Preemptive Queue Based Modified MAC Superframe for WBSN to Efficiently Transmit Pilgrims' Heterogeneous Data at Ritual Sites: An Analytical Approach

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Abstract
Providing real-time and the best healthcare facilities for the Pilgrims at overcrowded ritual sites is an emerging research issue, and a considerable challenge thus requires promising healthcare technology. Wireless Body Sensor Networks (WBSNs) is a modern healthcare technology has been proposed to facilitate the healthcare problems that consist of tiny sensors and a coordinator. The research aims to efficiently deal with pilgrims' heterogeneous physiological data through WBSNs at overcrowded ritual site. Therefore, a severity-priority index table, along with the data threshold value of various normal medical and emergency traffic, is created. By using classified normal and emergency medical data, we define multiple levels of data priority to be used by the coordinator of WBSN. In WBSN medium to minimize the overall delay, a preemptive queue-based modified Medium Access Control (MAC) superframe is proposed. In the proposed IEEE802.15.6 based MAC superframe for transmitting normal medical data, a Managed Access Period (MAP) and for the emergency medical data, and Exclusive Access Period (EAP) are preferred. From the numerical analysis, we have seen that the heterogeneous medical data with the highest priority are able to access the communication channel faster than that of low priority. Hence decreases the overall delay at the system. Thus our proposed analytical model can effectively be handling heterogeneous medical data even when more than one emergency traffic gathers at the coordinator from different sensors for faster transmission to the healthcare centers. To validate the analytical findings a broad experimental work will be carried out in our future research.

Key words:
WBSNs, MAC Superframe, Preemptive Queue, Heterogeneous Data, Pilgrims

1. Introduction

Every year during Hajj, which is one of the five obligatory pillars in Islam, near about 2-3 million pilgrims congregate at Haram in Makkah, Saudi Arabia from all around the world. Performing Hajj is a dynamic pilgrimage system which implies movement and travel at its ritual sites of about 27.4 sq. Km including Masjid-ul-Haram, Mina, Muzdalifa and Arafat [1].

Generally, elderly pilgrims are in danger and susceptible to get the infection or infectious diseases due to reduced rate of immune responses. Besides, physiological problems among the pilgrims are actively aggravated by other aspects such as disturbances in the dietary schedule, hard work, lack of rest and sleep and mental stress. During Hajj, some of the common causes for transmitting of infectious disease are airborne agents, waterborne agents along with pilgrims other health hazards such as injuries, trauma, extreme heat, lack of humidity, extended staying at overcrowded accommodation. Also, pilgrims at Hajj ritual sites come across severe mental stress and physical trauma and diseases due to extreme temperatures, lack of humidity and other environmental issues [2-3].

A basic structural design of a WBAN is shown in Fig. 1. WBAN comprises of various biological sensors and a body coordinator. A smart-phone, mobile phone or a PDA can be considered as body coordinator or hub which is also known as hub or sink. The body coordinator is accountable for collecting data from sensors, processing the collected data, data storage, controlling the sensors and transmitting data to the designated base stations or access points (APs). WBAN communication is manoeuvred in three modes, such as intra-outer-beyond WBAN communication. Using all these three modes, WBANs transmit physiological data to the healthcare authorities for further investigation [4-5].

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The IEEE 802.15.6 standard is mainly designed for medical applications that must support minimum power consumption, lower delay, high data rates, low complexity, low cost and sophisticated data communication. The main objective of this standard is to cope with short-range data communication between tiny body sensors, body coordinator and the surrounding environment of the human body. The IEEE 802.15.6 standard operates on DLL (MAC) and PHY layers and functions with star topology [6].

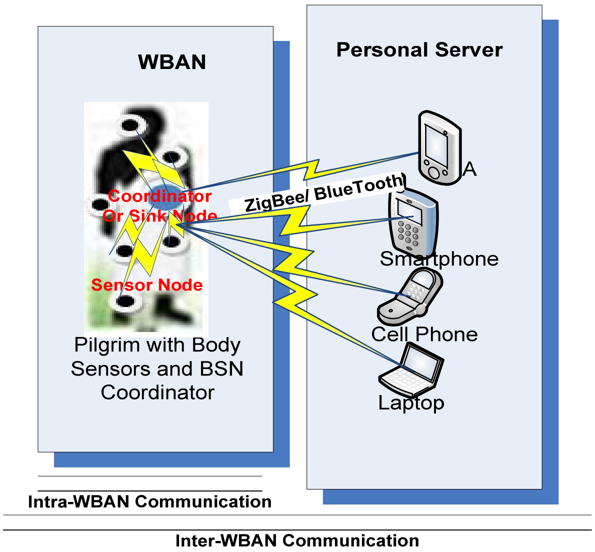

Fig. 1: WBAN: a comprehensive structure

The entire communication channel of the IEEE 802.15.6 based MAC protocol is divided into superframe structures. Each superframe is encircled by a beacon period of equal length. Using the IEEE802.15.6 standard and associated MAC protocols, WBANs are obliged to transmit data in different modes to access channel. The IEEE802.15.6 standard enabled MAC superframe structure is presented in Fig. 2.

