COMPARISON OF EFFICIENT ENERGY HARVESTING ROUTING ALGORITHM USING IEH-RCB PROTOCOL AND COMPARED WITH EH-RCB IN WIRELESS BODY AREA NETWORKS

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Abstract

Aim: The energy consumption minimization is the important criteria for this research work. The Efficient cluster based routing protocol which minimizes the energy consumption in remote medical applications for WBAN by robust and efficient Improved Energy Harvested-aware Routing clustering body area network (IEH-RCB) protocol using Clustering approach is proposed and compared with Energy Harvested-aware Routing clustering body area network (EH-RCB) protocol.
Materials and Methods: In IEH-RCB protocol the energy consumption is achieved using Cost function (CF) selection parameters such as Signal to Noise Ratio (SNR),transmission power, node distance,energy and Innovative node Bandwidth of the node are used. The forwarder node selection enhances the efficiency of the routing protocol in WBAN. In this work there are two groups in which each group has 20 sample sizes (n=20) collected by varying numbers of rounds and it was calculated by calculator.Net with pre-test power of 80% (G-power). To evaluate the effectiveness of the IEH-RCB protocol in terms of Residual energy and Packet Drop Ratio.
Results: Simulation results show that IEH-RCB protocol has performed better than EH-RCB Protocol in terms of throughput and energy consumption. The proposed IEH-RCB protocol increased (3.1%) in Residual energy and decreased (2.8%) in packet drop ratio compared with IEH-RCB protocol. The sample T-test also shows that there is a significant difference in IEH-RCB and EH-RCB protocol values in terms of residual energy and packet drop ratio ($p<0.05$).
Conclusion: Depending on the experimental results and independent statistical T-test shows that proposed IEH-RCB protocol has achieved higher performance when compared to EH-RCB protocol.

Keywords: Forwarder node, Clustering, Cost function, Packet drop ratio, Residual energy, WBANs, Innovative node bandwidth.

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1. Introduction

Recent days due to the advancement in communication technology and sensors, a modern network has emerged called WBANs. It has been emerging because of its low cost, usage in widespread various applications such as healthcare and remote monitoring. WBANs consist of a variety of intelligent, small size, low cost, low powered, light weight invasive or non-invasive personal computer devices that can be worn or implanted. These sensor nodes with limited battery energy not only impose performance drawbacks, but also depletes quickly, limiting the service availability. (Qu, Zheng, Wu, et al. 2019) WBANs has many applications like sports, social welfare, and medical treatment.It suggests promoting services in a variety of fields, including mobile health care, defense, industry, research, and business (Khan et al. 2021) and (Qu, Zheng, Ma, et al. 2019).

Over the past 5 years, nearly 100 articles have been published in IEEE Access and 98 articles are published in Science Direct related to EH-RCB protocol for WBANs. In WBANs the cluster based routing algorithm brings a new way to enhance the energy consumption of the forwarder nodes (David et al. 2021). In this scheme CF is calculated using various parameters such as SNR,transmission power,distance between nodes, total available energy, but the coverage area is less in this scheme which leads to inefficient CF selection methodology. (HajilooVakil, Khani, and Shirmohammadi 2021) proposed CF based routing scheme for WBANs, in this methodology residual energy is considered for CF selection and this scheme is not suitable for WBANs environment, due to high energy consumption in the routing process. (Rudra and Chakraborty 2017) illustrate that a sensor node which is capable of consuming minimum energy consumption, gains the required energy from various sources available in the surrounding environment such as body temperature, motion, vibration, ambient light etc, and converts it into usable energy. (Prieto 2011) proposed a scheme that mainly focuses on energy consumption, lifetime, delay and packet drop ratio. Various sensors are placed at different locations of the human body and two sink nodes are placed at the center in front and back side of the human body (Zhang and Ma 2018) and (Senthilkumar and Martin Leo Manickam 2017) it used many applications such as remote health monitoring and IOT based health monitoring.

