A Mathematical Framework for Optimizing the Routing Model for Quality of Service using Decision Based Path Formation in Cluster Based Wireless Sensor Network

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Abstract
A wireless sensor network contains plenty of distributed sensor nodes mainly deployed to sense and deliver the collected information towards the destination node. sensor nodes are have limited resources like minimum memory, less computation capability, short range transmission and unreplaceble batteries, hence maintaining a reasonable network lifetime with better packet transmission rate for certain guarantee of Quality of Service is highly challenging. Currently, hierarchal routing schemes are widely used to face the design challenges to provide better efficiency for routing the packets and network lifetime enhancement using different routing approaches. However, hierarchical routing algorithms focus more on clustering of the nodes and routing for network lifetime and Quality of Service. In this work, author introduced different hierarchal routing algorithms with respect to quality of service. The proposed decision based routing scheme offers desired network performance followed by better results over existing state of routing protocol. Decision based routing algorithms computes the optimal path among the cluster heads which are used to transmit the data. This new routing approach consider the distance from the particular cluster head where data is originated to the base station, neighbor cluster head to base station, residual energy of current round. We compute the decision value of all the eligible cluster heads. The largest decision value node is selected as the next hop for packet transmission. The comparative results shows that the proposed decision based approach gives better performance in terms of packet delivery ratio, end to end delay, throughput and other QoS Parameter.

Keywords: Decision Based routing, hierarchal routing algorithms , QoS, clustering

Introduction

The wireless sensor nodes are deployed to sense analog parameters in an environment. Generally these nodes deployed in remote locations to measure the analog data. The sensed analog data need to be converted to digital and process it further, handled efficiently to improve the network performance and to assure Quality of service, therefore there is a need for data routing algorithms. Transmitting redundant data to the destination node leads to waste of resources, therefore data aggregation techniques are applied across the network. The routing functions determine the best path from source(s) to destination(d) which in turn reduces the traffic, congestion, and packet loss. Energy-aware routing schemes, cluster based routing, multipath routing are some of the major approach used in improving the network lifetime and QoS. Direct transmission of packet from source node to base station consumes more energy. Mainly in flat routing, each node has capability to collect, process and transmit the data whereas in hierarchical, nodes are arranged in a hierarchal manner according to their capacity of data processing. Several researches have proved that the hierarchal routing achieves better performance, in terms of, improved network lifetime and network performance.

The heterogeneous WSN consists of sensor nodes at different levels namely normal sensor nodes (n), advanced sensor nodes (Ad), and super sensor nodes (ss). The n nodes generally sense their surroundings and transmit the data to the cluster head node which is an advanced node. The load balancing is an important in WSN which keeps network more stable and operable effectively and for longer duration. The cluster head nodes like advanced node collect the data and applies the data aggregation function for removing the redundant data and duplicate data. The data will be forwarded to destination (base station) from cluster head via efficient routing path to meet the QoS parameter. Various routing algorithms have been used to route the data from S to D but each of them could not dealt with the network issues like distance between cluster heads and cluster head and base station , residual energy of cluster head nodes both sender and receiver. For clustering the network issues like residual energy of nodes and distance and average distance are used and threshold value is calculated for every eligible nodes which are the subsets of network. The node which has highest threshold value will be the cluster head for particular round in WSN.

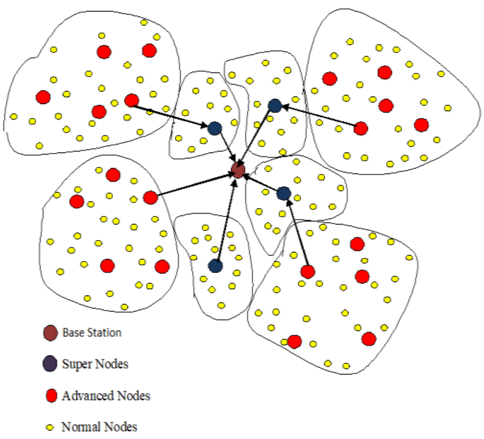

Figure: Heterogeneous WSN

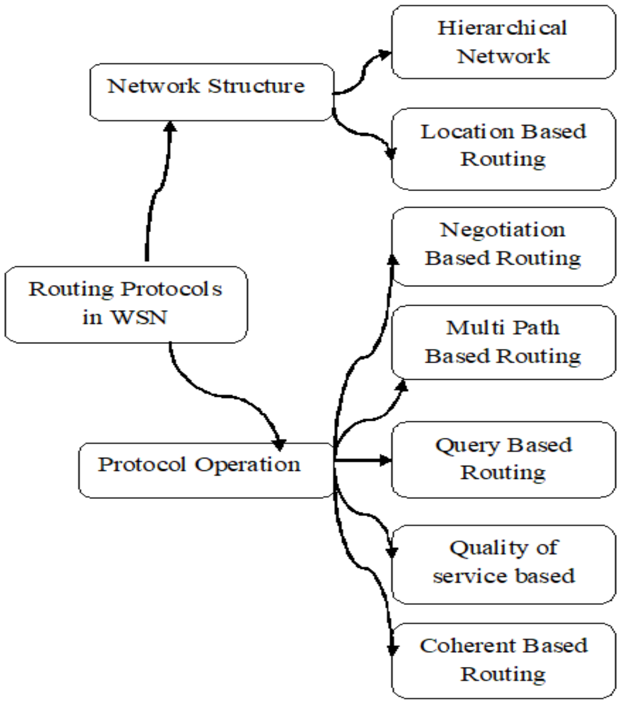

Figure 2.2: Classification of routing protocols in WSN

Routing protocols are classified based on network topology and protocol operation is shown in Figure 2.2. Several researches on clustering in wireless sensor networks have been done from various perspectives. Clustering is a method of forming the head node to report the sensed data by a set of nodes, also clustering offers the communication path that can be used by the sensors to report the event to the base station. Each cluster with a specific node which is called cluster head will coordinate with other cluster head for data transmission. Packets will be transmitted from a lower clustered layer to a higher cluster layer.

