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Minimization of End-to-End Delay for an Improved Dual-Sink Cluster-Based Routing in WBAN

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Abstract- **Wireless Body Area Networks (WBANs) are an integral part of a Wireless sensor network, where sensor nodes are strategically placed in the human body to sense physiological signals and transmit them to the medical personnel via server for medical observations. Every sensor node in WBANs has a general limitation in energy efficiency, end-to-end delay, residual energy, etc. Also, the high energy consumption in WBANs is mainly due to the number of hops covered during physiological signal transmission. This work developed a hop-distance scenario to address these challenges and improve on what others have done. It buffered traffic estimation schemes to minimize end-to-end delay and the total network energy efficiency. This work minimizes end-to-end delay dual-sink cluster-based routing in WBANs by improving the existing dual-sink-sink cluster-based scheme (iDSCB). The simulation result shows that the Minimization of end-to-end delay of the improved dual-sink cluster-based (iDSCB) enhanced the performance of the current article DSCB in terms of end-to-end delay and residual energy by 3.15% and 8.88%, respectively.**

Index Terms-- ***Buffer Traffic estimation, Cluster WBANs, Hop-distance scenario, Sink node, and Sensor nodes.***

I. INTRODUCTION

The latest evolution in wireless communication networks has introduced the occurrence of Wireless Body Area Networks (WBANs) because of the technology that enhances the standard health status of the patient [1, 2]. Due to the human health maintenance routine, body sensor nodes are integrated into or around the patient's body. The sole responsibilities of these body sensor nodes are to collect the body's physiological signals from the patient and send it to the Cluster head through a wireless link using a predetermined routing protocol. The Cluster head collects and aggregates the sensed physiological data and transmits these data to the medical personnel via the internet for thorough examinations. These sensor nodes are energy limited because of their finite state, and they always require rechargeable batteries for their network operation. Also, replacing these rechargeable batteries during network operation is very difficult. Hence a strategic and intelligent management network's energy must be deployed to continue network activities. Otherwise, the network will park due to insufficient energy [3-10]. The need for adopting a proper routing protocol technique is eminent because the efficient and successful delivery of these physiological packets is highly dependent. In this work, we will adopt a cluster-based routing protocol to ensure the network's energy efficiency. The application of a Wireless Body Area Network encourages a constant and distant examination of an ill person's vital signs by medical personnel. Still, the sensed physiological packets must be channelled in a manner that will be to get to their destination while minimizing the utilization of the network's energy, thereby encouraging prolonged network activities. [11-16]. The two schemes mentioned above will be adopted to ensure reduced end-to-end delay, improved throughput, and network lifetime maximization [17-20].

In this article, we are considering a Hop-Distance Scenario (H_{DS}) scheme and Buffer Traffic Estimation (BT_E) to manage the energy utilization during route selection and transmission and also to employ the use of buffer traffic estimation to specify the current nodal energy capacity during transmission of physiological packets, thereby saving energy in the individual nodes which will accumulatively result in the total network energy efficient for a continues network operation [7, 21-25]. The previous work on minimizing end-to-end delay in WBANs has some limitations that were not properly given attention. They are:

i) The inability to employ Hop–Distance Scenario (H_{DS}) during route selection in the transmitting phase to enhance more energy in the network.
ii) The inability to use Buffer Traffic Estimation (BT_E) to determine the individual node's current energy level before data is transmitted will help to ensure the node's residual energy to avoid dead nodes in the network.

The subsequent sections are organized in this form: Section II discusses related work, section III presents a brief discussion on the categorization of routing techniques, section IV discusses methodology, section V presents the result and discussion, and section VI concludes the work.

