OPEN ACCESS

International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Energy Efficient MAC Protocol for Heterogeneous Wireless Sensor Network using Cross-Layer Design

Manisha R. Dhage, Srikanth Vemuru

Abstract*: Over the last decade, Wireless Sensor Network (WSN) has gained considerable attention in various real-time applications. Since WSN works with battery operated nodes, utilization and optimization of node energy is one the primary challenge. For effectively handling and controlling the energy consumption problem in WSN, cross-layer optimization is one of the important methods. For a researcher working in the domain of WSN, energy constraint is a huge challenge to deal with. MAC layer is one of the major source of energy consumption so, an innovative energy efficient MAC protocol using a cross-layer approach in the heterogeneous wireless sensor network is proposed. In this protocol, first, packet retransmission by reducing packet loss is addressed by considering buffer space, channel state and remaining energy. Second, the synchronization scheme for a global schedule is implemented by deliberating adaptive listening using the length of the transmission queue. Finally, sleep time issue is worked out to reduce energy consumption. In this scenario, the nodes will be in sleep mode unless it has some packets to send or receive. The proposed protocol is implemented in Network Simulation (NS2). The simulation results show that the heterogeneous wireless network performs better in terms of energy consumption, packet data rate and energy buffer state while implementing through the proposed protocol.

***Index Terms*: cross-layer, energy efficiency, heterogeneous sensor nodes, wireless sensor network**

I. INTRODUCTION

The wireless sensor network consists of small tiny sensors having limited battery and limited processing power. Still, it can be used for various real-time applications involving a minimum volume of data transfer. Wireless sensor network has numerous advantages, including its suitability in hard hilly terrains, deep sea, dense forests and remotely isolated rural areas. Also, it is much extensible and very economical for deployment [1]. While establishing data communication using wireless sensor networks, one of the primary constraints is energy utilization.

Manuscript published on November 30, 2019.
* Correspondence Author

Mrs Manisha R. Dhage*, Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Guntur, 522502, Andhra Pradesh, India

Dr. Srikanth Vemuru, Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Guntur, 522502, Andhra Pradesh, India

As per research studies, around 80% of the total energy of the nodes is used for communication of packets. For prolonging the lifetime of the sensor networks, various algorithms including scheduling mechanisms with energy efficiency are used [4].

Of these algorithms, the approach using cross-layer design can be used to optimize the performance of WSN. In this approach, various parameters can be shared or controlled in a collaborative manner.

Various researches involving the cross-layer design of wireless sensor network focus on adaptive modulation and signal to noise ratio for reducing Bit Error Rate (BER). In the work, battery availability and state of buffer for transmission strategies are not considered [5] [6].

Medium Access Protocol (MAC) is used for implementation in which maximum energy is wasted due to idle listening and collision. In such situations, larger energy dissipation occurred when the radio portion is operating in idle mode. So ideal strategy for energy saving would keep the radio switched off when the node is in idle listening mode. But the disadvantage in such a situation is the particular node does not get surrounding communication. So the corresponding node should coordinate sleep schedule with other nodes. Hence the node should dynamically listen to the channel and sleep schedule should be maintained globally to save the energy. Similar to listen time, sleep time is also important for energy saving. So the node involved in communication should efficiently switch between sleep and wake up mode [7].

In this paper, we have designed an innovative energy efficient protocol using cross-layer design in the heterogeneous wireless sensor network (HWSN), where maximum energy can be saved in packet retransmission by means of avoiding packet loss. Then for reducing energy loss, adaptive listening and sleep time mechanism is introduced. The remaining paper is systematized as follows. A brief literature review about wireless sensor networks, energy saving mechanisms, cross-layer design, clustering, aggregation mechanisms and heterogeneous applications of WSN is presented in Section II. The proposed methodology consisting of Retransmission mechanism and Sleep synchronization and Adaptive listening Mechanism are presented in Section III. The simulation implementation of a heterogeneous wireless sensor network for improving energy efficiency along with other performance metrics such as latency and packet delivery ratio and the result

analysis comparing the proposed protocol with traditional approaches are analyzed in Section IV.
The summary of the simulation results along with the conclusion of the paper and directions for future research are presented in Section V.

II. LITERATURE REVIEW

A. Energy consumption in WSN

Physical Layer

Energy is used due to transmission and reception at physical layer. Modulation and data coding is performed at the transmitter and the receiver optimally performs demodulation and decoding. To consume energy effectively in WSN the node in idle mode is set to switch off mode and switching time between the receiver mode and transmitter mode is minimized along with energy optimization [8]. To reduce communication overhead (incurred due to all the nodes communicating to sink node) clustering is used with cluster head to diminish the energy and time to consume less energy.

