# INTERNET OF THINGS FRAMEWORK FOR ENHANCING ELECTRONIC HEALTH RECORD RETRIEVAL FOR MALAYSIAN PILGRIMS

**BY**

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# DECLARATION

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## ABSTRACT

The rise of global travel has increased the number of travelers who are exposed to illnesses in their destination country. Some problems arise during health care delivery at destination as they receive healthcare as non-local patients. When treating non-local patients, healthcare providers need access to the health record of those patients to determine their medical history and any chronic or inherited diseases. Electronic health record (EHR) systems are only effective for local healthcare services within the patient's country. Therefore, an effective EHR method should be adopted to support the global healthcare needs of travelers. The Internet of Things (IoT) technology is an effective solution to accomplish real-time retrieval of historical EHRs. In a pilgrimage environment such as the Hajj, IoT can be applied by identifying non-local patients through electronic tags; the tag data can be read with wireless sensors. The data collected using radio-frequency identification can be acquired from a wireless sensor network to accomplish many decisions, such as sending an ambulance to a patient's location, sending an emergency alert to this patient's immediate family circle, and retrieving the patient's EHR from a database. This research aims mainly to develop an IoT framework for real-time retrieval of Malaysian pilgrims' EHRs from a database in Malaysia by the Kingdom of Saudi Arabia's (KSA) healthcare facilities over the Internet. The sub-objectives for achieving the main research objective are as follows: identifying the most useful structure, facilities, and components of the proposed IoT framework; analyzing the challenges, importance, and viability of EHR retrieval using IoT from the Malaysian and KSA perspectives; and identifying the technical issues of IoT and pilgrims' EHRs that are required to formulate the proposed framework. To generate integrative conclusions from a multiple methods study, we adopted a triangulation method of developing the framework. The data collection methods included: questionnaire (close-ended and open), observation, and focus group discussion. The proposed framework was developed on the basis of the collected data and was validated by Malaysian experts. Results confirmed participants' support of the framework and identified salient features of effective framework. The validation results showed that the proposed framework can support the healthcare needs of Malaysian pilgrims. This research mainly contributes by developing an IoT framework for supporting non-local patients through the retrieval of EHRs between countries via the Internet network.

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| | | |
|---|---|---|
| A | : | Agree |
| BANs | : | Body Area Networks |
| CPOE | : | Computerized Physician Order Entry |
| D | : | Disagree |
| DoD | : | Department of Defence |
| DoS | : | Denial of Service |
| EHR | : | Electronic Health Record |
| EMR | : | Electronic Medical Record |
| EPR | : | Electronic Patient Record |
| FGD | : | Focus Group Discussion |
| GIS | : | Geographical Information System |
| GP | : | General Practitioner |
| GPRS | : | General Packet Radio Service |
| GPS | : | Global Position System |
| GSM | : | Global System for Mobile |
| GUI | : | Graphical User Interface |
| HBV | : | Hepatitis B Virus |
| HCV | : | Hepatitis C Virus |
| HIV | : | Human Immunodeficiency Virus |
| HL7 | : | Health Level Seven |
| HSM | : | Heuristic Systematic Model |
| ICT | : | Information and Communications Technology |
| ID | : | Identification |
| IoT | : | Internet of Things |

| | | |
|---|---|---|
| ISMS | : | Information Security Management Systems |
| ISP | : | Internet Service Provider |
| IT | : | Information Technology |
| KSA | : | Kingdom of Saudi Arabia |
| LM | : | Likelihood Model |
| LTE | : | Long-Term Evolution |
| M2M | : | Machine to Machine Communication |
| MANETs | : | Mobile Ad-hoc Networks |
| MERS-CoV | : | Middle East Respiratory Syndrome Corona Virus |
| MIBs | : | Management Information Bases |
| MIT | : | Massachusetts Institute of Technology |
| MOH | : | Ministry of Health |
| MUMPS | : | Massachusetts General Hospital Utility Multi-programming System |
| N | : | Neutral |
| NEHTA | : | National E-Health Transition Authority |
| NFC | : | Near Field Communication |
| NHS | : | National Health Service |
| NHSCRS | : | National Health Service Care Record Service |
| NPfIT | : | National Programme for Information Technology |
| OPV | : | Oral Polio Vaccine |
| P&G | : | Proctor and Gamble |
| PAS | : | Patient Administration Systems |
| RF | : | Radio Frequency |
| RFID | : | Radio-Frequency Identification |
| SA | : | Strongly Agree |
| SARS | : | Severe Acute Respiratory Syndrome |

| | | |
|---|---|---|
| SCR | : | Summary Care Record |
| SD | : | Strongly Disagree |
| SEHR | : | Shared Electronic Health Record |
| SNAP | : | Sensor Network for Assessment of Patients |
| TA | : | Thematic analysis |
| TCP | : | Transmission Control Protocol |
| UDP | : | User Datagram Protocol |
| UID | : | User Identification |
| US | : | United States |
| USB | | Universal Serial Bus |
| VA | : | Veterans Affairs |
| VHA | : | Veterans Health Administration |
| WHO | : | Worlds Health Organization |
| Wi-Fi | | Wireless Fidelity |
| WSN | : | Wireless Sensor Network |
| WSNs | : | Wireless Sensor Networks |
| IoT-FPEHR | : | Internet of Things – Framework of Pilgrim Electronic Health Record |

# LIST OF PUBLICATIONS

The following peer-reviewed outputs have been published in conjunction with this thesis:

- Latif Ali Ibrahim, Marini Othman, Norashikin Ali, Yahya H. Towards a Collaborative Electronic Patient Record Management to Improve Healthcare for Non-local Patients. e-health symposium; UNiTEN, Putrajaya, Malaysia 2014.

- Latif Ali Ibrahim, Marini Othman, Norashikin Ali, Yahya H, editors. Proposed framework for retrieval of pilgrims' electronic health records (EHR) using the internet of things (IOT). Poster presented at Postgraduate research exposition 2016; 2016; College of IT, UNITEN.

- Latif Ali Ibrahim, Marini Othman, Azizah Suliman, Mahdi OA. An Investigation of IoT Importance and Viability of Health Records Retrieval using Electronic Tags in Pilgrimage. Journal of Telecommunication, Electronic and Computer Engineering. 2016;8(10):95-98.

- Latif Ali Ibrahim, Marini Othman, Azizah Suliman, Daher AM. Current Status, Challenges and Needs for Pilgrim Health Record Management Sharing Network, the Case of Malaysia. International Archives of Medicine. 2016;9(1).

- Ali Ibrahim Latif, Marini Othman, Azizah Suliman, Omar Adil Mahdi, Aqil M. Daher. Feasibility of IoT application for real-time Retrieval of Malaysian Pilgrims' EHRs. Journal of Computational and Theoretical Nanoscience. 2019;16(3):1169-81

# CHAPTER 1

# INTRODUCTION

## 1.0 Background

With the rise of global travel, more travellers are exposed to health issues and problems in the country that they are visiting, which means that they may need to receive healthcare as a non-local patient. Travel has become a common activity in the lifestyles of many people today whether for business, leisure or a specific purpose, such as a religious pilgrimage. New concepts such as health tourism and discovery travel have emerged (Carrera & Bridges, 2006; Smith & Puczkó, 2014).

This situation is especially true for religious pilgrimages, where a great number of people travel from different countries and converge in crowded environments for a certain time period. People go on religious pilgrimages to different locations such as Muslims to Mecca, Saudi Arabia; Christians to the Vatican City; Buddhists to Lhasa, Tibet; and Hindus to Kumbh Mela, India, where they gather in large crowds to perform religious rituals. This scenario poses many public health issues, as well as potential threats and consequences to both local and international public health situations (Alzeer, 2009). The site becomes fertile ground for the propagation of communicable diseases, including the transmission of infectious diseases, such as meningitis, avian influenza, severe acute respiratory syndrome (SARS), the Middle East Respiratory Syndrome Corona Virus (MERS-CoV), and haemorrhagic fever. Such a situation poses a dangerous health risk to the holy land, the countries where infected pilgrims pass through on their return journey, and the countries to which they return (Alzeer, 2009; Barasheed et al., 2014).

One of the most important travel purposes for Muslims is the Hajj journey. The events of the annual pilgrimage to Mecca in Saudi Arabia take about one month and bring together more than two million pilgrims who risked being exposed to many health hazards. These health risks, which include various infectious diseases, are exacerbated because of the crowded conditions of the said event (Ahmed, Arabi, & Memish, 2006; Alqahtani, Rashid, & Heywood, 2015). However, when treating a non-local patient, a healthcare provider needs access to that patient's health record in order to be aware of his medical history which is necessary for effective treatment of the current health needs. The non-local pilgrims in KSA may need healthcare services and these services should be accomplished accurately in real-time, which require historical health records based electronic approaches. Electronic Health Record (EHR) retrieval for non-local pilgrims is still an issue due to many reasons such as the privacy of transferred information, delay in transfer information, and required equipment and architecture of the network technology (Hanauer et al., 2015). Thus, it is necessary to address this issue through effective technology approaches.

The health industry is a capital-intensive, labour-intensive and information-intensive one; therefore, the large amounts of information exchange in the healthcare industry are attracting the attention of professionals. If healthcare providers do not adopt advanced technology, they will be inefficient and lose the trust of their clients (Lu, Xiao, Sears, & Jacko, 2005; Scott, 2007).

In the era of rapid development of information technology along with the growing population of travellers, EHR-services have become widely accepted among enterprises and the trend is not only dominant in high tech and traditional industries, but also in medical industries.

Some healthcare providers, such as hospitals, are still hesitant to use modern technology for a number of reasons. These reasons may include: (1) longer payback periods resulting from high prices; (2) a lack of technological infrastructure including software, hardware, and middleware; (3) technical glitches; (4) patient privacy concerns; and (5) organizational resistance to change. That is to say, the adoption of sharing framework for sharing EHR in the healthcare service setting depends heavily on the healthcare provider's ability to overcome a host of inhibitors or to make a compelling case for the dramatic improvement in supply chain efficiency (Meskó, Drobni, Bényei, Gergely, & Győrffy, 2017).

The integration of IoT into healthcare paradigm started from sporadic application to detect vital signs of individuals to prediction of serious illness as those IT are usually real-time devices that gain immediate information from the patient (Albahri et al., 2018; X. Liu, Zhao, Li, Zhang, & Trappe, 2017). Nonetheless, sharing of EHR has been implemented not for real time use during emergency cases.

Since the very first of pilgrims-related work of prototype of WPAN technology for tracking pilgrims in KSA, a number of studies and reviews have focused on the new era of healthcare provision. We assign four medical information priorities to the nodes of wireless body area network. Accurate and quick prioritization of personal healthcare information is crucial for making efficient and real time decisions. We transfer the medical data to the access point in wireless body area network by mapping the patient vital signs into 4 dynamic access categories (Yi et al., 2015).

Mohamed Abdulnabi et al has ventured into using mobile in provision of healthcare. Mohamed posutaled that mobile phone are indispensable and widely accepted and used, thus he suggested mPHRs (medical Persoanl Health Records) that take the form of distributed storage units for health information, under the full control and direct possession of patients, who can have ready access to their personal data whenever needed. However, for the actual exchange of data with health information systems managed by healthcare providers, the latter have to be interoperable with patient-carried mPHRs. Computer industry has long ago solved a similar problem of interoperability between peripheral devices and operating systems. We borrow from that solution the idea of providing special interfaces between mPHRs and provider systems. This interface enables the two entities to communicate with no change to either end. The design and operation of the proposed approach is explained. Additional pointers on potential implementations are provided, and issues that pertain to any solution to implement NHIE are discussed (Abdulnabi et al., 2017).

Hindia et al explained the use of sensors as a key technology to enable Internet of Things oriented health-care monitoring systems. His team proposed a two-stage fundamental approach to facilitate the implementation of such a system. In the first stage, sensors promptly gather together the particle measurements of an android application. Then, in the second stage, the collected data are sent over a Femto-LTE network following a new scheduling technique. The proposed scheduling strategy is used to send the data according to the application's priority (Hindia, Rahman, Ojukwu, Hanafi, & Fattouh, 2016).

Although, EHR systems are developed due to its importance in healthcare services, utilization of the EHR system for travellers (global retrieval of EHR) is still lacking. The EHR systems are used for local retrieval of health records, whereby the patients' records are transfer from department to department in same origination, or between parties in same country (Abdelhak, Grostick, & Hanken, 2014; Adler & Stead, 2015). Carrera et al. (2006) mentioned that global EHR system for travellers aims to retrieve the traveller health record over long distances between countries. However, the lack of developed EHR systems is due to many reasons such as technology resources, training, capacity requirements, data security, and medico legal and cultural differences. This is evident by lack of published reports that discuss the collaborative approach. Thus, it is necessary to address this gap through effective technology approaches for global EHR retrieval (Sadlier, Bergin, & Merry, 2014).

Health records were defined merely as notes on an individual's medical history, ailments, complaints, and allergies, which can be consulted to treat any health problems (Abdelhak et al., 2014). However, different definitions have been developed because individuals have begun collecting and compiling information regarding their health, and new technologies, such as the Internet, have emerged. Still, the core meaning of the term remains the same. Notably, health records have raised a concern about the need for privacy, which the Health Insurance Portability and Accountability Act in the US and elsewhere have presented (Medicare & Medicaid Services 2010; Menachemi & Collum, 2011).

Nowadays, the use of EHR systems is important to speed up and improve the health services through accurate collection and retrieval of historical health records of patients (Adler & Stead, 2015). EHR systems retrieve and store in-depth and detailed patient information used by patients and healthcare providers during hospitalization over time and across care settings. Embedded clinical decision support and other tools potentially help clinicians provide safer and more effective care than based on memory and paper-based systems. In addition, EHRs facilitate the completion of hospitals' tasks to monitor, improve, and report data pertaining to healthcare safety and quality. In fact, EHR is the next step in continued progress of healthcare (Gellert, Ramirez, & Webster, 2015).

Hospitals typically use their EHRs to facilitate performance assessment, monitoring, and improvement. EHRs enable providers to cross boundaries to exchange information and coordinate care across the healthcare system (Silow-Carroll, Edwards, & Rodin, 2012). Such systems also help in improving patient safety through such features as automated alerts and reminders as well as new predictive analytics that identify potential problems before they become crises.

The overall aim of EHR is to improve the quality of care. Today, the changing role of EHR in providing support to clinical practice can be categorized using four primary functions to achieve the quality gains. These roles include the following:

- Memory aid: to reduce the need to depend on memory alone for required information to complete a task (Senathirajah, Kaufman, & Bakken, 2014).

- Computational aid: to reduce the need to classify, compare, and analyse information (Melton et al., 2014).

- Decision support aid: to enhance the hospitals' ability to integrate information from multiple sources, thus leading to more effective evidence-based decisions (Musen, Middleton, & Greenes, 2014).

- Collaboration aid: to enhance the ability to communicate information and results to providers and patients from other units (Cox et al., 2015).

According to the above roles, the main aim of EHR is to increase the quality of healthcare decisions in real-time. Although EHR is effective for local health services (hospitals within patient's home country), the implementations of EHR for global purposes is still an issue. EHR is not applicable for the persons who travel to other countries (de Lusignan, Morris, Hassey, & Rafi, 2013; Dwivedi, Bali, James, & Naguib, 2001; Weng et al., 2012). Therefore, it is necessary to adopt an effective EHR method to support the healthcare services of travellers.

EHR archival, management, and retrieval is the centre of models theory like Heuristic Systematic Model (HSM) (Petty & Cacioppo, 2012) and Elaboration Likelihood Model (ELM) (DUANE, 1999). These theory-based models are focused on the integration between technology systems and information management in order to enhance the information processes such as retrieval speed, information management, and information accessing. One of the main basics of ELM and HSM is the viability of adopting technology in various implementations of information retrieval and management to convert from the traditional situation to automated environment. Table 1.1 presents a comparison between ELM and HSM theories.

**Table 1.1: Comparison between ELM and HSM Theories**

| Theory | Integration between technology systems and information management | Enhance information management | Implementation viability of technology systems | Technical processes | Environmental Ability |
|---|---|---|---|---|---|
| ELM | ✓ | ✓ | *x* | ✓ | ✓ |
| HSM | ✓ | *x* | ✓ | *x* | ✓ |

Based on ELM and HSM theories, Internet of Things (IoT) technology could be an effective solution to retrieve health records of travellers from their original countries and relay it to healthcare staff in pilgrimage health centres. IoT is a mod ern technology that can potentially be used in various purposes such as Smart Meter, public security, health, and intelligent building (Berghella et al., 2014; Zhu, Wang, Chen, Liu, & Qin, 2010). Zhu et al., stated "IoT Gateway plays an important role in IoT applications, which facilitates the seamless integration of wireless sensor networks and mobile communication networks or Internet, and the management and control with wireless sensor networks". These sensors can be used in various types of local area connections such as Radio-Frequency Identification (RFID), Near Field Communication (NFC), Wireless Fidelity (Wi-Fi), Bluetooth, and Zigbee. Sensors also covers wide area of connectivity such as Global System for Mobile (GSM), General Packet Radio Service (GPRS), Third Generation (3G), and Long-Term Evolution (LTE)(Berghella et al., 2014).

IoT may be an emerging topic in the industry but it is not a new concept. In the early 2000s, Kevin Ashton was laying the groundwork for what would become IoT at the Auto-ID Center at Massachusetts Institute of Technology (MIT). Ashton was one of the pioneers who conceived this notion as he searched for ways that Proctor and Gamble (P&G) Company could improve its business by linking RFID information to the Internet (Ashton, 2011). The concept was simple but powerful. If all objects in daily life were equipped with identifiers and wireless connectivity, these objects could be communicating with each other and be managed by computers (Barker et al., 2014).

Outdoor services like travellers healthcare services require two main IoT Layers which are (Agrawal & Das, 2011): 1) lower layer, and 2) upper layer. Lower layer (RFID) consists of electronic tags and wireless sensors. Sensors read data of tags and transfer it to upper layer (Al-Turjman, Al-Fagih, Alsalih, & Hassanein, 2013; Zhu et al., 2010). Upper layer (WSN) consists of super nodes and base station. Super nodes handle data from lower layer and transfer it to base station (Al-Turjman et al., 2013; Zhu et al., 2010). Hence, data stored in base station are managed and processed automatically connecting with central web servers. The outputs of processed data (information) are displayed on output devices such as monitors.

IoT can be applied in many domains, including health. In health implications, the patients in global areas can be identified as electronic tags and the tags data can be read by wireless sensors (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014). The data collected using RFID can be acquired from WSN in order to accomplish many decisions such as sending an ambulance to the patient’s location, sending emergency treatment guidelines to the patient’s immediate family circle, and sending the patient’s EHR from the original healthcare centre of patient to other centres near to the health case. For global purposes, IoT can support EHR retrieval over internet network from a country to other countries.

This research focuses on using IoT facilities to retrieve EHR of Malaysian pilgrims from health database that is located in Malaysia to healthcare centres in KSA. EHR retrieval in real-time could improve the performance of healthcare services provided for Malaysian pilgrims.

## 1.1 Problem Statement

Providing healthcare services to travellers is very difficult especially when there is an urgent need to access their health records. Without proper EHR systems for global patients, the health services could face many challenges such as weak description of health cases, weak treatments of health cases, and weak collaboration to treat the health cases.

The communication between healthcare staff and patient may fail due to many reasons like lingual differences between healthcare staff and patients, and patients' weak skills of medical concepts. This may lead to delay or failure in understanding of health cases (Ku & Flores, 2005; O'Neill et al., 2014; Pottie et al., 2011).

Moreover, the weak understanding of health case history may lead to risks such as ambiguity of health case reasons, conducting wrong surgery, and prescribing restricted or unsuitable medicines to patients (Berwick, Nolan, & Whittington, 2008; Detmer, Bloomrosen, Raymond, & Tang, 2008; Holman, Bass, Rouse, & Hobbs, 1999; Kellermann & Jones, 2013).

Some health cases are complex, which requires more information from original specialties of health case. Without an effective EHR system, the healthcare staff cannot contact the hospitals or doctors that responsible for the EHR for further investigations about health cases (Cox et al., 2015; Rasmussen-Torvik et al., 2014).

According to above challenges of EHR, the healthcare services of Malaysian Muslim pilgrims face many problems such as during the pilgrim season, the hospitals face great difficulty in providing healthcare services to all pilgrims. This is mainly due to massive overcrowding, different ethnicities and hundreds of languages. Specifically, Malaysian pilgrims are among those facing problems in getting healthcare services during the Hajj. This is due to many reasons, including most of the Malaysian pilgrims are over the age of 60-year-old, and some of them are having some chronic diseases like diabetes or hypertension, so they are in need of special healthcare.

Malaysian pilgrims' health records are not accessible, as the Malaysian pilgrims are being provided with a manual health record written in the Malay language, which represents a barrier for the healthcare providers in the hospitals of KSA. In addition, there is a language barrier, as some Malaysians are unable to speak Arabic or English language. Therefore, there is a need for an accurate and fast communication system that enables access of patient's health records at the country of origin.

## 1.2 Research Aim

The main aim of this research is to propose IoT framework to addresses the need of global retrieval of the EHR of travellers. The IoT-EHR framework aims to retrieve patients' health records from a health database that is located in their original country and relay it to healthcare staff in the destination country (the attendance country of the traveller. As a case study of this research, the proposed IoT framework is for the pilgrims EHR retrieval, whereby the destination country is KSA. To propose the framework for the pilgrims EHR retrieval, the following research activities are required:

- Ra1: To provide a tool for retrieval of patients' health records from their country or residence (the case study of this research is Malaysia).
- Ra2: To develop an IoT framework for EHR sharing between country of residence and travelers destination ( KSA in this study)
- Ra3: To validate the proposed IoT framework to be used in healthcare services and centers.

To address the main aims of this research, IoT is utilized as a potential solution for retrieval of Malaysian pilgrims EHR. By using electronic tags that represent the pilgrims' ID, the request for needed health records could be relayed to the pilgrims' countries via an online network and the retrieved health records displayed for healthcare staff in KSA pilgrimage healthcare centres.

## 1.3 Research Questions

In line with the main research aim, the following research questions were explored:

- RQ1: What are the prerequisites to implement IoT in the global retrieval of pilgrims' EHR?

- RQ2: What are the challenges that face the utilizing IoT for global retrieval of pilgrims' EHR?

- RQ3: Is it feasible to utilize IoT for global EHR retrieval in pilgrimage environment?

- RQ4: What are the most suitable technical specifications of IoT (devices, distances, structure, etc) for global EHR retrieval?

- RQ5: What are the most suitable specifications of health records (structure, details, format, etc) to support the proposed framework?

- RQ6: What are the perceived benefits and challenges in adoption of the proposed IoT-EHR framework in pilgrimage environment?

## 1.4 Research Objectives

In line with the main research aim, and questions the following research objectives were achieved:

- Research objective 1: to explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries.

- Research Objective 2: to identify the most useful structure, facilities, and components of the proposed IoT-EHR framework.

- Research Objective 3: To measure the validity of the proposed IoT-EHR framework.

## 1.5 Research Approaches

In order to address the research objectives, the following research processes will be followed:

Firstly, two data collection methods (questionnaire and observation) will be conducted to address the first research objective. The data collection using the questionnaire and observation methods would helpful to analyse the importance and challenges of global EHR retrieval using IoT facilities.

Secondly, the open-ended survey and focus group discussion methods were conducted to address the second research objective. The basic structure of IoT framework for EHR can be identified through literature review, and the collected data using open-end survey and focused group discussion could helpful to identify the technical issues pertaining to the proposed IoT framework for EHR retrieval.

Lastly, the third research objective was addressed through open-ended survey with experts. The perceived benefits and challenges of the proposed IoT framework could validated through open-ended survey with expert panel.

## 1.6 Scope of Study

Research under the domain of EHR is huge because many parties and institutions are involved and are related to most healthcare providers. However, the current research shall confine the study on the management of EHR. This research focuses on utilizing IoT in EHR retrieval for non-local patients. IoT facilities could be applied to retrieve EHR of patients from one country to another country.

The case study of this research is targeting Malaysian parties, agencies, and organizations involved in the provision of information related to the healthcare of pilgrims. This research provides IoT framework to retrieve electronic records from Malaysia to healthcare staff in KSA and, thus improving healthcare delivery to pilgrims.

## 1.7 Research Significance

The current study aims to explore EHR implementation, which is an inevitable offshoot of the use of IoT technologies in the field of healthcare. The importance of implementing these technologies is supported by the potential benefits of EHR implementation and some weaknesses in travellers EHR retrieval. The use of IoT in EHR enhances the process of managing, storing, retrieving, and sharing medical information between countries. The core implementation of this research is for EHR retrieval for Malaysian pilgrims from healthcare centres that are located in KSA. IoT facilities such as electronic tags could retrieve pilgrims EHR from their original countries in real-time. This would improve the healthcare services that are provided in pilgrimage. Retrieval of managed EHR of pilgrims speeds up health services, provides accurate healthcare services, and reduces the communication difficulty between pilgrims and healthcare staff due to language differences.

## 1.8 Thesis Layout

The thesis is organized into seven chapters as follow:

1. **Chapter 1 (Introduction)** includes a description of the problem under study with its relevant information. It includes an overview of the health

status and demography of Malaysia. The problem statement was spelt out in this chapter along with research objectives and questions.

2. **Chapter 2 (Literature Review)** includes a detailed literature review and has been divided into different sections to tackle the important information about the subject. Health problems faced by travellers and pilgrims specifically has been discussed briefly, and concept in EHRs and models of sharing of electronic information. Furthermore, this chapter discusses IoT aspects and models in the context of EHR. Thus, the gap of IoT usage in EHR in pilgrimage is identified.

3. **Chapter 3 (Research Methodology)** presents the methodology of this research which includes the study design, sample and sampling, method of data collection and the statistical analysis.

4. **Chapter 4 (Data Analysis and Results)** discusses the analysis of collected data using various data collection methods. The findings that are presented in this chapter represent the bases of proposed framework importance and viability.

5. **Chapter 5 (Framework Development)** presents the proposed IoT framework for EHR retrieval based on the collected data from literature review and various data collection methods. The recommendation of proposed framework implementation is presented through various scenarios.

6. **Chapter 6 (Validation of Proposed IoT Framework for Malaysian Pilgrim EHR Retrieval)** presents the validation of the usability, usefulness, flexibility, and security of the proposed framework.

7. **Chapter 7 (Conclusions and Future Works)** summarizes the research outcomes and provides suggestions for further work.

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 Introduction

As mentioned in chapter 1, the main aim of this research is to propose IoT framework to addresses the need of global retrieval of the EHR of travellers. The pilgrims are the travelers' case study in this research. To support the construction of the proposed model it is necessary to identify the most suitable IoT architecture for global EHR retrieval, and to identify the research gap. For this purpose, this chapter aims to review the aspects and the conducts works of the EHR and IoT domains.

This chapter consists of eight main sections as shown in Figure 2.1. Section 2.1 overviews the challenges and importance of pilgrim health. Section 2.2 presents the concepts and aspects of electronic health records. Section 2.3 overviews IoT concepts, facilities, and architecture. Section 2.4 clarifies various layers of IoT framework. Section 2.5 discusses related works of pilgrim health utilizing IoT. Section 2.6 explains research gap based on the discussion of related works in sections 2.5. Section 2.7 presents the research conceptual framework. Lastly, Section 2.8 summarizes the directions of this chapter.

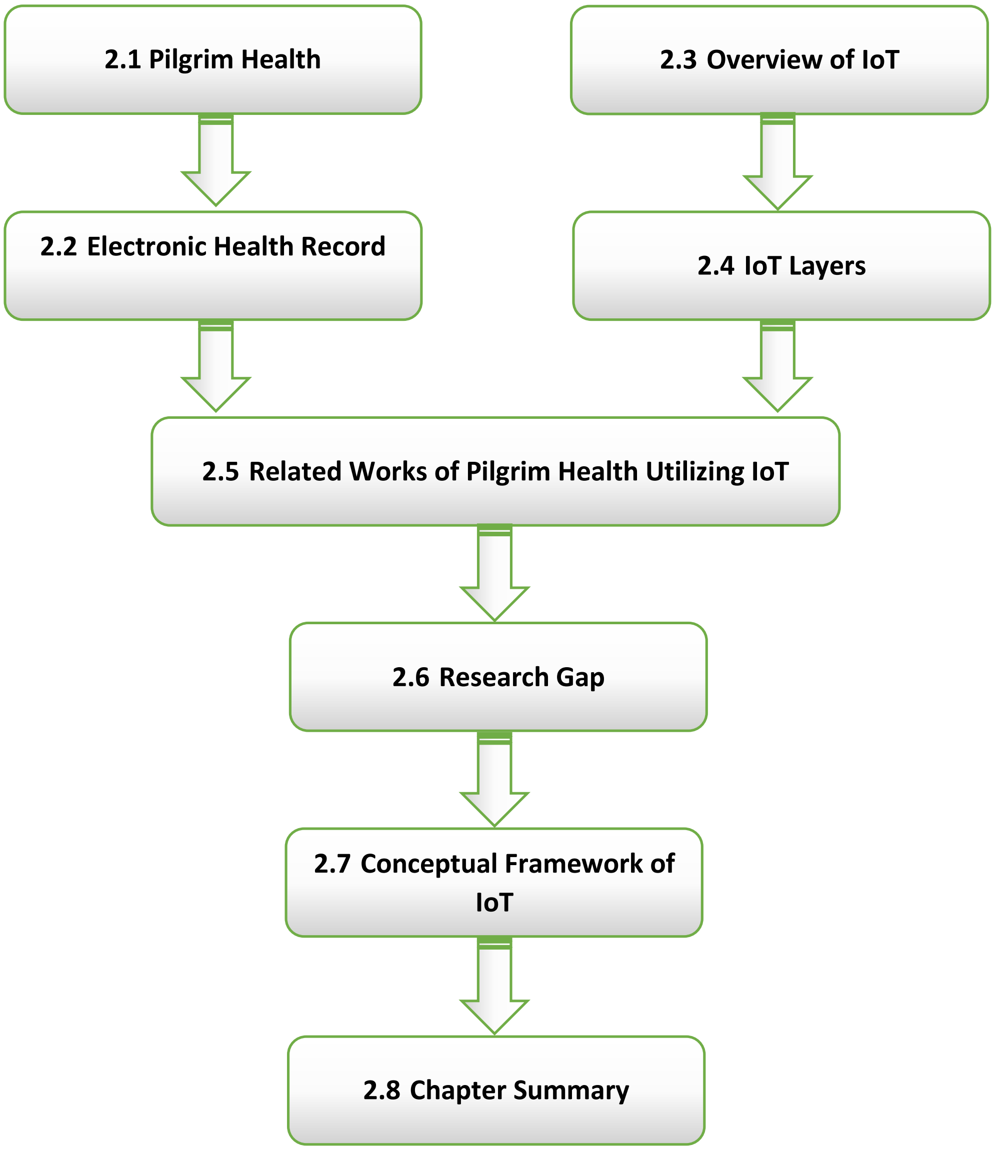



**Figure 2.1: General Structure of Literature Review**

## 2.1 Pilgrims' Health

In the last decades, many people have travelled abroad to different destinations and have been exposed to different cultures (Cossar, 2015; Devkota & Devkota, 2014; Laws, 2015). The growth in the number of international tourists corresponds to greater contact with emergency centers, which must attend to travelers who have critical mental or physical health issues (O'Neill et al., 2014; Pottie et al., 2011). Moreover, travel-related somatic and psychic health's problems occur more frequently but are less severe remain unreported and should be explored only in specific studies (Cossar, 2015; Page, Clift, & Clark, 1994). Remove et al

Travel may give rise to various health issues, serious injuries, such as those caused by transport accidents, or minor health issues, such as jet lag, as well as subject themselves to overexposure to the sun. Furthermore, international tourists might be affected by various factors such as holiday stresses and the adaptation to new environments that can reduce their resistance and exposes them to health risks. Also, travellers may become susceptible to health hazards as a result of the very nature of travel itself. In addition, travellers may be exposed to unfamiliar pathogens to which they have not built up a resistance. However, health problems that are associated with travel might be avoided by taking the necessary precautions (Clift, 1994; Cossar, 2015).

Hajj is the annual Muslim pilgrimage to religious sites in Mecca and Medina in the Kingdom of Saudi Arabia and is attended by more than two million Muslims from various countries. Health risks have been documented most notably during the Hajj (Ahmed et al., 2006; Alqahtani et al., 2015). Crowded conditions during the pilgrimage have led to traffic accidents, fire injuries, and stampedes. Deaths that occur during the Hajj are commonly caused by cardiovascular diseases. When the Hajj takes place during summer, pilgrims are at risk for dehydration and heatstroke. The possibility of the transmission of infectious diseases during the Hajj has been acknowledged for a long time. For fourteen centuries, serious health problems have arisen during the Hajj. The incidence of plague and cholera among a considerable number of pilgrims has been documented in historical records; stricken pilgrims were typically quarantined to control the spread of disease.

Overcrowding during the Hajj increases the probability of the spread of infectious diseases. Health authorities in Saudi Arabia needed to conduct mandatory vaccination using bivalent A and C vaccines when meningococcemia was transmitted among the pilgrims (Ahmed Q. & V, 2013). The quadrivalent meningococcal vaccine, which protects against sero-groups A, C, Y, and W135, must now be administered to pilgrims (Shibl, Tufenkeji, Khalil, & Memish, 2013).

Upper respiratory symptoms are also common among pilgrims, which is why influenza vaccinations are recommended because they can reduce influenza-like illnesses. Pilgrims over the age of 65 years should also have pneumococcal vaccinations. This vaccine should also be administered to pilgrims who have underlying medical conditions that can be aided with this medicine (Z. A. Memish et al., 2014).

Since 1989, cholera outbreaks have not occurred during the Hajj because sewage and water supply systems were improved. Pilgrims should be vaccinated against hepatitis A and other diseases such as tetanus, polio, diphtheria, and hepatitis B. Pilgrims who come from countries that are susceptible to the risk of yellow fever transmission also require a vaccine against the disease (Ciottone et al., 2015).

The Saudi Arabian Ministry of Health has been requiring all travellers from countries that are affected by polio and are under the age of 15 to provide evidence that they have been administered with the oral polio vaccine (OPV) since 2005 (Z. Memish, 2010). This evidence should be presented six weeks before these individuals apply for an entry visa to Saudi Arabia. OPV will also be administered to these travellers at the border points whether or not they have undergone it previously. In 2006, the Saudi Arabian Health Ministry also announced that additional OPVs would be administered to travellers from India, Pakistan, Nigeria, and Afghanistan when they arrive in the country.

### 2.1.1 Common Health Problems during Pilgrimage

Pilgrims are at high risk with regards to health because of their age (most of them are over 65 years old) or existing health condition. Therefore, pilgrims are considered vulnerable to a wide spectrum of diseases that may affect any human being.Most common diseases include meningococcal, influenza, water borne diseases, and blood borne diseases. Table 2.1 below demonstrates a brief description about the most common diseases.

**Table 2.1: Common and Documented Health Problems**

| Diseases | Symptoms of diseases | Descriptions | References |
|---|---|---|---|
| Meningococcal infections | • Fever<br>• Headache<br>• Stiff neck | Dangerous and damaging infection from the bacterium Neisseria meningitides and it is spread through coughing and sneezing. It is also a major cause of illness, disability, and death, yet, it can be prevented through vaccination | (Z. A. Memish et al., 2015; Rosenstein, Perkins, Stephens, Popovic, & Hughes, 2001) |
| Influenza | • Fever over 100.4 F (38 C)<br>• Aching muscles, especially in your back, arms and legs<br>• Chills and sweats<br>• Headache<br>• Dry, persistent cough<br>• Fatigue and weakness<br>• Nasal congestion<br>• Sore throat | Highly contagious infection of the respiratory tract. Vaccination recommended to prevent it. | (Y. Chen et al., 2013) |
| Food and waterborne diseases | • Diarrhea<br>• Nausea<br>• Fever<br>• Vomiting. | It comes by the consumption of contaminated food or beverages. | (Semenza, Suk, Estevez, Ebi, & Lindgren, 2012) |
| Blood borne infections | • Weight loss<br>• Persistent low-grade fever<br>• Night sweats<br>• Flu-like symptom | It is a transmitted disease spread by direct blood contact from one individual to another through skin injuries or a mucous membrane. The pathogens of primary concern are the human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV). | (Z. Memish, 2010) |
| Heat and sun related problems | • Throbbing headache<br>• Dizziness and light-headedness<br>• Lack of sweating despite the heat<br>• Red, hot, and dry skin<br>• Muscle weakness or cramps<br>• Nausea and vomiting<br>• Rapid heartbeat, which may be either strong or weak<br>• Rapid, shallow breathing | Variety of sicknesses due to environmental heat and sun exposure, which cause heat exhaustion, heat cramps, and heat stroke | (Leonardi et al., 2006) |

Deris et al. (2010) reported that pilgrims most commonly suffer from upper respiratory symptoms. The influenza vaccine can reduce the symptoms of influenza-like illnesses, which makes it highly recommended for pilgrims who will attend the Hajj (Deris et al., 2010). Furthermore, the last outbreak of cholera during the Hajj was in 1989 and infected Malaysian pilgrims as well. This cholera attack was attributed to the congested conditions and the lack of proper hygiene. After this outbreak, the government of Saudi Arabia has taken the initiative to improve the sewage and water supply systems, along with sanitation and water delivery to the Hajj sites.

Other common health problem is the blood borne infection which is often happen during Hajj (Alqahtani et al., 2015). During Wukuf, a ritual event during Hajj, where men have their heads shaved and women cut a small portion of their hair. Most men hire self-employed barbers, who are typically present near the Plain of Arafat, to shave their heads. A razor blade is often utilized in this procedure, and this blade will be used on several scalps before it is disposed of (Rafiq, Rashid, Haworth, & Booy, 2009; Shafi, Memish, Gatrad, & Sheikh, 2005). To counter the risk of blood borne diseases, authorized barbers use new blades provided by the government of Saudi Arabia for each customer. However, not all pilgrims utilize this service; some still opt to shave their own heads or avail the services of the self-employed barbers. Therefore, pilgrims should be informed and encouraged to use this facility. Apart from that, is the minor injuries that are frequently occur during the circumambulation of the Kaa'ba, which is performed in bare feet. Also, the stoning ritual causes more serious injuries when stampedes occur in Mina, and these injuries can sometimes be fatal. Another cause is death and trauma from traffic accidents. The aged and infirmed could consider asking other people, such as a guide, relatives, or friends to perform the rituals to avoid injury (Gatrad & Sheikh, 2005; Z. A. Memish et al., 2014). On July 2, 1990, approximately 1426 pilgrims from Malaysia, Indonesia, and Pakistan were trampled or suffocated in a stampede in an overcrowded pedestrian tunnel in Mina. On May 23, 1994, 270 pilgrims, most of whom were Indonesians, were killed in a stampede, and 388 pilgrims were killed in 1998. While in 2004, 251 pilgrims were killed during the stoning ritual at Mina. Another major accident took place on January 12, 2006, where approximately 400 pilgrims died and a thousand others were injured in a stampede on the last day of the pilgrimage.

On 24th September 2015, about 2,400 pilgrims were suffocated or crushed by a stampede in Mina, Mecca making it the deadliest Hajj disaster in history (Jon & Baba, 2015). One of the main causes of stampede were pilgrims who were carrying baggage while performing the stoning ritual because they wanted to go to Mecca directly after the stoning (Sim & Mackie, 2015; Uddin & Ozair, 2004). Pilgrims who entered or left the Jamarat Bridge in opposite directions because their accommodations were located on different sides of Jamarat were also involved. The stampede was worsened by pilgrims who hit other people with their elbows or tripped over baggage. Therefore, pilgrims are advised to avoid peak times.

Further to that, heat and sun related problems are common and can be fatal as well. A study found that heat was responsible for most of the 1700 fatalities during one particular single Hajj season. Incidences of severe dehydration and heatstroke tend to increase. Saudi officials provide information about the dangers of excessive sun exposure by disseminating such information through radio, television, and leaflets (Gatrad & Sheikh, 2005; Gautret, Benkouiten, Sridhar, Al-Tawfiq, & Memish, 2015) .

### 2.1.2 Challenges in Managing Pilgrim Health Services

Through the years, the Hajj has been and is a major public health challenge that requires great attention from the government and private sector in the KSA, especially its Ministry of Health (MOH) (Rafiq et al., 2009). The primary tasks of the MOH during the Hajj season include the following: ensuring the provision of healthcare for pilgrims, continuously expanding and improving healthcare facilities, deploying qualified health personnel, reducing bottlenecks at healthcare facilities, and establishing disaster or emergency plans in coordination with other relevant sectors. Another concern is protecting Saudi Arabia residents against potential risk factors or diseases arising from the short-term influx of about two million pilgrims from various countries (Razavi & Salamati, 2013) .

In the past, pilgrims suffer from various health problems and mass casualties, as seen through excessively high morbidity and mortality rates. Apart from various health problems such as cholera, meningitis, respiratory diseases, food poisoning, traffic accidents, and fire, environmental health problems with high fatality rates such as heat exhaustion and sun/heatstroke also serve as major challenges (Control & Prevention, 2013; Z. A. Memish et al., 2015; Rafiq et al., 2009; Razavi & Salamati, 2013).

Since the 1960s, pilgrimage health have become subject to international health regulations established under the WHO (Cowling, Zhou, Ip, Leung, & Aiello, 2010; Moattari, Emami, Moghadami, & Honarvar, 2012). From that time on, pilgrims were recognized as international travellers, marking a turning point in sanitation and healthcare improvements during the annual Hajj season. Since then, multi-disciplinary teams comprising Saudi Officials conduct frequent meetings every year to assess the situation and identify areas requiring further attention. Using this strategy, the Saudi hosts have established considerable expertise in solving medical-related problems and emergency situations related to the Hajj.

The development of health service provision during the Hajj season has achieved remarkable advances in recent years. The Saudi government allocated vast resources, including qualified personnel as well as better health facilities, amenities, infrastructure and logistics to better serve the pilgrims. For instance, permanent, temporary and seasonal health facilities are distributed in Mecca and other religious sites. These include 34 permanent and 80 temporary health centres, 14 permanent/seasonal hospitals, and 96 cooling units to manage heat exhaustion and stroke. A total of 1,778 of emergency beds and 4,624 hospital beds have been prepared in Mecca and Medina for regular and emergency cases during the Hajj season. Moreover, about 9,200 health personnel from MOH alone provide services to pilgrims. These data fluctuate annually depending on the expected number of pilgrims and the presence of high-risk groups among them.

Saudi officials provide many other services, such as providing safe water and transportation; safe and secure accommodation in the form of tents made of fire-resistant coated fibreglass; proper sanitation and waste disposal; monitoring of slaughter houses for proper sanitation; and the provision of health education and organization to ensure the safe and smooth passage of all pilgrims through the Hajj rituals (Z. A. Memish et al., 2014).

Without doubt, the Saudi government spends a substantial sum to provide comprehensive and integrated services for the pilgrims during their stay and also during their passage among the religious sites. For example, an efficient network of paved roads for cars and buses, along with shaded pedestrian pathways was constructed at a cost of SR 3.242 billion (approximately 800**$** million).

Morbidity and mortality rates of pilgrims have been minimized through the combined efforts and efficient response of various groups to epidemics and disasters. However, better plans to provide improved health services can be designed via a shift in goals and objectives. Indeed, many lessons are learned from the challenges of hosting the Hajj, such as the short-term influx of pilgrims from different countries. These challenges are summarized in the subsequent sections.

- **Large number of pilgrims:** The Hajj has become the epicentre of the mass migration of millions of Muslims with great ethnic diversity. Simply no other mass gathering can compare either in scale or in regularity (Z. A. Memish, Stephens, Steffen, & Ahmed, 2012). However, with such large gatherings, communicable and various infectious disease outbreaks during and after the Hajj have been repeatedly reported.

- **Language barrier:** Pilgrims with limited English proficiency are unable to receive quality healthcare because most of the health care centres either have inadequate or completely lack proper interpreter services (Alsafadi, Goodwin, & Syed, 2011). Often, those recruited to assist patients communicate with healthcare providers are not properly trained interpreters, and are usually family members, friends, fellow patients, untrained non-clinical employees, or non-fluent healthcare professionals. Reliance on such ad hoc and unprofessional services can have negative, if not fatal, clinical consequences.

- **Emerging infectious diseases:** Mass gatherings attended by a few millions of pilgrims from all over the world create an environment that promotes the rapid spread of bacterial and viral infections (Abubakar et al., 2012). Africa alone has a large Muslim population of over 250 million people (Kettani, 2010). More than one million pilgrims travel yearly to Mecca and Medina to join 10 million other pilgrims in performing either the annual Hajj pilgrimage or the Umrah, which is observed at any time of the year. A major public health concern concerning these pilgrimages is the importation/exportation of infectious diseases with epidemic potential (Z. A. Memish et al., 2014). For example, outbreaks of Rift Valley fever from East Africa have occurred in KSA and Yemen (Fagbo, 2002). Two outbreaks of meningococcal disease in KSA have also been linked to the Hajj (Aguilera, Perrocheau, Meffre, Hahné, & Group, 2002; Al-Gahtani, El Bushra, Al-Qarawi, Al-Zubaidi, & Fontaine, 1995).

- **Continuity of care:** This is considered a key factor in ensuring quality healthcare delivery, although it is under threat from commercialization (Mahrous, 2013). Related to this, pilgrim health creates varied challenges, such as whether patients have informed consent for treatment, and the implications of various side effects, complications, and post-operative care when faced with the lack of accurate treatment records for the patients.

- **Safeguarding quality and safety:** Modern healthcare is a complex and risky undertaking that is prone to medical malpractice and clinical errors, especially when healthcare is accessed in countries where providers are poorly regulated (Dibbi, Al-Abrashy, Hussain, Fatani, & Karima, 2006).

## 2.2 Electronic Health Record (EHR)

Patient care is the core of all health service activities, which aim to meet the healthcare needs and satisfaction of patients. Therefore, patient records are important for the patient healthcare process and health service processes and information (DesRoches et al., 2008). The main issues in managing patient health records include order entry/management, health information and data, reporting and population health management, and electronic communication and connectivity (Middleton et al., 2013).