TABLE I: SUMMARY OF PREVIOUS RECENT WORK DONE

Year of Pub. Ref.	Prosed scheme	Problem solved	H_{DS} &BT_E	Limitation
2022[33]	CRP	>End-to-end Delay >Delivery ratio	No	> High energy consu- ption which affects network lifetime maximization >High end-to-end delay Because of not consi- Dering H_{DS} & BT_E >Packet loss due to End-to-end delay
2021[34]	CSCB	>End-to-end Delay >Security		> High energy consu- ption which affects network lifetime > High end-to-end delay Because of not consi- Dering H_{DS} & BT_E > Packet loss due to End-to-end delay
2020[35]	EHCRP	>Network Lifetime >Throughput >end-to-end Delay	NO	> High energy consu- ption which affects network lifetime maximization > High end-to-end delay Because of not consi- Dering H_{DS} & BT_E > Packet loss due to End-to-end delay
2020 [36]	ESR-W	>Throughput >end-to-end Delay >Packet trans- Mission rate >energy	NO	> High energy consu- ption which affects network lifetime maximaziation > High end-to-end delay Because of not consi- Dering H_{DS} & BT_E > Packet loss due to End-to-end delay
2022[37]	e-CLDC	>End-to-end Delay >through	No	> High energy consu- ption which affects network lifetime > High end-to-end delay Because of not consi- Dering H_{DS} & BT_E > Packet loss due to End-to-end delay
2022[38]	CMW	>Packet Delivery Ratio >throughput	No	> High energy consu- ption which affects network lifetime > High end-to-end delay Because of not consi- Dering H_{DS} & BT_E > Packet loss due to End-to-end delay

As seen in Table I, this is the recent work done in this area; quite a lot of proposed techniques do not make use of hop-distance scenarios and buffer traffic estimation as a technique to minimize the end-to-end delay of sensed physiological signal transmitted in the WBANs, all the schemes make use of single node, and again almost all the protocols used in WBAN are not Clustering approach, as result of these, some challenges may occur which has not to be addressed, such as:

- The high level of occurrence of congestion in the network.
- Not applying dual-sink in WBAN leads to the absolute failure of the network (in terms of network load balancing)
- Using a single sink in the network degrades the total network performance, especially when multiple sensor nodes transmit the physiological signals simultaneously, leading to a low delivery ratio.
- For the accurate spread of sensor nodes in the body, more sensor nodes are needed, but if it were to be one cluster approach they used, it could cause a lot of load on the single sink node.

This problem mentioned above motivates us to devise a technique to minimize end-to-end delay for an improved dual-sink cluster-based routing in WBANs. This technique addresses the congestion and end-to-end delay in the network, hence having a better throughput, reduced end-to-end delay, and network lifetime maximization.

II. RELATED WORK

To ascertain the extent of the work done so far in this regard, quite a several works were examined to get state-of-the-art.

This work [6, 26-30] proposed adaptive energy, which is dominant in networks, to reduce interference with implementing adaptive patient body positions. In their work, they carried out a technique that coordinates the reduction of interference and maximum energy present. The simulation result shows that the improved algorithm performs better than the existing algorithm regarding the end-to-end delay, throughput, and energy. However, they did not consider the Hop-distance scenario and buffer traffic estimation degraded their network's energy.

The work of [8, 31-35] proposed a technique to maximize energy in the network for medical services using a remote examination of the ill person. They consider a coordinated power-structured Wireless Body Area Network in their work by implementing short-distance communication technology like ZigBee for medical services. Also, they kept the power utilization from the idle-activated nodes to save energy and also, and the entire energy of the transceiver nodes used was decreased, which led to the improvement of the network lifetime. However, non-consideration of the Hop-distance scenario and buffer traffic estimation brought extra attention to their work.

The authors in [9] proposed effectively delivering data using a defined protocol in the Wireless Body Area Network. They considered various quality of service limitations and came up with a transportation layer for effectively coordinating data delivery to its destination node. In their simulation result, the improved algorithm was better than the existing algorithm in terms of the network's energy, latency, and throughput. However, they did not pay attention to the hop distance and buffer traffic scenarios.

The authors in [10] proposed the effectiveness of power network systems in driving WBANs. Their work considered the importance of an overview of how collective energy can be and the point of routing easily during data transmission. However, they pay less attention to adopting both hop-distance scenarios and buffer traffic estimation.

In this work [11, 36-40], they proposed a technique that minimized the transmission of the packet's energy by the sensor nodes. In their work [41], they carry out the node's energy reimbursement for the true estimate's error threshold as juxtaposed from the future estimate to minimize the energy consumption in the network. The simulation result shows better performance as compared to the existing algorithm. However, non-consideration of the hop-distance scenario and buffer traffic estimation limits their network's energy.

In [14, 42] Dual sink using clustering driven was proposed. They consider placing several nodes in the human body for the transmission of physiological signals to a sink node with a defined routing protocol, and also, in their work, they choose a cost function that determines the forwarder node by link distance, TP, residual energy and so on to minimize the network energy consumption. The simulation result shows that the improved algorithm performs better than the existing algorithm regarding the end-to-end delay, throughput, residual energy, and number of dead nodes. However, no consideration of the hop-distance scenario and buffer traffic estimation limits the quantity of network energy they would have gotten due to the inability to curtail the end-to-end delay.