1.1. Hierarchical routing protocols

Clustering is a shape of routing to gather the sensed information from a nodes in a selected sector of a WSN, several studies were carried out primarily based on node clustering mechanisms and routing tactics which includes solid election protocol, Hybrid energy efficient distributed computing Protocol, disbursed strength efficient clustering (DEEC), Low power adaptive cluster hierarchical (LEACH) and advanced Leach. SEP is an advancement of LEACH. In SEP the nodes stage used are "normal" and "superior" nodes. The superior nodes play the role of as cluster head and normal node is handled as cluster member node. This protocol in particular complements the life of WSN through effective usage of heterogeneous nodes [6].

In HEED protocol, CHs are decided on primarily based on the quantity of power available and node density. The node with highest residual strength maybe selected to ahead the statistics in a multi-hop fashion [7]. In DEEC protocol, it overcomes the choice of CHs which can be probabilistic based process through making sure that a favored quantity of CHs are decided on in step with spherical [8].

These clustering techniques have numerous advantages together with removal of redundant data, minimization of bandwidth consumption by way of averting the redundant message exchange, growing the lifetime, decreased network overhead, and fewer entries in routing table. However, no matter of several advantages, those schemes suffer from numerous challenges in the WSN inclusive of greatest variety of clusters and Cluster Head choice. Clustering overhead for cell node, packet drop and network congestion and many others. for this reason, the existing clustering schemes need to be progressed for better performance of network.

1.2. Work contribution

In this article, author focus on developing an decision based routing algorithm which can choose the appropriate cluster head followed by next level cluster heads as the next hop for data transmission based on the energy left over, distance between cluster heads, distance between cluster heads and base station and also average energy of the network. The main aim of this work is to calculate the energy and distance parameter to route the data towards the destination to improve the reliability of the data transmition with less redundant data in a network and better network performance in terms QoS.

Organization

This article is arranged in following sections as: section II presents a various model used in hierarchal routing and quality of service issues, section III presents the solution for achieving the better network performance through routing and clustering techniques, section IV consists of the relative analysis of the proposed model over existing techniques and lastly, section V presents the concluding remarks and future scope and work in this research direction.

2. Proposed model

In this section, we optimize the different quality of service parameter against state of art routing algorithms used for quality of service in WSN. Various algorithms are proposed to describe the behavior of WSN with respect quality of service parameter. The main aim of this work is to analyze the algorithm of the different QoS parameter like end to end delay, throughput, packet delivery ratio, etc. First of all, we present the decision based routing algorithm for the hierarchical WSN and other algorithms applied for different QoS parameter.

2.1 Network model

Let us consider a sensor network where $\boldsymbol{N}$ numbers of sensor nodes are deployed deterministically in a 2D geographical region of radius r. In this WSN, subsets of heterogeneous sensor nodes (S^1) are deployed with direct communication to base station and also these nodes will perform the role of cluster heads to relay the data received from the nodes to the base station. Further the cluster head from the set of advanced nodes (AD^1) also selected based on the calculated threshold value for every round, if threshold value of the nodes are similar then they apply probability function to select the cluster head node and the node which is cluster head for current round will not participate in cluster head selection for next r rounds. These communications are performed, if the two communicating nodes are within the in the data transmission range.

For the reason that redundant data of the WSN which can be removed through unique aggregation nodes or cluster nodes, earlier than sending it to a sink node. The quantity of non redundant data that a network generates grows as O(logN), assuming that the network is sampling a physical observable statistics with a common accuracy requirement[4].

The community model for the wireless sensor community as graph G= {V, E, Pv, PE}. V and E denote vertices and edges of the network graph. Pv properties(set of functions that symbolize) of every node, along with its region, computational functionality, sensing modality, sensor output type, P_E specifies channel capacity, bandwidth, and quality.

2.2 Energy consumption

In this paper, we considered free space (fs) and multi route (mp) fading channels based totally on the space between transmitter and receiver in WSN. in step with the quantity of nodes (network density), the edge distance (d_0) is taken into consideration, if the distance among nodes is less than the given threshold distance then we follow free-space model (f_s) in any other case multipath model is used.

2.3.3 Energy consumption model

Consider that E_{elec} is the electronic circuit and amplifier energy in free space model ϵ_{fs} and multipath (mp)models respectively. Based on this hypothesis, the desired strength with the aid of radio to transmit the L bit message over a distance d is given as:

$$E_t(l,d) = \begin{cases} lE_{elec} + l\epsilon_{fs}d^2, & for\ d < d_0 \\ lE_{elec} + l\epsilon_{mp}d^4, & for\ d \geq d_0 \end{cases}$$

Likewise, the energy consumption by radio while receiving l −bit message will be calculated as:

$$E_R(l) = lE_{elec}$$

The energy consumption parameter E_{elec}depends on various factors which include modulation scheme, encoding version, filtering and signal spreading, the amplifier electricity is given as

$\frac{\epsilon_{fs}d^2}{\epsilon_{mp}d^4}$ depends on the distance between transmitter and receiver.

