

Improving the performance of WPAN during remote E-Health monitoring in crowded public patients room

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Abstract

Wireless Personal Area Network (WPAN) represents the first wireless network contact with patients in the applications of remote E-health monitoring using Wireless Sensor Network (WSN). In this paper, a way to improve the performance of the WPAN in the crowded public patient room was presented using a multiplied decreasing for both of packet size and packet inter-arrival time, as well as a multiple coordinating to achieve the best results in throughput and delay.

Keywords: wireless, WPAN, WSN, Zigbee.

1. Introduction

Wireless Personal Area Networks (WPANs) are an important network type that has much potential of playing a main role in remote E-Health monitoring using Wireless Sensor Network expressed as an emerging technology in the healthcare system. This WPAN technology permits short-distance communication and serves a specialized purpose such as networking medical sensing devices in healthcare system. Patients can carry wearable sensors as Wireless Body Area Network (WBAN) that can detect vital signs (such as, glucose level, heart rate, etc.) and can monitor the patient continuously using this WPAN [1]. After that, a personal gateway node collects all the sensor data from the WPAN and forwards them to a doctor or a remote online server in the hospital. IEEE 802.15.4/Zigbee is a standard base network protocol that is widely used for Low Rate WPAN (LR-WPAN). Zigbee and IEEE 802.15.4 are not the same. The ZigBee alliance was formed prior to the formation of the IEEE 802.15.4 group. Later, the ZigBee Alliance and the IEEE 802.15.4 group have decided to join forces and use ZigBee as the commercial name for this technology [5].

2. Related Work

Nahla A. and Fuad A. [7] tested the topological characteristics and performance of the IEEE 802.15.4 standard in terms of throughput and node to node delay using OPNET simulator, they investigated the self-healing feature on a mesh topology from earlier design until it supports a large number of end points (>64,000) with dynamic routing.

Hammoodi I., et al. [3] Studied and analyzed the QoS performance evaluation of the ZigBee protocol within the OPNET simulator for different WSN topologies and routing schemes.

Mumtaz M. Ali Al-Mukhtar and Teeb Hussein Hadi [6] investigated the performance of WSN based on various topologies, and adopted some techniques useful for managing wireless sensor networks.

Ramyah S. [9] analyzed the variations in load metric in hexagonal configuration by enabling and disabling acknowledgment message (ACK) depending on IEEE 802.15.4/ZigBee standard for WSN.

Ziyad K. [10] evaluated the performance of IEEE 802.15.4 standard Wireless Sensor Network (WSN) in star topology for large scale applications.

Our research introduces a suitable algorithm using the multiple coordinating for traffic distribution and the decreasing for both of packet size and inter-arrival time to address the degradation in performance of WPAN in public patient room through the throughput and delay enhancements.

3. ZIGBEE-802.15.4- OVERVIEW

The growth in wireless technology has led to an emergence of many standards, specifically in the ISM radio band with frequencies: 868 MHz, 915 MHz and 2.4 GHz. The 868 MHz frequency band is used mainly in Europe, the 915 MHz mainly in North America, while the 2.4 GHz is used worldwide. There is always a need for a standard communication between sensors with low data rate and low power consumption. As an answer to this plight, many companies forged an alliance to create a standard which could be accepted worldwide. It is the Zigbee Alliance which creates Zigbee [8].

ZigBee is a specification based on IEEE 802.15.4-2006 standard used for high level communication protocols, creating a personal area networks from small and low-powered digital radio system. ZigBee's are capable of transmitting data over long distances by passing data through intermediate devices, reaching more distant ones, thus creating a network. The key components of a Zigbee network are- PAN coordinator, routers and end devices. All of them can be configured to deal with multiple applications as large as 124 simultaneously. ZigBee's are employed in applications which require a lower data rate, longer battery life, and secured networking. It has a defined data rate of 250kb/s. The technologies determined in the ZigBee specification are designed to be simpler and less expensive than other (WPANs) technology [2].