Our institution is keen on working on latest research trends and has extensive knowledge and research experience which resulted in quality publications (Rinesh et al. 2022; Sundararaman et al. 2022; Mohanavel et al. 2022; Ram et al. 2022; Dinesh Kumar et al. 2022; Vijayalakshmi et al. 2022; Sudhan et al. 2022; Kumar et al. 2022; Sathish et al. 2022; Mahesh et al. 2022; Yaashikaa et al. 2022). This literature survey includes that mostly the cost function selection depends on Proximity distance and energy consumption of the sensor nodes. These parameters are not efficient to select the CF effectively. Hence IEH-RCB protocol is proposed, which selects the cost function using various parameters such as link SNR,transmission power,distance between nodes, total available energy and Innovative node Bandwidth of the node to minimize energy consumption of the sensor nodes in WBANs.

2. Materials and Methods

The research work was done in the Department of Biomedical and Engineering at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai,Tamilnadu, India. Two groups are required for this study. Group one consists of IEH-RCB protocol and group two represents EH-RCB protocol (Kumari and Nand 2018). The sample size was calculated by using a sample size calculator finding the mean and standard deviation.The sample size was 20 per group 80% of the pre-test power (G-power) used for this study. A PC with Ubuntu OS by VMware workstation and NS2 simulator software was used for execution of the project. The ns run command was given to execute the code in TCL script.

IEH-RCB Protocol

The clustering based routing algorithms are used to improve the performance of the WBANs routing protocol by enhancing the sensor nodes battery power in the network. The IEH-RCB protocol uses innovative cost function (CF) selection parameters such as Signal to Noise Ratio, transmission power, distance, energy and Innovative node Bandwidth.

The various steps involved in the forwarded node selection are described below.

Step 1: All the sensor nodes are deployed in a human body and formed WBAN.

Step 2: All the sensor nodes calculate their values using CF based forwarder node selection parameters such as link SNR,transmission power,distance between nodes, total available energy and Innovative node Bandwidth.

Step 3: The node which contains the highest rank that node becomes the Forwarded node

Step 4 : The CF aggregates the information from the sensor nodes using Hello and Reply message within the cluster and other sensors in the network.

Step 5: The Forwarded node routes the information to the mobile health monitoring server using the shortest routing path.

Step 6: The mobile health monitoring server gathers all the information from various forwarder nodes.

EH-RCB Protocol

The EH-RCB protocol used the following parameters to select cost function selection parameters such as link SNR,transmission power,distance between nodes, node Bandwidth the cost function based rules are used to select the super forwarder node among the forwarder node to route the information from the forwarder node to the base station.

Statistical Analysis

The statistical analysis was carried out using the SPSS tool.The significance is calculated using Independent t-test. It was performed for the two dependent variables such as packet drop ratio and residual energy. The independent variables are number of nodes, battery power and battery size. Using the SPSS software the standard deviation, standard error of mean were also calculated.

3. Results

Table 1 shows experimental results of data analysis of the IEH-RCB protocol under varying number of rounds and residual energy with reference to packet drop ratio. Experimental results of IEH-RCB protocol under varying number of rounds (0 to 16000) in terms of residual energy (achieved highest value 7.7 when the number of rounds is 800 and achieved lowest value 1.2 when the number of rounds is 16000).

Table 2 shows the experimental results of the IEH-RCB protocol under varying number of rounds (0 to 16000) in terms of packet drop ratio (achieved lowest value 0.15 when the number of rounds is 800 and achieved highest value is 2 when the number of rounds is 16000).

Table 3 Group statistical analysis of IEH-RCB protocol and EH-RCB protocol. Residual energy Mean value is 4.3650 in IEH-RCB protocol. Packet drop ratio Mean value is 0.6445 in IEH-RCB.

