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DESIGN OF CONGESTION CONTROL MECHANISM FOR MULTI-SOURCE DATA FUSION INFRASTRUCTURE IN TELEMEDICINE

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By

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Recent advances in wireless communications and integrated circuits have enabled design, development and implementation of wireless body area networks (WBANs). This class of network is paving techniques to develop innovative remote healthcare monitoring systems. The pervasive healthcare systems provide continuous monitoring for the chronically ill and elderly people to survive them in their independent lives. Despite having significant improvements, there are still many considerable issues and challenges that might influence quality of service (QoS) of WBANs. Therefore, the main objective of this research is to identify the existing gaps in providing a better QoS in the network. Although many problems can be addressed in this area, only one of them are studied in this thesis to address the issue of congestion. The congestion avoidance, congestion detection and control protocol are proposed to ensure acceptable data flows are maintained during the network lifetime. In this approach, the nodes play an important role in avoidance congestion, detecting congestion and also prioritizing the data received by them. That essentially helps to curb down problems caused due to congestion occurrence in healthcare applications. The proposed protocol contains of two phases. At the first phase, local data of sensor nodes is sent to avoid congestion by Active Queue Management (AQM) based on two methods to congestion Avoidance and supply QoS by proactively-dropping packets. With these system, congestion is capable of controlled, and network performance for example delay and packet loss. Second phase is based on three systems. The first system, sensor nodes are sent to congestion detection that based on two approaches that operates separately and respectively. The first approach of congestion detection based on node rate and mean inter arrival time, the second approach of congestion detection based on virtual queue state, node rate, packet service time and their automation to analyse the network traffic. According to the system output, congestion level is assessed. As for the second system, in case of congestion, the parent nodes dynamically compute and assign the new transmission rate for each of its children. In this system,

physiological signs are discriminated to ensure enhancing QoS by transmitting highly important data. Finally, the third system by implicit congestion notification method to send notification messages over the network. The results show that proposed protocol is better than Congestion Control Scheme based on Fuzzy Logic (CCSFL) and A Prioritization Based Congestion Control Protocol in WSNs (PBCCP) protocols with different QoS. The percentage of excellence for the proposed protocol in total of throughput reaches 51% and 52% compared to CCSFL and PBCCP protocols, respectively. On the other hand, the percentage of excellence in the proposed protocol was 66% and 75% compared to CCSFL and PBCCP protocols in terms of the packet loss. In addition, the proposed protocol decreases the energy consumption based on traffic load by about 59% and 66% compared to CCSFL and PBCCP protocols, respectively. Furthermore, the percentage of excellence in proposed protocol based on End-To-End delay was 68% and 81% compared to CCSFL and PBCCP protocols. While, the percentage of excellence in proposed protocol was 94% and 98% compared to CCSFL and PBCCP protocols in terms of jitter. The proposed protocol achieved better results even as the number of the nodes increased.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