ZigBee consists of four layers. The top two (Application and Network & security) layer's specifications are provided by the ZigBee Alliance to provide manufacturing standards. The bottom two (MAC and PHY) layer's specifications are provided by the IEEE 802.15.4-2006 standard to ensure coexistence without interference with other wireless protocols, such as Wi-Fi[10]. 802.15.4 defines two types of devices: Full Function Device (FFD) or a Reduced Function Device (RFD). An FFD can be configured to operate in three different modes: a coordinator, a router or an end device (IEEE 802.15.4 2003). An RFD on the other hand can only be used as an end device.

Physical Layer

- Zigbee uses three frequency bands for transmission of data:
- 868 MHz band with a single channel having a data rate of 20 kb/s.
- The 915MHz band with 10 channels, and each channel has a central frequency separated from the adjacent band by 2 MHz and data rate of 40 kb/s. BPSK modulation technique is used in which symbols are transmitted at 1 bit per symbol.
- The 2.4 GHz ISM band having 16 channels, 5 MHz wide offers 250 kb/s of data rate. It uses O-QPSK modulation with 4 bits/symbol transmitted using DSSS with 32 Bit chips. IEEE 802.15.4 operating channels in the 2.4GHz band is shown in Figure 1. [4]

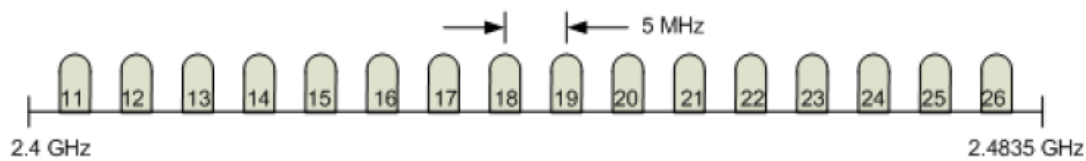


Figure 1 - IEEE 802.15.4 operating channels in the 2.4GHz band

MAC layer

The transmission Channel is accessed primarily through Carrier Sense Multiple Access-Collision Avoidance (CSMA-CA) protocol. The MAC layer can take care of transmitting data. The MAC layer decides whether to use slotted or unslotted CSMA-CA. It also takes care of scanning the channel, starting PANs, detecting and resolving PAN ID conflicts, and performing device discovery etc. [4].

4. Zigbee Network Topologies:

Star Topology

In star topology, a coordinator is the prime node and all other devices are directly connected to it. Every data exchange between 2 end devices must pass through the coordinator first. This topology is very much vulnerable to collapses since the whole network goes down if the prime node fails. Employing routers are a waste of energy here as their functionality is never actually used.

Tree Topology:

In tree topology, the prime node would be the root node of the network with hierarchical body. There is a point to point connection between any 2 nodes i.e. a single path exists for reaching a node. Due to the self-healing capability of dynamic routing employed, in case of collapses, the backup would be prepared from the vicinity instantly (if available) [4].

Mesh Topology:

In mesh topology, data packets can be directly relayed between the routers and then to nodes. They need not pass through the prime node. Such a network has multiple paths for reaching a node and hence a backup can be made easily in failure situations e.g. if a router stops working then any nearby router will tackle the traffic of that router in a very finite time without affecting the performance much[11].

Star topology is commonly used in Remote Patient Monitoring. A star-based ZigBee network uses the master (coordinator) and slaver (end devices) mode. The master node is usually put in the center of a WPAN. It initiates the WPAN and controls communication within the WPAN.

There are three main types of data transmission: from a coordinator to an end device, from an end device to a coordinator and between two coordinators. The mechanisms for these transmissions depend on the mode. Figure 2 illustrates the data transmission mode between a coordinator and an end device, which is commonly used in a ZigBee WPAN.