Table 4 Shows the independent sample T-test calculation of IEH-RCB protocol and EH-RCB protocol. The Residual energy and packet drop ratio are statistically significant ($p<0.05$)

4. Discussion

Figure 1 shows a comparison of residual energy in IEH-RCB with EH-RCB protocol under varying number of rounds and the residual energy is increased by 3.1% due to the routing based forwarded node selection. Figure 2 represents comparison of packet drop ratio of sensor nodes battery power in IEH-RCB with EH-RCB protocol. (Alkhayyat, Thabit, and Ali 2019). Under varying number of rounds the packet drop ratio minimized by 2.8% due to the position of the node. Figure 3 shows the bar chart representing the comparison of IEH-RCB protocol and EH-RCB protocol in terms of residual energy and achieved 3.1% higher residual energy when compared with EH-RCB protocol. X axis: IEH-RCB protocol vs EH-RCB protocol, Y axis: mean residual energy of detection ± 1 SD. Figure 4 illustrates that the bar chart representing the comparison of IEH-RCB protocol and EH-RCB protocol in terms of 2.8% pocket drop ratio when compared with the previous protocol of EH-RCB X axis: IEH-RCB protocol vs EH-RCB protocol, Y axis: Mean packet drop ratio ± 1 SD

Comparison of energy efficiency of IEH-RCB protocol and EH-RCB protocol is studied. The number of rounds of the proposed protocol is varied from 0 to 16000.(Kim and Cho 2009) and (Al-Turjman 2019)The residual energy is increased by 3.1% in IEH-RCB as shown in Fig 1. The packet drop ratio is decreased by 2.8% in IEH-RCB protocol with EH-RCB protocol under varying number of rounds as shown in Fig 2. By independent sample t-test calculation the residual energy and packet delivery ratio is statistically significant ($p<0.05$) by SPSS software shown in Fig 3 and Fig 4. The proposed IEH-RCB protocol has better performance in efficient routing when compared with the EH-RCB protocol with reference to the stimulation results.

Modification made in this research is that the forwarder node selection depends on multiple parameters such as link SNR,transmiss-ion power,distance between nodes, total available energy and Innovative node Bandwidth of the node are used (Yuce and Khan 2011) and (Ramirez, Vidal, and Universitat de Barcelona. Departament d'Electrònica 2014) This paper has similar research which uses the EH-RCB (Energy Harvested-aware routing protocol with clustering approach in body area network) protocol to improve the performance of the network routing in WBAN. (Bizon et al. 2017) in this paper the the authors used gateway nodes between the forwarder node for long distance communication which oppose the methodology of IEH-RCB protocol which uses an angle as a forwarder node selection parameter. The main limitation of this paper is high end-to-end delay is present in the network and battery size to be improved.

5. Conclusion

The proposed IEH-RCB protocol has better simulated outputs when compared to EH-RCB protocol in terms of residual energy increased by 3.1%, packet drop ratio is increased by 2.8% and also the sample T-test also shows that there is a significant difference in IEH-RCB and EH-RCB protocol values in terms of residual energy and packet drop ratio ($p<0.05$).

DECLARATION

Conflict of Interests

No conflict of interest in this manuscript.

Author Contribution

Author KD was involved in Methodology creation, simulation, data collection, data analysis, Manuscript writing. Author CS was involved in conceptualization, guidance and critical review of manuscript.

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6. References

Alkhayyat, Ahmed, Ahmed A. Thabit, and Ali Adil Ali. 2019. “WBAN Health Care-Based: Modeling Signal to Interference Ratio with Different MAC Protocols.” 2019 2nd International Conference on Engineering Technology and Its Applications (IICETA). https://doi.org/10.1109/iiceta47481.2019.9012969.

Al-Turjman, Fadi. 2019. “A Rational Routing Protocol for WBAN.” Internet of Nano-Things and Wireless Body Area Networks (WBAN). https://doi.org/10.1201/9780429243707-5.

Bizon, Nicu, Naser Mahdavi Tabatabaei, Frede Blaabjerg, and Erol Kurt. 2017. Energy Harvesting and Energy Efficiency: Technology, Methods, and Applications. Springer.

David, Yair Bar, Tal Geller, Ilai Bistritz, Irad Ben-Gal, Nicholas Bambos, and Evgeni Khmelnitsky. 2021. “Wireless Body Area Network Control Policies for Energy-Efficient Health Monitoring.” Sensors 21 (12). https://doi.org/10.3390/s21124245.

