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Enhancing Throughput Cluster-Based WBAN Using TDMA and CCA Scheme

Matthew Iyobhebhe*, A. S. Yaro, Habeeb Bello, E. E. Agbon, M. D. Al-Mustapha, and M. T. Kabir

Electronics and Telecommunication Engineering Department, Amhadu Bello University, Zaria, Nigeria
Corresponding author: Matthew Iyobhebhe (e-mail: mattoiyobhe@gmail.com).

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Abstract- **WBAN comprises multiple sensor nodes strategically located on patients' bodies. They collect physiological signals from a patient under medical observation and transmit them to the medical personnel for further analysis via a medical server. These sensor nodes are energy-dependent. The challenges associated with WBAN are the power source, delay, and so on. Since their energy source is derived from rechargeable batteries, it is impossible to stop the network operation to replace the battery. Past articles concentrated more on the problem of enhancing network delay and throughput. However, they did not look into the area of TDMA and CCA schemes to improve their work. This brings their work into network energy degradation, which reduces their throughput. This article implements Enhancing throughput cluster-based DSCB by improving the existing Dual-sink clustering approach (DSCB). The simulation result depicted that the Enhanced throughput of iDSCB improved the performance of the current work DSCB in terms of throughput and End-to-End Delay by 6.60% and 3.14%, respectively.**

Index Terms-- **CCA, Sink node, Transceiver nodes, TDMA, Throughput, WBAN.**

I. INTRODUCTION

Due to the increment in individual age, the long-standing health maintenance routine might be difficult to view, due to the need for medical services ahead for the ill person because of financial constraints. Because of the inadequate financial means to cater to the ill person/patient, it is unfeasible to provide for the medical bills that are ahead, for this reason, WBAN provides a platform for distance observation of a patient with a lesser economic cost-effective [1, 24, &25]. There is always a constant examination of patients to avoid deterioration of human health. WBAN permits the placement of low-energy transceiver nodes implanted in the patient to regularly examine His/Her conditions [16, &19]. The individual transceiver nodes in the network have the processing energy that transmits the information to the Cluster Head, aggregating these packets and sending them to the medical personnel for further analysis via the medical server [2, &18]. Wireless Body Area Network is an integral part of the Wireless Sensor Network, where the wireless body area network cannot conveniently utilize the protocol that is employed in the wireless sensor network because of some reasons such as its; architecture, data rate, delay, and so on [3,&4]. Essential conditions that are necessary for Wireless Body Area Network creates limitations for its blueprint in terms of routing schemes [5, &23], the routing scheme carries a vital part in the execution of the system in the form of energy availability, latency, throughput, and so on [17,&20]. The transceivers in the system are energy-limited for there to be an efficient continual operation of the network, there must exist a well-organized network in such a way that energy utilization must be minimized [22]. The application of Wireless Body Area Network reduces the economic cost of the medications because there is regular monitoring of health, and proper attention is always taken care of before deteriorating health status may set in, hence it is easier to maintain the healthcare system with WBAN than the conventional roll call/queue before a medical diagnosis is made. In this work, we are employing Time Division Multiple Access (TDMA) and Clear Channel Assessment (CCA) schemes to address the minimization of energy consumption while networking activities last. Applying these two schemes will improve the network throughput and reduce end-to-end delay during physiological transmission. Ensuring a well manage energy efficiency in the network because, if the network experiences a low throughput and a high end-to-end delay when the physiological signals are been transmitted, the information will not be able to get to the sink node and further sent to the doctor for analysis, the patient in question will be in a serious challenge. Enhancing throughput using the TDMA and CCA scheme secures the system's high throughput, reduces end-to-end delay, and maximizes network lifetime, leading to network stability.

The previous literature relating to enhancing throughput in WBANs has some weaknesses that were not properly addressed. They are:

- The inability to use TDMA scheme to address energy utilization in the network leads to low throughput.
- Inability to employ the CCA scheme to determine the state of transceiver node processing power, which help to avoid dead node during transmission of packets.

The subsequent sections have been organized in this manner: section II presents Research work, section III discusses Sleep and mode mechanism, clear channel assessment, and a brief of management of bandwidth, section IV presents throughput versus simulation time and end-to-end delay, and also section V concludes the discussion of the article.