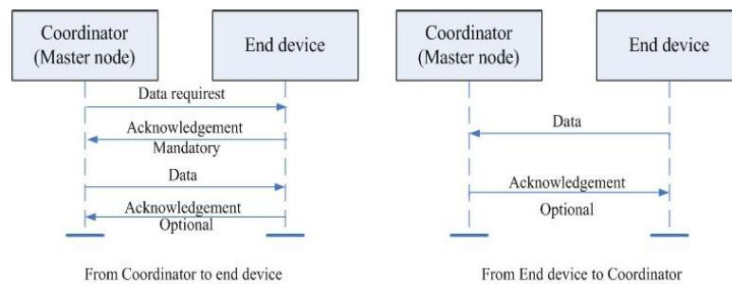


Figure 2 - Data transmission modes in a ZigBee WPAN

5. THE PROPOSED ALGORITHM

We introduced while statement to improve a performance of WPAN by multiplied decreasing in both packet size (Z) and the packet inter-arrival time (T) and multiplied increasing in the number of coordinators (K). To evaluate the performance of WPAN, firstly, set the number of patients to 3, 6 and 12, and set the number of sensors to 3 (for example) for each patient. Secondly initialize the packet size to 1024 bits. Thirdly, set the inter-arrival time to 1 sec. fourthly, set the number of coordinators (K) to 1 (single coordinating), and set C to 1 that will be used as a counter for increasing the decreasing operation. Fifthly, perform the first unslotted CSMA/CA operation during the single coordinating, then evaluate the performance after applying this CSMA/CA operation. If there is a degradation in the performance, then go to applying the decreasing operation of one half for default packet size and default packet inter-arrival time. After applying the decreasing operation of one half, we will again apply the unslotted CSMA/CA operation during the single coordinating, and increase the number of coordinators by 2 for the first multiple coordinating and the next unslotted CSMA/CA operations. After that, the last evaluation in performance for the single coordinating is performed; if there is a degradation in performance, then other decreasing operation of two halves and unslotted CSMA/CA operation are performed for the first multiple coordinating for $K = 2, 3$ and 5 for 3, 6 and 12 patients respectively, or decreasing operation of three halves and unslotted CSMA/CA operation are performed for the second multiple coordinating for $K = 3, 5$ and 9 for 3, 6 and 12 patients respectively. But if there is no degradation in performance, then the WPAN is accepted. A flowchart of the algorithm that uses while statement is shown in figure 3.

6. SIMULATION AND CONFIGURATION

For training the algorithm, we designed a WPAN in a patient room with 3, 6 or 12 patients, and each patient has 3 sensors, each sensor is simulated by zigbee_end_device and sends its data to a destination that is simulated by zigbee_coordinator. In the single coordinating, all zigbee_end_devices send data to only one zigbee_coordinator, but in the multiple coordinating, some zigbee_end_devices send its data to the first zigbee_coordinator and other send its data to the second zigbee_coordinator and so on. Each WPAN starts at the sensors that are attached to the surface of the patient body and ends at the coordinator. If the patients are found in the same location, such as this public patient room, we can implement one WPAN for all the patients using the single coordinating, but we can implement more than one WPAN using the multiple coordinating, depending on some reasons such as the financial ability of the patient or a mobility of the patient outside hospital.