Dinesh Kumar, M., V. Godvin Sharmila, Gopalakrishnan Kumar, Jeong-Hoon Park, Siham Yousuf Al-Qaradawi, and J. Rajesh Banu. 2022. “Surfactant Induced Microwave Disintegration for Enhanced Biohydrogen Production from Macroalgae Biomass: Thermodynamics and Energetics.” Bioresource Technology 350 (April): 126904.

HajilooVakil, Mahdieh, Mohammad Javad Khani, and Zahra Shirmohammadi. 2021. “An Efficient Compression Method to Improve Energy Consumption in WBANs.” 2021 7th International Conference on Web Research (ICWR). https://doi.org/10.1109/icwr51868.2021.9443125.

Khan, Inam Ullah, Muhammad Abul Hassan, Mohammad Dahman Alshehri, Mohammed Abdulaziz Ikram, Hasan J. Alyamani, Ryan Alturki, and Vinh Truong Hoang. 2021. “Monitoring System-Based Flying IoT in Public Health and Sports Using Ant-Enabled Energy-Aware Routing.” Journal of Healthcare Engineering 2021 (July): 1686946.

Kim, Dae-Young, and Jinsung Cho. 2009. “WBAN Meets WBAN: Smart Mobile Space over Wireless Body Area Networks.” 2009 IEEE 70th Vehicular Technology Conference Fall. https://doi.org/10.1109/vetecf.2009.5378899.

Kumari, Rani, and Parma Nand. 2018. “To Improve the Performance of Routing Protocol in Mobile WBAN by Optimizing the Scheduling Mechanism.” International Journal of Emerging Research in Management and Technology. https://doi.org/10.23956/ijermt.v6i9.90.

Kumar, J. Aravind, J. Aravind Kumar, S. Sathish, T. Krithiga, T. R. Praveenkumar, S. Lokesh, D. Prabu, A. Annam Renita, P. Prakash, and M. Rajasimman. 2022. “A Comprehensive Review on Bio-Hydrogen Production from Brewery Industrial Wastewater and Its Treatment Methodologies.” Fuel. https://doi.org/10.1016/j.fuel.2022.123594.

Mahesh, Narayanan, Srinivasan Balakumar, Uthaman Danya, Shanmugasundaram Shyamalagowri, Palanisamy Suresh Babu, Jeyaseelan Aravind, Murugesan Kamaraj, and

Muthusamy Govarthanan. 2022. "A Review on Mitigation of Emerging Contaminants in an Aqueous Environment Using Microbial Bio-Machines as Sustainable Tools: Progress and Limitations." Journal of Water Process Engineering. https://doi.org/10.1016/j.jwpe.2022.102712.

Mohanavel, Vinayagam, K. Ravi Kumar, T. Sathish, Palanivel Velmurugan, Alagar Karthick, M. Ravichandran, Saleh Alfarraj, Hesham S. Almoallim, Shanmugam Sureshkumar, and J. Isaac JoshuaRamesh Lalvani. 2022. "Investigation on Inorganic Salts K2TiF6 and KBF4 to Develop Nanoparticles Based TiB2 Reinforcement Aluminium Composites." Bioinorganic Chemistry and Applications 2022 (January): 8559402.

Prieto, Alvaro. 2011. Wireless Body Area Network Platform Utilizing Energy-Efficient Routing of Physiological Data.

Qu, Yating, Guoqiang Zheng, Huahong Ma, Xintong Wang, Baofeng Ji, and Honghai Wu. 2019. "A Survey of Routing Protocols in WBAN for Healthcare Applications." Sensors 19 (7). https://doi.org/10.3390/s19071638.

Qu, Yating, Guoqiang Zheng, Honghai Wu, Baofeng Ji, and Huahong Ma. 2019. "An Energy-Efficient Routing Protocol for Reliable Data Transmission in Wireless Body Area Networks." Sensors 19 (19). https://doi.org/10.3390/s19194238.

Ram, G. Dinesh, G. Dinesh Ram, S. Praveen Kumar, T. Yuvaraj, Thanikanti Sudhakar Babu, and Karthik Balasubramanian. 2022. "Simulation and Investigation of MEMS Bilayer Solar Energy Harvester for Smart Wireless Sensor Applications." Sustainable Energy Technologies and Assessments. https://doi.org/10.1016/j.seta.2022.102102.

