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Fuzzified Energy Efficient Mechanism (FEEM) in Wireless Sensor Network

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ABSTRACT

Wireless Sensor Network is one of the most rapidly developing technologies with a wide range of applications which includes a sensing process, security providence and surveillance, environmental sensing and military applications. Significant trend led to the emergence of small and low-cost computation and communication devices, called sensor nodes. Sensors are capable of sensing and transmitting process by consuming some amount of energy. The devices have the potential to serve as a catalyst for major changes. FEEM (Fuzzified Energy Efficient Mechanism) is a clustering based protocol proposed for continuous data-gathering with reduced energy consumption in WSN. The network is organized into clusters with cluster-heads periodically collecting, aggregating/compressing the data from nodes within the cluster, before sending them from Cluster head to Base station. Cluster-heads are changed periodically based on the Residual Energy available with the nodes in the cluster. The protocol is built based on the existing LEACH protocol to increase the lifetime of sensor network as well as to provide the energy efficiency at each node in WSN.

Key words: Cluster Selection, Energy, Fuzzy, Lifetime.

1. INTRODUCTION

In today's world we are facing various types of disasters in environments. We can protect the environment using WSN. If an emergency response system is defined this alerts the users in the forms such as pop-ups on a computer screen, SMS to cell phones and so on. Sensor networks are reliable for accessing and transforming the information at the time of the event occurring. The sensor nodes are maintained by the base station. Base station is having the capability of accessing and retrieving the data from the nodes. The sensor nodes in a WSN may be either mobile or fixed, and they collaborate with each other to carry out a specific action and provide some service. The sensor nodes in a WSN, perform three operations like sensing, processing, transforming the processing the data. The sensor base station also called as Sink.

The sink (Base Station) communicates with the user via internet or satellite communication. It is located near the sensor field or well-equipped nodes of the sensor network. Collected data from the sensor field and routed to the sink by a multi-hop infrastructure-less architecture. Some of these types of sensors are acoustic sensors, seismic sensors, thermal sensors, visual sensors, radar sensors, infrared sensors, magnetic sensors and so on. The routing protocol is initialized for the efficiency of the transmission. It depends on Latency (the delay), Energy efficiency, Accuracy, Fault-tolerance, Scalability, Security, Throughput, Availability [36] [37]. Some of the application domains of the sensor networks are Military, Environmental, Health (Scanning), Vehicular Movement, Exploration, Precision agriculture, Habitat monitoring, Tracking of containers and boxes.

These sensor network applications will be ubiquitous in the near future, since they support new opportunities for the interaction between humans and its physical world. In addition, sensor networks are expected to contribute significantly to pervasive computing and space exploration in the next decade. Deploying sensor nodes in an unattended environment will give much more possibilities for the exploration of new applications in the real world. The idea behind these Applications is densely deploying sensor nodes with the capabilities of sensing. Wireless communications and computation in an unattended environment will assist in measuring its ambient conditions and obtaining the characteristics about the phenomenon of interest surrounding these sensors by transforming these sensed/gathered data into electrical signals that can be processed. Other applications for wireless sensor networks can be seen in environmental monitoring and control field (e.g., robot control), high-security smart homes, tracking, and identifications and personalization.

In LEACH (Low Energy Adaptive Clustering Hierarchy) is a self-organizing, adaptive clustering-based protocol that uses randomized rotation of cluster-heads to evenly distribute the energy load among the sensor nodes in the network. From this protocol to enhancing the cluster formation with FCM to get the energy efficient sensor network with enhanced lifetime of the network.

2. RELATED WORKS

Wireless sensor network energy efficient protocols are designed, for increasing the lifetime of the network LEACH [1] [3] [5] [8] [12] [13] [33] [37] (Low-energy adaptive clustering hierarchy) is the first cluster based routing protocol in wireless sensor network (WSN) and is used to select the cluster heads (CH) among the sensor nodes.

CHEF (Cluster Head election Mechanism using Fuzzy logic) [12] uses energy and local distance as fuzzy variables in the fuzzy if-then rules. Here the CH's are more evenly distributed over the network and then CHEF further prolongs the network lifetime. But CHEF does not construct multi-hop routes in CH's. In REEMR (Reliable energy-efficient multi-level routing algorithm) [12][14], fuzzy if-then rules are mapped into fuzzy Petri nets for representation of a network topology. REEMR extends the sensors network lifetime approximately 13% above as compared to CHEF. PEGASIS (Power-efficient gathering in sensor information systems) [12] organizes sensor nodes into a chain by the greedy algorithm. PEGASIS has 42% less network lifetime of REEMR. HEED (Hybrid Energy-efficient Distributed) [12] Clustering protocol to prolong the network lifetime and support scalable data aggregation. Here the HEED selects the CHs based on both residual energy and communication cost. The basic difference between the HEED and improved Distributed Efficient Clustering Approach (DECA) [16] is how the nodes take the decision and the score computation.