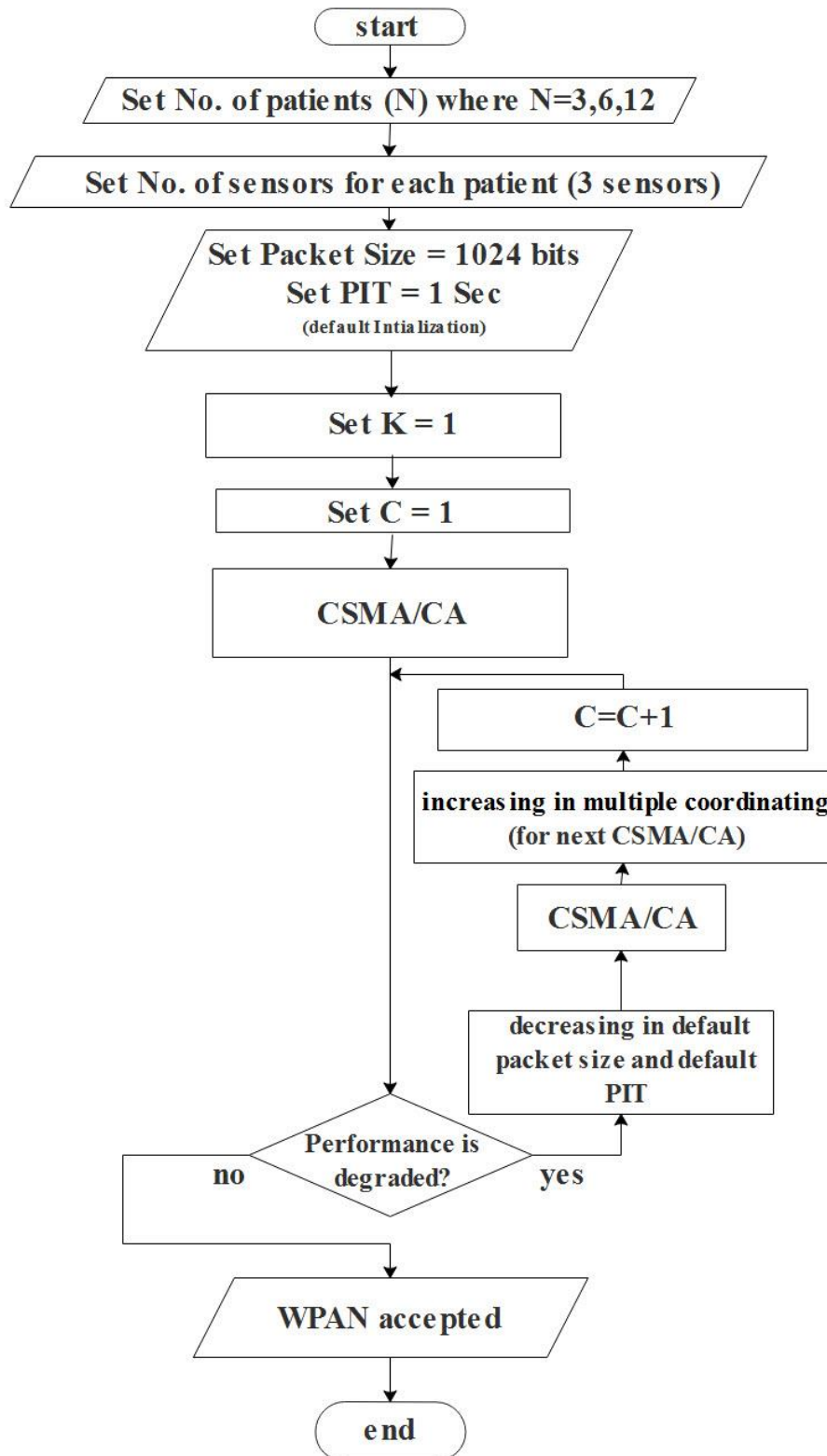
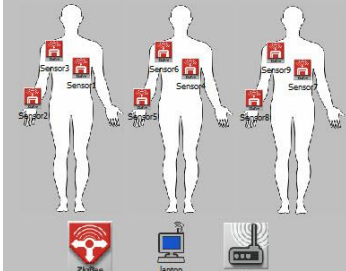
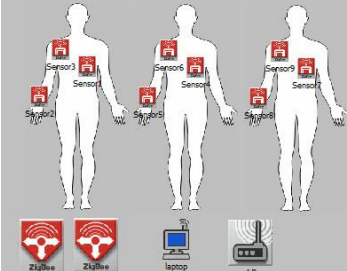
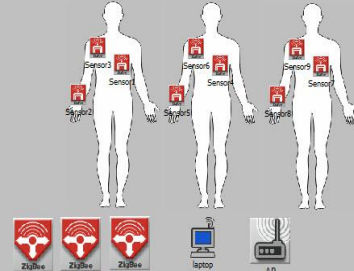
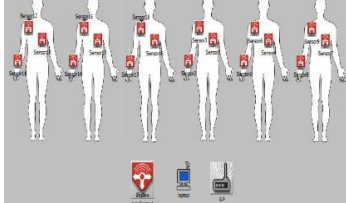
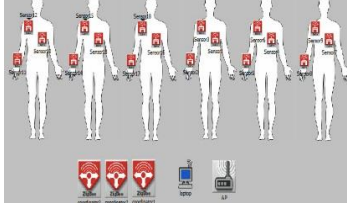
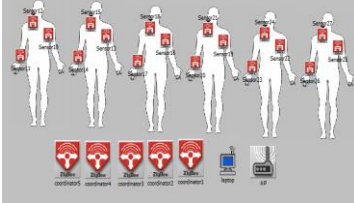
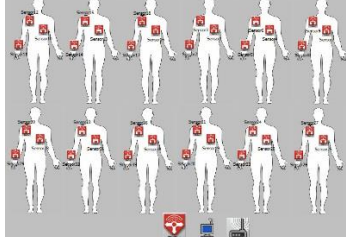
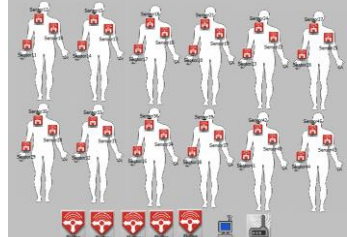
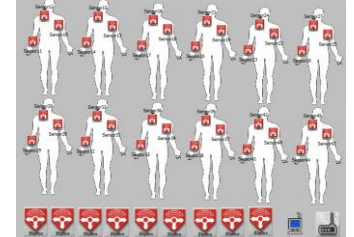