REKA BENTUK MEKANISME KAWALAN KESESAKAN UNTUK INFRASTRUKTUR PELAKURAN DATA PELBAGAI-SUMBER DALAM TELEPERUBATAN

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Kemajuan terkini dalam komunikasi wayarles dan litar bersepadu telah membolehkan reka bentuk, pembangunan dan pelaksanaan rangkaian kawasan badan wayarles (WBANs). Kelas rangkaian ini membuka teknik untuk membangunkan sistem pemantauan penjagaan kesihatan jauh yang inovatif. Sistem penjagaan kesihatan yang meluas menyediakan pemantauan yang berterusan untuk mereka yang mempunyai sakit kronik dan warga tua untuk terus hidup dalam keadaan yang lebih baik. Walaupun terdapat peningkatan yang ketara, masih terdapat banyak isu dan cabaran yang mungkin mempengaruhi kualiti perkhidmatan (QoS) WBANs. Oleh itu, objektif utama penyelidikan ini adalah untuk mengenal pasti jurang yang sedia ada dalam menyediakan QoS yang lebih baik dalam rangkaian tele-perubatan. Walaupun terdapat banyak masalah dalam hal ini, hanya satu sahaja yang difokuskan dalam tesis ini iaitu untuk menangani isu kesesakan. Penyekatan kesesakan, pengesanan kesesakan dan protokol kawalan dicadangkan untuk memastikan aliran data yang diterima dikekalkan sepanjang hayat rangkaian. Dalam pendekatan ini, nod memainkan peranan penting dalam mengelakkan kesesakan, pengesanan kesesakan dan juga mengutamakan data yang diterima oleh mereka. Pada asasnya ini dapat membantu mengatasi masalah yang disebabkan oleh kesesakan yang berlaku dalam aplikasi penjagaan kesihatan. Protokol yang dicadangkan ini mengandungi dua fasa. Pada fasa pertama, data tempatan nod pengesan dihantar kepada penyekatan kesesakan melalui pengurusan barisan aktif (AQM) berdasarkan dua mekanisma untuk mengelakkan kesesakan dan menawarkan QoS dengan paket yang dijatunkan secara proaktif. Dengan sistem ini, kesesakan mampu dikawal, begitajuga dengan prestasi rangkaian seperti kelewatan dan kehilangan paket. Fasa kedua berdasarkan kepada tiga sistem. Sistem pertama, nod pengesan dihantar ke pengesanan kesesakan yang berdasarkan kepada dua pendekatan yang beroperasi secara berasingan dan berturutan. Pendekatan pengesanan kesesakan pertama berdasarkan kadar nod dan min antara masa yang tiba, pendekatan kedua pengesanan kesesakan berdasarkan

status giliran yang berharga, kadar nod, masa perkhidmatan paket dan automasi mereka untuk menganalisis trafik rangkaian. Mengikut keluaran sistem, tahap kesesakan akan dinilai. Untuk sistem kedua pula, dalam kes kesesakan, nod induk dinamik ditugaskan untuk mengira dan menetapkan kadar penghantaran baru untuk setiap anaknya. Dalam sistem ini, tanda-tanda fisiologi didiskriminasikan untuk memastikan peningkatan QoS dengan menghantar data yang terpenting. Akhirnya, sistem ketiga adalah kaedah pemberitahuan kesesakan tersembunyi untuk menghantar mesej pemberitahuan melalui rangkaian. Hasilnya menunjukkan bahawa protokol yang dicadangkan lebih baik daripada protokol skim kawalan kesesakan berdasarkan logik fuzzy (CCSFL) dan protokol kawalan kesesakan berdasarkan prioriti dalam WSNs (PBCCP) dengan Qos yang berbeza. Peratusan kecemerlangan untuk protokol yang dicadangkan dalam keseluruhan pengedaran mencapai 51% dan 52% berbanding protokol CCSFL dan PBCCP, masing-masing. Sebaliknya, peratusan kecemerlangan dalam protokol yang dicadangkan adalah 66% dan 75% berbanding protokol CCSFL dan PBCCP dari segi kehilangan paket. Di samping itu, protokol yang dicadangkan mengurangkan penggunaan tenaga berdasarkan beban lalu lintas sebanyak 59% dan 66% berbanding protokol CCSFL dan PBCCP, masing-masing. Selain itu, peratusan kecemerlangan dalam protokol yang dicadangkan berdasarkan kelewatan akhir adalah hingga 68% dan 81% berbanding protokol CCSFL dan PBCCP. Sementara itu, peratusan kecemerlangan dalam protokol yang dicadangkan adalah 94% dan 98% berbanding protokol CCSFL dan PBCCP dari segi jitter. Protokol yang dicadangkan mencapai hasil yang lebih baik walaupun bilangan nod meningkat.

