FAULT-TOLERANT MHEALTH FRAMEWORK IN TELEMEDICINE ENVIRONMENT FOR CHRONIC HEART DISEASE PATIENTS

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UNIVERSITI PENDIDIKAN SULTAN IDRIS

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AHMED SHIHAB AHMED ALBAHRI

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"In the name of Allah, the Most Gracious and the Most Merciful"

Alhamdulillah, first and foremost, praise be Allah, the Cherisher and Sustainer of the World and to the Prophet Muhammad (Peace and Blessings of Allah Be upon Him) who was sent by Allah to be a great teacher to the mankind.

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ABSTRACT

This research aimed to improve the fault tolerance of healthcare services provided for Chronic Heart Disease (CHD) patients living in remote areas. A new fault-tolerant mHealth framework was proposed to solve existing problems in healthcare services due to frequent failures in the telemedicine architecture. This study used an experimental research design that was carried out based on two stages. In the first stage, the researcher proposed a new algorithm known as Three-level Localization Triage (3LLT) to exclude the triage process from a medical center (Tier 3) and to overcome alarm failures related to Tier 1. In the second stage, the proposed framework was used to assist the decision maker to make the appropriate hospital selection based on a Multi-Criteria Decision Making technique, namely the Analytic Hierarchy Process (AHP). Two datasets were used comprising a dataset of 572 CHD patients and a dataset of hospitals healthcare services, which were used in the triage stage and in the hospital selection stage, respectively, based on two scenarios. The first scenario involved real high-level services of 12 hospitals located in Baghdad, Iraq, and the second scenario was based on low-level simulated services of 12 hospitals located in Kuala Lumpur, Malaysia. The results showed that the AHP technique was highly effective in solving the failures of healthcare services and the problems related to hospital selection. Moreover, the results showed significant differences in the groups' scores, indicating that the ranking results were identical for the three groups. Clearly, such empirical results suggest that the ranking of hospitals cannot be determined in a specific situation with many combined factors that may have a significant impact on the priority setting at the hospital level. For the validation of the framework, the results showed that the ranking results were perfectly identical. The implication of this study is that medical organizations can use the proposed fault-tolerant framework to assign patients to appropriate hospitals that can provide them with prompt, effective healthcare services.

RANGKA KERJA mKESIHATAN TAHAN ROSAK UNTUK PEMILIHAN HOSPITAL BAGI PESAKIT SAKIT JANTUNG KRONIK DI DALAM PERSEKITARAN TELEPERUBATAN

ABSTRAK

Kajian ini bertujuan untuk mempertingkatkan toleransi kesalahan dalam perkhidmatan penjagaan kesihatan bagi pesakit jantung kronik yang tinggal di kawasan pendalaman. Satu rangka kerja mKesihatan tahan rosak dicadangkan untuk menyelesaikan permasalahan dalam perkhidmatan penjagaan kesihatan yang disebabkan kegagalan yang kerap berlaku dalam senibina teleperubatan. Kajian ini menggunakan reka bentuk kajian experimen yang dijalankan dalam dua fasa. Dalam fasa pertama, para penyelidik mencadangkan satu algoritma baru yang dikenali sebagai *Three-level Localization Triage* (3LLT) untuk mengasingkan process *triage* dari satu pusat perubatan (Tier 3) dan mengatasi kegagalan penggera yang berkaitan dengan Tier 1. Dalam fasa kedua, rangka kerja yang telah dicadangkan digunakan untuk membantu pembuat keputusan untuk melaksanakan pemilihan hospital berdasarkan teknik *Multi-Criteria Decision Making* iaitu *Analytic Hierarchy Process* (AHP). Kajian ini menggunakan dua dataset yang terdiri daripada satu dataset yang melibatkan 572 pesakit jantung kronik dan satu dataset berkaitan dengan perkhidmatan penjagaan kesihatan yang digunakan dalam fasa *tiage* dan dalam fasa pemilihan hospital, masing-masing, berdasarkan dua senario. Senario pertama melibatkan perkhidmatan beraras tinggi di 12 hospital di Baghdad, Iraq, dan senario kedua berdasarkan simulasi perkidmatan 12 hospital di Kuala Lumpur, Malaysia. Dapatan menunjukkan teknik AHP amat berkesan dalam menyelesaikan kegagalan dalam perkidmatan penjagaan kesihatan dan permasalahan dalam pemilihan hospital. Tambahan pula, dapatan mempamerkan perbezaan yang signifikan dalam skor kumpulan yang menunjukkan keputusan-keputusan pemeringkatan adalah sama untuk ketiga-tiga kumpulan. Jelas sekali, dapatan empirik berkenaan menunjukkan pemeringkatan hospital tidak dapat ditentukan di dalam satu situasi yang spesifik yang melibatkan gabungan pelbagai faktor yang mempunyai impak yang signifikan terhadap pengesetan keutamaan berdasarkan tahap hospital. Untuk pengesahan rangka kerja, dapatan menunjukkan keputusan-keputusan pemeringkatan adalah satu peratus sama. Implikasi kajian ini adalah organisasi perubatan boleh menggunakan rangka kerja tahan rosak ini untuk menempatkan para pesakit di hospital yang sesuai agar mereka dapat diberikan perkhidmatan penjagaan kesihatan dengan cepat dan berkesan.

