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ORIGINAL RESEARCH

An queueing model with improved delay sensitive medical packet transmission scheduling system in e-health networks

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Abstract
Electronic health (e-health) is commonly recognized as a promising model for raising the enormous pressure on conventional healthcare systems. In this paper, an improved delay-sensitive medical packet transmission scheduling system has been proposed to manage the medical packet transmission in e-health networks. It focuses on communication through the wireless body area network (over WBAN). Medical packets arrive at the gateway (generally with one patient). Their applications are reported with different time-sensitivities to the service provider (i.e., the base station), illustrates the value of their medical signal. Then the priority queue is designed for the order of transmission. The base station analyzes the service key parameters by developing the packet utility and the base station's profit functions. It creates an evaluation-compatible method so that all gateways are required to disclose their medical packet's actual delay sensitivities. Experimental analysis has shown that the proposed method will maximize the base station's profits, thus providing a higher priority medical packet service.

Keywords Wireless body area network · Electronic health networks · Medical packets

1 Introduction

Electronic health (e-health), which integrates communication and computer technology, is often recognized as a promising paradigm to reduce the impact on conventional health systems. e-Health benefits are remote access to medical care, substantial patient surveillance, and personalized health management (Yi et al. 2019). The wireless body area network (WBAN) is an essential component of e-health systems. Usually, a WBAN is used in emergencies and typically consists of a database (by example, a smartphone) and various medical sensors (Ullah et al. 2019). Such diagnostic devices are used continuously to detect specific types of physiological signals. Intra-WBAN communications standardized in IEEE 802.15.4 shall be used for exchanging information between wearable sensors and the gateway. The gate gathers signals and transmits them from medical sensors to government hospitals through WBAN (Le and Moh 2020). While numerous researches have been undertaken to establish e-health systems focused on WBAN, most of them limit the focus to WBAN communications (Albaeazanchi et al. 2019). In contrast, communications within WBAN have rarely been analyzed, while they are equally important (Chakraborty et al. 2013). Effective transmission task scheduling systems are essential for communications beyond WBAN because it needs (1) data transmissions beyond WBAN will enhance rapidly in the short term with the widespread usage of WBANs; (2) the optimal approach could not be identified in existing technology such as Wi-Fi and modern telecommunications networks to satisfy the demands of e-health services as a result (Kathe and Deshpande 2019).

The health of medical service quality is another distinctive requirement for the transmission of medical data (Pandey and Gupta 2020; Vilela et al. 2020). It needs (1) the monitoring of evolving public health alarms as a higher priority than non-emergent signals and (2) the dissemination of regular medical data jointly, given their contained information and their scarcity (Istepanaian and Zhang 2012). Data packets are usually categorized in e-health systems (Baskar et al. 2020) into specific categories depending on appropriate containment levels (Perumal and Nadar 2020). For example, electrocardiogram (ECG) sensing data is more

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essential than body temperature, although they are in non-emergency (Rigby et al. 2020). But the starvation (or unnecessary delays) of some medical knowledge may also reduce the quality of medical diagnosis (Premarathne et al. 2017; Bashshur et al. 2016; Nasralla et al. 2018). It needs to take priority over and beyond the WBAN transmission schedule, which is dependent on delay (Kumar et al. 2020).

Moreover, the proper execution of priority awareness (Singh and Chatterjee 2020) beyond the WBAN transmission schedule depends on individual medical packets' class information reported on by related gates (Asam et al. 2019; Pushpan and Velusamy 2019). Nevertheless, WBAN gateway services are called high-intelligence cognitive devices, strategically and cruelly behaved compared with simple structured sensors (Chavva and Sangam 2019). In other words, gateways intentionally misrepresent medical packet classes to take advantage of the transmission scheduling beyond WBAN (Hasan et al. 2019). Such inaccurate actions can be prevented in well-designed e-health structures (Choudhary et al. 2020). However, QoS will never be assured due to incorrect priority details reported, resulting in serious healthcare implications. Besides, it is essential to significantly increase support services (Joshi and Mohapatra 2019; Cicioğlu and Çalhan 2019) to simplify its implementation.

The main contribution of this paper is discussed as follows,

- The WBAN transmission scheduling is configured for a queueing model with a priority that depends on time and distance.
- A problem of network protection is developed to maximize and consider the possible misbehaviors of smart gateways.
- An optimal scheduling system for a simple queueing problem has been designed as a criterion.
- After studying the problem's features, an exact mechanism is proposed for transmission scheduling beyond WBAN, depending on the virtual queueing game's outcomes.
- Numerical simulations evaluate and test the performance of the proposed system

2 Literature survey

Wang et al. (2012) presented a distributed wireless body area network (DWBAN) for medical supervision. The system has three layers: a network sensor level, a mobile computing network level, and a network level for remote monitoring. It captures, displays, and retains vital information such as ECG, oxygen from the blood, body temperature, pulse rate. It is responsible for managing emergency care and warning of diseases. The system has several benefits, including convenience, low expense, low power, simple storage, comfortable transport, fast transplantation, efficient real-time, and comfortable contact between human–machine interactions.

Manickavasagam et al. (2020) introduced a software-defined network (SDN) for packet forwarding node selection. In the regular and emergency packet transmission, the SDN controller needs to select the fastest and efficient route between source and destination to improve network efficiency. E-health information for the emergency patient must be transferred directly to remote hospitals or doctors via a WBAN efficient packet routing approach. In WBAN, an efficient packet routing scheme designed based on packet priority with a greedy algorithm for SDN was developed to improve packet transmission.

In Sodhro et al. (2020), the author introduced Efficient service quality calculation (QoS) through intelligent evaluation methods in the medical data processing. Health emergency services frequently require essential data transmission and restrictive network quality of service (QoS) requirements. This paper makes three different contributions. First, it suggests a modern adaptive QoS computation algorithm (AQCA) evaluates performance indicators equally and efficiently (i.e.) power transfer, duties duration, and path selection for medical data processing in healthcare applications. In real, medium access (MAC) and network layers, the QoS computing system can be given in medical applications. Third, the proposed AQCA and quality of experience (QoE) computation mechanism has been developed.

Qureshi et al. (2020) introduced a protocol to energy-aware routing (EAR) to minimize energy usage and select the next step by assessing the connected node quality. To stabilize the load, reduce energy consumption, and maximize transmission, the proposed protocol analyses energy, connection efficiency, and remaining energy levels. Several simulations were carried out to assess the suggested protocol's energy consumption, data delivery, time, and data performance. Experimental results show that a better date-routing mechanism and a better alternative for minimizing sensor node energy in WBANs are provided.

In Jiang et al. (2017), the author proposed an energy-efficient, multicast, wireless multi-hop network routing approach for smart health applications. Unlike previous methods, we aim to maximize network energy efficiency. To this end, they use the topology control and cycle system to create the optimal routing technique for constructing the multi-tasking network with optimum energy output for the network. The results of the simulation show that the strategy described is practical and feasible.