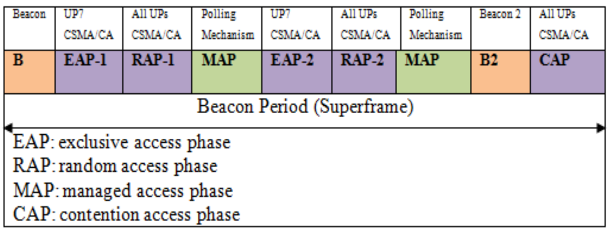

Fig. 2: IEEE 802.15.6 superframe structure

In the IEEE 802.15.6, EAP1 and EAP2 are exclusively reserved for the high priority traffic or emergency traffic and which are a contention-based phase or based mechanism (CSMA/CA or Slotted Aloha). Thus, according to the superframe structure of the IEEE 802.15.6 standard, the emergency traffics must contend to access the channel that may cause a collision between packets, more delay and data loss which may threaten the life of patients.

For better traffics adaptation and higher energy efficiency, an adaptive MAC protocol (A-MAC) which is based on the IEEE802.15.6 standard is proposed [7]. In this protocol data are classified into three priority classes, and the superframe structure of the IEEE802.15.6 is improved and restructured into four different phases. Energy-efficient medium access technique for emergency and normal data has been proposed by [8] where EAP 1 is proposed for emergency data, and RAP 1 is proposed for all types of data transmission. A multi-channel based energy-delay efficient MAC (EDMAC) protocol has been proposed in [9] where EAP and RAP periods are considered to transmit data and control signals. Modified MAC superframe structure based on emergency and non-emergency data is proposed in [10]. Beacon-enabled hybrid superframe structure consists of two mechanisms. Include periodic contention-free and aperiodic contention-based mechanisms. Several MAC superframe is discussed those are being served for particular applications. However, existing MAC superframe approaches don't support the situation when more than one similar data type approaches to get accessed to the same channel. Hence, there is an enormous research scope to modify and update the existing MAC superframe as per WBANs applications that should manage energy consumption and reduce delays, which is the aim of this research.

The remainder of the paper is organized as follows: In Section 2, the severity-priority index table is created. WBSN traffic classification, prioritization, network management are presented in Section 2. Section 3 presents the development of a modified MAC superframe structure for WBSN. Section 4 illustrates the traffic management procedure for MAC superframe. Finally, the paper ends with a conclusion in Section 4.

2. Severity/Criticality-Priority Index Table for WBSN

2.1 WBSN Heterogeneous Traffic Classification

As presented data in Table 1 along with WBANs user priority (UP), medical traffic is generally categorized into three main classes. Such as emergency (EM) traffic having the highest user priority UP_7, followed by on-demand (OD) traffic having the second-highest user priority UP_6, and normal (NR) traffic having third highest user priority UP_5. The mapping between different WBANs traffics and relevant user priority is illustrated in Table 1. However, traffic priorities may differ depending upon data threshold value and data that to be generated by sensors.

Table 1: WBANs medical traffics and associated mapping with user priority

User priority	*Traffic*	*Name*	*Description*
7	EM	Emergency traffic or critical medical data	Emergency medical traffics the most critical aperiodic traffic that is delay-sensitive. It consists of different data values lower or greater than the normal threshold value.
6	OD	On-demand traffic or high priority medical data	On-demand medical traffics not delay-sensitive and can be applied for both medical and non-medical applications
5	NR	Normal traffic or medical data	The lowest priority is given to normal medical traffic. Normal medical traffic is periodic and is not delay sensitive.

In general, medical traffic could be periodic or scheduled based and aperiodic or contention based, low or high medical traffic depending upon the physiological event being monitored. As mentioned earlier, emergency traffic is considered as the highest priority traffic and to be transmitted ahead of low priority traffic. In WBAN applications to transmit medical emergency data, a dedicated access phase is required for MAC superframe. In our research, we assume that body coordinator selects the beacon mode for superframe structure. As mentioned earlier, emergency data frames are categorized as the highest user priority-UP_7. But, the problem may occur when more than one emergency data from different sensors aggregate to the coordinator for further transmission to the healthcare stations. Hence, for efficiently handle medical data at ritual sites in this research, we propose a modified MAC superframe structure for WBAN.

2.2 The Classification of the Severity (Criticality) Level of Emergency Traffic

WBAN and its associated MAC protocols are applications specific. In our research, we propose to deploy WBAN for monitoring pilgrims' health conditions in a real-time manner. It has been found that among many diseases heart disease, respiratory problem, heart attack, body temperature, blood pressure, and diabetes are the major health problems for any patient. As discussed earlier, almost all medical signs, conditions and symptoms are interrelated and therefore, responsible for any health-related problem among the pilgrims during Hajj. It is evident that the signs and symptoms are considered as a warning of the presence of disease. In this research work, the criticality level of pilgrims' emergency health issues are classified and prioritized, considering the following order of symptoms and vital signs and the threshold values of diseases are also determined. The following Table 2 illustrates the mapping between the sign/indication and symptoms of diseases and their level of severity or criticality. Moreover, Table 3 focuses on the threshold value of each medical condition that should take into account by the WBAN sensors and coordinator during heterogeneous data transmission.

