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AN EVOLUTIONARY GAME-THEORY: FUZZY VERTICAL HANDOFF DECISION FOR PRIORITY-BASED TIME-SLOT ALLOCATION IN WIRELESS BODY AREA NETWORKS

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Abstract**—** In recent days health care monitoring is implemented in wireless body area network because of critical medical emergency situations such cases the critical information regarding patient's health are successfully distributed without any traffic. The local data processing units (LDPUs) is transmitting data packets of higher importance. In the existing paper they only discussed with priority based time slot allocation but not included handover mechanism. In this paper we additionally included the vertical handover technique when the nodes are moving from one network to another network. Our proposed system is going to discuss with vertical handoff technique during patient's critical data transmission. We prioritize users critical data based on Priority-based Allocation of Time Slots (PATS) that considers a fitness parameter which characterizing the criticality of health data.

The LDPU temporarily stores the health data specific to a patient and our paper focuses on WBAN-based remote healthcare and medical services in situations of medical emergencies. The priority based time slots allocation referred as constant model hawk–dove game, which allows the LDPUs to choose its strategy based on its fitness parameters what we taken for our research. The experimental results shows that our proposed research on critical data to patient's health record based on vertical handoff reduces waiting time and improved energy consumption and packet drop rate.

KEYWORDS**—Hawk–dove game, priority-based allocation of time slots, wireless body area network (WBAN).**

I. INTRODUCTION

A Body Area Network is formally defined by IEEE 802.15 as, a communication standard optimized for low power devices and operation on, in or around the human body (but not limited to humans) to serve a variety of applications including medical, consumer electronics / personal entertainment and other. BANs are highly localized wireless networks that can potentially support a variety of medical applications, from tracking vital signs to monitoring the functioning of implants and performing state-of-the-art endoscopic exams. Traditional patient monitoring consists of physiological sensors connected between a patient's body and a dedicated signal processing unit located nearby through unwieldy wires.

Those wires limit the patient's mobility and comfort, and some studies suggest they can be a source of in-hospital infections. Moreover, motion artifacts from the connected wires can negatively affect the measured results. A network of sensors is placed on or close to the surface of the patient's body or implanted statically into tissue to enable the collection of specific physiological data. Such an arrangement allows for the continuous monitoring of a patient's health regardless of the person's location. Sensed signals can be those for electroencephalography (EEG), electrocardiography (EKG), electromyography (EMG), skin temperature, skin conductance and electro oculography (EOG). Each of the sensors transmits collected information wirelessly to an external processing unit, located on the patient or at the patient's bedside.

The processing unit can then use traditional data networks, such as Ethernet, Wi-Fi or GSM, to transmit all information in real-time to a doctor's device or a specific server. The sensors used in a BAN generally require accuracy for their physiological parameter of interest and a certain level of low-power signal processing as well as wireless capability. The advantage is that the patient doesn't have to stay in bed, but can move freely across the room and even leave the hospital for a while. This improves the quality of life for the patient and reduces hospital costs. In addition, data collected over a longer period and in the natural environment of the patient, offers more useful information, allowing for a more accurate and sometimes even faster diagnosis.

Hawk–dove game

The name "Hawk-Dove" refers to a situation in which there is a competition for a shared resource and the contestants can choose either conciliation or conflict; this terminology is most commonly used in biology and evolutionary game theory. From a game-theoretic point of view, "chicken" and "hawk-dove" are identical; the different names stem from parallel development of the basic principles in different research areas. Biologists have explored modified versions of classic Hawk-Dove game to investigate a number of biologically relevant factors. These include adding variation in resource holding potential, and differences in the value of winning to the different players, allowing the players to threaten each other before choosing moves in the game, and extending the interaction to two plays of the game.

The exact value of the Dove vs. Dove playoff varies between model formulations. Sometimes the players are assumed to split the payoff equally (V/2 each), other times the payoff is assumed to be zero (since this is the expected payoff to a war of attrition game, which is the presumed models for a contest decided by display duration). The game of chicken models two drivers, both headed for a single lane bridge from opposite directions. The first to swerve away yields the bridge to the other. If neither player swerves, the result is a costly deadlock in the middle of the bridge, or a potentially fatal head-on collision. It is presumed that the best thing for each driver is to stay straight while the other swerves (since the other is the "chicken" while a crash is avoided). Additionally, a crash is presumed to be the worst outcome for both players. This yields a situation where each player, in attempting to secure his best outcome, risks the worst.