Link Layer

In energy- aware routing, link layer got significant attention with respect to energy consumption [10]. Instead of direct sensor to base station transmission, multi-hop data transmission can be used to reduce transmission power. Collisions between nodes radio transmission consume energy by keeping node active instead of shifting them to other modes like sleep [11]. Three main actives of sensor like reception, transmission and idle consume more energy during data transmission.
A research proved that power consumption in active state is more as compared to sleep state. Radio plays main role in energy consumption and network lifetime also [12].

MAC Layer

In designing MAC protocol, service of residual energy is having main concern [13]. Major energy consumption occurs in MAC layer due to control packet overhead, collision of nodes and overhearing of nodes. So energy efficient MAC protocol plays a vital role in lifetime of WSN. Time division multiple access (TDMA) and Code division multiple access (CDMA) are appropriate one to avoid energy consumption at link layer
In the research work [14], it is found that sleep synchronization among nodes affects energy consumption. Since the listening time in the MAC layer has to influence in relay delay and delivery ratio, the degree of sleep coordination between nodes yields the corresponding power consumption.
Similarly, in [15] the sleep time is considered to affect energy consumption. Periodically nodes wake up and then perform transmission and finally turn back to sleep. Hence, the length of the wake-up cycle has an impact on energy consumption.

Network Layer

The network layer is used for topology control, congestion control and routing for reducing energy consumption and improving lifetime of WSN. Communication overhead and energy is used in optimized way by reducing the acknowledgements and minimizing the communication range.

Topology

It is an important operation in WSNs to determine the best topology between nodes to send routing packets to the destination. There are several considerations that are crucial in choosing an appropriate topology, such as energy-efficient network lifetime deployment and maintenance, so the network accomplishes good connectivity with reduced energy consumption. Topology based control protocols are designed to establish robust network topology while minimizing energy consumption in topology formation and maintenance.
The challenges involved in topology control [1] are addressed using Geographic fidelity and cluster-based energy conservation protocols. The comparison discovered that in this order, grid topology had the highest energy consumption as compared to chain and random topologies. Better packet delivery rate showed by chain topology than others. In reality, the worst packet delivery rate and power consumption given by grid topology. The researchers found that, as the primary parameter in the comparison, the findings obtained were a direct result of the routing protocols.

Routing

Since routing is an important and expensive task in WSNs, energy efficient routing protocols are preferred to increase the lifetime of the WSN. Homogeneous sensor networks consist of similar nodes with same routing tasks while heterogeneous networks consist of dissimilar nodes with vary capabilities. The node in heterogeneous network can be assigned more responsibility with high capacity and thereby reduce overall energy consumption by optimizing arrangements.
To deliver data from source to destination, routing protocols works on topologies such as mesh, tree, and cluster. LEACH (Low-Energy Adaptive Clustering Hierarchy) is a cluster based routing algorithm. While LEACH is an efficient method to achieve extended network life, scalability, and safety of data, LEACH does not ensure optimal paths. The author pointed out in another paper [22] that transferring packets to the sink along the minimum energy route may decrease energy consumption but result in an unbalanced allocation of remaining energy among the sensor nodes; therefore, they suggested an energy-balanced routing policy to address this issue. Another protocol for energy-efficient routing with holes for WSNs, developed owing to irregular deployment, was suggested in [20].

Congestion Control

For wireless networks, congestion control algorithms used for wired networks are not suitable, as packets must be retransmitted and extra energy is used. According to the study in [16], the issue of energy consumption is caused by the times of retransmitting unsuccessful packets. There are many factors like buffer condition, system state, higher bit rate, power control mechanism and buffer over flow cost which increases retransmission of packets and hence increasing energy consumption.
In a wireless network, [23] authors simulated a TCP-like congestion control. Paper shows reduced throughput due to congestion and packet collision when the traffic load increases beyond a certain optimum level. Here the author suggests a technique that does hop-by-hop congestion control based on backpressure.

Application Layer

The primary proportionate in the application layer is an aggregator that mixes information from distinct nodes, removes redundant data and compresses it before transmission to the planned location, recalling that decreasing the amount of transmissions saves energy.

Mostly data aggregation is considered in routing at some nodes. Similarly, essential role played by routing protocol for data aggregation. Cluster head play important role in cluster-based protocols. It does data aggregation and perform in network processing. Fusing information from various nodes or aggregating information in particular needs time-synchronization of the WSNs. The ultimate objective is to consume less energy while transmitting all the information to the sink to enhance the network's lifetime.