Table 2: Mapping between signs of vital diseases and level of severity of the symptoms

Sign and Symptoms	*Level of Criticality (Severity) for Data belong to U_7 (Highest User Priority)*
Heart rate	Data Severity/criticality level 1=P_1C_1 Where, index=P_iC_i and P_i=P_1, P_1 indicates priority index=1, the highest priority
Heart sound	Data Severity/criticality level 2=P_1C_2
Respiratory rate	Data Severity/criticality level 3=P_1C_3
SpO2 (Oxygen level)	Data Severity/criticality level 4=P_1C_4
Temperature	Data Severity/criticality level 5=P_1C_5
Blood pressure	Data Severity/criticality level 6=P_1C_6
Blood pH level	Data Severity/criticality level 7=P_1C_7
Blood flow	Data Severity/criticality level 8=P_1C_8
Blood sugar	Data Severity/criticality level 9=P_1C_9
Electric activity of skeletal muscles	Data Severity/criticality level 10=P_1C_1
Electrical impulsive brain activity	Data Severity/criticality level 11=P_1C_{11}
Body motion	Data Severity/criticality level 12=P_1C_{12}

To deal with one emergency event at any moment is much more comfortable, encouraging and less challenging than that of multiple emergency events simultaneously at WBAN coordinator level. To build a priority MAC protocol in this research, we define data into three classes, as mentioned earlier. However, emergency data is further classified into various other categories, which is presented in Table 2.

Critical data are usually event-triggered traffic and is produced whenever a life-threatening circumstance occurs.

Hence, it is to be delivered and transmitted in WBAN medium with no delay, no loss and in a timely and real-time manner. On the other hand, non-critical normal physiological data require periodic monitoring hence does not restrict to strict delay or reliability constraints.

Table 3 represents the threshold value of each predefined sign and symptoms of diseases. In Table 2, the normal threshold limit is presented. The threshold value that exceeds the normal threshold level is called as abnormal or critical threshold level.

Table 3: Threshold ranges of vital parameters

Sign and Symptoms	***Periodic or Normal Threshold Value***	***Unit***
Heart rate	12-19	Bits per minute-bpm
Heart sound	94-99	-
Respiratory rate	60-100	Bits per minute-bpm
SpO2 (Oxygen level)	S3, S4 Inaudible, S1, S2 Audible Normal	Rhythm
Temperature	90-120	Bits per minute-bpm
Blood pressure	60-80	Bits per minute-bpm
Blood pH level	4.4-7.8	mmol/L
Blood flow	7	Blood's acidity or alkalinity
Blood sugar	37	°C-Degree Centigrade
Electric activity of skeletal muscles	6cc/second to 11cc/second	cc/second
Electrical impulsive brain activity	0.1-100Hz, 0.025-0.1mv	-
Body motion	Unsuccessful when the tandem stand is 1.56, 95% CI: 1.13–2.15 and solo stand is 3.08, 95% CI: 1.57–6.06	-

In our research, we develop a priority-severity/criticality index table as presented in Table 4 to support WBAN sensors and coordinator to transmit data on based on the level of priority. The severity-priority table is designed to transmit data with lower delay, high data rate and low energy consumption using the MAC protocol.

3. Proposed MAC Superframe for WBSN

From the discussion above, it is found that emergency traffic having the highest level of priority, followed by other normal medical traffic. Emergency data should not compete and collide data with lower priority, and must be sent promptly in a medium without any loss or delay. In this research, we recognize superframe with beacon periods which is one of the three operating modes for accessing channel as specified in IEEE802.15.6 standard. WBAN coordinator is responsible for selecting superframe with beacon period to transmit data in an appropriate medium. In addition, emergency data having the user priority UP_7 and Exclusive Access Phase (EAP) is dedicated to deal with vital medical data. Since EAP phase of IEEE 802.15.6 standard is contention access phase; hence there is a possibility of data collision. Moreover, data with the same user priority dedicated for emergency traffic UP_7 may increase during WBAN operations; hence collision probability will also increase. Therefore, to solve this problem as mentioned above, in our research, emergency data are further classified and prioritized using priority-criticality indices as presented in Tables 2-4.

In our research, a novel and modified superframe for priority MAC protocol is proposed that enables to allocate appropriate slots for all sorts of data including UP_7 for emergency data, UP_6 for on-demand and UP_5 for normal data. The proposed superframe scheme is capable of allocating slot for emergency data with various level of criticality without data collision, thus results in low delay, high throughput, low energy consumption.