GPRS

General packet radio service (GPRS) is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM). GPRS was originally standardized by European Telecommunications Standards Institute (ETSI) in response to the earlier CDPD and i-mode packet-switched cellular technologies. GPRS usage is typically charged based on volume of data transferred, contrasting with circuit switched data, which is usually billed per minute of connection time. Usage above the bundle cap is charged per megabyte, speed limited, or disallowed. GPRS is a best-effort service, implying variable throughput and latency that depend on the number of other users sharing the service concurrently, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection. In 2G systems, GPRS provides data rates of 56–114 kbit/second.

Protocols support

GPRS supports the following protocols:

Internet protocol (IP). In practice, built-in mobile browsers use IPv4 since IPv6 was not yet popular. Point-to-point protocol (PPP). In this mode PPP is often not supported by the mobile phone operator but if the mobile is used as a modem to the connected computer, PPP is used to tunnel IP to the phone. This allows an IP address to be assigned dynamically (IPCP not DHCP) to the mobile equipment. X.25 connections. This is typically used for applications like wireless payment terminals, although it has been removed from the standard. X.25 can still be supported over PPP, or even over IP, but doing this requires either a network-based router to perform encapsulation or intelligence built into the end-device/terminal; e.g., user equipment (UE).

When TCP/IP is used, each phone can have one or more IP addresses allocated. GPRS will store and forward the IP packets to the phone even during handover. The TCP handles any packet loss (e.g. due to a radio noise induced pause). A GPRS connection is established by reference to its access point name (APN). The APN defines the services such as wireless application protocol (WAP) access, short message service (SMS), multimedia messaging service (MMS), and for Internet communication services such as email and World Wide Web access. In order to set up a GPRS connection for a wireless modem, a user must specify an APN, optionally a user name and password, and very rarely an IP address, all provided by the network operator.

The channel encoding process in GPRS consists of two steps: first, a cyclic code is used to add parity bits, which are also referred to as the Block Check Sequence, followed by coding with a possibly punctured convolution code. The Coding Schemes CS-1 to CS-4 specify the number of parity bits generated by the cyclic code and the puncturing rate of the convolution code. The least robust, but fastest, coding scheme (CS-4) is available near a base transceiver station (BTS), while the most robust coding scheme (CS-1) is used when the mobile station (MS) is further away from a BTS.

Vertical handoff

Vertical handover or vertical handoff refers to a network node changing the type of connectivity it uses to access a supporting infrastructure, usually to support node mobility. For example, a suitably equipped laptop might be able to use both a high speed wireless LAN and a cellular technology for Internet access. Wireless LAN connections generally provide higher speeds, while cellular technologies generally provide more ubiquitous coverage. Thus the laptop user might want to use a wireless LAN connection whenever one is available, and to 'fall over' to a cellular connection when the wireless LAN is unavailable. Vertical handovers refer to the automatic fall over from one technology to another in order to maintain communication.

This is different from a 'horizontal handover' between different wireless access points that use the same technology in that a vertical handover involves changing the data link layer technology used to access the network. Vertical handoffs between WLAN and UMTS (WCDMA) have attracted a great deal of attention in all the research areas of the 4G wireless network, due to the benefit of utilizing the higher bandwidth and lower cost of WLAN as well as better mobility support and larger coverage of UMTS. Vertical handovers among a range of wired and wireless access technologies including WiMAX can be achieved using Media independent handover which is standardized as IEEE 802.21.

In traditional handovers, such as a handover between cellular networks, the handover decision is based mainly on RSS (Received Signal Strength) in the border region of two cells, and may also be based on call drop rate, etc. for resource management reasons. In vertical handover, the situation is more complex. Two different kinds of wireless networks normally have incomparable signal strength metrics, for example, WLAN compared to UMTS. In, WLAN and UMTS networks both cover an area at the same time. The handover metrics in this situation should include RSS, user preference, network conditions, application types, cost etc.

Based on the handover metrics mentioned above, the decision about how and when to switch the interface to which network will be made. Many papers have given reasonable flow charts based on the better service and lower cost, etc. while some others, using fuzzy logic, neuron network or MADM methods to solve the problem. The handover procedure specifies the control signaling used to perform the handover and is invoked by the handover decision algorithm. To support vertical handover, a mobile terminal needs to have a dual mode card, for example one that can work under both WLAN and UMTS frequency bands and modulation schemes.

Mobility management

When a mobile station transfers a user's session from one network to another, the IP address will change. In order to allow the Corresponding Node that the MS is communicating with to find it correctly and allow the session to continue, Mobility Management is used. The Mobility Management problem can be solved in different layers, such as the Application Layer, Transport Layer, IP Layer, etc. The most common method is to use SIP (Session Initiation Protocol) and Mobile IP.