In the work of [16, 43], the authors carried out a blend of WBANs and VANETs; in their work, WBAN is responsible for the remote healthcare system, whereas the VANET is responsible for messages that are uncommon from the physiological body of that patient been monitored to its destination. The transportation module from VANETs allots a definite link associated with the board transportation module. In their work also, they come up with three approaches for the transportation system module by employing severity of data, speed of the vehicle, and channel occupancy time. Their approach is AHP for the individual schemes in the VANET, and TOPSIS for the normalized priority value, thereby reducing the end-to-end delay of the data. Their simulation result shows that their approach outperforms the existing algorithm. However, non-consideration of the Hop-distance scenario scheme and Buffer traffic estimation degrades the end-to-end delay they got from their work [44].

In this work [17], the authors deployed the CRP technique to enhance the network's throughput and its lifetime maximization. CRP techniques enhance the rate of effective data communication to their delivering ends, and also reduce their end-to-end data delay in WBANs. Their result shows that the CRP techniques outperform the existing algorithm regarding the end-to-end delay with a delivery ratio of 0.8176 and 0.8118, respectively. However, they did not consider the Hop-distance scenario scheme and Buffer traffic estimation, more improvement in end-to-end delay would have resulted in their work.

Wireless Body Area Networks with several sensor nodes attached to them are worthy of note to ensure the meticulous use of energy during their transmission is paramount to having enough network energy for a prolonged operation during transmission. Hence maximizing network lifetime, residual energy, throughput and so on are achievable when we apply the Hop-Distance Scenario (H_{DS}) and Buffer Traffic Estimation (BT_E) to minimize end-to-end delay and improve individual nodal's residual energy in the network. A summary of the recent work done in line with end-to-end delay in WBANs is outlined in Table 1.

TABLE II: COMPARISON OF THE PREVIOUS WORK DONE

Year of Pub. Ref	Proposed Scheme	Problem Solved	H_{DS} & BT_E	Limitation
2022 [18]	B-DEAH	>Data loss >Network Stability	No	>Inability to manage residual energy >Energy Utilization Is on the high side >High level of end-To-end delay
2022 [19]	ITAEO	>Throughput >Energy	No	>Inability to manage residual energy >Energy Utilization Is on the high side >High level of end-To-end delay
2022 [20]	IEECBSR	>Residual Energy >Packet Drop	No	>Inability to manage residual energy >Energy Utilization Is on the high side >High level of end-To-end delay
2022 [21]	BOATSEE	>Energy >packet Delivery Ratio >end-to-end Delay >QoS	No	>Inability to manage residual energy >Energy Utilization on the high side >High level of end-To-end delay
2022 [22]	AOMDV	>Packet Drop ratio >end-to-end Delay >throughput	No	> Inability to manage residual energy >Energy Utilization Is on the high side >High level of end-To-end delay
2022 [23]	CATS	>End-to-end Delay >Throughput	No	> Inability to manage residual energy >Energy Utilization Is on the high side >High level of end-To-end delay
2022 [24]	ECMR	>Ened-to-end	No	> Inability to

		Delay >throughput >energy		manage residual energy >Energy Utilization Is on the high side >High level of end- To-end delay
2022 [25]	SGFTEM	>end-to-end Delay >Packet loss >energy	No	>Inability to manage residual energy >Energy Utilization Is on the high side >High level of end- To-end delay
2022 [26]	LL-OLSR	>Packet >delivery Ratio >End-to,end delay	No	>Inability to manage residual energy >Energy Utilization Is on the high side >High level of end- To-end delay
2022 [27]	EBHD	>Packet Reception Ratio >residual Energy >end-to-end Delay	No	> Inability to manage residual energy >Energy Utilization Is on the high side >High level of end- To-end delay
2022 [28]	SDN	>Energy >through	No	>Inability to manage residual energy >Energy Utilization Is on the high side >High level of end- To-end delay
2022 [29]	FOG	>end-to-end Delay >throughput	No	To-end delay manage residual energy >Energy Utilization Is on the high side >High level of end- To-end delay
2022 [30]	GNSDRPO	>Latency >Network Stability	No	> Inability to manage residual energy >Energy Utilization Is on the high side >High level of end- To-end delay

III. CATEGORIZATION OF ROUTING TECHNIQUES

The routing techniques can be categorized based on the limitations associated with Wireless Body Area Networks. The classification of routing techniques is briefly explained as follows:

"TEMPERATURE-BASED ROUTING TECHNIQUES": The radiation of energy, interference and absorption from the antenna creates limitations that need to be examined when implementing WBANs because the radiated energy brings about the increase in temperature of the electronic circuitry node. The purpose is to minimize the increment of the temperature of the implanted nodes during transmission by steering clear of routing in the direction of the hotspot [15].