Managing medical records in electronic forms can be more effective within the increasing number of patient population (Middleton et al., 2013). The recognized role of a networking system and the increasing use of technology have led to the adoption of the EHR system. Although the EHR system can suffer from slow uptake, it promises improved efficiency by facilitating easier information exchange among healthcare providers for the same patients. The demographic expansion leads to an increasing need for health and medical attention, treatment and medical information, including patient information that need to be systematically secured and managed (Kuo, 2011). Hence, adopting an EHR system for information sharing is crucial. Thus, there is a great need for a well-established electronic system that can deal with these cases of patients' health problems, to provide them with an adequate health services. Many countries have established an electronic system that deals with patients' health record and their health history by EHR (Coloma et al., 2013; P. Wang, Ding, Jiang, & Zhou, 2013).

EHR has been defined as follows: EHR encompasses all health information in all media forms regarding an individual and is primary source for recording and documenting patient health data (Bickford, Hunter, Saba, & McCormick, 2006). Wager et al. in 2009 provided another definition: Electronic health record: an electronic record of health-related information on an individual that conforms its nationally recognized interoperability standards and that can be created, managed, and consulted by authorized clinicians and staff across more than one healthcare organization (Wager, Lee, & Glaser, 2009).

Electronic Patient Record (EPR) and Electronic Medical Record (EMR) are considered as synonyms of EHR. EPR or EMR is defined as an electronic record of health-related information on an individual that can be created, gathered, managed, and consulted by authorized clinicians and staff within one healthcare organization (Wager et al., 2009).

### 2.2.1 Key Components of EHRs

Patients receive several services from supporting factions such as laboratories, radiology clinics, and pharmacies. An electronic record can be designed for each of these services. Some of these clinical systems support digital capture for nursing notes or orders of clinicians (Kellermann & Jones, 2013) . Often, these systems are not integrated with each other, and each system has its own patient identification system (Figure 2.2). Different vendors may supply each of these systems (Kuperman & McGowan, 2013). Therefore, different standards for vocabularies and identification systems are used for both user and patient. Clinicians require a log-in for different applications of different services to obtain information regarding their patients. EHRs combine data from all ancillary services with other medical care components. These clinical data have different methods for sharing or importing various components, such as presentation or data integration (Carter, 2008).

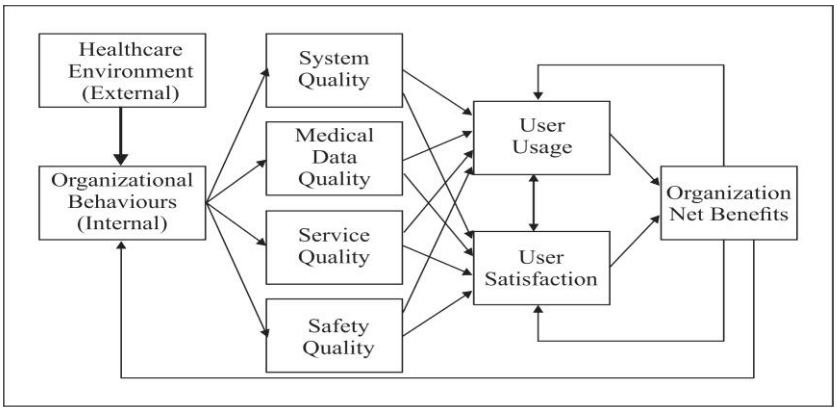



**Figure 2.2: Taiwan Electronic Medical Record System Evaluation Framework**

(Carter, 2008)

Definitive standards are needed to achieve the primary goal of EHR by representing relevant clinical information in a shared EHR system. The following demonstrates the importance of developing and adopting national and international standards for EHR interoperability (Schloeffel, Beale, Hayworth, Heard, & Leslie, 2006):

- Healthcare organizations can share clinical information in a multi-disciplinary, advanced shared-care environment.

- Interoperability between local and foreign healthcare providers is made possible.

- Interoperability between systems from different vendors is facilitated.

However, different approaches have been used in developing these standards (DeNardis, 2011). A definition and an outline of the key standards developed for representing and exchanging relevant medical information are provided below. A standard is a document established by consensus and approved by a recognized body that provides for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context (as cited in the European Telecommunications Standards Institute).

Traditionally, medical information systems recorded and stored the data regarding patients using formats that were incompatible with other systems. The goal of creating EHR standards is to establish the means to integrate relative medical patient information and enable other medical systems to use this information as well (DeNardis, 2011) .

Medical vocabularies and structured data organization are several examples of e-health standards as shown in Figure 2.3. These tools have significantly improved medical information systems in terms of effectively interoperating and interconnecting with each other. This improvement has resulted in successful EHR implementation (DesRoches et al., 2008; Romano & Stafford, 2011).

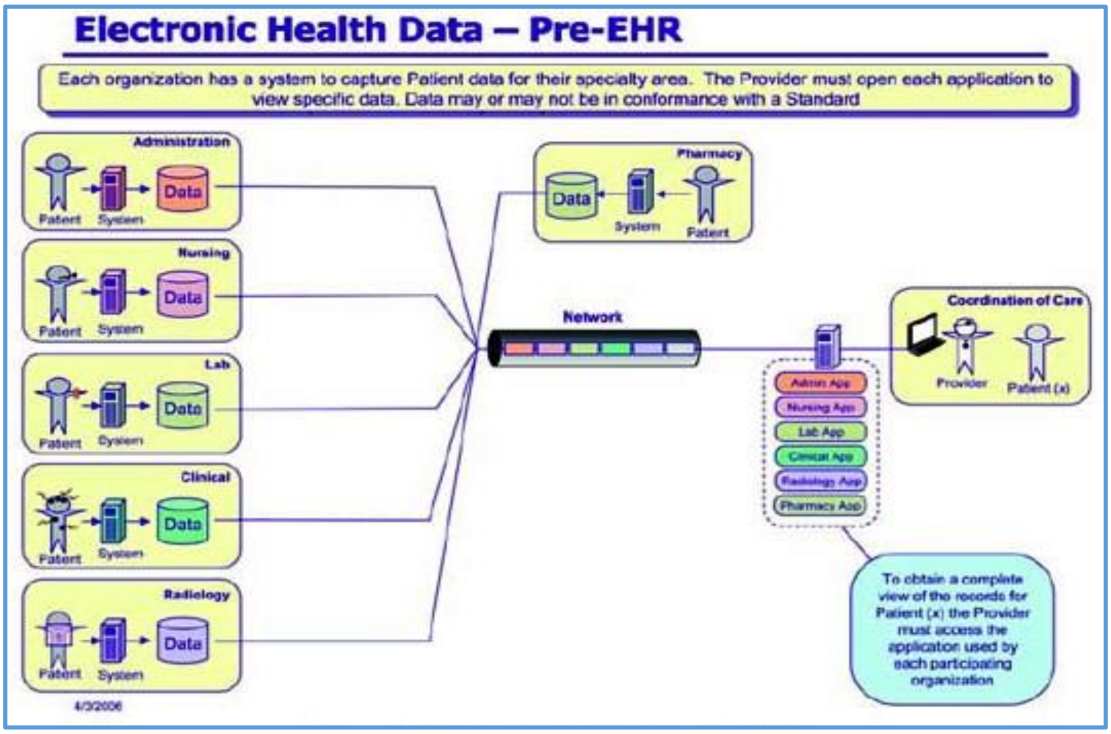



**Figure 2.3: Electronic Health Data**

(DesRoches et al., 2008)

Therefore, based on DeNardis (2011) standards and vocabularies, the review has identified EHR components as presented in Figure 2.4 and explained the following points.

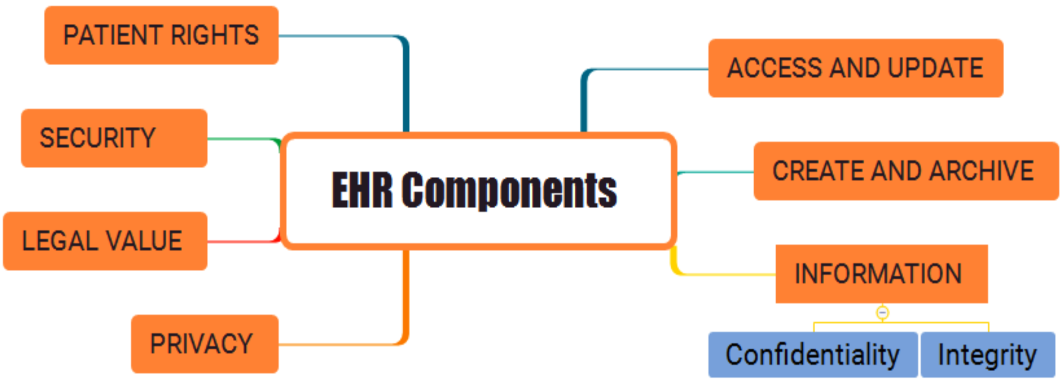



**Figure 2.4: EHR Components and Aspects**

#### 2.2.1.1 Creating and Archiving EHRs

Preserving and storing records for a long span of time must be planned efficiently and must therefore be included in the development of EHRs. In 2014, Gautam studied the function of the National Archives of India as the authorized agency that would supervise the implementation of recording practices in the Central Government of India. The preservation issues associated with electronic records were discussed, which included enabling the methodology for preserving, managing, and recycling electronically to be accessible to future generations (Gautam, 2014).

One key issue that was identified and discussed was the vulnerability of electronic documents to loss caused by the decay of the data storage medium, which then becomes inaccessible and unreadable, especially when the software must read this information or when the hardware that the software uses becomes out-dated (Gautam, 2014). Thus, creating a copy by using a new medium has become a necessity. However, this method will probably alter the information because of encryption, compression, or the change in data formats.

In England, Greenhalgh investigated three adopter sites in a somewhat lower-class urban location and one adopter site in a relatively affluent rural location. Greenhalgh et al. in 2008 aimed to study the summary care record (SCR), which is a central system of electronic patient records that is shared with others. This study comprised 250 interviews with staff, 170 focus groups and interviews with patients and carers, 1500 hours of ethnographic observation, and 2500 pages of documentation and correspondence. Statistics and surveys from other studies were used (Greenhalgh et al., 2008). Found that there are few factors that influence the different outcomes of the SCR program during the first year of operation. These factors were material properties of the technology. The concerns and attitudes of people, interpersonal influence, and the material properties of technologies that affect EHR technology at the micro-level, while other factors such as implementation, alacrity, and previous events affect EHR technology at the mesolevel. Finally, the surrounding environment, particularly in terms of politics and institutions, also affects EHR technology.

#### 2.2.1.2 Accessing and Updating EHRs

In 2005, Lin et al. conducted a controlled randomized trial to test the premise that patients and their respective doctors and medical institutions can communicate better through the use of patient portals. For a period of six months, the control group did not use a patient portal, whereas another group utilized a patient portal to directly communicate with their doctors. This group used the patient portal for several reasons, such as to replenish their medicine, schedule visits, and ask for referrals. A comparison between the content of telephone and portal communications found that the group that used the patient portal was more satisfied than the control group with the communication and care that they received. These patients held a high regard for the improved service that the portal provided, including the one-on-one answers of the doctors, as well as the increased convenience and approachability (Lin, Wittevrongel, Moore, Beaty, & Ross, 2005). In contrast with telephone calls, the messages that patients sent had more psychosocial and information data, as this will result in improving the relationship between doctors and their patients (Beard, Schein, Morra, Wilson, & Keelan, 2012).

In 2012, Beard et al. examined the diverse challenges and obstacles involved in creating accessible EHRs, which would be available to both physicians and patients. In this study, expenses, privacy, accountability, and stakeholder rights and responsibilities were the primary issues to be addressed. Beard et al. presented the following results: 59% of physicians and 67% of the public agree that test results should be electronically accessible to patients as soon as they are ready; 41% of physicians and 54% of the patients think that patients should be given the privilege to filter the information that will be shared with a new doctor; 49% and 47% of the public and physicians, respectively, believe that physicians should receive e-mails from their patients. Meanwhile, 36% of the doctors and 20% of the patients do not agree with the last statement (Beard et al., 2012).

#### 2.2.1.3 Security of EHR

Various departments in a healthcare unit have access to the information in EHRs, which is an aspect that requires a secure procedure. High security standards require high implementation and maintenance costs, which many healthcare providers may not be able to afford. Furthermore, clinicians may have different competencies in using EHR systems. This variation may become dangerous when vital information is either omitted or accidentally altered (Hoffman & Podgurski, 2008).

Apart from security concerns within organizations, health record systems may also be subject to unauthorized access and unwanted attacks from hackers, viruses, and other Internet-based security threats. Current security technology may have developed significantly, but problems in securing e-health information have not been eliminated (Shoniregun, Dube, & Mtenzi, 2010). Therefore, health services must continue to improve and apply protocols for the data security of both internal and external procedures. Services mainly aim to improve and elevate healthcare standards (Marchibroda, 2007; C. Wang, Wang, Ren, Cao, & Lou, 2012); secure operation and access to medical data aids this particular objective. Health services also face the challenge of erratic security systems that can be used in other systems. These characteristics hinder the creation of an effective security protocol. (Page et al., 1994) stated that the major deficiencies of any EHR system used today are the inconsistencies and interoperability in its security system.

In 2010, Yu et al. explored several issues related to information security management systems (ISMS) that must be considered in the design and implementation process of EPR. These issues include technical issues that enable ICT applications in healthcare service operations and processes. The systems must be updated within a relatively short time (S. Yu, Wang, Ren, & Lou, 2010). The second issue involves organizational issues, which include the handling of resources and management events, employee issues, and environmental issues (Whitman & Mattord, 2013). These issues occur within the organization, and the organization must control such issues through the effective use of policies and procedures. According to Yu et al, the ISMS have two levels, the first level, which includes planning, development, implementation, evaluation and maintenance. Processes and sub-processes must be taken into consideration in designing an EPR security implementation strategy. Katsikas (2000) suggested that there are three major categories for information systems security training, namely, legal, regulatory, and ethical framework. These three categories are relevant to information systems security, policies, and controls, respectively (Katsikas, 2000).

#### 2.2.1.4 Integrity of the Information

Integrity of the information is one of the main characteristics of information security. This requirement stresses that a signature must be implemented to protect information content integrity, and availability. Ferreira et al. defined integrity of information as the prevention of unauthorized modification of the information (Ferreira et al., 2004). Haas et al. (2011) argued that the life of a patient might depend on the information and data in his/her record. Therefore, only authorized people have the right to access and change information (Haas, Wohlgemuth, Echizen, Sonehara, & Müller, 2011; Parra & Hall, 2014). However, electronically stored health information may face the risk of unauthorized access, misuse, and abuse by unauthorized person (Hellesø & Ruland, 2001)

Unauthorized individuals can gain access to confidential data when authorized users take advantage of their benefits or when they violate the privacy of such records. Therefore, only authorized people, such as the GP, has the right to access and edit patient records. EHRs contain confidential information, which can affect patients' health and even their lives. Therefore, integrity and securing the privacy of these records is paramount.

Consent protocols are continuously developed to further secure patient information. However, consent should not hinder medicine practice while patient privacy is maintained. Therefore, incorporating multiple broadcast encryption schemes into EHRs could solve this problem (Susilo & Win, 2006). However, this method needs EHR users to be identified first, and EHR users to be assured of their safety and security. Doukas et al. analysed several topics regarding EHRs, communication, and the exchange of information and security. The result of this analysis found an approach that uses attribute-based encryption to preserve the confidentiality of patient information during EHR exchange among healthcare providers. Also, it reduces the risk of unauthorized access to sensitive information (Doukas, Pliakas, & Maglogiannis, 2010). This prototype has shown that attribute-based encryption addresses the restrictions of traditional approaches and facilitates the reinforcement of existing security policies over transmitted data.

#### 2.2.1.5 Confidentiality of the Information

Distinguishing between confidentiality and privacy is important because the terms are often used interchangeably, but they have different meaning and interpretation. Privacy can be defined as the right of an individual to not have his/her private information disclosed or exposed. Confidentiality is defined as the prevention of unauthorized disclosure of the information, whereby access to the information is limited to authorized individuals only (Ferreira et al., 2004). Parra and Hall (2014) argued that implementing effective EHR in health services is difficult because of two main constraints. The first constraint is the lack of trust in the IT infrastructure when sharing EHR. The second constraint is the need to include certain requirements, such as the use of appropriate and effective content encryptions and secure key management solutions (Parra & Hall, 2014). Haas et al. stressed that patient records must be considered private and confidential records that no unauthorized person should inspect. Authorized staff is the only ones who can access these records. The security system requires confidentiality of the data and information exchanged between the EHRs and the server in health service activities (Gungor & Hancke, 2009; Hyuk Park, Gritzalis, Hsu, Roman, & Lopez, 2009).

#### 2.2.1.6 Legal Value

A patient record is data that were obtained by a medical professional. Thus, the data have value. Haas et al. (2011) stated that the patient's records are the complete and unadulterated records of all actions taken by healthcare professionals on behalf of that patient, and should be the definitive source of information about all the said actions (Haas et al., 2011).

#### 2.2.1.7 Sharing and Interoperability

Sharing patient health data across platforms and organizations, including clinical systems (for example, hospital information systems, pharmacy management systems, physicians, EHR domains, etc.), provincial repositories (for example, shared health records, drugs, labs, etc.) and provincial registries (i.e., provider, client, location, and user), requires linking disparate e-Health systems to facilitate the exchange of information while ensuring the privacy of patient information (Weber et al., 2009).

One of the basic requirements of EHR systems is that they must be interoperable, which means that the clinical information of an individual must always be meaningful even when transferred among different EHR systems and between versions of the same software. Moreover, the recording of information has to be consistent to ensure effective comparisons as required (Marcos, Maldonado, Martínez-Salvador, Boscá, & Robles, 2013; J. Walker, Pan, Johnston, & Adler-Milstein, 2005).

Most countries suffer from a lack of healthcare IT standards, thus leading to interoperability barriers for healthcare IT adoption at both local and national levels.

European countries, such as France, Sweden, the Netherlands, and others, have attempted to standardize their EHRs either by implementing national standards or by using a variation of the Health Level Seven (HL7) standard to achieve interoperability among countries. At present, Denmark, Norway, and Sweden already collaborate with one another in the efficient exchange of electronic health information.

### 2.2.2 EHR Situation in Malaysia

The implementation of HIS varies between one country to another for example in Pacific Region, where it will be driven by factors of an increased expectation from patients and demands from clinicians and changes in disease patterns, from communicable to non-communicable including chronic diseases that requires changes in patterns of care and supporting system (Mohd & Syed Mohamad, 2005).

However, there are some initiatives that have been taken by the Malaysian Government to improve healthcare quality in public hospital. For example, RM13.7 million was given in 2009 to improve healthcare services and facilities. Other than that, in the Ninth Malaysia Plan (9MP), the government declared to improve hospital services, facilities and infrastructures such as medical equipment and information technology systems (Banerjee & Bagha, 2014; Noraziani et al., 2013). According to Frolick (Frolick, 2009), an essential factor in the administration of healthcare is the information technology (IT). It improves health care quality and service. Furthermore, according to Ismail et al. (Ismail et al., 2010), IT has made a major positive impact on the healthcare sector. Moreover, it provides more accurate and timely information regarding patient care.

### 2.2.3 Related Models of EHR

The review has chosen six EHR models throughout the globe, namely, the WorldVistA, NPfIT, HealthConnect, HealthLink, Hakeem and Eijad.

#### 2.2.3.1 EHR in the USA

The US healthcare system has often been described as a cottage industry, because it is fragmented at the national, state, community, and individual practice levels (Shih et al., 2008; Shoniregun et al., 2010). Although the Federal government bears the largest part of healthcare costs, no national agency or body of law or policy governs the system exclusively. At the state level, multiple public and private agencies are tasked with monitoring and providing care, whereas healthcare providers serving the same patient population rarely communicate with one another at the community level.

Healthcare is funded through a combination of public and private financing with multiple payers (Gusmano, Rodwin, & Weisz, 2010). Nearly 56% of Americans with health insurance are covered by an employment-based health insurance plan, and just over 30% of Americans with health insurance are covered by government health insurance programs, including Medicare, Medicaid, and military healthcare.

In 2005, approximately 23.9% of physicians in the US used EHRs in the ambulatory setting, and only 5% of hospitals used Computerized Physician Order Entry (CPOE) (Jha et al., 2006). A study on the levels of EHR adoption in the US revealed that only a few US hospitals maintained comprehensive electronic clinical information system, and many others only had parts of an electronic records system. Thus, it seems that financial support, interoperability, and training of information technology support staff by policy makers are necessary in strengthening the application of EHRs in US hospitals (Jha et al., 2006).

A general study of IT adoption in US healthcare (Christensen & Remler, 2009) concluded that technology adoption is more aligned to organizational and cultural issues than just system functionality. The authors found that the participation of clinical staff is the most important factor in health information system implementation. In particular, the end-user engagement of physicians those who champion the use of technology has also been recommended as a key element in the successful adoption of health information systems; (Bernstein, McCreless, &

Cote, 2007). Given the fragmentation of the US healthcare delivery system, a national EHR database can improve the quality, safety, and efficiency of healthcare in the US. Many of the EHRs being used today are based on these early electronic medical records (EMRs), such as the system used by the Veteran's Administration, first developed in academic medical centers and government clinical care organizations.

As a governmental sector, the US Department of Veterans Affairs (VA) has advanced its efforts to develop an extensive organizational health information system since the late 1970s. This system is called the Veterans' Health Information Systems and Technology Architecture (VistA). VistA uses the Massachusetts General Hospital Utility Multi-programming System (MUMPS), a program that can be used for disease case registries (Jha et al., 2009). VistA comprises about 160 integrated software modules that cover the areas of financial functions, clinical care, and infrastructure.

The Veterans Health Administration (VHA) manages the largest medical system in the US, providing care to over 8 million veterans. VHA employs 180,000 medical personnel and operates in 163 hospitals, more than 800 clinics, and 135 nursing homes throughout the continental US, Alaska, and Hawaii within a single electronic healthcare information network (Jha et al., 2009). About 25% of the country's population is potentially eligible for VA services and benefits because they are veterans, family members of veterans, or survivors of veterans. Furthermore, over 60% of all physicians trained in the US rotate through the VHA on clinical electives, making VistA the most familiar and widely used EHR in the US.

Nearly half of all US hospitals with a complete (inpatient and outpatient) enterprise-wide implementation of an EHR are VA hospitals using VistA. The success of VistA has led to spin-off EHR systems, including OpenVistA and WorldVistA. OpenVistA is a non-proprietary, open source EHR system that is based on the VA VistA software; it reduces the related costs by allowing VistA to run on the free and open source Linux operating system. OpenVistAalso enables client organizations to run the system on Windows. They can choose either InterSystemsCaché or Fidelity GT.Ml. Furthermore, it allows multiple clinicians to access various patient data simultaneously and in real-time. The OpenVistA system provides progress notes, various templates, ordering and reporting tools, audit capabilities, and electronic signatures, along with other features, such as document management, data integration tools, and CPOE.

In comparison, WorldVistA works on an open source format and is a spin-off from the Vista project. It was first created so that the original system would be available for use outside of its original format and setting within the US. The system comprises additional modules which are not normally used in the veteran's healthcare setting, such as paediatrics, obstetrics and patient billing. WorldVistAruns on a proprietary intersystem cache database (Stair & Reynolds, 2013). Depending on the environment, client-server and web-based configurations can be established on the system.

Additional functions can be created by users to this primary care system. As it is, WorldVistA already has functions for patient registration, drug allergy, and interaction checking. These functions are useful in viewing lab and imaging results; generating health maintenance reminders, clinical order entries, templates for obstetrics/gynaecology and paediatric care; and reports on demographics, medications, and various other medical problems.

#### 2.2.3.2 EHR in the UK

In England, the National Programme for Information Technology (NPfIT), under the National Health Service (NHS), is responsible for the country's EHR (Huston, 2006). In 2005, NHS established an EHR system that aimed to provide all 50 million NHS patients with an individual electronic NHS Care Record Service (NHSCRS) by 2010. The NHSCRS is supposed to securely store and share detailed records of each patient to different parts of the local NHS sites, using a unique identifier for each patient. All patients can easily access the database and obtain a summary of their important health information, known as their Summary Care Record (SCR), available to authorized staff in any NHS facility in England. Patients could also access their SCR via a secure website called Health Space. The initial budget of this project was around GBP 12.6 billion in 2006, and twice the project estimation since it was first launched. This project may have cost over 20 billion pounds (Nicolson et al., 2011). In October 2002, the NPfIT of the NHS was established in England, aiming for a single, centrally-mandated electronic care record for patients linking 30,000 GPs 300 hospitals, with secure accessibly authorized health professionals. However, the project was constantly marked by delays and was finally scrapped by the Conservative Liberal Democrat Government in September 2011.

Early research into the challenges and the effects of the NPfIT found that the timelines for delivery were not realistic. Moreover, there were major concerns regarding the effect of IT changes on the existing systems(Hendy, Reeves, Fulop, Hutchings, & Masseria, 2005). Thus, apart from focusing on technical and functional issues, emphasis should also be placed on handling cultural issues, managing organizational changes, and setting expectations. Similar conclusions have also been reported by (Christensen & Remler, 2009) in a study of IT adoption in healthcare in the US.

Dykes and Collins (2013) expanded on this theme with a study of the challenges involved in implementing the NPfIT in acute hospitals. This qualitative research study employed grounded theory and interviews with senior clinicians, trust executives, and IT directors to highlight the perceived challenges of using the NPfIT across the broad program. Although Collin et al. found wide support for the program and its strategic objectives, major concerns were raised about poor communication from Connecting for Health, the cost of the program, the prioritization ofthe program's implementation over other operational issues, delays in patient administration systems (PAS), risks to patient safety due to PAS delays, improper integration across the NHS, and dissatisfaction with the choose-and-book services. The authors concluded that the program should set more realistic targets for the delivery of the systems with better guidelines on implementing interim solutions or on prolonging the life of existing legacy systems. The study also supported the program with senior trust executives and managers, which increased during the 18-month research period. Interviews also claimed that their staffs were keen to adopt the program and found little evidence of resistance to its adoption. However, there were concerns regarding the capability of program managers to implement the program within acceptable timeframes (Dykes & Collins, 2013).

In studying five acute hospitals implementing EHR systems, (Robertson et al., 2010) found that the original top-down method used to deliver the national program has been largely replaced by a process of collaboration and choice, based on specific needs and contexts. The top-down approach, however, should not be replaced by a purely bottom-up approach, but a more flexible hybrid approach. Similarly, (Greengard, 2015) argued that the top-down approach failed to perform well in the case of the SCR. Thus, a middle-out approach should be used in which local authorities, governments, clinicians, and vendors should collaborate to create a flexible set of standards. Other challenges are the lack of IT skills and IT training resources, and the lack of awareness and knowledge of the overall purpose of the NPfIT(Robertson et al., 2010).This observation has been echoed by Wainwright and Waring (2007), who found the same lack of training resources and awareness in local primary care (Wainwright & Waring, 2007).

Meanwhile, Fehrenbach and Masmoudi (2008) reported that many applications developed for healthcare are not fit for their purposes, and recommended greater focus on cultural issues instead of technology alone (Fehrenbach & Masmoudi, 2008). Greenhalgh et al. (2010) reported that a centrally driven, top-down change model, in which timescales and cost are the priority, significantly influenced the SCR program in the NHS. They recommended that the national program adopt a socio-technical change approach. This socio-technical pull model focuses on the benefits and outcomes of the systems instead of the technology being an end in itself (Greenhalgh et al., 2010). The model employed by the Trust is mainly a top-down technology push model with increasing cost savings as its main goal. Clinical benefits are difficult to define, quantify and measure, and may include standardization of processes, reduction in prescribing errors, collection of accurate data for decision-making, and improved efficiency with simultaneous access to the data. Great efforts have been made to engage clinicians, and the projects are delivered through the direct involvement of a small group of trained clinicians and technology enthusiasts. However, the EHR program is clearly driven by cost and timescales which has resulted in poorly defined benefit models. The implementation approach is also driven by cost and timescales with a seemingly deliberate policy of fast-track delivery of systems and fixing operational issues on-the-fly.

For the reasons stated above, the EHR program has been perceived as an IT-driven technology push, despite the IT department having limited involvement in any decisions and has no real influence on the deployment and the deadline of the technology. The resulting chaos after the PAS went live and the poor performance of the clinical systems had a negative effect on the perception of both the EHR program and the IT department.

#### 2.2.3.3 EHR in Australia

Health Connect is an Australian joint state and territory government initiative with the aim to transform paper-based health records to EHRs for the benefit of health care providers and patients. Under this program, health information can be readily accessed and transferred among healthcare professionals under more secure conditions. The two main aims of this program are: (1) the accessibility of life-saving information in emergencies, and (2) the improvement of safety and quality of health information through a shared electronic health record (SEHR). The National E-Health Transition Authority (NEHTA), which helped develop the design for SEHR, was jointly funded by the State and territory governments in 2005 to develop national standards and EHR infrastructure across Australia (Ludwick & Doucette, 2009; J. Xu, Gao, Sorwar, & Croll, 2013).

#### 2.2.3.4 EHR in New Zealand

The role of IT in the implementation of healthcare in New Zealand ranges from basic use of communication system to advanced method of maintaining patients records to performing medical intervention like the surgical telemedicine. Nonetheless, it was reported that IT was used to share documents significantly more than to support discussions or to connect employees to experts. Discussions via teleconferencing, videoconferencing, and email lists were significantly more common than discussions via social media technologies: electronic discussion forums, blogs, and on-line chat rooms (Ludwick & Doucette, 2009).

HealthLink provides nearly all the clinical communications used throughout New Zealand, where almost all general practitioners use computerized systems, and almost all New Zealand citizens have an electronic patient record. HealthLink was created in 1993 as a result of the health reforms of the New Zealand government. Since then, the company has continued to develop systems and services that facilitate the exchange of clinical information since that time.

Since its inception, HealthLink has become a global leader in healthcare sector integration, achieving the exchange of 65 million items of clinical information between healthcare providers and the rest of the health sector in a year. This distinction gave the health sector of New Zealand the title of most automated health system in the English-speaking world. The company's latest service is Care Connect, an electronic referrals system developed for the three Auckland district health boards, for use across the Auckland region.

#### 2.2.3.5 EHR in Jordan

Launched in 2009, the Hakeem project was the first national e-health initiative in Jordan, which has an advanced healthcare system compared to other countries in the Middle East. This EHR integrates different types of health information systems, including the administrative, laboratory, radiology, pharmacy, computerised physician order entry and clinical documentation systems. Hakeem is based on the World VistA open source version of the U.S. Department of Veterans Affairs EHR platform known as 'VistA'. Starting with just one hospital and one comprehensive health center, Hakeem is being implemented in all public hospitals and health centers throughout Jordan, with the primary objective of improving the quality of patient care and safety (Dua'A, Othman, & Yahya, 2013).

Dua'A et al. (2013) mentioned that there are many challenges facing the implementation of Hakeem in Jordan: Hakeem deployment is costly, the Jordanian hospitals lack technology facilities, privacy of EHR in Jordan is not clear, stakeholders reject the technology changes, and employees require training courses to use Hakeem.

In implementing Hakeem, the Jordanian government faces mainly financial, technological and administrative challenges. The cost of implementing the EHR worked out to be an estimated USD 63,000 per bed, making the implementation cost in all hospitals and medical centers throughout Jordan very expensive. The high costs arose due to Jordan's lack of infrastructure required for implementation, including hardware, software, and IT specialists (Awokola et al., 2012), and the need for maintenance, support and training of stakeholders to use Hakeem.

Most of the hospitals in Jordan lack technological infrastructure, and some public hospitals do not even have an IT department (Awokola et al., 2012). The high rate of change in the technology compounds this problem. It is difficult to support and maintain databases because of the huge volumes of data, and there are also many ongoing problems with the system (for example, power failures, systems crashing, and data loss). In addition, there are threats against the integrity and security of the information from hackers and viruses. Moreover, privacy policies and regulations are not well defined in Jordan.

#### 2.2.3.6 EHR in Saudi Arabia

There is increasing concern that electronic health systems in Saudi Arabia are under-utilized. The implementation of e-health and electronic information systems has already begun in a number of hospitals and organizations, such as the King Faisal Specialist Hospital and Research Centre, National Guard Health Affairs, the medical services of the armed forces, and many other university hospitals. Although the uptake of e-health systems has moved slowly in MOH institutions, many such systems operate in the regional directorates and in central hospitals. Unfortunately, these systems are not linked to each other or to other private or specialized health organizations (Altuwaijri, 2008). To develop e-health services in the public sector, the MOH allocated a budget of SR 4 billion (USD 1.1 billion) to run a four-year development program from 2008 until 2011 (Qurban & Austria, 2008). In addition, the Saudi Association for Health Information held a series of conferences to emphasize the importance of e-health in enhancing the quality of healthcare delivery and to explore the necessary policies, strategies, applications and levels of coordination that must be achieved with other sectors to provide the required infrastructure such as Internet and phone services.

In 2009, the MOH of the KSA launched the Eijad System for Pilgrims' Health Services on the Internet, with the aim of serving the pilgrims and institutions related to the Hajj campaigns. This system links all the hospitals located in the areas of the Hajj pilgrimage, namely, Mecca and Medina. TheEijad system helps the pilgrims and concerned bodies in reporting cases of missing persons during the Hajj and in searching for them in all hospitals located in the pilgrimage areas. The system runs with bilingual Arabic and English interfaces on the Internet and can be accessed and used without restriction.

Table 2.2 presents a comparison between the established EHR models in the abovementioned six countries. From the table we can summarize that except the earlier model of New Zealand which was established in 1994, all other models are considered new advancement in the filed which started in the mid-decade of the

2000. Most of models are sharing same characteristics in relation to primary sharing media, storage location, patient identifier and data format. Their disadvantages directed us on what aspect of the planned sharing network for Malaysian pilgrims should be considered for example the availability of the data should aid immediate clinical decision especially during emergency treatment. It also tells us that such models need revision and improvement while some might stop because of the high cost. So sustainability of the proposed framework should be taken into consideration during design especially what is related to the cost.

**Table 2.2: Comparison between the Established EHR Models in Six Countries**

| Country | England, UK | US | Australia | New Zealand | Jordan | Saudi Arabia |
|---|---|---|---|---|---|---|
| **Model** | National Programme for IT (NPfIT) | Veterans' Health Information Systems and Technology Architecture (VistA) | Health Connect | HealthLink | Hakeem | Eijad |
| **Year launched** | 2009 | 2007 | 2008 | 1994 | 2009 | 2009 |
| **Type of records** | EPR | EMR | EHR | EHR | EHR | EHR |
| **Primary sharing media** | Internet patient portal | Internet patient portal | Internet patient portal | Internet patient portal | Internet patient portal | Internet patient portal |
| **Storage location** | Centralized repository | Centralized repository | Centralized repository | Linked data centers | Linked data centers | Linked data centers |
| **Adoption** | Comprehensive | Modular | Modular | Modular | Modular | Modular |
| **Data format** | HL7 | HL7 | Information not available | Information not available | Information not available | Information not available |
| **Patient identifier** | ID/encrypted medical record number | ID/encrypted medical record number | Medicare Number | Subscriber ID /Social Security number | National ID number | Passport number |
| **Patient access** | Yes | Yes | Yes | Yes | Yes | No |
| **Current status** | Discontinued in 2011 | Ongoing | Under review | Ongoing | Ongoing | Ongoing |
| **Advantages** | Centralized national repository | Open source and scalable | Appropriate level of functionality | Seamless referral system; primed for immediate physician intervention | Open source and scalable | Can be used to identify missing pilgrims |
| **Disadvantages** | Multiple vendors for a large project; slow and cumbersome | Need for a higher level of technical skill to fully use the software | Does not provide interactive clinical decision-support | | Costly implementation | Does not provide interactive clinical decision support |

### 2.2.4 Theoretical Models that Underpin IoT Framework

This research is grounded in the theory of reasoned action and applies the technology acceptance model (TAM) to the healthcare organization's intention to implement health records sharing framework.

Factors of TAM within the realm of health records include: diffusion of innovation, belief and trust), perceived usefulness and perceived ease of use (Agarwal & Karahanna, 2000; Mathieson, Peacock, & Chin, 2001; Moore & Benbasat, 1991).

The technology acceptance model (TAM) (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989) provides a conceptual framework for this study and grounded by the theory of reasoned action (TRA). According to TRA, beliefs influence attitudes, which lead to intentions that guide or generate behaviours. The TAM attempts to predict and explain the use of EHR sharing framework by means of perceived usefulness and perceived ease of use (Figure 2.5).

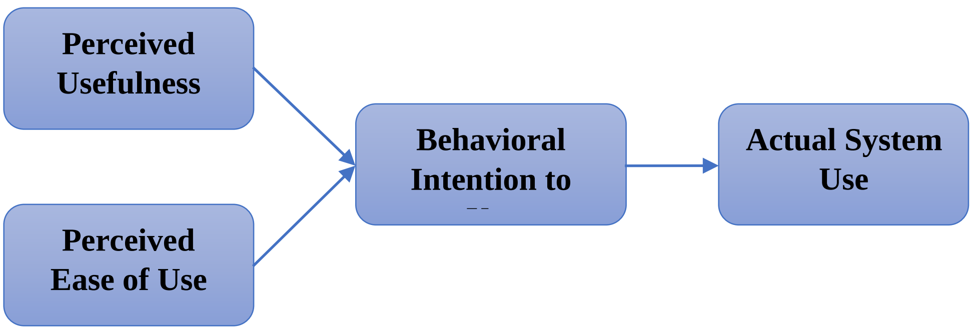



**Figure 2.5: Technology Acceptance Model**

The TAM model has informed the design of the questionnaire and the focus group discussion direction in order to explore users' intention. Nonetheless the Delone and Mclean information success model has inspired the researchers on what the requirements and components of the IoT framework should be (Figure 2.6). Delone model was used as an extension of TAM model as it incorporate the intention of use supported by quality of generated information with their infrastructure quality to produce an impact of benefits of the users. We postulated that good sharing framework would incorporate quality information that is generated by hospitals and clinics. System quality of the other side to be ensured by good infrastructure and trained staff. Service quality refers to the service provided (EHR provision). As stipulated with TAM model when the users feel easiness and benefits they will adopt the framework which will results in improvement of patients' care.

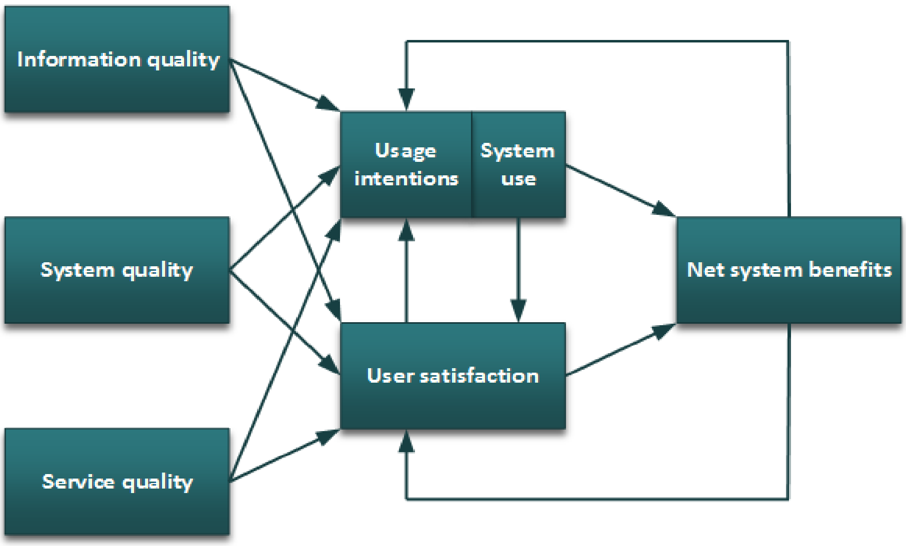



**Figure 2.6: Delone and Mclean Information Success Model**

## 2.3 Overview of IoT Communications Models

The "Internet of Things" (IoT) term was coined by Kevin Ashton, one of the founders of the original Auto-ID Center at MIT, who introduced it in 1999 during a presentation held at Procter & Gamble (P&G) (Albrecht & Michael, 2013). They imagined a world where the Internet is connected to the physical world through ubiquitous sensors and a platform based on real-time feedbacks, which has a huge potential to enhance comfort, security and control of our lives (Guinard, Trifa, Karnouskos, Spiess, & Savio, 2010).

IoT is a new paradigm that combines aspects and technologies coming from different approaches. Ubiquitous computing, pervasive computing, Internet Protocol, sensing technologies, communication technologies, and embedded devices are merged together to form a system where the real and digital worlds meet and are continuously in symbiotic interaction. The smart object is the building block of the IoT vision (Berghella et al., 2014; Zhu et al., 2010). By putting intelligence into every object, they are turned into smart objects that are not only able to collect information from the environment and interact with the physical world, but also interconnected to each other through the Internet to exchange data and information as shown in Figure 2.7. The expected huge number of interconnected devices and the significant amount of available data open new opportunities to create services that will bring tangible benefits to the society, environment, economy and individual citizens (Greengard, 2015).

A thing can be any real/physical object (for example, RFID, sensor, actuator, spime, smart item) but also a virtual/digital entity, which moves in time and space and can be uniquely identified by assigned identification numbers, names and/or location addresses (Borgia, 2014). Therefore, the thing is easily readable, recognizable, locatable, addressable and/or controllable via Internet. Moreover, this new generation of devices is smart, thanks to the embedded electronics allowing them to sense, compute, communicate, and integrate seamlessly with the surrounding environment.


**Figure 2.7: The Emergence of IoT**

Nowadays, IoT is able to combine in a particular operational entity all the bits and pieces of the world around us. IoT was initially called the sensing network at first, which connect any object with Internet, by using Radio Frequency Discerning (RFID) and sensor (Z. Yu & Tie-Ning, 2012), information gathering equipment, and according to the agreement agreed, realizing the information exchanging and communication, location, following, controlling and management intellectually. With its swift development and its widening use in logistics field, IoT technology has offered a new way of thinking and a new opportunity for the development of equipment support, and will also bring enormous changes to traditional modes and technology of equipment support.

### 2.3.1 RFID Technology

IoT is made up of “smart” objects such as today’s mobile phones, tablets, alarm systems, home appliances and industrial machines that are always connected to the internet. “Smart” objects also include things that are tagged with Radio Frequency Identification (RFID) tags and barcodes used for tracking purposes. Scanners could identify and communicate the objects and their location information. Middleware and frameworks could facilitate the development of application and service, adding intelligence and thus resulting in better services. The scale of the IoT could reach billions of interconnected things, all providing data, and many capable of performing actions based on the information it or others provide (Mashal et al., 2015).

RFID technology can be effectively applied for real-time tracking and identification (Lai & Cheng, 2014). RFID was developed in the 1940s by the US Department of Defence (DoD) which used transponders to differentiate between friendly and enemy aircrafts (Rieback, Crispo, & Tanenbaum, 2006). Since that time, RFID technology has been evolving to change the way people live and work. Many previous research projects have explored the possibility of integrating RFID in different areas, from toll collection (Yoo et al., 2008), agriculture (Voulodimos, Patrikakis, Sideridis, Ntafis, & Xylouri, 2010), access control (POPA, TURCU, GAITAN, TURCU, & PRODAN, 2006), supply chain (Goebel, Tribowski, Günther, Tröger, & Nickerl, 2009), logistics (Werner & Schill, 2009), healthcare (Lewis, Sankaranarayanan, & Rai, 2009), and library (Fennani & Hamam, 2008). RFID system consists of three main components (Want, 2006):

- RFID Reader (transceiver): sends an electromagnetic wave which carries a signal to identify objects. Then, the reader receives the information returned by these objects.

- RFID Tags (transponder): attached to these objects, reacts to receiving the signal sent by the reader in order to forward to it the requested information.

- The communication network between RFID reader and RFID tags.

Additional components may also include antennas that emit radio signals to activate the tag and read/write data to it, and a local control chamber sending reading/writing commands to all the readers as well as reading back tag information (Want, 2006).

The RFID reader is the more complex unit. Readers' cost and level of deployment mostly reflect that of the system as a whole. Tags, on the other hand, are usually mass produced which contributes to their lower cost compared to that of a reader. Each tag has an identification (ID) number and a memory that stores additional data such as manufacturer, product type, etc. (H. Liu, Liu, Gong, Liu, & Chen, 2014).

RFID has several advantages over traditional identification technologies (for example, barcodes) and influences many application domains including inventory control and supply chain management. RFID tags may serve as personal data recording devices in addition to providing positional accuracy that may surpass that of GPS especially in indoor settings. Most importantly, RFID systems stand at the forefront of the technologies driving IoT vision they are favoured because of their non-disruptive small size, low cost and extended lifetime (H. Liu et al., 2014).

#### 2.3.1.1 RFID Communication

RFIDs apply radio frequency (RF) electromagnetic fields to transfer data from tags to readers for the purposes of identification and tracking tagged objects (Manches, Duncan, Plowman, & Sabeti, 2015). The RFID tags could be classified as three main types: (1) Passive Tags, (2) Semi-passive Tags, and (3) Active Tags.

Passive and semi-passive RFID tags transmit their data by reflection or modulation of the electromagnetic field emitted by the reader (Chawla & Ha, 2007). Passive tags, however, do not have a power supply of their own and gain their energy from the reader's field within an interrogation zone ranging between 10cm and 3m. Common applications of passive RFID tags include credit cards and electronic door keys. Semi-passive tags operate similarly to passive tags. However, their circuitry includes a battery enabling them to transmit their data once interrogated by a reader for distances longer than passive tags. Data loggers which can take sensor readings automatically while running real-time clocks are common utilizes of semi-passive tags.