WIMAX

WiMAX (Worldwide Interoperability for Microwave Access) is a family of wireless communications standards initially designed to provide 30 to 40 megabit-per-second data rate with the 2011 update providing up to 1 Gbit/s for fixed stations. The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard. The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL.

WiMAX refers to interoperable implementations of the IEEE 802.16 family of wireless-networks standards ratified by the WiMAX Forum. (Similarly, Wi-Fi refers to interoperable implementations of the IEEE 802.11 Wireless LAN standards certified by the Wi-Fi Alliance.) WiMAX Forum certification allows vendors to sell fixed or mobile products as WiMAX certified, thus ensuring a level of interoperability with other certified products, as long as they fit the same profile. Additionally, given the relatively low costs associated with the deployment of a WiMAX network (in comparison with 3G, HSDPA, xDSL, HFC or FTTx), it is now economically viable to provide last-mile broadband Internet access in remote locations.

B. Contribution

Our paper addresses the aforesaid issues by analyzing priority-based time-slot allocation along LDPUs during critical medical emergency situations from an evolutionary game-theoretic perspective. The primary contributions of this paper are listed below.

1) Critical LDPU-properties such as the importance of health data to be transmitted, energy dissipation factor of an LDPU, and time elapsed since last successful transmission are taken into account to formulate a *fitness* parameter for each LDPU to which the sensor nodes broadcast. Through this formulation, we compute a relative measure of node importance and, thus, prioritize their influence.
2) We design an algorithm for *priority-based allocation of time slots* (*PATS*) based on an evolutionary game, referred to as the *constant model hawk–dove game*, which allows the LDPUs to choose its strategy based on its *fitness*. Adoption of such strategy enables the LDPUs with important health-data gain preference over the regular ones.

3) LDPUs with higher *fitness* are awarded with the highest preference ensuring minimum waiting time between suc-cessive transmissions of data packets.

II. Related Works

Karim *et al.* [7] proposed a priority-based preemptive packet scheduling algorithm that outperforms the traditional FCFS and multilevel queue schedulers in terms of transmission delay. A

limiting source traffic in the presence of transit traffic, and a

can remotely monitor patients' physiological condition in real time, and provide crucial medical suggestions in less time. Our paper focuses on WBAN-based remote healthcare and medical services in situations of medical emergencies. We propound an efficient solution of the challenges encountered from a com-munication perspective while health data are transmitted in a critical medical situation.

A. Motivation

In situations of medical emergencies, multiple LDPUs may transmit healthcare data simultaneously during the same time interval. It is important to discriminate the LDPUs transmitting critical heath data from the ones transmitting data of regular im-portance. In such cases, frequency division-based transmission in a multisource-single-**sink network results in flooding of the sink's** receiver buffer. This leads to packet loss and consequent retransmission of the regenerated packets. Moreover, it fails to establish priority among the transmitting LDPUs, based on the criticality of the healthcare information being transmitted. An

prioritized medium access control (MAC) protocol are imple-mented in [12] to improve WSN efficiency. But in context of WBANs, these protocols are deficient as no internode priority considerations are made. Therefore, no distinction can be drawn between LDPUs transmitting crucial health data from the ones that transmit regular health check-up related data packets. Also, a WBAN consists of heterogeneous sensor nodes—each node has a specific purpose to monitor some specific health parame-ters. Clearly, in a cluster of such nodes, every node should not be assigned the same priority.

In [13], the authors contributed toward the convergent fea-ture of traffic in WBANs in certain cases which involve packet loss, retransmission, delay in packet delivery, and consumption of extraneous energy arising due to congestion. The authors, however, do not enlighten on the importance of body sensors transmitting critical life-saving health data. A game-theoretic approach to minimize contention delay is proposed in [14]. A modified carrier sense multiple access with collision avoidance (CSMA/CA) protocol is used to allow one sensor at a time to deviate from the standard rules and act like a "cheater." The net-work performance is analytically derived using a Markov model for worst-case conditions. Misra *et al.* [15] proposed a learning automata-based congestion avoidance scheme (LACAS) that proves to be an efficient automata-based congestion avoidance policy. However, most of these works do not take into consid-eration the important factor associated with the health data to be transmitted. Our paper, nonetheless, is distinctive due to the specific contributions made for the use of WBANs in medical emergency situations.