The study in [17], which is about underwater acoustic sensor networks, suggests that the larger packet size and the longer distance between nodes caused more energy consumption. Due to longer distance propagation loss can increase and secondly due to finite buffer space, packet loss can be there which leads to retransmission.

In [18], which studies video transmission in sensor networks, it is presented that, the QoS requirements and video encoding parameters influence the energy consumption, and hence the network lifetime. The path scheduling, which is decided by packet priority, has direct impacts on the amount of energy consumption.

III. POSSIBLE SOLUTION TO INCREASE ENERGY EFFICIENCY IN WSN

A. *Cross-layer design*

The energy efficiency gains relatively much importance, as mentioned in the previous literature review, the WSNs are constrained by resource, especially the power. Cross layer design is broadly studied in WSNs for energy efficiency.

• The proposed approach in [16], uses adaptive modulation and adaptive power management in the physical layer, and reduces the retransmission times in the MAC layer, so as to reduce the power consumption. Based on the information of channel state from the physical layer, buffer overflow from MAC layer and battery power which are shared in the nodes. To improve power efficiency, the retransmission scheme can be modified.

• In [14], to produce synchronic and dynamic adaptive listening scheme author jointly considers listening time in MAC layer and routing scheme in the network layer, along with the channel information from the physical layer. The forward delay and energy consumption are reduced due to the coordination between nodes in terms of their sleeping time.

• In [15], according to the information from physical, the proposed approach can change the sleep and listen to patterns of MAC layer for energy efficiency, in use of the SYNC packets in the transportation layer. The SYNC packet is used to schedule the transmission between nodes, and its transmission is determined by the channel condition and the data transmission time from the physical layer and MAC layer.

The study in [17] suggests that the access to relays can be enhanced by improving administration scheme via optimizing routing (network), MAC layer and physical layers. The physical layer is used to calculate the propagation loss and to predict the next location; Mac layer allows the calculation of energy consumption and buffer space; network layer improves routing policy based on the previous information.

• In [18], the proposed approach adapts video encoding in the application layer, path scheduling in the network layer and priority queue in the MAC layer, to reduce the lifetime and hence the energy consumption. The video encoding scheme is influenced by the channel condition sensed by the physical layer, the quality of encoding decides the priority of traffic in the MAC layer and the path scheduling in the network layer.

B. *Heterogeneous environment*

Different heterogeneity like link heterogeneity, sensing capability, computing power, energy can improve energy efficiency [1]. Because of Link heterogeneity, it is feasible to transmit more reliable information because a high-speed network connection or high bandwidth offers less opportunity of data loss during transmission.

Some nodes have a faster microprocessor or microcontroller unit (MCU) and more storage room than ordinary nodes in computational heterogeneity networks. It is possible to create heterogeneous nodes with powerful computational resources, complex data processing and more temporary data storage.

In [19], a heterogeneous3-level network model for WSNs was proposed to improve the lifetime of the network. Using threshold function and weighted election probability, cluster head and cluster members selected with the help of Heterogeneous network model. The lifetime of the network in DEEC-3 and hetDEEC-3 rises by 154.17% and 182.67% respectively, increasing the complete power of the network by 100% compared to the initial DEEC.

C. *Clustering*

Clustering technique helps in energy conservation by organizing the senor nodes into clusters. And by adopting heterogeneity the life time of WSN is prolonged. Author [9] states that with heterogeneity the network responses and network life time increases by three and four times respectively. The clustering based approach shows the following advantages.

a. Localization of the route configuration helps in reducing routing table size.
b. Communication among nodes in the cluster helps in conservation of bandwidth
c. Possible to extended battery life of individual sensors
d. Reduces overhead due to topology maintenance.
e. Energy consumption level is minimized.

D. *Data Aggregation*

Data aggregation is widely used in the areas when abundant data is sent across WSN, but with data redundancy. Data aggregation is formed by the collection of data from all the senor nodes and then sent to base station. There is lot of advantages of data aggregation. Data aggregation is required in scenarios where aggregated data is preferred over individual reading. Hence Data aggregation is used in clustering approach. There are lot of advantages of data aggregation, firstly the communication cost is reduced and secondly shows improvement in the data transfer realizability.

Retrieval Number: D7789118419/2019©BEIESP
DOI:10.35940/ijrte.D7789.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

But the disadvantage is huge consumption of energy as multiple sensors are involved in aggregation. In heterogenous network the configuration of all the nodes vary unlike the homogenous nodes. Some nodes are more powerful than the others. Hence heterogeneous network are used in hierarchical routings. Hierarchical helps in minimizing the hardware cost of WSN. In hierarchical routing clusters are created with cluster head for each cluster.