II. RESEARCH WORK

Authors in [6] proposed wireless data and energy that can be exchanged to maximize data throughput in WBAN. In their work, they concurrently deploy wireless data and exchange energy using a relay in the WBAN. The relay gets energy by harvesting from the radio-frequency signal transmitted by the nodes, sending the energy to its destination, and forwarding the data to the source. They were able to realize an improved throughput compared to the existing protocol. But they do not consider TDMA and CCA schemes in their work. They would have realized a reduced end-to-end delay and better throughput than they got.

In the work of [7], they proposed reliable energy-efficient for better throughput in WBAN. In their work, packets are received from the nodes deployed in the patient's body. Power utilization was minimized by employing multi-hop communication, and a cost function was used. They realized a high throughput as compared to the existing schemes.

But non-consideration of TDMA and CCA schemes increase the end-to-end delay that degrades the level of throughput they would have gotten.

In the work of [8], they proposed an enhanced throughput by varying multipoint in a wireless body area network with an even distribution. In their work, the nodes send an authorized signal to the gateway by requesting the radio frequency power from the source. At the same time, the nodes placed in the patient send the body's vital signs to the gateway node. With this, a better throughput was realized compared to the existing one. But non, consideration of TDMA and CCA schemes puts their end-to-end delay on the high side, degrading their level of throughput.

The authors in [9] proposed analysis for throughput coexistence of physical –cyber network systems alongside WLAN systems. In their work, they considered IEEE 802.15.6-based WBAN using an unlicensed spectrum. Congestion and transmission probability were systematically estimated to enhance link access and coexistence of the networks. But they realized a better throughput compared to the existing algorithm. However, the non-consideration of TDMA and CCA schemes made their work experience more of an end-to-end delay due to congestion that caused degradation of the level of throughput they would have gotten.

In WBAN, which comprises multiple sensor nodes that are energy limited by design, it is imperative to manage the networks' energy consumption to a prolonged network operation during packet transmission so that the transmitting information from the sending node can get to their desired receptive node. The more we minimize the energy utilization in the WBAN by applying the TDMA and CCA schemes, the better the reduced end-to-end delay and improved throughput, which leads to sufficient energy in the entire network for a prolonged network operation. A summary of the current previous work was carried out in Table I to ascertain state of the art.

TABLE I: SUMMARY OF THE RECENT PREVIOUS WORK DONE

Year of Pub. Ref	Proposed scheme	Problem solved	TDMA &CCA	Limitations
2022.[26]	FETRO	> Energy >Throughput	No	>More energy consumption in the network which hinders the network's lifetime maximization > High level of End-to-End Delay due to not considering TDMA &CCA scheme >Packet loss due to End-to-End Delay
2022.[20]	CRP	>End-to-End delay >Network Lifetime	No	>High side of End-to-End Delay due to lack of TDMA &CCA >More energy consumption in the network which hinders the extent of the network lifetime >Packet loss was experienced
2022.[27]	Energy closeness based	>Energy efficiency >Enhanced security >Throughput >Network Lifetime	No	>More energy was utilised in the network due to no consideration of TMDA &CCA >Limited throughput in the network >Loss of packets
2022.[19]	LP	>Range b/w nodes >Residual energy	NO	>More energy was used in the network >More concentration on the nodes which degrades

				network lifetime
2022.[28]	SuFIS	>Number of dead nodes >Throughput >Residual energy >Path loss	No	>Limited network lifetime >limited network stability

III. METHODS AND MATERIALS

A. SLEEP MODE MECHANISM

The crucial area where energy is normally misused in WBAN is idle listening, that is, when sensor nodes are put in a state of activeness, yet no sensed packet at the instant of time to be transmitted by that node. A comprehensive sleep –mode can be activated to mitigate wastage of energy in the network by a node that is not in its assigned time.