III. Communication Architecture

Ubiquitous health monitoring relies on some special charac-teristics of wireless body sensor nodes. The basic principle of these sensors is that the source of the signals received is the liv-ing tissue. In this paper, we discuss the problem scenario

only from an on-body sensor perspective. These body sensor **nodes are mounted on the patient's body to enable remote** monitor-ing of health parameters.

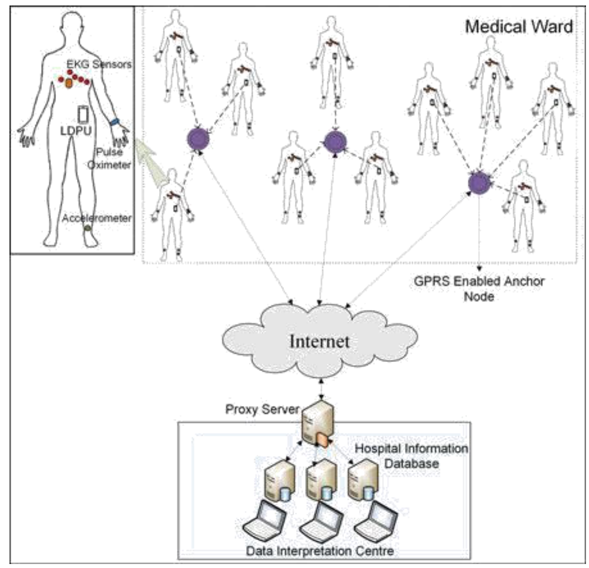

Fig. 1. Communication architecture.

health data is taken into account, and necessary actions, treat-ments, or even medicines are rushed to the concerned patient **as per doctor's recommendation. Fig. 1 provides a pictorial** pre-sentation of the WBAN communication architecture.

IV. Formulation of Utility Function

In this section, we focus on designing a *"fitness parameter"* that is used as a measure of LDPU priority. The value of the fitness parameter at time t (Ψ_t) for an LDPU is mathematically calculated based on certain parameters such as 1) the energy dis-sipation factor, 2) token starvation factor, and most importantly, 3) health-data criticality factor. We discuss the importance of these factors in the formulation of the fitness parameter below.

A. Energy Dissipation Factor

Sensor nodes are, in general, capacitated with limited amount of energy to survive on. Consequently, energy looms large as a constraint for these sensing devices, and, therefore, is crucially important to ensure that the rate of dissipation of energy can be minimized for these sensors. On the other hand, thermal energy harvesting has emanated to be path breaking [19], [20] in the context of body sensor nodes. Few popular sources to harvest energy for body sensors are movement of limbs, locomotion of the human, or even the human body temperature. The proto-type development of thermoelectric generator (TEG) chips has certainly acted as a major boost in practical implementation do-mains involving WBANs. Energy dissipation in an LDPU may result due to multiple reasons, as listed below.

Sensing energy (E_{sn}): As body sensor nodes continuously monitor and record the concerned health parameter of a person over time, there is continuous drainage of energy in sensing. The energy expanded due to sensing in a single time slot by each body sensor node is denoted as E_{sn}.

Transmission Energy (E_{tr}): The transmission energy of a body sensor node E_{tr} is the energy dissipated due to the trans-mission of a single data packet by that node. The packet may be either originated from the node itself, or it could have reached the node as an intermediate hop toward its destination. E_{tr} usually has a higher magnitude, as broadcasting of health parameters in the form of packets requires considerable amount of energy.

Processing Energy (E_{pr}): In a WBAN, a body sensor node not only acts as a sensing device, but also as a routing device. As a part of intra-WBAN communications, each body sensor receives numerous data packets from multiple other sensors, and route those data packets further, either toward the destination anchor node, or toward another body sensor in its path, after processing the data packet. Processing energy E_{pr} of a body sensor is the energy expended due to processing of a single packet retrieved from the input buffer, and subsequent mapping of the same to its destination through the routing table.

Computational Energy (E_{cm}): The energy consumed to per-form preliminary computations on the raw sensed data before it is converted into a packet is termed as the computational energy of that node, and is denoted by E_{cm}. It is noted that the energy consumption due to computations is much less compared to the energy exhausted due to transmission of a data packet.

Definition 1 (Nodal Energy Dissipation Factor): The nodal energy dissipation factor $E_{dt,i}$ is defined as the maximum en-ergy expended by the ith body sensor node after t time slots is defined as the sum of the energy consumed due to sensing E_{sn}, transmissions E_{tr}, processing E_{pr}, and computations E_{cm} pur-poses, and the energy exhausted due to channel conditions (such as path fading, path loss, and BER) and, varied signal strength (E_{ch}). $E_{dt,i}$ and is represented as

$$E_{dt,i} = E_{sn} \times t + E_{tr} \times N + E_{pr} \times n + E_{cm} \times (N - n) + E_{ch} \tag{1}$$

where n and N refer to the number of packets received and transmitted by a node during t slots.