In EECF (Energy-Efficient Cluster Formation) protocol [9][15] any sensor can be connected to a CH and it has to have at least one CH in its fixed transmission range. As EECF provides a better network lifetime and a better ratio of Number of CHs/Total number of sensors than EESH [27]. MOECS (Multi-objective optimization based cluster formation scheme) [12] scheme employs multiple metrics for cluster formation that are critical for balanced energy dissipation of the system. The cluster formation process starts at each node by constructing an options matrix (OM). In the OM, each node records the values of the metrics used in the cluster formation process. A Distributed Hierarchical Agglomerative Clustering (DHAC) [21]follows a bottom-up clustering approach by grouping sensor nodes before the cluster head is selected.

In SECA (Saving Energy Clustering Algorithm) [7] is providing efficient energy consumption in WSNs. To calculate the average distance between the sensor nodes and take into account the residual energy for selecting the particular cluster head nodes. Energy Efficient and QoS aware multi Routing protocol (EQSR) [5] provides the details of multiple path discovery and data transmission across. Minimum energy algorithm (MEA) [8] used data propagation technique with minimum energy consumption with the equal ring node propagation. RRCH [3] performs cluster formation only once to avoid the high energy consumption during clustering phase.

In STEM (Sparse Topology and Energy Management) scheme [6] each sensor node has two channels namely wakeup channel and data channel, which are operating at different frequencies. Its energy consumption is increasing slowly as pocket size increases. LEEM (Latency minimized an Energy Efficient MAC protocol) [6] is a MAC protocol. LEEM is a protocol with reservation mechanism for multi-hop data transmission in WSN. ROAM2 [4][22] uses one bit of memory to improve the quality of the paths. The usage of this bit of memory allows a significant efficiency improvement compared to memory less algorithms it can have the other state-of-the-art early obstacle avoidance algorithms.

Energy-efficient Transport Protocol (ERTP) [10] that ensures statistically reliable delivery of sensor data to the sink for data streaming applications in WSNs. Geographic and energy aware routing (GEAR) [01] constructing the node positions in WSN and explicit geographic packet transmits to the destination with efficiently disseminate queries and route replies.

Energy-efficient multi-level clustering algorithm EEMC [18][23]. In the EEMC sink node is located in remote, sensor nodes are stationary and forming. It has a less latency then LEACH. Energy-efficient CDS (EECDS) [11] [25] protocol EECDS has a poly prominent protocol which is used to constructing the topology for node construction. The network lifetime based on E-MCDS is longer than that of LEACH at least by 20% [24].

Energy-Efficiency Clustering Protocol (EECP) [20] is changed the transmission range dynamically to construct a connected cluster in WSN. The Group Key Agreement (GKA) [17] protocol is used for secure group communication and also [24] [19] used in the WSN for secure data transmission. In ERAPL 16] is improved the network lifetime while expanding energy efficiently by constructing the data gathering sequence (DGS) is used to avoid mutual transmission and loop transmission among node. This scheme evaluates the minimum energy consumption and residual energy of the node is calculated to achieve the optimum solution for energy consumption in the WSNs nodes. TEEN [2] and APTEEN [2] are designed to satisfy critical data collection by adding a threshold function it is not fit for a periodic information application. These techniques are tried to preserve and balance the energy in the sensor network.

A method E2M2MC2 [26] computes routes using back tracking search algorithm and it proves that the effectiveness of delay, packet loss rate, throughput, fairness index and energy consumption.The maximum throughput and packet delivery ration with less energy and bandwidth consumption is achieved using Cognitive Radio Network in [27].The proposed algorithm EEMRCP in [28] achieved greater network lifetime and it reduces the energy consumption and the algorithm proposed in [29, 30, 32] also save more energy of the network. NCLAR [31] improves the packet delivery ratio with maximum accuracy. The result in [34] shows that fuzzy based technique improves the network lifetime. The analysis in [35] shows that spectral distortion less than 1dB, which concludes efficient cooperative communication.

3. FUZZIFIED ENERGY EFFICIENT MECHANISM

3.1 Basic Idea

First, the FEEM protocol is forming a cluster head with fuzzy IF-THEN rules. This Fuzzy rules are evaluated with node attributes of energy and distance between the nodes. The rules are applied to the network to calculate the distance between the nodes. Then the distances are to be concluded with the LEACH protocol after that it forms a set of clusters. The cluster heads are communicated with the base station so the energy metrics are considered for choosing which cluster head is going to communicate with the base station. The metrics are consuming energy/packet transmission and remaining energy available in each cluster head. Applying the FCM algorithm for cluster head is chosen in each cluster with distance factor. The FEEM is to provide the energy efficient cluster formation and also cluster head selection for transmitting the data to the BS by efficient energy consumption to improve the lifetime of the network as compared to the LEACH.