The following Figure 3 illustrates the proposed MAC superframe for the priority MAC which is based on the synchronous mode (beacon mode with superframe) of IEEE802.15.6 standard. In our proposal, we assign an Exclusive Access Phase (EAP) for emergency traffic that is a combined version of both EAP1 and EAP2. User priority UP_7 set for to ensure its highest level of priority over all sorts of medical data. Medical data, particularly emergency medical data, are aperiodic and required contention-free access to the channel which is not scheduled based. Besides, in our proposed mechanism, for on-demand medical data Random Access Period (RAP) is assigned. RAP is a combined version of RAP1 and RAP2. And finally, for normal medical or non-medical traffic a scheduled based or query-based Managed Access Period or phase (MAP) is proposed, which is a combined version of both MAP 1 and MAP 2. Besides, the Contention Access Phase (CAP) is set to zero.

Again, as of Fig. 3, the proposed MAC superframe scheme allocates the phases such as beacon phase B, EAP, RAP, and MAP and other phases as compared to Fig. 2 are set to zero. T_{SF} is used to indicate the length of a superframe, including T_{EAP} indicates the length of EAP, T_{RAP} denotes RAP, and T_{MAP} represents MAP.

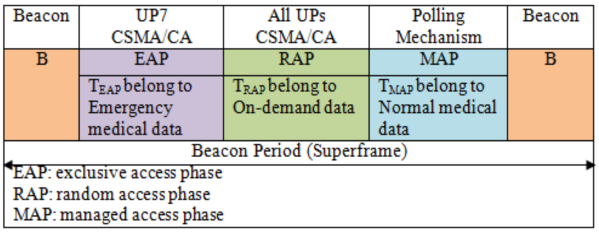

Fig. 3: Proposed MAC Superframe structure

Different UPs are used to indicate the importance of traffics and their access to the channel in the proposed superframe scheme that is listed in Table 4.

Table 4: Severity (Criticality)-Priority Index Table for WBAN Coordinator

Data/ Traffic Priority Level	***Priority Index***	***Criticality or Severity Index***			***Mapping with WBAN UPs***	***Traffic Designation and Frame Type***
Emergency medical traffics the most critical aperiodic traffic that is delay-sensitive. It consists of different data values lower or greater than the normal threshold value.	P_1 indicates the highest priority	Life-threatening disease orders for Pilgrims' during Hajj	Emergency Data Criticality Level	Priority-Criticality Index Table P_1C_i	7	Emergency medical situation. Data Frame
		According to our study				
		Heart problem	C_1EVHCT-Extremely very high critical traffic	P_1C_1		
		Heart sound	C_2EHCT-Extremely high critical traffic	P_1C_2		
		Respiratory disease	C_3ECT-Extremely critical traffic	P_1C_3		
		Oxygen stimulation (SpO2)	C_4VHCT-Very high critical traffic	P_1C_4		
		High fever or body temperature	C_5HCT-High critical traffic	P_1C_5		
		High or Low Blood Pressure	C_6CT-Critical traffic	P_1C_6		
		Blood pH (BpH)	C_7MCT-Moderately Critical traffic	P_1C_7		
		Blood flow (BF)	C_8MLCT-Moderately Low Critical traffic	P_1C_8		
		Diabetes or Blood Sugar	C_9MVLCT-Moderately Very Low Critical traffic	P_1C_9		

		Electric activity of skeletal muscles (EASM)	C_{10}LCT- Low Critical traffic	P_1C_{10}		
		Electrical impulsive brain activity (EIBA)	C_{11}VLCT- Very Low critical traffic	P_1C_{11}		
		Body Motion monitoring	C_{12}ELCT- Extremely Low Critical traffic	P_1C_{12}		
On-demand medical traffics not delay-sensitive and can be applied for both medical and non-medical applications	P_2 indicates the medium priority	ODT is aperiodic and is transferred upon requested by the physicians or healthcare providers (identification of Pilgrims, geographical position)			6	High priority medical data. Data or management Frame
The lowest priority is given to normal medical traffic. Normal medical traffic is periodic and is not delay-sensitive.	P_3 indicates the lowest priority	NT are periodic in nature			5	Normal medical data. Data or management Frame

Table 5 is created based on Table 4, as presented earlier. Aperiodic CAP has not been considered at all in our proposed scheme for the simplicity of the superframe structure. The access phases EAP, MAP and RAP are allocated to the emergency, normal and on-demand traffic. Again, the emergency traffic is classified into various classes and are identified by $C_i = \{1 \text{ to } 12\}$, and the level of criticality-priority level is designated using the index level P_1C_i. Again, P_1, P_2 and P_3 are defined as the level of priority.

Table 5: Allocation of channel access phases in the superframe

Providing User Priority (UP) according to IEEE802.15.6 standard	***Index of Data Priority***	***Index of Emergency Data Criticality***	***Criticality-Priority Index Table***	***Types of Access Phases***
UP_7 Emergency medical situation	P_1, the highest priority	C_i={1, ….., 12}	P_1C_i= {P_1C_1,...... .... P_1C_{12}}	EAP
UP_6 high priority medical data	P_2, medium priority	$P_1C_i = 0$		RAP
UP_5 normal medical data	P_3, low priority	$P_1C_i = 0$		MAP

4. Traffic Management in Proposed MAC Superframe

Different types of physiological data are being classified and prioritized in previous Table 4 and Table 5. It is also observed that the emergency data must get the highest priority to gain access to the data transmission channel over WBSN medium. In our research, user priorities are differentiated and classified into three types, but criticality levels of emergency traffic are distinguished into twelve categories, and the priority-criticality index table is defined accordingly for fast data transmission and allocation of slots without collision and retransmission of packets as depicted in Table 5 before. Proposed normal medical situation and emergency handling mechanism are presented in Fig. 4.