For nodes capable of harvesting energy, Definition 1 can be modifi

$$E_{dt,i} = E_{sn} \times t + E_{tr} \times N + E_{pr} \times n + E_{cm} \times (N - n) - E_{hr} \times t + E_{ch}. \tag{2}$$

Definition 2 (Energy Dissipation Factor): We define the en-ergy dissipation factor of an LDPU at time t (ξ_t) as the ratio of the total energy dissipated after t time slots by Z number of component body sensors connected to the LDPU to the sum of each of their initial energy levels. Mathematically,

$$\xi_t = \frac{\sum_{i=1}^{Z} E_{dt,i}}{\sum_{j=1}^{Z} E_{init,j}}, \quad 0 \le \xi_t \le 1 \tag{3}$$

where $E_{init,j}$ is the energy of the jth body sensor at time $t = 0$ and $E_{dt,i}$ follows from Definition 1.

B. Token Starvation Factor

In our algorithm, an LDPU may not transmit a data packet without bothering about the transmission status of the other LDPUs. It can only transmit its packets upon reception of a permission *token* from the anchor node it is connected .

packets over the acquired time slots. As we have shown before, $0 \leq \Psi_t \leq 1$. An LDPU chooses the hawk or dove policy ($S = \{H, D\}$) according to the following strategy:

$$S = \begin{cases} D & \text{if } 0 \leq \Psi_t < \phi_1 \\ D & \text{if } \phi_1 \leq \Psi_t < \phi_2 \quad \text{with probability } (1 - p) \\ H & \text{if } \phi_1 \leq \Psi_t < \phi_2 \quad \text{with probability } p \\ H & \text{if } \phi_2 \leq \Psi_t \leq 1 \end{cases} \quad (11)$$

where ϕ_1 and ϕ_2 are LDPU specific, experimental constants, typically ranging of $0 < \phi_1, \phi_2 < 1$ and $\phi_1 < \phi_2$. ϕ_1 indicates the value of Ψ_t, below which an LDPU is bound to adopt the *dove* strategy. If Ψ_t has a value above ϕ_2, the LDPU adopts the *hawk* policy. An intermediate value of Ψ_t lets an LDPU choose the *hawk* strategy with p probability, and the *dove* strategy with complementary probability, based on its learning. The value of p ($0 \leq p \leq 1$) is determined by a player as a part of its learning policy. Each LDPU chooses a policy whenever it opts to send some data packets, and sends its choice (H or D) to the connected anchor node. The anchor node receives multiple such requests for the contention of time slots. It, then, sends back tokens in a prioritized fashion among the LDPUs. For a set of LDPUs $L = \{L_1, L_2, \ldots, L_{m_t}\}$ connected to an anchor node,

$$\sum_{L_j \in A, A \subseteq L} k_1 \times L_j + \sum_{L_j \in B, B \subseteq L} 1 \times L_j = k, A \cap B = \emptyset, |A| + |B| = m_t \quad (12)$$

where $|A|$ and $|B|$ are the number of players adopting H or D strategies, respectively. k_1 is the number of slots allocated to each hawk. The total number of LDPUs willing to transmit at time t is given by m_t. Clearly, $m_t \leq M(t)$. We introduce a function $f(\cdot, \cdot)$ to compute the time slots to be distributed among the dove-strategic LDPUs. $f(\cdot, \cdot)$ considers the number of hawks h and doves d as inputs, such that $h + d = m_t$ and is expressed as

$$f(h, d) = \begin{cases} 1 & \text{if } d < k\%h \\ b, b \in \{0, 1\} & \text{otherwise} \end{cases} \quad (13)$$

where $k\%h$ are the slots remaining to be distributed among the doves. f assigns every dove a unit time slot if possible, otherwise it assigns unit time slot to few randomly chosen doves. We design and analyze the pay-off matrix corresponding to the *constant model hawk–dove game* as shown in Table I. It is designed for a specific scenario, where a total of ($m_t = x + y + 1$) LDPUs wish to transmit data at time t. For an h-hawk-d-dove system, hawks are each awarded with $\lfloor \frac{k}{h} \rfloor$ unit time slots, and the doves are awarded time slots as per $f(\cdot, \cdot)$. Algorithm 1 elaborates the time-slot allocation by the LDPU.