Dangi et al. (2020) requested a delayed analysis of emergency vital database packets (EVD Packets) in the hospital-centric wireless bodily surface network (HCWBAN). Monitoring the body's critical parameters such as body temperature, blood pressure, cardiac rate, electrocardiogram, and electroencephalogram are conducted on the HCWBAN sensor nodes activated by ZigBee. At a central node are processed sensitive vital parameters, and the data packets are sent to the personal-area network PAN coordinator. The key data packets are listed as standard-essential data packets and packets for necessary emergency information.

3 Improved delay-sensitive medical packet transmission scheduling system

This section describes the system's model under consideration by incorporating the communication framework in e-health systems for transmission scheduling. The problem is expressed in the improved delay-sensitive medical packet transmission scheduling system.

3.1 Network model

The standard e-health network is intra-WBAN and beyond WBAN, as shown in Fig. 1. All WBAN systems contain a gate and various heterogeneous biosensors used by several areas of the body. Each biosensor monitors and sends a signal at the gate. In a certain standard, including IEEE 802.15.4, IEEE 802.15.6 is known as simple intra-WBAN connectivity. The category IEEE 802.15 is based on standardizing the wireless network in the personal region, and even in the IEEE 802.15.4 standard, it categorizes wireless sensor networks. The IEEE 802.15.6 protocol is specified in the Body Area Networks. In this article, the findings of IEEE 802.15.4 and IEEE 802.15.6 will be evaluated on a similar configuration with the same parameters because the efficiency of devices configured with a specific standard used for another standard can be essential to measure.

An aggregator is a gateway where all medical knowledge is obtained from devices. The data is briefly processed in its buffer. The information is being transmitted to the health center via the outside WBAN via remote. To explain this, it ignores intra-WBAN details and concentrates on the schedule of transmission in communication outside WBANs.

The medical packets are classified in limited $\mathbb{C} = \{0,1,2 \ldots ..C\}$ classes according to IEEE 802.15.6, where $\{0\}$ and $\{1,2 \ldots ..C\}$ Class sets are respectively covering emerging alerts and non-emergent routines. The size of the different medical packets that conceptually differ and it presume that each class $c, \forall c \in \mathbb{C}$ has a random variable S_c, the probability density function (PDF) $f_{S_c}(.)$ and the absolute mean $E[S_c]$.

The data has been aggregated based on the portal that receives all medical knowledge from computers to momentarily process data in the buffer and transfer the information via remote WBAN to the health centre outside. The transmission rate beyond WBAN of each gateway $g, \forall g \in \{1, \ldots ..G\}$ is defined on each channel represented as

$$p_g = Dlog_2\left(1 + \frac{\left|h_g\right|^2 P_t q_g^{-\rho}}{\vartheta^2}\right) \quad (1)$$

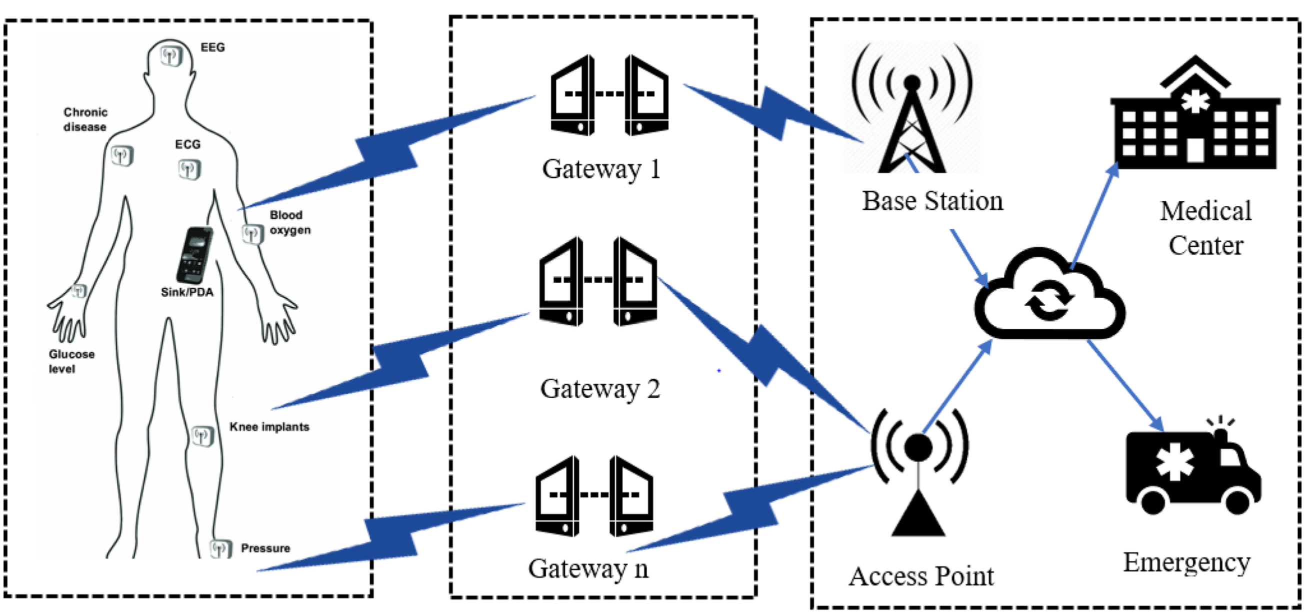


Fig. 1 e-Health network

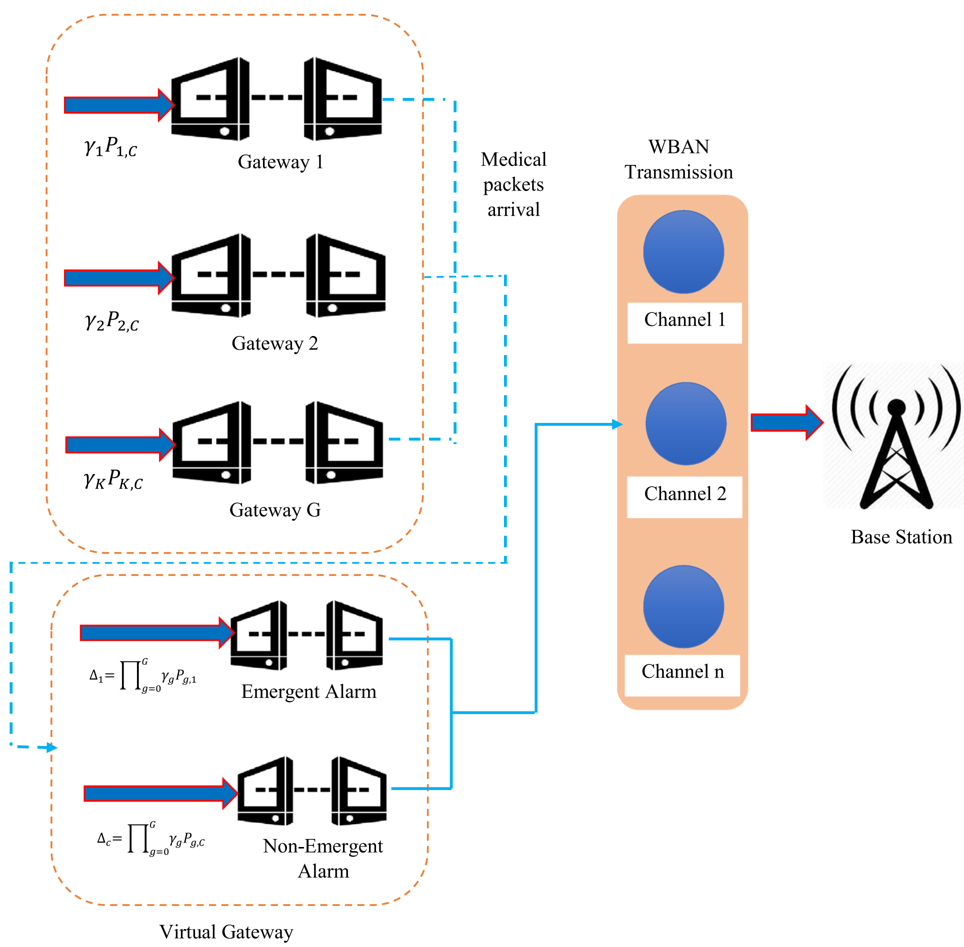
where D, P_t, ϑ^2 are indicating the channel length, propagation capacity, and variance of the Gaussian additive noise, respectively, $\left|h_g\right|^2$ measures the fading effect from the Rayleigh and assumes an exponential unity mean distribution, q_g defining the size of the g gateway to the BS, so $q_g^{-\rho}$ indicated as path loss where $\rho \geq 2$. The medical packets are known as IEEE 802.15.6 Minimal classes, where class sets cover new alerts and non-emergent routines, respectively. The various medical packets' measurements vary conceptually, and each class is supposed to be based on random variables and PDF.