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LIST OF ABBREVIATIONS

3LLT	Three Level Localization Triage
AAL	Ambient Assisted Living
ACS	Acute Coronary Syndrome
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
AQM	Active Queue Managements
AQM	Active Queue Managements
ATS	Australian Triage Scales
BAN	Body Brea Network
BEWS	Bispebjerg Early Warning Score
BP	Blood Pressure
CANet	Cane Network
CMS	Center for Medicare and Medicaid Services
CO	Coordinators
CPS	Cyber-Physical Systems
CTAS	Canadian Triage and Acuity Scale
CVD	Cardiovascular Disease
DM	Decision Making
DOS	Denial of Service
DSS	Decision Support System
ECG	Electrocardiogram
ED	Emergency Department
E-health	Electronic Health
EM	Evaluation Matrix

eMEWS	electronic Modified Early Warning Scorecard
EMI	Electromagnetic Interference
EMR	Electronic Medical Records
ESI	Emergency Severity Index
EWS	Early Warning Scorecard
GCI	Grade of Criteria Importance
GDM	Group Decision Making
GDP	Gross Domestic Product
GOe	Global Observatory for eHealth
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
GUDM	Automatic Generation of Unified Datasets
HAW	Hierarchical Adaptive Weighting
HOCA	Healthcare Aware Optimized Congestion Avoidance
HTTP	Hypertext Transfer Protocol
HWSNs	Healthcare Wireless Sensor Networks
IHE	Integrating the Healthcare Enterprise
IMDs	Interoperable Medical Devices
IOT	Internet-of-Things
IPSO	Improved Particle Swarm Optimization
IS	Information System
LAN	Local Area Network
LCS	Low Cost and Secure
LstT	Longest Time
LT	Long Time
MAC	Media Access Control
MADM	Multi Attribute Decision Making
MAHP	Multi Analytic Hierarchy Process

MANET	Mobile Ad-hoc Network
MBAN	Medical Body Area Network
MCDM	Multi Criteria Decision Making
MCIs	Mass Causalities Incidences
MEW	Multiplicative Exponential Weighting
mHealth	Mobile Health
MIMUs	Mainstream Magnetic and Inertial Measurement Units
MIs	Medical Institutes
MLAHP	Multi-layer Analytic Hierarchy Process
MSHA	Multi Sources Healthcare Architecture
MTS	Manchester Triage System
MTS	Manchester triage system
MUI	Mobile User Interface
Pa2Pa	Patient to Patient
PCAH	Priority based Congestion Avoidance Scheme
PCSs	Personal Coaching Systems
PDA	Personal Digital Assistant
PHDA	Priority based Health Data Aggregation
PTT	Pediatric Triage Tape
QOS	Quality of Service
RFID	Radio Frequency Identification
RHMSs	Remote Health Monitoring Systems
RT	Real-Time
RTPS	Real Time Publish Subscribe
SAW	Simple Additive Weighting
SOA	Service-Oriented Architecture
SpO2	Blood Oxygen Saturation Level
SstT	Shortest Time
ST	Short Time

START	Simple Triage and Rapid Treatment
STM	Sacco Triage Method
STM	Science, Technology and Medical
TAH	Time of Arrival of patient at the Hospital
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
WBAN	Wireless Body Area Network
WHO	World Health Organization
WoS	Web of Science
WPM	Weighted Product Method
WSM	Weighted Sum Model
WSN	Wireless Sensor Network

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the research topic, significant of study, the statement of the problem, research objectives, and questions. This chapter also presents the scope of this research where the experimental and technical scopes are explained. A brief background of the research components is presented in Section (1.2). Significant of study addressed in Section (1.3). The statement of the problem, on which the direction of the research is based, is identified and introduced in Section (1.4). This is followed by the objectives of the research, which are described in Section (1.5).

The research questions presented in Section (1.6), followed by the link between research objectives and questions in Section (1.7). The scope of the study is discussed in Section (1.8). The main structure of the thesis is briefly outlined in Section (1.9). Finally, a summary of the chapter is presented in Section (1.10).