Algorithm 1 Priority-Based Allocation of Time-Slots (PATS)

Input: Strategy vector comprising of individual strategies of m LDPUs, denoted by $S_L = \{S_{L_1}, S_{L_2}, \ldots, S_{L_{m_t}}\}$, such that $S_{L_i} \in \{H, D\}$.
Output: Allocation of time-slots based on the game outputs.

```
1: hawk_count = 0; dove_count = 0;
2: for each L_i do
3:     if S_{L_i} = H then
4:         hawk_count++ ;
5:     else
6:         dove_count++;
7:     end if
8: end for
9: hawk_slots ← hawk_count × ⌊k / hawk_count⌋ /* Total slots
   to be allocated to hawks */
10: dove_slots ← k − hawk_slots /* Total slots to be
    allocated to doves */
11: for each L_i do
12:     if S_{L_i} = H then
13:         Allocate ⌊k / hawk_count⌋ unit time slots;
14:     else
15:         if S_{L_i} = D and dove_slots ≠ 0 then
16:             Allocate unit time slot ;
17:             dove_slots −−;
18:         else
19:             Transmit NAK;
20:         end if
21:     end if
22: end for
```

Using PATS, we achieve two objectives. First, we distinguish the LDPUs possessing critical health data and willing to trans-mit from the ones transmitting regular health check-up related data. This helps us to increase the precedence of nodes transmit-ting important data packets, and, to ensure that critical health-care data packets are transmitted before the regular ones. Thus, we minimize the transmission delay for these critical packets. Second, we ensure that other nodes are restricted to transmit when a node with critical health data does so. This diminishes the chance of packet collision in the network, and also the chance of the LDPU input-buffer overflow. We now discuss some of the results obtained through PATS in WBAN.

Proposition 1: The running time complexity of PATS is $O(m_t)$, where m_t is the number of LDPUs that has a frame to transmit at time t.

Proof: We obtain the recurrence relation for PATS from Algorithm 1 as

$$T(m_t) = T(m_t - 1) + c, T(1) = \bar{c} \quad (14)$$

where $T(m_t)$ is the time taken to execute PATS for m_t number of LDPUs. The running time complexity for executing lines 12 through 21 of Algorithm 1 is $c = \Theta(1)$. We obtain the recurrence relation for the computational time complexity of PATS as

$$T(m_t) = T(m_t - k) + kc. \quad (15)$$

Finally, we get,

$$T(m_t) = T(1) + (m_t - 1)c$$
$$\Rightarrow T(m_t) = O(m_t - 1) \equiv O(m_t). \quad (16)$$

This completes the proof.

TABLE II

PAY-OFF MATRIX FOR *CONSTANT MODEL HAWK–DOVE GAME*

	(x+y) Hawks	x Hawks + y Doves	(x+y) Doves
Hawk	$\lfloor \frac{k}{x+y+1} \rfloor$	$\lfloor \frac{k}{x+1} \rfloor$	$k.$
Dove	$f(x+y,1)$	$f(x,y+1)$	$f(0,x+y+1).$

Corollary 1: For an h-hawk-d-dove system, the tightest lower bound of the LDPUs allowed to transmit within T interval is $O(h)$.

Proof: For a total of k time slots available during a single iteration, the hawks are allocated time slots as per Table II, prior to the doves. The total number of slots h_{tot} allocated to the hawks is given by

$$h_{tot} = h \times k/h. \quad (17)$$

Now, in order to obtain the tightest lower bound of the num-ber of LDPUs allowed to transmit, minimum number of doves should be allowed to transmit during the same iteration. Thus, we have

$$k = h_{tot} = h \times k/h$$
$$\Rightarrow k - (h \times k/h) = 0$$
$$\Rightarrow k = ch, c = 1, 2, \ldots, \text{upto } \infty$$
$$k\%h = 0.$$

This implies that no time slots are allocated for doves. Only the hawks are allowed to transmit. Thus, the tightest upper bound for the number of LDPUs transmitting within T interval is equal to $O(h)$.This completes the proof.

Proposition 2: Unlike the existing time-based or frequency-based transmissions of m_t LDPUs within time T, PATS reduces the number of transmitting LDPUs by $m_t - h - \min(d, k\%h)$.