3. QoS Algorithm Description

Various QoS parameter with respect to routing of the packets from source to destination based on the effective utilization of the resources by finding optimal path from source to destination are proposed.

Algorithm for Cluster-Formation (G):

Input: G, Where G is a set of nodes in a WSN.

R<- number of rounds

P_i<-probability of the node to become CH (Auto read)

Output: Cluster Head(CH) is selected based on threshold value $T(S_i)$

Step1: Initialize the 2 random number between 0 and 1 to all the Advance nodes

for i<-1 to n

$T(S_i)$:= 0 to 1

Step2: Read probability & r (rounds) of each neighbor nodes in the network

Step3: Compute W_i (Weightage parameter)

$$W_b = A\frac{E_i(r)}{\bar{E}(r)} + B\left(1 - \exp\left(-\frac{d_{avg}}{d(i)}\right)\right)$$

Step4: Calculate threshold value for each CH node in the network.

$$T(s_i) = \begin{cases} \frac{W_b p_i}{1-p_i\left(r\, mod \frac{1}{p_i}\right)}, if\ s_i \in G \\ 0, otherwise \end{cases}$$

Compare threshold value of each node, find max threshold node & assign it as Cluster Head node (Having more energy and short distance to destination node comparative to another node in the cluster)

Step5: stop

The algorithm computes the value of W_b for each node during r rounds. Generally the node which has higher W_b gets the chance to become the cluster head as per the formula shown in the algorithm. The lower value of W_b consists of the values of the nodes which are farthest away from the Base station, also the battery level of the node is considered [31].

Algorithm for Decision Based Routing ( ):

Aim: to establish the path from source node to destination node with QoS in view.

Input: Source address, Destination Address

Output: Packet routed from Source S to

destination D after establishing the path from S to D.

Step1: Initialize Source node with the packet need to send to receiver.

Step2: Generate query packet & transmit it to all the adjacent nodes, so as to form DAG. Update packet is received from destination node.

Step3: Find and assign CH(cluster head) by the decision function as given below.

For i=1 to G

$$W_n(i) = \frac{E_{res}(j)}{E_{res}(i)} + \frac{2 \times d\ (ch_i, bs)}{d(ch_i, ch_j) + d(ch_j, bs)}$$

If $W_i > W_{i+1}$, then W_i is assigned as a cluster head ∀ i Є n

Step4: find the next desired hop so as to reach destination.

Step5: repeat step3 and step4 until destination node found or else host the message that the destination is not found.

Step6: Transmit the packets from S to D.

The calculated decision function requires the values like, twice the distance between cluster head and base station, cluster head and next level cluster head (next hop), cluster head to base station also the residual energy of the node and its neighbour nodes. To find the optimal path the node which has highest decision function value will be the next hop for data transmission from source to destination node.

The algorithm computes the QoS parameters like packet delivery ratio, which is the delivery of amount of data successful transmitted in a given period of time from source to destination. End to end delay is one of the more useful parameter to measure the overall network performance. As higher the bandwidth lowers the congestion and delay from source to destination. The throughput is used to measure percentage of data being transmitted successfully as shown in the algorithm. There is dependency between the QoS parameter such as delay, queue size, congestion, throughput, packet delivery ration.

3.1 Heterogeneous WSN Mathematical Model

Mathematical models help to understand the complex situations into simplest and effective way of representing the phenomena through mathematical derivations and equations. Generally modeling process involves understanding the problem, choosing variables, making assumptions, fixing the equations, deciphering the answer, validating the version, and criticizing and enhancing the model. In this section, the algorithms are proposed are described using mathematical equations which enhance interpretation of the solution against the problem definition. The proposed algorithm illustrates the behavior of WSN with respect quality of service parameter. The objective of mathematical Model is to describe the various Quality of Service parameter while ensuring the better stability of the network for the amounts of energy used, increase of packet delivery ratio, end to end delay. The notation is as follows.

i, j, k	indices of node (I, J, K = 1, 2,.. ., n)
n	All the nodes of the network
N	number of normal nodes ($i, j, k \in N$)
N_a	Number of advanced nodes
N_s	Number of super nodes
s	source node indexes
s_k	sink node
c	Number of clusters
Parameters 1. Distance	
d_{ij}	distance from node i to node j, for all i, j∈ N
d_{max}	maximum distance between the nodes
2. Energy	
e_i	initial energy of node i, for all i ∈ n ($E_i > 0$)
E_w	Constant energy consumption during wakeup of the nodes
E_t	Transmission energy
Decision variables	
X_{ij}	1, if node i and j are linked; 0, otherwise, for all $i, j \in N$
E_i	energy of node i, for all $i \in N$
d(th)	threshold distance between normal nodes

3.1.1 CLUSTER HEAD SELECTION MODEL

The cluster head node can be decided based on the obtained threshold value. A sensor sends out radio signals if you want to connect to different nodes. However, the distance of a radio signal varies between different nodes in case of heterogeneous WSN. Because sensors are self-organized, additionally they have electricity obstacles. Therefore, every sensor is on standby inside the sleep mode, idle mode, which makes it feasible to minimize energy consumption. When an event occurs, the sensor enters the wake-up mode and gets information. Then, it searches for different sensors with the purpose of sending data to the base station (sink node) (Fig. 1).