3.2 Queueing model

Hundreds of interdependent biosensors are used in each WBAN. For the complete entry of medical packets with several specific biosensors, the Poisson process may be approximated by the γ_g at each gateway g. However, this proposed method is often compatible with more theoretical frameworks. Furthermore, it is assumed, through long-term tracking, that there is an existing known $P_g = (P_{g,0}, P_{g,1}, \dots P_{g,C})$ distribution at each gateway g when arriving medical packets from different classes where $P_{g,c}$ indicates the probability of a received medical packet at gateway g belonged to class $c, \forall c \in \mathbb{C}$ and $\prod_{c=0}^{C} P_{g,c} = 1$. Assuming P_g, the average rate of arrival for gth class medical packets can be determined as $\gamma_g P_{g,c} = 1$ at any gateway g. If a gateway receives a packet from its biosensor, the BS is automatically informed of a transmission request beyond WBAN. Both packets are placed in gateways in buffers for a short time. A buffer excess is ignored in this situation since medical packets are typically 100 kg, and existing mobile devices are stored in gigabytes. Each WBAN uses hundreds of interdependent biosensors. Medical packages can approximate the Poisson method at each gate for the full entry of medical packs containing many separate biosensors. This methodology has consistent with more analytical constructs. In comparison, a long-term monitoring strategy suggests that each gateway has an established known distribution that shows the likelihood of a medical packet being received at the gateway when medical packets in various groups have arrived.

Figure 2 displays the designed queue model of the transmission scheduling beyond WBAN. The BS schedule medical packet transfers beyond WBAN as the network controller. All scheduling would be based on the criticality

Fig. 2 Queueing model



of patient packets and separate gateways to guarantee medical-grade QoS. Figure 2 includes two virtual buffers, and the BS handles transmission requests from one virtual gateway for developing packets and one for non-emergent packets. As a result, the $C + 1$ module form in $\mathbb{C}$ is essential for many packet delivery processes on the virtual gateway. Poisson still distributes aggregate packet delivery processes because of the independence of the gateway, and the typical rate of arrival is $\Delta_c = \prod_{g=0}^{G} \gamma_g P_{g,c} = 1, \forall c \in \mathbb{C}$. While all medical packets address potential delivery delays beyond WBAN, sensitive information in health applications must be correctly prioritized rather than regularly protected. The BS handles transmission requests from one virtual gateway for developing packets and one for non-emergent packets. As a result, several essential packet delivery processes on the virtual gateway are processed based on Poisson aggregate packet delivery processes, prioritizing the sensitive information.

As observed in Fig. 2, the transmission scheduling queue model is built beyond WBAN. As a network controller, the BS software moves medical packages through WBAN. Both schedules should be based on patient packets' criticality on different gateways to ensure quality medical consistency. It implies that the QoS of emergency packet transmissions must be assured regardless of non-emergent transmissions. For examples, a condition is represented as follows,

$$E[D(0)] \leq \gamma_{th} \tag{2}$$

where the estimated delay for emerging packet transmissions in beyond WBAN is $E[D(0)]$ and γ_{th}, and its respective required QoS threshold. Intuitively, to adhere, the BS should selectively send M_{min}^{0} channels for the distribution of evolving packets. In practice, M_{min}^{0} maybe focused on higher-order statistics for new packet transmissions. It can be exploited on all other channels for non-emergent packet transmission via $M - M_{min}^{0}$. Mostly, the transfer scheduling should be configured as a queue method where the time of service is for each type of medical packets. Similar to the increase in transit time dependent on transfer timing, the medical packet's transmission value would be analyzed based on the queue method.

$$Z_c = \frac{s_c}{A(M - M_{min}^{0})}, \quad \forall c \in \mathbb{C}\{0\} \tag{3}$$

s_c and A is the packet sizes for the lth class and the transmission rate beyond WBAN for each wave, respectively. Therefore, the approximate delay for evolving packet transfers beyond WBAN is determined based on the respective QoS. The BS can send channeled to disperse emerging packets intuitively.

3.3 Problem definition

As the duration of transmission of a medical packet is constant, it may correctly be assumed that each service's reliability (for example, the transfer of a single medical packet) should be consistent at first and shown by v. In other terms, the transmission value of a medical packet will decrease similarly with the rise in the transmission period. Therefore, for every packet, it determines the cost of waiting according to the delayed sensitivity.

$$b(\delta) = \delta E[W(\delta)] \tag{4}$$

where δ represents the delay sensitivity of packets and indicates the per-unit expense of expectation period. The mean waiting time given the sensitivity to δ is $E[W(\delta)]$. Therefore, the δ medical packet is more concerned about the potential delay since the wait time is challenging. It is essential to assess the importance of medical products. For particular, the index of the severity of medical packets can be described,

$$\vartheta = \rho \left| \frac{(\sigma_v - \sigma)^2 - (\sigma - \sigma_c)^2}{(|\sigma_v| - |\sigma_c|)^2} \right| \tag{5}$$

As the transmission time of a medical packet is constant, each service's reliability (for instance, the transmission of a single medical packet) may correctly be verified at first to be consistent and implied based on QoS parameters. In other words, with the increase in the transmission period, the medical packet's transmission value would be processed in separate gateways. Where σ is the detected signal, and The higher and lower limits of the standard spectrum are both $\sigma_v and \sigma_c$ with a specific health parameter. ρ is a coefficient of weight where the higher value is calculated with a more significant application. A medical signal's seriousness tends to be measured by tests of the divergence of the sensed signal from the standard values. Indeed, it may define a direct function of ϑ, i.e.,$\delta = F(\vartheta)$. Remember that it is simple to extend the model to any function $F(\cdot)$. A j, δ_j is a unique knowledge for a medical packet j, i.e., it is only accessible at the related portal inaccessible to every other gateway and the base station.