Cluster aggregates data from cluster members and transfer data to sink node. Since the data is sent in aggregation from the cluster head to sink node, than each node communicating to sink node, energy consumption is reduced drastically. Due to large distance between the sensor node and sink node, huge energy is consumed. This can be avoided using multihopping. But the nodes nearer to the cluster head, consume highest energy loss in multi-hopping because relaying. . As a consequence, there may be a non-uniform pattern of energy release in WSN. Analysis in [21] showed that cluster-based techniques are appropriate for HWSN (heterogeneous network of wireless sensors).

IV. PROPOSED METHODOLOGY

As we have seen in related work that factors responsible for energy consumption. Many researchers work on these factors to reduce energy consumption but the problem with the above methods is that they have worked on either of the factors. So here in our proposed method, we are going to consider multiple factors to make the wireless sensor network, more energy efficient. In addition to that, we use heterogeneous sensors which will further improve energy efficiency.

A. *Significance Statement*

To design and develop innovative energy efficient protocol using a cross-layer approach in the heterogeneous wireless sensor network where first, packet retransmission by reducing packet loss is addressed by considering buffer space, channel state and remaining energy. Second, the synchronization scheme for a global schedule is considered by deliberating adaptive listening using the length of the transmission queue. Finally, sleep time issue is worked out to reduce energy consumption.

B. *Retransmission Mechanism*

Like packet transmission and reception, packet retransmission is additionally a significant supply of energy consumption. Here we are able to save energy in packet retransmission by reducing packet loss. The next variety of packet loss due to PER (Packet Error Rate) and buffer overflow that triggers the retransmission of packets. In, this work, we've got thought of completely different parameters to scale back energy consumption and these are the channel state, packets out there within the buffer and, battery state.

The Retransmission Mechanism in Adaptive S-MAC algorithm is shown in Table 1 and shown in Figure 1.

Channel state information (CSI) needs to be estimated at the receiver and usually quantized and feedback the transmitter. Therefore, CSI can be different for transmitter and receiver. CSIT and CSIR respectively referred as CSI at transmitter and CSI at receiver. Using this CSI information combined effect of fading, power decay with distance and scattering can be represented. Channel state data is taken into account supported the signal to noise ratio (SNR) from the physical layer. The second parameter is buffer space at receiver side B_S from Network layer which we will get from acknowledgment and the third parameter is remaining energy ER of the receiver from the physical layer.

Table 1: Retransmission Mechanism in Adaptive S-MAC algorithm

Retransmission Re= 1 if SNR<Sth Bs>Bth ER>Eth 0 Else	(1)

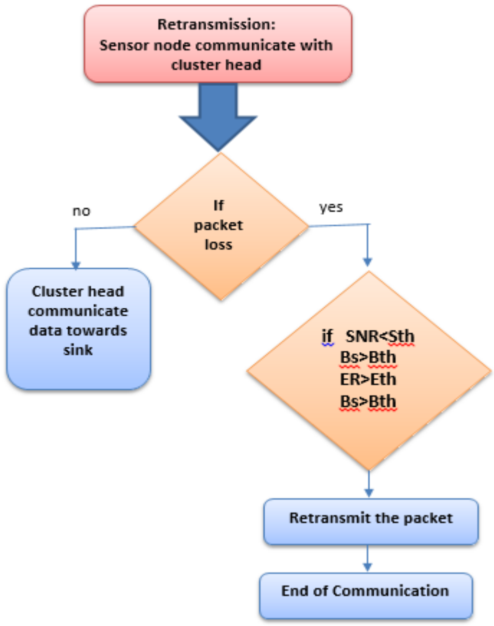

Figure 1: Retransmission Mechanism

C. *Sleep synchronization and Adaptive listening Mechanism*

It is found that sleep synchronization among nodes affects energy consumption [14]. Since the listening time in the MAC layer has influence in relay delay and delivery ratio. In addition to sleep synchronization dynamic adaptive listening that adjusts the listening schedule in keeping with the length and variation trend of the transmission, the queue is planned to scale back forward delay Based on synchronization theme and adaptive listening scheme,

a cross-layer route theme may be designed that utilizes the synchronization info and queue message to ascertain and update route.

S-MAC and adaptive S-MAC [14] weaken energy potency because of a distributed algorithmic program that forms multiple clusters and due to that border nodes hear multiple sleep schedule which lacks contact which different and which ends in severe sleep delay, therefore it's vital to take care of coordinated synchronization schedule among sleep nodes.

D. *Sleep Synchronization*

Sink node which acts like a coordinator, periodically broadcasts the sleep schedule to all the other nodes. The nodes only listen the sleep schedule and accordingly take decision.