3.2 System Model and Assumptions

This section presents a detailed sketch about the Wireless sensor Network, the energy efficient metrics are possessed by the nodes and distance scheme with the fuzzy rules are generated to achieve an efficient cluster formation. As well as the assumptions are considered for designing the proposed architecture and cluster head selection scheme.

3.3 System Architecture

The FEEM focuses on supporting the development of essential service of energy consumption as to improve the network lifetime. It is established by three integrated modules: input module, clustering module and routing module. Figure 1 illustrates these modules. FEEM is designed to operate in the distributed way; however it can be easily modified to work in the centralized way too. Each node in the network implements and performs these three modules independently.

3.3.1 Input Collection Module

The input collection module is designed to collect the required input data from the existing LEACH protocol. This module consists of three independent components. They are Number of nodes which are initializing the network, Initial energy of each node and the rounds of the transmitting information to the BS. All these values are collected after implementing the existing LEACH routing protocol.

3.3.1.1 Nodes

A source node in the wireless network consists of multiple paths to reach a destination node. The total number of nodes deployed depending on the application and usage that nodes are having initial energy 10 Joules/node. The nodes are deployed randomly in the network area 1000*1000. The goal is to use the node energy with efficient manner and increase the lifetime of the node.

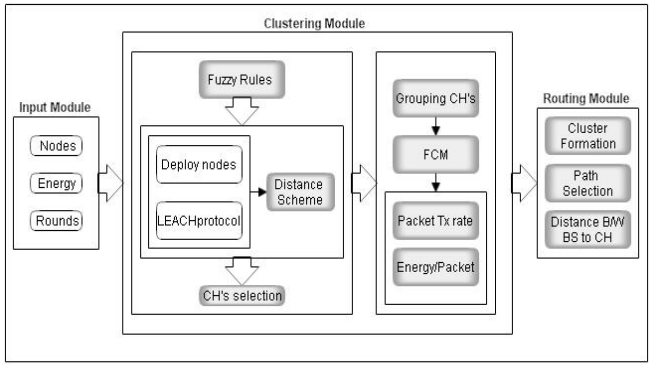

Figure 1: FEEM Architecture

3.3.1.2 Energy

The total amount of energy available in a sensor node is expressed as joules. The joule is a unit to measure of electrical power of the sensor, symbolically represented as j (capital letter "J"). Except for the very end of the sensor's life, the energy in most senses dissipates at a linear rate, for a constant power load to evaluate how many joules of energy a component on the sensor nodes draws in the process. Each node is having different power consumption to generate the data and transmit the same to BS. The stages of data transmission from node are considered as sleep state, operation state .The states are consuming power with depends on the application and the usage of nodes. In this module to calculate the energy consumption follow the below:

i) The energy power used in the initial phase of the network's life when each wireless sensor node's are locates to establish with the base node.

ii) The energy power used to compute the monitoring or the sensing mode is high as compared to the initial phases. It is used to sense the environmental changes by the analog. The processing unit in the sensor node should process the sensed signals then it converts into the digital signal by the processing unit. Then the signal is ready to transmit to the other node.

iii) The active mode on when the wireless sensor node is in transmission mode .The sensing data should transmit to the other node by using transmission protocols. The protocols to transmit the data with efficient path selection. It consumes the higher amount of energy as compared to the sensing process.
iv) The receiving state of power usage is that which is used to receive another sensor node's reading. The equal amount of energy consumed for receiving as a transmitting category of power usage requires.

3.3.1.3 Rounds

A WSN's lifetime is depending on the equal rounds of accessing all nodes. The duration of each round is same and the activities initially within around are similar to accessing the information. At the beginning of a round, all active nodes turn to their ready state for gathering the information and wait a fixed amount of time to receive the packet. All active sensors send their previous round's sensed data to the BS. This is the time when all in-network data routing occurs according to the data routing tree preset for the corresponding round. After that, all nodes turn off their radios and the transition to their low power state. This is the time when sensors start sensing. The sensors also transition to their lower energy state once they finish sensing. All nodes remain in their low power state until the next round begins.

3.3.2 Clustering Modules

Clustering is the method of grouping sensor notes with various attributes depends on the application. The energy consumption during the clustering process concentrated attributes related to the distance between the nodes. The initial energy of the nodes and the threshold values of each sensor node are considered here. The clustering relies on a centralized management approach which makes the nodes available. The availability of nodes should take the data to transmit to the base station. This module forms different clusters in the network and each cluster has its own cluster head (CH) .This CH is used to transmit the data to the BS from the cluster region. The cluster formation is a technique used to reduce the energy consumption then to increase the life time of network's sensor nodes.

3.3.2.1 Fuzzy If-Then Rules

A static/dynamic sensor node in WSN which makes use of fuzzy sets is called a fuzzy system. Most common fuzzy systems are using if-then rules and it is called rule-based systems. It's also known as fuzzy models. An if-then rule generally takes the form of If antecedent proposition then consequent proposition. Fuzzy rules are initialized in WSN sensor nodes for taking the model for clustering with attribute selection.