The signal observed has been analyzed using the higher and lower standards depending on the particular health parameter. The discrepancy in sensed signals from normal values tends to assess the magnitude of a medical signal. A direct feature can be defined as a function that is not accessible to any other gateway and station on the relevant portal. As a result, the delaying sensitivities of medical packets are heterogeneous, and their types1 are parameterized according to δ. The delays of all packets (as a result of medical gravity) are obtained from an interval defined distribution with probability density (PDF) function $f_\delta(.)$

and cumulative distribution function(CDF) $F_\delta(.)$, where $\bar{\delta}$ remains at the upper limit. When a medical packet with δ_j arrives, the transmitting portal will declare a request for transmission in the Base Station by recording this packet's delay sensitivities. Although, the gateway that may report δ'_j and δ_j. In addition, the transmitted packets will be indicted for gateways. Because payment is based on the level of service (i.e., waiting time), the reported delayed sensitivity, refers to as $p(\delta'_j)$ relies on it. As a result, medical packets delaying sensitivities are heterogeneous, with type-1 parameterized from a given interval PDF and CDF delivery. The transmitting portal will announce the Base Station's medical packet application by recording this packet's sensitivities for the delay. In summary, the gateways for the transmission of a medical packet (j) with truthful type can be defined as,

$$U\left(\delta'_j \middle| \delta_j\right) = u - \delta_j E\left[V\left(\delta'_j\right)\right] - p(\delta'_j) \tag{6}$$

where u is the initial value, $E\left[V\left(\delta'_j\right)\right]$ and $p(\delta'_j)$ are packet j payment and waiting for cost. Note that the overhead report potential and delay in (6) are not known to be minimum compared to regular medical packets. This gateway will demonstrate a more energetic sensitivity to delay in reducing the overall wait time of the service and increasing the transmissibility of medical packets.

In the meantime, the Base Station is targeted at maximizing its gateways to provide services to medical packet transmissions. If the actual delays of all medical packets are recorded, the estimated benefit of the base station can be measured as

$$R = \gamma \int P(\delta) f_\delta(\delta) d\delta \tag{7}$$

The pricing and distribution functions for δ are the average accumulation of the medical packet arrivals. γ is the average medical packet arrival rate as described in $P(\delta)$ and $f_\delta(\delta)$.

In summary, the problem of developing an Improved Delay-Sensitive Medical Packet Transmission Scheduling can be expressed as follows,

$$\underset{P(.)}{\arg\max}\, \gamma \int P(\delta) f_\delta(\delta) d\delta \tag{8}$$

$$U\left(\delta' | \delta\right) \leq U(\delta | \delta), \forall \delta, \delta' \in \delta$$

$$E = \delta$$

As observed from the Eq. (8), The base station aims to maximize its portals for facilities in delivering medical packages. The base station's expected gain can be calculated if all medical packages' real delays are reported.

A first limitation suggests a state of incentive consistency and means that a typo δ medical packet will never produce any added benefit from a misreport δ. This last constraint means that all medical packets must be individually rational.

4 Characteristics of the IDSMPTS

If the IDSMPTS proposed validates all of the system's requirements, some attributes can be attained initially. It examines some corollaries of the price function p (·) assuming that incentive integration is accomplished.

Corollary 1 *For two medical packet classes under IDSMPTS (e.g., c and c′).*

$$\pi(c) \geq \pi\left(c'\right), \quad if\, \alpha_c \geq \alpha'_c, \quad \forall c, c' \in \mathbb{C}\{0\} \tag{9}$$

Proof According to the page limit, this proof is ignored.

Figure 3a shows the WBAN transmission service (without delay), and Fig. 3b shows the WBAN transmission service (with delay). This implies that $\pi(c)$, $\forall c, c' \in \mathbb{C}\{0\}$ as a function and it should be increased by α'_c. In this respect,

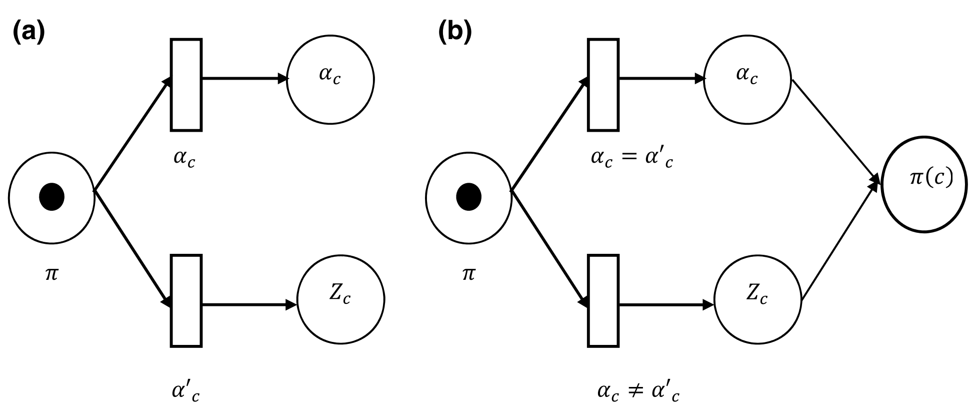


Fig. 3 **a** WBAN transmission service (without delay) **b** WBAN transmission service (with delay)

every cth medical packet with a larger α_c must be charged a higher price to achieve better beyond WBAN transmission. It is logical to see that service charges will be focused not just on the latency but also on the coverage period (i.e., the time to use other radio resources of WBAN). In other words $\alpha_c, \forall c, c' \in \mathbb{C}\{0\}$ is expected to be an increasing $E[Z_c]$ function. It is represented as

$$\pi(c) = \pi\left(\alpha_c, E\left[Z_c\right]\right), \quad \forall c, c' \in \mathbb{C}\{0\} \tag{10}$$

Corollary 2 *If the pricing feature needs to comply and for several medical packets, δ_j and δ_i, it must be compatible with,*

$$p\left(\delta_j\right) \geq p\left(\delta_i\right), if\, \delta_j > \delta_i, \quad \forall \delta_j, \delta_i \in E \tag{11}$$

Proof Initially, it assumes the contradiction function for analyzing the pricing function of the medical packets

$$p\left(\delta_j\right) < p\left(\delta_i\right), if\, \delta_j > \delta_i, \quad \forall \delta_j, \delta_i \in E \tag{12}$$

Although $\delta_i \in E$ and the cost function follow the constraint of (8), then it can be represented as,

$$U(\delta_j|\delta_i) > 0 \text{ and } U(\delta_i\big|\delta_i) \geq U(\delta_i\big|\delta_j) \tag{13}$$

Therefore, $E[V(.)]$ decreases as a higher delay-sensitiveness value is never expected to result in a longer waiting time. It can be described as follows,

$$E\left[V\left(\delta_j\right)\right] < E\left[V\left(\delta_i\right)\right] if\, \delta_j > \delta_i, \quad \forall \delta_j, \delta_i \in E \tag{14}$$

For each of the two types $\delta_j > \delta_i$ (11) and (13), then

$$u - \delta_i E\left[V\left(\delta_i\right)\right] - p\left(\delta_j\right) < u - \delta_j E\left[V\left(\delta_j\right)\right] - p(\delta_j) \tag{15}$$

It implies the $U(\delta_i\big|\delta_i) < U(\delta_j|\delta_i)$. The implies The criteria of incentive matching shown in (13) seem to be contradictory. Therefore, in (12), this is not assumed that the statement is proven.