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TABLE OF CONTENTS

		Page
ABSTRACT		i
ABSTRAK		iii
ACKNOWLEDGEMENTS		v
APPROVAL		vi
DECLARATION		viii
LIST OF TABLES		xiii
LIST OF FIGURES		xiv
LIST OF ABBREVIATIONS		xvi
CHAPTER		
1	**INTRODUCTION**	1
	1.1 Background	1
	1.2 Problem Statement	2
	1.3 Motivation of Study	4
	1.4 Objectives	4
	1.5 Scope of Study	4
	1.6 Thesis Organization	5
2	**LITERATURE REVIEW**	6
	2.1 Introduction	6
	2.2 WBAN Main Features	7
	2.2.1 Node Types	7
	2.2.2 Node Characteristics	8
	2.2.3 Limitation of Resources	9
	2.2.4 Accessibility	9
	2.3 WBAN Applications	9
	2.3.1 Medical Applications	10
	2.3.2 Non-Medical Applications	12
	2.4 WBAN Performance Requirements	12
	2.4.1 Security and Privacy	12
	2.4.2 Data Transmission Parameters	12
	2.4.3 Mobility	13
	2.4.4 Energy Consumption	14
	2.4.5 Usability	14
	2.5 WBAN Topologies	15
	2.5.1 Point-to-point topology	15
	2.5.2 Star Topology	15
	2.5.3 Mesh Topology	16
	2.5.4 Cluster Tree Topology	16
	2.5.5 Hybrid Topology	17
	2.6 Communication Architecture of WBANs	17
	2.6.1 Intra-BAN communications	18

2.6.2 Inter-BAN communications 18
2.6.3 Beyond-BAN Communication 19
2.7 Modelling of WBAN and multi-source data fusion 19
2.7.1 Disaster Scene 19
2.7.2 Aging Population 20
2.7.3 Related Work for Multi-Source Data Fusion in a Remote Monitoring Approach 21
2.7.4 Adapted Systems for Multi-Source Data Fusion 22
2.8 Congestion Control Mechanisms 22
2.9 Chapter Summary 26

3 METHODOLOGY 28
3.1 Introduction 28
3.2 Multi-Source Data Fusion Architecture 29
3.2.1 Tier-1 (Data Gathering) 31
3.2.2 Tier-2 (Base Station) 31
3.2.3 Tier-3 (Server) 32
3.3 Problem Description 33
3.3.1 Problem Formulation 35
3.4 Work Method in Simulation 37
3.5 Congestion Detection, Avoidance and Control Approach 37
3.5.1 Congestion Detection Unit (CDU) 39
3.5.1.1 The First Approach of the Congestion Detection 39
3.5.1.2 The Second Approach of the Congestion Detection 40
3.5.2 Congestion Avoidance Algorithm 47
3.5.3 Proposed Rate Adjustment Unit (RAU) 51
3.5.3.1 Calculation of Rate Adjustment 52
3.5.4 Implicit Congestion Notification (ICN) 56
3.6 Chapter Summary 56

4 SIMULATION RESULTS AND PERFORMANCE EVALUATION 57
4.1 Performance Metrics 57
4.2 Simulation Setup 59
4.3 Performance Results and Discussion 61
4.3.1 Network Throughput 61
4.3.2 Packet Loss 64
4.3.3 Rate Adjustment of Source Data Transfer 68
4.3.4 End-to-End Delay 71
4.3.5 Energy Performance 73
4.3.6 Effect of Prioritization 75
4.4 Chapter Summary 77

5 CONCLUSION 78
5.1 Summary 78
5.2 Research Contribution 79
5.3 Future Directions 79

REFERENCES 81
APPENDICES 91
BIODATA OF STUDENT 100
LIST OF PUBLICATIONS 101

LIST OF TABLES

Table		Page
2.1	Comparison of WBANs with WSNs	7
2.2	WBAN In-Body/On-Body technical features	10
2.3	Requirements of selected WBAN applications	13
2.4	List of Congestion Control Algorithms in Selected QoS Metrics	24
2.5	Compartion of Congestion Control Algorithms in Terms of Methods	26
3.1	Data rate requirements of the selected BAN applications	35
3.2	Notations	36
4.1	Simulation parameters	60
4.2	Effect of node prioritization	76