At any point of time a node listens to multiple sleep schedule. Among all the sleep schedule received it accepts the sleep schedule of the one which has minimum depth and in the neighboring table it records the parent's node having depth lesser than itself. Otherwise the node just drops the received synchronization packet. Sleep synchronization helps in accelerating sleep schedule to the entire network, thereby reducing the cost incurred for idle listening and also minimizes the memory cost managing the large schedule table and neighbor table.

Here each node wakes up and listens to the communication channel periodically. And later goes to sleep mode for some time. The listening interval comprised of three different phases namely SY phase, R phase and S phase. SY phase is used to sending synchronization packet. R phase is used for receiving either the data packets or synchronization packet. And finally, the S phase is used for sending only data packets. The synchronization timing chart shows the overlapping of SY phase with R phase. R phase overlapping with S phase between neighbor nodes. The time sequences of stagger listening between nodes of another neighbor level is being constructed dynamically.

.

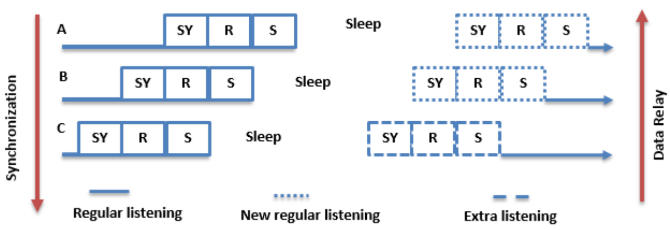

Figure 2: Synchronization Timing Chart

This approach uses relative timestamp for finding the nodes listening schedule similar to S-MAC. Instead of fixed time stamp, the time stamp in synchronization packet determines the time period left until the sender changes to sleep mode. The nodes that receive synchronization packet will adjust the sleep schedule based on the time stamp and transmission delay. This shows that the synchronization precision has a role to play in estimation of transmission delay, instead of the clock drift of each node.

E. *Dynamic Adaptive Listening*

WSN provides a lot of challenges in Sleep mode at MAC layer. This observation is for fixed listening interval. There are three major reason for having variable listening interval. Firstly, huge end – to – end delay is incurred due to bust traffic and secondly different listening interval is need for various WSN application to balance end to end latency. Third funneling effect of WSN. To solve the above issues dynamic and adaptive listening techniques are used. Listening schedule for adaptive listening consist of two stages. At the first level extended listening is used, where the node add an additional listening interval after any listening interval quickly when transmission queue is full. Empty queue information is obtained from network layer. The child node needs to inform parent node about changed listening schedule. In dynamic adaptive listening mechanism, node request the parent node for additional listening by sending ReqExt. Or by using ReqAdp to increase the duty cycle of regular listening. The parent node may deny the request to avoid buffer overflow. And may accept when extra listening and minimum duty cycle is available. The parent node agrees to extra listening with AckExt-T or use IncAdp-T. Figure 2 shows the duty cycle increase to maximum by node A and node B. and extra listening by node C. The dynamic adaptive listening is shown in Table 2.

Table 2: Dynamic Adaptive Listening in Adaptive S-MAC Algorithm

Transmission queue length= Tr_{ql}	
Listen interval = Li	
Extra listening interval= AvailableExt	
If Tr_{ql} !< 0 after listen interval	
Li + AvailableExt)	(2)
(if parent node permit extra listening)	
Else	
Parent node send negative acknowledgment	

F. *Sleep time Mechanism*

In our proposed method to reduce energy consumption at the MAC layer, info from physical layer is used.

First, for this, the parameter was recognized in the physical layer that could enhance the MAC protocol. The parameter was then went to the layer of the MAC. The sleep pattern is altered depending on the physical layer data. The nodes should be in sleep mode to decrease energy consumption unless they have some packets to send or obtain. According to data obtained from the physical layer, the issue of idle listening during the DATA span can therefore be prevented. Here the state of nodes like sending or receiving from the physical layer is provided to the MAC layer then the SYNC duration is increases otherwise it is reduced. SYNC duration shifts the node's duration of sleep and DATA. To change the SYNC period child node would ask the parent node for extra sleep time (ReqSLT). Then the parent node will broadcast this new schedule.

The overall flowchart of the energy efficient protocol using a cross-layer approach is shown in Figure 3.

V. PERFORMANCE ANALYSIS

The performance analysis using cross-layer design in heterogeneous WSN is carried out in Network Simulator 2. The simulation is performed with the following environment as shown in Table 3. The proposed algorithm Adaptive S-MAC (at network layer- EEFCLP routing) is compared with the existing, DSR-S-MAC and 802.11 -Static routing algorithms.