Figure 4a shows the Medical packet transmission, where $\delta_j < \delta_i$ and Fig. 4b shows the medical packet transmission, where $\delta_j > \delta_i$. Corollary 2 states that the delayed medical packet (i.e., a more new delay) would spend additional time on the service and increase the quality. It would also demonstrate that the medical packet that arrives will be delivered with incentive precision in compliance with a threshold condition.

Corollary 3 *The pricing function p(.) benefits compatible. When the medical bundle with type $\delta_0 = \delta$ doesn't even have a negative value, so it has no negative use for any medical packet to type $\delta = \delta_0$.*

Proof Cost of the packet with $\delta_0 \in E$, then

$$U(\delta_0\big|\delta_0) = \text{v} - \delta_0 E[V\left(\delta_0\right)] - p\left(\delta_0\right) \geq 0 \tag{16}$$

where $\delta < \delta_0$,

$$u - \delta_0 E\left[V\left(\delta_0\right)\right] - p\left(\delta_0\right) < u - \delta_0 E\left[V\left(\delta_0\right)\right] - p(\delta_0) \tag{17}$$

The following effects emerge with incentive compatibility:

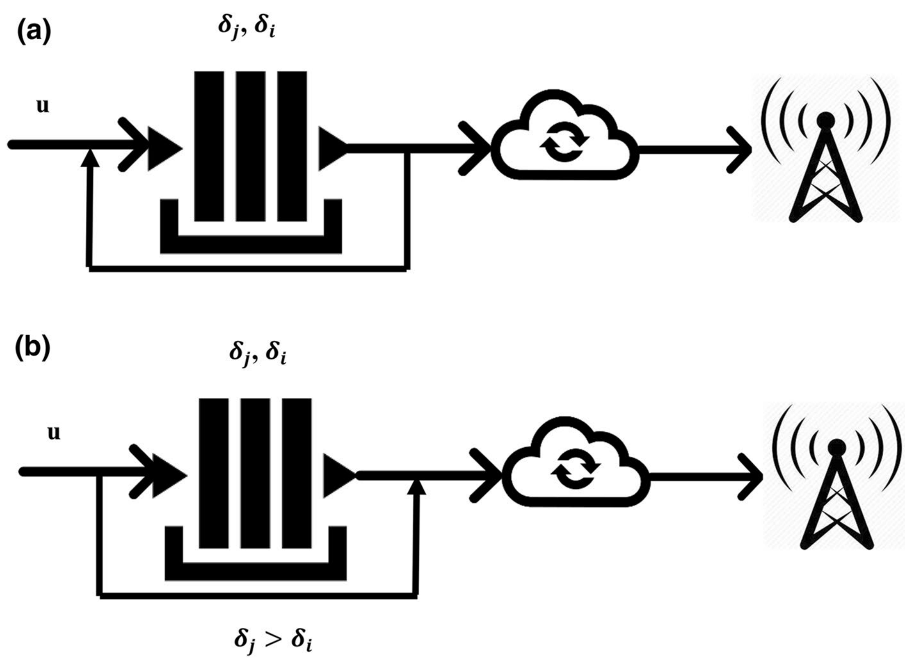


Fig. 4 **a** Medical packet transmission where ($\delta_j < \delta_i$). **b** Medical packet transmission where ($\delta_j > \delta_i$)

$$u - \delta E\left[V\left(\delta_0\right)\right] - p\left(\delta_0\right) = U(\delta_0|\delta) \leq U(\delta|\delta) \tag{18}$$

Based on (16)–(18), it can be described as

$$U(\delta|\delta) \geq U(\delta_0|\delta_0) \geq 0 \quad if\, \delta \leq \delta_0 \tag{19}$$

It means that $\delta \in E$ will be transmitted, i.e., a medical packet with δ.

Figure 5 shows the medical packet transmission where ($\boldsymbol{\delta = E}$)**.** Corollary 3 helps one to assume that the pricing function is designed according to δ, the upper delay sensitivity boundary to ensure $\delta = E$ (i.e., that no packet is lost in this system). Therefore, corollary 3 also implies the vulnerability to delay is finite. A mathematical modeling calculation essentially contributes to the output distance. Thus, the shorter the time it takes to wait, the longer the delay is raised. It has been processed due to the less emergency in the medical kit with more relevant information (i.e., which must be delivered immediately) based on the delay sensitivity boundary. Given the possible delay's sensitivities, the mean waiting time is difficult because the processing period is difficult.

Corollary 4 *From initial value v for each packet transmission, if $p(\cdot)$ fulfills reward consistency, then it must have* $\delta < +\infty$.

Proof If $\bar{\delta}$ is infinite, the delay sensitivity value may be selected between 0 and $+\infty$. Consider the extreme case of δ, and it is described as follows,

$$\lim_{\delta \to +\infty} U(\delta|\delta) = u - \lim_{\delta \to +\infty} \delta E[V(\delta)] - \lim_{\delta \to +\infty} p(\delta) \tag{20}$$

As the meantime of expectation is reduced by increased delay sensitivity, it has $\lim_{\delta \to +\infty} \delta E[V(\delta)] = 0$. In comparison, $p(\delta)$ is raised by δ in conjunction with corollary 2 then $\lim_{\delta \to +\infty} p(\delta) = +\infty$.

$$\lim_{\delta \to +\infty} U(\delta|\delta) = u - \infty \times 0 - \infty < 0 \tag{21}$$

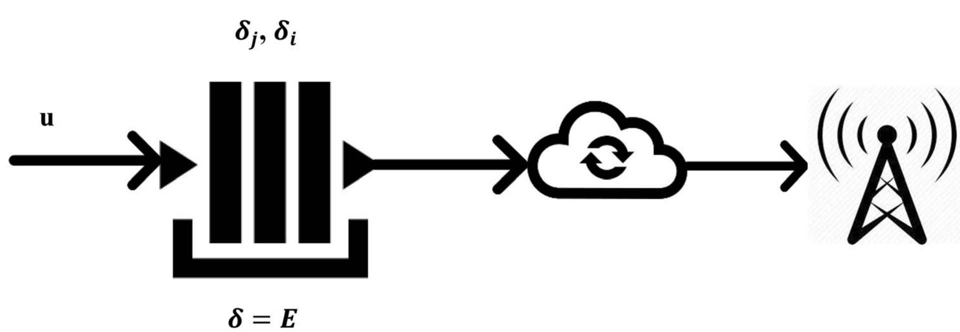
The above inequality implies that such packets are not transmitted by $\delta \to +\infty$ since these packets' utility is negative. To ensure that the network doesn't miss a medical packet required $\delta < +\infty$.