Conversely, an active RFID tag self-broadcasts its data for extended communication ranges of up to 100m without the need for an interrogating reader. Since active communication requires larger batteries and more advanced circuitries, the typical price of active tags is five to ten times the price of semi-passive RFID tags. Each of the tag types has a separate range of transmission frequency band. Passive tags, for instance, usually transmit at a low frequency (120-150KHz), while semi-passive and active tags use high (13.56MHz) and ultra-high frequency (433MHz) bands (Want, 2006).

A depiction of RFID reader-tag communication according to tag type is shown in Figure 2.8. The number of tags within each reader's interrogation zone determines the interrogation delay of that reader. The overall interrogation delay of the system is determined by the longest delay associated with a single reader. Therefore, reducing overlaps and balancing the load of readers, in addition to reducing the delay and monetary cost of the system, are all considerable constraints for any efficient RFID system (Nikitin, Ramamurthy, Martinez, & Rao, 2012).

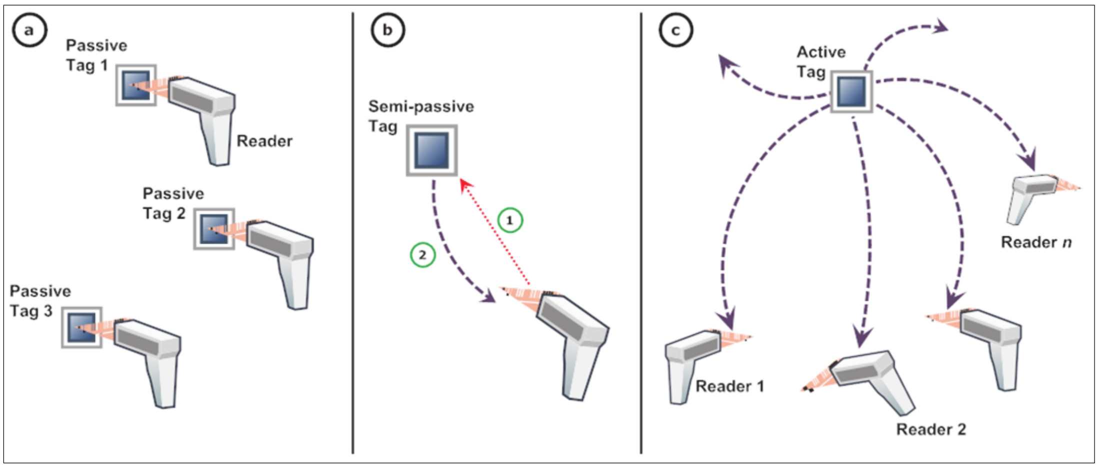



**Figure 2.8: Reader-tag Communication**

(Dobkin, 2012)

#### 2.3.1.2 RFID Specifications

Choosing the optimum locations for readers, tags or both are of utmost importance for a variety of considerations. Some RFID systems achieve a maximum coverage of 90% of the intended area without overlaps due to the nature of electromagnetic readers' fields of communication (Al-Fagih, Al-Turjman, Hassanein, & Alsalih, 2012).

Tag placement may be broadly classified into either dynamic or static. Examples of dynamic placement include tags assigned to individuals moving across a given workplace or a city-section, or transported items to be tracked by real-time inventory and supply chain management solutions. As for static tag placement, its applications include defining boundaries within buildings for security measures, or to assist the visually-impaired. For instance, an intelligent system is proposed to automatically suggest the tag placement locations and calculate the number of tags required for implementing an indoor navigation system for the visually impaired (Nikitin et al., 2012).

RFID reader placement is more complex in terms of cost and coverage constraints (Al-Fagih et al., 2012). The two broader reader placement approaches are controlled and random (ad-hoc). Controlled reader placement is usually pursued for indoor (Reza, Geok, & Dimyati, 2011) and city-scape applications (Anuradha & Sendhilkumar, 2011) where tagged items are expected to follow a high level of predictability in their mobility, as opposed to tags in environmental applications.

The random reader placement approach, on the other hand, is generally applied for item-level tagging applications (N. Li & Becerik-Gerber, 2011). Yet, Ad-hoc reader placement results in the intersection of their electromagnetic interrogation zones, which is known as reader-to-reader collision. This phenomenon typically invokes running redundancy elimination algorithms to turn off redundant readers that are not covering any tag in the vicinity to improve the system's performance and lifetime (Y. Liu, Du, & Xu, 2011).

Chen (2010) and Chen et al. (2006) argued that the average space coverage of the RFID readers is 2-3 square meters. However, this space may differ depending on the technology specifications of the RFID devices (C. Chen, 2010; C. Chen, Aneke, Ebaugh, & Hong, 2006). The detection range of AMB315920 is around 1.8m, SkyeTek RFID reader has a marked detection range of around 1.5m, and EPC Class 1 Gen1 and Gen 2 tags are around 0.5m (C. Chen, 2010). There are advanced productions of passive and semi-passive tags that can send the data to RFID readers within 17-20 square meters average space (N. Li & Becerik-Gerber, 2011).

### 2.3.2 Wireless Sensor Networks

Traditionally, Wireless Sensor Networks (WSNs) are viewed as dense deployments of tiny low-powered sensor nodes with restricted computational, communicational and power capabilities (Mainetti, Patrono, & Vilei, 2011). Sensor nodes read physical phenomena such as temperature, motion and levels of contamination and use multi-hop communication to research their readings, usually via relay nodes, to specific base stations or access points that are connected to the Internet; Figure 2.9 depicts this WSN model.

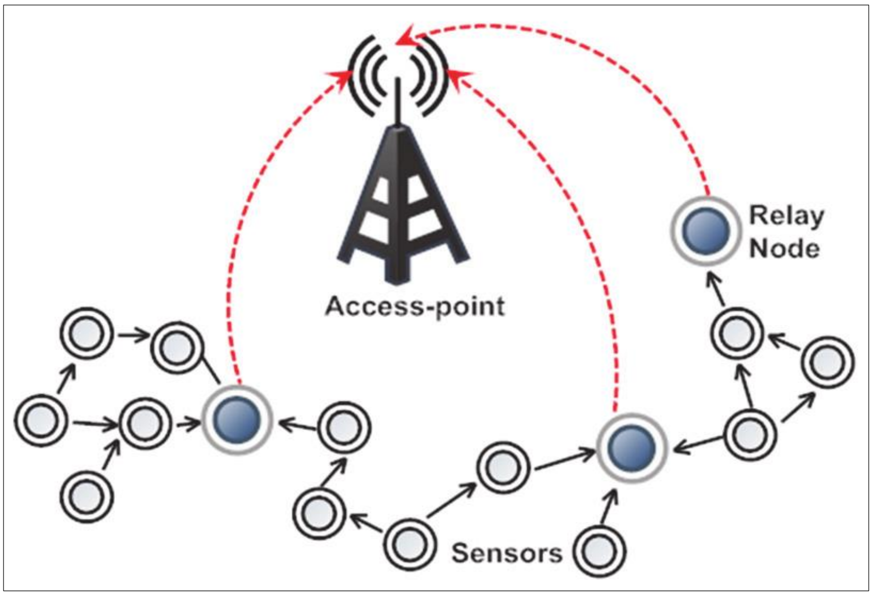



**Figure 2.9: Wireless Sensor Network Model**

(Mainetti et al., 2011)

WSN deployments may also include a wider set of contemporary topologies, viz. Mobile Ad-hoc Networks (MANETs), where sensors on board vehicles and ambient personal devices (for example, smartphones) form sensory networks that are more advanced in terms of mobility, buffering, processing and transmission capacities. It has been noted that such ambient devices are considered to be core components of envisioned IoT paradigm (Reina, Toral, Barrero, Bessis, & Asimakopoulou, 2013). Hence, it has shown that such an expanded view of a WSN that includes systems of heterogeneous cost-effective devices such as sensors, cellular phones, tablet-PCs and relay nodes that vary in their functional capabilities. These devices are expected as well to apply a variety of wireless standards including WiFi, Bluetooth, Zigbee and Body Area Networks (BANs) (M. Chen, Gonzalez, Vasilakos, Cao, & Leung, 2011).

In a typical WSN topology, if every node communicates directly with the access point, regardless of its position in the network, then the communication load would exhaust the system's power resources. Thus, sensors operate in a decentralized multi-hop fashion to maintain connectivity while extending the system's lifetime such that a subset of sensors is responsible for relaying the aggregate data to access points (Goyal & Tripathy, 2012).

#### 2.3.2.1 WSN Communications

Data delivery in WSNs is application dependent (Anastasi, Borgia, Conti, & Di Francesco, 2011). The data delivery model from the sensor to the access point can be classified as either: continuous, event-driven, query-driven, and hybrid. In the continuous model, each sensor sends data periodically. In event-driven and query-driven models, the transmission of data is triggered respectively when an event occurs or a query is generated by the access point. Some networks apply a hybrid model using a combination of continuous, event-driven and query-driven data delivery (Yigitel, Incel, & Ersoy, 2011). Many delivery protocols (routing protocol) have been proposed for WSNs (Anastasi et al., 2011). And the importance can be summarized as the following points:

- Nature of WSN management—what do the Management Information Bases (MIBs) of the protocol cover? What sorts of show commands are available for taking a network baseline?

- Ease of configuration—how many commands will the average configuration require in your network configuration? Is it possible to configure several routers in your network with the same configuration?

- On-the-wire efficiency—how much bandwidth does the routing protocol take up while in steady state, and how much could it take up, at most, when converging in response to a major network event?

These protocols can be further classified into hierarchy-based, data-centric or location-based. Hierarchical protocols aim at clustering the nodes so that cluster heads aggregate and reduce the transmitted data to save energy (Singhal & Suri, 2014). Data-centric protocols are query-based and depend on the naming of desired data, which helps in eliminating redundant transmissions. Location-based protocols utilize the position information to relay the data to the desired regions rather than broadcasting to the whole network, which reduces both bandwidth and energy consumption (Mahgoub & Ilyas, 2016).

The routing protocol applied in a WSN is highly influenced by the data delivery model, especially, with respect to managing the networks lifetime and energy resources (Ben-Othman & Yahya, 2010). For instance, it has been shown in that for environmental monitoring applications where data are continuously transmitted to the access point, a hierarchical routing protocol is the most efficient alternative. This is due to the fact that such an application generates significant redundant data that can be aggregated on route to the sink, thus reducing traffic and saving energy (Atzori, Iera, & Morabito, 2010).

#### 2.3.2.2 WSN Features

Node placement is crucially important to achieve optimization goals in terms of coverage, connectivity or lifetime extension. WSN placement approaches may be classified into static and dynamic depending on whether the optimization is performed at the time of deployment or whiles the network is operational, respectively.

Static placement approaches may be further classified into controlled (grid-based) (Al-Turjman, Hassanein, Alsalih, & Ibnkahla, 2011; K. Xu, Takahara, & Hassanein, 2006) and random (ad-hoc) (X. Li, Nayak, Simplot-Ryl, & Stojmenovic, 2010). Controlled node placement is necessary when sensors are expensive or when their operation is significantly affected by their position. Grid-based controlled deployment is a particularly attractive approach for coverage-oriented deployments due to its simplicity and scalability. Nonetheless, in practice, it is often infeasible to guarantee exact placement due to deployment errors such as misalignments and random misplacement. Thus, for guaranteed coverage it is necessary to increase the grid resolution so that the deployment is resilient to these errors. In large-scale grid deployments, however, relay nodes with advanced transmission capabilities must be placed to assure full connectivity which is proven to be NP-hard and requires applying optimization solutions (Lee & Younis, 2010).

In contrast to the controlled placement, random sensor placement is performed in most WSN applications. This is due to the inaccessibility of the monitored areas (Alemdar, Durmus, & Ersoy, 2010). Yet, random placement does not provide satisfactory coverage of the area unless an excessive number of nodes is deployed. Moreover, Ad-hoc placement approaches entail the execution of redundancy elimination algorithms to raise the cost-efficiency.

One option to improve coverage quality is to move nodes, such that sensors, relay nodes and even access points are relocated to areas where coverage or connectivity levels are unsatisfactory. The ability to dynamically reposition nodes while the network is operational is necessary to further improve its performance.
Dynamic placement approaches for sensor nodes may be triggered by failure poor coverage, high traffic or network partitioning. The objective of node relocation among the aforementioned approaches varies from maintaining coverage to lifetime connectivity (Abbasi, Younis, & Akkaya, 2009).

Dynamic relocation could be feasible in some applications such as environmental monitoring where sensors can be moved closer to the phenomenon to increase the fidelity of their data, or in military applications for the sake of keeping the base station out of the range of hostile fire. However, dynamic relocation does not apply to topologies where the sensor's mobility follows human (for example, cellular phones and medical sensors) or vehicular mobility traces. In fact, there are differentiations between movable and mobile nodes. The former may adhere to some dynamic placement schemes, while the latter are not necessarily susceptible to obey a relocation algorithm. The stochastic mobility nature of these nodes represents additional challenges to delivery and coverage solutions in wireless settings.

The traditional WSN coverage space is 8 square kilometres (Taylor, Tillery, & Schwartz, 2002). However, the spaces specifications of the WSN nodes are differing depend on the type and quality of the node device. The ZigBee-compliant devices space coverage is 10-75m and the amplifier range can be boosted to 100m (C. Chen, 2010). According to Chen et al. (2006), the distance between any two nearby super nodes is expected to be around 10 to 30 square meters (C. Chen et al., 2006). On the other hand, Fishkin et al. (2005) mentioned that the traditional coverage area of the super nodes is between 15 to 30 square meters (Fishkin, Philipose, & Rea, 2005).

### 2.3.3 Integration between RFIDs and WSNs

The integration of the promising technologies of RFID and WSNs will maximize their effectiveness, give new perspectives to a broad range of useful applications, and bridge the gap between the real and the research/academic world. This is because the resulting integrated technology will have extended capabilities, scalability, and portability as well as reduced unnecessary costs (Al-Turjman, Al-Fagih, & Hassanein, 2012; Mitrokotsa & Douligeris, 2009).

- Extension of capabilities and functionalities: Considering the fact that RFID networks can provide critical information, such as the identity and the location of an object, by merging RFIDs with WSNs additional information can be retrieved, while the potential for exploiting this information is multiplied. For instance, in supply chain management it able not only to track food products but also to monitor their environmental conditions and detect when perishables go off. The following advantages can be gained based on the integration between RFID and WSN technologies.

- Scalability–portability: RFID systems integrated with WSNs enjoy the advantages of wireless communication. The transmission and processing of critical data and information is facilitated without the burden and inconvenience of wired transactions while saving valuable time. Portable RFID readers can further speed the collection of data and ease procedures in varying applications. For instance, healthcare applications, including monitoring everyday medication of elderly or monitoring patients for diagnosing deceases, can be extremely facilitated without rendering patients immobile through cumbersome data wirings.

- Reduce unnecessary costs: Reducing the cost of employed services is a critical factor in many applications including industrial ones. The requirement is to achieve the desired goal with the minimum possible cost by supporting backup solutions in case of undesired circumstances. For instance, perishable goods can be monitored so that in case they are not preserved properly their transport can be terminated, thus avoiding unnecessary additional transport costs.

However, the integration of RFIDs and WSNs should be performed in such a way that specific requirements are met to have an efficient and effective solution (see Figure 2.10). Some of the most important requirements that should be taken in consideration are the following (Cho et al., 2007):

- Accurate and reliable communication: In traditional client server networks, large data streams are transferred from servers to clients. However, in integrated RFID and WSNs the data flow is mainly transferred from a large number of devices (clients) to a few servers. Subsequently, servers are expected to process all the received information from RFIDs and sensors in a reliable way and to allow the appropriate action to be taken within a short span of time. Reliability and accuracy are also expected for the data transferred to the applications (or users) of the integrated system within a tolerable latency. Of substantial importance is the capability of the integrated RFID-sensor network to deliver data to the required destination with reliability and to provide a confirmation for the successful completion of a task. The reliability and accuracy of an integrated RFID-sensor network is also dependent on the criticality of the specific application. In not so critical applications a lower degree of reliability is required.

- Energy efficiency: Considering that both sensor nodes and active RFID tags present scarce resources, the integrated RFID-Sensor Network should take into account this limitation. The integrated system should be energy efficient to make sure that accurate and reliable communication will be achieved with the minimum possible energy consumption.

- Network maintenance survivability: Considering the large number of devices that can be employed in an integrated RFID-sensor network, among the most important requirements for such a network is the ability to perform remote device configuration and remote device software updates. Thus, a high survivability and an efficient maintenance of the network with an acceptable cost can be achieved. Furthermore, it is important that the integrated network is able to recover in case of possible of device failure or possible Denial of Service (DoS) attacks. A possible way to achieve that would be the adoption of intrusion tolerance and mitigation mechanisms such as replicating critical network devices.

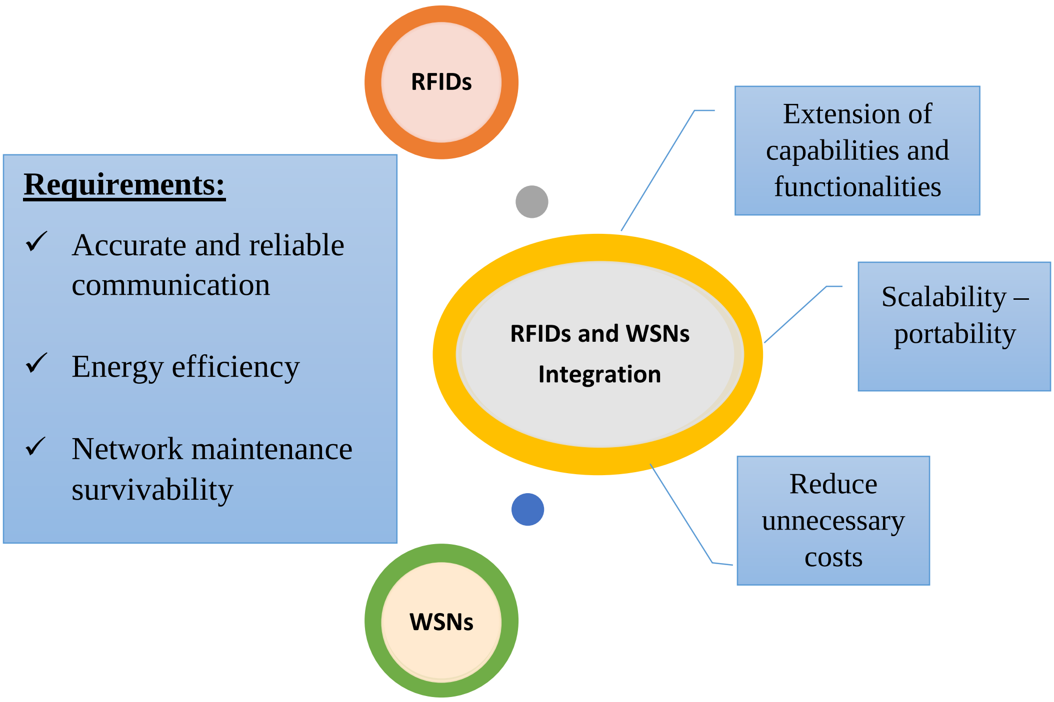



**Figure 2.10: Integration of RFIDs and WSNs**

## 2.4 IoT Layers

There are multiple layered architectures of IoT proposed (three, four and five layers) (Burhan, Rehman, Khan, & Kim, 2018). Our frame work proposed four main layers of IoT environment which can be described as the following:

IoT architecture is needed to represent, organize and structure the IoT in a way that enables it to function effectively. In particular, the distributed, heterogeneous nature of the IoT requires the application of hardware, network, software, and process architectures capable of supporting these devices, their services, and the work flows they will affect. However, there is no agreement on a single architecture that best fits the IoT. A number of articles proposed various conceptual architecture designs, while others proposed criteria for the assessment of proposed architectures (Främling & Nyman, 2008)as well as a conceptual architecture to meet the requirements of smart objects (Kortuem, Kawsar, Sundramoorthy, & Fitton, 2009).

General IoT architecture is built based on a three-layer or four-layer architecture. The three-layer architecture is described as follows (S. Li, Da Xu, & Zhao, 2015; Ning & Wang, 2011): connectivity layer, network layer and application service layer. The connectivity layer senses the physical objects and obtains data, and the network layer collects and transmits data to the application service layer, the application service layer provides services for various users. While the only difference in the four-layer architecture in Mas research (Ma, 2011) is decomposing the network layer into the access layer and the abstraction layer. To get the proper understanding of the main functionalities and the importance of each layer in this process, refer to the detailed reviews presented in next subsections.

According to above section, the framework of IoT consists of four main layers which are: 1) connectivity layer, 2) access layer, 3) abstraction layer, and 4) service layer.

### i. Connectivity Layer

This layer represents the lower layer of IoT, the connectivity layer (perception) consists of main physical devices which are electronic tags and wireless sensors. The electronic tags should be in very short distance of wireless sensors (i.e. 3 meters). Moreover, the electronic tags represent real objects such as persons ID and the data of these tags accessed by wireless sensors. Data are transferred from electronic tags through sensors to the next layer (access layer) (Khan, Khan, Zaheer, & Khan, 2012; Tsai, Lai, & Vasilakos, 2014).

The tag type is the most important specification of electronic tags in this layer. For example, the active tags specifications are different of passive tags. The selection of tag type depends on the purpose of IoT implementation. On the other hand, the wireless sensors selection depends on many features such as coverage space. In conclusion, the main aim of connectivity layer is to read data of tags by wireless sensors and transfer to access layer (WSN layer).

### ii. Access Layer

This layer represents the upper layer of IoT, the access layer (support) consists of main physical devices which are super nodes and base stations. Super nodes acquire data from connectivity layer and transfer it to base stations. The sensors should be in short distance of super nodes (i.e. 100m). The distance between super nodes and base station would be within 8km radius (C. Chen, 2010; C. Chen et al., 2006; X.-Y. Chen & Jin, 2012).

The distribution of super nodes and base stations is the most important specification of this layer. There are two main kinds of super nodes and base station placement which are: 1) static placement is effective for small and environments areas (i.e. many kilometers), and 2) dynamic or random placement which is effective for large environments areas such as countries.

Base station involve many data management activities such as manage priority of data processing, schedule data to avoid processes confliction, and send data retrieving orders from other devices (like web servers of external locations). Data retrieval from external locations require data gathering via network which represent the abstraction layer.

### iii. Abstraction Layer

This layer is responsible for transfer of data from base station to central web servers through open gateway such as internet infrastructures. This allows data transfer over large distances (i.e. across countries around the world).

The abstraction layer (network) is based on machine to machine communication (M2M) (Swetina, Lu, Jacobs, Ennesser, & Song, 2014). M2M refers to systems that enable machines to communicate with back-end information systems and/or directly with other machines, in order to provide real-time data (Balamuralidhara, Misra, & Pal, 2013). M2M communication can be event-based, that is triggerred by the occurence of a particular event, and/or polling based, that takes place in predefined time intervals. M2M applications that realize M2M communication include four basic stages (M. Chen, Wan, & Li, 2012; Gubbi, Buyya, Marusic, & Palaniswami, 2013).

- Data collection: in this stage the collected data from base station in access layer (source machine) is managed as requesting orders of information.
- Transmission of specific data over a communication network: the data collected from access layer is transmitted via network to destination machine (external webservers).
- Assessment of the data: the data or requesting orders are evaluated and analyzed by destination machine.
- Response to the available information: the destination machine sends response, information, or decisions to source machine (i.e. base stations) via network.

The IoT model of Perera et al. (2014) clarifies the above four stages of abstraction layer. Perera et al. explained that using IoT devices the concept of smart city can be developed (Perera et al., 2014). Smart city is about connecting the physical objects (tags) in city with sensors to enhance the various provided services in this city automatically in real time. People safety is one of the most important services that would be enhanced in cities. Persons can be identified as physical objects using electronic tags. In case of health problem, persons can press the emergency button attached in their tags. Wireless sensors read tags ID (connectivity layer) and send emergency signal to base station through super nodes (access layer). In abstraction layer, the base station send request to serve the patients via network. The data or request transferred via network to nearby healthcare centres. Then the received data is processed by web servers (destination machine). The final stage is send response such as inform that ambulance is move to position of health case.

Thus, the effectiveness of abstraction layer is identified by the network specifications that communicate between base station and central web server in service layer (service layer explained in next section). The most important specifications of network are as the following (Balamuralidhara et al., 2013; Jing, Vasilakos, Wan, Lu, & Qiu, 2014; Swetina et al., 2014):

- Security: The security of network is necessary to protect the transferred data from attackers. There are many methods can be used to increase the security level of netwwork such as firewalls, data encryption, SSL and VPNs technologies, and use fiber optic technology.
- Transferring protocol: The transferring protocols are necessary to improve the transferring speed of data and reduce data droping due to network traffic. UDP and TCP are the most known transferring protocols. TCP is used widely in internet communication due to data transfer stability based on this protocol. Furthermore, TCP provide encryption services of data to secure the transferred data.
- Communication type: There are many communication types between machines via network such as unicast, anicast, multicast, and broadcast. Unicast is used when two network nodes need to talk to each other. Anicast is used when many nodes of network need to talk with few nodes. Multicast is comunication between many to many network nodes. Broadcast is comunication between a single node to many nodes of network.
- Kind of data transfer: There are two kinds of data transfer which are sending data as one block or sending data as many sequence packets. Data segmentation is effective to speed up transfer of big data.

### iv. Service Layer

i. This layer is about providing real-time IoT services, the data delivered from abstraction layer are processed and the results displayed on output devices such as monitors. These monitors are usually connected to the tags in connectivity layer. Thus, the results of data processing are sent from service layer (application) to connectivity layer through access and abstraction layers respectively. The specification of service layer depends on availability and accessibility variables of information stored in the web server (Da Xu, He, & Li, 2014; Swetina et al., 2014).

## 2.5 Related Works of Pilgrim Healthcare Utilizing IoT

Through review literature, only four related studies to Pilgrim Healthcare Utilizing IoT were found, which are a developed a framework for Emergency Stations in the Grand Mosque of Mecca using Wireless Sensor Network, Wireless sensor networks for pilgrims tracking, A novel control of disaster protection (NCDP) for pilgrims by pan technology, and Pilgrim Assistance Using RFID Technology. However, these studies are about pilgrims' health assistance rather than EHR retrieval for pilgrims.

Nizari and Amer (2011) developed a framework for Emergency Stations in the Grand Mosque of Mecca using Wireless Sensor Network (WSN). The main aim of their research is to design a Wireless Sensor Network using sensor nodes to respond to any emergency alert inside the Grand Mosque of Mecca and the areas surrounding the mosque. The design includes fixed stations containing two switches: one for medical help, and the other for the people who are lost. It is designed to help the pilgrims in need of medical assistance or security, for example, missing children, or elderly people during the Hajj time, and inform appropriate authorities in real time (Nizari & Amer, 2011).

The research of Nizari and Ameris based on two main layers of IoT which are connectivity layer (RFID) and access layer (WSN). Each pilgrim would own his/her electronic tag that identifies his position. Once any pilgrim presses the emergency button using tag, the data of his/her position is accessed by wireless sensor and relayed to base station through super nodes. Thus, automatic alerts (position of pilgrim) will appear to suitable decision makers to assist the need of pilgrims. Technically, Nizari and Amerused 10 sensor nodes to cover the distances of Grand Mosque of Mecca. The advantage of these sensors is that wireless sensor called “SNAP” is attached as USB with super nodes which avoid overlap connection between connectivity and access layers.

On the other hand, Mohandes et al. (2012) mentioned that tracking the movement of such a large number of people during the Hajj is crucial to the pilgrims themselves and the authorities managing the whole event including health assistance and positions identifications. This led to design and implementation a real-time pilgrim tracking system(Mohandes, Haleem, Deriche, & Balakrishnan, 2012). The system relies on a dedicated delay-tolerant wireless sensor network (WSN) which is interfaced to the Internet through gateway(s) available from an internet service provider (ISP). Energy efficiency, robustness, and reliability are key factors considered in the design of the system. Each pilgrim is given a mobile sensor unit which includes a Global Position System (GPS) chip, a microcontroller, and antennas. A network of fixed units is installed in the Holy area for receiving and forwarding data. Periodically, each mobile unit sends its user identification (UID), latitude, longitude, and a time stamp. A central server maps the latitude and longitude information on a geographical information system (GIS). The developed system was used to track a specific or a group of pilgrims. The developed system was tested during the two pilgrim seasons and it was able to successfully track all pilgrims who participated in the experiment. Figure 2.11 illustrates the flow commands of the Mohandes system.

Moreover, Gunasekaran and Suresh (2014) have developed a novel control of disaster protection for pilgrims to track the pilgrims in the natural disaster site and giving the priority to human with heartbeat signal. Each pilgrim is given a mobile sensor unit which includes a GPS, a microcontroller, and antennas. A network of fixed units is installed in the Holy area for receiving and forwarding data. Periodically, each mobile unit sends its user identification (UID), latitude, longitude, and a time stamp. A central server maps the latitude and longitude information on a geographical information system (GIS) (Gunasekaran & Suresh, 2014).

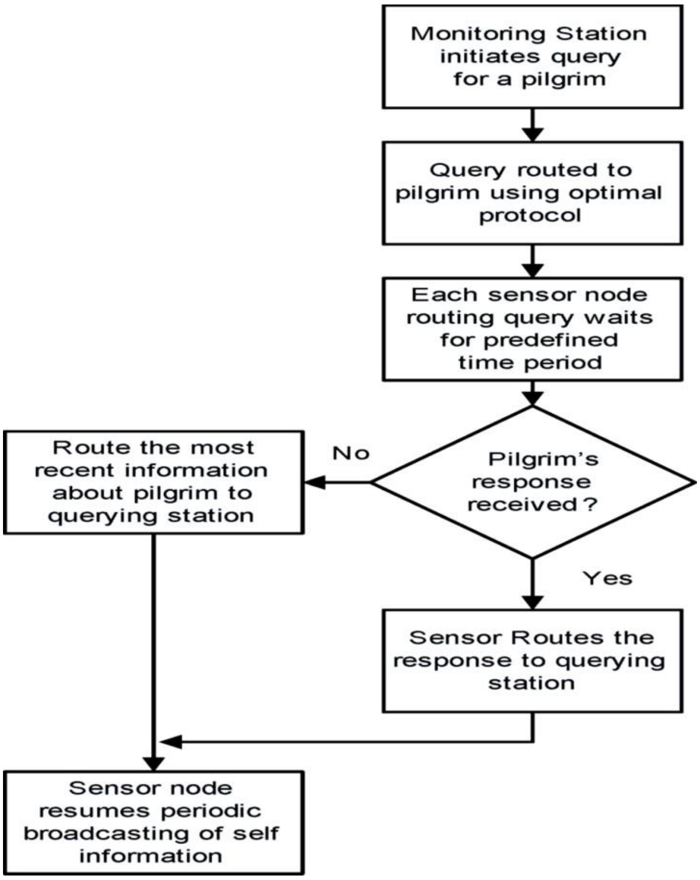



**Figure 2.11: Flow Commands in Pilgrims Tracking**

(Mohandes 2012)

The Gunasekaran and Suresh system consists of two architectural modules one is person side module control consists of heart beat sensor, multi-color LED, buzzer and another module is in surveillance side control (Gunasekaran & Suresh, 2014). On rescue operation, module containing heart beat sensor is continuously measure the heart beats of the pilgrim then the output signal is given to signal conditioning unit in which the signal is conditioned. After that the signal is transmitted to surveillance side with the help of ZigBee protocols. The ZigBee transceiver in the surveillance side captures the number of count depends upon the person's count in that disaster area. Multicolor LED and buzzers used in the person's side indicates the signal only when the pilgrim is alive to avoid the confusion between the living and nonliving condition of the pilgrims while on the rescue operation near by the person side to surveillance side. Communication protocol used in this method enables operate signals without the aid of satellites and helps to rescue the pilgrims. Figure 2.12 illustrates the block diagram of the Gunasekaran and Suresh system.

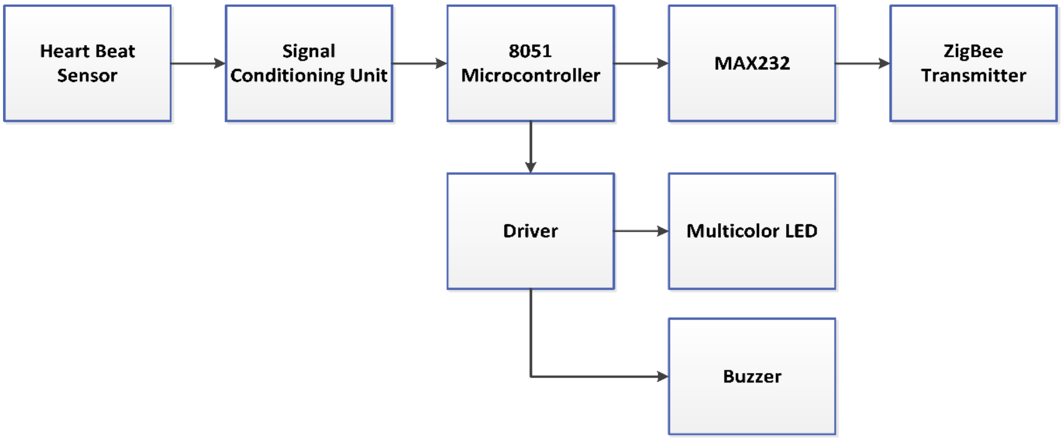



**Figure 2.12: Block Diagram of Gunasekaran and Suresh (2014) System**

In same context of the Gunasekaran and Suresh research, Nair and Daniel (2014) mentioned that at present, there are so many problems regarding the crowd control, medical emergencies, security issues, identification and tracking of the pilgrims in the holy areas (Nair & Daniel, 2014). Especially during pilgrimage, the pilgrimage authority finds it difficult to manage the situation. The technologies implemented in Saudi Arabia during Hajj pilgrimage to reduce these types of problems were not so effective in solving these problems.

Nair and Daniel system utilised with RFID technology which describes the design and implementation of a system for tracking and monitoring the pilgrims. The propoed system consists of transmitting and receiving sections. The pilgrims will have the RFID tag. The transmitting section consists of RFID reader, microcontroller and Zigbee transceiver. Every pilgrim will have a unique ID. The transmitting unit will send the current location and unique ID to the server unit using Zigbee transceiver. The receiver unit consists of Zigbee transceiver, external EEPROM unit and microcontroller unit. The received location and unique ID will be stored into the external EEPROM periodically. A heartbeat sensing unit is connected to the transmitting section to monitor the medical condition in case of emergency. The pilgrims can be thus tracked and sent the medical assistance in no time. Figure 2.13 illustrates the block digram of the Nair and Daniel system.

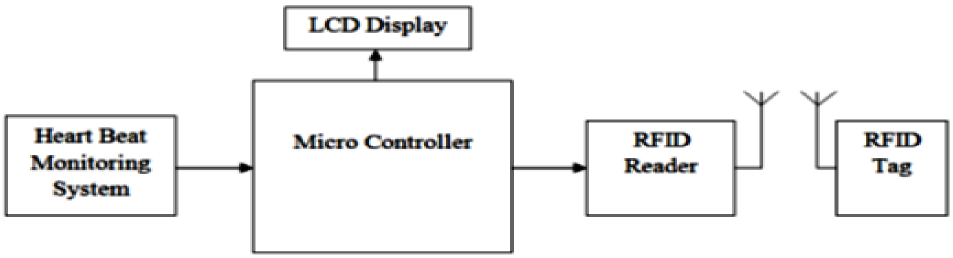



**Figure 2.13: Block Diagram of Nair and Daniel (2014) System**

Table 2.3 presents the summary of related works of utilizing IoT in healthcare for pilgrimage. All related works applied RFID and WSN to support the healthcare activities for local patients.

**Table 2.3: Summary of Related Works**

| Author | Main Objective | Scope | Layers Involved | Technology Used | |
|---|---|---|---|---|---|
| | | | | WSN | RFID |
| (Nizari & Amer, 2011) | Design a Wireless Sensor Network using sensor nodes to respond to any emergency alert inside the Grand Mosque of Mecca and the areas surrounding the mosque. | Mosque of Mecca | Connection and Access | | |
| (Mohandes et al., 2012) | Designed and implemented a real-time pilgrim tracking system to support healthcare activities | Pilgrimage | Connection and Access | | ✓ |
| (Gunasekaran & Suresh, 2014) | Developed a novel control of disaster protection to track the pilgrims in the natural disaster sites, giving priority to humans with heartbeat signal. | Pilgrimage | Connection and Access | ✓ | ✓ |
| (Nair & Daniel, 2014) | Developed a system for tracking and monitoring the pilgrims to support healthcare activities | Pilgrimage | Connection and Access | ✓ | ✓ |

## 2.6 Research Gap

First of all, the related works confirmed that the health assistance of pilgrims is neeccessary due to health challanges that face pilgrims while completing their holy events. IoT can be used effectively to provide health assistance for pilgrims through identifying their postions and their need forhealthcare.

The main gap of this research is that all related works is about identifying pilgrims postions in the context of health assistance rather than EHR retrieval for pilgrims to improve the healthcare services provided for pilgrims. Pilgrims EHR retrieval from their original countries is neccessary to give healthcare staff in pilgrimage a good understanding of the health case and provide effective treatment.

Another research gap is that the current related research proposed two main layers of IoT which are connectivity layer and access layer. These layers are effective to manage health activities of pilgrims based on local environment (inside KSA). However. for global environment such as retrieving pilgrims EHR from other countries to KSA, it is neccessary to additionally adopt the other two layers of IoT which are abstraction and service layers. The abstraction layer represents the online network connection via internet between access layer in KSA and service layer in other country. The service layer represents the EHR (i.e. database) that is located in the original country of the pilgrim.

## 2.7 Conceptual Framework of Internet of Things

A number of IoT aspects have been investigated in numerous studies from the literature. However, there are three main IoT aspects according to (Paul & Saraswathi, 2017). The first one focus on network concerned with aspects of IoT. The IoT would connect both virtual and physical generic objects as a global network, It also enlarge the importance of the traditional Internet related technologies and framework in the development of IoT. This concept has many real-world implementations using the smart sensor. Besides usual wireless communication, memory, and elaboration capabilities, this smart sensor is equipped with new potentials and capabilities such as autonomous and intense behavior, context recognition, collaborative communications and elaboration. It will act as one of atomic components in the positioning of IoT (Singh, Tripathi, & Jara, 2014) . The second view focus on pervasive objects which are connected over the network. The vision of "Things" target on “objects" into a mutual infrastructure, the vision of "Internet" defines the network concerned definition. The IP for Smart Objects (IPSO) promotes the network technology for connecting Smart Objects all over the world through Internet Protocol. To give brief summaries, the IoT will provide the current IP of any object and make those objects addressable and reachable from any location. Finally, the third view is semantic oriented which is based on standard communication protocols in which the object specifically addressable to worldwide network of interconnected system. Lot of physical world objects is allowed to be connected to IT framework. In such circumstances, semantic technologies could play a key role in modelling such as things description, semantic execution and communication and storing infrastructure.

Depending on the previous IoT aspects the architecture of the Internet of things can be primarily divided into three layers, which are perception layer, network layer, and Application layer. The perception layer assume information collection, can be applied technology including smart card, RFID tags, identification code, sensors, etc. While the network layer assume information transmission, can be achieved borrowing existing wireless network, mobile network, hard link, Internet, radio network, etc. In application layer the realize recognition and perception between objects and objects, people and objects, perform intelligence function (Yuqiang, Jianlan, & Xuanzi, 2010).

Outdoor services like pilgrims’ healthcare services require two main IoT Layers which are: 1) lower layer, and 2) upper layer. Lower layer (RFID) consists of electronic tags and wireless sensors. Sensors read data of tags and transfer it to upper layer. Upper layer (WSN) consists of super nodes and base station. Super nodes handle data from lower layer and transfer it to base station. Hence, data that stored in base station are managed and processed automatically connecting with central web servers. The outputs of processed data (information) are appeared on output devices such as monitors. By reflecting the above two layers of IoT in technical implementations, there are four main layers of IoT environments which can be described as the following (Figure 2.14):

i. Connectivity Layer: This layer represents the lower layer of IoT, the electronic tags should be in very short distance of wireless sensors (i.e. 3m). Data transferred from electronic tags through sensors to next layer (access layer).

ii. Access Layer: This layer represents the upper layer of IoT, the sensors should be in short distance of super nodes (i.e. 100m). Data are transferred to base station from sensors through super nodes. The distance between super nodes and base station would be 8km or less (C. Chen, 2010; C. Chen et al., 2006).

iii. Abstraction Layer: This layer responsible of transfer the data from base station to central web servers through open gateway such as internet infrastructures. This allows data transfer over large distances (i.e. across countries around the world).

iv. Service Layer: This layer is about providing real IoT services, the data that delivered from abstraction layer are processed and the results displayed on output devices such as monitors. These monitors are usually connecting with the tags in connectivity layer. Thus, the results of data processing send from service layer to connectivity layer through access and abstraction layers respectively.

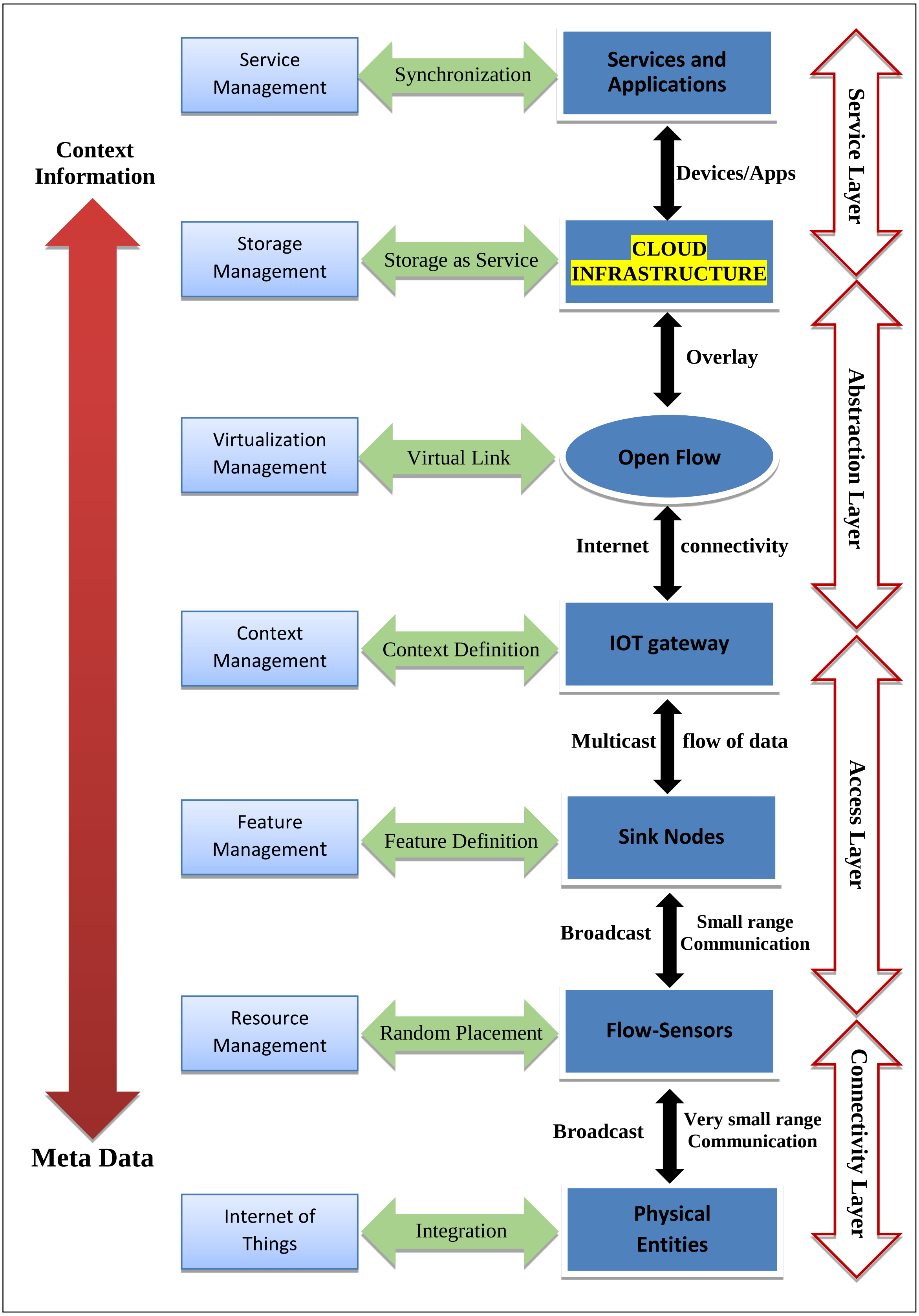



**Figure 2.14: IoT Conceptual Framework**

The above conceptual framework of IoT could effectively support our proposed idea of pilgrims EHR retrieval. Malaysian pilgrims need to have an electronic tag which identifies their personality (ID). In case of need for health services, health center contains wireless sensors to read pilgrim tag. Data are transferred from wireless sensor to base station via super nodes. Base station sends request via internet network to Malaysia in order to acquire pilgrim EHR from health database in central web server. Web server sends pilgrim EHR via internet network to base station. Base station display outputs on monitor that is connected with the sensor that sends tag data. It is pertinent to state that security is an integral part of the framework development, however it is not shown in the framework. In fact, security is not a hardware or a layer, but it can be conceptualized as an overall concern and challenge that need to be accounted for in each step of design and implementation. So, for any aspect of the framework, the security should be ensured with proper device, encryption and protocols.

## 2.8 Chapter Summary

This chapter presents the literature review of many related fields to this research such as pilgrims' health, EHR, and IoT. Through literature review, two main research gaps were identified: (1) there are no related works which focus on EHR retrieval from a pilgrim's original country to improve the healthcare services provided in pilgrimage, and (2) there are no related works which adopt the full map of IoT framework for the purpose of data transfer between countries. According to above research gaps, this research focuses on develop a conceptual framework based on four IoT layers (connectivity, access, abstraction, and service). The utilization of IoT for EHR retrieval is postulated to improve the health services provided for Malaysian pilgrims. This would be done through transfer of Malaysian pilgrims from Malaysia EHR reporository to healthcare centers in pilgrimage to help Healthcare staff in provision of an effective treatments for Malaysian pilgrims based on the historical EHR. The next chapter presents the research methodology and explains the various methods that were conducted to collect research data.