The antecedent proposition is always a fuzzy proposition of the type 'X-attribute is A-range', where x is a linguistic variable and A-range is a linguistic constant. The rules attributes 'X attributes' is defined by the application.

Rule: IF energy is high AND distance is small THEN select Cluster

3.3.2.2 Leach Protocol

Low Energy Adaptive Clustering Hierarchy ("LEACH") is a TDMA-based MAC protocol which is integrated with clustering and a simple routing protocol in WSN. The LEACH is to evaluate the low consumption of energy in the cluster and to improve the lifetime of the WSN. LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads receives and transmits the data and forwards it to the BS. Each node is initialized in the LEACH algorithmic process to form clusters in the WSN. LEACH assumes that each node has a radio powerful enough to directly connect the base station or the nearest cluster head, but using this radio at full power all the time would waste energy. Suppose a node that have been acted as cluster head is unable to become cluster head again for P rounds, where P is the desired percentage of cluster heads. Each node has a 1/P probability of becoming a cluster head in each round. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster. The cluster head then creates a schedule for each node in its cluster to transmit its data. All nodes which are not cluster heads only communicate with the cluster head. Then the cluster head is to transmit the data to the BS.

$$T(n) = \frac{P}{1-P\times(r \bmod P^{-1})} \frac{E_{N\_current}}{E_{N\_max}} \qquad (1)$$

$E_{N\_current}$: is the current amount of energy

$E_{N\_initial}$: is the initial amount of energy

The formula should take the threshold value of each sensor node energy evaluation.

The fuzzy production rules produce the output in terms of the linguistic variables. These variables will be mapped to the corresponding numerical values in the truth scale for certainty factor. Table 1 represents the set of truth scale for certainty factor and its corresponding numerical values. Based on the certainty factor values the cluster head are formed.

3.3.2.3 Distance Scheme

The Distance scheme is the main attribute of the energy consumption process. From LEACH and FUZZY RULES generated the new distance scheme for evaluating the distance between the sensor nodes.

Table 1: Truth Scale for Certainty Factors

Truth Scale	Numerical Intervals
Strongest	0.91-1.0
Strong	0.71-0.90
Normal	0.61-0.70
Average	0.51-0.60
Weak	0.41-0.50
Weakest	0.30-0.40
Inconsiderable	0.00-0.29

3.3.2.4 Cluster Formation

The cluster formation depends on the generated new distance scheme. Fuzzy rules are generated using the distance as a factor among the nodes. From that distance evaluation the cluster head selection carried by the FCM. Then each cluster has to select the cluster head for communicating with the base station.

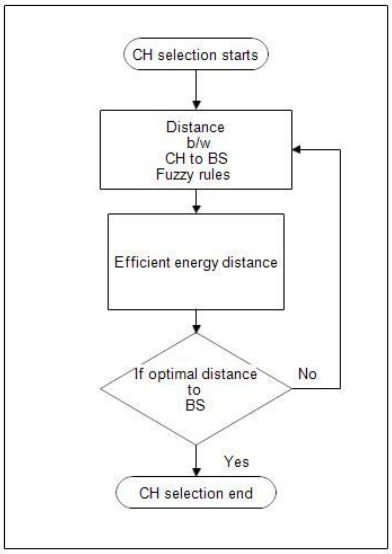

Figure 2: CH Selection using fuzzy rules

3.3.2.5 Fuzzy Cluster Means

In fuzzy clustering, each data point belongs to a cluster to a degree specified by a membership grade. Thus, data points on the edge of a cluster are lesser in degree than data in the center of the cluster. Any data point *x* has a set of coefficients giving the degree of being in the quiet cluster *wk(x)*. The centroid of a cluster is the mean of all points. By using fuzzy c-means the centroid can be calculated by,

$$C_k = \sum_x \frac{w_k(x)x}{w_k(x)} \left| \frac{E_{N\_current}}{E_{N\_initial}} \right. \quad (2)$$

The degree of belonging, *wk(x)*, is related inversely to the distance from *x* to the cluster center as calculated on the previous pass.

3.3.2.6 Cluster Head Selection

The Cluster Head selection process for which cluster is going to transmit the information to the BS is depicted in Figure2. Figure 3 represents pictorial representation to form energy efficient cluster head to communicate to the BS. The cluster head selection considers the cluster attributes energy and distance to the base station. The FCM used to propose the cluster head selection with efficient path for accessing the base station.

The cluster head considers the residual energy of the node,

Residual energy= (Initial energy- Consumed energy) /CH

The distance between the CH and BS is used to evaluate by the Fuzzy rules.