"POSTURAL MOVEMENT –BASED ROUTING TECHNIQUES": The network topology influenced the body's postural movement, bringing about link disunion if proper care is not taken.

"CLUSTER-BASED ROUTING TECHNIQUES": It is suitable for energy minimization in the network by putting the entire network into subdivisions of clusters.

In this proposed work, we are adopting Cluster-based due to its energy formation in the network: focusing more on energy saving, better throughput and so on.

CLUSTERING TECHNIQUE

The finite nature of the power source associated with Wireless Body Area Networks is the principal limitation that needs to be examined. Thus, reducing power utilization and improving the network's lifetime will be enhanced by employing various systematical Cluster-based strategies proposed for the Wireless Body Area Networks [12]. In clustering, the entire network is subdivided into clusters. The individual Clusters consist of Cluster-head and a member node. Various implementations create for the Cluster-head selection [13]. The transmissions of packets between the member nodes and the base station are only attainable through the Cluster head. The principal purpose of this technique is to minimize the number of times direct transmissions from source nodes to sink nodes, thereby minimizing the network power utilization, which culminates in the network lifetime maximization [14].

IV. METHODOLOGY

This article proposes the Minimization of an End-to-End delay for an improved Dual -Sink based protocol in WBAN using H_{DS} and BT_E to mitigate the sensor node's energy utilization during packet routing in the network because sensor nodes in WBANs are energy dependent. This scheme implementation enhances a prolonged network operation. The second scheme will estimate the nodal buffer capacity when transmitting packets to ensure the equivalent nodal energy can match the packet transmitted.

HOP-DISTANCE SCENARIO (H_{DS}) SCHEME

WBAN has a major limitation which is the network's energy because the sensor nodes that are made up of WBANs are energy-dependent and have been powered via rechargeable batteries, replacement of drained batteries during a prolonged network operation is impossible because the entire network activities will be put on hold, this portends danger to the human life whose physiological signals have been transmitting. Hence a strategic and calculative method would be deployed to improve network activities for continuous activity. It requires urgent attention to coordinate the packet transmission of the network to avoid several dead nodes due to an unmanaged scheme in analyzing the routing of packets with the nodal energy capacity. Since the WBANs is energy–dependent, an efficient and well-organized systemic adoption of the scheme must be applied during packets transmission because the rechargeable batteries will not depend on your replacement If by peradventure, one or two sensor nodes' batteries get drained completely during the network operation, and this will hinder the vital information that needs to been sent in time (Real-Time) to the medical personnel which is caused by high end-to-end delay. Hence, a good management approach is needed for a prolonged network operation and delivers its packets efficiently. It is worthy of note that not until there is sufficient energy in the individual nodes of the network, the packets transmitted from the source node will not be able to get to its destination node, which leads to low throughput in the WBANs. This can be avoided by the Systematic management approach of energy within the individual nodes in the network during the routing of packets. This will be made possible by using the H_{DS} scheme developed.

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From Figure 1, let distance (a_1, a_2,….a_n) be represented by X.
i.e $a_1 = X_1$, $a_2 = X_2$ and so on.
Hence, the model equation for this proposed work is

$$H_{DS(i+1)} \leq d_i / 2 \qquad (1)$$

Where X >2, X= 3,4………..

Where, "H_{DS} "denotes Hop-Distance Scenario Scheme,
"X_2" Represents the distance between the second hop from the preceding node towards a given destination node. (a). "n" signifies the distance the transmitting packets cover from the source node toward its destination node.

This proposed work also lets the distance between the third hop from the preceding node towards a destination node (a_3) be X_3.