1.2 Research Background

These days with the ascending of new technologies, telemedicine is becoming a real center of interest with regard to the research domain (Çalişkan, 2013). Simply, telemedicine is a medical application of information technology enabling patients to have medical consultations outside hospitals by using video-conferencing or digital imaging systems. Telemedicine architecture contained on three-tier, Tier 1 represents sensor-based, Tier 2 represent gateway-based and mobile health (mHealth) (both Tier 1 and 2 represent the client side), while Tier 3 represents medical center server side that connected with distributed hospitals servers (Chang, Pang, Michael Tarn, Liu, & Yen, 2015; Figueredo & Dias, 2004; Kalid, Zaidan, Zaidan, Salman, Hashim, et al., 2018; Kovalchuk, Krotov, Smirnov, Nasonov, & Yakovlev, 2018; J. Wang, Qiu, & Guo, 2017). Telemedicine benefits by a vast bibliography but practical challenges remain to organize the risk management in the context of continuous improvement of healthcare services (Sene, Kamsu-Foguem, & Rumeau, 2015). The rising healthcare services costs and the aging of the world population add to the headways in telemedicine for the delivery of several healthcare services (Negra, Jemili, & Belghith, 2016).

For remote patients, continuous monitoring from a distant hospital is highly desirable to ensure adequate care and provide suitable guidelines for proper medication (Mirkovic, Bryhni, & Ruland, 2012; Sanders, Devergnas, Wichmann, & Clements, 2013). Remote patient care is now becoming a subject of major concern in healthcare services (Sarkar & Sinha, 2014). The burden of cardiovascular disease is growing worldwide and is projected to emerge as the No. 1 cause of death worldwide by the year 2020 (Moser et al., 2006; World Health Organization, 1996). Moreover, triaging patients for detecting the emergency level of the patient is calculated after evaluating their vital signs (Derlet, Kinser, Ray, Hamilton, & McKenzie, 1995; Salman, Rasid, Saripan, & Subramaniam, 2014). Triaging is required to link with compatible healthcare services package to complete the processing of healthcare services provisions (Salman et al., 2014).

Several challenges outlined in telemedicine architecture related to healthcare services at Tier 3 such as scalability and server failures. Scalability challenges arise when the number of patients increases that expected to occur in several aspects, namely: aging population, disasters and Mass Causalities Incidences (MCIs) (i.e., increase demand for healthcare services and online doctor visits) (Jeong et al., 2012; Salman et al., 2014; van Dyk, 2014). While server failures challenges is a complex issue because of many possible configurations of client/server environments and failure modes of a client, server and network devices (Bellod Cisneros & Lund, 2017; Duong-Ba, Nguyen, Bose, & Tran, 2014; Wood, 1995). The addressed challenges caused to severe consequences in providing healthcare services from the medical centre in a telemedicine environment.

Moreover, usually developing countries suffer a shortage of doctors as well as hospitals. Therefore, patients in these countries basically suffer the physical and monetary burdens of traveling around the country to see doctors. However, from their economic conditions, these countries may not easily agree to increase the number of hospitals. Hence, instead of adding a few new hospitals, it is a rationale that they rather choose to deploy as many telemedicine facilities, which generally cost much less than hospitals, as they can (Xiao & Chen, 2008). In addition, Sensor in Tier 1 is playing an ever more important role in medical technology with the aim of making medical devices even more effective and safer (Salman et al., 2014). The detection of sensor failure should be considered since it’s significant to measure the emergency status of a patient. These concerns, which are directly related to patients’ lives, are our research problems.

Fault-tolerant is the property that enables a system to continue operating properly in the event of the failure (or one or more faults within) some of its components (Randell, Lee, & Treleaven, 1978). In the other words, a fault-tolerant in distributed system is the ability to isolate and recover from failures, self-healing capability; no single point of failure (Lounis, Hadjidj, Bouabdallah, & Challal, 2016; Murtaza, Al, & Email, 2013). it’s a property that can be implemented in different ways (Lounis et al., 2016).

A terminology definition for Fault-tolerant term is a capability of a computer system, electronic system or network to deliver uninterrupted service, despite one or more of its components failing (Spada & Kim, 2018). Fault tolerance also resolves potential service interruptions related to software or logic errors. The purpose is to prevent catastrophic failure that could result from a single point of failure. In this context, a fault-tolerant framework in telemedicine architecture should recover telemedicine system parts such as Tier 1 and 3 from various failures.