3.3.2.7 Transmission Energy

The transmitted energy evaluates the bits of data transmit to the destination. It's calculated by the bits and the distance between the nodes.

$$T_{trans}(k,d) = T_{elec}(k) - \text{Bits} + T_{amp}(k,d) \quad (3)$$

k - Transmission bits
d - Distance of transmission

3.3.2.8 Energy Node

Each node is having the separate lifetime for transmitting the information to the CH or BS. The node consumes energy for each transmission when it is deployed in the usage. Consumption of energy should evaluate by the time factor.

$$E_{consumed,i} = \left(E_{individual,i} + E_{local,i} + E_{sink,i} + E_{global,i} + E_{battery,i}\right)(t) \quad (4)$$

In this formula is used evaluate the energy consumption for each node, which act as the three states such as individual states, local state, global state. These three states are working under the consumable energy power. The constraint means a node should have enough energy to do network tasks otherwise it is not active and should be removed from the network activities. Each constraint is expressed in terms of key parameter of energy.

3.3.3 Routing Module

In this module the CH to transmit the information to the base station by the energy efficient path. To provide the energy efficient transitions to the BS, the fuzzy rules are used to evaluate the nodes by the distance, energy, threshold values then the values are applied to the LEACH protocol. The LEACH protocol provides the cluster head selection among a group of nodes. FCM is initialized in the cluster to take the efficient cluster head for transmitting the data to the base station.

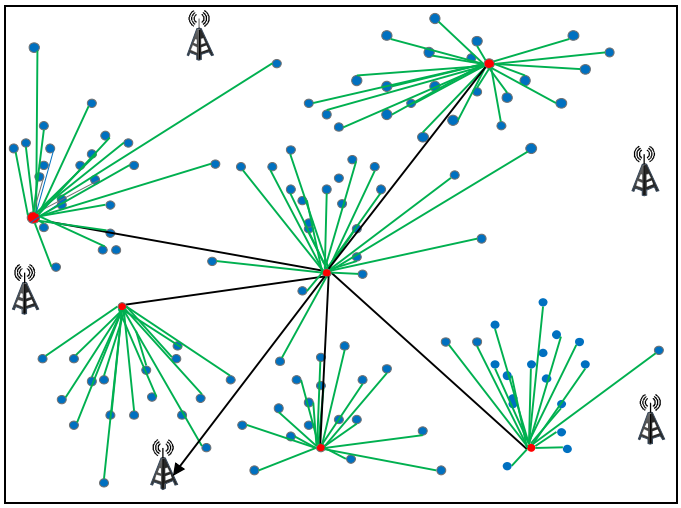

Figure 3: Path Selection to communicate Base Station

3.3.3.1 Cluster Head Selection for Base Station

The cluster head selection process is done using FCM. Figure 3 represents a set of clusters which are interacting with the BS. The transmission process continues up to the CH having energy in certain level. The FCM takes another CH selection process if CH losses in energy level.

3.3.3.2 Path Selection for Routing

The routing protocol takes the path which is using Fuzzy rule and FCM. Fuzzy provides the node selection which is best for communicating to the BS. Then FCM takes a optimal path or energy efficiency.

3.3.3.3 Distance between CH to BS

The distance factor is combined with the LEACH protocol for providing the path selection to communicate with BS and CH selection among the nodes. The CH to BS path consumes time and also the higher energy.

4. RESULT AND DISCUSSION

Four network parameters are mainly considered for evaluating the performance of the proposed routing protocol. They are Delay, Packer Delivery Ratio (PDR), Throughput, and Residual Energy. Each parameter is used in different scenarios such as, by varying the simulation time and the number of nodes. The protocol proposed in this paper is named as Fuzzified Energy Efficient Mechanism (FEEM) in Wireless Sensor Networks.

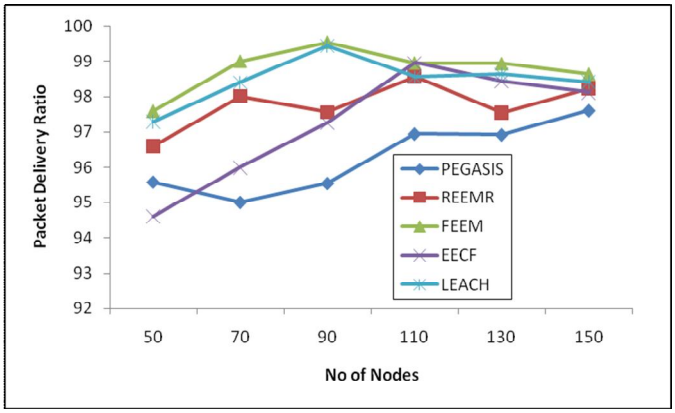

Figure 4: Packet Delivery Ratio (PDR) Vs No. of Nodes

Figure 4 shows the simulation result of PDR with respect to the number of nodes. In this network when there are no nodes, then the PDR achieves up to 98%. When the number of nodes in the network increases, the PDR will decrease.