LIST OF FIGURES

Figure		Page
1.1a	Example of how information flow from sensors to sink node can cause congestion	3
1.1b	The impact of congestion on transmitting ECG signal	3
2.1	Network size in a WBAN	8
2.2	WBAN applications based on IEEE 802.15.6 classifications	11
2.3	Comparison of average energy consumption of wireless communication and processing circuits in a typical WBAN	14
2.4	P2P topology	15
2.5	Star topology	16
2.6	Mesh topology	16
2.7	Cluster Tree topology	17
2.8	Hybrid topology	17
2.9	Communication architecture of WBANs	18
3.1	Multi-Source Data Fusion Architecture	30
3.2	A high-level scheme of node-level and link-level congestion	33
3.3	The structure of proposed protocol	38
3.4	The Proposed Congestion Detection Approach	46
3.5	The queue of physical and how to divide it into a queue of virtual	48
3.6	The Proposed Congestion Avoidance Approach	50
3.7	Pritorization unit in each PDA	51
3.8	Rate adjustment model	55
4.1	Radio energy dissipation model	59
4.2	The single path topology used in the simulation	60

4.3	Normalized throughput comparison with number of node 15	62
4.4	Normalized throughput comparison with number of node 31	63
4.5	Normalized throughput comparison with number of node 60	63
4.6	Packet loss probability with number of node 15	65
4.7	Packet loss probability with number of node 31	66
4.8	Packet loss probability with number of nodes 60	66
4.9	Cumulated packet loss with number of nodes 15	67
4.10	Cumulated packet loss with number of nodes 31	67
4.11	Cumulated packet loss with number of nodes 60	68
4.12	Node 0 source rate	69
4.13	Node 5 source rate	70
4.14	Node 7 source rate	70
4.15	End-to-end delay with different nodes	72
4.16	Jitter comparison over time	73
4.17	Average energy consumption per packet with respect to traffic load with different nodes	74
4.18	Average energy consumption per packet over the time with different nodes	75
4.19	Normalized throughput over time with considering node priority	76
4.20	End-to-end delay over time with considering node priority	77

LIST OF ABBREVIATIONS

AAL	Ambient Assisted Living
AIMD	Additive Increase Multiplicative Decrease
Aps	Access Points
AQM	Active Queue Management
BASNs	Body Area Sensor Networks
BANs	Body Area Networks
BER	Bit Error Rate
BP	Blood pressure
BS	Base Station
CAU	Congestion avoidance unit
CCF	Congestion Control and Fairness
CCSFL	Congestion Control Scheme Based on Fuzzy Logic
CDU	Congestion Detection Unit
CDMA	Code Division Multiple Access
CI	Covariance Intersection
CM	Control Message
CNU	Congestion Notification Unit
CO	Coordinators
CODA	Congestion Detection and Avoidance
CP_j^i	Child Priority
CVDs	Cardiovascular Diseases
ECN	Explicit Congestion Notification
ECG	Electrocardiography
ECODA	Enhanced Congestion Detection and Avoidance
EMG	Electromyography
ESRT	Event-to-Sink Reliable Transport
FACC	Fairness-Aware Congestion Control Scheme
GIS	Geographic Information System

GP^i	Global Priority
GPR_j^i	Global Priority Ratio
GPS	Global Positioning System
GPRS	General Packet Radio Service
HOCA	Healthcare aware Optimized Congestion Avoidance
HWSNs	Human Wireless Sensor Networks
ICN	Implicit Congestion Notification
LA	Learning Automata
LACAS	Learning Automata-Based Congestion Avoidance Scheme
LACCP	Learning Automata based Congestion Control Protocol
LTE-SAE	Long Term Evolution – System Architecture Evolution
MAC	Medium Access Control
MLAF	Multimedia Location Aided Flooding
MSHA	Multi Sources Healthcare Architecture
PBCCP	Prioritization based congestion control protocol
PCCP	Priority-based Congestion Control Protocol
PDA	Personal Digital Assistant
PS	Personal Server
P2P	Point-to-Point
QCCP-PS	Queue based Congestion Control Protocol with Priority Support
QL	Physical queue
QoS	Quality of Service
RAU	Rate adjustment unit
STP^i	Static Priority
T	Temperature
TDAT	Time Difference of Arrival Time
T P^i	Transit Data Priority
TW_j^i	Average traffic weight
UWB	Ultra Wide Band