# CHAPTER 3

# RESEARCH METHODOLOGY

In this chapter, the methodology and approach employed by the research is presented. Each stage of the research is discussed and the activities and tasks to implement the entire methodology are summarized.

## 3.0 Introduction

Research methodology can be defined as various research activities and methods that are carried out to achieve the main research objective (Fellows & Liu, 2015). Dawson (2002) mentioned that research methodology is the proposed processes to address sequence of related research objectives in the context of research development (Dawson, 2002). According to Marshall and Rossman (2014), research methodology is important due to many reasons such as to clarify the researcher's vision of research development, simplify the research understanding for readers, and clarify the inter-relationship between various research activities in terms of research development (Marshall & Rossman, 2014).

The design of research methodology should be useful to achieve the research objectives (Easterbrook, Singer, Storey, & Damian, 2008). Dawson (2002) and Jassim et al. (2014) identified five main phases of research methodology that are suitable for research development in various fields. These phases are as the following (Dawson, 2002; Jassim, Mahmoud, & Ahmad, 2014):

- Preliminary phase: This phase aims to identify the main research direction such as problem statement, research objectives, and research questions. The preliminary review of previous works considered as main data sources in this phase (Krauss et al., 2009).

- Review stage: This stage is based on literature review to understand the related concepts and models to research fields and to identify the research gap.

- Data collection: The main aim of this phase is to collect and analyze the necessary data to address the main and sub-research objectives. The questionnaire (open and close-ended), and observation are examples on data collection methods in this phase.

- Development phase: The main aim of this phase is to clarify the research findings based on data collection in previous phase. The findings can be explained using various approaches such as development of system, framework, models, and/or strategies.

- Evaluation phase: The main aim of this phase is to evaluate the performance of research findings in previous phase. The findings can be evaluated using many factors such as usefulness, acceptance, ease of use, and reliability.

## 3.1 Research Methodology Design

The methodology design of this research is consist of five main phases; preliminary phase, review phase, data collection phase, development phase, and validation phase. These phases are adopted from the Dawson (2002) study due to many reasons such as the following:

- These phases can be applied usefully in any research of various study domains.
- The methodology design is clear and can be applied simply.
- The methodology phases are strongly interrelated with each other which manage the research development based on clear vision.

As outlined in Chapter 1, the main aim of this research is to propose IoT framework to addresses the need of global retrieval of the EHR of travellers in order to enhance the healthcare services provided during pilgrimage. There are three main objectives involve the construction of the proposed framework; (1) To explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries, (2) To identify the most useful structure, facilities, and components of the proposed IoT framework, and (3) To measure the validity of the proposed IoT-EHR framework. These research objectives are constructed based on the preliminary study (section 2.2), and based on the research objectives, the data collection approaches is designed (section 2.4).

The second methodology stage is the review phase, which support the construction of the proposed IoT- EHR framework through identifies the conceptual and theoretical directions of IoT and EHR domains. Also, the research gap is identified through the review phase.

The third methodology stage is the data collection stage, whereby the data collection methods for the research objectives are selected based on the natures of these objectives. The first research objective needs exploration about the importance, challenges, and viability of the idea of global EHR retrieval. Thus, the first objective requires data collection for investigation purposes. The second research objective requires data collection for the purpose of understand the technical issues of global EHR retrieval. The third research objective focuses on measure the validity of proposed framework, whereby the data validation data collection is required. According to nature differences of the required data collection to achieve the research objectives, it is not useful to adopt one data collection method for all research objectives.

Based on the research objectives and questions, the mixed methods data collection is necessary in this research. Mixed methods data collection has been defined as a research data collection based on various methods due to different nature of research objectives (Creswell & Clark, 2007). The philosophical rationale that compels mixing of qualitative and quantitative models of research into a single study is pragmatism (Morgan, 2007). Simply put, pragmatism is the belief in doing what works best to achieve the desired result. As an underlying philosophy for inquiry, pragmatism supports researchers in choosing between different models of inquiry as research questions being addressed intrinsically determine which methods are best suited (Palinkas et al., 2015). That is, certain research objectives are best addressed using qualitative analysis while others using quantitative methods.

On other hand, the mixed methods is a philosophically underpinned model of inquiry combining qualitative and quantitative models of research so that evidences are mixed and knowledge is increased in a more meaningful manner (Aarons, Hurlburt, & Horwitz, 2011; Creswell & Clark, 2007; LANDSVERK et al., 2012; Palinkas et al., 2011). Thus, the same objectives can be achieved by more than one data collection method. Furthermore, Mixed method designs are viewed as preferable in implementation research because they provide a better understanding of research issues than either qualitative or quantitative approaches alone (Palinkas et al., 2011).

The triangulation technique of the mixed methods data collection is used in this research design. The triangulation technique is the convergence of multiple perspectives that can present greater confidence that what is being targeted is being accurately captured (DeVos, Goddyn, Mohar, Vertigan, & Zhu, 2005). Thus, the concept of triangulation is sometimes used to delegate a conscious combination of quantitative and qualitative methodology. Ruffinet al. (2009) explained that the triangulation is the process of corroborating information from different individuals, types of data, or methods of data collection. This ensures that the study will be truthful because the information draws on multiple sources of information, individuals or processes. In this way, it encourages the researcher to develop a report that is both precise and credible (Ruffin, Creswell, Jimbo, & Fetters, 2009).

Based on the opinion of Ruffinet al. (2009), concurrent triangulation is procedures used to converge or merge quantitative and qualitative data in order to offer a comprehensive analysis of the research problem. In this design, the investigator collects both forms of data at the same time and then amalgamates the information during interpretation of the overall results. In this design, the researcher may entrench one smaller form of data within another larger data collection in order to analyse different types of questions. De Vos (2005) mentions the following advantages of triangulation:

- It allows researchers to be more confident of their outcomes.
- It can help to uncover the deviant dimension of a phenomenon.
- It may lead to a synthesis of theories.
- Triangulation can serve as the critical test of competing theories.
- The utilization of triangulation increases the validity of findings (Burton & Bartlett, 2009).

This research follows a concurrent triangulation mixed-methods design, due to the choice to do quantitative research (questionnaires) and qualitative research (focus group discussion, open-ended survey and observations) simultaneously. The thought of involving both quantitative and qualitative research methods is underpinned by aiming at strengthening the findings made by the researcher.

The first research objective is to explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries. Thus, to address the first research objective, the data collection using questionnaire and observation data collection methods is useful due to effectiveness of these methods for exploration activities. Quantitative data collection using questionnaire is effective to explore the opinions of large respondents about specific idea (such as idea importance and challenges) (Cohen, Cohen, West, & Aiken, 2013; Trochim & Donnelly, 2001). Also, the data collection method using questionnaire is suitable for the exploration activities (such as the first research objective) due to the following reasons (Silverman, 2015):

- Ability to collect data from large number of respondents.
- Ability to find the relationships between the various research factors or variables.

- Simple data collection in short time and efforts.
- Reflect the real situation of the respondent in the study area.
- Ability to find relationships or connection between the collected data to support the research paradigm.

In addition, the data collection using observation method is important to support the achievement of the first research objective. The observation method support the data collection based on observes the real environment, which allows the researchers to acquire new and reliable knowledge about specific idea. Through observe the real environment of patients' treatment in pilgrimage, the prerequisites, challenges, importance, and viability of global EHR retrieval for pilgrims could be explored.

On the other hand, the second research objective is to identify the most useful structure, facilities, and components of the proposed IoT framework. This objective requires technical data collection form experience persons. The experts are able to give valuable knowledge about the technical issues more than the people of low experiences in the domain. Furthermore, the technical specifications in specific field are useful to be collected based on quantitative methods through open discussion with people who have adequate experiences in this field (Krauss et al., 2009). Hence, for effective achievement of the second research objective, it is useful to collect data using open-ended survey and Focused Group Discussion (FGD) methods. Beside the open-ended survey and FGD methods, the literature review is important data source to support the achievement of the second research objective. The literature review could provide rich data about the technical features of IoT technology and EHR retrieving.

The open-ended survey with experts from KSA needs to be conducted in order to identify the required facilities to apply the global IoT-EHR systems in pilgrimage environment. On the other hand, the focused group discussion with Malaysian experts needs to be conducted in order to identify the useful structure and components of global IoT to share the EHR of Malaysian pilgrims for KSA parties.

The fourth methodology stage is conducted based on the results of first and second research objectives, the proposed IoT-EHR framework can be constructed through explains the technical and conceptual components of this framework.

The fifth research methodology stage is related to third research objective which is to measure the validity of the proposed IoT-EHR framework. This objective requires the confirmation of the perceived benefits that could be gained through adopt the proposed IoT-EHR framework in pilgrimage environment. The validation of framework usefulness can be conducted through open-ended survey with experts. Through the open-ended survey data collection, the experts can provide clear opinions and suggestions about if the proposed framework is valid to be adopted or not.

In total, the research methodology is based on five stages which are: (1) the preliminary phase is to identify the main research directions such as problems statement and research objectives; (2) The review phase is to identify the gap of theoretical and practical previous research of pilgrim EHR utilizing IoT; (3) The data collection phase is to address the research objectives and questions through various data collection methods: questionnaire and observation for 1$^{st}$ research objective, and open-ended survey and focus group discussion for the second research objective; (4) based on the first and second research objectives, the proposed IoT-EHR can be constructed, which represent the development phase; (5) the validation phase represent the third research objective, and it is focuses on gauge the adoption usefulness of proposed IoT-EHR framework. Figure 3.1 illustrates the five main phases of this research methodology.

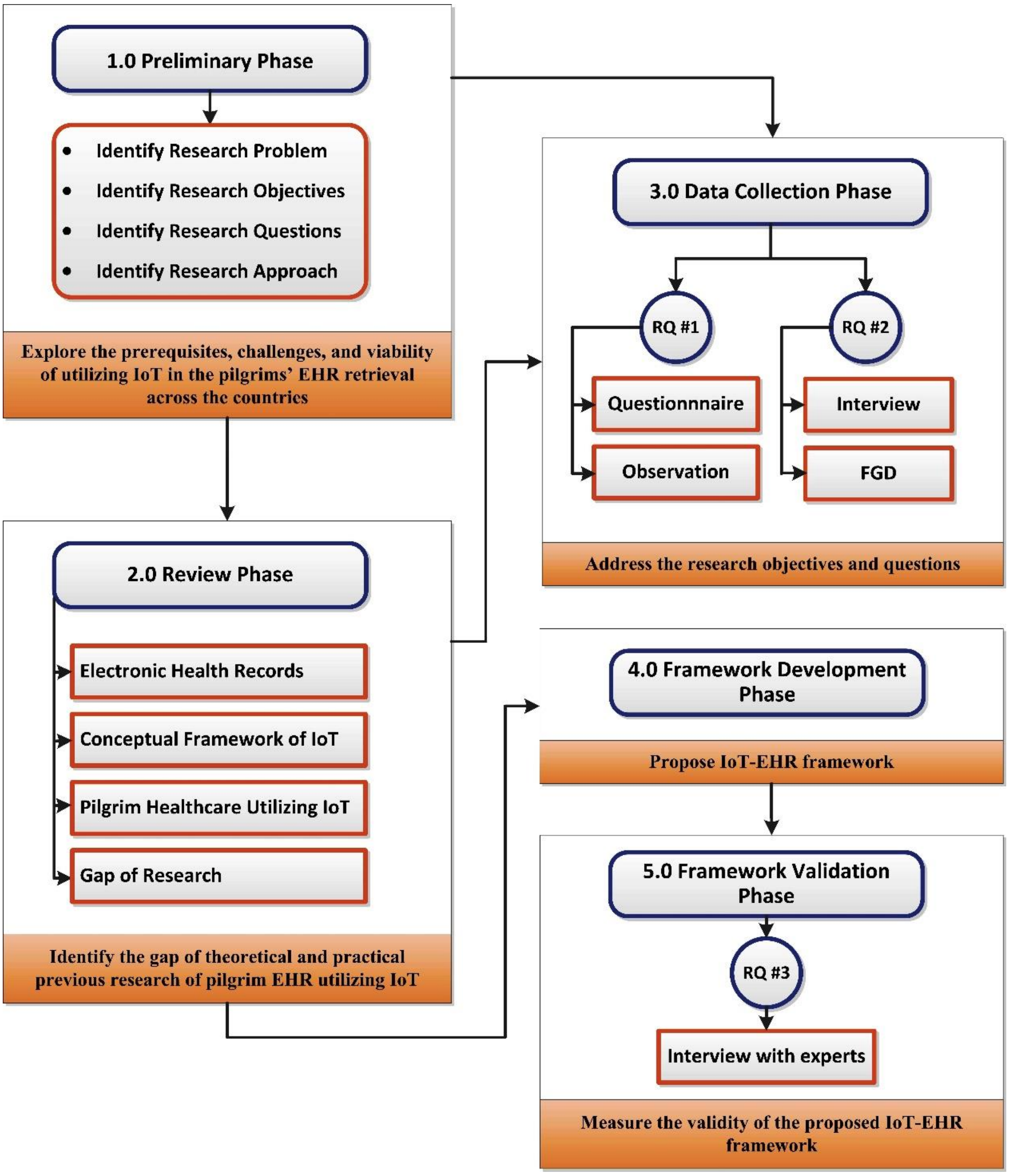



**Figure 3.1: Research Design**

## 3.2 Preliminary Phase

Krauss et al. (2009) described the preliminary review as the processes of clarify the main idea of research such as identifying research problem, research objectives and questions, and research scope(Krauss et al., 2009).

By reviewing several studies related to the health domain, the main challenge that faces the healthcare services is the need of make accurate health decisions in the right time. The health decisions made by healthcare staff like doctors and nurses are sensitive and may affect the life of the patients. Thus, inaccurate health decisions or the delay in healthcare services may increase the risk of health cases. The healthcare staff needs to have good understanding of the health cases to make the right decisions accurately and in good time. Patient's health records represent important sources that support the health decisions. However, the traditional retrieval systems of health records such as paper based system are still face many problems such as probability of damage or harm the health records, and time requirement of health records collecting, managing, and retrieving. These challenges and more could delay or effect on the accuracy of health services.

According to above challenges of traditional retrieval systems of health record, the researchers focus on EHR to retrieve the patient's records accurately in real-time. The main aim of EHR is to increase the accuracy of healthcare decisions and speed up the health services.

Although EHR is effective for local health services (for example, hospitals within the patient's country), the implementations of EHR for global purposes is still an issue. EHR is not applicable for the persons who travel to other countries. Therefore, it is necessary to develop EHR that support the healthcare services of travellers.

One of the most important travelling purposes for Muslims is the pilgrimage. There are millions of Muslims travelling to KSA every year to complete pilgrimage rites. Pilgrims may need healthcare services and these services should be accomplished accurately in real-time which required historical health records based electronic approaches. This indicates the importance of global EHR retrieval for pilgrims. The health staff in pilgrimage environment (KSA) need to retrieve the full historical records of the patient pilgrim in real time, which requires EHR transfer from the original country of pilgrim to KSA based on the health staff requests. Based on this ides, the IoT facilities seem as suitable technology to support the global EHR retrieval. Consequently, the main aim of this research is to propose IoT framework to addresses the need of global retrieval of the EHR of travellers. However, the adoption of IoT technology for global EHR retrieval faced many concerns such as the viability of adopts this technology and the technical issues like data security and privacy. Therefore, three research objectives and several research questions are formulated to address the main aim of this research. Table 3.1 summarizes the research objective, research questions, and the selected data collection methods that justified in the previous section.

**Table 3.1: Research Objectives and Data Collection Methods**

| Research Objectives | Research Questions | Research Methods |
|---|---|---|
| To explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries | - How can utilize IoT in the global retrieval of pilgrims' EHR?<br>- What are the challenges that face the utilizing IoT for global retrieval of pilgrims' EHR?<br>- Why to utilize IoT for global EHR retrieval in pilgrimage environment? | Questionnaire + observation |
| To identify the most useful structure, facilities, and components of the proposed IoT framework. | - What are the most suitable technical specifications of IoT (devices, distances, structure, etc) for global EHR retrieval?<br>-<br>- What are the most suitable specifications of health records (structure, details, format, etc) to support the proposed framework?<br>- | Open-ended survey + focus group discussion |
| To measure the validity of the proposed IoT-EHR framework. | - What are the perceived benefits and challenges in adoption of the proposed IoT-EHR framework in pilgrimage environment? | open-ended survey with experts |

To address the research objective, especially the second research objective, the review stage (literature review) is necessary to collect data about the IoT and EHR domains, as well as identifying the research gap. The next section discusses the review stage.

## 3.3 Review Phase

Literature review is considered as a qualitative method to collect useful data to support research development (Krauss et al., 2009; Walliman, 2005). Literature review is the act of reviewing related works of research idea to understand the concepts, aspects, methods, and gap of the research field (Hagen-Zanker & Mallett, 2013; D. Walker, Bergh, Page, & Duvendack, 2013).

The literature review support the identifying of the most suitable IoT architecture for the purpose of pilgrim EHR retrieval, as well as identify the research gap. According to critical review of previous related works, two main research gaps were identified: (1) there are no related works focused on EHR retrieval of pilgrims' records from their original countries to improve the healthcare services provided in pilgrimage, and (2) there are no related works which adopt the full map of IoT framework for the purpose of data transfer between countries.

On the other hand, the literature review supports the addressing of the second research objective. In general, outdoor services like pilgrims' healthcare services require two main IoT layers which are lower layer (Agrawal & Das, 2011) and upper layer. Lower layer (RFID) consists of electronic tags and wireless sensors. Sensors read data of tags and transfer it to upper layer. Upper layer (WSN) consists of super nodes and base station. Super nodes handle data from lower layer and transfer it to base station (Zhu et al., 2010). Hence, data stored in base station are managed and processed automatically connecting with central web servers. The outputs of processed data (information) are displayed on output devices such as monitors. Hence, the EHR of patient pilgrims can be requested by the health staff using the electronic tag of the pilgrims (ID). Based on this request the EHR can be retrieved from the original country of the pilgrims through the IoT layers.

The EHR retrieval through global network (such as IoT) face many challenges like the security and privacy concerns, and the literature review provide rich data about the solutions for the challenges that face the EHR retrieval through the IoT facilities (more explanations in chapter 5).

## 3.4 Data Collection Phase

As explained in section 3.1, the selection of data collection methods to address the research objectives is determined by the nature of these objectives. Triangulation technique of the mixed methods data collection is used in this research design. The questionnaire and observation data collection methods are conducted to address the first research objective. The open-ended survey and FGD methods were conducted to address the second research objective. The open-ended survey with experts is conducted to address the third research objective, and this method is explained in section 3.6 due to its relation with the validation phase. In this section the processes of data collection methods of the first and second research objectives are clarified.

### 3.4.1 Data collection for First Research Objective

As explained in section 3.1, the questionnaire and observation data collection methods are suitable to address the first research objective (to explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries). This section explains the processes of these two methods.

#### 3.4.1.1 Data Collection from KSA Healthcare Providers Using Questionnaire

According to Cohen et al. (2013), the quantitative data collecting method using questionnaire is effective to explore the current and expected implementations of specific methods in real environments (Cohen et al., 2013). Therefore, the quantitative data using questionnaire was collected to explore the prerequisites and challengesof utilizing IoT in the pilgrims' EHR retrieval across the countries.

Due to limitations in the previous questionnaires in this domain, the questionnaire of this study was developed by the researcher according to need of the first research objective. The items were derived from different sources of published studies (Ajami & Bagheri-Tadi, 2013; Hoover, 2016; Hydari, Williams, & Zimmer; Mathai, Shiratudin, & Sohel, 2017; Rios-Zertuche et al., 2018; Weiskopf, Hripcsak, Swaminathan, & Weng, 2013). Table 3.2 summarizes developed questionnaire parts, which was validated by two experts; one from information systems domain and a lecturer who is specialised in questionnaire to design assure the effectiveness of the questionnaire parts in relation with the first research objective. The questionnaire, the validators' profiles and sample of answers are attached in Appendix A, A1 and A2 respectively.

**Table 3.2: Questionnaire Parts**

| Part | Items |
|---|---|
| Demographic Data | Gender, age, job role, experience years, working status, and number of Hajj seasons attended |
| Availability domain of EHR in pilgrimage | 1-7 |
| Challenges of health records retrieval | 8-16 |
| Importance of EHR in pilgrimage | 17-22 |

- **Sample and Population**

As mentioned previously in Chapter 1, the pilgrimage healthcare services are the main environmental scope of this research. Thus, the community of this study is composed of the healthcare staff that involved the pilgrimage healthcare services. The healthcare services of pilgrims are provided by healthcare centres or hospitals in three main areas in KSA: Mecca, Medina, and Jeddah. These areas are visited usually by pilgrims in their journey.

The researcher distributed the questionnaire to 64 healthcare staff members. However, four responses were invalid due to incomplete answers. Therefore, the sample of the study is composed of 60 healthcare staff in four healthcare centers; (1) Albayt Medical Center, (2) Makkah Medical Center, (3) Makkah Al Noor Medical Centerand (4) Jeddah Al Madinah N.G. Family & Community Medical Center. The total number of healthcare staff in these centers is about 350 workers. The sample of the study composed a percentage of 17.1% (60/350) of the total number of workers in the selected healthcare centres.

According to Yount (2006), the sampling rate should be 10% at minimum for a population size between 101-1000 workers (Yount, 2006). Thus, the sampling rate of this research is valid (i.e. 17.1% of study population). Table 3.3 summarizes the required sampling rate according to the size of the population.

**Table 3.3: Sampling Rates**

| Size of Population | Sampling Rate |
|---|---|
| 0-100 | 100% |
| 101-1000 | 10% |
| 1001-5000 | 5% |
| 5001-1000 | 3% |
| 10000+ | 1% |

- **Sampling technique**

We adopted a two stage sampling method; stratified sampling technique followed by simple random sampling. Each hospital was considered as a strata. In each strata the sampling frame was obtained from hospital management office. Out of each list a random number was selected using SPSS software.

- **Criterion of Questionnaire**

The researcher followed certain procedures in the questionnaire application processes which are as the following:

- The data was collected in 2014 from the study sample.
- Use the questionnaire instructions to clarify the objectives and importance of the study, such as the study data will only be used for scientific research purpose. The researcher illustrated to respondents the way to answer the questions as it is mentioned in the instructions section.
- The respondent answers collected are based on 5-likert scale: 1 for strongly disagree (SD), 2 for Disagree (D), 3 for Neutral (N), 4 for Agree (A), and 5 for Strongly Agree (SA).
- The questionnaire data collected based on Haan and Kloub criterion (Haan & Kloub, 2013). The criterion is considered one of the main things to build instruments as illustrated in Table 3.4.

**Table 3.4: Criterion Degree for Each Level of Answers**

| **Scale Index** | **Answer** | **Agreement Level** |
|---|---|---|
| 1-1.49 | Strongly Disagree | Very Low |
| 1.5-2.49 | Disagree | Low |
| 2.5-3.49 | Neutral | Moderate |
| 3.5-4.49 | Agree | High |
| 4.5-5 | Strongly Agree | Very High |

The researcher considered the means and their percentage in the previous Table 3.4 is the criterion of response level of the study questionnaire according to the response means due to item, factor and total degree.

- **Questionnaire Analysis**

There are many statistical analyses that could be conducted based on the questionnaire data such as reliability, validity, frequencies, descriptive, correlation, and regression analyses. However, the descriptive and correlation are the most important analyses to achieve the research objective that related to questionnaire data collection.

In this research, SPSS version 20.0 (Statistical Package for the Social Sciences) was used to conduct many statistical analyses which are as the following:

1. **Reliability Analysis:** Questionnaire reliability is defined as the stable interrelation between item responses (Waters, 2002). Random answers are considered unstable responses. Reliability involves correlating the responses to each question with other questions in the questionnaire. According to Waters (2002), Low reliability reduces correlation coefficients and diminishes statistical power in group comparisons, and it doesn't guarantee both stability and validity, and it is not a property of the construct being measured, and also affected by the range of individual differences in the sample. There are no unreliable traits or behaviours only unreliable measures. The reliability of any measurement can always be increased to any level required by increasing the amount of observation, aggregating multiple observations. Coefficient alpha is the most frequently method used for calculating internal consistency that used as a measure of reliability for the variables of the study, where $\alpha > 0.7$, that

indicates satisfactory internal consistency reliability (Nunnally & Bernstein, 1994) .

2. **Frequency Analysis:** Frequency analysis is a collection of measurements representing the entire population, by deriving a useful summary of data set for demographics or the study variables (Waters, 2002). Frequency analysis was conducted on demographic data part to assure the validity of respondents' characteristics to provide useful data for this research.

3. **Descriptive Analysis:** Descriptive statistics is a collection of measurements representing the entire population, by deriving a useful summary of data set for demographics or the study variables. Descriptive statistics that include frequency and means helps understanding of the importance levels, study variables and concludes a clear image of the study. The descriptive analysis was conducted to analyze two main directions of data: (i) the responsibility of participants (demographic data) to provide useful answers to support the main purpose of questionnaire, and (ii) the main questionnaire variables.

4. **Correlation:** The correlation analysis was conducted through using Person correlation coefficient (r) to test the relationships between the challenges of current health records retrieval methods and the importance of EHR implementations in pilgrimage.

#### 3.4.1.2 Data Collection Using Observation Method of Malaysian Pilgrims in KSA

The observation data collection method is conducted to support the achievement of the first research objective (to explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries). Observation is the active acquisition of information from a primary source. In living beings, observation employs the senses. In science, observation can also involve the recording of data via the use of instruments. The term may also refer to any data collected during the scientific activity. Observations can be qualitative, that is, only the absence or presence of a property is noted.

For the observation data collection, the researcher decided to follow a purposeful sampling approach, which comprised of people based on a particular quality whatever the sample size. Thus, the observation data should be collected from persons who involve the pilgrimage healthcare services. For the purpose of this research, the observation is conducted on four Malaysians pilgrims who travel for Umrah with Malaysians group of 40 pilgrims. The researchers observed the health treatment for two pilgrims without using any historical health records, while the other two patient pilgrims are treatment based on their historical health records. Table 3.5 summarizes the sample of the observation method.

**Table 3.5 Sample of the Observation Method**

| Observation population | Observation sample | Type of observation | Sample number |
|---|---|---|---|
| Umrah group of 40 Malaysians pilgrims | 4 Malaysians pilgrims | Treatment without historical health records. | 2 |
| | | Treatment based on historical health records | 2 |

The purposeful sampling selection for observation data collection is identified by two characteristics; the understand ability of the importance and challenges of health care services in pilgrimage, and the involvement of pilgrimage healthcare services. On the other hand, the observation data should be collected from real environment of pilgrimage healthcare services.

Based on the above requirements of purposeful sampling selection for observation data collection, the health services of Malaysian pilgrimage were observed. For this purpose, the researcher travel for Umrah with group of Malaysian pilgrimage. The observation data was collected based on the following procedures:

- The researcher registered and travelled for Umrah with Malaysian citizens in 2014.
- The researcher accompanied the Malaysians pilgrims in all Umrah activities.
- The researcher took note of the healthcare services that were provided to some Malaysians pilgrims.
- The researcher gave full historical reports of two Malaysian pilgrims to the healthcare staff to provide the healthcare services for these pilgrims based on the owned historical reports.
- The researcher obtained feedback from the healthcare staff and Malaysian pilgrims to compare the healthcare services with and without historical reports.
- The collected data (researcher's notations and feedbacks) were structured, reviewed many times, and analyzed as comparisons between the current healthcare services and healthcare services based on EHR.

### 3.4.2 Data Collection for the Second Research Objective

As explained in section 3.1, the open-ended survey and FGD methods are suitable to address the second research objective (to identify the most useful structure, facilities, and components of the proposed IoT-EHR framework). This section explains the processes of these two methods.

#### 3.4.2.1 Data Collection Using Open-ended Survey with Healthcare Professional in KSA

The open-ended survey is an important method to collect useful data from experts to support the second research objective. The open-ended survey can be defined as a method to collect qualitative data, using open questions to analyze useful variables or methods according to research case study (Jassim et al., 2014).

For the open-ended survey data collection, the researcher decided to follow a purposeful sampling approach. According to Van der Stoep and Johnston (2008), purposeful samples are comprised of people based on a particular quality whatever the sample size (VanderStoep & Johnson, 2008). Thus, the open-ended survey data should be collected from qualified persons in the ICT implementations in health domain.

The purposeful sampling selection for open-ended survey data collection is identified by two participants' characteristics; the experiences in health services, and the experiences in information systems implementations. On the other hand, the open-ended survey data should be collected from institutions that involve the pilgrimage healthcare services.

Based on the above requirements of purposeful sampling selection for open-ended survey data collection, the open-ended survey was conducted with five experts from three known hospitals in KSA : these hospitals are : Alawi Tunsi Hospital in Mecca, Al Ansar General Hospital in Madinah, and Jeddah Clinic Hospital in Jeddah. These hospitals were selected due to its strong relationships with pilgrimage healthcare services. These hospitals are located in the cities that the pilgrims are usually visiting in their pilgrimage journey. Therefore, the experts are having good ideas about the current situations of pilgrimage healthcare services. The experts are working as leaderships in ICT departments in the selected hospitals such as information management departments. Thus, they have effective experiences and knowledge to provide information about technical implementations of IoT and EHR. The questions of the open-ended survey, experts' profile and sample of response are enclosed in Appendix B , B1and B2.

As a matter of fact, due to time constrain and resource availability, five experts from best leading healthcare provider during pilgrimage was deemed satisfactory. Although it might be seeming a small sample size but it conforms to other studies. An analysis of 119 original studies haphazardly chosen from five leading behavioral journals suggests that the selected sample size reflects an influence of constraints more often than a rational optimization process (Roberts et al., 2009).

The open-ended survey was designed and developed as four sections to support the addressing of second research objective and the main open-ended survey parts are as the following:

- Importance of EHR in pilgrimage
- Challenges of EHR implementations in pilgrimage.
- EHR utilizing IoT in pilgrimage
- Personal information of respondent
- EHR utilizing tag reading to support pilgrimage healthcare services: this part aims to study the features of utilize EHR supporting tag reading to improve the healthcare services in pilgrimage environment.
- Structure of IoT- EHR to support healthcare services in pilgrimage: this part aims to identify the required components and structure for IoT-EHR framework.
- Personal information to ensure the expertise (validity of experts): this part aims to ensure the validity of expert characteristics such as experience years, and domain expertise.

In order to validate the contents of the collected answers regarding to related objective, the open-ended survey was conducted based on face to face discussion with experts. Thus, any required updates on the open-ended survey questions, any ambiguity in the parts and items, and any further details that need to address the related objectives are conducted directly with the experts. In other words, the experts play important role to validate the open-ended survey contents according to explained objectives. The procedures of open-ended survey validation are as the following:

- The research ideas were discussed with the experts.
- The research objectives that relate to open-ended survey were clarified for expert.

- The experts update the open-ended survey contents according to research ideas and related objectives.
- The new open-ended survey contents were confirmed based on discussion between the researcher and the experts.
- The experts accomplish the open-ended survey based on good understanding of open-ended survey purpose.

The content analysis method was used to analyses the responses of open-ended survey. Content analysis method can be defined as any qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings. In other words, the qualitative content analysis items usually consist of texts that purposely selected to inform and answer the research questions. The content analysis is effective when the sample of collected data is small (i.e. less than 10 interviews) (Patton, 2002). Thus, the content analysis of is suitable to analyze the open-ended survey responses in this research due to sample number (five experts). The following procedures are accomplished to analyze the open-ended survey contents:

- Design open-ended survey as structured four parts and each part managed through several specific questions to cover the basic variables of this model.
- The experts take a considerable time and discussion during the open-ended survey sessions in order to finalize the suitable answers.
- The collected responses were arranged depend on open-ended survey objectives and questions.
- The researcher reviews the responses carefully many times.
- The findings of each question in the open-ended survey are figured out and finalize based on all answers collected from all the experts.
- The findings of each part in the open-ended survey are figure out and the final conclusion is deduced.
- The overall all findings of open-ended survey are figured out finally.

#### 3.4.2.2 Data Collection through Focus Group Discussion

The focus group discussion (FGD) is the other method that was used to support the achievement of the second research objective. FGD is a good way to gather together people from similar backgrounds or experiences to discuss a specific topic of interest. The group of participants is guided by a moderator (or group facilitator) who introduces topics for discussion and helps the group to participate in a lively and natural discussion amongst them. The strength of FGD relies on allowing the participants to agree or disagree with each other so that it provides an insight into how a group thinks about an issue, about the range of opinion and ideas, and the inconsistencies and variation that exists in a particular community in terms of beliefs and their experiences and practices.

For the FGD data collection, the researcher decided to follow a purposeful sampling approach, which comprised of people based on a particular quality whatever the sample size. Thus, the FGD data should be collected from persons who experts in the Malaysian pilgrimage situation like pilgrimage healthcare services.

The purposeful sampling selection for FGD data collection is identified by two participants' characteristics; the understand ability of the current situation of pilgrimage healthcare supporting of Malaysian pilgrimage, and the ability to make decisions in the issues of pilgrimage healthcare. Thus, the data was collected through FGD with leaders of the Malaysian agency in two rounds: (1) FGD with eight leaders to gather information about EHR with regards to requirements, challenges and feasibility to introduce/implement the EHR sharing framework, and (2) a follow-up FGD with six leaders to discuss the technical issues of utilizing IoTin EHR. The main aim of the first round is to validate the contents of FGD, while the second round is to collect the final data based on FGD.

The approach to thematic analysis (TA) that we developed involves a six-phase process:

- **Familiarisation with the data:** This phase involves reading and re-reading the data, to become immersed and intimately familiar with its content.
- **Coding:** This phase involves generating succinct labels (codes!) that identify important features of the data that might be relevant to answering the research question. It involves coding the entire dataset, and after that, collating all the codes and all relevant data extracts, together for later stages of analysis.
- **Searching for themes:** This phase involves examining the codes and collated data to identify significant broader patterns of meaning (potential themes). It then involves collating data relevant to each candidate theme, so that you can work with the data and review the viability of each candidate theme.
- **Reviewing themes:** This phase involves checking the candidate themes against the dataset, to determine that they tell a convincing story of the data, and one that answers the research question. In this phase, themes are typically refined, which sometimes involves them being split, combined, or discarded.
- **Defining and naming themes:** This phase involves developing a detailed analysis of each theme, working out the scope and focus of each theme, determining the 'story' of each. It also involves deciding on an informative name for each theme.
- **Writing up:** This final phase involves weaving together the analytic narrative and data extracts, and contextualising the analysis in relation to existing literature.
- **Sample size guidance:** In line with most adopted guidelines, an average number of 5-10 participants are usually selected during FGD. In this study we recruited 8 experts from Tabung Haji for the first FGD and another six leaders for the second FGD (Rabiee, 2004).

More details about the FGD questions and procedure are attached in Appendix D-D1.

### 3.5 Framework Development

The development phase defined as the integration of overall collected and analyzed data using various methods to formulate the main research outcomes. The research outcomes can be explained through various approaches such as models, strategies or/and framework through textual and illustration explanations. These explanations should be provided in simple and clear structure for readers.

The main aim of development phase is to propose IoT framework to addresses the need of global retrieval of the EHR of travellers. Figure 3.2 illustrates the development sources of the proposed framework.

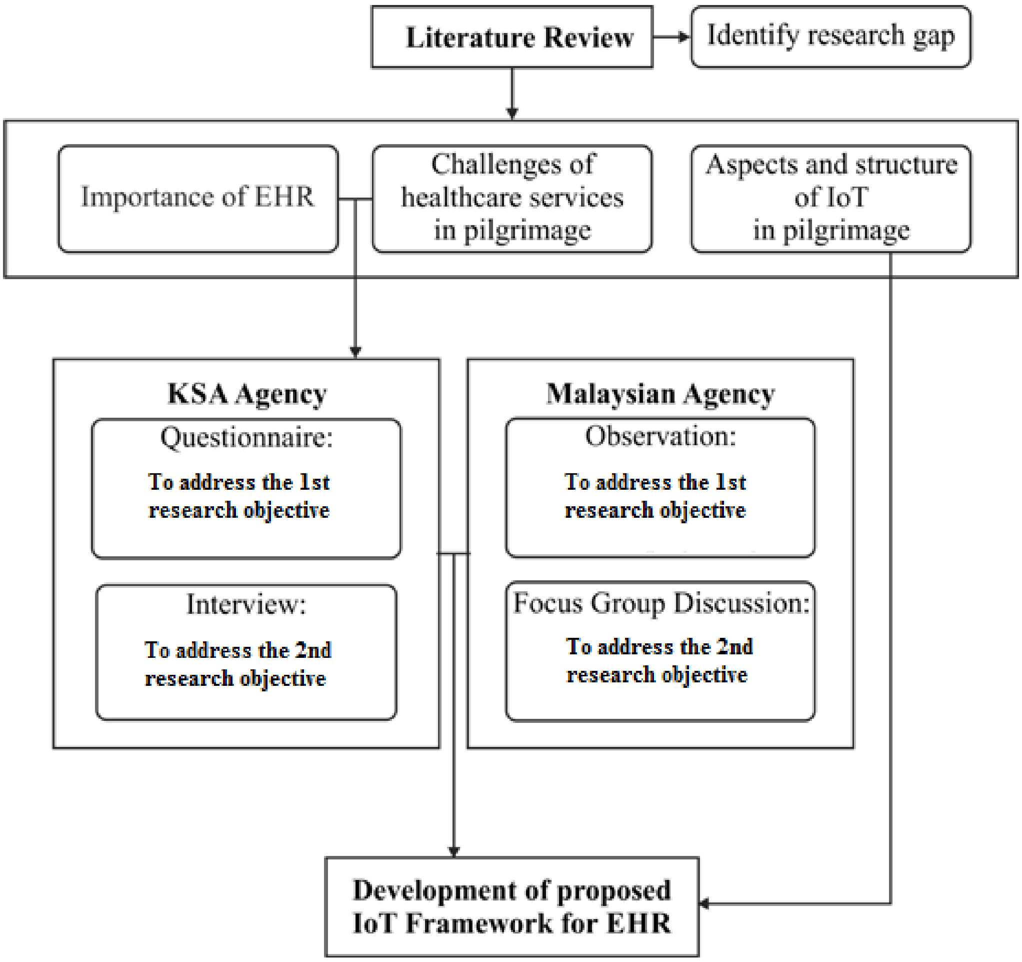



Figure 3.2: Development Sources of the Proposed Framework

### 3.6 Framework Validation

This stage aims to address the third research objective, which is to measure the validity of the proposed IoT-EHR framework. The validity measuring can be conducted based on common factors that used in validating component-based frameworks by other researchers. In (Yusof, Kuljis, Papazafeiropoulou, & Stergioulas, 2008) the authors defined the testing or validation stage as the processes of confirm the performance of the research outcomes i.e. usefulness, usability or reliability. Table 3.6 summarizes the most important validation factors of theoretical and practical outcomes.

**Table 3.6: Validation Factors**

| Factor | Aim | Sources |
|---|---|---|
| Usefulness | Believes degree to which the proposed methods or system is suitable to address specific objectives. | (Pfeffer, 1982); (Chuttur, 2009) |
| Ease of Use | Believes degree to which the proposed system functions is easy to be used. | (Chuttur, 2009) |
| Usability | Ensure that the proposed system or methods are executed properly and add benefits to working environment. | (Shackel, 2009) |
| Flexibility | Test the technology characteristic that allows or enables adjustments and other changes to the business process. | (Nelson, Nelson, & Ghods, 1997) |
| Security | Test the security performance of proposed systems or models. | (Sokolova, Japkowicz, & Szpakowicz, 2006) |
| Accuracy | Test the accuracy of system functions according to working activities. | (Sokolova et al., 2006) |
| Speed | Test the processing speed of proposed systems. | (Hall, Hall, & McCall, 2000) |
| Cost | Validate the feasibility study (expenses) of proposed system. | (Cooper & Kaplan, 1992) |

As noticed from Table 3.6 above, the usefulness, usability, flexibility, and security considered as the most acceptable validation factors for this research. The other validation factors such as accuracy, cost, and speed are suitable to test the validity of systems rather than theoretical frameworks.

To validate the proposed framework, an open-ended survey was conducted with eight experts from Tabung Haji of Malaysia. Most of the experts have at least 10 years in information management systems and Malaysian pilgrimage activities. For further information about the validation open-ended survey, refer to Appendix E and E1.A sample of response was included as well.

The open-ended survey was conducted based on summative review technique (Khoja et al., 2007). Summative review can be defined as discussing the architecture, components, and formulas of the model with experts and updating the proposed models according to expert comments. All comments were considered and taken into the research account and the final version of the proposed model was formulated based on these comments.

## 3.7 Chapter Summary

This chapter reviews the methodology phases that followed to develop this research. Research methodology consists of five main phases which are preliminary phase, review phase, data collection phase, development phase, and validation phase. The aims, methods, and processes of each phase are clarified and the interrelation between these stages is justified. The next chapter clarifies the analysis and results of data collected using the various methods.

# CHAPTER 4

# DATA ANALYSIS AND RESULTS

This chapter presents the analysis of various data collection methods that followed in this research. This chapter divided into main parts which are: data analysis of EHR implementations in pilgrimage from the KSA agency, and data analysis of EHR implementations in pilgrimage from the Malaysian agency. Furthermore, the relationship between the analyzed data from both agencies is discussed.

## 4.0 Introduction

The main aim of this chapter is to analyze the environmental and technical issues of EHR utilizing IoT in pilgrimage. As mentioned in Chapter 1, the scope of this study is the healthcare services for Malaysian citizens in pilgrimage. Therefore, the data collection methods were conducted to analyze the aspects of EHR utilizing IoT in pilgrimage from KSA and Malaysian perspectives. Figure 4.1 illustrates the data collection and the main aim of each method connecting with other methods.

The first research objective is to explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries. Two main data collection methods were conducted to addresses the first research objective; (1) quantitative data collection using questionnaire collect data from the KSA agency. The questionnaire was conducted with 60 healthcare staffs in KSA that have experiences in healthcare services in pilgrimage, and (2) observation method through Umrah travel with four Malaysian pilgrims to explore the challenges that face them in healthcare service and the importance of EHR to improve these services.

The second research objective is to identify the most useful structure, facilities, and components of the proposed IoT-EHR framework. Two main data collection methods were conducted to address the second research objective; (1) qualitative data collection using open-ended survey with five ICT experts in KSA hospitals, and (2) two rounds of FGD with leaders from Tabung Haji in Malaysia. The first FGD round was conducted with eight leaders, while the second FGD round was conducted with six leaders.

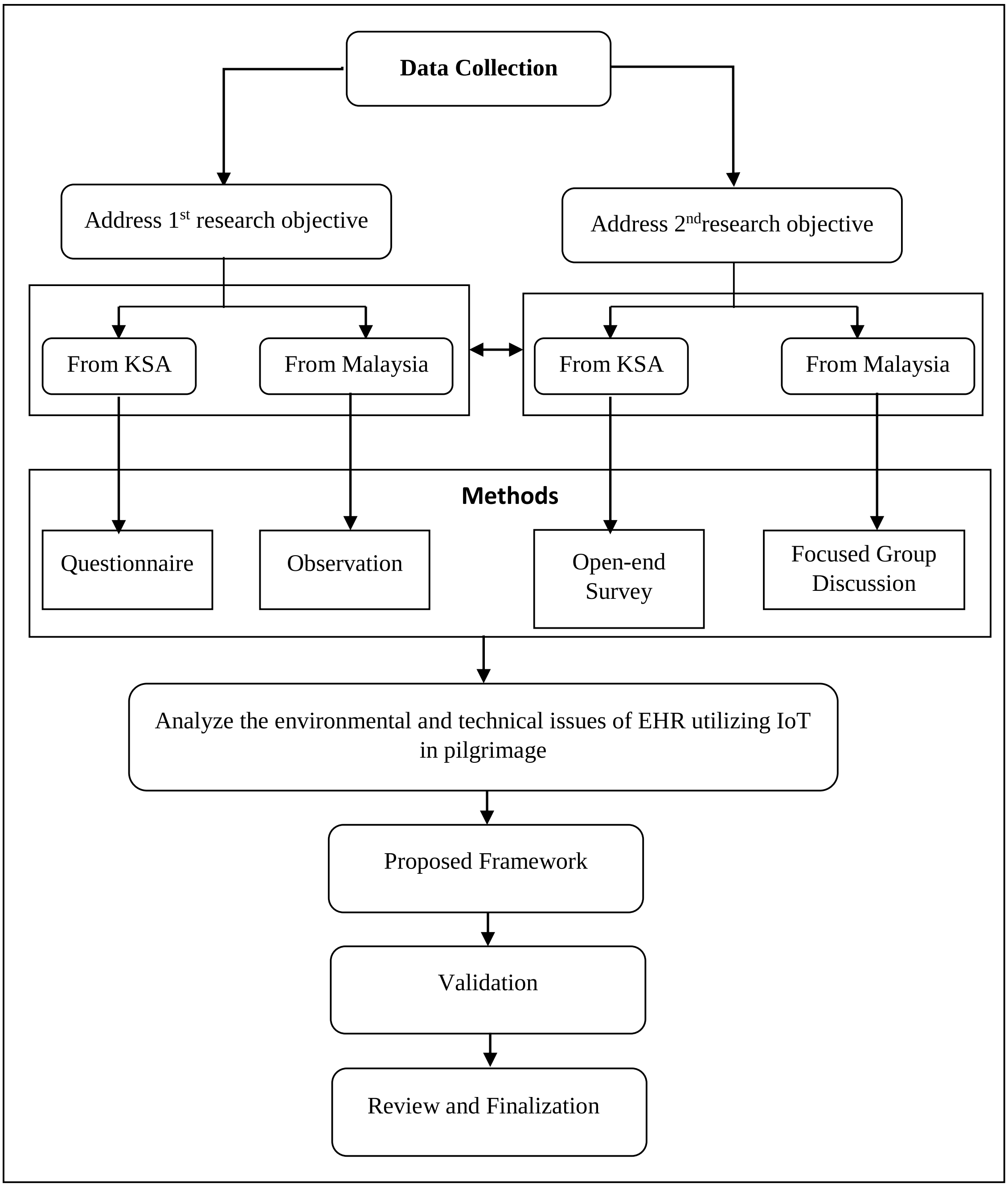



**Figure 4.1: Data Collection Methods**

From the above Figure 4.1, it can be noticed that each research objective could be supported by data collection methods from both KSA and Malaysian agencies. Hence, the mixed data collection could be integrated usefully to enrich the data collection for each objective. Table 4.1 summarizes the integration purposes of the various data collection methods in the context of the first and second research objectives.