MHealth, the attractive parts in telemedicine architecture offers the potential for sensor networks and information combination to improve patient care and provide healthcare services. A number of definitions of mHealth exist. The definition of mHealth by (Pawar, Jones, van Beijnum, & Hermens, 2012) as *'M-health is the application of mobile computing, wireless communications and network technologies to deliver or enhance diverse healthcare services and functions in which the patient has the freedom to be mobile, perhaps within a limited area'*. However, mHealth is an important link between Tier 1 and Tier 3 and focused on mobility of patients involved in the healthcare system.

The position of mHealth, telemedicine, and other paradigms according To (Pawar et al., 2012) are formulated in Fig. 1.1.

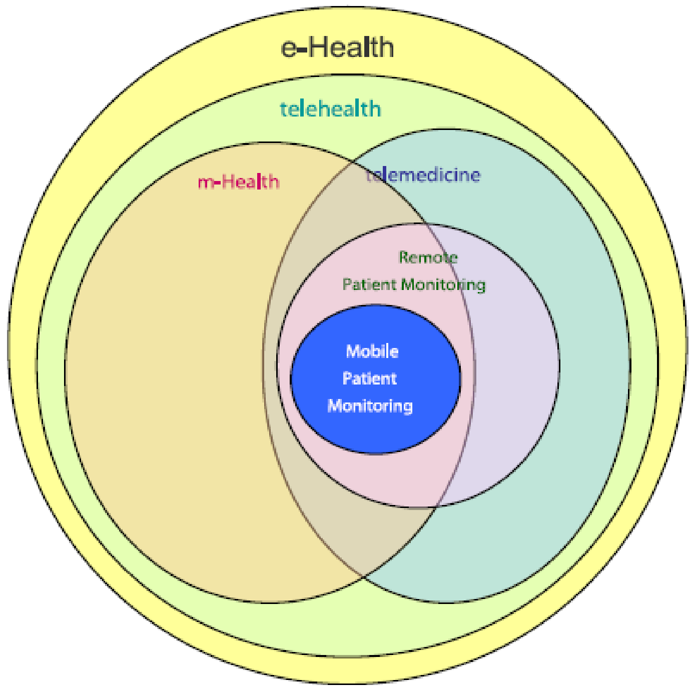

Figure 1.1. Relationship between Mhealth, Telemedicine, and E-Health Paradigms

Continuing providing healthcare services and treatments within mHealth (Tier 2) during various failures is considered as a fault-tolerant system in telemedicine architecture. However, such challenges increase when mHealth providing healthcare services in case of medical center in normal mode, but the issues of provide services directly from distributed hospitals in case of medical center failure or network failure are not considered (Besaleva & Weaver, 2013; Boursalie, Samavi, & Doyle, 2015; Kalid, Zaidan, Zaidan, Salman, Hashim, et al., 2018; Rahmani et al., 2018; Zhu-juan, 2015).

Time of arrival of patients at the hospital (TAH) has proved to be very important in the hospital selection (Barsan et al., 1993; Kalid, Zaidan, Zaidan, Salman, Hashim, et al., 2018; RG, KL, LB, K, & TR, 1984; Wizig, 2004). A hospital selection to provide healthcare services based on triage level and the chance of survival is consider a complex (Ashour & Okudan, 2010; Kovalchuk et al., 2018; X. Liu et al., 2011), since the decision is made based on a set of attributes (Faulin, Juan, Grasman, & Fry, 2012) which are healthcare services and TAH. Therefore, hospital selection within mHealth is a complex, multi-attribute decision-making process, especially in a remote monitoring environment. Such processes raise questions such as how mHealth can recover the mentioned failures, while the important question is how hospitals can be prioritized and selected in case of medical center failure or even network failure.

1.3 Significant of Study

1. Benefits to patients:
    - Enhance the patient's confidence in the healthcare system by ensures continues providing healthcare services within mHealth when various failures occurred in telemedicine environment (De Backere, Bonte, Verstichel, Ongenae, & De Turck, 2017; Moutacalli, Marmen, Bouzouane, & Bouchard, 2013).
    - Improve health monitoring of CHD conditions and the ability of patient diagnosis system that aim to improve patient care at low cost (Salman et al., 2014).
    - Support patients with a distinctive quality of care in a modern lifestyle and maintain their independence in a normal living environment (Lamprinakos et al., 2015; Teijeiro, Félix, Presedo, & Zamarrón, 2013).