VSs	Virtual sinks
WBANs	Wireless Body Area Networks
WBSN	Wiresless Body Sensor Network
WCDMA	Wide-based Code Division Multiple Access
WFQ	Weighted Fair Queueing
WHMS	Wearable health-monitoring system
WM	Warning Message
WSNs	Wireless Sensor Networks

CHAPTER 1

INTRODUCTION

Modern advances in Wireless Sensor Networks (WSNs) advanced technologies like suitable for wearing and planting sensors have put in the investigation of Wireless Body Area Networks (WBANs). A WBAN depends on biomedical-sensor nodes which is able to be integrated in or on a human body [1]. Sensors in WBANs are placed wisely to register-biological and physiological vicissitudes like body temperature, blood pressure, glucose level or Electrocardiography (ECG) signals. The gathered information thereafter will be sent to a Base Station (BS) for more operations. Characteristically, a BS has more power than other body sensors and can be analysed and transfer the gathered information to the next destination [2]. The BS in this scenario is able to be as Personal Digital Assistant (PDA) that is lock to the user and extradite information from the sensors. Significant cases in WBAN applications contain guarantee high standard of performance, dependability and high accuracy [2]. So, it is constantly needful to think quality of service (QoS) in WBANs. QoS is based on the requirements of WBANs and can be used in different meanings and prospective. However, QoS in any WBANs is used to improve the performance of the network for users [3]. In this thesis, QoS is analyzed based on the consideration of different requirements such as energy consumption, delay, throughput, packet loss probability, jitter and source rate.

1.1 Background

Monitoring physiological and vital-parameters for various illnesses in humans is one of the main defies in healthcare-applications. In order to overawed this defy, WBAN proposed as a new sub-field of WSNs. In other words, usually usage for WBANs contain Wireless Body Sensor Networks (WBSNs), Body Area Networks (BANs) or Body Area Sensor Networks (BASNs). WBANs is able to be utilized in assortment of real-word applications. For example, medical and emergency services, consumer electronics, health fitness in addition to lifestyle monitoring and personal health applications [4]. While, in separate features can be various from one application to another in WBANs, the main goal of whole applications is to enhance quality-of-life [5].

WBAN is one kind of wireless networks which are used for communication between sensor-nodes. It processes in or about the human body to observe several decisive parameters and also body movements [6]. The WBAN mechanism has been advanced in 1995 via sighting wireless personal area network (WPAN) advanced mechanism for communications on, within easy reach and about the human body [6].

Nowadays, WBAN technology has been paid a lot of attentions among medical professions and health care practitioners including engineers in information and communication technology field. This mechanism is a key element that can contribute to the future of e-health initiative to make main refinement in patient-care and health examination. For instance, this WBAN technology could make some of the specialist treatments more accessible and efficient as well as cost-effective. In addition, as these wireless networks are planted on the body and also easy to wear, it requires specific studies and analysis under difficult constraints containing less radioactive energy, flexibility, small device size and low weight. The struggle among the demands of the body area of the network such as security, effectiveness and safety are further challenged by the remediation to address and observe [7].

WBANs is suitable for health observation services offer for continuous diagnosis of patients. Significantly, it is able to monitor all cases by the patient with very high efficiency [1]. In addition, the survival of patients in the hospital requires a high cost in terms of services and personnel. Then, in respect of supply a low expense and improved quality healthcare system, it is required to change toward e-health systems. The term e-health defines the integrated usage of electronic communication and data mechanisms in the healthcare in the healthcare systems to have a safer, and improved quality health-care [8]. E-health systems will give health practitioners faster and secure access to all information they need to treat patients. This protocol aims to minimize the negative effects caused by the congestion problem and that all packets are simultaneously sent, which makes the system unable to recognize or control incoming packets.

1.2 Problem Statement

In spite of the vast admission of WBANs in different remote control and observing applications, there are still clear challenges which need to be addressed. Significant QoS cases for example, real-time warranty, energy competence, network throughput and delay still remain to be solved [9-13]. Sensor nodes are designed to be comparatively small, battery-powered and low-cost. The characteristics of these design made them vulnerable to suffering in terms of processing-power and low-memory and this limit their performance to a convinced standard [14].