Fig 3: Flowchart using While statement to Improve performance of WPAN

Scenarios

The algorithm of this first improvement level is simulated by 12 scenarios. The first four scenarios use 3 patients, the second four scenarios use 6 patients and the last four scenarios use 12 patients. The first scenarios in each group named WSN_3_3_1_nodcr, WSN_6_3_1_nodcr and WSN_12_3_1_nodcr, where 3, 6 and 12 patients are monitored respectively. Each patient has 3 sensors, all the patients are coordinated by one coordinator, and no decreasing operations in packet size and PIT are used. Only one WPAN is used in these scenarios. The second scenarios in each group named WSN_3_3_1_dcr, WSN_6_3_1_dcr and WSN_12_3_1_dcr that are like the first scenarios, but here the decreasing operations of one half ($\frac{1}{2}$) are used. The third scenarios named WSN_3_3_2_dcr, WSN_6_3_3_dcr and WSN_12_3_5_dcr where 2, 3 and 5 coordinators are used respectively, also the decreasing operations of two halves ($\frac{1}{4}$) are used. So, multiple WPANs are used in these scenarios. The fourth scenarios named WSN_3_3_3_dcr, WSN_6_3_5_dcr and WSN_12_3_9_dcr, where 3, 5 and 9 coordinators are used respectively, and the decreasing operations of three halves ($\frac{1}{8}$) are used. The modeling of this algorithm are shown in Figures (4, 5, 6, 7, 8, 9, 10, 11 and 12).