2. Benefits to medical organizations:
   - Strengthening the health system in distributed hospitals and promote their dynamic processes (H. K. Kim, 2014).
   - Help to understand multiteam systems (i.e., health care professionals from multiple departments working together) and creating a climate for teamwork to better improve patient outcomes (Alnanih, Ormandjieva, & Radhakrishnan, 2013).
   - Commercial healthcare and medical services (Rajkumar & Sriman Narayana Iyengar, 2013).
3. Benefits to Doctors:
   - Assist medical teams through providing a decision making support for hospitals selection in term of time support for doctors and other medical staff (Niswar et al., 2015).

1.4 Problem Statement

Various failures addressed in telemedicine architecture and can play important issues and significantly effective in a patient life. These failures frequently occur in telemedicine systems especially at Tier 1 (sensor-based), Tier 3 (medical center server), and even in the networks between these systems parts according to (Dong & Yang, 2015; Kalid, Zaidan, Zaidan, Salman, Hashim, et al., 2018; Salman et al., 2014). Firstly, sensor characteristics may be partial or complete failure, which can degrade the performance or even destroy the stability of the overall systems (Dong & Yang, 2015), as well as the network failure between Tier 1 and Tier 2 cause a shortage in data transmission in client side (Salman et al., 2014), in this case, the measuring of patient's condition is either inaccurate or is already missing.

In large numbers of critically ill or injured patients, providing healthcare services to patients is required (Azeredo, Guedes, Rebelo de Almeida, Chianca, & Martins, 2015; S. Wang, Hu, & Kingdom, 2012). Scalability is also related to the connection between a Wireless Sensor Network (WSNs) and the server side; thus, this telemedicine system is subjected to a large number of queries (Diallo, Rodrigues, & Sene, 2012), thus network congestion and failure occurs on Tier 3 (Cardellini, Colajanni, & Yu, 1999; Kalid, Zaidan, Zaidan, Salman, Hashim, et al., 2018; Salman et al., 2014). Furthermore, telemedicine services are based on client-server architecture (Figueredo & Dias, 2004). Client/server availability is a complex issue due to the many possible configurations of client/server environments and failure modes of client, server, and network devices (Bellod Cisneros & Lund, 2017; Duong-Ba et al., 2014; Wood, 1995). Such complexity makes it difficult to properly account for availability in client/server architectural design (Bellod Cisneros & Lund, 2017; Wood, 1995; G. Zheng, Ning, & Wang, 2010). All these challenges caused several types of failures at Tier 3 and any disruption to the telemedicine network and server side can lead to link outage, potentially leading to severe consequences (Gogan, Davidson, & Proudfoot, 2016; P. F. Hu et al., 2017; Woo, Lee, & Park, 2018).

In the normal case, the medical center server connected with distributed hospitals to providing healthcare services remotely to patients (Chang et al., 2015; Kovalchuk et al., 2018; C. T. Liu, Long, Li, Tsai, & Kuo, 2001; J. Wang et al., 2017; Wizig, 2004). In the existing systems, mHealth delivered solutions about provide healthcare services in case of medical center in normal mode, but the issues of continues these services in case of medical center server failure are not considered (Besaleva & Weaver, 2013; Boursalie et al., 2015; Kalid, Zaidan, Zaidan, Salman, Hashim, et al., 2018; Rahmani et al., 2018; Zhu-juan, 2015). Failures occurred at Tier 3 -or even in its network-, mHealth should connect directly with distributed hospitals to select the best one. However, hospitals' selection to provide healthcare services is considered a complex decision-making general problem (Akdag et al., 2014; Khan, Prasad, & Rajamanoharane, 2010). Thus, the understanding of the exact hospital' selection criteria and their weights is important (Khan et al., 2010; Leister & Stausberg, 2007; Lingsma et al., 2009).

In order to describe the specific problems in term of issues for the hospital selections within fault- tolerant, the healthcare services packages for chronic heart disease -as a study case- can provide to the patient from hospitals through five packages based on triage level (Salman et al., 2014). In addition, TAH represents an important factor for choosing appropriate hospital spatially with chronic heart disease patients (Barsan et al., 1993; RG et al., 1984; Wizig, 2004). Thus, the process of hospital selection regarding with multi-attribute (healthcare services packages and TAH) with respect to the proper weight assigned for each attribute is considered a multi-attribute decision matrix (Faulin et al., 2012; Kovalchuk et al., 2018), and this considered the first issue. The different weights are often given for the mentioned attributes by decision makers (doctors) which further increase the complexity of the task (Yas, Zaidan, Zaidan, Rahmatullah, & Karim, 2017) and this considered as the second issue of the specific problem.