4.1 Predicted waiting time analysis

The primary priority prevention strategy for avoiding packet transfers of lower importance on the network while medical packets with higher priorities (whether in queue and service) has arrived in this paper. If the packets do not have high priority, the service will be restored in preventative packets. This paper's essential purpose is to stop the transmission of packets that are of better quality through the network. In contrast, medical packets with higher priority have been transmitted (either at the queue or a service). If no high-priority packets are available, preventive transmissions are started. This control in the pre-emptive restored queue showed that e-health systems usually need a priority rule. In other terms, further necessary medical packets will be immediately transmitted, even how lower-priority packet carriers are generated. The medical packets' priority in this problem will be focused on delay values within known distribution, relative to the current priority queue analysis, where patients are listed as specific priorities. To analyze the expected time of waiting, it has been divided into two parts:

- If the medical packet type arrives, it is appropriate to prevent all other packets' transmission with a low priority, even if handled. Still, the early packet arrived with requirements equal or similar to δ cannot be ignored in the network. This waiting time can be defined as $E[V_1(\delta)]$. Equally, all medical packets with priorities above or equivalent to a specific priority level, and the total processing period for such packets is exactly $E[V_1(\delta)]$ can be assessed. Since low-priority packets may not impact high-priority packet service, $E[V_1(\delta)]$ equals $E[V_{1q}(\delta)]$. Here $E[V_{1q}(\delta)]$ stands for the mean waiting time of a queue at the rate of delivery $\gamma[F_0(\delta) - F_0(\delta)]$, where $F_0(\delta) - F_0(\delta)$ is the probability that a packet of the type less than δ and greater or equal to δ.
- Once the medical packet has reached the network, new packets with preferences higher than δ will be added to the medical packet type δ. Because they have higher pre-

Fig. 5 Medical packet transmission where ($\boldsymbol{\delta = E}$)



ventive priorities, their time would add to the packet's processing time for type δ. This part of the waiting time called $E[V_2(\delta)]$.

$$E\left[V_2(\delta)\right] = E[T(\delta)].\gamma\left[F_0(\delta) - F_0(\delta)\right].D/H \tag{22}$$

where $E[T(\delta)] = E\left[V_2(\delta)\right] + D$ is the mean response time, including medical packet waiting times and service time, and where D/H is the system average service rate. Therefore, Eq. (22) indicates the maximum service period for priority packets higher than δ, that arrive while waiting and packets transmission.

4.2 Pricing function design

The cost function has been designed for the requirements of the device. It formulates the cost method with incomplete value information using a single static auction process. It is described as follows,

Pricing function formulation: the payment for the transfer is established for every medical packet with sensitivity $\delta \in \delta$ to delay is described as follows,

$$p(\delta) = u - \delta E[V(\delta)] - \int_{\delta}^{\bar{\delta}} E[V(\delta)]dt \tag{23}$$

The complicated delivery of medical packets and the delay approach simplify the issue. To ensure that (23), the function of the medical system is possible and appropriate.

5 Results and discussion

The average delay for medical packets with specific delay sensitivities in the designed system, as shown in Fig. 6. This figure initially indicates that the study findings are following the simulation's outcome, particularly for an integrated service facility.

The performance gap primarily comes from a statistical modeling estimation. Therefore, increasing the delay sensitivity of the packet, the shorter the meantime it takes to delay. The medical packet containing more important details (i.e., which must be delivered promptly) is always provided with less emergency than the others. By comparing Fig. 6a–c, it observes that packets with the same time sensitivity are waiting for more significant times if γ increases. A greater γ means that the system will move through further packets to raise standards. Such results demonstrate that average packet time decreases exponentially with an increasing delay sensitivity, and with a higher γ, this pattern becomes more apparent.

In Fig. 4, the costs to wait for medical packets with several delays are examined. The cost of waiting is shown to be higher by delay, then the δ cost increases from $0 to\ \bar{\delta}$ all of the time. The waiting costs are measured according to the delays and the average service delay in Eq. (5). Therefore, for two drastic situations, the waiting expense appears to be 0. (1) if $\delta \to 0$ implies that the packet is not necessary to reduce the potential delay;(2) When $\delta \to \delta$ has been the most highly important for the delivery of the packet, it is served immediately. Therefore, since processing times are raised with the packet delivery rate, as seen in Fig. 6, the processing expense, as seen in Fig. 7, decreases with the packet arrival rate.

Figure 8 demonstrates the connection between the sensitivity to payment and the delay in the medical packets. The figure indicates that the payment increases with the early duration, which corresponds to the statement in corollary 2. The greater efficiency packet should pay more for transmission such that a better connection can be given (i.e., a shorter delay). The slope for a higher packet delivery rate is improved significantly. It is attributed to the dramatically enhanced quality, while γ is high (i.e., the time to wait is shortened exponentially, as in Fig. 6c). The delivery channel becomes more congested, with a higher arrival rate of the packets often contributing to the same packet being reduced.

The effect on the estimation of payment of the maximum limit of delay duration, δ is addressed in Fig. 9. For example, with δ increasing, the cost of transmission of a medical packet decreases. The reason is that, probably because of the higher value of δ, the waiting senses of individual packets will increase, and operation for the medical packet of form δ will be longer. The figure illustrates that payment with time constraints is more significant than payment in Fig. 5. Remember that the transmission's original value tends to be $\delta = 1$ for the actual sum of the packet fees, while $\delta = 1$. Since this packet has the highest priority for delivery, there is no waiting cost, and no other packets can impact the service.

Figure 10 demonstrates the incentive efficiency of the proposed system. With the service system's queuing control, gateways will strategically monitor a medical packet's delay vulnerability to optimize its efficiency gains. Figure 10 shows the trend for curves that the usefulness of a single packet has been increased with the observed δ. In this way, our system records the delay severity of a medical packet concisely. Figure 10 indicates that the larger δ packet provides less energy. It is because the initial value of all packet transmissions is specified as homogeneous, and the packet with a larger δ is received in more significant amounts, as seen in Fig. 7.