For performance analysis, the simulation metrics, Retransmission Energy Consumption for various channel and various Buffer State are measured and observed for comparison and also measured energy consumption versus transmitted power in different SYNC period.

The definition of the simulation metrics used are explained as follows:Retransmission Energy Consumption: It is measured as the energy consumed by the heterogeneous node in the WSN environment during the retransmission of packets

Buffer State: It is also important factor. If buffer state is higher, then number of packets for transmission are more

If SYNC period increases, it increases listen period and reduces the sleep time which consumes more energy of nodes.

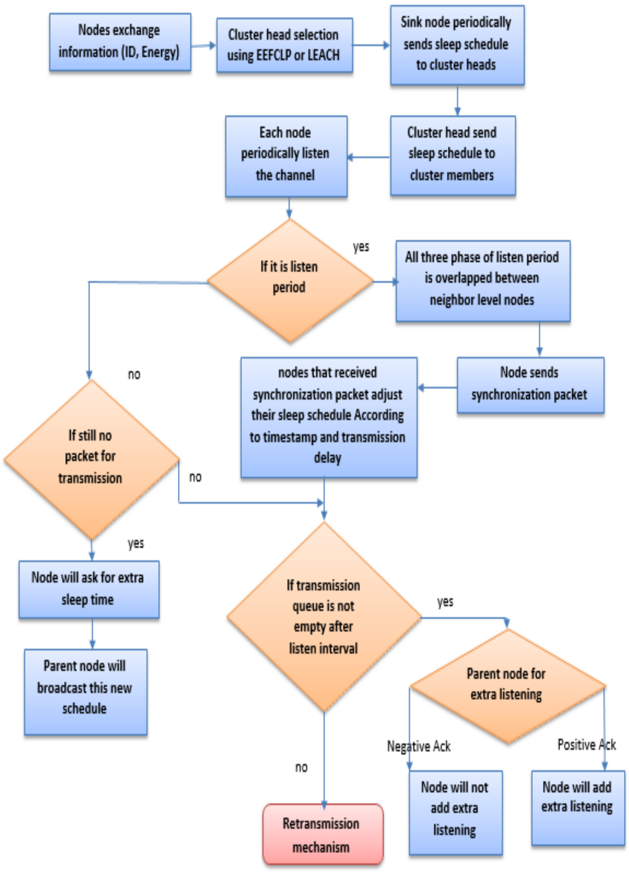

Figure 3: Flowchart of the energy optimized Adaptive S-MAC using a cross-layer approach

Table 3: Simulation Environment for Heterogeneous WSN with Cross-layer Design

Simulation Parameter	Simulation Value
Configuration Tool	Network simulator version 2.34
MAC layer protocol	Adaptive S-MAC
Network Layer protocol	EEFCLP (Multi-hop Routing Using Energy Efficient Fuzzy Based Cross Layer Protocol
Antenna	Omni Directional
Channel Propagation	Wireless / Two ray ground
Network Field	1500m x 1500m
Simulation metrics	Retransmission Energy Consumption, Overall energy consumption, Buffer State, SNR

The performance analysis is accomplished for the proposed algorithm Adaptive S-MAC and compared with other existing algorithms like DSR-S-MAC and 802.11 Static Routing in the HWSN environment. The simulation results are depicted as follows. In Figure 4 shows the energy consumption during retransmission is reduced by reducing number of packets for retransmission of the HWSN while at various channel. Adaptive S-MAC reduces packet loss in first attempt. The results show that energy consumption of the sensor node is reduced drastically while using Adaptive S-MAC algorithm. This significantly increases the overall network lifetime. In Figure 5, shows energy consumption in retransmission for different buffer state. DSR-SMAC and 802.11 are not having policy with respect to buffer state so these methods not gives best solution for saving energy in packet retransmission

In Figure 6 shows comparison between proposed Adaptive S-MAC, DSR-SMAC and 802.11 static routing using SYNC period. Here 10 cycles set to SYNC period. Proposed Adaptive SMAC changes listen period adaptively according to physical layer information. Due to that nodes sleeps for longer time and which improves lifetime of node.