**Table 4.1: Integration of Collected Data**

| Method | Perspective | Main Aim | Research objective |
|---|---|---|---|
| Questionnaire | KSA | • Explore the challenges that face the current healthcare service for pilgrims.<br>• Explore the Importance of EHR in pilgrimage health care services | First research objective |
| Observaion | Malaysia | • Explore the prerequisites of utilizing IoT in the pilgrims' EHR retrieval across the countries.<br>• Explore the challenges that face the healthcare service for Malaysian pilgrims.<br>• Explore the viability of utilize IoT-EHR in pilgrimage health care services. | |
| open-ended survey | KSA | • Identify the most useful facilities of EHR utilizing IoT in pilgrimage.<br>• Identify the most useful components of EHR utilizing IoT in pilgrimage. | Second research objective |
| FGD | Malaysia | • Identify the most useful facilities of EHR utilizing IoT in pilgrimage.<br>• Identify the most useful components and structure of EHR utilizing IoT in pilgrimage. | |

## 4.1 Data Analysis of First Research Objective

This section presents the data analysis of the collected data using the questionnaire and observation methods in order to support the achievement of first research objective.

### 4.1.1 Questionnaire Data Analysis

This section presents the data analysis of the questionnaire that was conducted with 60 workers in healthcare centers and hospitals in KSA. The questionnaire was developed under the scope of what are the challenges that face the utilizing IoT for global retrieval of pilgrims' EHR and why to utilize IoT for global EHR retrieval in pilgrimage environment?

Thus, the questionnaire parts were designed and formulated to support the 1st objective of this research. Table 4.2 presents the main parts of the questionnaire.

**Table 4.2: Main Parts of the Questionnaire**

| Part | Items Type | Items No. | Main Aim |
|---|---|---|---|
| Demographic Data | Nominal and Ordinal | 1-6 | To ensure the validity of participants' characteristics in order to confirm the responses validity |
| Availability of Health Records | Scaled | 1-7 | To analyze the availability of pilgrims health records to support the healthcare services |
| Challenges of Health Records Retrieval | Scaled | 8-16 | To analyze the challenges that face the current retrieval methods of pilgrims' health records |
| Importance of EHR | Scaled | 17-22 | To analyze the EHR importance to support healthcare services |

As explained in chapter 3, there are four important data analysis of the questionnaire: (1) questionnaire reliability, (2) Frequency (demographic) data analysis, (3) descriptive analysis, and (4) correlation analysis.

#### 4.1.1.1 Questionnaire Validity and Reliability

In this research, two methods of ensuring validity and reliability of the used questionnaire were used. The first method is the content and face validity and the second one is the statistical analysis which is presented below. For the content validity, we have aggregated a list of questions that are assumed to capture the whole aspect of our research inquiry. The list of questions then was examined by experts from the field. After few rounds of discussion and refining the contents, we brought the list of questions to sample of potential participants to ensure the face validity. In both process, feedback was obtained until we reached the final questionnaire whom results of analysis is shown below.

The questionnaire reliability is defined as stable inter-relation between items responses (Waters, 2002), for example, the random answers of items considered as an instable questionnaire item. The Cronbach alpha is an efficient method to measure the internal consistency and reliability of the questionnaire. The acceptable coefficient alpha could be more than 0.7 (Waters, 2002). Table 4.3 shows that the coefficient alpha is 0.71 based on 60 responses and 22 scaled items of questionnaire. Thus, the questionnaire of this research is reliable due to acceptance level of coefficient alpha.

**Table 4.3: Coefficient Alpha of Questionnaire**

| Scale | No. of Items | Number of Responses | Coefficient Alpha |
|---|---|---|---|
| Availability | 7 | 60 | 0.72 |
| Challenges | 9 | 60 | 0.73 |
| Importance | 6 | 06 | 0.65 |
| All | 22 | 60 | 0.71 |

The data of the questionnaire were analysed using SPSS version 21 software. Numerical variables were described with mean and standard deviation while categorical variables were described with frequency and percentages.

Unit of analysis included rating of individual cases for questionnaire items. These items then were summed into mean item score. However, frequency of responses was shown to indicate agreement with each statement. More complex method would be applied like structural equation modelling if we were testing relationship between latent variables. Nonetheless, our objectives are to obtain an infight from respondent about attributed related to the development of the framework.

#### 4.1.1.2 Demographic Data

The main aim of demographic data analysis is to ensure the effective characteristic of the participants which affect the responses validity of the questionnaire. For example, the participants who have a good number of years of experience are able to provide more valid responses than the participants who have less experience.

The demographic data of this questionnaire includes six variables: (1) gender, (2) age, (3) job role, (4) experience years, (5) working status, and (6) number of pilgrimage seasons attended.

Calculation of percentage was obtained by dividing the number of participant of specific category by the total number of participants i.e. algebra of relative frequency.

In regards to gender, there was a total of 60 participants, out of them there was 13 females and 47 males. The Percentage of female gender is (13/60*100%) resulting in 22 % of participants are females. While the percentage of male gender is (47/60 *100%) resulting in 78% of participants are males.

Thus, the collected data reflect the opinions of both genders with majority to male gender. The percentage of gender variable considered as reflect the reality of health activities in pilgrimage. Male staff is usually involved in the pilgrimage health activities more than female staff. Figure 4.2 illustrates the respondents' percentages based on gender variable.

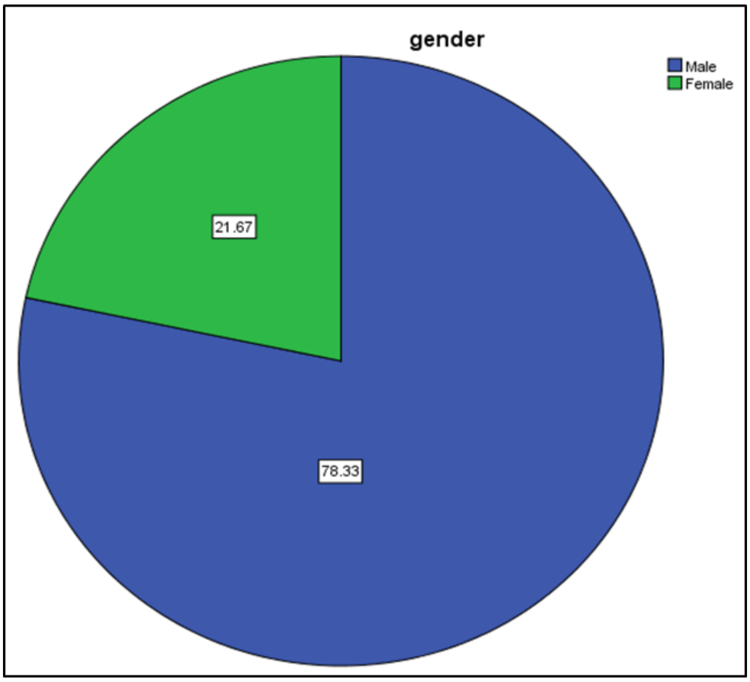



**Figure 4.2: Gender Variable**

Figure 4.3 illustrates the respondents' percentages based on their age. Most of respondents' ages are between 30-40 years which represent 65% of respondents (39 respondents). Thus, the presented data from the respondents will be efficient for future development i.e. the respondents will work in the health domain in KSA for a long time (for example, 15 years). The respondents who age between 40-50 years represent 32% of all respondents (19 respondents). This is followed by 3% of respondents who are aged between 20-30 years (two respondents).

According to Figure 4.4, there are 29 respondents working as nurses (48% of respondents' total) followed by 24 respondents working as doctors (40% of all respondents). There are also 7 respondents working as support staff (12% of total respondents). Most respondents are mainly involved in the healthcare activities (i.e. doctors and nurses). Thus, the provided responses reflect effective opinions according to job roles.

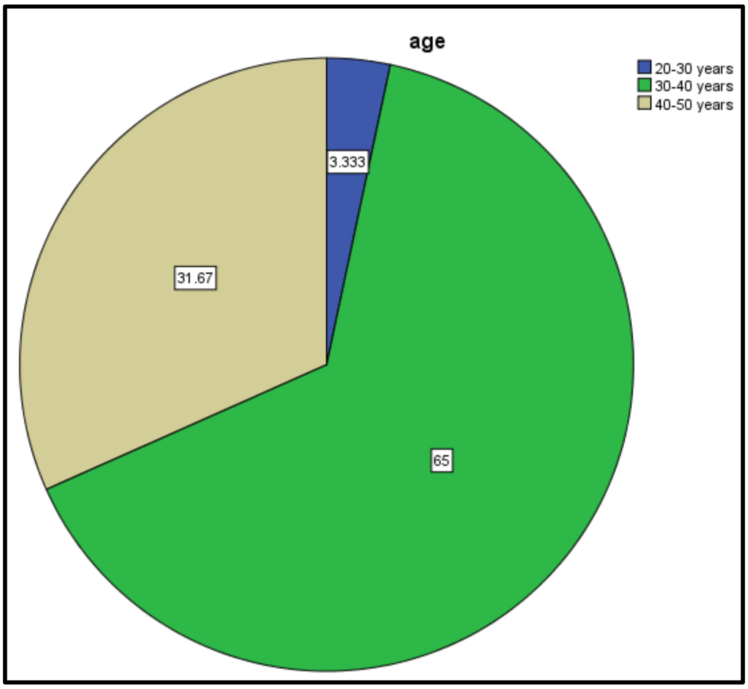



**Figure 4.3: Age Variable**

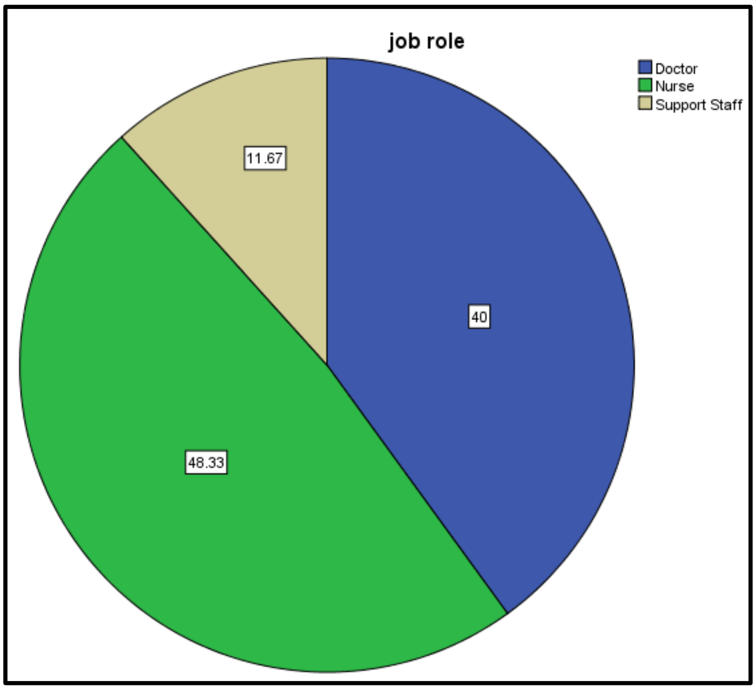



**Figure 4.4: Job Role**

With regards to the experience years of the respondents, 55% of total respondents have between 4-7 years of experience (33 respondents), followed by 37% of all respondents with more than 7 years of experience (22 respondents). There were 5% of respondents (3 respondents) with less than two years' experience followed by about 3% (2 respondents) having 2-4 years of experience. Thus, the majority of the study participants have more than 4 years of experience. Therefore, this segment of respondents is matured enough to provide the needed information for the study, the employees with long experience can provide rich data to support the questionnaire analysis usefulness. Figure 4.5 illustrates the experience years' variable.

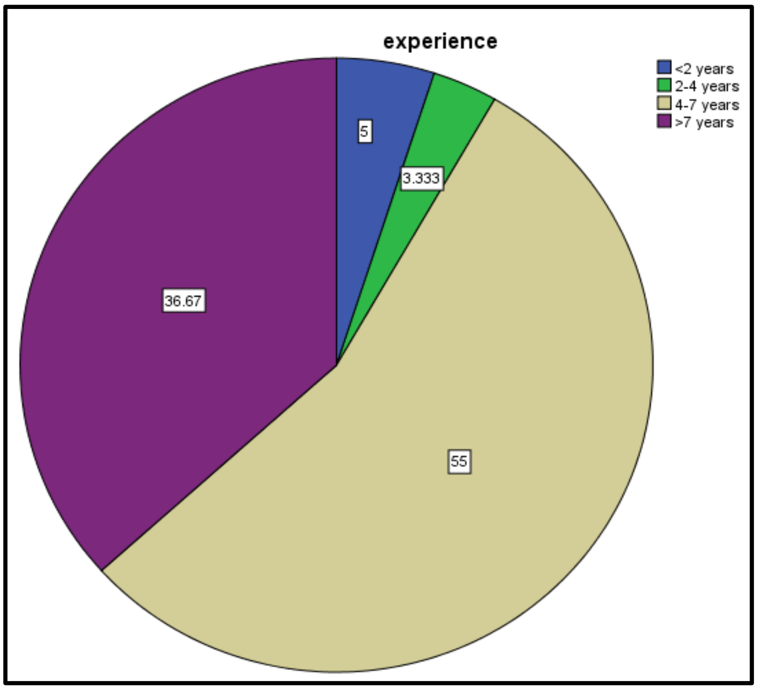



**Figure 4.5: Years of Experience**

With regards to the respondents' employment status, all respondents are full time employees. Therefore, the provided responses are provided based on good vision of healthcare activities due to effective number of daily health services accomplished by respondents. Figure 4.6 illustrates the respondents' employment status.

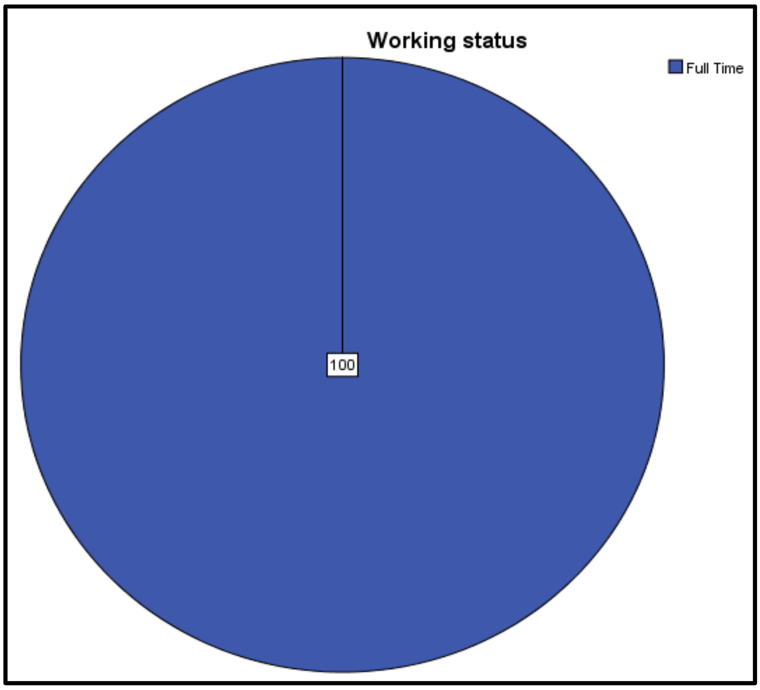



**Figure 4.6: Employment Status**

With regards to the number of pilgrimage attended by respondents, about 43% of total respondents attended more than one pilgrimage (26 respondents). There were 22% of total respondents who attended 4-7 pilgrimage seasons (13 respondents), followed by 20% of all respondents that were attended 2-4 pilgrimage seasons (12 respondents). The respondents that attended less than two pilgrimage seasons are 15% of all respondents (9 respondents). Therefore, the respondents are able to provide valid responses based on real situation of pilgrimage healthcare activities. Figure 4.7 illustrates the attended pilgrimage seasons.

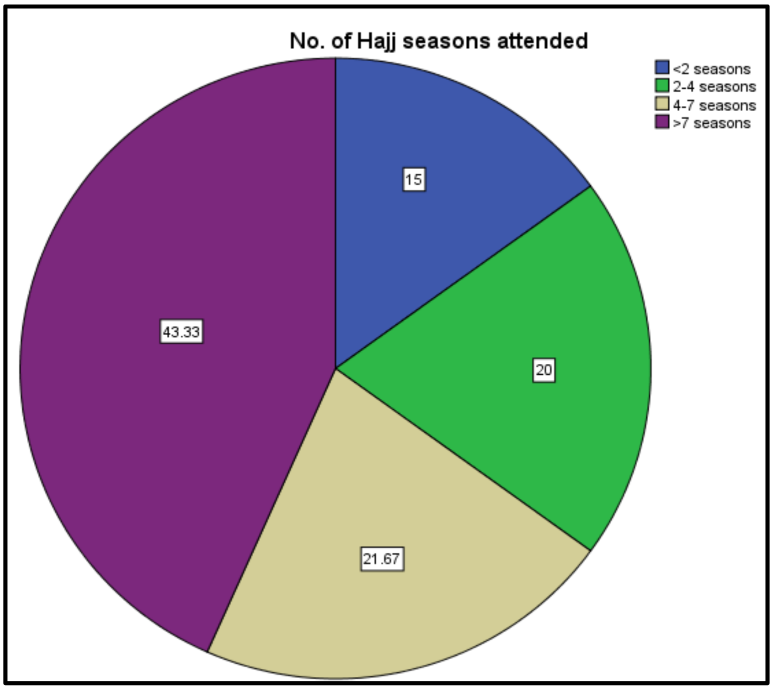



**Figure 4.7: Pilgrimage Seasons Attended**

Table 4.4 summarizes the frequency analysis of the demographic data of the questionnaire respondents.

**Table 4.4: Frequency Analysis**

| **Variable** | **Items** | **Frequency** | **Percentage** |
|---|---|---|---|
| Gender | Male | 47 | 21.67% |
| | Female | 13 | 78.33% |
| Age | Less than 20 Years | 0 | 0% |
| | 20-30 years | 2 | 3.33% |
| | 31-40 years | 39 | 65% |
| | 41-50 years | 19 | 31.67% |
| | More than 50 years | 0 | 0% |
| Job Role | Doctors | 24 | 40% |
| | Nurse | 29 | 48.33% |
| | Assistance staff | 7 | 11.67 |
| | Others, specify | 0 | 0% |
| Experience Years | Less than 2 years | 3 | 5% |
| | 2-4 years | 2 | 3.33% |
| | 4-7 years | 33 | 55% |
| | More than 7 years | 22 | 36.67% |
| Working Status | Full Time | 60 | 100% |
| | Part Time | 0 | 0% |
| Number of pilgrimage seasons attended | Less than 2 seasons | 9 | 15% |
| | 2- 4 seasons | 12 | 20% |
| | 4-7 seasons | 13 | 21.67% |
| | More than 7 seasons | 26 | 43.33% |

#### 4.1.1.3 Descriptive Analysis

The descriptive analysis is conducted to analyze the challenges that face the current retrieval methods of pilgrimage health records, and the importance level of adopt electronic retrieval methods of health records to enhance the performance of pilgrimage healthcare services. This section presents the discussion of descriptive analysis of three questionnaire parts which are: (1) pilgrimage health records availability to support the healthcare services, (2) the challenges that face the retrieving of pilgrimages' health records, and (3) the importance of electronic retrieval methods to support the pilgrimage healthcare services.

As mentioned in Chapter 3, the questionnaire responses were collected based on 5-likert scales: 1 for Strongly Disagree (SD), 2 for Disagree (D), 3 for Neutral (N), 4 for Agree (A) and 5 for Strongly Agree (SA).

The agreement level of each item was calculated based on the items responses means. Table 4.5 summarizes the criterion degree for each level of answers.

**Table 4.5: Criterion Degree for Each Level of Answers**

| Scale Index | Answer | Agreement Level |
|---|---|---|
| 1-1.49 | Strongly Disagree | Very Low |
| 1.5-2.49 | Disagree | Low |
| 2.5-3.49 | Neutral | Moderate |
| 3.5-4.49 | Agree | High |
| 4.5-5 | Strongly Agree | Very High |

- **Availability of Pilgrim Health Records**

The main question that required to be answered in this part is: Are the historical health records of pilgrims available to support the healthcare services in pilgrimage? To answer this question, the responses of seven items are descriptively analyzed to understand the health records' availability (Table 4.6).

The respondents strongly disagree with items 1 (Each pilgrim has his/her personal records), 2 (Each pilgrim has his/her health records), 3 (Health records are continuously updated), 4 (Pilgrim can access his/her own records), 5 (There are systematic methods to access health records of pilgrim), and 6 (The development has an electronic management for healthcare and emergencies). On the other hand, the respondents are strongly agreeing with item number 7 (There is necessity to store and retrieve the pilgrim health records in different formats such as images and texts).

The mean is calculated here for each question for the whole sample and it is not based on single participant answer only. In this regards, we calculated the mean of each question by summing the answers of all the participants for that specific question, multiply it by the criterion rating strongly agree (5) to strongly disagree (1) then divide it by the total number of participants who answered that question.

The score is calculated by multiplying number who endorsed specific category by the rating of the category (as indicated in sub-section 4.1.1.3 and chapter three as well). As an illustration of what is stated in the table below.

First question of table 4.6

55 answers with SD = 55*1 = 55

4 answers with D = 4*2 = 8

1 answer with N = 1*3 = 3

Total score is 55+8+3 = 66

Mean 66/60 = 1.1

**Table 4.6: Descriptive Analysis of Availability of Health Records**

| Item No. | Item | SD | D | N | A | SA | Mean | Agreement Level |
|---|---|---|---|---|---|---|---|---|
| 1 | Each pilgrim has his/her personal records | 55 | 4 | 1 | 0 | 0 | 1.10 | Very Low |
| 2 | Each pilgrim has his/her health records | 56 | 4 | 0 | 0 | 0 | 1.06 | Very Low |
| 3 | Health records are continuously updated | 55 | 3 | 2 | 0 | 0 | 1.11 | Very Low |
| 4 | Pilgrim can access his/her own records | 56 | 3 | 1 | 0 | 0 | 1.08 | Very Low |
| 5 | There are systematic methods to access health records of pilgrim | 56 | 4 | 0 | 0 | 0 | 1.06 | Very Low |
| 6 | The development has an electronic management for healthcare and emergencies | 57 | 1 | 2 | 0 | 0 | 1.08 | Very Low |
| 7 | There is necessity to store and retrieve the pilgrim health records in different format such as images and texts | 0 | 0 | 0 | 8 | 52 | 4.86 | Very High |

According to the participants' responses in the above Table 4.6, there are no electronic retrieval methods adopted to support the healthcare services in pilgrimage. Also, there are no managed methods adopted to retrieve the pilgrim health records. The healthcare services for pilgrims are accomplished based on the healthcare staff notice of health case supported by brief explanation which is provided by the pilgrims about their health case history. Usually, the paper-based approach is adopted by healthcare staff to store and retrieve the health records to support the future healthcare services. However, these records are used during a particular pilgrimage season and not stored as historical reports.

- **Challenge of Health Records Retrieval**

The main questions that are required to be answered in this part are: are there problems in using the traditional retrieval methods (such as paper-based method) in the context of pilgrim healthcare services? And what are the problems that face the development and adopt electronic methods of health records retrieval? To answer these questions, the responses of nine items are descriptively analyzed (Table 4.7).

The respondents totally agree with items number 13 (The traditional healthcare approaches −for example, paper-based− delay the health services for pilgrims), 14 (The traditional healthcare approaches decrease the understanding of health cases), 15 (The traditional healthcare approaches increase the expenses of healthcare services), and 16 (There are challenges in understanding the non-Arabic pilgrims in the context of healthcare services). On the other hand, the respondents are not sure that the privacy of health data limits the use of the electronic healthcare systems (item number 12).

Moreover, the respondents totally disagree with items number 8 (There are not enough staffs to manage the electronic healthcare systems), 9 (The staffs do not have enough computer skills to manage the electronic healthcare system), 10 (There are not enough technology facilities to deploy the electronic healthcare systems), and 11 (There is budget limitation in developing and deploying the electronic healthcare systems).

According to the participants' responses in the Table 4.7, the traditional retrieval methods of pilgrim health records such as paper-based methods are not effective to support the healthcare services. The traditional retrieval methods are having many drawbacks such as slowing down the time of healthcare services, the physical expenses of these methods are high, and the paper reports that are written in non-Arabic language increase the difficulty of understanding the health cases.

The participants see that the development and deploying of electronic retrieval approaches of health records is applicable due to availability of human and technology skills. Also, there is sufficient budget to develop and deploy the electronic retrieval approaches of health records.

It seems that the respondents are not familiar with the technical issues of electronic healthcare methods. Therefore, they are not sure about the privacy effectiveness of electronic health approach.

**Table 4.7: Descriptive Analysis of Challenges of Health Records Retrieval**

| Item No | Item | SD | D | N | A | SA | Mean | Agreement Level |
|---|---|---|---|---|---|---|---|---|
| 8 | There are not enough staff to manage the electronic healthcare systems | 55 | 5 | 0 | 0 | 0 | 1.08 | Very Low |
| 9 | The staff do not have enough computer skills to manage the electronic healthcare system | 54 | 6 | 0 | 0 | 0 | 1.10 | Very Low |
| 10 | There are not enough technology facilities to deploy the electronic healthcare systems | 55 | 5 | 0 | 0 | 0 | 1.08 | Very Low |
| 11 | There is budget limitation in developing and deploying the electronic healthcare systems | 59 | 1 | 0 | 0 | 0 | 1.01 | Very Low |
| 12 | Privacy of health data limit the use of the electronic healthcare systems | 0 | 5 | 49 | 6 | 0 | 3.01 | Medium |
| 13 | The traditional healthcare approach (e.g. paper-based) delays the health services for pilgrims | 0 | 0 | 0 | 2 | 58 | 4.96 | Very High |
| 14 | The traditional healthcare approach (e.g. paper-based) decreases the understanding of health cases | 0 | 0 | 0 | 1 | 59 | 4.98 | Very High |
| 15 | The traditional healthcare approach (e.g. paper-based) increases the expenses of healthcare services | 0 | 0 | 0 | 1 | 59 | 4.98 | Very High |
| 16 | There are challenges in understanding the non-Arabic pilgrims in the context of healthcare services | 0 | 0 | 0 | 1 | 59 | 4.98 | Very High |

- **Importance of EHR Retrieval**

The main question that is required to be answered in this part is: Could EHR retrieval address the drawback of traditional methods? To answer this question, the responses of six items are descriptively analyzed (Table 4.8).

The participants totally agree with all items of this part: 17 (The EHR speeds up the healthcare services), 18 (The EHR supports the accuracy of healthcare services), 19 (The EHR based on Arabic language increases the usefulness of healthcare services), 20 (The EHR based on Arabic language makes the healthcare services easier), 21 (EHR can increase the performance of communication with the pilgrims' country –i.e. Health Ministry– to describe health cases accurately), and 22 (EHR reduces the expense of traditional healthcare approaches–i.e. paper-based).

In other words, the participants see that the electronic retrieval methods of healthcare records could avoid the drawbacks of the traditional method through many advantages such as speeding up the healthcare services through fast health records retrieval, reducing the physical expenses of traditional methods, and better understanding of health cases, especially if the electronic records are stored and retrieved using Arabic language.

**Table 4.8: Descriptive Analysis of Importance of EHR Retrieval**

| Item No | Item | SA | A | N | D | SD | Mean | Agreement Level |
|---|---|---|---|---|---|---|---|---|
| 17 | The EHR speeds up the healthcare services | 55 | 4 | 1 | 0 | 0 | 4.80 | Very High |
| 18 | The EHR supports the accuracy of healthcare services | 56 | 4 | 0 | 0 | 0 | 4.86 | Very High |
| 19 | The EHR based on Arabic language increases the usefulness of healthcare services | 55 | 3 | 2 | 0 | 0 | 4.88 | Very High |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20 | The EHR based on Arabic language makes the healthcare services easier | 56 | 3 | 1 | 0 | 0 | 4.93 | Very High |
| 21 | EHR can increase the performance of communication with the pilgrims’ country (i.e. Health Ministry) to describe health cases accurately | 56 | 4 | 0 | 0 | 0 | 4.91 | Very High |
| 22 | EHR reduces the expense of traditional healthcare approaches (i.e. paper-based) | 57 | 1 | 2 | 0 | 0 | 4.91 | Very High |

#### 4.1.1.4 Correlation Analysis

Is the electronic retrieval method of health records effective to address the drawbacks of traditional retrieval methods? This is the main question related to this part. To answer this question, correlation (i.e. relationships) between two dependent variables is conducted. The dependents variables are the challenges that face the traditional health records retrieval methods and the importance of electronic methods to address these drawbacks.

According to Table 4.9, the correlation between Challenges of Traditional Methods variable and EHR Importance variable is 0.352; the correlation is significant at the 0.05 level. Thus, there is positive and very strong correlation between the two variables.

In other words, the EHR approach could be an effective method to avoid the challenges of traditional methods in the context of healthcare services. This result is matched clearly with the descriptive analysis of sections 2 and 3 of the questionnaire. The EHR could provide many advantages over the traditional health records retrieval such as speeding up healthcare services, reducing the physical expenses, and enhancing the accuracy of healthcare services.

**Table 4.9: Correlational Analysis**

| | | EHR Importance |
|---|---|---|
| Challenges of Traditional Methods | Pearson Correlation | 0.352 ** |
| | Sig. (2-tailed) | 0.004 |
| | N | 60 |

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

### 4.1.2 Data Analysis of Observation Method

The data collection using observation method was conducted to explore the prerequisites, importance, and viability of EHR retrieval utilizing IoT from Malaysian perspective (1st research objective). Observation is the active acquisition of information from a primary source. In living beings, observation employs the senses. In science, observation can also involve the recording of data via the use of instruments. The term may also refer to any data collected during the scientific activity. Observations can be qualitative, that is, only the absence or presence of a property is noted (Kosso, 2011).

As mentioned in Chapter 3, the observation data was collected during an Umrah trip in October 2014 organized by a travel agency recognized by Tabung Haji. The following procedures were undertaken for observation data collection:

- The researcher registered and travelled for Umrah with a group of Malaysian citizens.
- The researcher accompanied the Malaysian pilgrims in all the Umrah activities.
- The researcher notices the healthcare services that are provided to some Malaysians pilgrims.
- The researcher took full historical reports that belong to two Malaysian pilgrims and let the healthcare staff provide the healthcare services for these pilgrims based on the historical reports.

- The researcher obtained the feedback from the healthcare staff in order to compare between the healthcare services with and without historical reports.

According to the collected observation data, 4 out of 40 Malaysian pilgrims need healthcare services which represent the importance of healthcare services in pilgrimage. The time of each health case takes about half to one hour for the services pilgrims without a historical report. Most of required time is to investigate the health cases and register the details using paper format. The healthcare staff just attempts to provide primary treatments to help the pilgrims complete their Umrah activities. However, the provided treatments were given without understanding the permitted or restricted medicines for the patients.

Using the above analyzed data, the researcher discussed the challenges that face the healthcare services with Malaysian pilgrims and healthcare staff. They mentioned that the main challenge is the communication language. The pilgrims do not have the effective skills to explain their historical health cases in Arabic or English language and the healthcare staff cannot understand the Malay language.

On the other hand, the pilgrims are not aware of the importance of bringing full historical reports from their country. However, the healthcare staff explained that the historical reports of health cases are necessary to understand how to treat the pilgrims. Also, the healthcare staff explained that the historical health reports could minimize the required time of health services and reduce the communication difficulty with pilgrims to investigate the health cases.

Moreover, the pilgrims do not remember the names of the permitted or restricted medicines. Thus, the healthcare staff does not completely understand the effects of the provided medicines in the health cases.

Furthermore, the pilgrims are not in favour of going to hospitals and having more health tests done due to time and financial costs. Some pilgrims will literarily say

"We will do the necessary tests when we are back in Malaysia". We need to maximise every minute to pray in Mecca". The healthcare staff explained that some health cases are critical and require immediate treatment. Some health cases may worsen in a matter of hours. Therefore, it is better to provide effective healthcare services in real-time.

To understand the importance of health records to enhance and address the current challenges of healthcare services, the researcher showed full historical health records in English language that belong to two pilgrims to healthcare staff and asked them to simulate how they can render the healthcare services based on these records. Firstly, the health case staff reviews the health records of pilgrims and they ask the pilgrims some quick and simple questions. The staff provides the healthcare services within minutes and writes down the current situation at the end of historical records.

Regarding to health services based on historical health records, it is noted that the pilgrims hardly communicate with healthcare staff. The healthcare staff provides the health service in less time and with less effort. The healthcare staff understands the health cases without much investigation. The healthcare staff shows us that the allowed and restricted medicines are written in the historical reports. Thus, they can sure of the appropriate better medicines and therapy for the health case. The healthcare staff mentioned that the historical health records are an effective aspect to speed up and provide accurate health services. On their part, the pilgrims trust the provided medicines and therapy. Furthermore, the healthcare staff explained that they can easily update the historical records for future use of these records by other healthcare staff to understand the historical updates on health cases.

Table 4.10 summarizes the observation analysis as a comparison between healthcare services with and without historical health records.

**Table 4.10: Observation Analysis**

| **Indicator** | **Health services without historical records** | **Health services based on historical records** |
|---|---|---|
| Service Time | Half to 1 hour | Few minutes |
| Communication Difficulty | Difficult due to different languages | Simple (if written in English or Arabic language) |
| Accuracy of Provided Services | Not assured | Assured |
| Updating the records | Not possible | Possible |

Based on the above Table 4.10, it can be noticed that the EHR is important to avoid many challenges that face healthcare services in pilgrimage.

### 4.1.3 Summary of Data Analysis for the First Research Objective

Depend on the collected data using the questionnaire and observation methods, it can be answered about the research questions that related to the first research objective.

According to the questionnaire and observation analysis, the current healthcare services in pilgrimage are not supported by EHR. The paper forms are used for specific purposes such as collect statistics about the numbers of pilgrims' treatments.

The questionnaire analysis shows that the EHR is helpful to enhance the health services for pilgrims. However, the expenses of utilize EHR system is expansive. Thus, it is necessary to find innovated solutions to retrieve the pilgrims' EHR in low cost and real time.

On the other hand, the observation analysis shows that the pilgrims are not care of bring their historical health record either in electronic or paper forms, and the pilgrims' postpone the critical healthcare services until back to their original counties.

Hence, the EHR retrieval of pilgrims' should be conducted in real time and low requirements based on the health staff requests without pilgrims need to bring and health records from their countries. This indicates how to utilize the IoT for EHR retrieval of pilgrims. The full layers of IoT should be applied for this purpose. The user need to have only electronic identity tag, and the health staff can use these tags to request the EHR from the original countries of the pilgrims. Here, the IoT requirements in KSA are low; the tags readers and the monitors to show the requested EHR, which reduce the required costs by KSA for the global EHR retrieval systems for pilgrims. Through, the global network, the requested EHR based on the identity tags can be retrieved from database that located in the original countries of pilgrims, and the requested EHR can be displayed using the monitors in lower IoT layer.

EHR implementation in pilgrimage faces many challenges such as time, effort and financial costs. As discussed in the above points, the full IoT layers for EHR retrieval could avoid these challenges.

However, there are another challenges should be addressed in the utilizing IoT for global retrieval of pilgrims’ EHR such as retrieve the EHR based on understood language by healthcare staff, retrieve full historical reports of EHR based on various format such as images and texts, retrieve clear and structured historical reports of EHR, and allow the real time collaboration between KSA health staff and health staff in original countries of pilgrims for effective treatments. All of these challenges represent the prerequisites of proposed IoT-EHR framework, which need to be addressed in the collected data of the second research objective.

By utilize IoT for global EHR of pilgrims, the health staff can request the EHR of pilgrims by on click or touch on the electronic tags. EHR utilizing IoT is a promising solution to enhance the healthcare services and avoid the challenges of EHR implementations in pilgrimage. The use of EHR in pilgrimage could speed up and improve the quality of healthcare services. Retrieve full and clear historical EHR in real time helps the health staff to understand the health case and diagnosis accurately. Furthermore, the health staff can show the allowed and restricted medicines for the health case.

## 4.2 Data Analysis of Second Research Objective

This section presents the data analysis of the collected data using the open-ended survey and FGD methods in order to support the achievement of the second research objective.

### 4.2.1 Data Analysis of Open-ended Survey

This section analyses and discusses the qualitative data collected using open-ended survey with five ICT experts in the health domain in KSA. As mentioned in Chapter 3, the experts are working as ICT leaders in KSA hospitals which support the validity of the provided open-ended survey responses. The open-ended survey was conducted to address the 2$^{nd}$ objective of this research (to identify the most useful structure, facilities, and components of the proposed IoT-EHR framework). The open-ended survey format was designed and developed as four sections which are: (1) personal information to ensure the expertise validity of experts, (2) importance of EHR to support healthcare services in pilgrimage, (3) challenges of EHR implementations in pilgrimage healthcare services, and (4) EHR utilizing IoT to support pilgrimage healthcare services.

- **Personal Information of Experts**

The open-ended survey was conducted with experts from three known hospitals in KSA: these hospitals are Alawi Tunsi Hospital in Mecca, Al Ansar General Hospital in Madinah, and Jeddah Clinic Hospital in Jeddah. These hospitals were selected due to its strong relationships with pilgrimage healthcare services. These hospitals are located in the cities that the pilgrims usually visit in their pilgrimage journey. Therefore, the experts have good ideas about the current situations, challenges, and possible improvements of pilgrimage healthcare services.

The open-ended survey was conducted with five experts working as leaders in ICT departments in the selected hospitals such as information management departments. Thus, they have effective experience and knowledge to answer the open-ended survey questions that are related to EHR importance and challenges, and the technical implementations of EHR utilizing tag reading.

It might be argued that respondent of this open-ended questionnaire should be drawn from same hospitals of the questionnaire. The motive behind this selection is to increase the coverage of health professionals from different institutes rather than focusing on smaller source of data.

- **Importance of EHR in Pilgrimage**

According to the experts, the current healthcare services of pilgrimage are accomplished through four main steps: (1) The healthcare staff is tasked with the pathological case in any health centre constructed in the pilgrimage areas, (2) The healthcare staff asks the pilgrim some questions about his/her health case, (3) The healthcare staff treats the pilgrim or transfers the pilgrim to any nearby hospital, and (4) The healthcare staff registers the healthcare data using paper forms.

However, the registered data are not used as historical health reports to support the future health services (the data are used usually to produce some reports about pilgrimage services).

Therefore, there are three main challenges face the current healthcare services in pilgrimage which are: (1) The healthcare staff expends some time in asking and understanding the health case because they do not have previous reports about the health cases, therefore they expend time to register the health cases data, (2) The decisions of healthcare service may not be accurate due to limitations of health cases descriptions (i.e. historical reports), and (3) The communication between healthcare staff and non-Arabic pilgrims may not be efficient which will affect the understanding of health cases.

Consequently, the EHR is very important to speed up and improve the healthcare services in pilgrimage. The EHR allows the healthcare staff to review the historical reports of health case which support the accuracy of provided services. On the other hand, the healthcare staff could save the health services time through fast retrieval and registering of health data. However, the EHR requires meeting many specifications such as the following:

- The EHR could be stored in an understood language for healthcare staff like Arabic or English languages.
- The EHR could be stored according to different formats such as text, images, and videos.
- The EHR should be stored based on standard structure such as classify the health case according to historical time, types of pathological cases, and permitted or restricted medicines.
- The EHR should be retrieved based on different computer device types such as PCs and smart phones.
- The EHR should be updated (i.e. not read only).
- The pilgrim EHR should be approved by formal institutions such as hospitals or health ministries.

- **Challenges of EHR Implementations in Pilgrimage**

According to the experts, the pilgrims usually visit the KSA once in their lifetime; and the KSA hospitals do not have any records for the pilgrims which require collecting the EHR from their countries. This process consumes time, effort, and money. The KSA and other countries would have to work hardcover long span of time to manage and store the historical health reports for about three million pilgrims each year. On the other hand, it is not effective to allocate large technology facilities such as data storages to improve the healthcare services for pilgrims. However, the pilgrims may not need healthcare or may have few numbers of healthcare services (i.e. one time). Therefore, the feasibility of EHR implementations in pilgrimage may fail due to processing time, effort and cost challenges.

On the other hand, there is other challenges facing EHR implementations in pilgrimage such as the ability to meet the effective EHR requirements that was explained in the previous section (i.e. the EHR could be stored in an understood language for healthcare staff, like Arabic or English languages).

However, the experts mentioned that if these challenges are avoided through some proposed solutions, then the KSA should not have problems in other supportive issues such as the workers, budgets, and technology facilities.

- **EHR Utilizing IoT in Pilgrimage**

First of all, the idea of EHR retrieval based on IoT in pilgrimage is discussed with the experts to give them a better vision of this idea. The experts understand the proposed idea clearly and in general they are interested in this idea.

According to the experts, EHR retrieval utilizing IoT could avoid most of EHR implementations challenges in pilgrimage such as the following:

- The KSA agency is not required to expend time, efforts, and money to manage and store the EHR. The KSA agency only needs to install the RFID technology which is wireless sensors to read the electronic tags of patients.
- EHR managing and storing should be done as database located in the countries of pilgrims. Thus, the required time and efforts of these processes could be distributed (i.e. thousands of pilgrims from each country).
- The electronic tag that represents the pilgrim ID could be prepared by the original countries of pilgrims.
- The tags can be used by other pilgrims in the subsequent year which reduces the cost requirements of EHR processes.

The experts mentioned that the proposed idea of EHR utilizing IoT is a promising solution and can achieve many advantages. However, there are many technical issues should be addressed in this technology. The security and privacy concerns are the most important issue, the confident health data that transferred via the global network could attacked or damaged by strangers. Thus, it is important to assure the security performance in the proposed IoT-framework.

Another technical issue is the features of IoT facilities like the electronic tags, wireless readers, and super nodes. These facilities features like the power supply, coverage spaces, and connections should be suitable for pilgrimage environment. For example, pilgrims should not charge their electronic tags frequently due to limitation of energy plugs in some pilgrims' area.

The experts argued that the area of pilgrimage is large, and the pilgrims could visit other cities outside Mecca such as Jeddah and Al-madinah. Thus, the distribution of the wireless readers, super nodes, and base stations is critical issue. The proposed framework should take in account the useful distribution of IoT facilities to cover the large area of pilgrimage.

Furthermore, the large size of historical EHR that could retrieve via the global network is important issue. The large sizes of data many cause slow transferring or data lose. Therefore, the protocol or techniques of data transfer should be explained in the proposed framework, and these protocols must match with the nature of transfer data.

In addition, the network may down in the pilgrimage season due to stress of data transfer on this network such as international calls, messages, data transfer for TV and radio. Here, it is necessary to give high priority the data transfer of EHR via IoT facilities, or allocate specific transfer channel for this purpose.

In summary, key points that reflects importance of EHR ; Time needed for obtaining historical information form patient; Inaccuracy of the information provided by patient or his relatives and Difficulty in communication due to language barriers.

In terms of challenges, large space of storage is needed and language coding of the information pose main challenge on implementation. While in regards to utilization, the healthcare provider need to have the ability to support RIFD based network; database should be located in the healthcare provider country while the electronic tags are to be prepared by the country of origin.

### 4.2.2 Focus Group Discussion

The focus group discussion (FGD) is the other method that was used to support the achievement of the second research objective. FGD allows people from similar backgrounds or experiences to discuss a specific topic of interest through the facilitation of a moderator who introduces topics for discussion and helps the group to participate in a lively and natural discussion amongst them (Edmunds, 2000).

As mentioned in Chapter 3, FGD with top leaders in Tabung Haji of Malaysia was conducted in two rounds: (1) FGD with eight leaders to gather information about EHR with regards to requirements, challenges and feasibility to introduce/implement the EHR sharing framework, and (2) FGD with six leaders to discuss the technical issues of utilizing IoT in EHR retrieval, specifically through tag reading.

During the 1st FGD, the following questions (in Table 4.11) were posed and the final answers derived by thematic analysis.

**Table 4.11: Thematic Analysis with Codes of 1st FGD**

| | | |
|---|---|---|
| **Theme:** Organizational Capacity<br>Codes<br>• Inadequate financial resources<br>• Staffing (skills, number, attitudes, etc)<br>• Security (viruses, unwanted access)<br>• Hardware availability<br>• Software availability | **Theme:** Data Complexity<br>Codes<br>• Data entered as free text instead of formatted fields<br>• Different abbreviations used<br>• Incoming data not compatible | **Theme:** Legal Considerations<br>Codes<br>• Concerned about internal breach<br>• Concerned about hacking<br>• Concerned about data loss |
| **Theme:** Difficult Permission to Access<br>Codes<br>• Governmental hospital barriers<br>• Private clinics are not practicing EHR<br>• Patients might refuse disclosure | **Theme :** IT Structural Complexity<br>Codes<br>• Lack of interoperability<br>• Too many layers of security<br>• High costs of vendors | **Theme:** Full Access to Patient Record<br>Codes<br>• Able to see patient history and medication list<br>• Able to share record securely with other providers<br>• Able to see patient demographics<br>• Access records<br>• Multi-user access |

| | | |
|---|---|---|
| **Theme:** Improving Patients' Care<br><br><u>Codes</u><br>• Granting the pilgrim rights to allow/ disallow sharing<br>• Allowing clinical decision support<br>• Reducing the number of vendors and platforms.<br>• Restricting the EHRs from being used for commercial gain | **Theme:** Advanced IT Security Software<br><br><u>Codes</u><br>• Access controls<br>• Encryption<br>• Audit trail | **Theme:** No Proper Storage or Sharing<br><br><u>Codes</u><br>• Error checked, validated and merged into database<br>• Passed through a workflow management tool<br>• Used immediately |
| **Theme:** Holistic Fulfillment of Requirements<br><br>**<u>Codes</u>**<br>• Technology<br>• Customer acceptance<br>• Financial support<br>• Infrastructure | | |

The purpose of the 2nd FGD is to explore understanding and possibility of applying IoT in pilgrim EHR retrieval, examining the technical challenges and opportunities. The results would aid the design of proposed framework (Table 4.12).