The analysis for this parameter shows that the variations in the PDR with varying number of nodes. In the presence of 50 nodes the PDR is 97.58%, where as it is increased to 98.99% with 70 nodes. Similarly, the PDR is decreased from 98.9% to 98.6%, for 70 to 150 nodes deployed in the network. Finally achieved average PDR is 98.43% and this considered as high when compared to other existing routing protocols.

The variations in the delay at different time intervals, and also the comparison of other protocols with FEEM result is presented as below.

Figure 5 shows the simulation result of delay with respect to the number of nodes. The simulation time is set from 100 to 600 seconds then it is converted into hours. Initially the delay is the main factor of energy consumption process. The proposed method achieves up to 97%. As the simulation time increases the delay time is getting decreased. When compared to other routing protocols, on an average FEEM achieves around 96.3%.

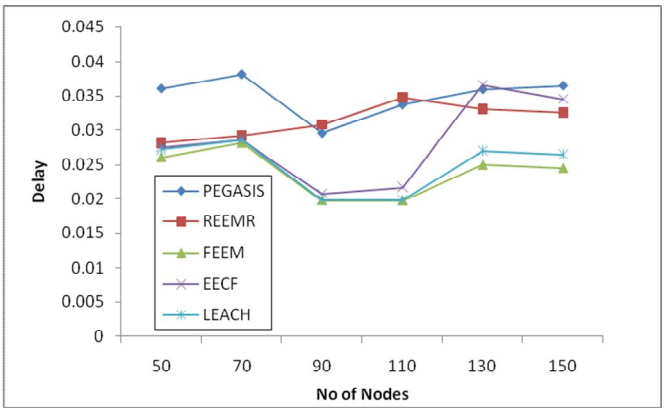

Figure 5: Delay Ratio Vs No. of Nodes

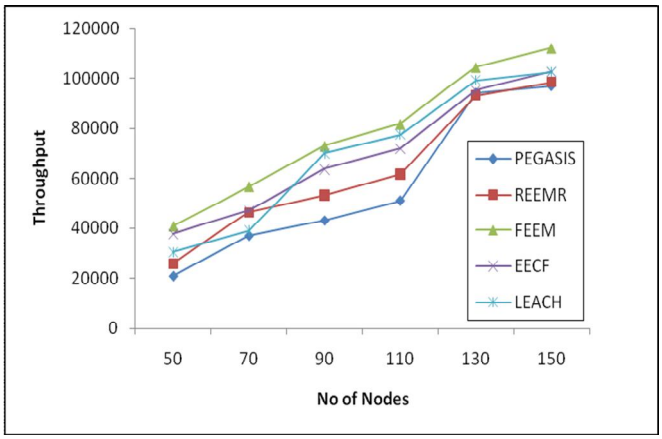

Figure 6: Throughput Vs No. of Nodes

Figure 6 shows the simulation result of the average throughput of packets in-between the source and the destination with the varying number of nodes. The throughput increases gradually when increasing the nodes in the network. LEACH and FEEM has same throughput when 90 nodes are deployed then it achieves 65% of throughput. Therefore, FEEM protocol achieves high throughput than the other existing protocols.

Figure 7 illustrates the comparison between residual energy and number of nodes. FEEM has produced a high residual energy in each node when compared to other routing protocols at different time intervals and also during the increased number of nodes. At initial stage 50 nodes are deployed and it achieves up to 70% of residual energy. When

increasing the area of network and number of nodes then FEEM achieves up to 96.5% residual energy.

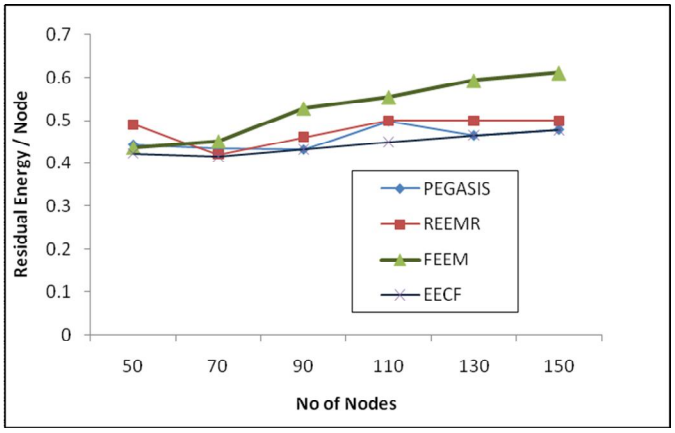

Figure 7: Residual Energy Vs No. of nodes

5. CONCLUSION

Though the wireless sensor networks have a wide range of application and advantages, all these can be achieved by means of energy available with the sensor nodes. So the energy should be efficiently utilized. So many works have been proposed to improve the energy efficiency. In this proposed work the Fuzzy C-Means Clustering algorithm was used in order for efficient cluster head selection. After the cluster head selection the cluster head is connected to the base station, this is chosen based on the cluster head with the highest energy level. In this proposed Fuzzified Energy Efficient Mechanism (FEEM) it highly reduced the energy consumption of each and every node that is present on the network. As well, the proposed protocol is achieved a higher PDR, minimal delay and it also achieves the high residual energy. This work can be enhanced by implementing the clustering algorithms in order for effective cluster formation by using various attributes. Hence it is considered to be more efficient than the other protocols.