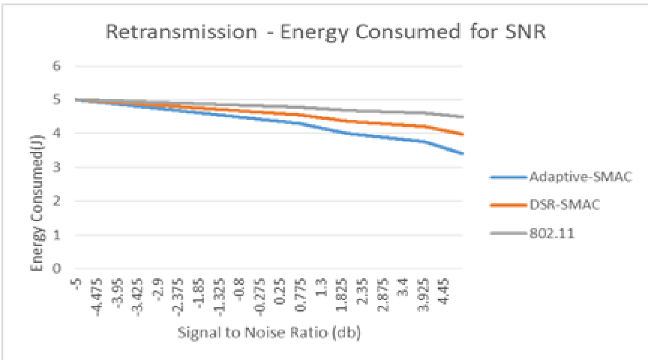

Figure 4 Retransmission energy consumption at various channel

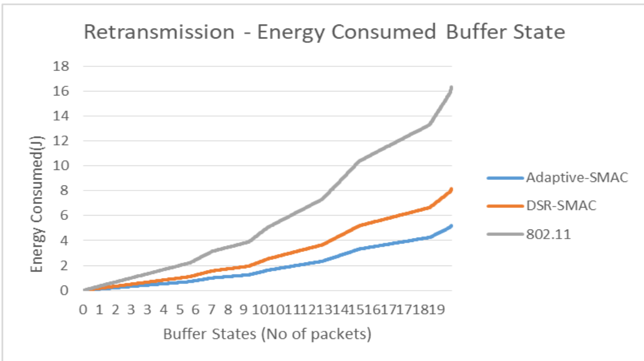

Figure 5. Retransmission energy consumption at various buffer state

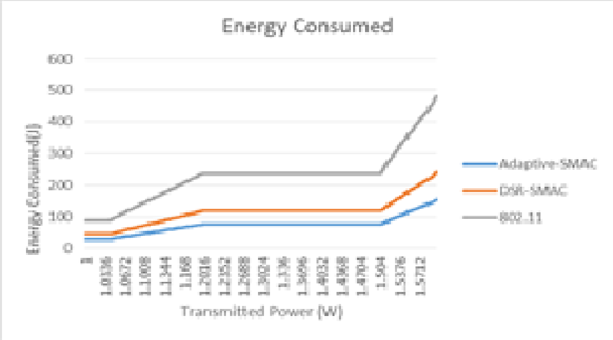

Figure 6. Comparison of proposed Adaptive S-MAC scheme, DSR-SMAC and 802.11 using SYNC period

VI. CONCLUSION AND FUTURE WORKS

Heterogeneous Wireless sensor networks meritoriously syndicate with the Cross-layer Medium Access Control design. The improved energy efficiency of the network will lead to dynamic applications scaling from Grid Computing, Sensor Web and Internet of Things (IoT) domains. The HWSN environment has got better performance with the cross-layer design using the proposed Adaptive S-MAC algorithm. In the proposed method, packet retransmission by reducing packet loss is addressed by considering buffer space, channel state and remaining energy. Then, the synchronization scheme for a global schedule is implemented by deliberating adaptive listening using the length of the transmission queue. Finally, sleep time issue is worked out to reduce energy consumption. From the simulation analysis with the metrics, Retransmission energy Consumption, Overall Energy consumption, it is shown that the proposed Adaptive S-MAC algorithm shows better results when compared with the other existing algorithms. As a future research work, the utilization of improved energy efficient HWSN sensor nodes in state of art real-time applications in the Internet of Things domain.

ACKNOWLEDGMENT

I would like to show my gratitude to the Dr. Srikanth Vemuru for sharing his pearls of knowledge with me during the course of this research, and I thank 3 “anonymous” reviewers for their so-called insights and their comments on an earlier version of the manuscript.