**Table 4.12: Thematic Analysis with Codes of 2nd FGD**

| | | |
|---|---|---|
| **Theme:** Tag Option<br><br>Codes<br>• The tags can be reused by other pilgrims in the following year which reduces the implementation costs<br>• The tags can be accessed by simple devices such as tag readers<br>• The pen drives or CDs may be lost (i.e. misplaced in bags or pockets) but the tags can be worn as watches which increases the difficulty of device loss,<br>• The data managing, storing, accessing, and updating is simple based on tag devices | **Theme:** Monitoring<br><br>Codes<br>• Monitoring of pilgrims<br>• Monitoring of vehicles<br>• Monitoring of equipment and infrastructure<br>• Access of information | **Theme:** Health Records Collection<br><br>Codes<br>• The health records can be collected by the pilgrims from their hospitals or clinics<br>• Tabung Haji is just responsible for storing the records in tags<br>• A collaboration and mandate should be instituted to obtain EHR of pilgrims |
| **Theme:** Need for Global or Internal Language<br><br>Codes<br>• Usually the health records are stored in English language<br>• If there is a necessity for translation, Tabung Haji can expend some effort to do that or assign some links to do the necessary translations<br>• English is an international language | **Theme :** Availability of Gadgets and Network<br><br>Codes<br>• Presence of smart phones<br>• Presence of internet networks all over the country<br>• Easy method of payment for using internet | **Theme:** Cost and Reliability<br><br>Codes<br>• Most tags and readers are not yet affordable enough<br>• Power sources are challenging for cheap but long-life sensors<br>• High reliability requirements in large-scale systems with thousands of tags and devices |

| Theme: Government Engagement | Theme: Security is a Major Concern | Theme: Roaming is Supported |
|---|---|---|
| <u>Codes</u><br>• Technical standards have been set for different applications and stakeholders<br>• Security permission is needed for using tags in the KSA.<br>• The standards usually limits entrance to the field | <u>Codes</u><br>• Security vulnerabilities in IoT systems let attackers access private data<br>• Need further development of privacy and consumer protection rules.<br>• Security concerns are always present in IoT | <u>Codes</u><br>• Presence of a different network could enable better service from a different provider.<br>• As part of global practice, roaming is available for almost all users |

In their answers, the leaders expressed interest about the proposed idea and wanted to understand the technical issues of health records based on tag reading in depth. Also, the leaders provided the following comments and recommendations and comments:

- Overall, the proposed idea is very good and is possible to be implemented.
- The implementation costs may be high but the usage purpose overcomes this based on the consideration that the Malaysian citizens' health is more important than money.
- There are many issues that need to be resolved such as arrangements with KSA authorities, and technology analysis and development of this idea in Malaysia.
- The main recommendation is to develop a full research or framework to explain the overall aspects of this idea to forward the idea's development based on a clear vision.
- The leaders are very interested in this idea and have requested the researcher to re-visit them to discuss the final framework in detail.

### 4.2.3 Summary of Data Analysis for the Second Research Objective

Based on the collected data using the open-ended survey and the FGD, it can be concluded that the most important technical issues that should be addressed in the proposed framework are: (1) data security and privacy; (2) the IoT facilities should cover the pilgrimage are and any place could be visited by the pilgrim; (3) the kinds of electronic tags should be suitable for the pilgrims; (3) the EHR should structured in standard form; (4) the priority of transfer EHR via network should be high; (5) the transfer protocol must be useful for large size of data.

## 4.3 Chapter Summary

This chapter presented the analysis of various data collection methods used in this research. Two data collecting methods were conducted to support the achievement of the first research objective; (1) questionnaire with healthcare staff in KSA, and (2) observation of Malaysian pilgrims in Umarh. The collected data using these two methods show that the use of EHR in pilgrimage could speed up and improve the quality of healthcare services. However, EHR implementations in pilgrimage face many challenges such as time, effort and financial costs. Thus, EHR utilizing tag reading is a promising solution to enhance the healthcare services and avoid the challenges of EHR implementations in pilgrimage.

On the other hand, two data collection methods were conducted to support the achievement of the second research objective; (1) open-ended survey with experts in ICT fields in KSA hospitals, and (2) FGD with Malaysian leaders in Tabung Haji. The finding of these methods shows that the proposed IoT-EHR should take in account many technical issues such as the data security and spaces coverage.

In summary, the IoT facilities are able to support EHR retrieval in real-time, and in a language and description which can be easily understood. Thus, there are many challenges that could be overcome such as inaccurate treatment due to poor understanding of health cases, and weakness of communication between healthcare staff and patients. Furthermore, the IoT can avoid the technical challenges of global EHR such as privacy, management, and connectivity. The next chapter presents the development of the proposed framework based on the findings of this chapter.

# CHAPTER 5

# FRAMEWORK DEVELOPMENT

## 5.0 Introduction

This chapter presents the development of utilizing IoT in EHR (IoT-EHR) framework for pilgrims. The collected data from various sources (questionnaire (open and close-ended, observation, focus group discussion, and literature review) are clarified in the context of framework development.

This chapter consists of five main sections. Section 5.1 overviews the conceptual layers and elements of the proposed IoT framework. Section 5.2 discusses the findings of research basis (questionnaire (open and close-ended), observation, and focus group discussion). Section 5.3 explains the development of the proposed framework. Section 5.4 clarifies the simulation scenarios of the proposed framework. Lastly, section 5.5 summarizes the overall direction of the proposed framework development. Figure 5.1 illustrates the main structure of this chapter.

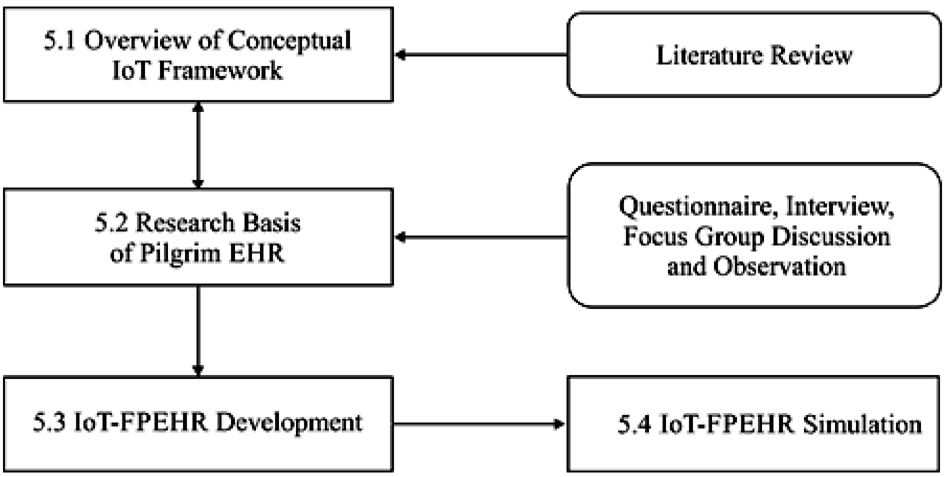



**Figure 5.1: Chapter Structure**

## 5.1 Projected Results and Framework Components

As mentioned earlier, the triangulation design was used in this research to combine different sources of data into a single notion that would direct the development of the framework.

In this study, we collected both quantitative and qualitative data at the same time and then amalgamated the information to come up with a common platform out of which summary results were used. Two types of methodology under triangulation was used that included 4 different data sources which are: quantitative research (questionnaires) and qualitative research (focus group discussion, open-ended survey and observations) simultaneously.

The starting point of data collection was series of discussion and brain storming with tabung Haji professionals to understand the background of pilgrims' health management during Haji. After that we proceeded to collect data from KSA Healthcare Providers Using Questionnaire. We wouldn't be aware of the need of healthcare provider of EHR without exploring the current situation of the healthcare provider and the receiver of the care (Malaysian pilgrims). Thus the questionnaire was conducted to explore the prerequisites and challenges of utilizing IoT in the pilgrims' EHR retrieval across the countries. Out of which the main prerequisites were identified as infrastructure and human resource capacity while participants reflected on the great importance of implementing HER. Moreover, it was identified that the EHR approach could be an effective method to avoid the challenges of traditional methods in the context of healthcare services.

While the observation method concluded lengthy time of understanding the patient's problem by the health care provider, difficulty in getting historical data , was a fundamental obstacle, that would help better and faster diagnosis combined with language barriers. Consistent with the data that collected from healthcare provider through questionnaire, the first FGD with experts from Tabug Haji identified main themes which are closely related to those of healthcare provider which mainly are Organizational capacity, Legal considerations, Improving patients' care. The results of both data sources has informed us on the basic requirement of the framework and necessity of it and these are mainly infrastructure related to IoT components.

We proceeded with collecting another round of data from healthcare provider using open-ended questionnaire to gain more understanding of the EHR related matters in real setting. Respondents has identified challenges, recognized importance and endorsed the benefits of utilizing HER. This step has shaped our ideas and plans of next data collection which is the second FGD. The result of second FGD has emphasized earlier finding from KSA professionals and it mainly highlighted main IoT components that need to be included in the framework where the major themes concluded included tag option, security and accessibility, cost and infrastructure.

## 5.2 Conceptual IoT Framework

Based on the needs and expected challenges that have been identified so far, the proposed framework was stipulated to cover the implement aspects of providing timely and reliable EHR for health professionals. The main structure of the framework lies in the sequence of transmitting the health data over large distances using many IoT layers such as: 1) lower layer, and 2) upper layer. Lower layer (RFID) consists of electronic tags and wireless sensors. Sensors read data of tags and transfer it to upper layer. Upper layer (WSN) consists of super nodes and base station. Super nodes handle data from lower layer and transfer it to base station. Hence, data stored in base station are managed and processed automatically connecting with central web servers. The outputs of processed data (information) are displayed on output devices such as monitors. By reflecting the above two layers of IoT on technical implementations, there are four main layers of IoT environment which can be described as the following:

- **Connectivity Layer:** This layer represents the lower layer of IoT, the electronic tags should be in very short distance of wireless sensors (i.e. 3

meters). Data are transferred from electronic tags through sensors to the next layer (access layer).

- **Access Layer:** This layer represents the upper layer of IoT, the sensors should be in short distance of super nodes (i.e. 100m). Data are transferred to base station from sensors through super nodes. The distance between super nodes and base station would be within 8km radius (C. Chen, 2010; C. Chen et al., 2006).

- **Abstraction Layer:** This layer is responsible for transfer of data from base station to central web servers through open gateway such as internet infrastructures. This allows data transfer over large distances (i.e. across countries around the world).

- **Service Layer:** This layer is about providing real-time IoT services, the data delivered from abstraction layer are processed and the results displayed on output devices such as monitors. These monitors are usually connected to the tags in connectivity layer. Thus, the results of data processing are sent from service layer to connectivity layer through access and abstraction layers respectively.

IoT could effectively support our proposed idea of pilgrim EHR retrieval. Figure 5.2 illustrates the proposed IoT architecture for pilgrim EHR retrieval. The pilgrims need to have an electronic tag which identifies their personality (ID). In case of the need for health services, each health canter is equipped with wireless sensors to read pilgrim tag. Data transfer from wireless sensor to base station via super nodes. Base station sends request via internet network to original country of the pilgrim to acquire pilgrim EHR from health data base in central web server. Web server sends pilgrim EHR via internet network to base station. Base station display outputs on a monitor that is connected to the sensor that sends tag data.

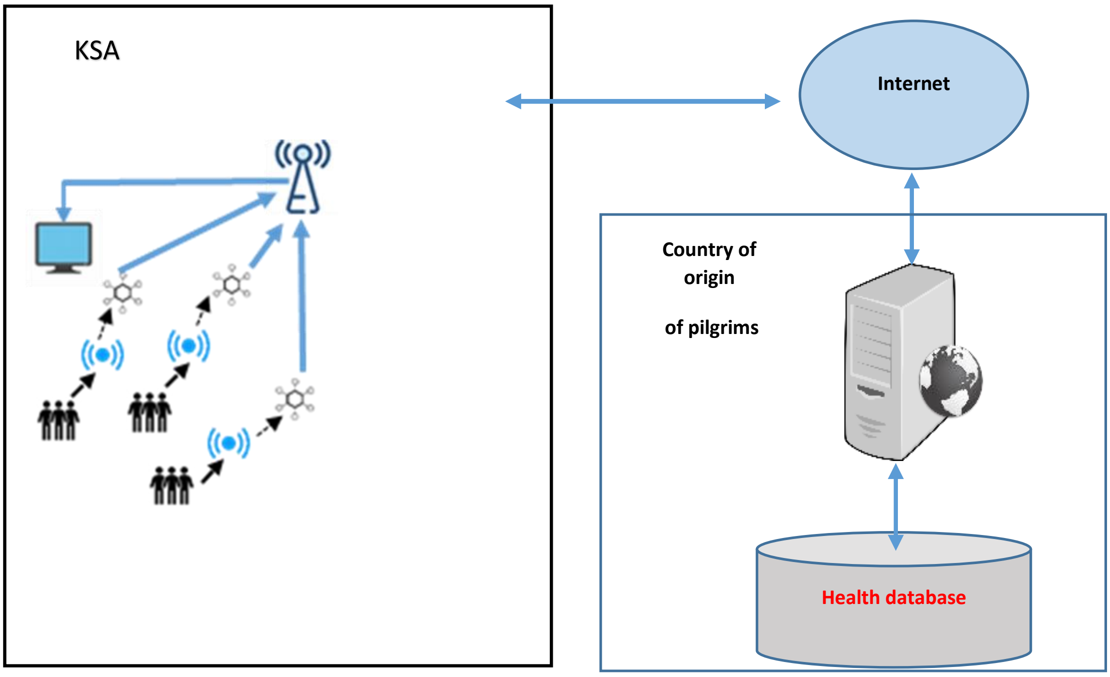



**Figure 5.2: Proposed IoT Architecture for EHR**

Based on the conceptual idea of retrieving pilgrim EHR utilizing IoT tag reading, there are many data collection methods were conducted to collect and analyze the environmental and technical issues of the proposed framework. The next section discusses the findings of the collected data.

## 5.3 Data Sources of Proposed IoT- EHR Framework

As mentioned in Chapter 4, four data collection methods were conducted to support the construction of the proposed IoT-EHR framework. The questionnaire and observation data collection methods were conducted to explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries (1$^{st}$ research objective). As a case study the questionnaire was conducted with health staff from KSA, and the observation was conducted on Malaysian pilgrim.

On the other hand, the open-ended survey and focus group discussion data collection methods were conducted to identify the most useful structure, facilities, and components of the proposed IoT-EHR framework (2nd research objective). The open-ended survey was conducted with experts in KSA hospitals, and the focused group discussion was conducted with leaders in Tabung Haji of Malaysia.

In the context of the first research objective, the findings of questionnaire with healthcare staff in KSA show that current health services in pilgrimage are provided traditionally without any EHR retrieval method of patients' health records. Furthermore, health cases recorded are not registered using any methods such as papers or electronic systems. Only, some data are registered about health cases for statistical purposes.

The respondents (healthcare staff) agree that providing healthcare services without historical records decreases the accuracy of provided services due to weak understanding of health cases history. On the other hand, they expended time to ask pilgrims many questions to understand their health cases. This slows down the provided health services and this is not helpful due to work stress in pilgrimage environment where a large number of services have to be provided within a short span of time.

Moreover, the communication between pilgrims and healthcare staff in context of health services is not effective due to languages differences. The respondents mentioned that the communication based Arabic or English languages are useful to understand health cases and provide accurate services. However, pilgrims from various countries may have not effective skills of these languages. For example, many Malaysian pilgrims cannot communicate with healthcare staff using Arabic or English languages and healthcare staffis not good in the Malay language.

According to the questionnaire findings, the above challenges clarified and supported the importance of EHR for pilgrims. The respondents agree that retrieving historical health records of health cases would speed up healthcare services, provide accurate services, and avoid the difficulty of communication with pilgrims. EHR supports healthcare staff to understand the background of health cases effectively, to understand the allowed and restricted medicines, to provide health services without need to acquire information from pilgrim, and to promote accurate diagnosis of current health case. In the same context, the respondents mentioned that the budgets and technology resources are not the main problems in healthcare sectors in KSA. The current technology resources such as internet facilities, hardware, and software are available and the adoption of new technologies is viable due to budgets that allocated to develop the healthcare services in various environments in KSA.

To support the achievement of the first research objective, the observation method was conducted. The researcher registered for Umrah with a Malaysian group and cooperated with them through all Umrah stages. Through observation of health services provided for Malaysian pilgrims in healthcare centers in KSA, we noticed that the main challenge in providing service is the difficulty of communication between Malaysian pilgrims and Arabic healthcare staff. The pilgrims face difficulty in describing their cases and the healthcare stafffaces difficulty in understanding the Malay language. Healthcare staff gives the pilgrims' medicines based on general notice of their cases regardless whether these medicines are allowed or restricted for the pilgrims. In two cases, we show the historical reports based on English language that belong to health cases. Healthcare staff clarified that these reports reduce the efforts of communication with patients and helped them to understand the cases accurately. Relevant information can be quickly accessed without risking misinformation provided by the pilgrims.

In conclusion, healthcare based on historical reports is more effective and safer than healthcare without any previous records. In the same context, the healthcare staff mentioned that the historical health records is necessary for pilgrims due to many reasons such as some health services are critical or sensitive and need to be diagnosed carefully, and usually the pilgrims are old, which requires prompt health services because they could be easily affected by any small development of their cases.

The findings of the questionnaire and the observation data collection show that the proposed retrieval technology of IoT-EHR is important to improve the health care services of the pilgrims. Its viable to apply the IoT-EHR due to budgets availability in this domain, and this technology could be effective to avoid many challenges of the face the health care services of pilgrims. However, the technical issues of IoT-EHR should be explored to support the construction of the proposed framework.

In the context of the second research objective, the technical issues of the proposed IoT-EHR framework are explored. The findings of open-ended survey with ICT experts in healthcare centers confirm that EHR for pilgrims is necessary to avoid the same challenges that discussed in the questionnaire and observation findings. The experts mentioned that it is difficult to adopt electronic retrieval system for pilgrims' health records due to many reasons such as: (1) The difficulty in acquiring and managing health records of about two million pilgrims per year − this requires huge efforts and technology facilities; (2) The health record acquiring requires agreements between countries because we collect health records for persons from other countries; (3) Even electronic system of health records retrieval require effective computer skills of healthcare staff which mean a lot of training courses; and (4) EHR systems require continuous maintenance.

The experts argued that the proposed idea of pilgrim EHR retrieval utilizing IoT could address the various challenges of EHR implementations in the pilgrimage. Electronic tag reading from sensors and retrieving health records from pilgrims' countries do not require much effort in acquiring and managing health data. The database in pilgrims' countries is managed already and the data acquired by one touch only. However, there are many technical issues should be covered by the proposed IoT-EHR framework, these issues are:

- Data security and privacy.
- Useful distribution of IoT facilities according to pilgrimage environment (visited places by the pilgrim).
- The IoT features like the power supply, coverage spaces, and connections should be suitable for pilgrimage environment.

- The protocol or techniques of data transfer should be explained in the proposed framework, and these protocols must match with the nature of transfer data.
- It is necessary to give high priority the data transfer of EHR via IoT facilities, or allocate specific transfer channel for this purpose.

The experts argued that there is no need for critical agreements between KSA and other countries to retrieve health records because the other countries are administrating and monitoring the data access. The experts see that the pilgrim EHR utilizing electronic tags does not require professional computer skills, it works just like “touch-and-go”. The experts clarified that the proposed idea of pilgrim EHR retrieval utilizing electronic tags is useful to improve healthcare services in pilgrimage. Retrieving historical reports of patients’ health record is necessary to provide accurate healthcare service in right time. Hence, the proposed EHR utilizing electronic tag reading would retrieve health records based on various formats such as images, video, and texts. These records should be retrieved based on Arabic or English languages to allow healthcare staff to understand these records effectively.

In total, the experts agree that the proposed idea is viable and can be implemented in KSA due to low effects and technology resources that are required in KSA. KSA need to prepare the RFID readers (sensors) and effective internet facilities which is not a major issue according to technology resources in KSA. On the other side, the pilgrim’ countries should construct the EHR database and store it in database that connected with global network. Thus, the KSA health staff can retrieve the EHR of specific pilgrim from the global database.

To support the achievement of the second research objective, the technical issues of the IoT-EHR retrieval were discussed with leaders from Tabung Haji Malaysia as a focus group discussion. The leaders mentioned that the proposed idea is promising and interesting. The main challenge of idea implementation is the required efforts and financial cost to acquire and manage health records of Malaysia pilgrims per year as a structured database. But, providing effective health for

Malaysian pilgrims is more important. The EHR retrieval utilizing electronic tag reading can Speeds up the healthcare service, Provides accurate healthcare services, and Reduces the communication difficulty based on different languages Thus, this idea is very viable from the Malaysian perspective due the advantages that could be gained from the proposed idea (Singh et al., 2014; Yuqiang et al., 2010).

The leaders explained that the Malaysian responsibilities is scoped by prepare the global EHR database of pilgrims, and the KSA is responsible about prepare the resources of EHR tag reading. The leaders mentioned that it is viable to translate the health records to English language through translation experts or health centers in Malaysia. Also, it is viable to provide health records based on various format such as images, videos, and texts. The internet network can be used to transfer the EHR from Malaysian Database to KSA physical resources. However, the communication between both sides should be secured effectively due to sensitivity of transferred data. The leaders argued that the EHR database should be controlled by Malaysian side to assure the data privacy, which require full reports about any conducted data requesting/sending from/to KSA side

Based on the findings of the collected data using the various data collection methods, the review of literature involves the achievements of the first and second research objectives. The literature shows that main technical resources of IOT are the lower layer, and upper layer. Lower layer (RFID) consists of electronic tags and wireless sensors. Sensors read data of tags and transfer it to upper layer. Upper layer (WSN) consists of super nodes and base station. Super nodes handle data from lower layer and transfer it to base station. However, these resources are effective for the local IoT implementations.

For global IoT implementations, it is necessary to adopt four IoT layers; (1) connectivity layer which represent the RFID resources, (2) access layer which represent the WSN resources, (3) abstraction layer which transfer the data from base station to central web servers through internet infrastructures, and (4) service layer which provide the services depend on the data requests from connectivity layers through access and abstraction layers. Also, the provided services transferred from service layer to access layer, then to abstraction layer, and finally to connectivity layer.

The above technical structure of global IoT framework is suitable for the EHR retrieval of pilgrims. The connectivity and access layers resources would be constructed by KSA in the pilgrimage environment. Through these resources the requests of patient (pilgrim) EHR can be produced through electronic tag reading. The requests transfer from access layer to service layer through abstraction layer. Based on the EHR, the EHR report will be produced by database in service layer and this report will transfer to connectivity layer. The literature identifies further technical requirements of global IoT framework, and these requirements are explained in the discussion of proposed framework development (section 5.3)

Furthermore, the literature shows that electronic tags and wireless sensors are the main components of connectivity layer. This layer also should contains output devices to show the services that provided by service layer based on the construct request of EHR. On the other hand, the main components of access layer are the super nodes and base station. These components should be distributed effectively to cover the distance of pilgrimage environment. Moreover, the abstraction layer represents the internet connection between the base station and the services layer. The transferred data via the internet connection should be secured and managed effectively. In addition, the service layer is mainly represented by the EHR database that allocated in pilgrims country. The provided service form this layer could be showed for health staff in KSA using output devices. Table 5.1 summaries the findings of the various data collection sources; questionnaire (open and close-ended), observation, and focus group discussion.

**Table 5.1: Findings of Research Basis**

| Basis | Perspective | Aim | Findings |
|---|---|---|---|
| Questionnaire | KSA | Explore the environmental issues of the proposed IoT-EHR framework. | • There are no retrieval methods currently applied to retrieve pilgrim health records. Specifically, EHR systems are not applied in pilgrimage environment<br>• Health services are provided traditionally through general diagnosis of health cases<br>• Traditional health services are not accurate due to weak understanding of health cases background<br>• Traditional health services are consuming time which slows down the processing of these services<br>• There is difficult communication between pilgrims and healthcare staff due to languages differences<br>• IoT-EHR could Speeds up the healthcare services<br>• IoT-EHR could provide accurate healthcare services<br>• IoT-EHR could reduce the communication difficulty based on different languages. |
| Observation | Malaysia | | |
| open-ended survey | KSA | Explore the technical issues of the proposed IoT-EHR framework. | • The security and privacy is the most important issue of the proposed IoT-EHR.<br>• Useful distribution of IoT facilities according to pilgrimage environment (visited places by the pilgrim).<br>• IoT features like the power supply, coverage spaces, and connections should be suitable for pilgrimage environment.<br>• The protocol or techniques of data transfer must match with the size and format of transfer data.<br>• The proposed IoT-EHR should transfer the data in various format like video, audio, texts, and images.<br>• It is necessary to give high priority the data transfer of EHR via IoT facilities, or allocate specific transfer channel for this purpose.<br>• The KSA agency is not required to expend effort and resources to implement the idea<br>• The Malaysian agency sees that the required efforts and resources are outweighed by the importance of the idea<br>• Does not require effective computer skills<br>• Does not require critical agreements between KSA and Malaysia for health records acquiring and privacy |
| focus group discussion | Malaysia | | |
| Literature Review | Conceptual | Identify the main element and layers of proposed idea of EHR utilizing IoT in pilgrimage | • There are four main layers of IoT to implement the proposed idea: connectivity, access, abstraction, and service layers<br>• Physical elements belong to connectivity (RFID) and access layers (WSN)<br>• Internet connection belongs to abstraction layer<br>• Health records as database belong to service layer<br>• The result of EHR requests are displayed on output monitors in connectivity layer |

The next section discusses the development of proposed framework based on technical aspects such as IoT devices types, features, and connections.

## 5.4 IoT-FPEHR Development

Based on the findings of the data collection, this section presents the development of proposed Internet of Things – Framework of Pilgrim Electronic Health Record (IoT-FPEHR) as four main layers which are connectivity, access, abstraction and service layers.

### 5.4.1 Connectivity Layer

This layer consists of three main elements that are connected to each other; (1) electronic tags, (2) wireless sensors, and (3) output device like monitors. Wireless sensors read tag data and send it to access layer. Furthermore, these sensors are connected to output device to view the final results of data processing (retrieve healthcare records from service layer).

For electronic tags specifications, the active tag is considered as an effective type for the purpose of this research. Active tags are cheaper than other types of electronic tags such as passive and semi-passive types. Active tags can be charged for 1-5 years and usually pilgrims need to use these tags for two months at maximum. Usually, active tags can send wireless signs within 7-9 square meters. Thus, these tags could be designed as a wristwatch to increase the difficulty of tag loss. The wristwatch tag should be water-resistant to protect the electronic data against damage from rain or immersion in water. Also, the tags should be lightweight for the convenience of pilgrims.

Moreover, there will be a level of security based on the authentication which consist of electronic tag, face recognition and fingerprint authentication. The first authentication factor is the electronic tag, the main goal of this stage is to ensure that all information have been retrieved from the database are integrated, updated, availability and related to the same person who is carried the electronic tag.

The second factor of proposed authentication model will be divided in two parts, one of them will be used, either the face recognition or fingerprint, but not the both. Furthermore, the camera will be added to the tag to be the authentication factor level to recognize the person who claims he/she the same person is carried the electronic tag. If the two-factor authentication levels are compatible with the same information was added through the signup level, then the information will be delivered to the hospital correctly. On the other hand, if the face recognition factor was not work (sensor couldn't recognize the face of patient, then the fingerprint authentication will be used to confirm that the person who identified himself as an authorized person is the actual authorized person, if the information will be compatible with the database was added before that related to the authentication part, then the information will be delivered to the hospital. Otherwise, access will be denied.

Electronic tags store small data that represent pilgrim Identification Data (ID). The number of Malaysian pilgrims is about 5,000 pilgrims per year. This number can be covered using 11 ID digits as three ID parts (xxxx-xxx-xxxx); the first four digits represent the current pilgrimage year, the second three digits represent the Malaysian pilgrim's country code (for example, MAY), and the last four digits represent the pilgrim's serial number. The proposed ID format could distinguish Malaysia pilgrims from other countries pilgrims in the event of tag reading adoption by other countries. Furthermore, the proposed ID format distinguishes Malaysian pilgrims from each other through the pilgrimage year and serial number.

Regarding the wireless sensors specifications, the Synapse SNAPstick sensor is an effective type for this research. SNAP works as a middleware between the bridge and the GUI software. It is used to allow a third party, who is the client, to easily access a SNAP wireless network through GUI applications. It provides a terminal for the client programs to interact with remote station nodes. SNAP exposes the functions contained in SNAPpy Scripts including the standard SNAP built-in functions. Figure 5.3 outlines the message exchange sequence between the SNAP server and the client application, as well as between the server and a remote SNAP node.

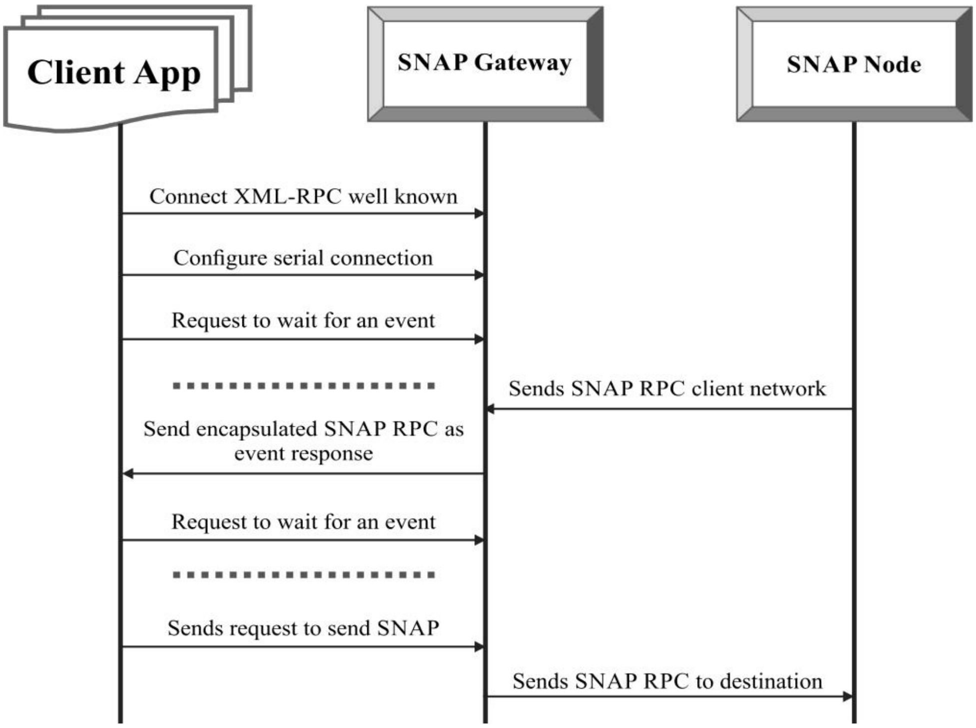



**Figure 5.3: SNAP Connection Messages**

SNAP sensor was selected due to many reasons which are as the following:

- Matches with all electronic tag types.
- Can read data in any format and/or pattern.
- Can be attached to client PCs as USB devices which provide data reading anytime anywhere. This also allows dynamic retrieval of data from service layer to specific output device that is connected to SNAP sensor.
- Effective to read data from tags within a range of 66 square meters.
- Effective to send data to super nodes within a range of 110 square meters.

The selection of SNAP covers an important issue which is the sensors' distribution according to physical locations. Through the observation method mentioned in Chapter 3, we notice that the health centres in pilgrimage do not follow standard building architecture or distances. Some centres consist of one room (16m x16m) while other centres consist of three rooms or more (6m x 6m for each room). Whatever the center's architecture and rooms distances, SNAP sensors can be attached to client PCs to read the tags directly when health cases are noticed by healthcare staff.

Consequently, SNAP reads electronic active tags via a wireless network and displays the health records retrieved from service layer on an output device that is connected to SNAP. This avoids the difficulty of dynamic connection between sensors that send data request and output devices. Figure 5.4 illustrates the specifications and structure of connectivity layer. It is necessary to mention that the responsibility of connectivity layer is to read the ID of pilgrims, relay it to access layer, and deliver the health records through output devices.

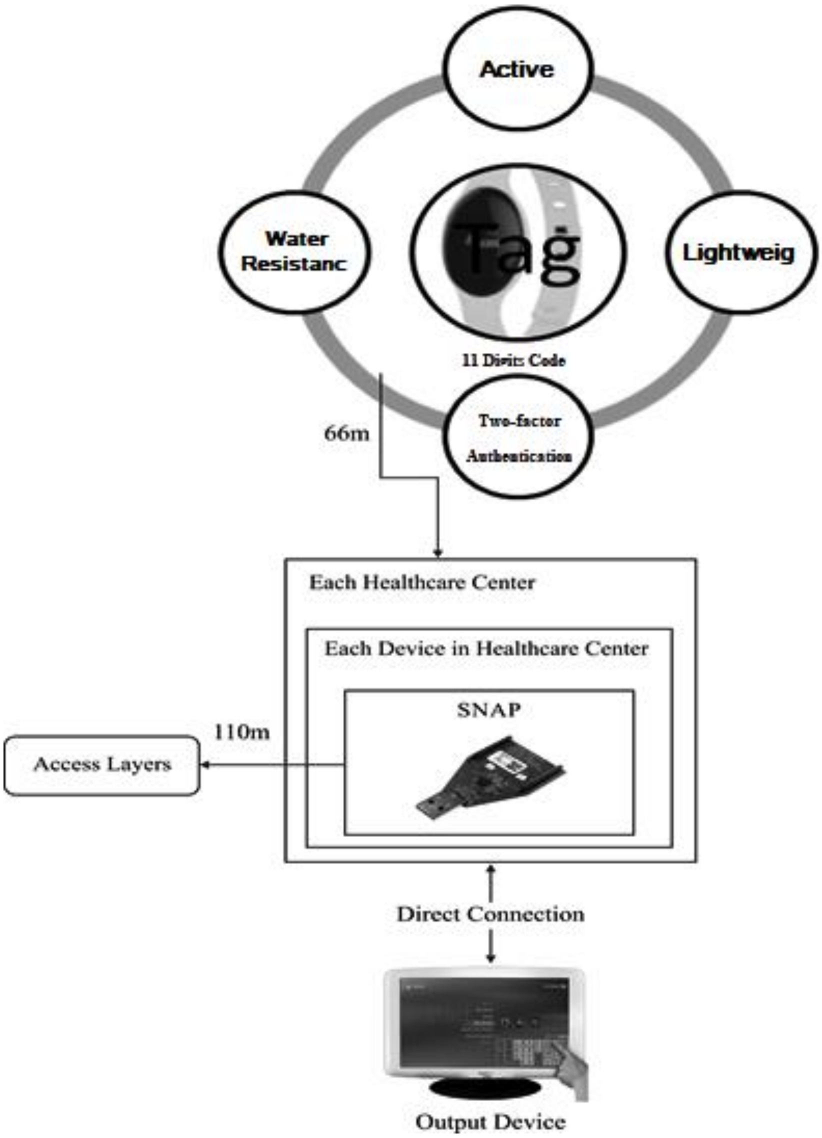



**Figure 5.4: Connectivity Layer**

### 5.4.2 Access Layer

This layer consists of two main elements that are connected to each other: (1) super nodes, and (2) base station. Super nodes acquire data from connectivity layer and send it to base station. Base station manages the data that are acquired from various super nodes and send request of services based on these data to abstraction layer.

Regarding to specification of super nodes, the nodes should be distributed effectively to cover the distance range of all wireless sensors in connectivity layer. The average coverage of super nodes is 350 square meters (Nizari & Amer, 2011). Thus, any wireless sensors should within 350 square meters of any super nodes. Based on the coverage space of super nodes, hybrid placement approach of super nodes was adopted in two main folds. Firstly, static placement approach was adopted to read the data from wireless sensors in determined areas such as health center in the pilgrimage areas of Mecca, Medina and Jeddah. Secondly, random placement approach was adopted to read data from wireless sensors that are distributed randomly on long areas such as roads between Mecca, Medina and Jeddah. It is difficult to place static wireless sensors and super nodes to cover large areas i.e. 500 square km.

Figure 5.5 shows the map and distances between Mecca, Medina and Jeddah. The distance between Mecca and Medina is about 454 km. The distance between Medina and Jeddah is about 465km. The distance between Mecca and Jeddah is about 99km.

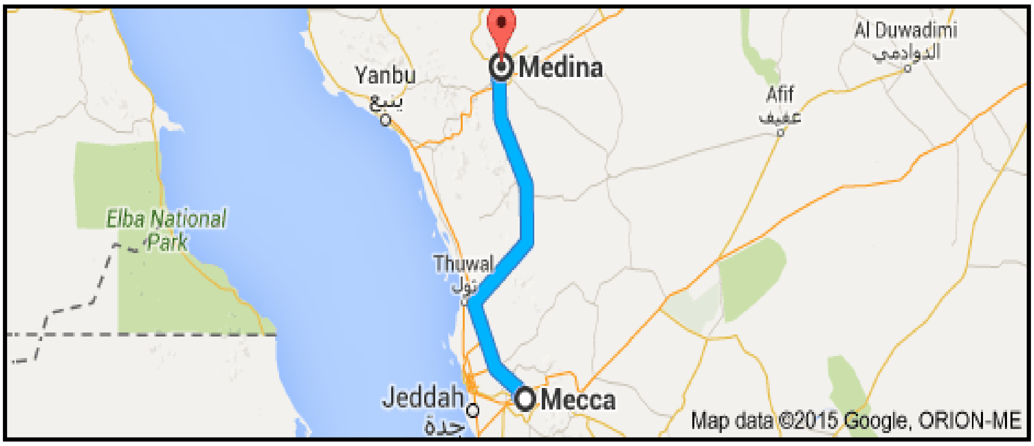



**Figure 5.5: Map of Proposed Pilgrimage Areas**

Consequently, wireless sensors in each healthcare center that provide health services for pilgrims can be covered statically using one super node. The road between Mecca and Medina can be supported randomly by 5 super nodes (1 for each 100km). The road between Medina and Jeddah can be supported randomly by 5 super nodes (1 for each 100km). The road between Mecca and Jeddah can be supported randomly by 1 super node (1 for each 100km).

Regarding to specifications of base stations, the average base station coverage space is 8 square km (Taylor et al., 2002). Thus, each super node in the proposed framework should be within (8km) of base station. Usually, pilgrims visit five places in Mecca to accomplish their pilgrimage rituals (proposed places of healthcare centers). These places are Mikat, Kaaba (Almsjid Al-haram), Mina, Muzdalifah and Arafat (Figure 5.6). These places can be covered using three base stations. The first base station can cover the super nodes that belong to Mikat and Kaaba (around 8km), and the second base station can cover the super nodes that belong to Mina and Muzdalifah, and the third base station can cover the super nodes that belong to Arafat.

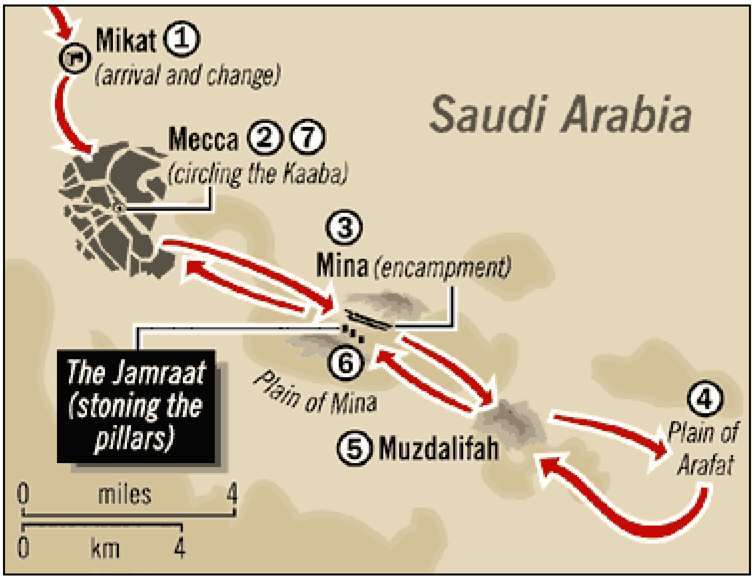



**Figure 5.6: Pilgrimage Places in Mecca**

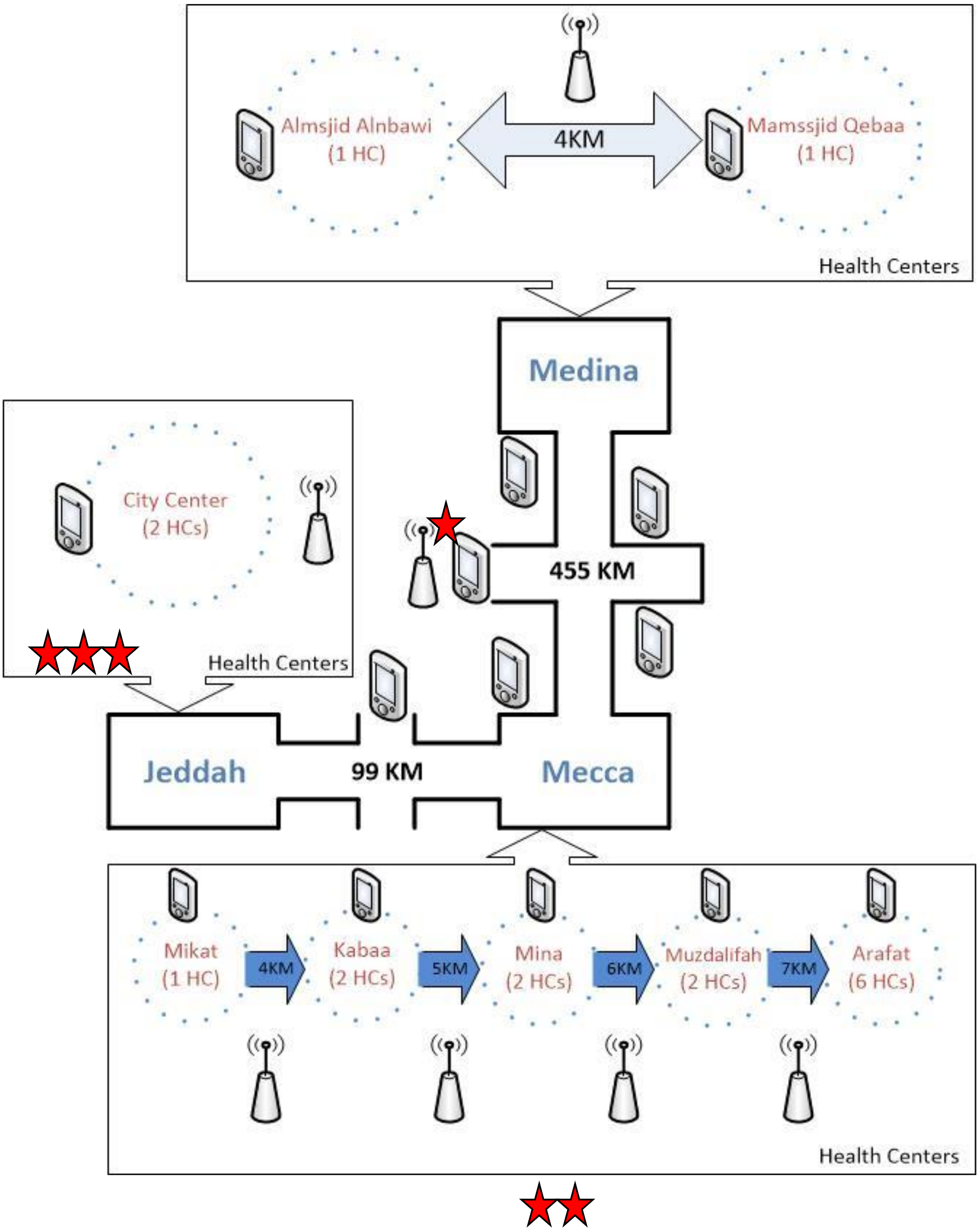
Source: newworldencyclopedia.org, 2012

On the other hand, pilgrims visit two main places in Medina for secondary pilgrimage activities (proposed places of healthcare centres). These places are Almsjid Alnbawi and Masjid Keba’a (Figure 5.7). The distance between these two places is around (4 km). Therefore, the super nodes that belong to these places can be covered using one base station.


**Figure 5.7: Medina Places**

Furthermore, Malaysian pilgrims usually visit Jeddah at the end of their pilgrimage activities so that they can depart by direct flight from Jeddah to Malaysia. In Jeddah, pilgrims could visit the markets and stay in hotels. Thus, the super nodes of health centres in Jeddah city center can be covered using one base station (city center is around 6 square km).

In total, access layer contains 10 static super nodes that belong to healthcare centres in Mecca, Medina and Jeddah, and 11 dynamic super nodes distributed along the road between cities (one super node for each 100 km). Static and dynamic super nodes can be covered using 17 base stations. Three base stations in Mecca, two in Medina, one in Jeddah, and 11 base stations are required to cover the dynamic super nodes. Figure 5.8 illustrates the access layer elements and communication.