REFERENCES

1. Ali Chamam, Samuel Pierre, **A distributed energy-efficient clustering protocol for wireless sensor networks**, Journal of Computers & Electrical Engineering, Vol.36, No.2, pp. 303-312, 2010.
2. Busola S. Olagbegi, Natarajan Meghanathan, **A review of the energy efficient and secure multicast routing protocols for mobile ad hoc networks**, International journal on applications of graph theory in wireless ad hoc networks and sensor networks (GRAPH-HOC) Vol.2, No.2, pp. 1-15, 2010.
3. ChrisKarlof, David Wagner, **Secure routing in wireless sensor networks: attacks and countermeasures**, Elsevier Ad-Hoc networks Sensor Network Protocols and Applications, Vol.1, No. 2–3, pp. 293–315, 2003.
4. Chung-Horng Lung, Chen Juan Zhou, **Using hierarchical agglomerative clustering in wireless sensor networks: An energy-efficient and flexible approach**, Elsevier Ad Hoc Networks , Vol.8, No.5, pp. 328–344, 2010.
5. Djohara Benyamina, Abdelhakim Hafid, and Michel Gendreau, **Wireless Mesh Networks Design — A Survey**, IEEECommunications surveys & tutorials, Vol.14, No.2, pp. 299-310, 2012.
6. Florian Huc, Aubin Jarry, Pierre Leone B, Jose Rolim, **On the efficiency of routing in sensor networks**, Elsevier J. Parallel Distrib. Comput, Vol.72, No.7, pp. 889-901, 2012.
7. Gholam Hossein Ekbabtanifard, Reza Monsefi, Mohammad H, Yaghmaee M and Seyed Amin Hossein S, **Queen-MAC: A quorum-based energy-efficient medium access control protocol for wireless sensor networks**, Elsevier Computer Networks, Vol.56, No.8, pp. 2221-2236, 2012.
8. Hassaan Khaliq Qureshi, Sajjad Rizvi, Muhammad Saleem, Syed Ali Khayam, Veselin Rakocevic and Muttukrishnan Rajarajan, **Poly: A reliable and energy efficient topology control protocol for wireless sensor networks**, Elsevier Computer Communications Journal, vol. 34, no. 10, pp. 1235-1242, 2011.
9. Jabal Ben-Othman and Bashir Yahya, **Energy efficient and QoS based routing protocol for Wireless sensor networks**, Elsevier Journal of Parallel and Distributed Computing, Vol.70, No.8, pp. 849-857, 2010.
10. Jain-Shing Liu, Chun-Hung Richard Lin, **Energy-efficiency clustering protocol in wireless sensor networks**, Elsevier B.V. Vol.55, No.15, pp. 3256-3274, 2011.
11. Kiran K. Rachuri, C. Siva Ram Murthy, **Energy efficient and low latency biased walk techniques for search in wireless sensor networks**, J.Parallel Distrib. Computer, Vol.71, No.3, pp 512-522, 2011.
12. M. Dhanaraj, B. S. Manoj, C. Siva Ram Murthy, **A New Energy Efficient Protocol for Minimizing Multi-hop Latency in Wireless Sensor Networks**, In proc. IEEE conf., Pervasive Computing and Communication ISBN-0-7695-2299, 2005.
13. Mohsen Nickray, Ali Afzali-Kusha, Riku Jantti, **MEA-an energy efficient algorithm for dense sector-based wireless sensor networks**, Springer Journal on Wireless Communication and Networking -85, 2012.
14. Martin Mauve, Jorg Widmer, Hannes Hartenstein, **A Survey on Position-Based Routing in Mobile Ad Hoc Networks**, IEEE Network, Vol. 15, No.6, pp. 30-39, 2001.
15. Pitipatana Sakarindr, Nirwan Ansari, **Security services in group communications over wireless infrastructure, mobile ad hoc, and wireless sensor networks**, IEEE Wireless Communication, Vol.14, No. 5, pp. 8-20, 2007.
16. Qiang Tang, Kun Yang, Ping Li, Jianming Zhang, Yuansheng Luo, Bing Xiong, **An energy efficient**

MCDS construction algorithm for wireless sensor networks, Journal on Wireless Communications and Networking-83, 2012.