REFERENCES

1. Manisha R. Dhage, Srikanth Vemuru, "Routing Design Issues in Heterogeneous Wireless Sensor Network", International Journal of Electrical and Computer Engineering, vol. 8, no. 2, 2018
2. Zheng, J., Jamalipour, A.: ‘Wireless sensor networks: a networking perspective’ (Wiley Press, Hoboken, USA, 2009)
3. Alkhdour, T., Baroudi, U., Shakshuki, E., et al.: ‘An optimal cross layer scheduling for periodic WSN applications’, Proc. Int. Conf. Ambient Systems, Networks and Technologies, 2013, 19, pp. 88–97
4. Kumar, D.: ‘Performance analysis of energy efficient clustering protocols for maximising lifetime of wireless sensor networks', IET Wirel. Sensor Syst., 2014, 4, (1), pp. 9–16
5. 5 Han, C., Jornet, J.M., Fadel, E., et al.: ‘A cross-layer communication module for the internet of things’, Comput. Netw., 2013, 57, pp. 622–633
6. Al-Bzoor, M., Zhu, Y., Liu, J., et al.: ‘An adaptive power controlled routing protocol for underwater sensor network’, Int. J. Sensor Netw., 2015, 18, (4), pp. 238–249
7. P. Huang, L. Xiao, S. Soltani, M.W. Mutka, N. Xi, "The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey," IEEE Communications Surveys & Tutorials, vol. 15, no. 1, pp. 101-120, 2013.
8. V. Raghunathan, C. Schurgers, Sung Park and M. B. Srivastava, "Energy-aware wireless microsensor networks," in IEEE Signal Processing Magazine, vol. 19, no. 2, pp. 40-50, March 2002.
9. S. Park, W. Lee and D. Cho, "Fair Clustering for Energy Efficiency in a Cooperative Wireless Sensor Network," 2012 IEEE 75th Vehicular Technology Conference (VTC Spring), Yokohama, 2012, pp. 1-5.
10. Akkaya K and Younis M, “A Survey on Routing Protocols for Wireless Sensor Networks”, Elsevier Journal of Ad Hoc Networks, Vol. 3, No. 3, Pp. 325-349, 2005.
11. Xu, S. & Saadawi, T., “Does the IEEE 802.11 MAC protocol work well in multihop wireless ad hoc networks?” Comm. Mag., 39, 130-137, 2001.
12. Langendoen., T. D. A. K., "An adaptive energy-efficient MAC protocol for wireless sensors networks". In Proceedings of SenSys"03, 2003.
13. Kurtis Kredo, I., Mohapatra, P. “Medium access control in wireless sensor networks.”, Comput. Netw., 51, 961-994, 2007
14. S. D. Trapasiya and H. B. Soni, “Energy efficient policy selection in wireless sensor network using cross layer approach,” IET Wireless Sensor Systems, vol. 7, no. 6, pp. 191–197, 2017.
15. J. Shi and Y. Ma, “A dynamic cross-layer and energy-efficient protocol for wireless sensor networks,” in Computer Science and Network Technology (ICCSNT), 2016 5th International Conference on. IEEE, 2016, pp. 502–506.
16. A.M. Jacob, S. V. Rao, and S. S. Pillai, “Reducing energy consumption by cross layer design in wireless sensor networks,” in Control, Instrumentation, Communication and Computational Technologies (ICCICCT), 2016 International Conference on. IEEE, 2016, pp. 93–97.
17. Prajapati and S. D. Trapasiya, “Cross layer design approach for energy optimization in underwater acoustic sensor network,” in Recent Trends in Electronics, Information & Communication Technology (RTEICT), IEEE International Conference on. IEEE, 2016, pp. 1282–1286.
18. M. E. E. D. A. El, A. A. Youssif, A. Z. Ghalwash et al., “Energy aware and adaptive cross-layer scheme for video transmission over wireless sensor networks,” IEEE Sensors Journal, vol. 16, no. 21, pp. 7792–7802, 2016.
19. Samyaveer Singh, Aruna Malik, Rajeev Kumar, " Energy efficient heterogeneous DEEC protocol for enhancing lifetime in WSNs" Engineering Science and Technology, an International Journal, ISSN: 2215-0986, Vol: 20, Issue: 1, Page: 345-353 Publication Year:2017
20. GHAFFARI, A., “An Energy Efficient Routing Protocol for Wireless Sensor Networks using A-star Algorithm”. Journal of Applied Research and Technology, 12, 815-822, 2014
21. Nandini. S. Patil, Prof. P. R. Patil, "Data Aggregation in Wireless Sensor Network," IEEE International Conference on Computational Intelligence and Computing Research, 2010
22. FENGYUAN REN, J. Z., TAO HE, CHUANG LIN, SAJAL K. DAS, "EBRP: EnergyBalanced Routing Protocol for Data Gathering in Wireless Sensor Networks". IEEE Transactions on Parallel and Distributed Systems, 22, 2108-2125, December 2011
23. SCHEUERMANN, B., LOCHERT, C. & MAUVE, M., “Implicit hop-by-hop congestion control in wireless multihop networks”. Ad Hoc Netw. 6, 260-286, 2008.

AUTHORS PROFILE

Mrs M. R. Dhage received the BE Degree in Computer Science and Engineering from the Shivaji University , Maharashtra ,India, in 2000, and the ME Degree in Computer Science and Engineering from the Shivaji University, Maharastra, India, in 2008. She is currently pursuing PhD in the Department of Computer Science and Engineering at K.L. University Vijaywada, Andhara Pradesh , India . Her current research interests include energy conservation, clustering, routing algorithms and network survivability in wireless sensor networks

Dr. Srikanth Vemuru obtained his B.Tech and M.E degrees in Computer Science and Engineering from Madras University, Tamilnadu, India and PhD in Computer Science and Engineering from Nagarjuna University, India. Presently working as Professor & Dean- Skill Development Computer Science and Engineering, K.L. University,Vijaywada, Andhra Pradesh , India. His research interests are in the areas of energy conservation in Sensor Network, underwater sensor networks.