Whenever the services availability within hospitals at high level and the arrival of patient at the hospital takes a little period of time, this has a significant impact in the selection of the best hospital (Berglas et al., 2018; Nicholl, West, Goodacre, & Turner, 2007; Wei et al., 2008). Thus, this inverse relationship between both attributes causing a tradeoff and presenting the third issue. Finally, the TAH and the availability of services is varied from hospital to another (Busse, Schreyögg, & Smith, 2008; Kalid, Zaidan, Zaidan, Salman, Hashim, et al., 2018; Wizig, 2004), therefore the selection process involves simultaneous consideration from multiple attributes of distributed hospitals in different situations generate a data variation which considered the fourth issue (the data that representing services and TAH is varied among hospitals). Thus, the selection process of hospitals within mHealth is a complex multi-attribute decision-making problem, in which each hospital is considered an available alternative for the decision maker. The problem statement configuration is illustrated in Fig. 1.2.

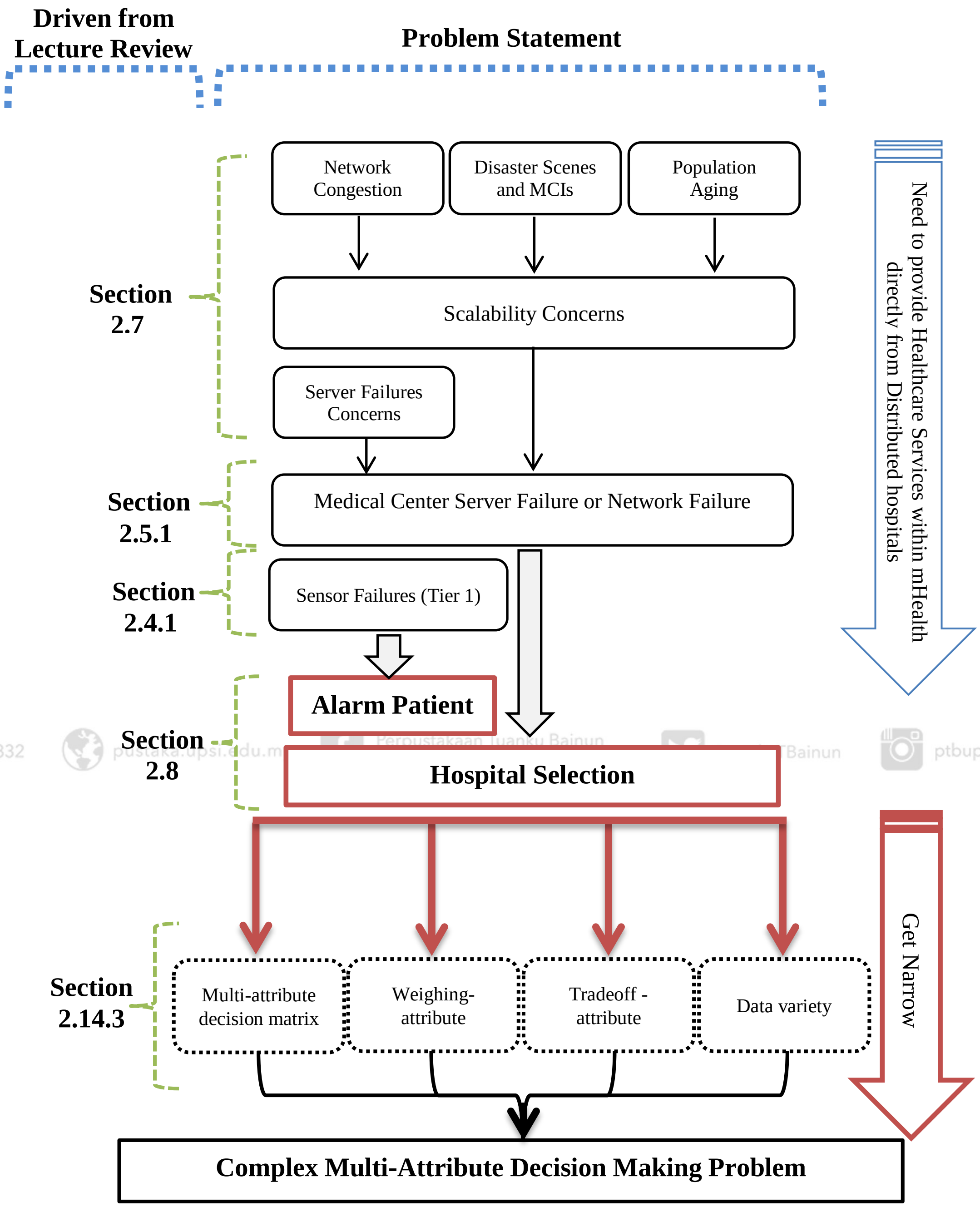

Figure 1.2. Problem Statement Configuration

1.5 Research Objectives

1. To investigate the existing technologies of providing healthcare services, triage or prioritize based body sensor in telemedicine applications.
2. To propose a new triage algorithm for chronic heart disease patients and can detect failures at Tier 1.
3. To identify a decision matrix for hospital selection based on proposed triage algorithm.
4. To develop a fault-tolerant mHealth framework based on identified proposed decision matrix.
5. To validate the developed framework objectively.