*5 base stations (1 for each super node)

**1 super node for each healthcare center

***1 super node for each healthcare center

**Figure 5.8: Access Layer**

### 5.4.3 Abstraction Layer

An abstraction layer is a generalization of a conceptual model or algorithm, away from any specific implementation. These generalizations arise from broad similarities that are best encapsulated by models that express similarities present in various specific implementations. The simplification provided by a good abstraction layer allows for easy reuse by distilling a useful concept or design pattern so that situations where it may be accurately applied can be quickly recognized (Batet, Gibert, & Valls, 2007).

A layer is considered to be on top of another if it depends on it. Every layer can exist without the layers above it, and requires the layers below it to function. Frequently abstraction layers can be composed into a hierarchy of abstraction levels. The OSI model comprises seven abstraction layers. Each layer of the model encapsulates and addresses a different part of the needs of digital communications, thereby reducing the complexity of the associated engineering solutions (Siddha, Ishiguro, & Hernandez, 2012).

The abstraction layer represents the connection between access layer and service layer via internet facilities. The main aim of abstraction layer is to transfer the data (tag ID) that are acquired from base station in access layer and relay it as a request message to the web server in service layer via an online network. In this research, the data (request messages) are transferred through the Internet from access layer in KSA to service layer in Malaysia. Therefore, the network requirements are the main focus of abstraction layer. There are various requirements that should be available in the network in abstraction layer as follow (Figure 5.9):

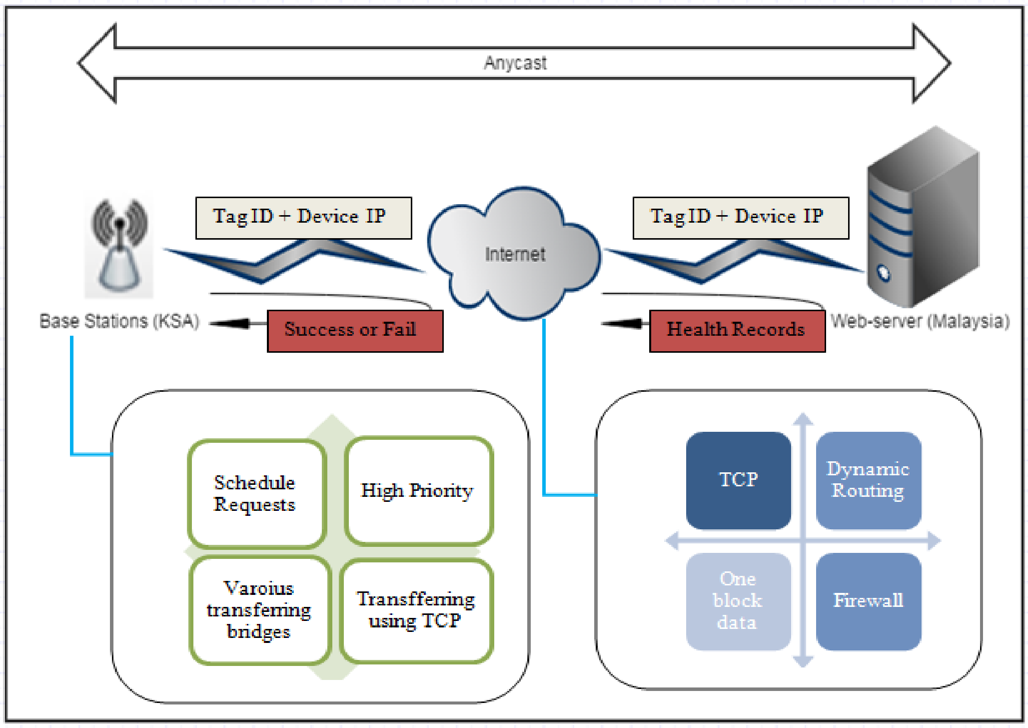



**Figure 5.9: Requirements of Abstraction Layer**

Firstly, the data must be transferred using network based on any cast delivery mode. Any-cast mode sends data from multiple source devices to a specific or few destination devices. This mode is suitable in this research because the tag data are sent from many base stations in access layer to specific web server in service layer. The selection of delivery mode is necessary to manage data transfer via network such as transferring priority and scheduling. Other delivery modes such as uncast (one-to-one device), multicast (many-to-many devices), and broadcast (one-to-many devices) are not suitable according to purpose of abstraction layer in this research.

Secondly, data or messages scheduling should be supported. Each base station may acquire many tags data that need to be sent through abstraction layer. Thus, base station should manage data sending as scheduled to avoid conflict of sending orders. The data would be scheduled based on acquiring time or queue time (first acquired first transferred). In case of acquiring two orders at the same time, they will be transferred to service layer one by one.

Thirdly, notification of data success or failure sending should be available. It is necessary to get feedback from abstraction layer to access layer about the data sending case. The confirmation of data sending allows the users to await response from service layer. The failure of data sending allows the users to send another request. These notifications are important to avoid services conflicts due to same request orders.

Fourthly, messages priority should be addresses. Base stations may be used to acquire and send data for other purposes than tag data sending. Thus, it is necessary to program the base stations such that the primary priority is tag data sending and other purposes are considered as secondary priority.

Fifthly, dynamic transfer paths of network must be adopted. Transferred data may be delayed or lost due to internet traffic. Thus, it is necessary to allow data transfer using dynamic network paths from KSA to Malaysia. Data transfer using static network path may hold the data for long time (i.e. hours) until completing the data queue in this path.

Sixthly, data sending from various devices types must be supported. The base station may acquire and transfer data to abstraction layer using various bridges types such as switches, routers, mobiles devices or web servers. Therefore, the network in abstraction layer should be able to listen for sent data using any type of transfer bridges.

Seventhly, trusted transfer protocols are a primary requirement. The selection of transfer protocols, such as TCP or UDP, affects data security and transfer speed. TCP considered as most stable transferring protocol. TCP provides high level of data security (i.e. data encryption) and the transfer speed using TCP is not affected by data drop rate. Usually, repeat data sending (drop rate) delays the transfer speed of data.

Lastly, data sending must be transferred as one packet (continuous transfer). There are two main approaches of data sending: (1) segmenting data and sending it as sequence and related packets to destination device, and (2) sending data as one block to destination device (continuous transfer). Data segmentation is useful for large data. Tag data are considered as small data (i.e. 10 digits), thus continuous transfer is a suitable approach in this research. Continuous transfer approach avoids packet loss or time requirement to manage received packets by destination device.

### 5.4.4 Service Layer

The service layer mainly contains the database of pilgrim health records and this database is stored in a web server located in Malaysia. Tabung Haji in Malaysia could administrate the pilgrim health records database.

According to collected data from open and close-end questionnaire and observation methods, pilgrim health records should be stored based on English or Arabic language and based on group discussion method the health records could be translated to English language due to ease of translation from Malay to English language. Thus, the health records of pilgrims are proposed to be stored in the English language.

Based on the collected data from open-end questionnaire and observation, pilgrim health records would be stored using various formats such as texts, images, and videos. Health records based on various formats allow the healthcare staff to understand the health cases effectively and provide accurate health services.

Based on collected data from open-end questionnaire and observation, it is necessary to retrieve additional information of health records such as the allowed and restricted medicines for pilgrims. Also, the recommendations or advice of pilgrims' doctors in Malaysia can support the accuracy of provided health cases. Additionally, the contact of pilgrims' doctors in Malaysia should be attached with health records for better communication and discussion between healthcare staff in Malaysia and KSA in case of complex health cases.

Large size of health records slows the transfer time of data from service layer to connectivity layer and consequently decreases the effectiveness of data transfer in real-time. Therefore, it is better to classify health records as many classes depend on type of data request from connectivity layer. There are six main diseases classes which are: blood diseases, heart diseases, diabetes, bones diseases, neuro-degenerative diseases, and general diseases (for example, ears and eyes). The health records of pilgrims can be stored under these six classes of diseases.

Another important issue of health database is the ability to write data on pilgrims' dataset (not read only). Thus, any new health records can be updated from healthcare staff in KSA on pilgrims' records in Malaysia. Here, the new updates can be stored in secondary or external database in web server to distinguish the original records from the new health records which allow accurate health cases tracking in future.

To assure health records privacy, any request or data transfer from web server can be registered in a separate database. Registering of data requests and data transfer allows Malaysian administrators to review the transactions that happen on the database and register the devices IPs of connectivity layer in KSA that request these data. This would simplify formal communication between Malaysian and KSA agencies in case of unusual data requests. Figure 5.10 illustrates the specifications of service layer.

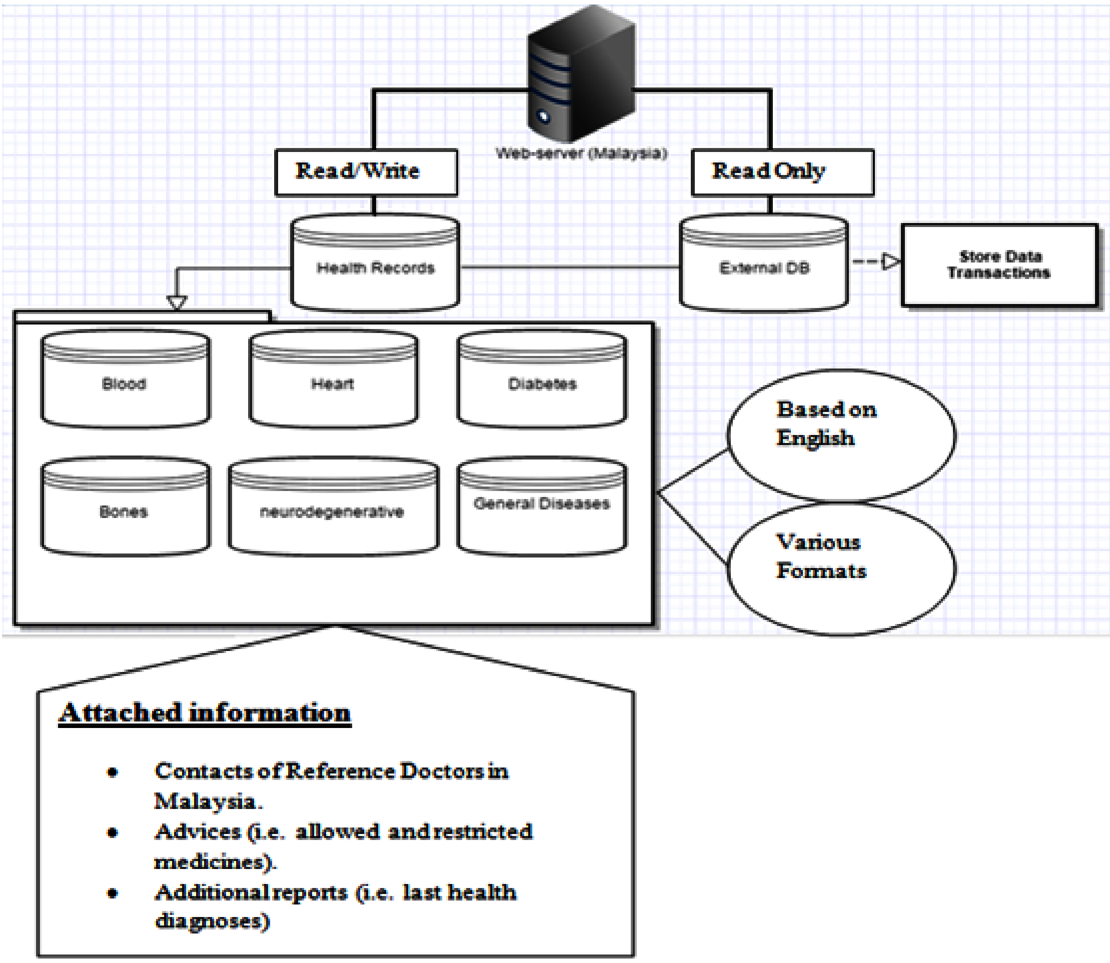



**Figure 5.10: Specifications of Service Layer**

## 5.5 Simulation of IoT-FPEHR

As far as the scope of this research is to propose a sharing framework which could be materialised into a practical application after fine tuning of the components, and due to limitation of resources, we have opted to present a hypothetical scenario that would help the reader to visualise and understand how the framework would work once it is implemented.

In connectivity layer, the wireless sensors read the tag data (pilgrims ID) and the healthcare staff identify the request type health records (for example, blood or heart records). The access layer acquires data from connectivity layer and sends it to service layer through abstraction layer. The acquired data are tag ID, type of requested records, and device IP that is connected to wireless sensor. Once data request is submitted to service layer, the specific health record type of pilgrim ID will be retrieved and transferred to access layer via abstraction layer. Device IP that send the request is transferred with retrieved records. The retrieved records delivered from access layer to output device that is connected to device IP.

Among the various implementations of the proposed IoT framework, the following are the three main implementations that are related to the Malaysian context:

- Supports accurate and real-time healthcare services for Malaysian pilgrims: the main implementation of proposed framework is to retrieve health records of Malaysian pilgrims based on English language to treat them in pilgrimage. Retrieving clear and complete health records allow KSA healthcare staff to understand health cases accurately, avoid the communication difficulty with pilgrims due to language differences, and serve the health cases in real-time without the need to do many tests. To clarify this implementation of proposed framework, consider the following scenarios:

  *Ali and Mohammad are two Malaysian pilgrims and they travel together to complete the pilgrimage activities. Ali has heart disease and Mohammad has diabetes. In Mecca (Arafat), Mohammad and Ali feel unwell due to stress of pilgrimage activities on Arafat. Both of them visit the nearby healthcare center to treat their health cases.*

  *Healthcare staff starts asking Ali many questions to understand his case, the staff face difficulty in understanding the Malay language spoken by Ali, and they take about half hour trying to understand Ali's case. Finally, the healthcare staff decides to transfer Ali to any nearby hospital. Ali refuses this decision because he wants to complete his pilgrimage activities in the right way. Here, healthcare staff is stuck due to the ambiguity of Ali's health case and the difficulty of providing accurate health service. Ali prefers to* *complete pilgrimage activities and ignore the treatment until he's back in Malaysia.*

*In Mohammad's case, he tells the academic staff that they can retrieve his health records of diabetes by using smart tags. With one touch, the sensor reads Mohammad's tag and the academic staff press number three (identification number of diabetes). In 10 seconds, the full diabetes health records in English of Mohammad are retrieved from pilgrims' health database in Malaysia. The healthcare staff does not need to ask Mohammad any question. Accurate medicines are provided to Mohammad based on his case and his health records in minutes.*

- Allows the communication between Malaysian healthcare staff and KSA healthcare staff to serve complex health cases of Malaysian pilgrims: Health records retrieval in real-time allows the healthcare staff in KSA to communicate with healthcare staff in Malaysia and discusses the complex health cases accurately. The healthcare staff in KSA may need the help of pilgrims' doctors in Malaysia in some cases. Retrieving of health records allow KSA healthcare staff to describe and discuses health cases accurately. To clarify this implementation, consider the following scenario:

*Abdurrahman is a Malaysian pilgrim and he has history of blood diseases. Healthcare staff in Jeddah Hospital retrieves Abdurrahman's health records of blood using his smart tag. However, they are wary of providing some medicines to Abdurrahman due to side effects of these medicines. The contacts of Abdurrahman's doctor in Malaysia are found in the health records. Directly, healthcare staff in KSA calls Abdurrahman's doctor and describes the health case and proposed treatment. Abdurrahman's doctor advice is that medicine is restricted based on Abdurrahman case and it is better to treat him with another medicine.*

- Identifies the positions of Malaysian pilgrims in KSA: the proposed framework can be used in other implementations other than health treatments like identify the approximate or exact positions of Malaysian pilgrims. Wireless sensors can read each electronic tag of pilgrims frequently, and tag data can be transferred to servers in KSA or Malaysia to track the movements of pilgrims. Position identification using smart tags is effective for many purposes such as to assure pilgrims' safety, to locate lost pilgrims quickly, and to monitor the movement of every pilgrim to assure that he/she is in the right location according to the pilgrimage schedule. To clarify this implementation, consider the following scenario based on a known case in pilgrimage:

----------------------------------------------------------------------------------------------

GULF NEWS, SAUDI ARABIA
January 9, 2017

**Dead are yet to be identified and relatives scramble from hospital to morgue**

*Dubai: "We can't find him" was the lament of anxious relatives and friends on Saturday as they scoured hospital wards and the morgue, two days after the disaster at the Haj.*

*Those killed have yet to be identified after Thursday's crush in Mina, near the Saudi city of Makkah, during the "stoning of the devil" ritual at the annual pilgrimage to Islam's holiest sites.*

*The death toll rose to 769 on Saturday, a Saudi minister said. More than 800 people were also injured in the Mina incident.*

*On Friday, Pakistan's foreign ministry said that 236 of its citizens were missing, but later reported that 86 of them had been located.*

*Frustrated families have been left with the painful task of trying to find out for themselves whether loved ones are dead or alive.*

*"They say they don't have his name registered," an agitated Egyptian pilgrim said after arguing with reception staff at Mina Emergency Hospital.*

*The pilgrim, who gave his name only as Abdullah, said he was searching for his 36-year-old neighbour.*

*"I've been going around hospitals but couldn't find him. They told me go to the morgue," said Abdullah.*

*"We can't find him, neither among the wounded nor among the dead."*

*Leaving the hospital was another Egyptian, looking for a fellow pilgrim who was staying in the same part of Mina's tent city used for the Haj.*

*"I don't have the nerves to talk," he said. "His wife is breaking down at the camp. She didn't even perform the Haj rituals."*

*Upstairs, another man, Tareq, went from room to room seeking the wife of a fellow pilgrim.*

*"Her husband is at the camp and couldn't look for himself, he's in such a state of shock. We are helping him," said the Egyptian, rushing from internal medicine to the surgical ward.*

*Rushing up and down the stairs, Mohammad Bilal, also Egyptian, looked in vain for a friend's 60-year-old mother, whose phone has been switched off since the disaster.*

*"The first thing we did was go check if she's among the dead in Muaisem, but we found nothing," he said, referring to an area near Mina where the morgue is located.*

*"We then began going from hospital to hospital."*

*On his tour of hospitals, Bilal, 35, showed staff the woman's picture on his mobile phone.*

*"I have her name and picture. I went to the information desk. They said she's not here... I went up to search for her in the intensive care unit and other rooms," he said.*

*At the information desk, a frustrated black-clad Saudi woman, who was with her husband, asked about her missing 43-year-old brother.*

*They had been searching hospitals, floor by floor, to find him, she said, asking not to be named.*

*"We gave his name and picture to all hospitals," and the family asked relatives in other Saudi cities to also check, in case he had been transferred elsewhere, she said.*

*Officials referred them to the Muaisem morgue. The brother wasn't there but her husband came out in tears, distraught at the scene he had witnessed.*

*"We haven't slept or eaten since yesterday as we rush on foot from one hospital to the next," she said.*

*Hospital manager Ayman Al Yamani said "the identities of some cases in intensive care remain unknown", with many still on respirators.*

*With countries around the world struggling to draw up a final list of fatalities among their nationals, consular officials have also converged on Mina to try to identify the victims.*

*Yamani said the Saudi health ministry has set up a hotline to locate the missing, although many friends and relatives said it was of no help.*

*He said translators for six languages were among the staff, but hospital workers still appeared to have difficulties communicating with the pilgrims.*

*In one room, a Saudi nurse was seen resorting to sign language with an elderly Indian man with stitches on the forehead complaining he was unwell.*

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Based on the above three cases and other accidents that have happened since 1990 in pilgrimage, Malaysian and KSA government cannot provide accurate and real-time reports about the safety of Malaysian pilgrims. Pilgrims' families are waiting for many hours to know the safety cases of parents, family members, or friends. By using smart tags, Malaysian and KSA governments can identify the positions of Malaysian pilgrims in real-time and know if these pilgrims are near or far away from the accident site. Thus, they can estimate the safety situation of Malaysian pilgrims and provide real-time reports based on this estimation.

## 5.6 Chapter Summary

This chapter presents the development of proposed IoT framework of pilgrim EHR as a result of research data collection. Four data collection methods were conducted to explore the environmental and technical issues of the proposed IoT-EHR framework. These methods are open and close-end questionnaire, observation and focus group discussion. The main architecture and components of proposed framework is developed based on literature review of IoT layers and components. IoT consists of four main layers which are connectivity, access, abstraction, and services layers. The structure, components, and futures of proposed framework was developed according to the main architecture of IoT, and reality of KSA environment (i.e. distances), and effective requirements of health services for the pilgrims.

# CHAPTER 6

# VALIDATION OF PROPOSED IOT FRAMEWORK FOR MALAYSIAN PILGRIM EHR RETRIEVAL

## 6.0 Introduction

This chapter aims to address the third research objective which is to measure the validity of the proposed IoT-EHR framework. This chapter discusses the validation process of the proposed IoT-EHR framework for pilgrim. It summarizes the processes as well as the results of validation. The proposed framework was validated by eight experts from Tabung Haji in Malaysia using open-end questionnaire analyzed with summative review technique. The profile of the experts is shown in appendix E2.

As explained in Chapter 3, the main aim of the validation phase is to test the acceptance of research outcome (proposed framework). There are many aspects that can be examined in relation to the proposed framework to test the research outcome such as accuracy, speed, cost, usability, usefulness, flexibility, and reliability. The most suitable validation factors for this research (i.e. theoretical outcome) are the usability, usefulness, flexibility, and security. Other validation factors such as speed and cost are suitable for systems validation rather than theoretical models or frameworks. The main aims of validation factors of proposed framework show in the following Table 6.1.

**Table 6.1: Aims of Validation Factors of Proposed Framework**

| Validation Factor | Main Aim |
|---|---|
| Usability | To validate the viability of using the proposed IoT framework for EHR retrieval of Malaysian pilgrims |
| Usefulness | To validate the compliance, conformance, and suitability to address the needs of EHR retrieval of Malaysian pilgrims |
| Flexibility | To validate the features and tasks flexibility of IoT framework for EHR retrieval of Malaysian pilgrims based on the changes that could happen in the medical management technology |
| Security | To validate the security level of IoT framework for EHR retrieval of Malaysian pilgrims |

The summative review technique is adopted to collect feedback from experts using semi-structured open-end questionnaire method. Summative review is a technique to collect feedback from experts and update or enhance the proposed framework according to the experts' comments (Khoja et al., 2007). Figure 6.1 illustrates the validation processes of proposed framework.

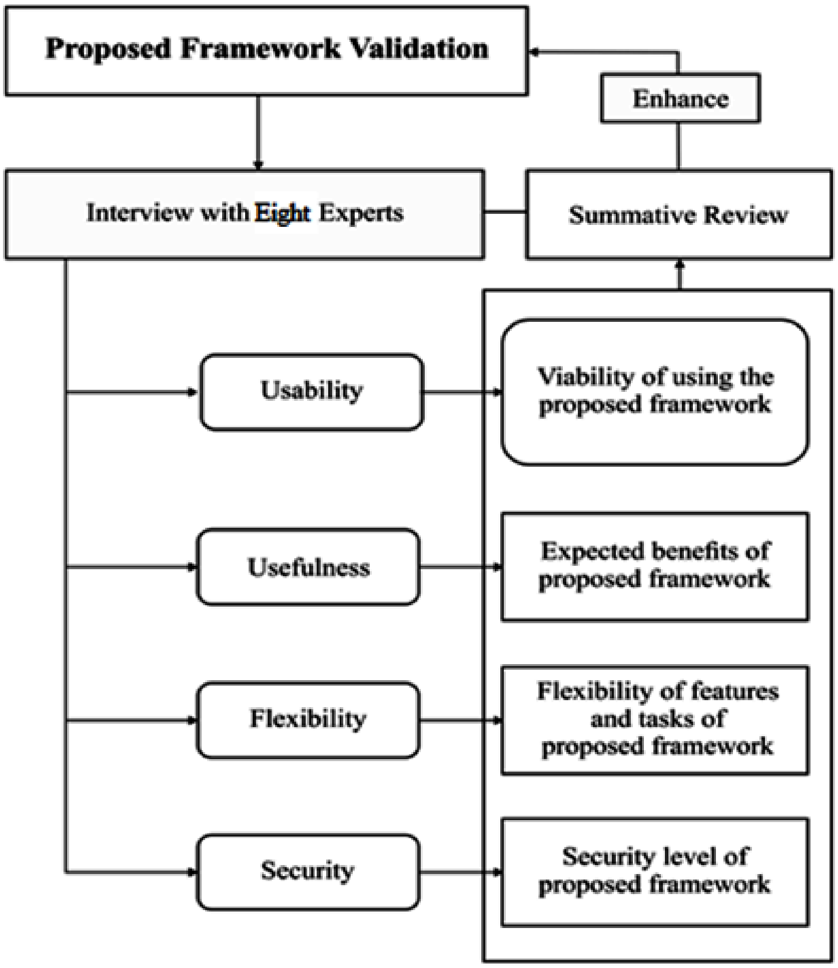


**Figure 6.1: Validation Process**

The next four sections discuss the validation results of proposed framework, and the last section summarizes the overall directions of this chapter.

### 6.1 Validation of Proposed Framework Usability

The main aim of usability validation is to validate the viability of using the proposed IoT framework for Malaysian pilgrim EHR retrieval. The responses by experts about the proposed framework usability is summarized as the following Table 6.2.

**Table 6.2: Responses Summary of Usability Validation**

| | Question#1 | Question#2 | Question#3 | Question#4 |
|---|---|---|---|---|
| **Expert#1** | Yes | Yes | Yes | Yes |
| **Expert#2** | Yes | Yes | Yes | Yes |
| **Expert#3** | Yes | Yes | Yes | Yes |
| **Expert#4** | Yes | Yes | Yes | Yes |
| **Expert#5** | Yes | Yes | Yes | Yes |
| **Expert#6** | Yes | Yes | Yes | Yes |
| **Expert#7** | No | Yes | No | No |
| **Expert#8** | Yes | Yes | Yes | Yes |

The first question was: Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? Seven experts agreed that the proposed framework can be developed practically as a communication system to retrieve Malaysian pilgrim EHR to enhance the healthcare services for Malaysian pilgrims in Hajj.

The second question was: Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT? All experts agreed that the proposed framework can be implemented using IoT facilities to retrieve Malaysian pilgrim EHR through an online network.

The third question was: Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? All experts, except one, are agreed that the proposed framework can avoid the conflicts of retrieving the Malaysian pilgrim EHR using traditional retrieval systems such as paper-based systems.

The fourth question was: Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? Seven experts agreed that the proposed framework can be developed easily as communication system due to good understanding of framework terminologies. However, one expert disagreed that the terminologies of proposed framework are clear. However, no comment was provided about this issue. It is important to highlight that it was the same expert who wasn't sure about the answer of the three questions. Upon further probing, he just mentioned that he can't decide about those aspects.

From the above Table 6.2, it can be noticed that the experts totally agree that the usability of proposed framework is valid. In other words, the proposed IoT framework can be developed and used as a system for Malaysian pilgrim EHR retrieval to enhance the healthcare services for Malaysian pilgrims in Hajj.

## 6.2 Validation of Proposed Framework Usefulness

The main aspects of usefulness that have been examined are the compliance, conformance, and suitability to address the needs of Malaysian pilgrim EHR retrieval. Table 6.3 summarizes the expert responses of usefulness validation.

The first question was: Has the framework adopted a suitable IT protocol such as IoT-FPEHR? Six experts agreed that the adopted IT protocol (IoT layers) is suitable for the purpose of Malaysian pilgrim EHR retrieval while three experts did not agree with the adopted IoT facilities. However, the disagreeing experts did not provide any comments about the reasons for their negative responses.

The second question was: Does the framework have structured layers for effective retrieval of EHR? The majority of the experts' responses show that the layers of proposed IoT framework are structured effectively. Two experts disagreed that the framework has structured layers for effective retrieval of EHR.

The third question was: Does the framework demonstrate a logical sequence of events? Six out of the eight experts see that the sequence of events of the proposed framework is managed logically, while two experts disagree that the proposed framework demonstrates a logical sequence of events. However, the disagreeing experts and the unsure one did not provide any comments about the reasons for their negative responses.

The fourth question was: Does the framework demonstrate well-structured database utilization? All the experts except one see that the proposed framework demonstrates a well-structured database for Malaysian pilgrim EHR retrieval.

**Table 6.3: Responses Summary of Usefulness Validation**

| | **Question#1** | **Question#2** | **Question#3** | **Question#4** |
|---|---|---|---|---|
| **Expert#1** | Yes | Yes | Yes | Yes |
| **Expert#2** | Yes | Yes | Yes | Yes |
| **Expert#3** | No | No | No | No |
| **Expert#4** | Yes | Yes | Yes | Yes |
| **Expert#5** | Yes | Yes | Yes | Yes |
| **Expert#6** | Yes | Yes | Yes | Yes |
| **Expert#7** | No | No | No | Yes |
| **Expert#8** | Yes | No | Not sure | Yes |

In the above table, it can be noticed that the experts totally agree that the proposed framework is useful for Malaysian pilgrim EHR retrieval to enhance the healthcare services of Malaysian pilgrims in Hajj.

## 6.3 Validation of Proposed Framework Flexibility

The flexibility validation includes the features and tasks flexibility of IoT framework for Malaysian pilgrim EHR retrieval based on the dynamic changes of medical management technology. Table 6.4 summarizes the expert responses of flexibility validation. The following are the responses to the questions related to flexibility validation.

The first question was: Do you think that the structure is flexible enough to cope with advances in medical management? The majority of the experts agree that the structure of proposed framework is flexible to cover the management issues in medical records retrieval. Two experts disagreed with this question. However, there are no further comments provided by the experts to enhance the flexibility of proposed framework.

The second question was: Do you think that the framework takes into account any change in priority of accessing the database? Half of the experts (4/8) agree that the proposed framework takes into account the priority of accessing the database, while other experts see that the proposed framework is not flexible enough to manage the priority of accessing the database. However, there are no further comments provided by the experts to enhance the issue of accessing database priority.

The third question was: Do you think that the framework can be adapted to different IT protocols? All experts, except one, agree that the proposed framework can be adapted to different IT protocols.

The fourth question was: Do you find that different alternatives have been set in case of unexpected events? Five out of the eight experts agree that the proposed framework is flexible to find that different alternatives have been set in case of unexpected events, while two experts disagreed with this question. However, there are no further comments provided by the experts to enhance the issue of unexpected events detection.

**Table 6.4: Responses Summary of Flexibility Validation**

| | Question#1 | Question#2 | Question#3 | Question#4 |
|---|---|---|---|---|
| **Expert#1** | Yes | No | Yes | Yes |
| **Expert#2** | Yes | Yes | Yes | No |
| **Expert#3** | No | No | No | Not Sure |
| **Expert#4** | Yes | Yes | Yes | Yes |
| **Expert#5** | Yes | Yes | Yes | Yes |
| **Expert#6** | No | No | Yes | Yes |
| **Expert#7** | Yes | No | Yes | No |
| **Expert#8** | Yes | Yes | Yes | Yes |

In the above table 6.4, it can be noticed that the experts totally agree that the proposed framework is flexible to support the Malaysian pilgrim EHR retrieval to enhance the healthcare services for Malaysian pilgrims in Hajj.

## 6.4 Validation of Proposed Framework Security

The main aim of proposed framework security validation is to validate the security level of IoT framework for Malaysian pilgrim EHR retrieval. Table 6.5 summarizes the expert responses of usefulness validation. The following are the responses according to the questions that related to security validation:

The first question was: Has the framework taken data encryption into consideration? Five out of the eight experts agree that the proposed framework security is assured through encrypting the Malaysian pilgrim EHR, while three experts did not agree with this question. However, there are no further comments provided by the experts to enhance the issue of data encryption.

The second question was: Has the framework taken firewall-related issues into consideration? Most of the experts (4/7) agree that the proposed framework takes firewall-related issues into consideration, while two experts did not agree with this question and unsure one. However, there are no further comments were provided by experts to enhance the firewall-related issues.

The third question was: Has the framework taken the protection of stored data into consideration? The majority of the experts (4/7) agree that the proposed framework has taken the protection of stored data into consideration. Two experts disagreed with this question while one wasn't sure. However, there are no further comments provided by the experts to enhance the data protection performance.

**Table 6.5: Responses Summary of Security Validation**

| | **Question#1** | **Question#2** | **Question#3** |
|---|---|---|---|
| **Expert#1** | No | No | No |
| **Expert#2** | No | No | No |
| **Expert#3** | Not sure | Not sure | Not sure |
| **Expert#4** | Yes | Yes | No |
| **Expert#5** | No | Yes | Yes |
| **Expert#6** | No | No | No |
| **Expert#7** | No | Yes | Yes |
| **Expert#8** | Yes | Yes | Yes |

From Table 6.5 above, it can be noted that the experts totally agree that the proposed framework is secure enough to support the Malaysian pilgrim EHR retrieval to enhance the healthcare services of Malaysian pilgrims in Hajj.

## 6.5 Chapter Summary

This chapter presents the validation processes and results of proposed IoT model for the purpose of Malaysian pilgrim EHR retrieval. The validation factors were about framework usability, usefulness, flexibility, and security. The significant results of validation show that the proposed framework is usable, useful, flexible, and secure to support the Malaysian pilgrim EHR retrieval to enhance the healthcare services of Malaysian pilgrims in Hajj. The next chapter summarizes the research findings and suggests further works based on the current research findings.

# CHAPTER 7

# CONCLUSIONS AND FUTURE WORKS

## 7.0 Introduction

This chapter summarizes the outcomes of this research according to research objectives. The contribution and implementations this research are also explained. In a glance, the various limitations of this research are also presented and recommendations for future works are proposed.

## 7.1 Summary of Research Outcomes

Retrieving EHR in real-time can enhance and speed up the health services that provided to pilgrims. Three research objectives were formulated to address the main aim of this research. The first objective was addressed using the questionnaire and observation data collection methods. The second objective was addressed using open-end questionnaire and focus group discussion methods. Furthermore, the literature review is important data source to support the first and second research objectives. The third research objective was addressed using the open-end questionnaire based on summative review technique. The details of the research objectives and how they were achieved is explained as follows:

### 7.1.1 Achievement of Objective 1

Objective 1 is to explore the prerequisites, challenges, and viability of utilizing IoT in the pilgrims' EHR retrieval across the countries.

In order to address this objective a questionnaire survey was conducted with 60 healthcare staff from health centres in KSA, and observing the healthcare services of Malaysian pilgrimages. The significant results of the collected data show that the current healthcare services in pilgrimage are not supportive by EHR. Hence, the use of EHR in pilgrimage could speed up and improve the quality of healthcare services. On the other hand, the health record retrieval in pilgrimage faces many challenges such as time, efforts, and financial costs. Thus, the EHR utilizing IoT is a promising solution to enhance the healthcare services and avoid the challenges of EHR implementations in pilgrimage.

### 7.1.2 Achievement of Objective 2

Objective 2 is to identify the most useful structure, facilities, and components of the proposed IoT-EHR framework.

In order to address this objective a data was collected through open-end survey with five experts who work in hospitals in KSA, and focus group discussion with six leaders from Tabung Haji Malaysia. The significant results of the collected data show that there are five main technical requirements of the proposed IoT-EHR framework; (1) data security and privacy, (2) transfer protocols based on data size, (3) characteristics of IoT facilities according to pilgrimage environment, (4) the distribution of IoT facilities based on the pilgrimage environment, and (5) the high priority to transfer the EHR. All of these technical issues and more are taken in the consideration of the proposed IoT-EHR framework.

### 7.1.3 Achievement of Objective 3

Objective 3 is to measure the validity of the proposed IoT-EHR framework.

Based on the various data collection sources, the proposed IoT-EHR framework is constructed. Firstly, the proposed IoT framework for EHR retrieval consists of four main layers (connectivity, access, abstraction, and service).

The conceptual framework of IoT is identified as four main layers: (1) connectivity layer, (2) access layer, (3) abstraction layer, and (4) service layer. The connectivity layer represents the RFID facilities which include the electronic tags and wireless sensor. The wireless sensor reads the data from electronic tags within a small range of space and relays it to access layer. In access layer, the super nodes read the data that collected from wireless sensors and relay it to base station. The space between wireless sensors and super nodes should be few meters (i.e. 100m) while the base station cover the super nodes with in many kilometers (i.e. 8km). The abstraction layer represents the network between base station and web server in service layer. The abstraction layer gathers the data between the access layer and the service layer. Lastly, the service layer provides the required data or information to connectivity layer via abstraction layer and access layer. The response data is usually displayed on output device in connectivity layer.

Based on the findings of first four objectives, in connectivity layer, the wireless sensors read the tags data (pilgrims ID) and the healthcare staff identify the request type health records (i.e. bold records or hearts records). The access layer, acquire data from connectivity layer and send it to service layer through abstraction layer. The acquired data are tag ID, type of requested records, and device IP that connected to wireless sensor. Once data request is submitted to service layer, the specific health record type of pilgrim ID will be retrieved and transferred to access layer via abstraction layer. Device IP that sends the request is transferred with retrieved records. The retrieved records are then delivered from access layer to output device that is connected with device IP.

The proposed IoT-EHR framework was validated based on four factors; usability, usefulness, flexibility, and security. The proposed framework was validated by eight experts' from Tabung Haji in Malaysia using semi-structured open-end survey based on summative review technique. The significance results of validation show that the proposed framework is usable, useful, flexible, and secure to support the EHR retrieval for Malaysian pilgrims in order to enhance the healthcare services of Malaysian pilgrims in Hajj.

## 7.2 Research Contribution

There are three main contributions of this research, which are the following:

### i. Develop RFID Model to Retrieve Pilgrim EHR

The RFID model represents the connectivity layer that includes the wireless sensors and electronic tags. In this model, the most suitable specifications of electronic tags and wireless sensor were analyzed according to pilgrimage environment. These specifications were analyzed depend on many variables such as spaces between the areas and cities that involve the pilgrimage activities, and the features that assure the effectiveness of tags and wireless deployment.

The contribution of the proposed model is that the RFID components are constructed based on pilgrimage environment. The proposed RFID model in this research address the lacks of previous RFID models for pilgrimage environment. The model of Mohandes et al. (2012) focused on real-time pilgrim tracking using RFID facilities. On the other hand, Gunasekaran and Suresh (2014) model focused on control of disaster protection using RFID to track the pilgrims in the natural disaster sites. Moreover, Nair and Daniel (2014) model was utilized the RFID to tracking and monitoring the pilgrims to assure the attending in planned locations. All of previous models were not covered the implementations of RFID for EHR retrieval. Hence, the proposed model in this research considered as new model of utilizing electronic tags reading to support the EHR retrieval from systematic database. The proposed model takes in the consideration the environmental and technical issues of pilgrimage.

### ii. b. Develop WSN Model to Retrieve Pilgrim EHR

The WSN model represents the access layer that includes the super nodes and base station. In this model, the most suitable specifications of super nodes and base station were analyzed according to pilgrimage environment.

These specifications were analyzed depend on many variables such as spaces between the areas and cities that involve the pilgrimage activities, and the placement approaches of super nodes and base stations.

The contribution of the proposed model is the filled gap of the previous models. Models such as (Mohandes et al., 2012), (Gunasekaran & Suresh, 2014), and (Nair & Daniel, 2014) was not covered the environmental and technical issues of WSN implementations in the pilgrimage. They were not focused on the distribution techniques of WSN resources according to pilgrimage facilities and distances. On the other hand, the previous models were not covered the security issues of transferred data via WSN resources. Moreover, the WSN utilizing for EHR retrieval was not explained by the previous models. Therefore, the proposed model covers the environmental and technical issues of WSN utilizing in EHR retrieval according to various specifications of pilgrimage environment.

### iii. c. Develop IoT Framework for Global Retrieval of Pilgrim EHR

In addition to development of connectivity layer (RFID) and access layer (WSN), the abstraction and services layers were developed in the context of global EHR retrieval for pilgrims. The integration between these four layers represents the full map of IoT framework. This framework allows the healthcare staff in KSA to request and retrieve EHR of Malaysian pilgrims from databases that are located in Malaysia.

All of the previous models such as Nizari and Amer (2011), Mohandes et al. (2012), Gunasekaran and Suresh (2014), and Nair, A. M., & Daniel, S. J. (2014) were focused on IoT for local implementations in pilgrimage environment. The abstraction and services layers were not adopted by these models for global IoT implementations. Actually, the previous models were not focused on the global pilgrims EHR retrieval. Thus, the proposed model considered as new model for the purpose of EHR retrieval between countries. The proposed model takes in the account the various technical and environmental issues of IoT utilizing for global EHR retrieval such as the distance coverage, manage the transfer EHR, secure the transfer HER, the languages, the central database management, the structure and components of IoT layers, and the sequence and attributes of EHR transactions.

## 7.3 Research Implications

There are various benefits of proposed IoT framework for EHR retrieval. The most important implications are as follows:

- In pilgrimage, the healthcare staff can provide healthcare services for Malaysian pilgrims effectively in less time based on the historical EHR of pilgrims.

- Reduces the communication complexity between healthcare staff in KSA and Malaysian pilgrims through provide EHR based on English language and various formats i.e. video and text.

- Allows the collaboration between KSA and Malaysian healthcare staff in case of complex health cases. The proposed framework allows the healthcare staff in KSA to see the recommendations of Malaysian healthcare staff, and provide hot contacts with specific doctors that understand the health case of each pilgrim.

- In cases of lost pilgrims, the KSA police can find the pilgrims by tracking their electronic tags.

- In cases of pilgrimage accidents, Malaysian and KSA governments can identify the positions of Malaysian pilgrims in real-time through their electronic tags, and know if these pilgrims are near or far from the accident area. Thus, they can estimate the safety situation of Malaysian pilgrims and provide real-time reports depend on this estimation.

- The healthcare staff in KSA can update the EHR of pilgrims based on the provided health services. Hence, the EHR updates can be included in historical reports and seen in future by other doctors in Malaysia for accurate health services.

- The retrieval and updating of pilgrim EHR by healthcare staff in KSA allow the Malaysian government to understand how to prepare the pilgrims in future through many procedures such as doing specific tests and giving the pilgrims the necessary medications.

- The proposed IoT framework allows the Malaysian government to track the path and current positions of Malaysian pilgrims and perform some procedures such as delay the movement to next pilgrimage if this area is risky (i.e. heavy rain).

## 7.4 Research Limitations

There are many limitations facing the development of IoTframework for EHR retrieval. These limitations can be summarized as follows:

- Evidences limitation of global EHR retrieval utilizing IoT: limitation of theoretical and practical works on IoTframework for global pilgrims EHR retrieval increases the difficulty of construct the proposed framework. Thus, several data collection methods were conducted to analyze the perspective of KSA and Malaysia about the aspects of the proposed framework.

- Development of practical system: the privacy of pilgrims' data and necessity to make primary agreement between KSA and Malaysian government prevents the possibility of developing a practical or real system to deploy the proposed framework.

## 7.5 Future Works

The results of this research show that the proposed framework is valid for global EHR retrieval for Malaysian pilgrims. Many future works can be conducted based on current research outcomes such as follows:

- Develop a model for electronic tag tracking: the current RFID and WSN models allow the tracking of electronic tags within specific areas. For effective tracking of electronic tags positions, it is required to distribute the wireless sensors, super nodes, and base stations to cover the whole spaces of pilgrimage area. This requires careful analysis of various RFID and WSN specifications based on static placement approach of IoT facilities.

- Simulation of proposed IoT framework: the simulation of proposed framework is necessary before the real deployment as a system. The simulation requires real EHR for some Malaysian pilgrims, produce electronic tags for these pilgrims, apply wireless sensors in some place in pilgrimage are, and apply the full IoT map between KSA and Malaysia. This simulation can detect the benefits and proposed enhancement on the proposed IoT framework.

- To conduct research to proposed IoT framework for monitoring and tracking systems in various domains such as patients (new born children) in hospitals, wild life, and students in schools.

# APPENDICES

## Appendix A: Questionnaire of KSA Healthcare Providers

Dear Respondent:

I am now doing research on “IOT Utilization in EHR Retrieval for Pilgrims”. I would highly appreciate if you could spare some time to complete the questionnaire. Your cooperation is very essential to my research. You will be asked to answer questions related to your experience and knowledge about healthcare services in Hajj. This is not a quiz or test, so there are no right or wrong answers. Your answers will be kept confidential. By answering the questions, you give consent to participate in this study.

Thank you for your cooperation.

**Part A: Demographic Data**

- Gender
  1. Male
  2. Female

- Age
  1. Less than 20 Years
  2. 20-30 years
  3. 31-40 years
  4. 41-50 years
  5. More than 50 years

- Job Role
  1. Doctors
  2. Nurse
  3. Assistance staff
  4. Others, specify…

- Experience Years
  1. Less than 2 years
  2. 2-4 years
  3. 4-7 years
  4. More than 7 years

- Working Status
  1. Full Time
  2. Part time

- Number of Hajj seasons attended
  1. Less than 2 seasons
  2. 2- 4 seasons
  3. 4-7 seasons
  4. More than 7 seasons

**Part B: Availability Domain**

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 1 | Each pilgrims has his/her personal records | | | | | |
| 2 | Each pilgrims has his/her health records | | | | | |
| 3 | Health records are continuously updated | | | | | |
| 4 | Pilgrim can access his/her own records | | | | | |
| 5 | There is systematic methods to access/archive health records of pilgrims | | | | | |
| 6 | The department have a electronic management for healthcare and emergencies | | | | | |
| 7 | There is necessity to store and retrieve the pilgrims health records in different format i.e. images and texts | | | | | |

## Part C: Challenges of EHR

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 8 | There is not enough staff to manage the electronic systems of healthcare | | | | | |
| 9 | The staff does not have enough computer skills to manage the electronic systems of healthcare | | | | | |
| 10 | There are not enough technology facilities to deploy the electronic systems of healthcare | | | | | |
| 11 | There is budget limitation in developing and deploying the electronic systems of healthcare | | | | | |
| 12 | Privacy of health data limits the use of the electronic systems of healthcare | | | | | |
| 13 | The traditional healthcare approaches (i.e. paper based) delay the health services of pilgrims | | | | | |
| 14 | The traditional healthcare approaches (i.e. paper based) decrease the understanding of health cases | | | | | |
| 15 | The traditional healthcare approaches (i.e. paper based) increase the expenses of healthcare services | | | | | |
| 16 | There are challenges in understanding the non-Arabic pilgrims in the context of healthcare services | | | | | |

## Part D: Importance of EHR

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 17 | EHR speeds up the healthcare services | | | | | |
| 18 | EHR supports the accuracy of healthcare services | | | | | |
| 19 | EHR-based Arabic language increases the usefulness of healthcare services | | | | | |
| 20 | EHR-based Arabic language makes the healthcare services easier | | | | | |
| 21 | EHR can increase the performance of communication with pilgrim's country (i.e. health ministry) to describe health cases accurately | | | | | |
| 22 | EHR decreases the expense of traditional healthcare approaches (i.e. paper-based) | | | | | |

**Appendix A1: Validators' profile**

| N | Profile | Expert 1 | Expert 2 |
|---|---|---|---|
| 1 | Designation | IT executive | Lecturer |
| 2 | Working place /institute | Tabung Hajj | UiTM |
| 3 | Age | 47 years | 43 years |
| 4 | Gender | Male | Male |
| 5 | Years of experience | 18 years | 9 years |
| 6 | Area of Specialty | Analyst | Questionnaire Design |

## Appendix A2: Sample Response from KSA Healthcare Providers

Dear Respondent:

I am now doing research on "IOT Utilization in EHR Retrieval for Pilgrims". I would highly appreciate if you could spare some time to complete the questionnaire. Your cooperation is very essential to my research. You will be asked to answer questions related to your experience and knowledge about healthcare services in Hajj. This is not a quiz or test, so there are no right or wrong answers. Your answers will be kept confidential. By answering the questions, you give consent to participate in this study.