		
<p>Fig 4 OPNET modeling of 3 patients with 3 sensors for each and 1 coordinator is used</p>	<p>Fig 5 OPNET modeling of 3 patients with 3 sensors for each and 2 coordinators are used</p>	<p>Fig 6 OPNET modeling of 3 patients with 3 sensors for each and 3 coordinators are used</p>
		
<p>Fig 7 OPNET modeling of 6 patients with 3 sensors for each and 1 coordinator is used</p>	<p>Fig 8 OPNET modeling of 6 patients with 3 sensors for each and 3 coordinators are used</p>	<p>Fig 9 OPNET modeling of 6 patients with 3 sensors for each and 5 coordinators are used</p>
		
<p>Fig 10 OPNET modeling of 12 patients with 3 sensors for each and 1 coordinator is used</p>	<p>Fig 11 OPNET modeling of 12 patients with 3 sensors for each and 5 coordinators are used</p>	<p>Fig 12 OPNET modeling of 12 patients with 3 sensors for each and 9 coordinators are used</p>

Configuring a sensor of patient

We set specified properties when we configured the sensor (sensor1 for example) of the patient based on the Table 1.

Table 1: Setting specified properties of the sensor

property	value
name	Sensor1
model	zigbee_end_device
Data rate	250000 bps
Transmission band	2.4 GHz
Transmission Power	0.05 W
Destination	Coordinator1 (for example)
Packet Inter-arrival Time (PIT)	1 sec in scenarios WSN_3/6/12_3_1_nodcr 0.5 sec in scenarios WSN_3/6/12_3_1_dcr 0.25 sec in scenarios WSN_3/6/12_3_2/3/5_dcr 0.125 sec in scenarios WSN_3/6/12_3_3/5/9_dcr
Packet Size	1024 bits in scenario WSN_3/6/12_3_1_nodcr 512 bits in scenario WSN_3/6/12_3_1_dcr 256 bits in scenario WSN_3/6/12_3_2/3/5_dcr 128 bits in scenario WSN_3/6/12_3_3/5/9_dcr

Configuring a coordinator in WPAN

We set specified properties when we configured the coordinator (coordinator1 for example) of any WPAN based on the Table 2.

Table 2: Setting specified properties for configuring WPAN coordinator

property	value
name	Coordinator1
model	zigbee_coordinator
Destination	No Traffic

Experimental Results and Discussion

All the statistics are obtained for delay and throughput results. Figures 13 and 14 represent the statistics of the throughput and delay results respectively for 3 patients using the single coordinating (one coordinator is used) and the multiple coordinating (2 and 3 coordinators are used) with or without decreasing operations, Figures 15 and 16 also represent the statistics of the throughput and delay results respectively but for 6 patients using the single coordinating (one coordinator is used) and the multiple coordinating (3 and 5 coordinators are used) with or without decreasing operations. Figures 17 and 18 also represent the statistics of the throughput and delay results respectively but for 12 patients using the single coordinating (one coordinator is used) and the multiple coordinating (5 and 9 coordinators are used) with or without decreasing operations. From the results we got the best throughput and delay in the scenarios WSN_3_3_3_dcr, WSN_6_3_5_dcr and WSN_12_3_9_dcr where the scenarios have much more increasing in coordinators that enhanced the distribution of the single WPAN load using other WPANs, and much more

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increasing in the decreasing operations that increased the packetizing on the data to give small sizes of packets with the best small distance between these packets. So the multiple coordinating and the decreasing for both of packet size and packet inter-arrival time are participated in improve the performance of the patients monitoring using WPAN network technology.

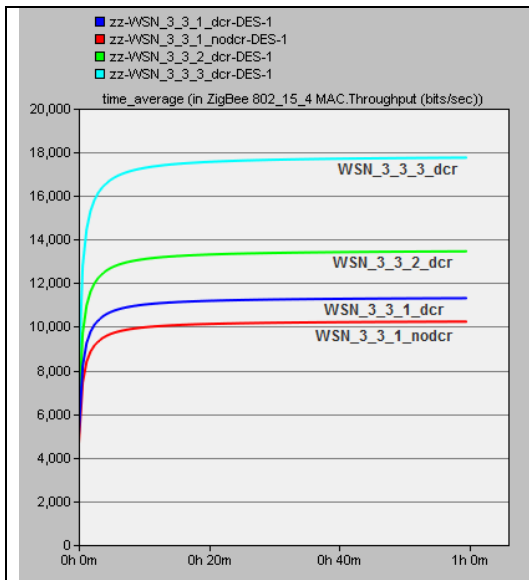


Fig 13: The throughput results of monitoring 3 patients using single coordinating (one coordinator is used) and multiple coordinating (2 and 3 coordinators are used) with or without decreasing operations