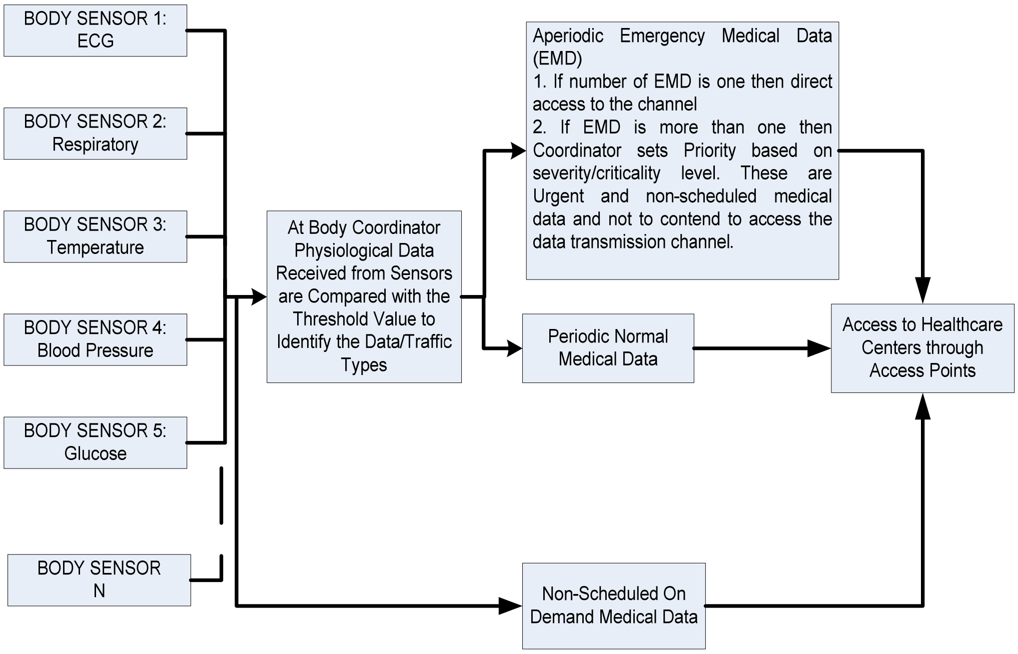

Fig. 4: Heterogeneous traffic management mechanism

4.1 Slot Allocation for Different Classes of Traffic of Proposed MAC Structure

Superframe slots are assigned to traffic upon the classification of different data and their level of priority. WBSN coordinator, in collaboration with sensor nodes distributes data to the slots for further communication through the channel. In this process EAP, MAP and RAP are allocated for an emergency, normal and on-demand data transmission based on CSMA/CA mechanism.

Emergency data can access the channel based on the level of priority. Emergency data with the highest priority should access the channel before that of low priority. Upon classification phase, depending on the traffic types, data are to be distributed among the queues. All emergency data shall proceed to slot EAP based on their criticality level and queuing process. on the other hand, non-emergency data are to proceed through MAP and RAP phases. In our proposed model, we present a preemptive queue method. Traffic preemptive queuing process at the data transmission scheme of MAC level is illustrated in Fig. 5. It is to be noted that, emergency traffics aperiodic in nature, and normal medical or on-demand traffic is periodic. Besides, emergency traffic is delay sensitive; hence it should not wait for a long time on the queue. In our proposed queue technique, data with a high level of priority must server ahead of that of low priority level.

4.2 Delay Sensitive MAC Superframe Based On M/M/1 Preemptive Method

The overall delay for the heterogeneous traffic at coordinator level is calculated using the M/M/1 preemptive technique. In this process, traffic with the highest priority should not wait on the queue and must proceed faster to the channel for communication.

we will analyze the model in order to find the waiting time or sojourn time that is a combination of exponential inter-arrival times with mean $\frac{1}{\lambda}$ and exponential service times with mean $\frac{1}{\mu}$ that works with a single server for our case, the coordinator of WBAN. Traffics are served in order of arrival. It requires in order that, $\rho = \frac{\lambda}{\mu} < 1$, since, otherwise, there is a possibility of exploding the queue length. The quantity ρ identifies the fraction of time the server is working. Besides, the mean service time $\frac{1}{\mu}$ is analyzed as the interval or period from point of packet arrival at the head of the queue to the point when the packet is effectively and successfully broadcasted.