Thank you for your cooperation.

**Part A: Demographic Data**

- Gender
  1- Male
  2- Female
- Age
  1- Less than 20 years
  2- 20-30 years
  3- 31-40 years
  4- 41-50 years
  5- More than 50 years
- Job Role
  1- Doctors
  2- Nurse
  3- Assistance staff
  4- Others, specify…

- Experience Years
  1- Less than 2 years
  2- 2-4 years
  3- 4-7 years
  4- More than 7 years

- Working Status
  1- Full Time
  2- Part time

- Number of Hajj seasons attended
  1- Less than 2 seasons
  2- 2- 4 seasons
  3- 4-7 seasons
  4- More than 7 seasons

**Part B: Availability Domain**

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 1 | Each pilgrims has his/her personal records | | | | ✓ | |
| 2 | Each pilgrims has his/her health records | | | | | ✓ |
| 3 | Health records are continuously updated | | | ✓ | | |
| 4 | Pilgrim can access his/her own records | | | | ✓ | |
| 5 | There is systematic methods to access/archive health records of pilgrims | | | | ✓ | |
| 6 | The department have a electronic management for healthcare and emergencies | | | | ✓ | |
| 7 | There is necessity to store and retrieve the pilgrims health records in different format i.e. images and texts | | | | | ✓ |

**Part C: Challenges of EHR**

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 8 | There is not enough staff to manage the electronic systems of healthcare | | | | ✓ | |
| 9 | The staff does not have enough computer skills to manage the electronic systems of healthcare | | | | | ✓ |
| 10 | There are not enough technology facilities to deploy the electronic systems of healthcare | | | ✓ | | |
| 11 | There is budget limitation in developing and deploying the electronic systems of healthcare | | | ✓ | | |
| 12 | Privacy of health data limits the use of the electronic systems of healthcare | | | | | ✓ |
| 13 | The traditional healthcare approaches (i.e. paper based) delay the health services of pilgrims | | | | ✓ | |
| 14 | The traditional healthcare approaches (i.e. paper based) decrease the understanding of health cases | | | | ✓ | |
| 15 | The traditional healthcare approaches (i.e. paper based) increase the expenses of healthcare services | | | | ✓ | |
| 16 | There are challenges in understanding the non-Arabic pilgrims in the context of healthcare services | | | | | ✓ |

**Part D: Importance of EHR**

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 17 | EHR speeds up the healthcare services | | | | | ✓ |
| 18 | EHR supports the accuracy of healthcare services | | | | | ✓ |
| 19 | EHR-based Arabic language increases the usefulness of healthcare services | | | | ✓ | |
| 20 | EHR-based Arabic language makes the healthcare services easier | | | | ✓ | |
| 21 | EHR can increase the performance of communication with pilgrim's country (i.e. health ministry) to describe health cases accurately | | | | | ✓ |
| 22 | EHR decreases the expense of traditional healthcare approaches (i.e. paper-based) | | | ✓ | | |

Dear Respondent:

I am now doing research on "IOT Utilization in EHR Retrieval for Pilgrims". I would highly appreciate if you could spare some time to complete the questionnaire. Your cooperation is very essential to my research. You will be asked to answer questions related to your experience and knowledge about healthcare services in Hajj. This is not a quiz or test, so there are no right or wrong answers. Your answers will be kept confidential. By answering the questions, you give consent to participate in this study.

Thank you for your cooperation.

**Part A: Demographic Data**

- Gender
  1- Male
  2- Female

- Age
  1- Less than 20 years
  2- 20-30 years
  3- 31-40 years
  4- 41-50 years
  5- More than 50 years

- Job Role
  1- Doctors
  2- Nurse
  3- Assistance staff
  4- Others, specify…

- Experience Years
  1- Less than 2 years
  2- 2-4 years
  3- 4-7 years
  4- More than 7 years

- Working Status
  1- Full Time
  2- Part time

- Number of Hajj seasons attended
  1- Less than 2 seasons
  2- 2- 4 seasons
  3- 4-7 seasons
  4- More than 7 seasons

**Part B: Availability Domain**

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 1 | Each pilgrims has his/her personal records | | | | X | |
| 2 | Each pilgrims has his/her health records | | | X | | |
| 3 | Health records are continuously updated | | | X | | |
| 4 | Pilgrim can access his/her own records | | | | X | |
| 5 | There is systematic methods to access/archive health records of pilgrims | | | | X | |
| 6 | The department have a electronic management for healthcare and emergencies | | | X | | |
| 7 | There is necessity to store and retrieve the pilgrims health records in different format i.e. images and texts | | | | X | |

**Part C: Challenges of EHR**

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 8 | There is not enough staff to manage the electronic systems of healthcare | | | | | X |
| 9 | The staff does not have enough computer skills to manage the electronic systems of healthcare | | | X | | |
| 10 | There are not enough technology facilities to deploy the electronic systems of healthcare | | X | | | |
| 11 | There is budget limitation in developing and deploying the electronic systems of healthcare | | | | X | |
| 12 | Privacy of health data limits the use of the electronic systems of healthcare | | | | | X |
| 13 | The traditional healthcare approaches (i.e. paper based) delay the health services of pilgrims | | | | X | |
| 14 | The traditional healthcare approaches (i.e. paper based) decrease the understanding of health cases | | | | X | |
| 15 | The traditional healthcare approaches (i.e. paper based) increase the expenses of healthcare services | | | | | X |
| 16 | There are challenges in understanding the non-Arabic pilgrims in the context of healthcare services | | | | X | |

**Part D: Importance of EHR**

| Item Number | Item | SD | D | N | A | SA |
|---|---|---|---|---|---|---|
| 17 | EHR speeds up the healthcare services | | | | | X |
| 18 | EHR supports the accuracy of healthcare services | | | | | X |
| 19 | EHR-based Arabic language increases the usefulness of healthcare services | | | | | X |
| 20 | EHR-based Arabic language makes the healthcare services easier | | | | | X |
| 21 | EHR can increase the performance of communication with pilgrim's country (i.e. health ministry) to describe health cases accurately | | | | | X |
| 22 | EHR decreases the expense of traditional healthcare approaches (i.e. paper-based) | | | | X | |

## Appendix B: Open-end Survey with Healthcare Professional in KSA

Dear expert

Asslamao Alaikom and Good day

I am Ali Ibrahim Latif, a PhD student at college of information technology, Universiti Tenaga Nasional, Malaysia. I am at the last stage of my research entitled "INTERNET OF THINGS FRAMEWORK FOR ELECTRONIC HEALTH RECORD RETRIEVAL OF MALAYSIAN PILGRIMS". I present list of questions to elicit your kind opinion in regards to the stated attributes of the proposed framework which are Electronic Health Records (EHR) and Internet of Things (IoT).

- **Importance of EHR in Pilgrimage**

1. What do you think about importance of EHR in providing healthcare services to pilgrims?

………………………………………………………………………………….
………………………………………………………………………………..

2. Are historical health reports used to support the health services during pilgrimage?

………………………………..…………………………………………….. 
………………………………..…………………………………………….. 

3. Is there necessity to adopt EHR for health services in pilgrimage?

……………..…………………..……………………………………………..
………………………….……………………………………………..…..

- **Challenges of EHR Implementations in Pilgrimage**

1. What the limitations of utilizing EHR systems to support health services in pilgrimage?
………………………………………………..…………………………
…..……………………………………………………………………………

2. What are the technical challenges of utilizing EHR systems to support health services in pilgrimage?
…………………………………………..………………………………
……………………………………………………………………………..

3. What are the environmental challenges of utilizing EHR systems to support health services in pilgrimage?
……………………………………………………………………………..
………...……………………………………………………………………

4. According to your opinion, is it applicable to utilize EHR systems to support health services in pilgrimage?
……………..……………..………………………………………………
……………………………………………………………………………...

- **EHR Utilizing IoT in Pilgrimage**

1. According to your experiences, is it viable to utilize tag reading to retrieve pilgrims' EHR from database that is located in their countries?
………………………………………………………………………………
………………………………………………………………………………

2. What are the advantages of utilizing IoT for retrieval of patients' EHR in pilgrimage?
…..……………………………………………………………………………..
………………………………………………………………………………

3. How can we avoid the challenges of current health records retrieval methods by utilizing IoT for EHR retrieval in pilgrimage?

…………….………………………………………………...……………………
……………………………………………………………………………………

- **Personal Information of Experts:**

Thank you for answering the questions

Name: …………………………………………….. (Optional)

Designation/Position:………………………………………. Expertise Domain:......................

Years of experience:……………………………………….

Signature/Stamp

## Appendix B1: Profile of Healthcare Experts from KSA

| No. | Name | Position | Years of experience | Hospital | City |
|---|---|---|---|---|---|
| 1 | Dr. Said Hamid Said | QC Manager | 10 | Al-Ansar | Medina |
| 2 | Anissa Helen Alug | IT coordinator | 7 | Alawi Tunsi | Mecca |
| 3 | Dr. Salem mohammed | Ophthalmologist | 16 | King Faisal | Mecca |
| 4 | Fahad Othman | IT Manager | 12 | King Faisal | Mecca |
| 5 | Dr. Lojayn Adil | Practicing Physician | 4 | Al Amal | Jeddah |

## Appendix B2: Sample Answers of Open-end Survey from KSA Healthcare Professional

3. What are the environmental challenges of utilizing EHR systems to support health services in pilgrimage?

   ……not much as of save environment For Both countries.……

4. According to your opinion, is it applicable to utilize EHR systems to support health services in pilgrimage?

   ……yes, need resources and time……

   ……………………………………………………………

- **EHR Utilizing IoT in Pilgrimage**

1. According to your experiences, is it viable to utilize tag reading to retrieve pilgrims' EHR from database that is located in their countries?

   ……according to the countries database and EHR, but internet and It is more ways now.

2. What are the advantages of utilizing IoT for retrieval of patients' EHR in pilgrimage?

   ……Simplify treatment plans, History and decrease cost, improve quality and integrity.

3. How can we avoid the challenges of current health records retrieval methods by utilizing IoT for EHR retrieval in pilgrimage?

   ……By planning, Implementing and studying.

   ……………………………………………………………

- **Personal Information of Experts:**

Thank you for answering the questions

Name: ……Dr. Sayed Hamid…… (Optional)

Designation/Position: Director TQM and PS…… Expertise Domain: TQM - HIS

Years of experience: ……11 Years……

……Hamid (signature)

Signature/Stamp

مستشفى الأنصار - إدارة الجودة

مستشفى الانصار العام
المدينة المنورة

د. سيد حامد سعيد
مدير ادارة الجودة

جوال : 0509382991
فاكس: 04-8362208
ايميل forsayed@gmail.com
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صندوق بريد 41047
رمز البريدى 41521
المدينة المنورة ، المملكة العربية السعودية

2

3. What are the environmental challenges of utilizing EHR systems to support health services in pilgrimage?
...........not much as of save environment For Both countries.........................................

4. According to your opinion, is it applicable to utilize EHR systems to support health services in pilgrimage?
........Yes, need resources and time.......
..........................................................................................

- **EHR Utilizing IoT in Pilgrimage**

1. According to your experiences, is it viable to utilize tag reading to retrieve pilgrims' EHR from database that is located in their countries?
......according to the countries database and EHR, but internet and It is more ways now.

2. What are the advantages of utilizing IoT for retrieval of patients' EHR in pilgrimage?
...Simplify treatment Plans, History and decrease cost, improve quality and integrity.

3. How can we avoid the challenges of current health records retrieval methods by utilizing IoT for EHR retrieval in pilgrimage?
...By Planning, Implementing and studying.
..........................................................................................

- **Personal Information of Experts:**

Thank you for answering the questions

Name: ...Dr. Sayed Hamid............ (Optional)

Designation/Position:. Director TQM and PS.... Expertise Domain: TQM - HIS

Years of experience:.........11 Years.........................

....[signature]
18/2/18.
Signature/Stamp


مستشفى الانصار العام
المدينة المنورة
د. سيد حامد سعيد
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رمز البريدي 41521
المدينة المنورة ، المملكة العربية السعودية


2

Dear expert

Asslamao Alaikom and Good day

I am Ali Ibrahim Latif, a PhD student at college of information technology, Universiti Tenaga Nasional, Malaysia. I am at the last stage of my research entitled "INTERNET OF THINGS FRAMEWORK FOR ELECTRONIC HEALTH RECORD RETRIEVAL OF MALAYSIAN PILGRIMS". I present list of questions to elicit your kind opinion in regards to the stated attributes of the proposed framework which are Electronic Health Records (EHR) and Internet of Things (IoT).

- **Importance of EHR in Pilgrimage**

1. What do you think about importance of HER in providing healthcare services to pilgrims?

   EHR is important in providing healthcare services to pilgrims as this kind of program allows access to external tools and information that can be used to make decisions.

2. Are historical health reports used to support the health services during pilgrimage?

   yes.

3. Is there necessity to adopt EHR for health services in pilgrimage?

   yes, if needed

- **Challenges of EHR Implementations in Pilgrimage**

1. What the limitations of utilizing EHR systems to support health services in pilgrimage?

   None, there are no limitations.

2. What are the technical challenges of utilizing EHR systems to support health services in pilgrimage?

   There may be a limited use of key functions

3. What are the environmental challenges of utilizing EHR systems to support health services in pilgrimage?

There are none

4. According to your opinion, is it applicable to utilize EHR systems to support health services in pilgrimage?

yes if the program can be supported then it will be benefcial to health services

- **EHR Utilizing IoT in Pilgrimage**

1. According to your experiences, is it viable to utilize tag reading to retrieve pilgrims' EHR from database that is located in their countries?

yes, if scanning devices are available

2. What are the advantages of utilizing IoT for retrieval of patients' EHR in pilgrimage?

Data and information can be accessed at any time

3. How can we avoid the challenges of current health records retrieval methods by utilizing IoT for EHR retrieval in pilgrimage?

challenges of current health records retrieval can be avoided by utilizing effective and efficient systems

- **Personal Information of Experts:**

Thank you for answering the questions

Name: Dallal Petros (Optional)

Designation/Position: System analyst Expertise Domain: It Expert

Years of experience: more than 10

Signature/Stamp

Dear expert

Asslamao Alaikom and Good day

I am Ali Ibrahim Latif, a PhD student at college of information technology, Universiti Tenaga Nasional, Malaysia. I am at the last stage of my research entitled "INTERNET OF THINGS FRAMEWORK FOR ELECTRONIC HEALTH RECORD RETRIEVAL OF MALAYSIAN PILGRIMS". I present list of questions to elicit your kind opinion in regards to the stated attributes of the proposed framework which are Electronic Health Records (EHR) and Internet of Things (IoT).

- **Importance of EHR in Pilgrimage**

1. What do you think about importance of HER in providing healthcare services to pilgrims?

   EHR ~~HER~~ as I understand is an external program that provides health information for a patient. It is indeed an excellent idea although it might require extra effort for the physicians.

2. Are historical health reports used to support the health services during pilgrimage?

   YES

3. Is there necessity to adopt EHR for health services in pilgrimage?

   YES, IF REQUIRED.

- **Challenges of EHR Implementations in Pilgrimage**

1. What the limitations of utilizing EHR systems to support health services in pilgrimage?

   NONE

2. What are the technical challenges of utilizing EHR systems to support health services in pilgrimage?

   DEVICE USED COMPATIBILITY
   PROGRAMMING IF NEEDED

1

3. What are the environmental challenges of utilizing EHR systems to support health services in pilgrimage?

NONE

4. According to your opinion, is it applicable to utilize EHR systems to support health services in pilgrimage?

YES IT IS APPLICABLE WITH EXTRA EFFORTS.

- **EHR Utilizing IoT in Pilgrimage**

1. According to your experiences, is it viable to utilize tag reading to retrieve pilgrims' EHR from database that is located in their countries?

VIABLE IF SCANNING DEVICES ARE AVAILABLE WITH REQUIRED APP

2. What are the advantages of utilizing IoT for retrieval of patients' EHR in pilgrimage?

HEALTH INFORMATION AVAILABILITY AT ANYTIME

3. How can we avoid the challenges of current health records retrieval methods by utilizing IoT for EHR retrieval in pilgrimage?

CHALLENGES WILL ALWAYS BE THERE. BUT AN EFFICIENT SYSTEM FRIENDLY-USER SYSTEM WILL MINIMIZE THE CHALLENGES.

- **Personal Information of Experts:**

Thank you for answering the questions

Name: ANISSA HELW (Optional)

Designation/Position: SYSTEM ANALYST Expertise Domain: APPLICATION

Years of experience: 30 YRS

Signature/Stamp

Medical Report
Alawi Tunsi Hospital

2

Dear expert

Asslamao Alaikom and Good day

I am Ali Ibrahim Latif, a PhD student at college of information technology, Universiti Tenaga Nasional, Malaysia. I am at the last stage of my research entitled "INTERNET OF THINGS FRAMEWORK FOR ELECTRONIC HEALTH RECORD RETRIEVAL OF MALAYSIAN PILGRIMS". I present list of questions to elicit your kind opinion in regards to the stated attributes of the proposed framework which are Electronic Health Records (EHR) and Internet of Things (IoT).

- **Importance of EHR in Pilgrimage**

1. What do you think about importance of HER in providing healthcare services to pilgrims?
   EHR can provide knowledge and information to individuals
2. Are historical health reports used to support the health services during pilgrimage?
   Yes
3. Is there necessity to adopt EHR for health services in pilgrimage?
   Yes

- **Challenges of EHR Implementations in Pilgrimage**

1. What the limitations of utilizing EHR systems to support health services in pilgrimage?
   Little to none
2. What are the technical challenges of utilizing EHR systems to support health services in pilgrimage?
   None

3. What are the environmental challenges of utilizing EHR systems to support health services in pilgrimage?

None.................................................................................................

.......................................................................................................

4. According to your opinion, is it applicable to utilize EHR systems to support health services in pilgrimage?

Yes...................................................................................................

.......................................................................................................

- **EHR Utilizing IoT in Pilgrimage**

1. According to your experiences, is it viable to utilize tag reading to retrieve pilgrims' EHR from database that is located in their countries?

Yes...................................................................................................

.......................................................................................................

2. What are the advantages of utilizing IoT for retrieval of patients' EHR in pilgrimage?

Acces to better healthcare...........................................................................

.......................................................................................................

3. How can we avoid the challenges of current health records retrieval methods by utilizing IoT for EHR retrieval in pilgrimage?

N/A..................................................................................................

.......................................................................................................

- **Personal Information of Experts:**

Thank you for answering the questions

Name: Amir Braz.............................. (Optional)

Designation/Position: Manager.............................. Expertise Domain: IT Management

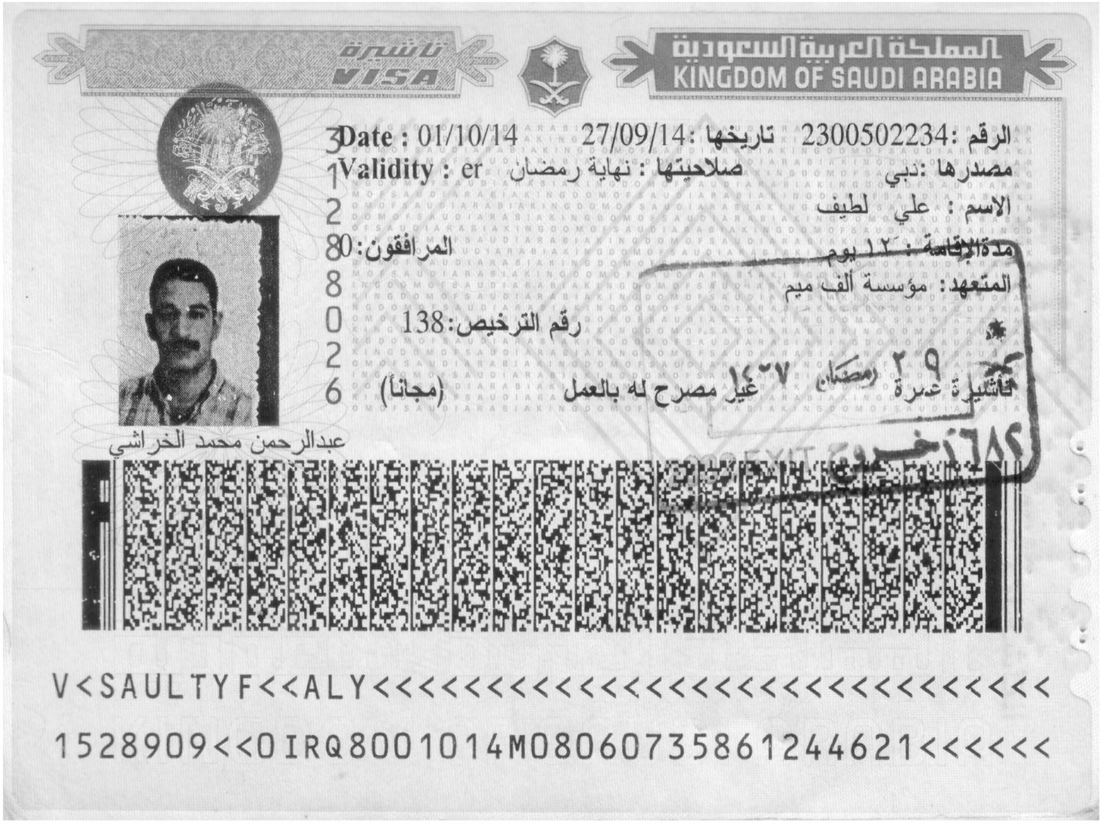
Years of experience: 12..............................

...................

Signature/Stamp

## Appendix C: Umrah Details for Observation

The researcher travelled to the KSA for Umrah in 2014, accompanied fellow Malaysian pilgrims in all Umrah activities, and took note of the healthcare services that were provided to some Malaysians pilgrims.



# Appendix D: Focus Group Discussion

## Questions for 1st Focus Group Discussion

Question 1: What might be needed to implement EHR sharing framework?

Question 2: What problems do you encounter with the data format of the EHR?

Question 3:What do you think about privacy, security and reliability of a web-based EHR?

Question 4: What problems do you anticipate in obtaining the necessary privileges to access the shared records?

Question 5: What is the pain point of your current practice in the management and sharing of EHR?

Question 6: What are your expectations about efficient sharing framework?

Question 7: What are the expected benefits of implementing EHR?

Question 8: How is patient privacy and confidentiality maintained in your organization?

Question 9: What happens to the new information as it arrives?

Question 10: In your opinion, what are the enablers for the EHR in your organisation?

## Questions for 2nd Focus Group Discussion

Question 1: Do you see benefits of tags over pen drives or CDs?

Question 2: What are the areas of IoT applications in healthcare?

Question 3: How can the health records of pilgrims be collected?

Question 4: Are the records stored based on global language?

Question 5: What are the enablers of IoT in Hajj?

Question 6: What are the challenges that you might see regarding IoT?

Question 7: Does the government set some standards for initiating and using IoT?

Question 8: Do you find any security privacy/ethical/legal concerns with utilizing tag reading for EHR retrieval?

Question 9: Do you think roaming and network switching is well-developed in Malaysia and KSA?

# Appendix D1: Sample Transcription of Focus Group Discussion

**Sample transcription of Focus group discussion**

**FGD:** 1st round
**Moderator:** Ali Ibrahim LAtif
**Date of Interview:** 24 February 2014
**Location of Interview:** Tabung Hajji meeting room level 3

List of Acronyms: AI=ALI IBRAHIM, ZZ=ZULQARNAIN ZULKIFLI ML=MOHAMED LUQMAN HI=HAFIZI ISMAIL IZ=IZZUDDIN MUSTAPA ZM: ZAMBI MUSA MA: MOHD AMIRUL ZZAKI MM: MAZNAH BINTI MOHAMAD IS: INTAN SURAYA BINTI MOHD BUKHARI

Transcript 00:00:43

AI: What might be needed to implement EHR sharing framework?

ZZ: Well, it is known that for every new service you need to provide a budget, infrastructure and capacity building in terms of hardware and software along with staff training. In my opinion requirement are well identified but the procurement and supply is a challenge.

IZ: Ye, only that.

[00:00:36]

MM: Staff training and skill acquisition seems the most important aspect that you need to look after. Providing a new technology or idea won't be feasible if you don't have motivated staff with enough experience to pursue the project. These my two cents

We had some request form other agency for service improvement but we failed to oblige due to lack of funding.

IS: I agree.

ML: Don't forget the number of staff needed, payment, wedges and so forth. Our country is suffering as a part of global economic recession.

[End Transcript 00:01:19]

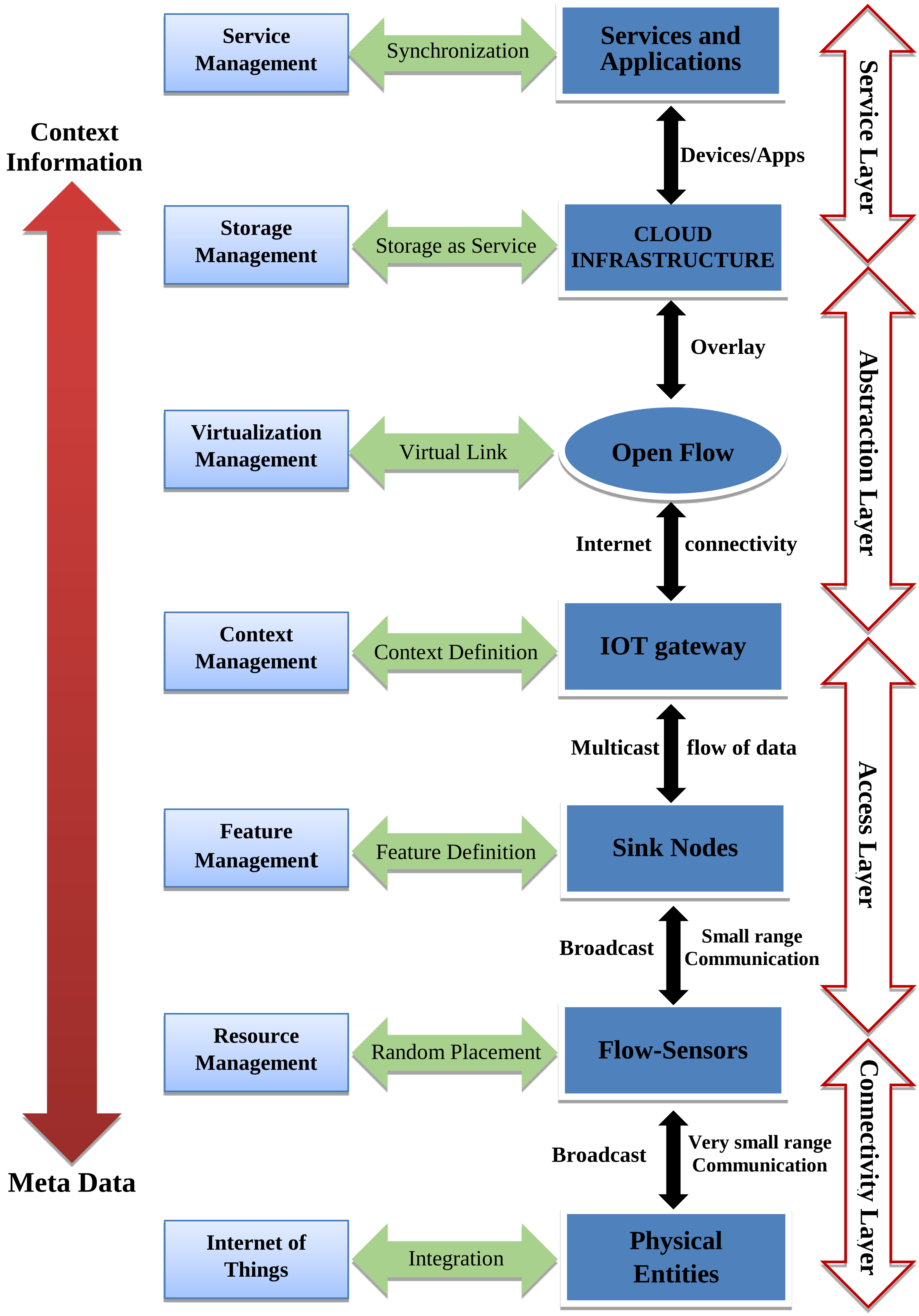
## Appendix E: Framework Validation Questionnaire

Dear expert

AsslamaoAlaikom and Good day

I am Ali Ibrahim Latif, a PhD student at college of information technology, Universiti Tenaga Nasional. I am at the last stage of my research entitled “INTERNET OF THINGS FRAMEWORK FOR ELECTRONIC HEALTH RECORD RETRIEVAL OF MALAYSIAN PILGRIMS”. I have proposed the below-shown framework after going through many steps; the last one was similar to this in regards to having expert opinion about the framework. The last round experts from your esteemed organization had given their comments, so we refined the framework and presented it again for final opinion before submission for further action.

I will appreciate some of your time to answer the following questions after checking the framework



Service Management
Synchronization
Services and Applications
Service Layer
Context Information
Devices/Apps
Storage Management
Storage as Service
CLOUD INFRASTRUCTURE
Overlay
Abstraction Layer
Virtualization Management
Virtual Link
Open Flow
Internet
connectivity
Context Management
Context Definition
IOT gateway
Multicast
flow of data
Access Layer
Feature Management
Feature Definition
Sink Nodes
Broadcast
Small range Communication
Resource Management
Random Placement
Flow-Sensors
Connectivity Layer
Broadcast
Very small range Communication
Meta Data
Internet of Things
Integration
Physical Entities

**Please tick the answer with (✓)**

| Validation Factor | Questions | Yes | No |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | | |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | | |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | | |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | | |
| | Does the framework have structured layers for effective retrieval of EHR? | | |
| | Does the framework demonstrate a logical sequence of events? | | |
| | Does the framework demonstrate well-structured database utilization? | | |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | | |
| | Do you think that the framework takes into account any change in priority of accessing the database? | | |
| | Do you think that the framework can be adapted to different IT protocols? | | |
| | Do you find that different alternatives have been set in case of unexpected events? | | |
| Security | Has the framework taken data encryption into consideration? | | |
| | Has the framework taken firewall-related issues into consideration? | | |
| | Has the framework taken the protection of stored data into consideration? | | |

Thank you for answering the questions
Name: …………………………………………….. (Optional)
Designation:………………………………………
Years of experience:……………………………………….

Signature/Chop

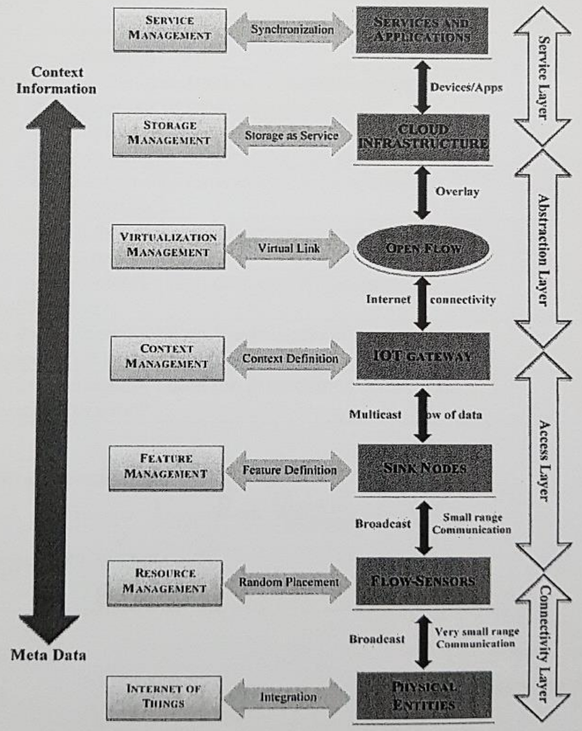
# Appendix E1: Sample of Validation Response

Dear expert

Asslamao Alaikom and Good day

I am Ali Ibrahim Latif, a PhD student at college of information technology, Universiti Tenaga Nasional. I am at the last stage of my research entitled "INTERNET OF THINGS FRAMEWORK FOR ELECTRONIC HEALTH RECORD RETRIEVAL OF MALAYSIAN PILGRIMS". I have proposed the below-shown framework after going through many steps; the last one was similar to this in regards to having expert opinion about the framework. The last round experts from your esteemed organization had given their comments, so we refined the framework and presented it again for final opinion before submisiion for further action.

I will appreciate some of your time to answer the following questions after checking the framework



**Please tick the answer with (✓)**

| Validation Factor | Questions | Yes | NO |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | ✓ | |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | ✓ | |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | ✓ | |
| | Does the framework have structured layers for effective retrieval of EHR? | ✓ | |
| | Does the framework demonstrate a logical sequence of events? | ✓ | |
| | Does the framework demonstrate well-structured database utilization? | ✓ | |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | ✓ | |
| | Do you think that the framework takes into account any change in priority of accessing the database? | | ✓ |
| | Do you think that the framework can be adapted to different IT protocols? | ✓ | |
| | Do you find that different alternatives have been set in case of unexpected events? | ✓ | |
| Security | Has the framework taken data encryption into consideration? | | ✓ |
| | Has the framework taken firewall-related issues into consideration? | | ✓ |
| | Has the framework taken the protection of stored data into consideration? | | ✓ |

Thank you for answering the questions

Name: Shaharul Nizam bin Ben Yamin (Optional)

Designation: System Analyst

Years of experience: 18

Signature/Chop

**Please tick the answer with (✓)**

| Validation Factor | Questions | Yes | NO |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | ✓ | |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | ✓ | |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | ✓ | |
| | Does the framework have structured layers for effective retrieval of EHR? | ✓ | |
| | Does the framework demonstrate a logical sequence of events? | ✓ | |
| | Does the framework demonstrate well-structured database utilization? | ✓ | |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | ✓ | |
| | Do you think that the framework takes into account any change in priority of accessing the database? | ✓ | |
| | Do you think that the framework can be adapted to different IT protocols? | ✓ | |
| | Do you find that different alternatives have been set in case of unexpected events? | | ✓ |
| Security | Has the framework taken data encryption into consideration? | | ✓ |
| | Has the framework taken firewall-related issues into consideration? | | ✓ |
| | Has the framework taken the protection of stored data into consideration? | | ✓ |

Thank you for answering the questions

Name: …HAFIZ SALMAN BIN MOHD JAMIDAN…(Optional)

Designation:…EKSEKUTIF TEKNOLOGI KESELAMATAN ICT

Years of experience:……8……………………………

…………………………

Signature/Chop

**Please tick the answer with (✓)**

| Validation Factor | Questions | Yes | NO |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | ✓ | |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | ✓ | |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | | ✓ |
| | Does the framework have structured layers for effective retrieval of EHR? | | ✓ |
| | Does the framework demonstrate a logical sequence of events? | | ✓ |
| | Does the framework demonstrate well-structured database utilization? | | ✓ |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | | ✓ |
| | Do you think that the framework takes into account any change in priority of accessing the database? | | ✓ |
| | Do you think that the framework can be adapted to different IT protocols? | | ✓ |
| | Do you find that different alternatives have been set in case of unexpected events? | | unsure |
| Security | Has the framework taken data encryption into consideration? | | unsure |
| | Has the framework taken firewall-related issues into consideration? | | unsure |
| | Has the framework taken the protection of stored data into consideration? | | unsure |

Thank you for answering the questions

Name: …………………………………………….. (Optional)

Designation:……Manager………………………….

Years of experience:……18 yrs……………………….

[signature]

**Please tick the answer with (✓)**

| **Validation Factor** | **Questions** | **Yes** | **NO** |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | ✓ | |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | ✓ | |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | ✓ | |
| | Does the framework have structured layers for effective retrieval of EHR? | ✓ | |
| | Does the framework demonstrate a logical sequence of events? | ✓ | |
| | Does the framework demonstrate well-structured database utilization? | ✓ | |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | ✓ | |
| | Do you think that the framework takes into account any change in priority of accessing the database? | ✓ | |
| | Do you think that the framework can be adapted to different IT protocols? | ✓ | |
| | Do you find that different alternatives have been set in case of unexpected events? | ✓ | |
| Security | Has the framework taken data encryption into consideration? | ✓ | |
| | Has the framework taken firewall-related issues into consideration? | ✓ | |
| | Has the framework taken the protection of stored data into consideration? | ✓ | |

Thank you for answering the questions

Name: ……………………………………………. (Optional)

Designation:……Manager……………………………

Years of experience:………20……………………………

……………………

Signature/Chop

**Please tick the answer with (✓)**

| Validation Factor | Questions | Yes | NO |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | ✓ | |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | ✓ | |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | ✓ | |
| | Does the framework have structured layers for effective retrieval of EHR? | ✓ | |
| | Does the framework demonstrate a logical sequence of events? | ✓ | |
| | Does the framework demonstrate well-structured database utilization? | ✓ | |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | ✓ | |
| | Do you think that the framework takes into account any change in priority of accessing the database? | ✓ | |
| | Do you think that the framework can be adapted to different IT protocols? | ✓ | |
| | Do you find that different alternatives have been set in case of unexpected events? | ✓ | |
| Security | Has the framework taken data encryption into consideration? | | ✓ |
| | Has the framework taken firewall-related issues into consideration? | ✓ | |
| | Has the framework taken the protection of stored data into consideration? | ✓ | |

Thank you for answering the questions

Name: ....................................................... (Optional)

Designation:....Senior PMO Manager...........

Years of experience:..............20 yrs old.........................

HAJI MOHAMMAD SIRAJJUDDIN BIN SABARUDDIN
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Bahagian Teknologi Maklumat
Lantai 12, Ibu Pejabat TH
201, Jalan Tun Razak
50400 Kuala Lumpur

..............................
Signature/Chop

**Please tick the answer with (✓)**

| Validation Factor | Questions | Yes | NO |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | ✓ | |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | ✓ | |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | ✓ | |
| | Does the framework have structured layers for effective retrieval of EHR? | ✓ | |
| | Does the framework demonstrate a logical sequence of events? | ✓ | |
| | Does the framework demonstrate well-structured database utilization? | ✓ | |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | | ✓ |
| | Do you think that the framework takes into account any change in priority of accessing the database? | | ✓ |
| | Do you think that the framework can be adapted to different IT protocols? | ✓ | |
| | Do you find that different alternatives have been set in case of unexpected events? | ✓ | |
| Security | Has the framework taken data encryption into consideration? | | ✓ |
| | Has the framework taken firewall-related issues into consideration? | | ✓ |
| | Has the framework taken the protection of stored data into consideration? | | ✓ |

Thank you for answering the questions

Name: ……NOOR SHAFFINA SHAHUDDIN PENGURUS KANAN…… (Optional)

Designation:……PEJABAT KETUA PEGAWAI OPERASI LEMBAGA TABUNG HAJI……

Years of experience:……17 years……

………………………

Signature/Chop

**Please tick the answer with (✓)**

| **Validation Factor** | **Questions** | **Yes** | **NO** |
|---|---|---|---|
| Usability | Can the EHR practitioner practically or appropriately use this framework in developing a communication system for Hajj healthcare services? | | ✓ |
| | Can the EHR practitioner practically or appropriately use this framework to make efficient utilization of IoT | ✓ | |
| | Can the EHR practitioner practically or appropriately use this framework in developing a mechanism of avoiding conflicts? | | ✓ |
| | Can the EHR practitioner practically or appropriately understand the terminologies used in this framework to develop an easily accessible communication system? | | ✓ |
| Usefulness | Has the framework adopted a suitable IT protocol such as IoT-FPEHR? | | ✓ |
| | Does the framework have structured layers for effective retrieval of EHR? | | ✓ |
| | Does the framework demonstrate a logical sequence of events? | | ✓ |
| | Does the framework demonstrate well-structured database utilization? | ✓ | |
| Flexibility | Do you think that the structure is flexible enough to cope with advances in medical management? | ✓ | |
| | Do you think that the framework takes into account any change in priority of accessing the database? | | ✓ |
| | Do you think that the framework can be adapted to different IT protocols? | ✓ | |
| | Do you find that different alternatives have been set in case of unexpected events? | | ✓ |
| Security | Has the framework taken data encryption into consideration? | | ✓ |
| | Has the framework taken firewall-related issues into consideration? | ✓ | |
| | Has the framework taken the protection of stored data into consideration? | ✓ | |

Thank you for answering the questions

Name: ……………………………………………. (Optional)

Designation: MANAGER

Years of experience: 13 YEARS

[signature]

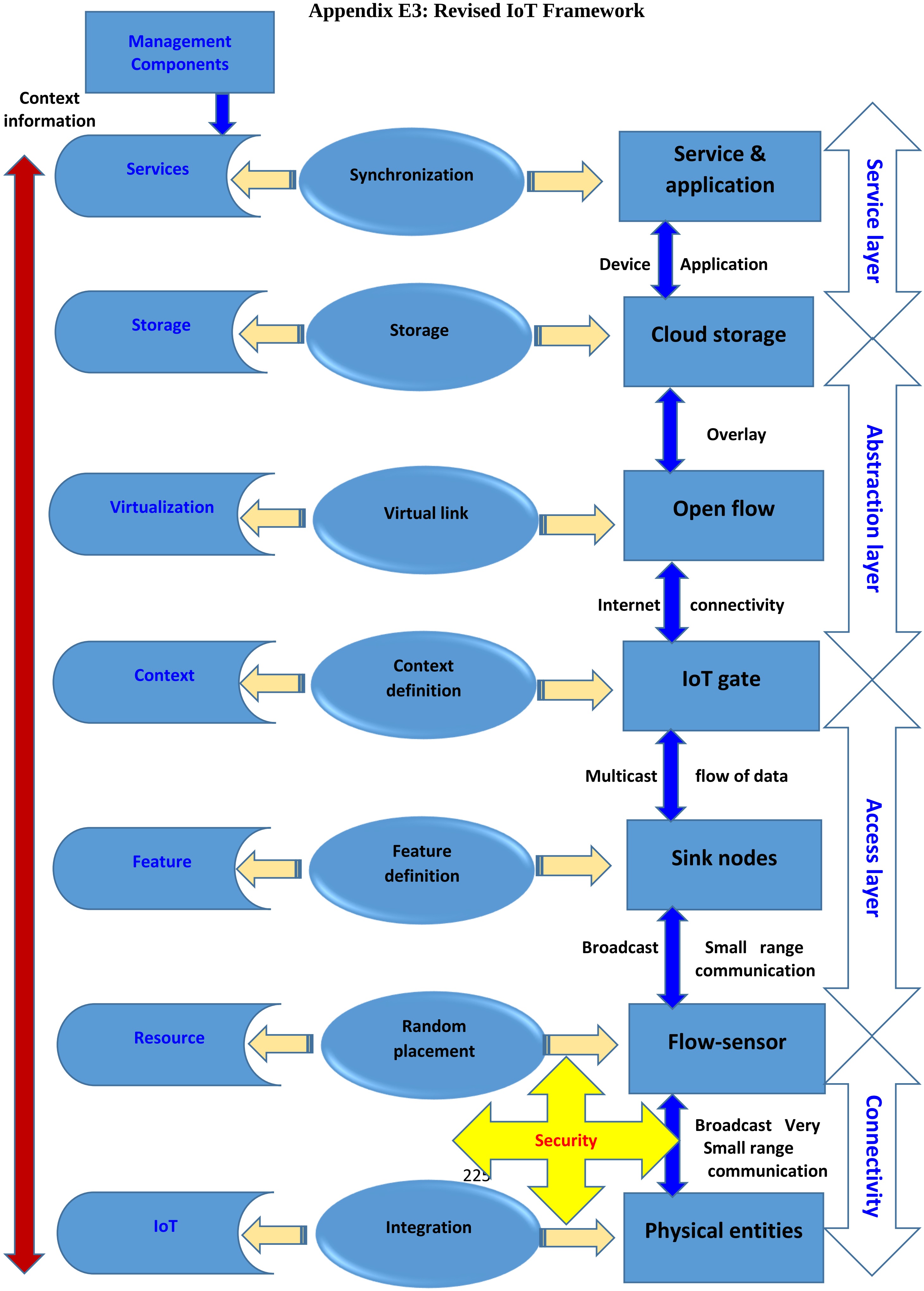
……………………

Signature/Chop

## Appendix E2: Profile of 8 Experts from Tabung Haji Malaysia

| SN | Designation/Position | Expertise | Years of experience |
|---|---|---|---|
| 1 | Senior operation manager | Operation | 17 |
| 2 | Senior IT Manager | IT | 20 |
| 3 | Manager | Health coverage | 13 |
| 4 | System analyst | | 15 |
| 5 | Executive information safety | ICT | 8 |
| 6 | Manager | | 20 |
| 7 | Manager | IT | 18 |
| 8 | System analyst | IT | 18 |

## Appendix E3: Revised IoT Framework



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