Considering a source node transmitting physiological packets from a given source towards the destination node, that is, from a_1 to a_3 in figure 1 below, such a source node, when transmitting packets, will compare first, the distance of the second hop (a_2) from the preceding hop (a_1), if the distance of the second hop (a_2) is equal to or less than half the distance of the preceding hop (a_1), the source node will transmit its physiological packets to the third node as depicted from the Fig. 1, thereby saving energy in the second node due to proximity of that node. This transmission pattern will continue in the entire network operation until the end of the network activities. Note that, from the initialization phase of every network operation, there is a broadcast Hello packet from the sink node to the cluster members, which includes IDs, location, and destination. Upon reception, the cluster member's reply includes their IDs, location, buffer capacity, and so on. Instead of transmitting packets from one node to the other, until it gets to its destination node, more individual node's energy would have been wasted, hence it can consider a node that is near another during the routing of packets, and apply for the given model equation role, thereby saving the individual node's energy that is in closed proximity to each other.

When this is done, the accumulative individual node saved energy will be aggregated as the entire network's energy, with this systematic approach, one would have succeeded to a great extent reduce the number of dead nodes, end-to-end delay in the network and enhancing improved throughput, stability of the network, and network lifetime maximization.

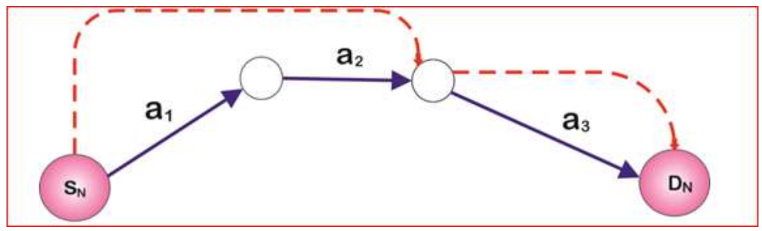

FIGURE 1: Framework of hop-distance scenario (h_{ds}) scheme

BUFFER TRAFFIC ESTIMATION (BT_E)

The application of the developed Buffer Traffic estimation in the WBAN whose responsibility is to specify the current nodal buffer capacity during packet transmission from the source node toward its destination node. During the operation of network activities by transmitting packets, each node has been attached to nodal buffer traffic estimation, which specifies their current buffer capacity. When packets have been transmitted from the source node towards its destination nodes using intermediary routing, the sensor nodes tend to reduce energy due to the operation of network activities. Network operation continues by sending packets to the available nodes. If the supposed node that will receive the packet has less processing power than the energy of the packet sent, that sensor node will die; that is the dead node. With the help of the developed BT_E, it will specify the current nodal buffer capacity, and if it is not able to handle such a packet due to its residual energy, it will specify it and show the node that has the such processing power to get the work done, a threshold value has been set for every individual sensor nodes in the network to ascertain the current capacity of the sensor node at every particular given time along the network operation activities. Due to the adaptive nature of the network, an average of the individual sensor nodes' buffer traffic estimation has been used as the set threshold for this work. Suppose, by peradventure, a node dies before the packets get to the sensor node due to unspecified buffer traffic conditions. In that case, it will lead to network instability, and the message that the packets are carried will not get to the destination.

$$BT_{E\,th} = \frac{bte1 + bte2....bten}{T} \qquad (2)$$

BT_{Eth} denotes the buffer traffic estimation threshold of a given number of sensor nodes in the WBANs bte_1 specifies the BT_E of the individual sensor node in the WBAN, T defines the total number of sensor nodes in the WBAN.

When this developed scheme is properly used, the number of dead nodes will be reduced and also specify the individual node's residual energy during network operation. The transmitted physiological packets will get to their destination effectively.

