore, the quality of ping is excellent since the result is below 20 ms.

5.4 Project Challenges

This project faced some challenges. Firstly, the OMNeT++ v6.0.1 and INET framework v4.5.0 are not suitable to develop the simulation of 4G network in healthcare. Some functions and nodes that required are involved in the latest version have issues since that the latest version not stable yet. Therefore, this project use OMNeT++ v5.6.2 and INET framework v4.2.2 to build the simulation model. Besides that, there are some simulation configurations are not set up clearly in the simulation model. After doing more and more research, the parameters of 4G network that utilized in the real-world are successfully set up. Moreover, the objectives of this project have been changed. The previous objectives are not covered properly in this project.

5.5 Objectives Evaluation

1. **To study the quantitative approach to discuss issues related to 4G network architecture for real-time applications.**

   Partially archived. The 4G network behave with the number of eNobeBs is displayed in the above performance specifications. The simulator environment is set up with the number of LTE to EPC network. However, the simulation model does not develop with the real-time applications.

2. **To study literature about healthcare IoT applications and challenges for IoT in healthcare**

   Archived. The chapter 2 literature review are reviewing nine IoT applications and systems which are developed in healthcare industry. There have ambient assisted living, community healthcare, mobile H-IoT, wearable device access, blood pressure monitoring, oxygen saturation monitoring, rehabilitation system, wheelchair management and internet of health things and digital telehealth. Besides that, the challenges for IoT in healthcare also be mentioned which are data privacy, managing device diversity and integration. Hence, this project archived the study of literature about IoT applications in healthcare and the challenges for IoT in healthcare.

3. **To analyze the performance for 4G network by using real-world parameters**

   Archived. The results shown in 5.3 Connectivity Test which are using parameters in real-world. Other than that, the performances of latency, packet loss and jitter are evaluated by utilizing real-world measurement of performance. The quality of each performance refers to the real-world 4G network. Therefore, this project archived the analyze of performance for 4G network in simulation model by using real-world parameters.

4. **To study the simulation environment in OMNeT++**

   Partially archived. Figure 4.2 shows that the simulation of 4G network in healthcare. There has the completed network topology from patients' side to hospital's side. The simulation model is built and ran successfully. However, the OMNeT++ can be used to develop various types of communication network in a real world. OMNeT++ also support large scale simulation and parallel simulation execution. Hence, this project is just partially archived the study of simulation environment in OMNeT++.

Concluding Remark: The connectivity test of simulation model in this project are evaluated based on performance of 4G and the performance measurement of real-world. There are some challenges for this project and the objectives evaluation mentioned at section 1.2.

Chapter 6

Conclusion

The range of healthcare applications and services that can be developed by combining IoT with healthcare systems. There has ambient assisted living, community healthcare, mobile H-IoT and wearable device access. These systems that are developed in healthcare industry provide patients the newest medical services. Moreover, H-IoT applications which are developed to assist people in keeping track of their own health conditions, including heart disease, diabetes, pregnancy, mental health, and more. The H-IoT applications such as blood pressure monitoring, oxygen saturation monitoring, rehabilitation, and wheelchair management. The systems will be assisted with surgical procedures and therapy, and many more. These services and applications are important in healthcare area by using 4G network.

In this project, simulation of 4G network in healthcare is implemented by using OMNeT++ v5.6.2 and INET framework v4.2.2. The model consists of layered detailed E-UTRAN, mobility model and channel modelling. The advantage of modularized approach is that it offers flexibility for changing network node configurations and testing various network situations. The simulation model provides extensive configuration change support, allowing users to simulate various real-world circumstances and evaluate the connectivity test in terms of latency, packet loss and jitter. The establishment of a network between all the entities involved in the delivery of healthcare, including hospitals, doctors, and patients.