1.6 Research Questions

The following research questions have been framed to set the direction for this research:

1. What are the available technologies for providing healthcare services in telemedicine applications?
2. What are the requirements needed for the fault-tolerant framework for continuous providing healthcare services within mHealth?
3. What are the available triage standards and guidelines?

4. Can the existing triage standards and guidelines localize the triage process within only Tier 2 (mHealth) for chronic heart disease patients as well as detect Tier 1 failures?
5. Does there any integrated platforms included available healthcare services and TAH for hospitals?
6. What are the suitable techniques to develop a fault-tolerant mHealth framework?
7. What type of tests should be carried out to ensure that the results undergo systematic ranking?

1.7 The Link between Objectives and Research Questions

Research questions are framed to provide guidance to the research and Table 1.1 depicts the obvious connection between the objectives and research questions:

Table 1.1

Link Between Objectives And Research Questions

Research Questions	Research Objectives
1. What are the available technologies for providing healthcare services in telemedicine applications? 2. What are the requirements needed for the fault-tolerant framework for continuous providing healthcare services within mHealth?	1. To investigate the existing technologies of providing healthcare services in telemedicine applications.

(Continue)

Table 1.1 *(Continued)*

Research Questions	Research Objectives
3. What are the available Triage standards and guidelines? 4. Can the existing triage standards and guidelines localize the triage process within only Tier 2 (mHealth) for chronic heart disease patients as well as detect Tier 1 failures?	2. To propose a new triage algorithm for chronic heart disease patients and detect Tier 1 failures.
5. Does there any integrated platforms including available healthcare services and TAH for hospitals?	3. To identify a decision matrix for hospital selection based on proposed triage algorithm
6. What are the suitable techniques to develop a fault-tolerant mHealth framework?	4. To develop a fault-tolerant mHealth framework based on identified proposed decision matrix
7. What type of tests should be carried out to ensure that the results undergo systematic ranking?	5. To validate the developed framework objectively.

1.8 Research Scope

This research is a cross-domain involving an expert system and healthcare was focused on providing healthcare services for remote health monitoring patients. The research method involved in the study to solve the problem that classified as a multi-disciplinary problem. The case study which is chronic heart disease dataset is adaptive to propose a new triage algorithm based on real healthcare services packages by using data fusion techniques. Then this research proposes decision matrixes for ranking hospitals based on the selected package by using MCDM within mHealth in case of medical center server failure.

In the final stage, the hospitals were scored based on a decision matrix using experts' opinions interpreted by decision making technique. The outputs are expected from this research type is a framework performed via several steps that improve the process of identifications and development for the fault-tolerant mHealth system in a telemedicine environment. The general scheme for our research and the view that represents the research method, research type, and research domain are presented in Fig. 1.3.