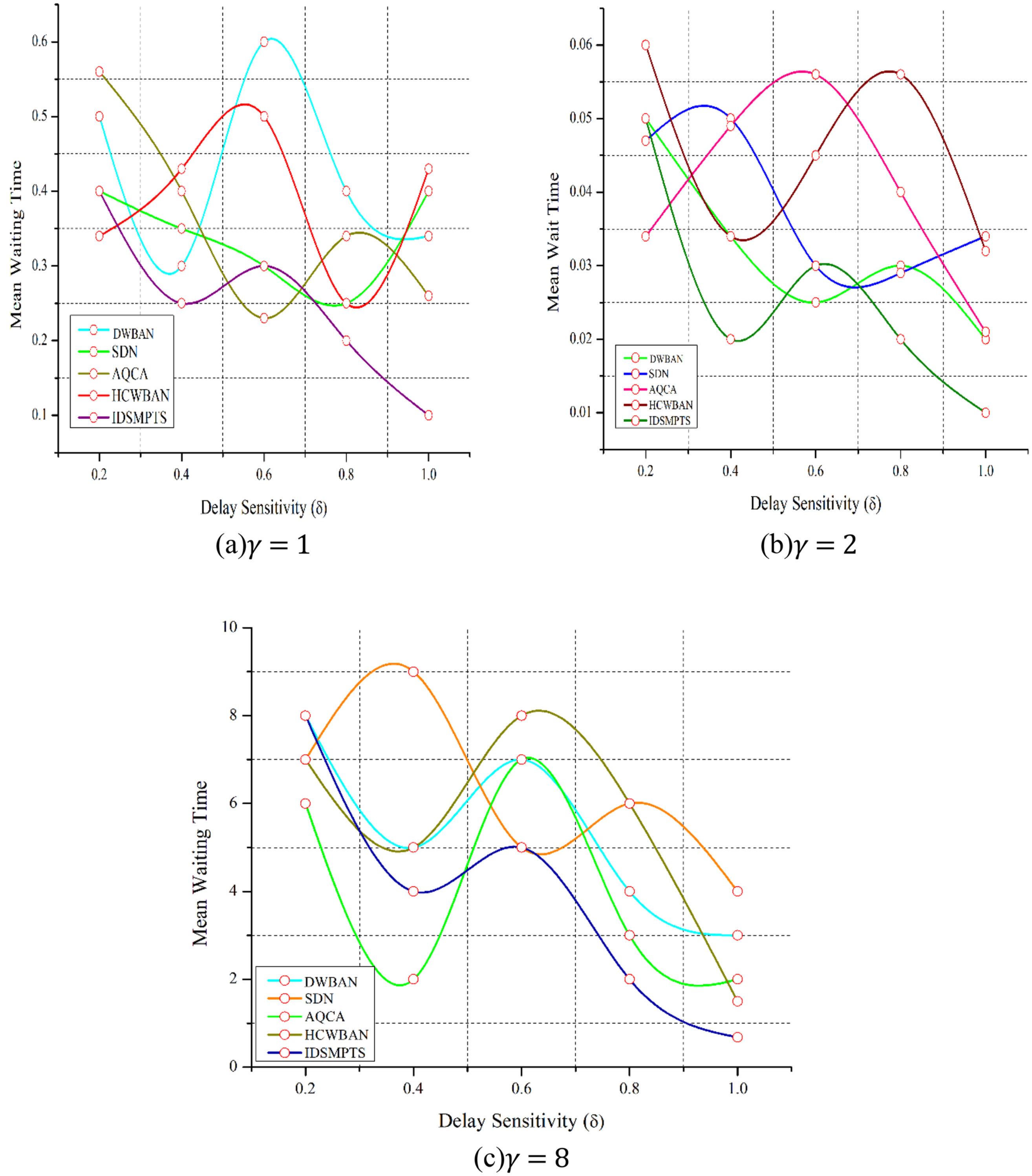


Fig. 6 Mean waiting time

6 Conclusion

This paper has been proposed an improved delay-sensitive medical packet transmission scheduling system (IDSMPTS), beyond WBAN medical packet transmissions in e-health networks. A queueing model with a generally distributed response period and a time-sensitive hierarchical priority system are developed to describe the dynamic complexity of transmission

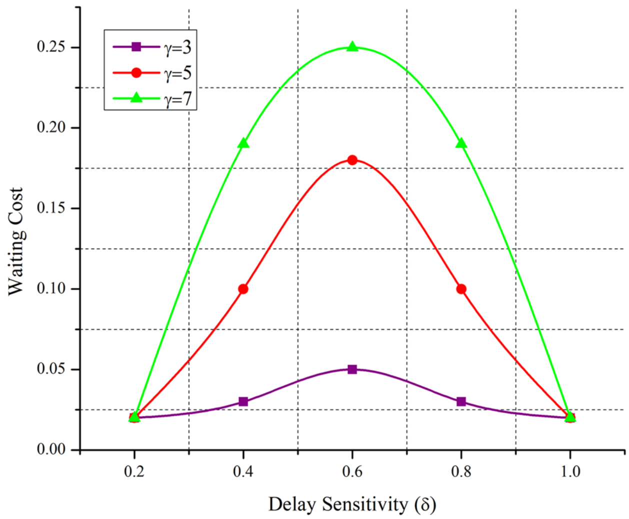


Fig. 7 Waiting cost for packets with various (δ)

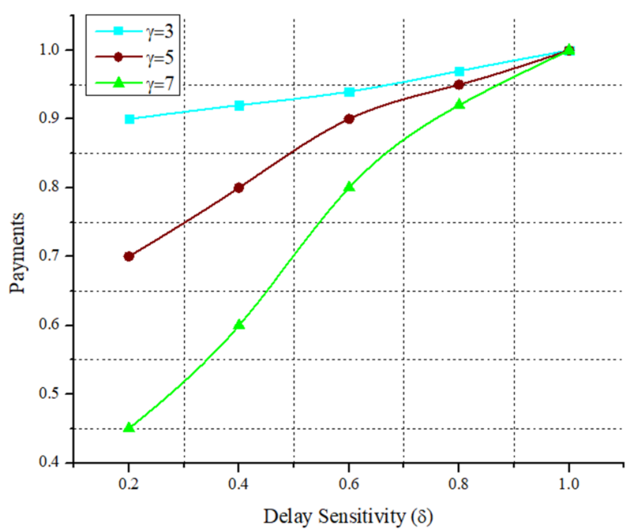


Fig. 8 Payments for packets with various (δ)

scheduling beyond WBAN. A novel system named IDSMPTS has been designed to optimize the network gain and avoid potential malicious actions from smart WBAN gateways. The simulation findings demonstrate that, as well as ensuring that all gateways for reporting the demands for delivery of the medical packets include the actual class details, the methods are recommended to minimize the estimated average network waiting delay costs compared with other systems.