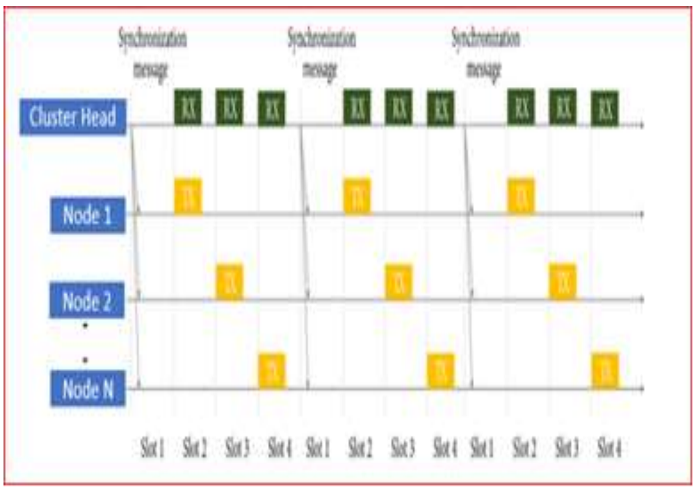

FIGURE 1: Time allocation for Time slot by the receiver node

Figure 1 is the time slot allocation for WBAN communication amongst the transceiver nodes. In this article, the allocation of a time slot to all the member nodes in the cluster is executed by the Sink node, also called the receiver, and it adopts TDMA techniques for that purpose. All the nodes in the network can transmit physiological signals when they have data to transmit, and also at the same time when they are in their own assigned time by the receiver/sink node. The sink node uses the TDMA scheme to allocate a one-time slot to only one wireless channel at a time [15]. Figure 1 depicts conveying physiological signs from the patient's body using TDMA techniques predicated on the Sink node, the receiver node [15]. Using the first period, the sink node sends a synchronization signal to all node members. The member nodes receive the synchronization signal, the sequence information of the current packet based on the signal, and transmit the message which contains the health packet and the sequence number to the sink node. Any nodes with physiological data to send will now send an Acknowledgement signal back to the receiver/sink node. Access will be granted for such a node in the form of activation to transmit its sensed physiological signals to the receiver. In contrast, those without a physiological sign to send will remain in sleep mode [15]. Immediately, the nodes that have data to send to the receiver finish their transmission at a time and will also go into sleep mode, thereby saving energy in that nodes. This action continues for each node in the cluster [15]. The accumulation of these aggregates saving of the individual node's energy culminates in the entire network energy. This helps the network to minimize energy wastage during transmission, hence enhancing the energy in the network for a prolonged operation, thereby enhancing throughput and network lifetime.

B. CLEAR CHANNEL ASSESSMENT (CCA) SCHEME

Any time the wireless channel in WBANs is idle, the transceiver nodes will commence transmitting data packets when it has one to transmit at their own assigned time. In CCA techniques, when the transmission of physiological signals begins, the CCA scheme looks out for the wireless links in the WBANs that is free from packet processing during transmission or empty nodes before a vital sign is being sent for its processing when the energy of a data that is to be transmitted into a particular node has an energy that is greater than that of the transceiver node, the node will experience dead node, and hence the information in that particular node will get lost and not get to the destination node. The function of the CCA scheme is to sense and monitors the nodes that are either empty or still have

Some data to process at a time. If a particular node has some data that are been processed at a time, and another data is mistakenly added in the course of that transmission without knowing if it has more residual energy to process that data received, there will be congestion in that wireless link first of all, which leads to the presence of high end-to-end delay and might leads to the dead node if care is not taken. Therefore, using the CCA scheme addresses End-to-end Delay and the individual nodes' energy which has been accumulated by the aggregation of the entire network energy, hence improving throughput, reducing End-to-End Delay, and maximizing network lifetime. Table 2 shows the grouping of the CCA scheme and their assignment depend on the situation in the network, these groupings are: Energy detection method, carrier sensed method and Hybrid method.

In Table II, if peradventure during a congestion state, the WiFi will be used to transmit physiological signals related to critical and periodic data. In the CCA group1: Make use of periodical data such as body temperature with the help of ZigBee. In the CCA group 2: Make use of critical data such as High blood pressure and glucose with the help of WiFi. In CCA group3: There is a combination of group1 and group2 simultaneously.

The Energy detection method has been employed by sensing other kinds of Radiofrequency communication by the CCA scheme in the network. It uses the free-licensed band with 2.4GHz, and 4.98GHz bands. The Carrier sense method: it takes into cognizance that other Wi-Fi radio does not send packets on the same link when it is already busy in the network. The hybrid mode is more associated with a logic combination of Energy detection mode and carrier sense mode. They always sense energy level that is above the set threshold.