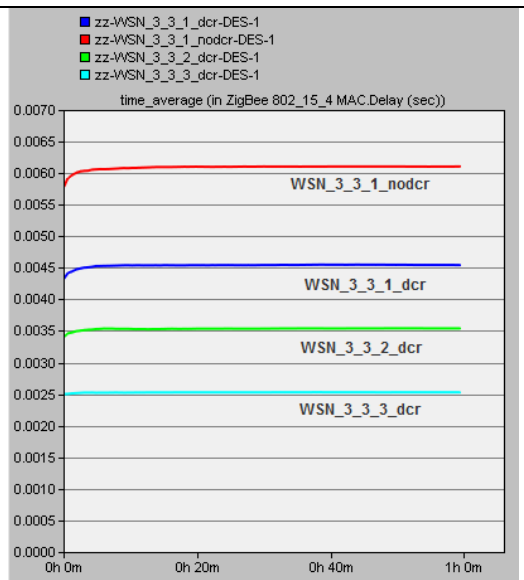


Fig 14: The delay results of monitoring 3 patients using single coordinating (one coordinator is used) and multiple coordinating (2 and 3 coordinators are used) with or without decreasing operations

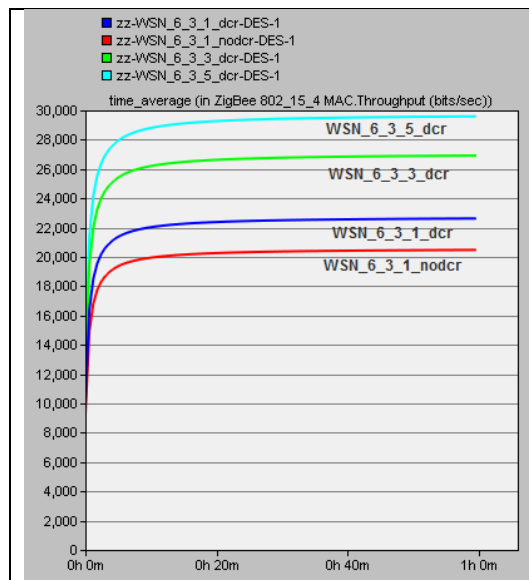


Fig 15: The throughput results of monitoring 6 patients using single coordinating (one coordinator is used) and multiple coordinating (3 and 5 coordinators are used) with or without decreasing operations

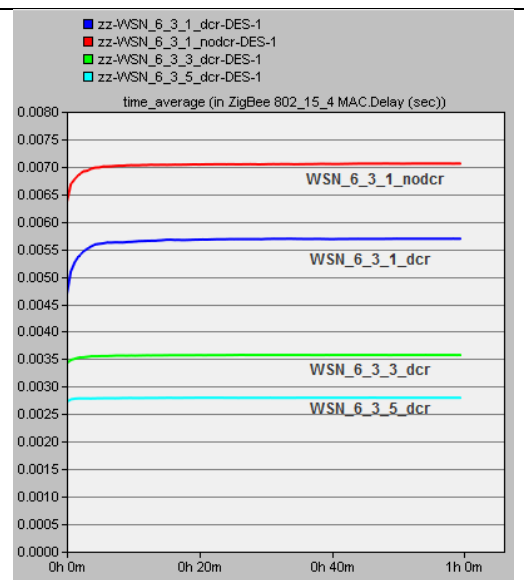


Fig 16: The delay results of monitoring 6 patients using single coordinating (one coordinator is used) and multiple coordinating (3 and 5 coordinators are used) with or without decreasing operations