Ramirez, Ernesto Antonio Ibarra, Manuel Puig i. Vidal, and Universitat de Barcelona. Departament d'Electrònica. 2014. Energy Harvesting-Aware Resource Management for Wireless Body Area Networks.

Rinesh, S., K. Maheswari, B. Arthi, P. Sherubha, A. Vijay, S. Sridhar, T. Rajendran, and Yosef Asrat Waji. 2022. "Investigations on Brain Tumor Classification Using Hybrid Machine Learning Algorithms." Journal of Healthcare Engineering 2022 (February): 2761847.

Rudra, Jayanti, and Mrittika Chakraborty. 2017. "Increase in Lifetime by Harvested Energy and Analysis of RC5 along with Efficient Energy Consumption in WBAN." ENVIRONMENTAL AND EARTH SCIENCES RESEARCH JOURNAL. https://doi.org/10.18280/eesrj.040203.

Sathish, T., V. Mohanavel, M. Arunkumar, K. Rajan, Manzoore Elahi M. Soudagar, M. A. Mujtaba, Saleh H. Salmen, Sami Al Obaid, H. Fayaz, and S. Sivakumar. 2022. "Utilization of Azadirachta Indica Biodiesel, Ethanol and Diesel Blends for Diesel Engine Applications with Engine Emission Profile." Fuel. https://doi.org/10.1016/j.fuel.2022.123798.

Senthilkumar, C., and J. Martin Leo Manickam. 2017. "REAS: Residual Energy Aware Angle Based Routing Protocol for Cluster-Based Wireless Sensor Networks." Sensor Letters. https://doi.org/10.1166/sl.2017.3858.

Sudhan, M. B., M. Sinthuja, S. Pravinth Raja, J. Amutharaj, G. Charlyn Pushpa Latha, S. Sheeba Rachel, T. Anitha, T. Rajendran, and Yosef Asrat Waji. 2022. "Segmentation and Classification of Glaucoma Using U-Net with Deep Learning Model." Journal of Healthcare Engineering 2022 (February): 1601354.

Sundararaman, Sathish, J. Aravind Kumar, Prabu Deivasigamani, and Yuvarajan Devarajan. 2022. "Emerging Pharma Residue Contaminants: Occurrence, Monitoring, Risk and Fate Assessment – A Challenge to Water Resource Management." Science of The Total Environment. https://doi.org/10.1016/j.scitotenv.2022.153897.

Vijayalakshmi, V. J., Prakash Arumugam, A. Ananthi Christy, and R. Brindha. 2022. "Simultaneous Allocation of EV Charging Stations and Renewable Energy Sources: An Elite RERNN-m2MPA Approach." International Journal of Energy Research. https://doi.org/10.1002/er.7780.

Yaashikaa, P. R., P. Senthil Kumar, S. Jeevanantham, and R. Saravanan. 2022. "A Review on Bioremediation Approach for Heavy Metal Detoxification and Accumulation in Plants." Environmental Pollution 301 (May): 119035.

Yuce, Mehmet R., and Jamil Khan. 2011. Wireless Body Area Networks: Technology, Implementation, and Applications. CRC Press.

Zhang, Puning, and Jie Ma. 2018. "Channel Characteristic Aware Privacy Protection Mechanism in WBAN." Sensors 18 (8). https://doi.org/10.3390/s18082403.

TABLES AND FIGURES

Table 1. Experimental results of IEH-RCB protocol and compared with EH-RCB protocol under varying number of rounds (0 to 16000) in terms of Residual energy (achieved highest value 7.7 when the number of rounds is 800 and achieved lowest value 1.2 when the number of rounds is 16000).