TABLE II: GROUPS OF CCA SCHEME

CCA Group	Categories
CCA Group 1	Energy detection method [13]
CCA Group1	The Carrier sense method only recognizes data that are from the same communication standard with different priorities[13].
CCA Group3	A hybrid method for recognizing the data from different communication standards with different priorities [13]

C. MANAGEMENT OF BANDWIDTH

Packet transmission in WBAN must align itself with the principle of bandwidth management for its effective delivery. In WBAN Uplink and Downlink are not symmetrical. Conventionally, transceiver nodes receive packets, and thereafter transmit this packet to the sink node via Uplink. Uplink contains higher packets compared to downlink with a lower packet which is why the period cycle of Downlink is smaller than that of Uplink. The Downlink is normally utilized when the sink node broadcast commands by giving information to the transceiver nodes in the network. The allocation of resources bandwidth scheme in the sink node is responsible for determining the duration of the Downlink [10].

IV. RESULTS AND DISCUSSION THROUGHPUT VERSUS SIMULATION TIME

The successful arrival of packets from the transmitting nodes to the receiver node in a unit of time is what described the throughput. Figure 2 depicts the throughput performance of the developed algorithm against the existing DSCB algorithm with simulation parameters in Table III. Mathematically,

$$[(DSCB-IDSCB)/DSCB] *100 \quad (1)$$

TABLE III: THE SIMULATION PARAMETERS [14 & 15]

Parameter	Value
Simulator	MATLAB 2017
Initial Energy	0.6 J
Minimum supply voltage	1.8 V
Frequency (f)	2.4GHz
$E_{Tx\text{-}amp}$	1.98nJ/bit
$E_{Tx\text{-}CCT}$	16.7nJ/bit
$ER_{x\text{-}CCT}$	36.3nJ/bit
DC current (TX)	10.6 Ma
DC current (RX)	17Ma
Wavelength (λ)	0.138m
Γ_{max}	7

From Fig. 2, it was discovered that the throughput and simulation Time increase for both algorithms. This happens, because of the employing of two sink nodes that help in the communication of data to the sink node per time. Equation (1) was used to generate the plot. However, the improved algorithm performs better than the existing algorithm due to the consideration of some parameters by the improved algorithm such as TDMA and CCA scheme in the selection of neighbour nodes for data transmission and energy management in the network, and also whose effect reduces the drop of packets ad End-to-E delay due to high traffic in the node. The iDSCB algorithm shows an improvement of 6.60% when compared with the existing DSCB algorithm.

Table IV shows the percentage improvement evaluation of the iDSCB algorithm over the existing DSCB algorithm. In Fig. 3, it was discovered that as the simulation time increases, the end-to-end delay diminishes because of the use of two sink nodes that secure on-time transmission amongst the cluster members and their respective sink nodes which reduces the transmission distance. It was observed from 0 to 3997 seconds, the improved algorithm experience a little delay because of the time it takes to adopt the developed scheme. When the processing time goes beyond 3997 seconds, the iDSCB algorithm performs smarter than the Existing WBAN DSCB algorithm, because of the implementation of the developed scheme CCA which ensures there is no congestion in the wireless channel during transmission. Simulation results depicted that the improved algorithm displayed a better end-to-end delay enhancement of 3.14% over the existing algorithm as displayed in Table V.

TABLE IV.: THROUGHPUT PERFORMANCE ANALYSIS OF DSCB AND IDSCB

S/N	Algorithm	Average Throughput	Percentage Improvement Using Equation (1)
1	DSCB	2.28	6.60%
2	iDSCB	2.43	

TABLE V: END-TO-END DELAY PERFORMANCE ANALYSIS OF DSCB AND IDSCB

S/N	Algorithm	Average delay (sec)	Percentage Improvement Using equation (1)
1	DSCB	244	3.14%
2	iDSCB	237.3	