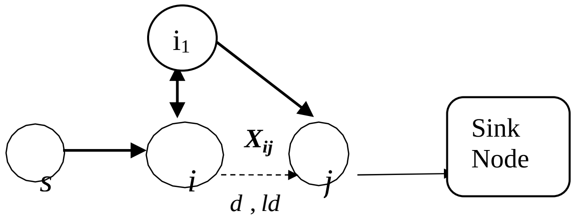

Fig 1: Schematic diagram of WSN.

WSN models have several requirements. There are several sensor nodes and a sink node (a base station). The source sensor must reach the sink node. It is assume that the location of the sink does not change the entire duration of the process of collecting data from the sensor nodes also assume that sensor nodes are aware of their geographical coordinates in the field.

Every sensor has resource constraints (in regards to strength and distance), and the sink node has no electricity constraints. In Fig 1 , we schematize the notation used in the mathematical modeling.

WSN Model is formulated as integer linear program:

Avg=$\sum_{i\in n,}^{n} E_i$ average residual energy of all the nodes for all i ∈ N

N(i)= E(i)>z.Avg for all i ∈ N , z is a variable coefficient of Average energy

Subjected to

$$T_S = \frac{W_b p_i}{1 - p_i\left(r \bmod \frac{1}{p_i}\right)}, \text{if} s_i \epsilon G ------(1)$$

Where

$$W_b = a\,\frac{E_R}{A_E} + b\left(1 - \exp\left(-\frac{d_{istavg}}{d(i)}\right)\right) \text{---------------------} (2)$$

Here, a and b are the two constant which are ranging from 0 to 1, the sum of a and b is 1, d_{istavg}denotes the distance between CH and BS, E_R denotes the remaining energy of node in r^{th} round and A_E is the average energy in r^{th} round.

G(i)=Max ((T_S)) for all i ∈ G, G *is* $a \cap N$

Let d(ij)>= *d(th)*

Ch(i)= G(i(Ts)) > G(j(Ts)) for all $i, j \in G$

Ch(j)= G(j(Ts)) > G(k(Ts)) for all *j,k neighbor nodes* ∈ G,

$Ch(i) \in C$ C is a number of clusters, i=0,1…C

S_{ch}=Max $\{E_i\} \in Ch$ forr all $i \in N$, *S_{ch} is a Secondary CH*

$C(S_{ch}) = E(Ch(i)) < E(S_{ch}(i))$

3.1.2 THE ROUTING MODEL

A novel mathematical framework is proposed for analyzing routing protocols. The aim is to get a mathematical formula that consists of finding a relation between the distance, energy and number of hops from the source to the destination. The mathematical terms are as follows:

• d is the distance between the consecutive nodes i, i+1

• E is the residual energy at time t of the round r.

Nodes, cluster head uses the threshold distance to distinguish that whether cluster head is near or far from the base station. It can be expressed as:

$$d_h = \beta d_0$$

It is concluded that if the d_h is larger than d_0 then multi-path model is used.

The routing path selection based on the decision function calculated by the cluster head nodes. Moreover, the cluster head nodes decision value is includes how to find the optimal path from the cluster head to base station and as follows.

$$\mathrm{W_n(i)} = \frac{E_{\mathrm{R}}(\mathrm{j})}{E_{\mathrm{R}}(\mathrm{i})} + \frac{2 \times D_{\mathrm{ist}}(\mathrm{ch_i}, \mathrm{bs})}{D_{\mathrm{ist}}(\mathrm{ch_i}, \mathrm{ch_j}) + D_{\mathrm{ist}}(\mathrm{ch_j}, \mathrm{bs})}$$

From the above equation, an ideal state model for more accurate calculating probability of cluster heads and determining routing path between the cluster head for packet transmission. Where $D_{\mathrm{ist}}(\mathrm{ch_i}, \mathrm{bs})$denotes distance between cluster head and base station, $D_{\mathrm{ist}}(\mathrm{ch_i}, \mathrm{ch_j})$ is the distance among ch_i and ch_j. During the first phase of communication, the CHs broadcast their own packet which incorporates statistics as node id, residual electricity and node distance from base station.

Initially, we measure the distance among cluster head and base station as d(ch_i,bs). If this distance is more than the threshold distance, then we use multi-hop routing. Here, we use the proposed decision function to find its value and consider the values of two neighboring cluster heads to make out the path selection. The cluster head with biggest cost is chosen as next-hop to transmit the packet similarly. On the other hand, if value of $\mathrm{d}(\mathrm{ch_i}, \mathrm{bs})$ is less than the threshold, then cluster head can communicate directly to the base station.

Routing

$\sum_{\substack{i \in c, \\ i \neq j}} Ch_{(i)} + \sum_{\substack{j \in c, \\ j \neq k}} Ch_{(j)} = 1$ for all i,j $\in N$ -------*(3)*

*Throughput = (packetsize * Rec * 8) / ((t2-t1)*1000)*

Total flow from node *i* to node *j* except in the case of the source node *s* and sink *bs*.

Let t1 be the send time of first packet by Ch(i), t2 be the send time of last packet by Ch(i)

$$Avg = \sum_{\substack{i \in ch, \\ i=0,n-1}} p_{(i)} \quad p_{(i)} \longrightarrow \text{Total Packet sequence number count}$$

$$Total\_delay = \sum_{\substack{i \in ch, \\ i=0,n-1}} p(t2 - t1)_{(i)}$$

$$Avg\_delay = Total\_delay \, / \, Avg$$

Subjected to

$$W_n(i) = \frac{E_R(j)}{E_R(i)} + \frac{2 \times D_{ist}(ch_i, bs)}{D_{ist}(ch_i, ch_j) + D_{ist}(ch_j, bs)}$$

$Ch_{ij}=1$, $Ch_{jk} = 1$, 1, if node *i* ,*j* and j, k are linked; 0, otherwise, for all *i*, *j*, *k* $\in G$- (4)

Constraint (4) eliminates sub paths.