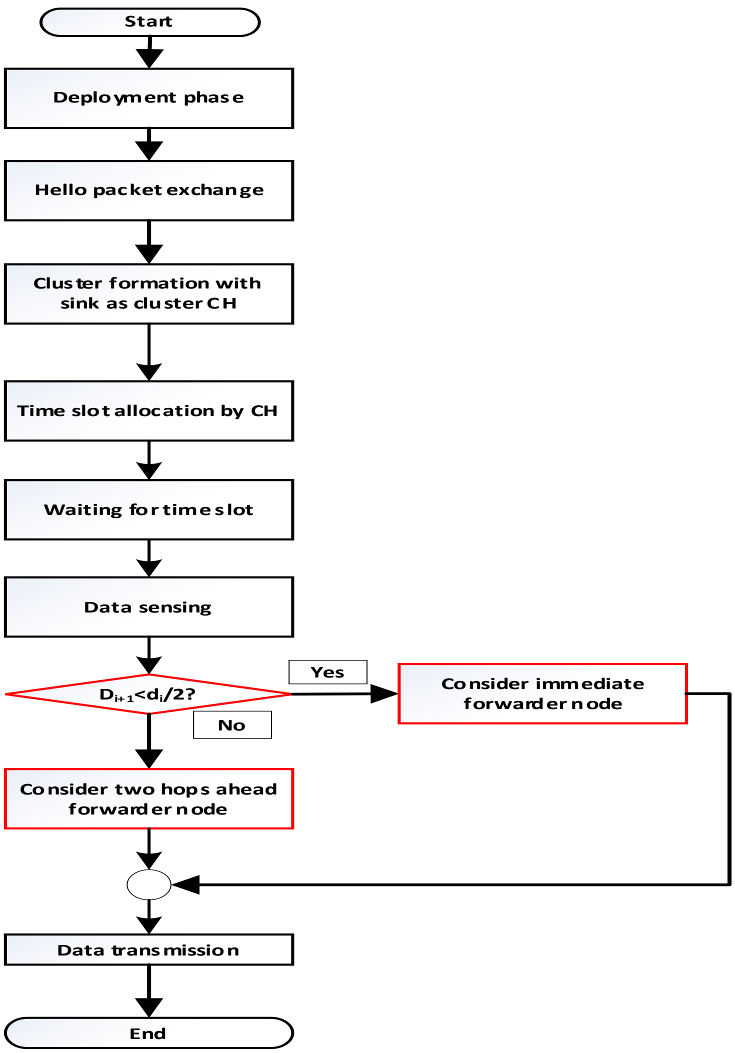

FIGURE 2: Hop-distance Scenarios

Figure 2 is the flowchart of the developed algorithm iDSCB. It depicts the methodology for the modified scheme, with the addition of a new parameter used, such as buffer traffic estimation and hop-count-distance scenario as a criterion during routing of packets. In the developed scheme, a new distance-based decision formula was generated, which was used as a criterion during physiological signal forwarding. This distance-based that was included helps to the saving retransmission energy by the neighbour sensor nodes when the nodes are in close proximity to each other. By saving these nodes' energies, its cumulative effect improves the general energy of the BAN network. The area highlighted with red are our interventions for a better transmission of packets that will culminate the overall network energy- efficiency.

Table III: Simulation Setup parameters

Parameters	**Value**
Simulator	MATLAB 2017
Initial Energy	0.6J
Minimum supply voltage	1.8 V
Frequency (f)	2.4GHz
$E_{TX\text{-}amp}$	1.98Nj/BIT
$E_{TX\text{-}CCT}$	16.7nJ/bit
DC current (TX)	36.3Nj/bit
Dc current (RX)	10.6Ma
Wavelength (λ)	0.13m
Γ_{max}	7

The Developed iDSCB routing algorithm over the existing one in terms of percentage improvement.

% Improvement = [(DSCB- iDSCB) / DSCB] * 100 (3)

IV. RESULT AND DISCUSSION

When transmitting physiological packets in WBANs, the time gap between the transmitting nodes and the sink node is called end-to-end delay. Figure 3 shows the performance of the developed scheme against the existing scheme in terms of End-to-end delay versus processing time with the parameters for its simulation in Table III and the conservation of the energy nodes after a successive given transmission operation is called residual energy. Figure 4 shows the performance of the developed scheme against the existing scheme in terms of residual energy versus processing time with the corresponding parameter for the simulation in table 3.