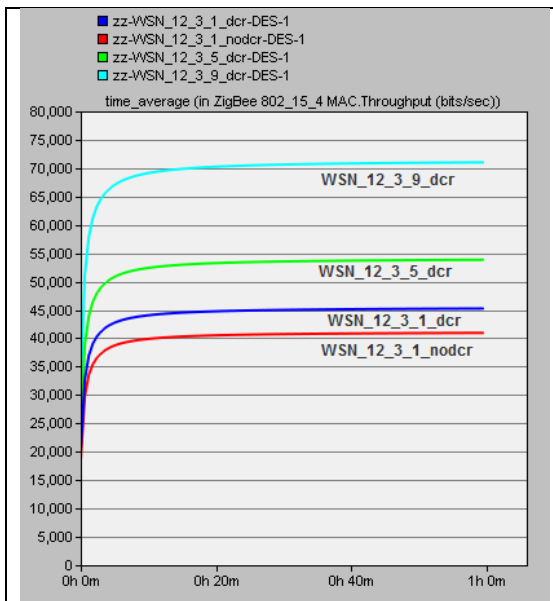


Fig 17: The throughput results of monitoring 12 patients using single coordinating (one coordinator is used) and multiple coordinating (5 and 9 coordinators are used) with or without decreasing operations

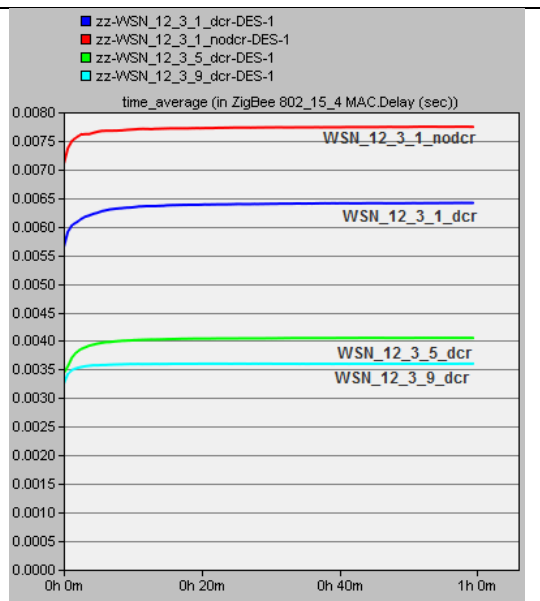


Fig 18: The delay results of monitoring 12 patients using single coordinating (one coordinator is used) and multiple coordinating (5 and 9 coordinators are used) with or without decreasing operations

Conclusions

From the results and analysis, the improvement level was implemented to enhance the performance of WPAN in public patient room using the decreasing for both the packet size and packet inter-arrival time and the multiple coordinating where an algorithm with While statement is used. We have noticed that more increasing in the throughput and more decreasing in the delay were produced when much more of both multiple coordinating and multiplied decreasing operations were performed.

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تحسين أداء شبكة المنطقة الشخصية اللاسلكية أثناء المراقبة الصحية الإلكترونية عن

بعد في غرفة المرضى العامة المزدهمة

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المخلص

شبكة المنطقة الشخصية اللاسلكية (WPAN) تمثل الاتصال الشبكي اللاسلكي الأول مع المرضى في تطبيقات المراقبة الصحية الإلكترونية عن بعد باستخدام شبكة التحسس اللاسلكية (WSN). في هذه الورقة قدمنا طريقة لتحسين أداء شبكة WPAN في غرفة المرضى العام المزدهمة باستخدام التنقيص المضاعف لكلا حجم الرزمة والمسافة البينية بين الرزم وأيضاً باستخدام التنسيق المتعدد لتحقيق أفضل النتائج في الإنتاجية والتأخير.

الكلمات المفتاحية: شبكة المنطقة الشخصية اللاسلكية، شبكة التحسس اللاسلكية، الزيجبي.