$\sum_{\substack{s \in c \\ i \neq bs \\ i \in c}} Ch_{si} =1$ -- (5)

$\sum_{\substack{j \in c \\ j \neq bs}} Ch_{jk} =1$ -------- -- (6)

$\sum_{\substack{k \in c \\ k \neq bs}} Ch_{kbs} =1$ -------- -- (7)

Constraints of (5) (6) & (7) there must be flow out of source node *s* and into sink *bs*.

Max =Ch(j(Wn)) > Ch(k(Wn)) for all j, k ∈ C… $W_n(i)$ is a decision variable-----(8)

Ch(i) =Ch(i)+ Max for all i ∈ G ---------(9) Constraint(9) Add the path Max

$E_i = e_i + E_w \, . \sum_{\substack{j \in n, \\ i \neq j}} Ch_{in} + E_t \, . \sum_{\substack{j \in n, \\ i \neq j}} d_{ij} . Ch_{ij}$ ------------- (10)

Equation (10) the remaining energy of a node is equal to the initial energy minus the wake-up energy and the transmission energy associated with the linked nodes.

$\text{Min} \sum_{\substack{i \in n, \\ i \neq n}}^{n} e_i - \sum_{\substack{i \in n \\ i \neq n}}^{n} E_i$ --- (11)

Energy consumption is subjected to

$\sum_{\substack{i \in n, \\ i \neq k}} Ch_{ik} - \sum_{\substack{j \in n \\ j \neq k}} Ch_{jk} =0$ all k ∈ $G, k \neq s, k \neq n,$ ----- (12)

Constraint of (12) is the flow conservation constraint, which is the total flow from node i to node k is same as the total flow from node k to node j except the flow from the source node s and sink node n.

4. Results

This section describes the final results of proposed algorithms based on hierarchal routing schemes for the hierarchical WSN.

Simulation

In this ns-2 simulation, WSN is deployed with the varied range of node from a hundred to 400. Proposed method achieves better performance for every community state of affairs whilst as compared with country-of-artwork strategies. in this test, we received better result via comparing the alternative most widely used algorithms of WSN along with HEED, LEACH, and EQMR as proven in the graph.

Figure 1 illustrates the comparative evaluation in terms of network lifetime where we have measured the dead node rate with the aid of figuring out the rounds of dead node counts. The received overall performance is compared with LEACH [20], HEED [21], and EQMR [22] for distinctive variety of nodes.

In figure 2, we measured the overall performance in phrases of packet delivery ratio against the full range of packets dispatched from source to destination. The acquired overall performance is compared with LEACH [20], HEED [21], EQMR [22] for various number of nodes. Followed by various figures each one compares the Quality of service parameter.