Number of Rounds	IEH-RCB	EH-RCB
800	7.7	4.2
1600	7.6	3.8
2400	6.6	3
3200	6.4	2.8
4000	6.1	2.4
4800	6	2.2
5600	5.6	2
6400	5.2	1.4
7200	4.8	1.2
8000	4.4	1
8800	4	0.38
9600	3.7	0.35
10400	3.4	0.32
11200	3	0.28
12000	2.8	0.26
12800	2.6	0.24
13600	2.4	0.22
14400	2.2	0.2
15200	1.6	0.14
16000	1.2	0.1

Table 2. Experimental results of IEH-RCB protocol and compared with EH-RCB protocol under varying number of rounds (0 to 16000) in terms of packet drop ratio (achieved lowest value 0.15 when the number of rounds is 800 and achieved highest value is 2 when the number of rounds is 16000)

Number of Rounds	IEH-RCB	EH-RCB
800	0.15	1.2
1600	0.21	1.8
2400	0.28	2.5

3200	0.31	2.8
4000	0.33	3
4800	0.34	3.1
5600	0.35	3.2
6400	0.36	3.3
7200	0.38	3.5
8000	0.4	3.7
8800	0.41	3.8
9600	0.42	3.9
10400	0.44	4.1
11200	0.45	4.2
12000	0.46	4.3
12800	1	4.5
13600	1.2	4.6
14400	1.6	4.7
15200	1.8	4.8
16000	2	5

Table 3. Group statistical analysis of IEH-RCB protocol and EH-RCB protocol. Residual energy Mean value is 4.3650 in IEH-RCB protocol. Packet drop ratio Mean value is 0.6445 in IEH-RCB

	Group	**N**	**Mean**	**Std.Deviation**	**Std. Error mean**
Residual energy	IEH-RCB	20	4.3650	1.97305	0.44119
	EH-RCB	20	1.3245	1.32833	0.29702
Packet drop ratio	IEH-RCB	20	0.6445	0.55756	0.12468
	EH-ECB	20	3.6000	1.00995	0.22583

Table 4. Shows the independent sample T-test calculation of IEH-RCB protocol and EH-RCB protocol. The Residual energy and packet drop ratio are statistically significant($p<0.05$)

		Levene's Test for Equality of variances		**T-test for Equality of Means**						
		F	**Sig**	**t**	**df**	**Sig.(2-tailed)**	**Mean Difference**	**std.Error Difference**	**Lower**	**Upper**
Residual Energy	Equal variances assumed	4.44	0.042	5.717	38	<.001	3.04	0.53185	1.96	4.117
	Equal variances not assumed			5.717	33.28	<.001	3.04	0.53185	1.9587	4.122
Packet drop ratio	Equal variances assumed	5.76	0.021	-11.45	38	<.001	-2.95	0.25796	-3.477	-2.43
	Equal variances not assumed			-11.45	29.59	.001	-2.95	0.25796	-3.482	2.23