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APPENDIX

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2, Y3	**Study week no.:** 2
Student Name & ID: Chia Sook Jing 20ACB05587	
Supervisor: Ts Dr Goh Hock Guan	
Project Title: Simulation of 4G Network in Healthcare	

1. WORK DONE [Please write the details of the work done in the last fortnight.] - FYP 1 done - Met supervisor to discuss what should need to do in FYP 2
2. WORK TO BE DONE - Chapter 1 and Chapter 2
3. PROBLEMS ENCOUNTERED - No problem
4. SELF EVALUATION OF THE PROGRESS - Work in progress

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2, Y3	**Study week no.:** 4
Student Name & ID: Chia Sook Jing 20ACB05587	
Supervisor: Ts Dr Goh Hock Guan	
Project Title: Simulation of 4G Network in Healthcare	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Chapter 1 and chapter 2 done

2. WORK TO BE DONE

- Chapter 3 proposed method / approach
- Simulation model add several locations of hospital

3. PROBLEMS ENCOUNTERED

- Link between hospitals and packet data network gateway

4. SELF EVALUATION OF THE PROGRESS

- Work in progress

素晶

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2, Y3	**Study week no.:** 6
Student Name & ID: Chia Sook Jing 20ACB05587	
Supervisor: Ts Dr Goh Hock Guan	
Project Title: Simulation of 4G Network in Healthcare	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Simulation model add several hospitals site
- Chapter 3 done

2. WORK TO BE DONE

- Simulation model server should save the data which sent from patients and hospitals site
- Chapter 4 System Design

3. PROBLEMS ENCOUNTERED

- The server cannot save the data

4. SELF EVALUATION OF THE PROGRESS

- Work in progress

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2, Y3	**Study week no.:** 8
Student Name & ID: Chia Sook Jing 20ACB05587	
Supervisor: Ts Dr Goh Hock Guan	
Project Title: Simulation of 4G Network in Healthcare	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Tried made the server save data but not worked

2. WORK TO BE DONE

- Simulation model hospital receive data from patients not just ping
- Chapter 4 System Design

3. PROBLEMS ENCOUNTERED

- Find a simple application to add into simulation model

4. SELF EVALUATION OF THE PROGRESS

- Work in progress

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Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2, Y3	**Study week no.:** 10
Student Name & ID: Chia Sook Jing 20ACB05587	
Supervisor: Ts Dr Goh Hock Guan	
Project Title: Simulation of 4G Network in Healthcare	

1. WORK DONE [Please write the details of the work done in the last fortnight.] - Chapter 4 done
2. WORK TO BE DONE - Chapter 5 Results and discussion - Complete simulation model
3. PROBLEMS ENCOUNTERED - No problem
4. SELF EVALUATION OF THE PROGRESS - Work in progress

Supervisor's signature

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Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2, Y3	**Study week no.:** 12
Student Name & ID: Chia Sook Jing 20ACB05587	
Supervisor: Ts Dr Goh Hock Guan	
Project Title: Simulation of 4G Network in Healthcare	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Chapter 5 done