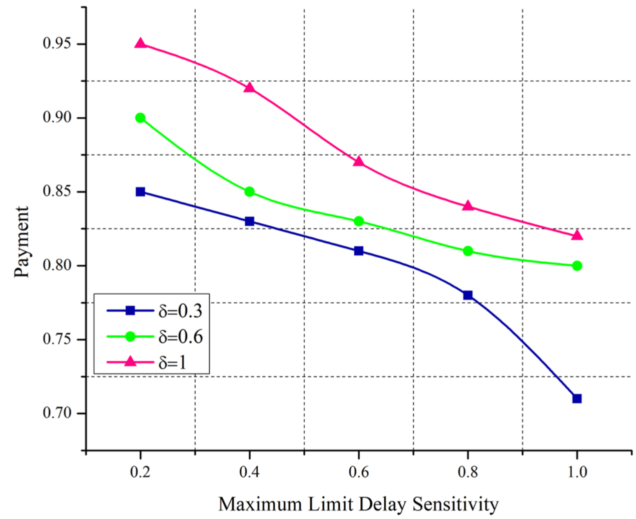


Fig. 9 The benefit of greater $\bar{\delta}$ on payments

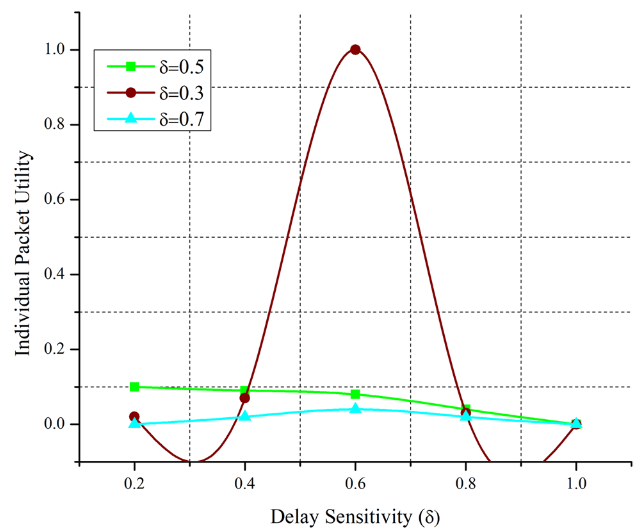


Fig. 10 Individual packet utility with δ

References

Albaeazanchi I, Abdulshaheed HR, Shawkat SA, Selamat SRB (2019) Identification key scheme to enhance network performance in wireless body area network. Period Eng Nat Sci 7(2):895–906

Asam M, Ajaz A, Jamal T, Adeel M, Hassan A, Butt SA, Gulzar M (2019) Challenges in wireless body area network. Proc Int J Adv Comput Sci Appl. https://doi.org/10.14569/IJACSA.2019.0101147

Bashshur RL, Howell JD, Krupinski EA, Harms KM, Bashshur N, Doarn CR (2016) The empirical foundations of telemedicine interventions in primary care. Telemed e-Health 22(5):342–375

Baskar S, Shakeel PM, Kumar R, Burhanuddin MA, Sampath R (2020) A dynamic and interoperable communication framework for controlling the operations of wearable sensors in smart

healthcare applications. Comput Commun 149:17–26. https://doi.org/10.1016/j.comcom.2019.10.004
Chakraborty C, Gupta B, Ghosh SK (2013) A review on telemedicine-based WBAN framework for patient monitoring. Telemed e-Health 19(8):619–626
Chavva SR, Sangam RS (2019) An energy-efficient multi-hop routing protocol for health monitoring in wireless body area networks. Netw Model Anal Health Inform Bioinform 8(1):21
Choudhary A, Nizamuddin M, Sachan VK (2020) A hybrid fuzzy-genetic algorithm for performance optimization of cyber physical wireless body area networks. Int J Fuzzy Syst 22:548–569. https://doi.org/10.1007/s40815-019-00751-6
Cicioğlu M, Çalhan A (2019) SDN-based wireless body area network routing algorithm for healthcare architecture. Etri J 41(4):452–464
Dangi KG, Bhagat A, Panda SP (2020) Emergency vital data packet transmission in hospital centered wireless body area network. Procedia Comput Sci 171:2563–2571
Hasan K, Biswas K, Ahmed K, Nafi NS, Islam MS (2019) A comprehensive review of wireless body area network. J Netw Comput Appl 143:178–198
Istepanaian RS, Zhang YT (2012) Guest editorial introduction to the special section: 4G health—the long-term evolution of m-health. IEEE Trans Inf Technol Biomed 16(1):1–5
Jiang D, Li W, Lv H (2017) An energy-efficient cooperative multicast routing in multi-hop wireless networks for smart medical applications. Neurocomputing 220:160–169
Joshi A, Mohapatra AK (2019) Authentication protocols for wireless body area network with key management approach. J Discrete Math Sci Cryptogr 22(2):219–240
Kathe KS, Deshpande UA (2019) A Thermal Aware Routing Algorithm for a wireless body area network. Wirel Pers Commun 105(4):1353–1380
Kumar MS, Dhulipala VS, Baskar S (2020) Fuzzy unordered rule induction algorithm based classification for reliable communication using wearable computing devices in healthcare. J Ambient Intell Humaniz Comput. https://doi.org/10.1007/s12652-020-02219-0
Le TTT, Moh S (2020) Energy-efficient protocol of link scheduling in cognitive radio body area networks for medical and healthcare applications. Sensors 20(5):1355
Manickavasagam B, Amutha B, Priyanka S (2020) Optimal packet routing for wireless body area network using software defined network to handle medical emergency. Int J Electr Comput Eng 10(1):427
Nasralla MM, Razaak M, Rehman IU, Martini MG (2018) Content-aware packet scheduling strategy for medical ultrasound videos over LTE wireless networks. Comput Netw 140:126–137
Pandey AK, Gupta N (2020) An energy efficient distributed queuing random access (EE-DQRA) MAC protocol for wireless body sensor networks. Wirel Netw 26:2875–2889
Perumal AM, Nadar ERS (2020) Architectural framework and simulation of quantum key optimization techniques in healthcare networks for data security. J Ambient Intell Human Comput. https://doi.org/10.1007/s12652-020-02393-1
Premarathne US, Khalil I, Atiquzzaman M (2017) Reliable delay-sensitive spectrum handoff management for re-entrant secondary users. Ad Hoc Netw 66:85–94
Pushpan S, Velusamy B (2019) Fuzzy-based dynamic time slot allocation for wireless body area networks. Sensors 19(9):2112
Qureshi KN, Din S, Jeon G, Piccialli F (2020) Link quality and energy utilization based preferable next hop selection routing for wireless body area networks. Comput Commun 149:382–392
Rigby MJ, Chronaki CE, Deshpande SS, Altorjai P, Brenner M, Blair ME (2020) European Union initiatives in child immunization—the need for child centricity, e-health and holistic delivery. Eur J Public Health 30(3):449–455
Singh A, Chatterjee K (2020) An adaptive mutual trust based access control model for electronic healthcare system. J Ambient Intell Human Comput 11:2117–2136. https://doi.org/10.1007/s12652-019-01240-2
Sodhro AH, Malokani AS, Sodhro GH, Muzammal M, Zongwei L (2020) An adaptive QoS computation for medical data processing in intelligent healthcare applications. Neural Comput Appl 32(3):723–734
Ullah F, Ullah Z, Ahmad S, Islam IU, Rehman SU, Iqbal J (2019) Traffic priority based delay-aware and energy efficient path allocation routing protocol for wireless body area network. J Ambient Intell Humaniz Comput 10(10):3775–3794
Vilela PH, Rodrigues JJ, Righi RDR, Kozlov S, Rodrigues VF (2020) Looking at fog computing for e-health through the lens of deployment challenges and applications. Sensors 20(9):2553
Wang C, Wang Q, Shi S (2012) A distributed wireless body area network for medical supervision. In: 2012 IEEE international instrumentation and measurement technology conference Proceedings, pp 2612–2616. IEEE
Yi C, Cai J, Su Z (2019) A multi-user mobile computation offloading and transmission scheduling mechanism for delay-sensitive applications. IEEE Trans Mob Comput 19(1):29–43

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