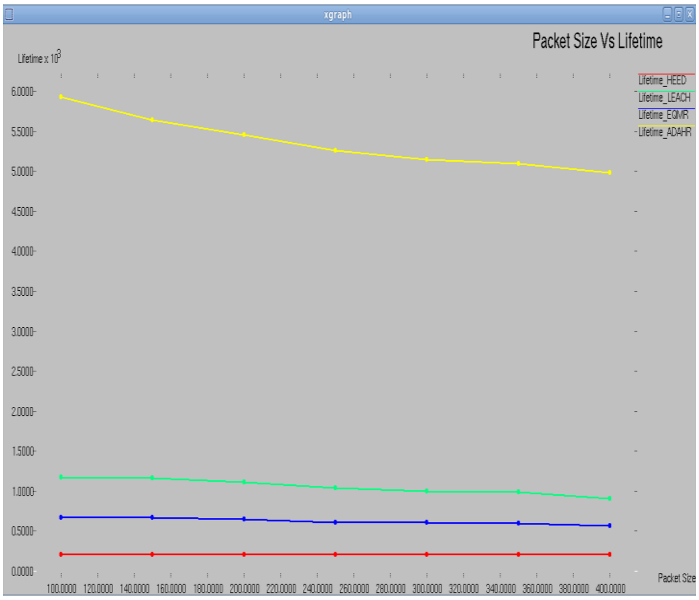

Fig.1. Network Life time

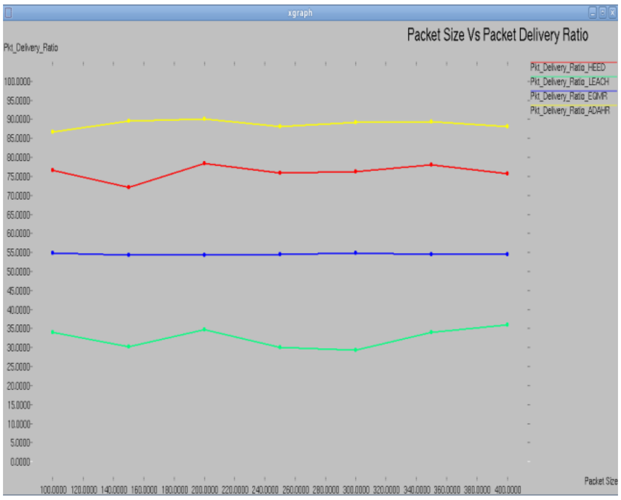

Fig.2. Packet delivery ratio

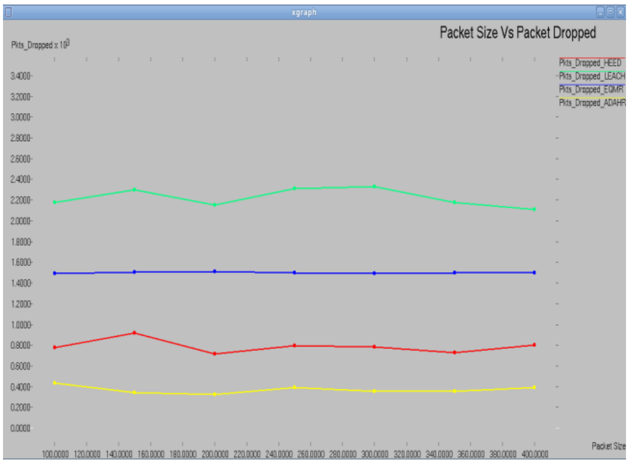

Fig.3. Number of packets dropped

In figure 3, due to various reasons like congestion, bandwidth, and buffer overflow the packets may get dropped while transmitting it. The applied algorithms reduce number of packets dropped with the applied mechanism as a result we are able obtain better network performance. The obtained performance is compared with LEACH [20], HEED [21], and EQMR [22] for varied number of nodes.

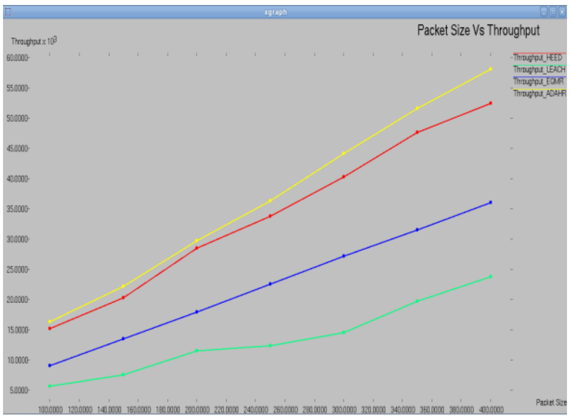

Fig.4. Throughput comparison

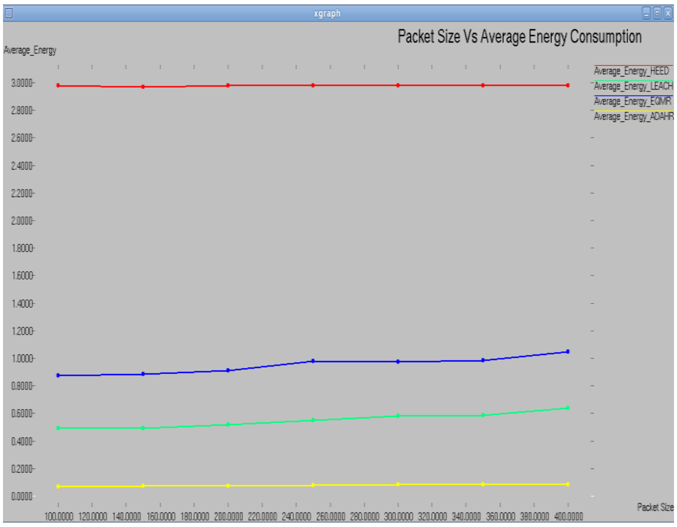

Fig.5. Average energy consumption

In figure 4, 5, 6 we have used the number of node from 100 to 400 the results like number of packets drops, percentage of throughput and energy consumption has been analyzed respectively to achieve the desired network performance. These algorithms are based on the clustering mechanism and routing from source cluster head to destination node. As the number of rounds and nodes are increasing, the simulation results (NS-2) shows the better results.