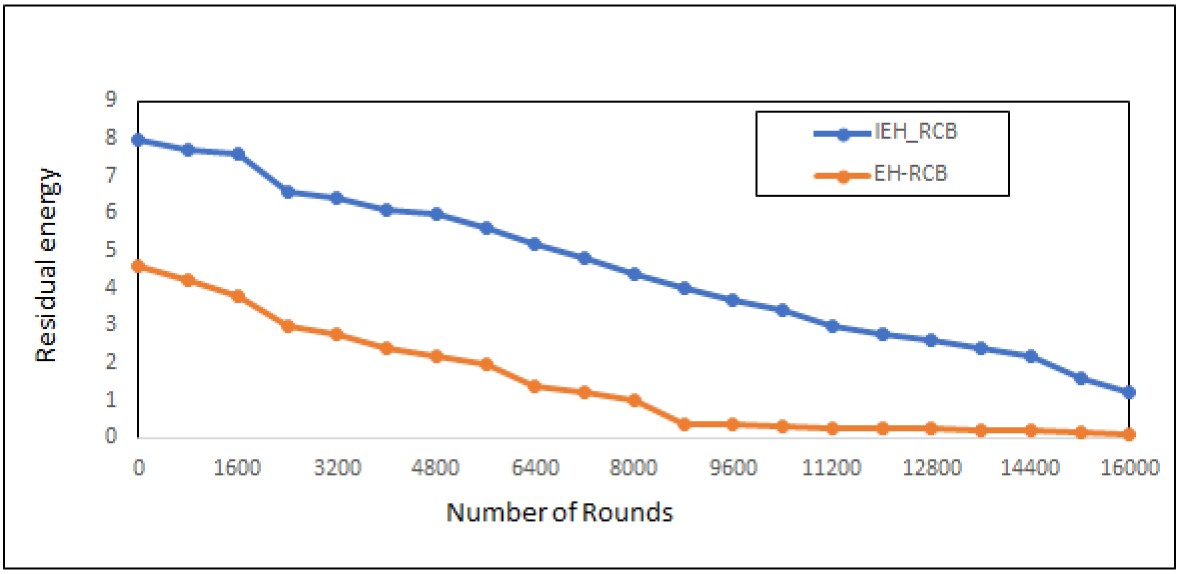

Fig. 1. Comparison of residual energy in IEH-RCB protocol with EH-RCB protocol. Under varying.number of rounds the residual energy is increased by 3.1% due to routing based forwarder node.

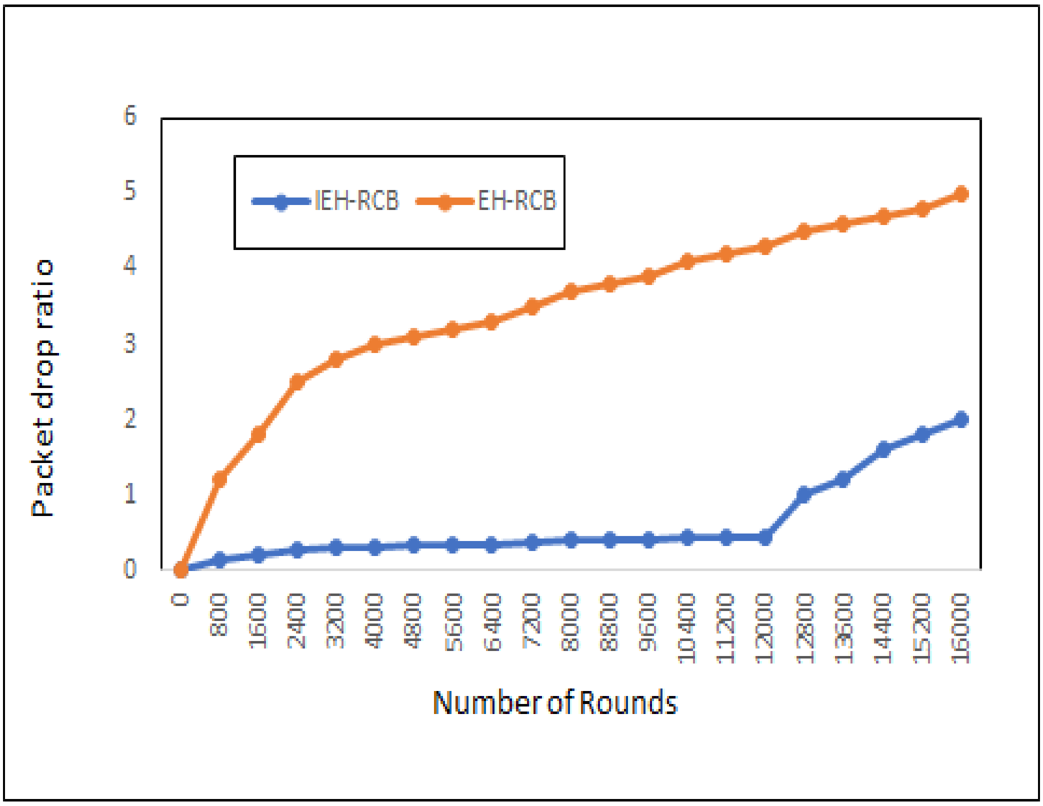

Fig. 2. Comparison of packet drop ratio in IEH-RCB protocol with EH-RCB protocol. Under varying number of rounds the pocket drop ratio is decreased by 2.8% due to routing based forwarded node.