Furthermore, in WBAN the overall amount of the sensed information cumulative at each sensor-node is able to be comparatively great. This problem issues a dispute between the packets waiting to receive over the following node that has restricted ability [10]. In addition, congestion is a case of traffic overloading due to buffer overflow. The reason for the congestion is by sending from many to one information method in the WBANs. In case of emergency, where a huge number of sensors send the sensed information to a few sink nodes, an abrupt surge of data communication happens. This will result in high notify rates at the sink-node and may generate a lack of resources such as buffer space. Moreover, the vast amount of notify information may as well generate dispute of intense packets at the total buffer and issue QoS

degradation like increase in delay, low network productivity and extra energy consumption.

This thesis is focused on heavy congestion problem that may occur when multiple leads from a patient have information to be sent to the gateway which is constrained because of limited resources, and sensors from several patients are also sending their readings at the same time. A congestion scenario in WBANs is shown in Figure 1.1a. This scenario may repudiate the intermediate nodes are capable of handling the extra streams incoming from the downstream nodes which results in the loss of a large number of packets. Congestion leads to loss of much energy and useful resources and has caused many of collapse in real time applications in WSNs and WBANs that need high quality emphasis [15]. Therefore, dependability and timely delivery are significant cases to be collected in these fields [16, 17].

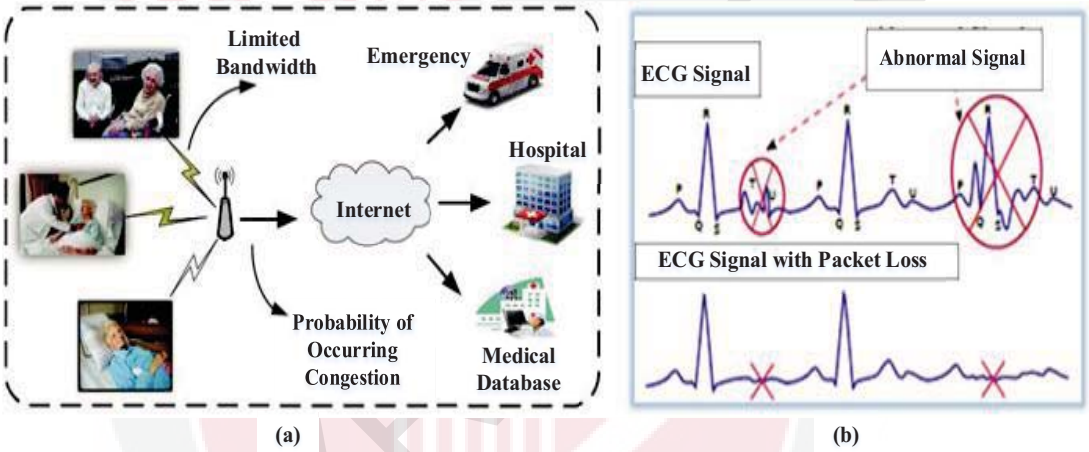

Figure 1.1 : (a) instance of how data flows from node of sensors to node of sink that is able to issue congestion. (b). The congestion effect on send ECG signal

The problem of congestion is bad in a greater number of hops traversed. Moreover, the packets tour, the extra energy is missed and the congestion impact is able to be huge as well. The information will be neglected because of high delay and re-transmission process. In addition, waiting of sensor information through space of not available become agreeable at the sink-node then can be stale and expire. This fact could lead to inaccuracies in data and may involve the loss of much data as well.