We can obtain mathematical expressions for the mean number of traffics in the system *E(n)* and the mean time spent in the system *E(t)* from the balanced or equilibrium probability. For the mean number of traffics in the system *E(n), we get* $E(n)=\frac{\rho}{1-\rho}$ ....*(1)*

And by applying Little's law, we find, $E(t)=\frac{\frac{1}{\mu}}{1-\rho}$..*(2)*

Significantly, both *E(n)* and *E(t)* grow to infinity (time without end) as ρ approaches unity.

Let us consider data arrival rate of class *'i'* incoming traffic based on criticality level of data is λ_i, and the number of departure packets per unit time which is called service rate is denoted by μ. Upon arrival, data are distributed among the queues, as presented in Fig.5.

We propose an analytical model which is based on the M/M/1 queuing system that serves different types of traffics. We used a Poisson distribution process to analyze the packet arrival rate of different traffics. Suppose, a number of 'n' different traffics arrive according to the Poisson process with rate λ_n and the service time is exponentially distributed, hence the mean value is calculated as $\frac{1}{\mu}$, thus $\sum_{i=1}^{n} \rho_i$ where the occupation rate due to variable traffics i, we find, $\rho_i = \frac{\lambda_i}{\mu}$. Our proposed waiting time determination model is used to detect sojourn time of different emergency traffics based on their criticality level of WBANs sensors being generated from various events. The analytical result considering the overall delay of different data at the coordinator level is calculated as follows.

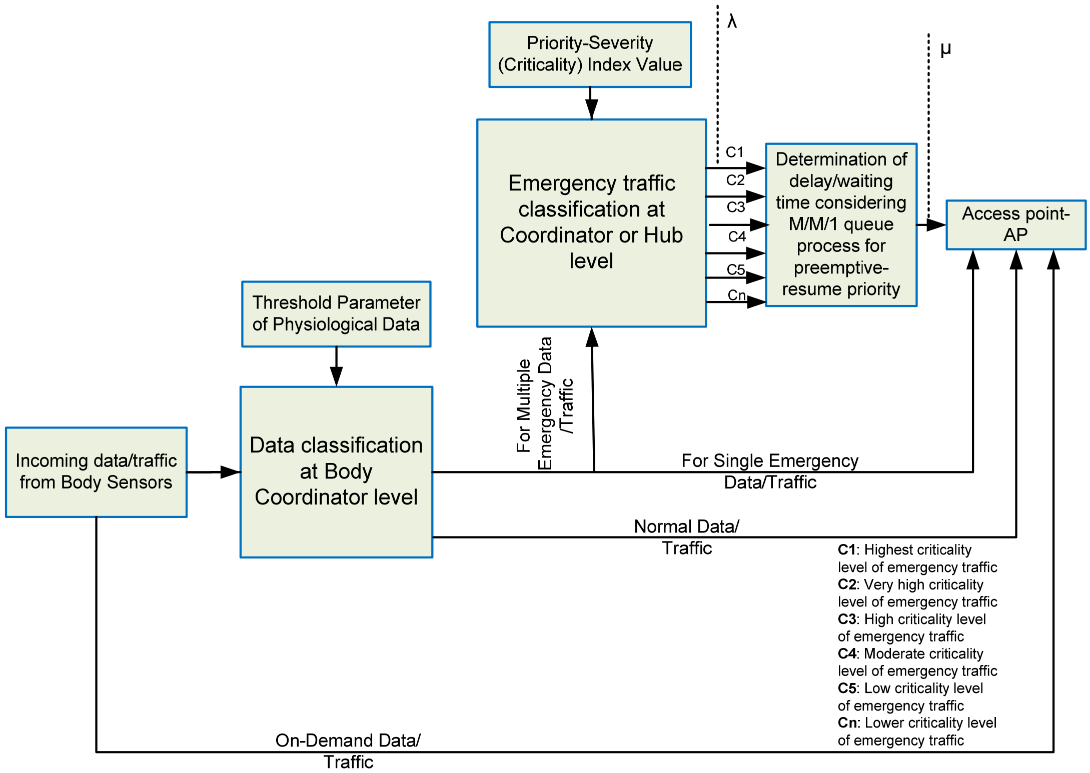

Fig. 5: Preemptive queue mechanism for the proposed MAC superframe

$$E(n_{p1ci}) = \frac{\rho_{p1c1}+\rho_{p1c2}+\rho_{p1c3}+\rho_{p1c4}+\rho_{p1c5}}{1-\rho_{p1c1}-\rho_{p1c2}-\rho_{p1c3}-\rho_{p1c4}-\rho_{p1c5}} - \frac{\rho_{p1c1}+\rho_{p1c2}+\rho_{p1c3}+\rho_{p1c5}}{1-\rho_{p1c1}-\rho_{p1c2}-\rho_{p1c3}-\rho_{p1c4}} = \frac{\rho_{p1ci}}{(1-(\sum_{i=1}^{n-1}\rho_{p1c_i}))\,(1-(\sum_{i=1}^{n}\rho_{p1c_i}))} \text{..............(3)}$$

And applying Little's law, $E(t_{p1ci}) = \frac{E(n_{p1ci})}{\lambda p1ci} = \frac{\frac{1}{\mu}}{(1-(\sum_{i=1}^{n-1}\rho_{p1c_i}))\,(1-(\sum_{i=1}^{n}\rho_{p1c_i}))}$............(4)

Where data arrival rate is denoted by λ, μ is represented as the number of packets that depart per unit of time. The traffic intensity level or traffic rate, which is the ratio of the arrival and service rates at the coordinator is defined by ρ.