2. WORK TO BE DONE

- Chapter 6 Conclusion
- Presentation slides

3. PROBLEMS ENCOUNTERED

- No problem

4. SELF EVALUATION OF THE PROGRESS

- Work in progress

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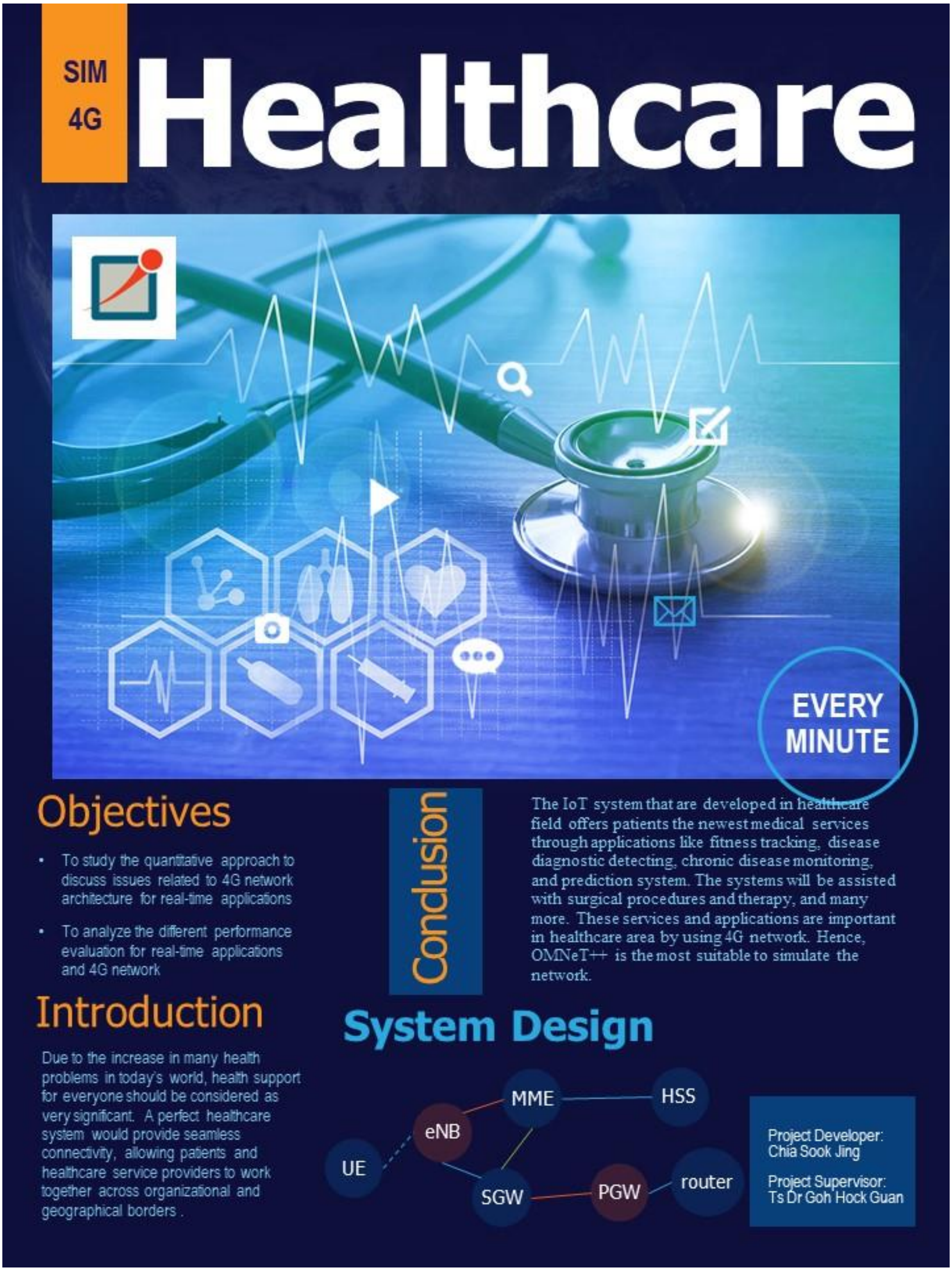
Student's signature

POSTER


SIM
4G
Healthcare
EVERY MINUTE
Objectives
• To study the quantitative approach to discuss issues related to 4G network architecture for real-time applications
• To analyze the different performance evaluation for real-time applications and 4G network
Conclusion
The IoT system that are developed in healthcare field offers patients the newest medical services through applications like fitness tracking, disease diagnostic detecting, chronic disease monitoring, and prediction system. The systems will be assisted with surgical procedures and therapy, and many more. These services and applications are important in healthcare area by using 4G network. Hence, OMNeT++ is the most suitable to simulate the network.
Introduction
Due to the increase in many health problems in today's world, health support for everyone should be considered as very significant. A perfect healthcare system would provide seamless connectivity, allowing patients and healthcare service providers to work together across organizational and geographical borders .
System Design
MME
HSS
eNB
UE
SGW
PGW
router
Project Developer: Chia Sook Jing
Project Supervisor: Ts Dr Goh Hock Guan

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ID Number(s)	20ACB05587
Programme / Course	Computer Science
Title of Final Year Project	Simulation of 4G Network in Healthcare

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Name: Goh Hock Guan	Name:
Date: 25/4/2023	Date:

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FACULTY OF INFORMATION & COMMUNICATION TECHNOLOGY (KAMPAR CAMPUS)

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Student Name	Chia Sook Jing
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