In healthcare-applications, include suitable access of the sensed information over climacteric times is critical. For example, in healthcare-monitoring of ECG and EMG information, the signals have to be given during a specific time of period to become valid for a decision-making operation. Delayed access of the information and data damage in this situation is intolerable as data will seem to become outdated, causing a false diagnosis that could imperil the patient. A congestion causes some part of patient's abnormal ECG signals to become missing. As an outcome, erroneous data around the patient's existing case will be received through physicians and this will lead to false diagnosis as illustrated in Figure 1.1b. In addition, including the appropriate

delivery for packets and keeping careful data in those real-time applications are between greatest importance as it will help to avoid false alarms that might lead to wrong diagnoses. According to all above-mentioned cases, congestion avoidance is a topic worth studying. Then, the motivation behind this thesis is to come up with a new and dependable solution to congestion control, congestion detection and congestion avoidance in healthcare WBAN applications.

1.3 Motivation of Study

In spite of important enhancements, there are still further restrictions connected to WBANs such as limited buffer capacity, bandwidth, processing speed and energy. Those restrictions able to be negatively influence the network QoS mostly in emergency conditions [1]. With extremely restricted capacities of bandwidth and storage, the buffer is highly probable to be suppressed via huge volumes of sensor readings. This problem, that is intuitively known as congestion problem, has intimidated almost whole types of networks and seems to be even more challenging in life-threatening applications. To solve this problem, this protocol concentrates on how to detect, avoid and control congestion especially during the high demand and emergency event monitoring process especially over high request and emergency event monitoring-process. Massive amounts of information created over critical intervals may result in a poor performance that may impact the underlying applications. Especially, this thesis goal to control congestion and reduce the effect of traffic overload because of huge sensor readings over concurrent data-transmissions. In another sense, it is aiming to decrease intense impacts from congestion problem where packets are delivered with each other, causing the system to be unable to confirm the incoming packets.

1.4 Objectives

1- To propose a congestion control system for utilize in the designed Multi-Source Data Fusion framework with the major features of enhancing the total network for QoS.
2- To analyse and compare proposed protocol with other protocols mechanisms using different QoS metrics.
3- To show the results of the new proposed congestion control system based on the performance metrics.

1.5 Scope of Study

This thesis proposed a new protocol to avoid, detect and control congestion for utilize in healthcare WBAN applications. The proposed approach contains of two phases. At the first phase, local data of sensor nodes is sent to avoid congestion by Active Queue Management (AQM) based on two approaches to congestion avoidance and supply QoS by proactively-dropping packets. With these system, congestion is capable of

controlled, and network performance for example delay and packet loss. After that, second phase that contain based on three systems. The first system sensor nodes are sent to congestion detection that based on two approaches that operates separately and respectively. The first approach of congestion detection based on node rate and mean inter arrive time, the second approach of congestion detection based on virtual queue state, node rate, packet service time and their automation to analyse the network traffic. According to system output, congestion level is assessed. In case of congestion, parent nodes dynamically compute and assign the new transmission rate for each of its children, this is second system. The main objective of the rate adjustment is to prioritize physiological signals and sent them based on their level of significant. Finally, the third system by implicit congestion notification method to send notification messages over the network. In this thesis, the proposed protocol was evaluated and studied by combining OPNET and MATLAB simulations. Then, the proposed protocol is compared with the existing protocols and the approach achieves the best performance and the fairest in terms of minimize energy consumption, packet loss probability, loss cumulated of packet, delay, jitter and in turn rising the overall network throughput.

1.6 Thesis Organization

This thesis is organized as follows:

Chapter 1 : This chapter presents a broad and comprehensive introduction for healthcare WBANs applications. In addition, it presents problem statement and objectives of this thesis.

Chapter 2 : It provides a comprehensive literature review of WBANs and their related challenges. This chapter starts with an understanding of fixed advantages of WBANs. After that, this chapter discusses solutions to congestion problems in WBANs. In addition, it presents an inclusive review of congestion control methods and discusses the advantages and disadvantages of this approach.

Chapter 3 : The methodology of the proposed protocol that contains of two phases in Multi-Source Data Fusion infrastructure is presented. Furthermore, it is discussing all the details for a Multi-Source Data Fusion architecture and method of work.

Chapter 4 : It presents the performance analysis and compare of proposed congestion control protocol with other protocols utilizing combine OPNET and MATLAB simulations.

Chapter 5 : This chapter presents a comprehensive summary of the main objectives of this thesis and future work.

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