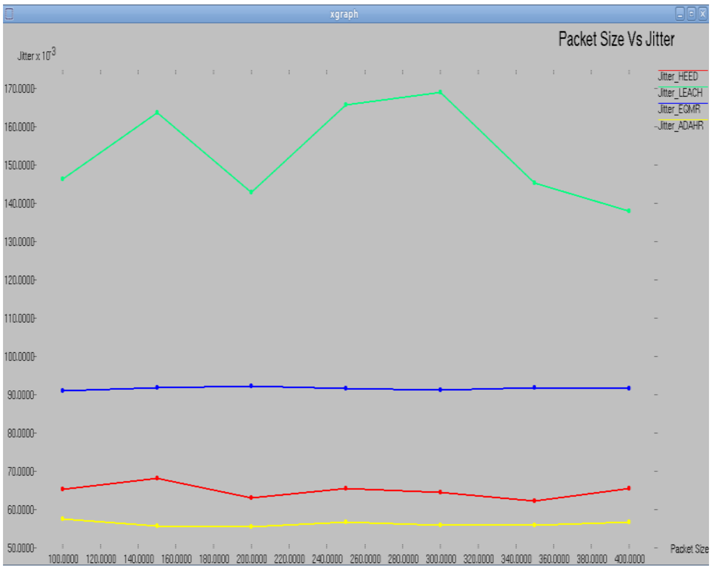

Fig.6. Jitter comparison

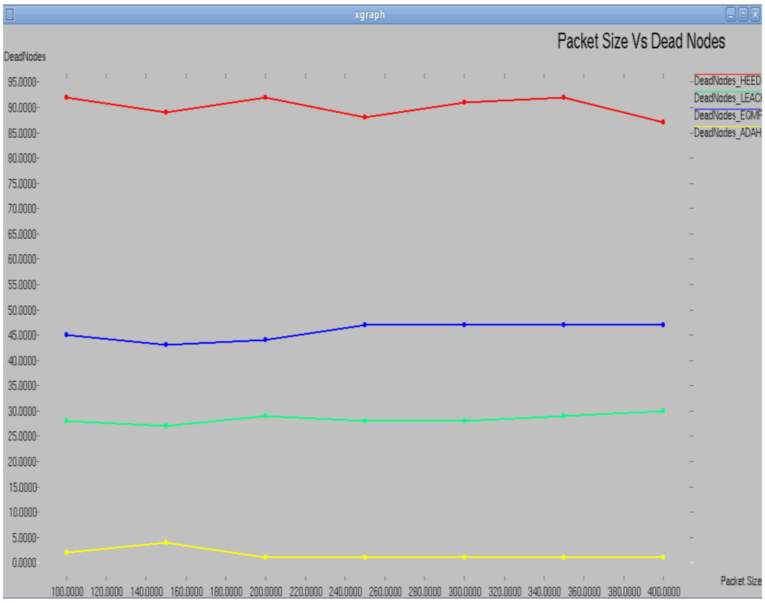

Fig.7. Dead nodes

According to this experiment, we have proved that proposed approach prolongs the network lifetime because in this approach, the less number of dead node is identified on particular simulation time and last dead node is obtained at the maximum simulation time (network lifetime) which is higher than the existing approaches. The number of alive nodes at a simulation time for 100 numbers of nodes as shown in figure 8.

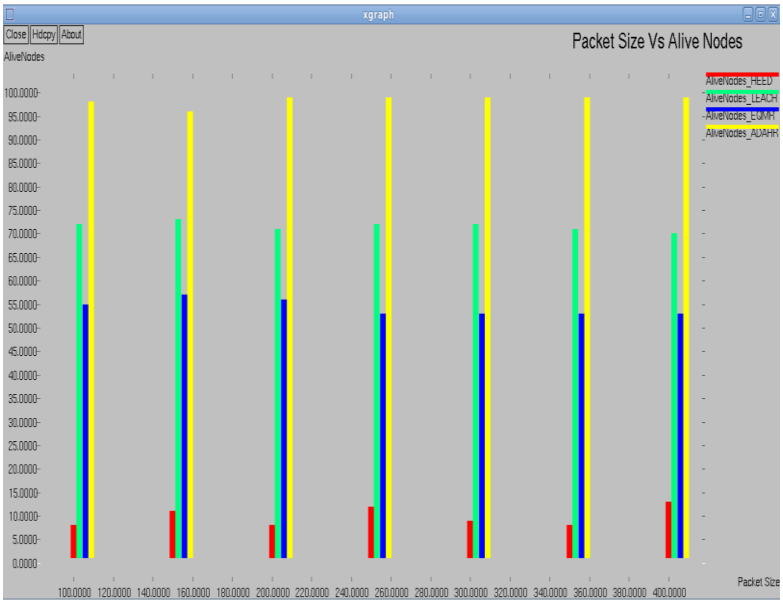

Fig.8. Alive Nodes comparison

5. Conclusion

In this article, author discusses the different node parameter on improvement of a performance of wireless sensor network in terms of energy efficiency and Quality of Service. The clustering and hierarchal routing is used to gain the favored performance in WSN. several routing protocol were studied in the past based totally on hierarchal routing but those strategies do no longer comprise the distance, power, average power and many others. Due to congestion issue and delay nodes will drop the packets which affect the network performance and overall QoS. In order to deal with these issues, author used the hierarchal routing approach which calculates a newly designed routing path based on the decision function. The performance of routing scheme and various algorithms which are presented is compared with the advance routing algorithms. The comparative analysis validates that the proposed approach for better QoS and desired WSN performance.

References

1. Radi, M., Dezfouli, B., Bakar, K. A., & Lee, M. (2012). Multipath routing in wireless sensor networks: Survey and research challenges. Sensors, 12(1), 650–685. 5.
2. Rachedi, A., Rehmani, M. H., Cherkaoui, S., & Rodrigues, J. J. (2016). The plethora of research in Internet of Things (IoT). IEEE Access, 4, 9575–9579.
3. Dubey, T., & Sahu, O. P. (2013). Self-localized packet forwarding in wireless sensor networks. Journal of Information Processing Systems, 9(3), 477–488.
4. Elsmany, E. F. A., Omar, M. A., Wan, T. C., &Altahir, A. A. (2019). EESRA: energy efficient scalable routing algorithm for wireless sensor networks. IEEE Access, 7, 96974-96983.
5. Singh, S. K., Kumar, P., & Singh, J. P. (2017). A survey on successors of LEACH protocol. Ieee Access, 5, 4298-4328.
6. Fang, W., Wen, X., Xu, J., & Zhu, J. (2019). CSDA: a novel cluster-based secure data aggregation scheme for WSNs. Cluster Computing, 22(3), 5233-5244.
7. O. Younis and S. Fahmy, "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks", IEEE Trans. Mobile Comput., vol. 3, no. 4, (2004), pp. 366–379.
8. Qing, Q. Zhu and M. Wang, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks", Computer communications, vol. 29, no. 12
9. F. Xiangning and S. Yulin, "Improvement on LEACH protocol of wireless sensor network", Proceedings of International Conference on Sensor Technologies and Applications (Sensor Comm), (2007), pp. 260–264,
10. Hu, S., Liu, L., Fang, L., Zhou, F., & Ye, R. (2019). A Novel Energy-Efficient and Privacy-Preserving Data Aggregation for WSNs. *IEEE Access*, *8*, 802-813.
11. Latha, A., Prasanna, S., Hemalatha, S., &Sivakumar, B. (2019). A harmonized trust assisted energy efficient data aggregation scheme for distributed sensor networks. Cognitive Systems Research, 56, 14-22.
12. Lakshmi, V. S., & Deepthi, P. P. (2019). A secure channel code-based scheme for privacy preserving data aggregation in wireless sensor networks. International Journal of Communication Systems, 32(1), e3832.
13. Guleria, K., &Verma, A. K. (2019). Comprehensive review for energy efficient hierarchical routing protocols on wireless sensor networks. Wireless Networks, 25(3), 1159-1183.