Proof: We assume that m_t is the total number of transmitting LDPUs present in the system at time t. For an h-hawk-d-dove system (where, $h + d = m_t$), the total number of time slots allocated to h hawks is given by $h \frac{k}{h}$. Therefore, the number of remaining slots for that iteration is $k - h\frac{k}{h} = k\%h$. This implies that the total number of doves that are allowed to transmit is expressed as $\min(d, k\%h)$. Therefore, the total number of LDPUs that are awarded with time slots during an iteration w is expressed as

$$w = h + \min(d, k\%h). \quad (18)$$

Clearly, $m_t \geq w$. Consequently, the number of LDPUs that are debarred from transmission during that cycle is

$$m_t - w = m_t - h - \min(d, k\%h). \quad (19)$$

On the contrary, in existing time-based or frequency-based data transmission techniques, all the requesting LDPUs are al-lowed to transmit during every cycle. Therefore, in such cases, the number of transmitting LDPUs remain m_t. This completes the proof.

VI. SIMULATION RESULTS

In this section, we evaluate the performance of the proposed algorithm, PATS, using MATLAB. We study the variation of Ψ_t with the variation of each contributing factor, and measure and compare the results in each such case. We also project some performance comparison of PATS with standard TDMA and FDMA transmission protocols.

A. Effect of the Contributing Factors on the Fitness Parameter

Experimental Settings: The experimental WBAN system con-sists of 30 LDPUs. We first show the impact while plotting the LDPU-fitness Ψ_t against a parameter, the other two parameters are kept constant (in our case, 0.5). Also, the values of λ_1, λ_2, and λ_3 are taken as 3, 2, and 5, respectively, to ensure ordered preference among the three factors.

Fig. 2(a) shows the plot of the energy dissipation factor ξ_t against Ψ_t. Analyzing the graph, we observe that, with a wide range of variation in the value of ξ_t, Ψ_t varies mostly between 0.35 and 0.65, denoting a variation of around 0.15 in either side of its mean value (0.5). Fig. 2(b) depicts the fluctuation of the value of Ψ_t with the change in the token starving factor γ_t. We observe that the variation of the values of Ψ_t lies within 0.1 units of the mean value, in each side of it, symbolizing a comparative low impact of γ_t on Ψ_t. In Fig. 2(c), the plot of health severity index ρ_t against Ψ_t is shown. Unlike the previous two cases, we observe that the values of Ψ_t are generally spread widely between 0.25 and 0.75, in either side of the mean (0.5). A higher variance indicates a higher influence of ρ_t on Ψ_t, compared to the other two factors.

After analyzing the above three graphs thoroughly, we at-tain a clearer perspective regarding the influence of certain factors on Ψ_t, and also an impression on the assignments of the weights (λ_1, λ_2, and λ_3) corresponding to each of the factors.

B. Performance Analysis

Experimental Settings: The experiments performed for per-formance analyses involve wireless communication over a sin-gle AWGN channel for 20 LDPUs over 20 time slots. The data modulation scheme used is BPSK and the buffer size at the receiver end are assumed to be constant throughout the experiments.

Fig. 3(a) demonstrates the comparison of the number of LDPUs allowed to transmit to the total number of such LD-PUs present in the system. Unlike the standard TDMA solu-tions, PATS considers the fitness of the LDPUs while allocat-ing time slots, thereby prioritizing the critical data transmitting LDPUs by rewarding with higher number of time slots. PATS also outperforms traditional FDMA and advanced orthogonal FDMA (OFDMA) [23] solutions with respect to the number of packet drops, as shown in Fig. 3(b). Since the number of transmitting LDPUs is considerably reduced, eventually only the critical data packets manage to the receiver end success-fully, thereby, improving the packet drop rate remarkably. As a