According to the Little's law, a basis for forecasting the performance of the individual queues is defined by

$$E(n) = \lambda * E(t) \text{ ....(5)}$$

4.3 Operation Procedure of Preemptive Queue Based Modified MAC Superframe for WBSN

According to Fig. 6, normal medical data being generated by the sensors with the same priority level will directly send to the coordinator for further processing.

On the other hand, according to Fig. 7, data with different level of priority also will send to the coordinator.

At the coordinator level, data are further classified based on the severity-priority index table and send for further processing.

However, as presented in Fig. 8, each node can generate the emergency traffic only and different emergency data from different sensor nodes aggregate to body coordinator nodes where emergency traffic is further prioritized based on criticality level of emergency traffic. As we know, the emergency traffic occupies the highest user priority; however, in our research, we propose a criticality-priority index table as presented in Table 4. The emergency traffic with high priority level should access the channel ahead of low criticality level. This is one of the most crucial research objectives of our research.

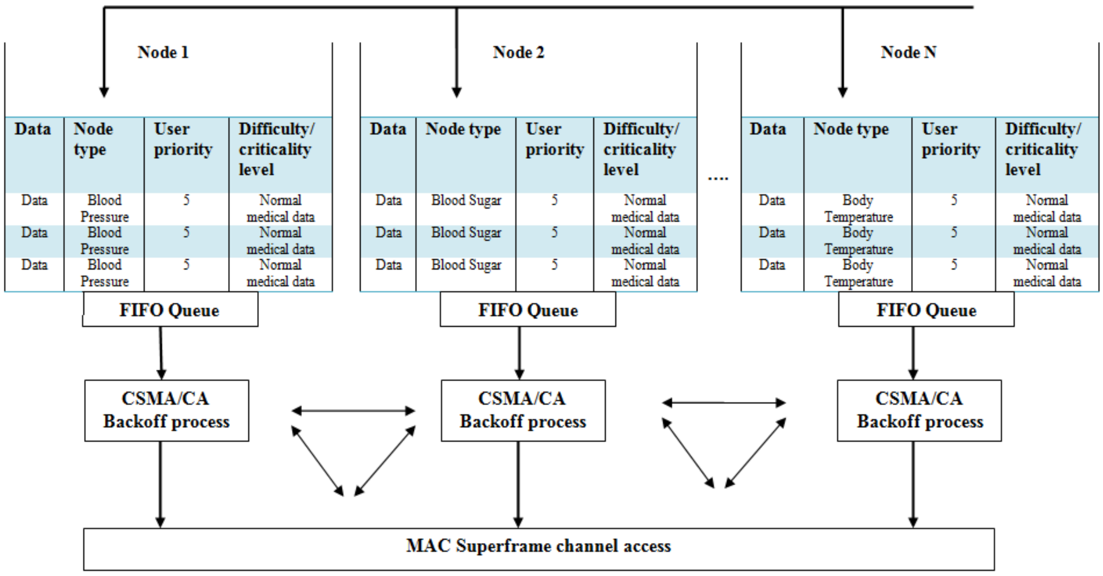

Fig. 6: Function of normal medical traffic with the same priority level

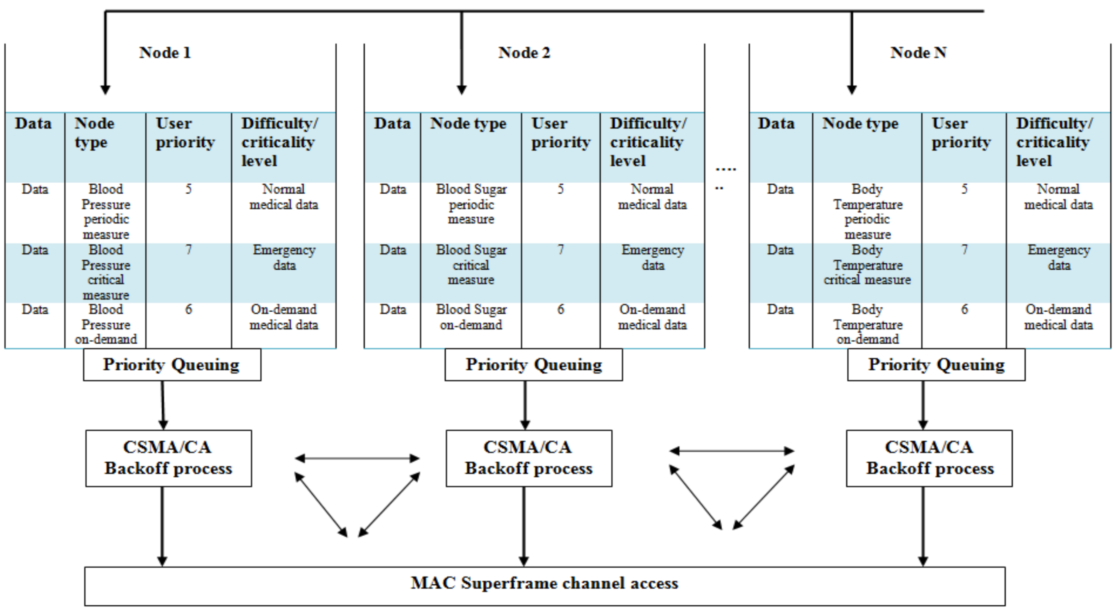

Fig. 7: Function of heterogeneous traffic with a different priority level

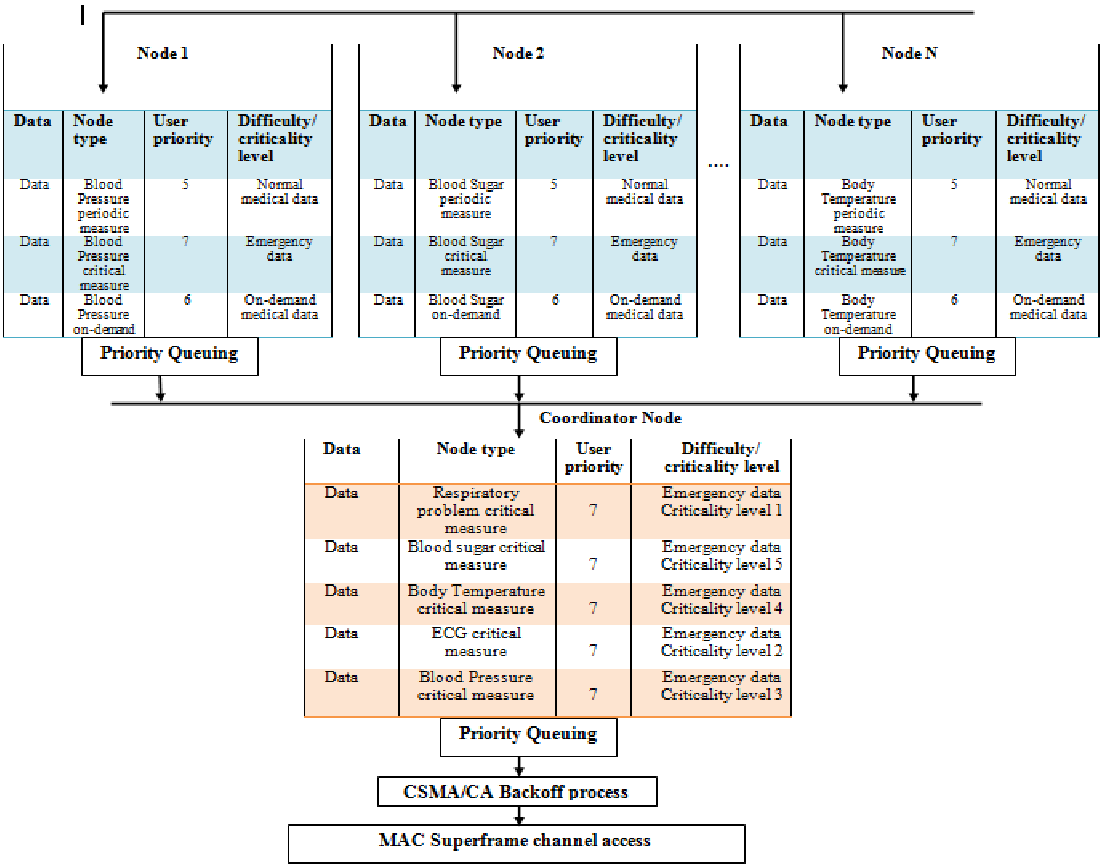

Fig. 8: Function of emergency traffic with a different severity level

5. Conclusion and Future Work

Every year throughout the world during various religious festivals, millions of pilgrims aggregate and suffer different infectious and chronic diseases. Considering the overcrowded environment and pilgrims' health-related issues, it is vital to provide real-time and the best healthcare facilities. Therefore, in this research, we propose to deploy WBSN to facilitate the healthcare problems that consist of tiny sensors and a coordinator. To transmit normal medical and emergency medical, physiological data of pilgrims using WBSNs to the healthcare station at the overcrowded ritual site is our primary research concern. Besides, based on pilgrims' emergency and normal medical data, a severity-priority index table is proposed. By using classified normal and emergency medical data, we define various levels of data priority to be used by the coordinator of WBSN. In order to minimize the overall delay of transmitting life-critical and normal medical data for the network a preemptive queue method based modified MAC superframe for WBSN is designed and presented to handle pilgrims' heterogeneous traffic with low delay efficiently.

Finally, an extensive experimental will carry out to validate the analytical findings as presented in the previous sections.

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Conflict of Interest

The authors declare that they have no competing interests.

Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

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