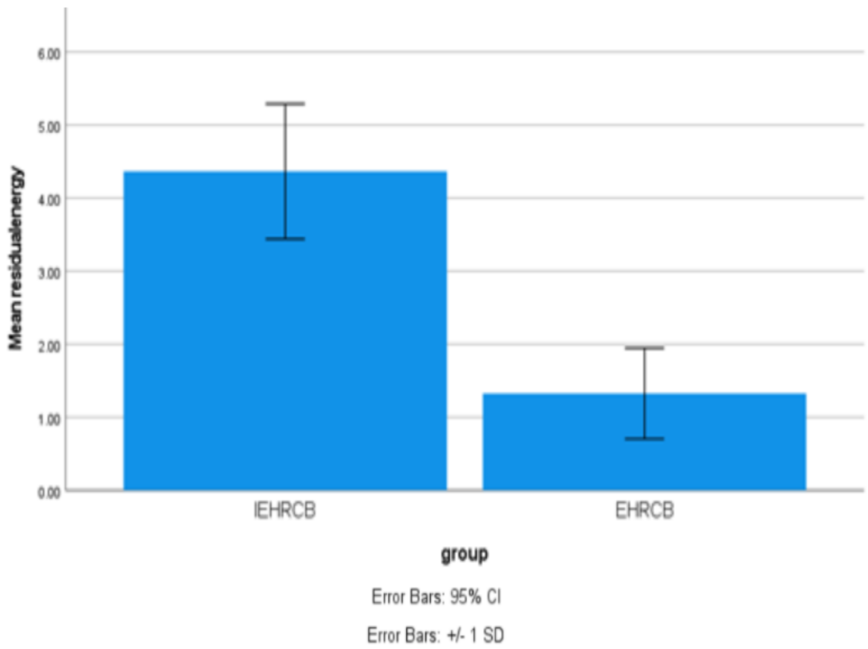

Fig. 3. Bar chart representing the comparison of IEH-RCB protocol and EH-RCB protocol in terms of Packet Drop Ratio. The IEH-RCB protocol achieved a 3.1% increased residual energy when compared with the EH-RCB protocol. X Axis: IEH-RCB protocol vs EH-RCB protocol protocol, Y Axis: Mean residual energy of detection ± 1 SD.

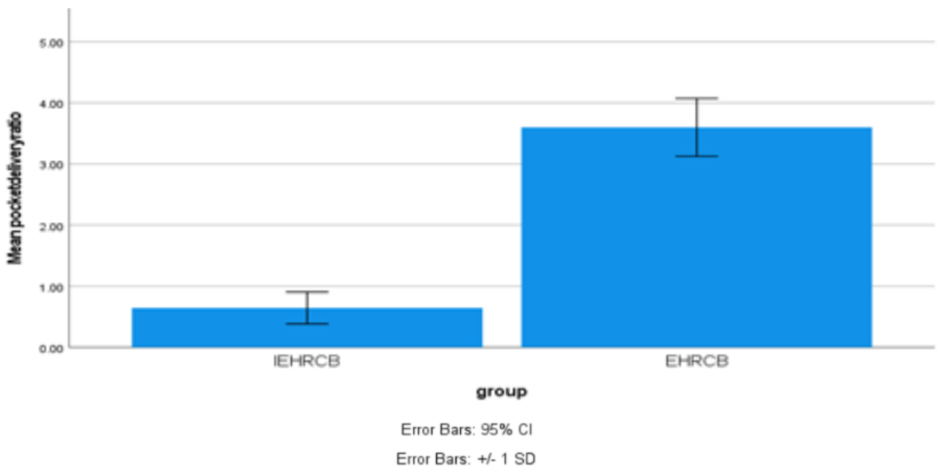

Fig. 4. Bar chart representing the comparison of IEH-RCB protocol and EH-RCB protocol in terms of Packet Drop Ratio. The IEH-RCB protocol achieved a 2.8% minimized pocket drop ratio when compared with the EH-RCB protocol. X Axis: IEH-RCB protocol vs EH-RCB protocol protocol, Y Axis: Mean residual energy of detection ± 1 SD.