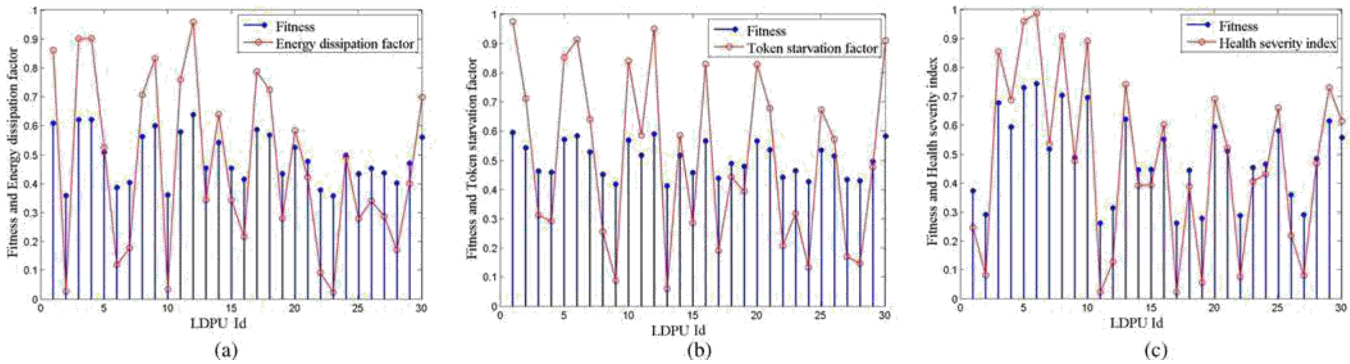

Fig. 2. Effect of contributing factors on fitness parameter. (a) Fitness versus energy dissipation factor graph. (b) Fitness versus token starvation factor graph. (c) Fitness versus health severity index graph.

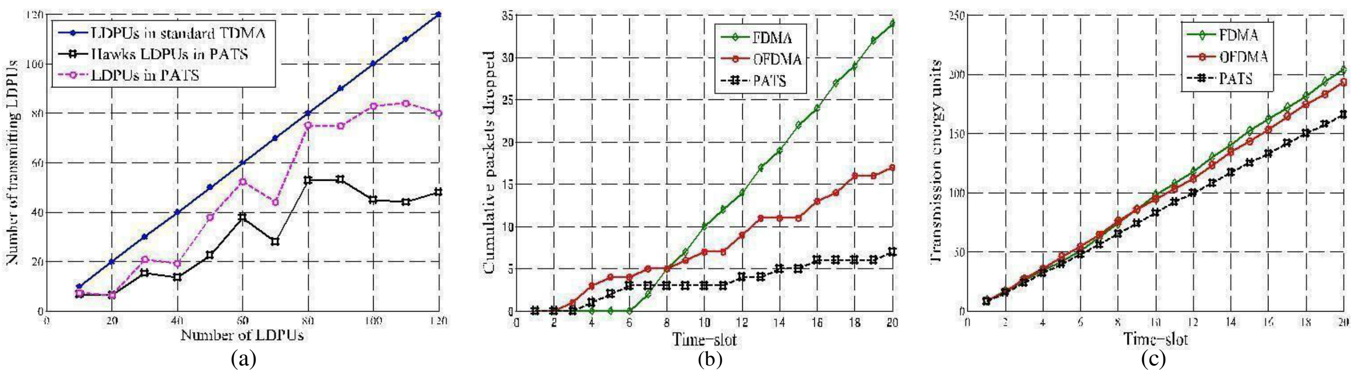

Fig. 3. Performance analysis of PATS. (a) Comparison of number of transmitting LDPUs. (b) Comparison of packet drops. (c) Comparison of transmission energy dissipation.

consequence of the packet drop rate, the total energy exhausted due to transmission and successive retransmission(s) is also re-duced, as reflected in Fig. 3(c).

VII. Conclusion

In our proposed system we discussed with PATS which achieve two main objectives. First, we distinguish the LDPUs possessing critical health data and willing to transmit from the ones transmitting regular health check-up related data. This helps us to increase the precedence of nodes transmitting important data packets. Then we proposed an evolutionary game theory model that allows an LDPU to choose whether active or passive sensed data to compete the game. Most important function of PAT is it providing critical LDPUs with higher number of time slots, and also prioritizing patients with high severity in their health conditions. It prioritizes the critical data coming from different users and based on the data criticality the user's data are allocated to the doctors for further processing. Then the doctors provide prescription according to their health condition. Finally, PAT reduced the packet drop rate and also reduced the energy dissipation problem discussed in the existing system

Appendix A

Reference Range Calculation

The upper and lower limiting values of the range is often estimated by the *t-distribution*. For a normal sample size of n ($n > 0$), first the mean($\bar{x}$) is computed as

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}, \forall x = 1(1)n.$$

Then, the standard deviation of the sample s_x is computed as

$$s_x = +\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2}.$$

However, as the population mean μ and the population standard deviation σ_x both are unknown for most practical cases, we predict the limiting values of the reference range using the *t-distribution*. The $(1-\alpha)100\%$ confidence interval (CI) [also referred to as the prediction interval (PI)] is then computed for $(n-1)$ degrees of freedom. The equations for estimating the values of Θ_{lc} and Θ_{uc} are given below

$$\Theta_{lc} = \bar{x} - \sqrt{\frac{n+1}{n}} \times s_x \times t_{\alpha,n-1}$$

$$\Theta_{uc} = \bar{x} + \sqrt{\frac{n+1}{n}} \times s_x \times t_{\alpha,n-1}.$$

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