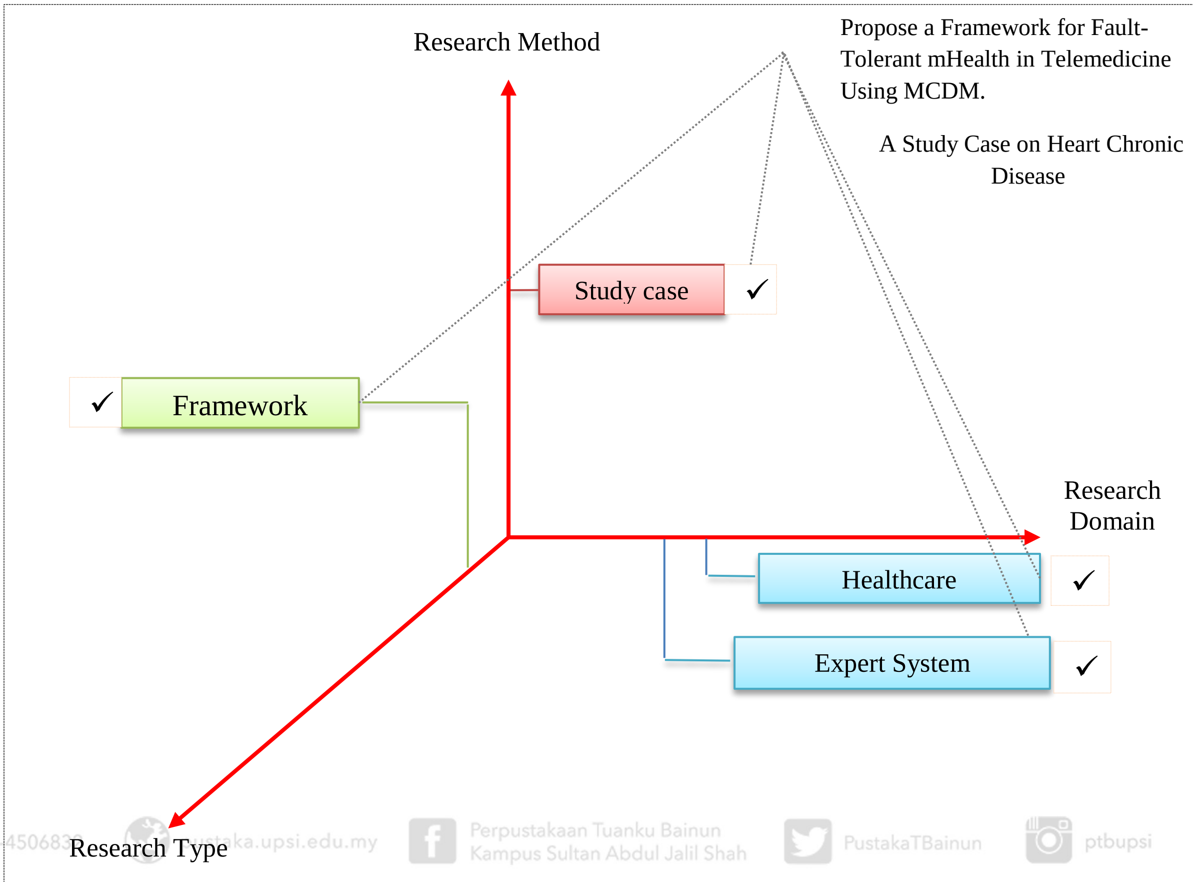

Figure 1.3. General Scheme and Scope of the Study

1.9 Research Organization

This research is composed of six chapters. These chapters are briefly reviewed as follow:

Chapter 1, provides the research background, significant of study, research problem. Moreover, this chapter demonstrates the research objectives, research questions, the link between them, and research scope.

Chapter 2, reviews a systematic review protocol for the area of telemedicine application, followed by an overview of telemedicine application in Tier 1, Tier 3 and Tier 2. The healthcare services challenges in telemedicine application are illustrated, followed by gap analysis for telemedicine applications. The remote health monitoring over telemedicine is also reviewed, followed by chronic diseases in remote healthcare monitoring. Sources used to measure patient' medical vital signs are presented. This chapter also reviewed triage standards and guidelines, followed by healthcare services packages and TAH to show the involved healthcare services packages in common chronic diseases monitoring studies and explain the importance of TAH towards distributed hospitals. This chapter ends with open issues to the research problems and highlights what should be done to solve those problems.

Chapter 3, gives the full description of the research methodology, which consists of four phases, namely, preliminary study phase, identification phase, development phase, and validation phase. Each phase corresponds to and addresses one or more research objectives, except the second phase which addresses the second and third objectives.

Chapter 4, presents the results based on the proposed method in four sections. Each section has its own aims. These sections show the sequences result for evaluation of the decision matrixes of hospitals, the weighting for main and sub-criteria used in this research, and the results of ranking hospitals.

Chapter 5, presents the results of validating the proposed method. In this chapter, several steps have been involved in the validation processes in order to test the ranking results of three packages (package 1, 2, and 3) and improving the identical process of ranking hospitals in telemedicine environment to overcome the research problems.

Finally, Chapter 6, presents the conclusion and the contributions of this research. The areas to be pursued as future works are also suggested.

1.10 Chapter Summary

This chapter provides background about the main goal of the presented study which focused on improving and providing healthcare services during various failures in telemedicine architecture. In the statement of the problem, several failures highlighted in telemedicine architecture related to Tier 1 and Tier 3. A new triage algorithm can propose to detect the emergency level of patient and then linked with the compatible package, also can alarm the failures occurred within Tier 1. Then mHealth can connect directly with distributed hospitals when failures occurred within Tier 3, whereas the hospital selection determined as a complex decision-making problem with multiple attributes from healthcare services and TAH. The hospitals' selection within mHealth, remote monitoring, and the specific question linked with research objectives are also discussed.

Finally, the extent and constraints of this study are elaborated. The final part of this chapter presented the general idea of the other chapters of this thesis.