14. Nagesh.R., Dr Sarika Raga., & Shakti Mishra. “Elimination Of Redundant Data to Enhance Wireless Sensor Network Performance using Multi Level Data Aggregation Technique”. 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT)-2019.
15. Dr Sarika Raga. “An Anchor Based Data Conduction Algorithm For Improving Lifetime Ratio Of WSN”. International Journal Of Computer Applications -2017, VOL 170,NO-10.
16. Zhao, Z., Shi, D., Hui, G., & Zhang, X. (2019). An energy-optimization clustering routing protocol based on dynamic hierarchical clustering in 3D WSNs. IEEE Access, 7, 80159-80173.
17. Harb, H., Makhoul, A., Laiymani, D., &Jaber, A. (2017). A distance-based data aggregation technique for periodic sensor networks. ACM Transactions on Sensor Networks (TOSN), 13(4), 1-40.
18. Fang, W., Wen, X., Xu, J., & Zhu, J. (2019). CSDA: a novel cluster-based secure data aggregation scheme for WSNs. Cluster Computing, 22(3), 5233-5244.
19. . Kakhandki, A. L., Hublikar, S., et al. (2018). Energy efcient selective hop selection optimization to maximize lifetime of wireless sensor network. Alexandria Engineering Journal, 57(2), 711–718. 19.
20. Deepa, O., & Suguna, J. (2017) An optimized QoS-based clustering with multipath routing protocol for wireless sensor networks. Journal of King Saud University-Computer and Information Sciences. 20.
21. Hammoudeh, M., & Newman, R. (2015). Adaptive routing in wireless sensor networks: QoS optimisation for enhanced application performance. Information Fusion, 22, 3–15. 21.
22. Dr Sarika Raga. “Energy Efficient MANET based Emergency Communication Module for Post Disaster Recovery”. International Journal of Ethics in Engineering & Management Education -2014.
23. Nagesh.R., Dr Sarika Raga., & Shakti Mishra. “Design of an Energy efficient Routing Protocol using Adaptive PSO Technique in wireless sensor Networks”. Springer ICERECT-2018. LNEE, volume 5, 1039-1053.
24. Razzaque, M. A., Ahmed, M. H. U., Hong, C. S., & Lee, S. (2014). Qos-aware distributed adaptive cooperative routing in wireless sensor networks. Ad Hoc Networks, 19, 28–42. 22.
25. Sun, X., Chen, H., Wu, X., Yin, X., & Song, W. (2016). Opportunistic communications based on distributed width-controllable braided multipath routing in wireless sensor networks. Ad Hoc Networks, 36, 349–367. 23.
26. Dr Sarika Raga. “An Active Trust:Secure and Trustable Routing in Wireless Sensor Network”. IJERT-2017.
27. Heinzelman, W. R., Kulik, J., & Balakrishnan, H. (1999). Adaptive protocols for information dissemination in wireless sensor networks. In Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking (pp. 174–185). ACM 24.

28. Intanagonwiwat, C., Govindan, R., & Estrin, D. (2000) Directed difusion: A scalable and robust communication paradigm for sensor networks. In Proceedings of the 6th annual international conference on Mobile computing and networking (pp. 56–67). ACM 25.
29. Heinzelman, W. R., Chandrakasan, A., & Balakrishnan, H. (2000) Energy-efcient communication protocol for wireless microsensor networks. In Proceedings of the 33rd annual Hawaii international conference on system sciences (pp. 10–pp). IEEE 26.
30. Yu, Y., Govindan, R., & Estrin, D. (2001) Geographical and energy aware routing: A recursive data dissemination protocol for wireless sensor networks. Technical report ucla/csd-tr-01-0023, UCLA Computer Science Department.
31. Nagesh.R., Dr Sarika Raga. "A combined adaptive data aggregation and hierarchical routing protocol to improve the QoS and lifetime of WSN". Turkish Online Journal of Qualitative Inquiry (TOJQI). Vol. 12 No. 7 (2021), 6744-6757.
32. Amgoth, T., & Jana, P. K. (2015). Energy-aware routing algorithm for wireless sensor networks. Computers & Electrical Engineering, 41, 357–367.
33. Qiu, T., Qiao, R., Han, M., Sangaiah, A. K., & Lee, I. (2017). A lifetime-enhanced data collecting scheme for the internet of things. IEEE Communications Magazine, 55(11), 132–137. 29.