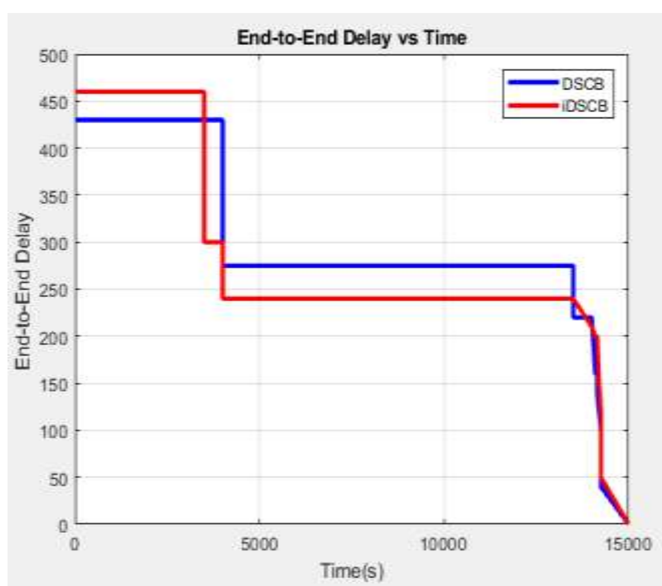

Figure 3: End-to-end Delay against Processing Time

TABLE IV: End-to-end delay performance analysis of existing algorithm and improved algorithm

S/N	Algorithm	Average no of dead nodes	% improvement using equation (3)
1	DSCB	245	3.15%
2	iDSCB	237.4	

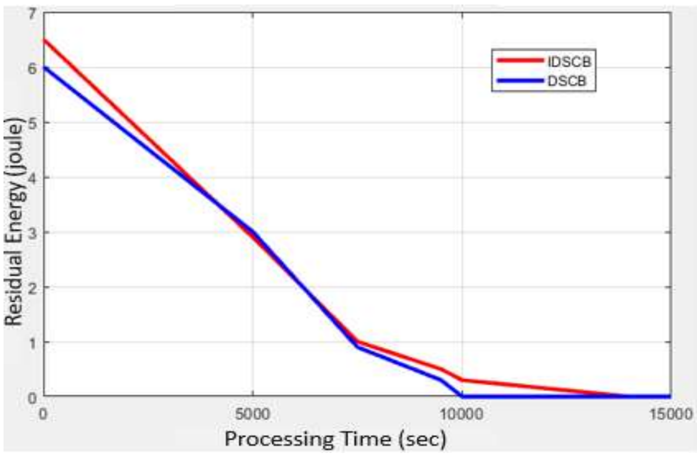

FIGURE 4: Residual Energy against Processing Time

TABLE V: Node residual energy performance analysis of dscb and idscb

S/N	Algorithm	Average Residual Energy	Percentage Improvement Using Equation (3.)
1	DSCB	2.25	8.88%
2	iDSCB	2.44	

From Fig. 2, we find out that the end-to-end delay, as the simulation time increases, the end-to-end delay decreases. This is because of employing dual sink nodes, which leads to the on-time direct transmission between the transmitting nodes and the two sink nodes, thereby decreasing the transmission distance and consequently resulting in reduced end-to-end delay. The result shows the performance of the existing and developed schemes in terms of end-to-end delay against network processing time. The improved scheme suffers a little delay as juxtaposed to the existing scheme between the zero to four thousand seconds processing time. This is due to the initial time it takes to adopt the developed hop-distance scenario and buffer traffic estimation. As time went beyond the four thousand seconds of processing, the improved scheme performed better than the existing scheme due to the implementation of the developed algorithm such as H_{DS} and BT_E, whose effect specifies allows the on-time transmission of physiological packets to the sink node. Simulation results show a percentage improvement of 3.15% when juxtaposed with the existing scheme, and table 4 depicts the performance evaluation of the improved scheme over the existing scheme. Figure 3 shows as the processing time increase, the residual energy of the nodes drops, this is because of the limited energy of the transceiver nodes which decreases over time as the processing time increase. It was discovered that the node residual energy for the improved scheme is better than the existing scheme. This is because of employing the developed algorithm like Buffer Traffic Estimation which aids the WBANs to control their transmission. Figure 3 shows the developed scheme has a percentage improvement of 8.88% over the existing scheme. Table 5 was used for the percentage evaluation of the existing scheme

V. CONCLUSION

For efficient physiological signal transmission in WBANs, this work developed a minimization of end-to-end delay for an improved dual-sink cluster-based routing in WBAN. The hop-distance scenarios were employed to ensure minimized end-to-end delay of the physiological signal during transmissions. The buffer traffic estimation of the individual nodes was estimated. And also, the improved scheme improved the performance of the WBANs, especially when implemented with the developed clustering scheme alongside the hop-distance scenarios and buffer traffic estimation in dual-sink. Simulation results depicted that the improved WBANs algorithm enhanced the performance of the WBAN in terms of end-to-end delay and residual energy when compared with the existing work. In the future, I recommend that the work be extended by developing a routing protocol that mitigates the initial time complexity during packet routing.

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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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