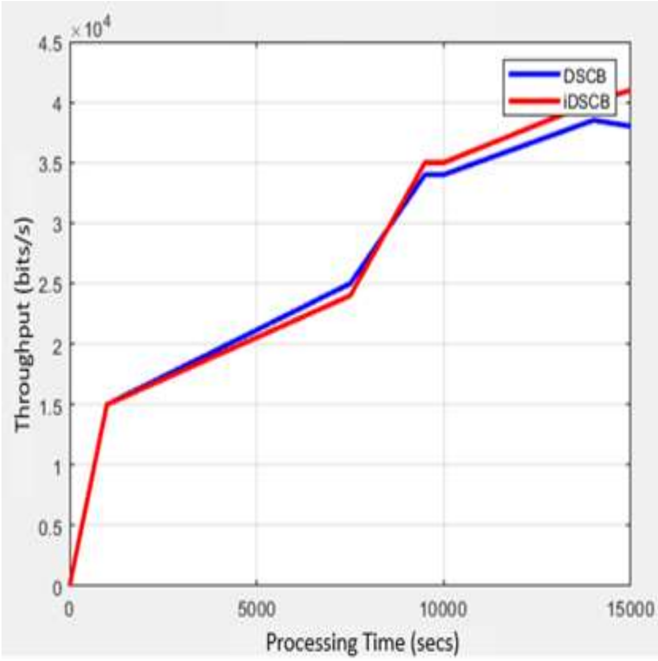

FIGURE 2: Throughput versus Simulation Time.

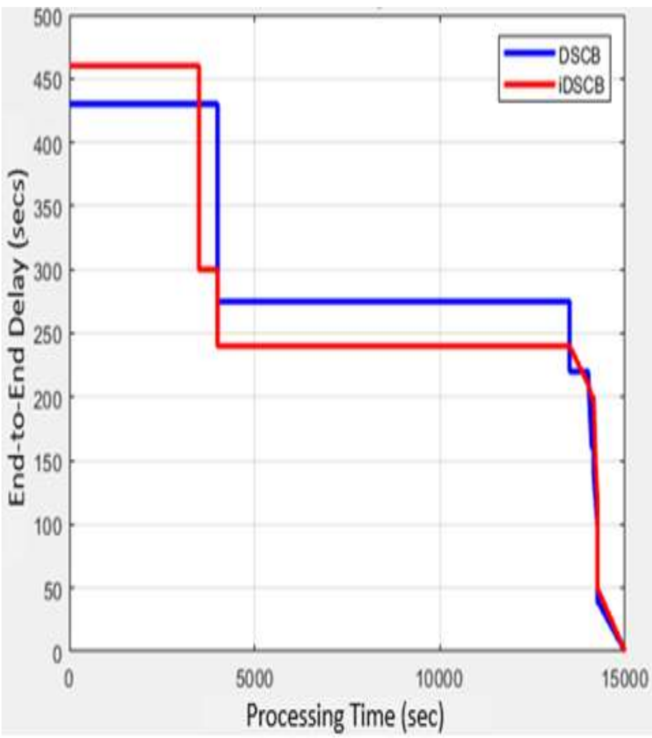

FIGURE 3: Plot of End-to-end Delay versus Simulation time

V. CONCLUSION

For effective packet transmission, the need for well-organized energy efficiency in the network must be pertinent. Suppose a particular sensor node is transmitting a packet to the intermediary nodes. The current energy status in that WBAN during the network operation of a certain transceiver sensor does not have sufficient energy to process that packet. In that case, there is a likelihood for that node to experience an End-to-End delay, dead node, hence low throughput. The TDMA and CCA scheme was implemented to improve the transmission of transceiver data for effective network energy management, leading to an End-to-End reduced delay and improved throughput. The simulation results depict that both the throughput and end-to-end delay were highly improved upon, leading to a prolonged network operation. Also, the enhanced algorithm improved the performance of WBANs when it was implemented with the utilization of both TDMA and CCA schemes. Simulation results showed that the improved algorithm exhibited better than the existing algorithm in terms of throughput and end-to-end delay.

CONTRIBUTION OF THE STUDY

Results from the simulation depicted that iDSCB improved the throughput and end-to-end delay by 6.60% and 3.14%, respectively, over the existing algorithm.

LIMITATIONS OF THE STUDY

The initial time complexity for setting up conditions for the forwarder node selection in WBAN could not be avoided. This caused more end-to-end delay in the initial processing time during the simulation process of the iDSCB algorithm

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CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest to report regarding the present study.

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