17. Tarique Haider, Mariam Yusuf, **A Fuzzy Approach to Energy Optimized Routing for Wireless Sensor Networks**, The International Arab Journal of Information Technology, Vol. 6, No. 2, 2009.
18. Thomas Kunz, Rana Alhalimi, **Energy-efficient proactive routing in MANET: Energy metrics accuracy**, Elseiver Ad Hoc Networks, Vol.8 , No.7, pp. 755-766, 2010
19. Tuan Le, Wen Hu, Peter Corke and Sanjay Jha, **ERTP: Energy-efficient and Reliable Transport Protocol for data streaming in Wireless Sensor Networks**, Elsevier Journal of Computer Communications, Vol.32, No. 7-10, pp 1154-1171, 2009.
20. Yan Jin a, Ling Wang, Yoohwan Kim, Xiaozong Yang, **EEMC: An energy-efficient multi-level clustering algorithm for large-scale wireless sensor networks**, Elsevier Computer Networks, Vol. 52, No.3, pp. 542-562, 2008.
21. Jau-Yang Chang, Pei-Hao Ju, **An efficient cluster-based power saving scheme for wireless sensor networks**, Springer Journal on Wireless Communications and Networking Vol.30.No.7, 2012.
22. Yi-Hua Zhu, Wan-Deng Wu, Jian Pan, Yi-ping Tang, **An energy-efficient data gathering algorithm to prolong the lifetime of wireless sensor networks**, Elsevier Computer Communications, Vol.33 No.5, pp. 639-647, 2010.
23. Yong Zhang,kequi Li, Dan huang, Yingwei Jin and dong Yang, **A moment-based optimization method for energy efficiency in wireless sensor networks**, Springer Journal on Wireless Communication and Networking -133, 2012.
24. Zhenhua Yu, Xiao Fu, Yuanli Cai, Mehmet C. Vuran, **A Reliable Energy Efficient Multilevel Routing Algorithm for Wireless Sensor Networks Using Fuzzy Petri Nets**, Sensors Journal Vol.11, No.3, pp. 2282-3400, 2011.
25. Zhu Yong, Qing Pei, **A Energy-Efficient Clustering Routing Algorithm Based on Distance and Residual Energy for wireless sensor networks**, Elsevier Procedia Engineering Vol.29 No. 0, pp. 1882-1888, 2012.
26. Pallavi, L., Jagan, A., & Thirumala Rao, B., **BTS algorithm: An energy efficient mobility management in mobile cloud computing system for 5G heterogeneous networks**, Journal of Theoretical and Applied Information Technology, 97(1), 48-60, 2019.
27. More, A. R., Prasad, M. S. G., & Wankhede Vishal, A., **Optimized throughput and minimized energy consumption through clustering techniques for cognitive radio network**, International Journal of Innovative Technology and Exploring Engineering, 8(4S2), 474-479, 2019.
28. Srikanth, N., & Ganga Prasad, M. S., **Efficient clustering protocol using fuzzy K-means and midpoint algorithm for lifetime improvement in WSNs**, International Journal of Intelligent Engineering and Systems, 11(4), 61-71, 2018. doi:10.22266/ijies2018.0831.07.
29. Malar, A.C.J., Kowsigan, M., Krishamoorthy, N. et al **Multi constraints applied energy efficient routing technique based on ant colony optimization used for disaster resilient location detection in mobile ad-hoc network**. J Ambient Intell Human Comput(2020). http//doi.org/10.1007/s12652-020-01767
30. Gummadi, A., & Raghava Rao, K., **EECLA: Clustering and localization techniques to improve energy efficient routing in vehicle tracking using wireless sensor networks**, International Journal of Engineering and Technology(UAE), 7, 926-929, 2018.
31. Karthikeyan, T., Brindha, V., & Manimegalai, P., **Investigation on maximizing packet delivery rate in WSN using cluster approach**, Wireless Personal Communications, 103(4), 3025-3039, 2018. doi:10.1007/s11277-018-5991-z.
32. Mallikarjuna Rao, Y., Subramanyam, M. V., & Satya Prasad, K., **Cluster-based mobility management algorithms for wireless mesh networks**, International Journal of Communication Systems, 31(11), 2018. doi:10.1002/dac.3595.
33. Sundaraiah, P., Sri Kapardi, K., Jaya Lakshmi, C. H., Srinivas, K., & Uday Kumar, M. V., **Comparative study of leach and pegasis energy efficient protocols**, Journal of Advanced Research in Dynamical and Control Systems, 9, 1949-1954, 2017.
34. Buvanesvari, M., Uthayakumar, J., & Amudhavel, J., **Fuzzy based clustering to maximize network lifetime in wireless mobile sensor networks**, Journal of Advanced Research in Dynamical and Control Systems, 9(Special Issue 12), 2133-2143, 2017.
35. Samant, T., Mukherjee, P., Mukherjee, A., & Datta, A., **TEEN-V: A solution for intra-cluster cooperative communication in wireless sensor network**. Proceedings of the International Conference on IoT in Social, Mobile, Analytics and Cloud, I-SMAC 2017, 209-213, 2017. doi:10.1109/I-SMAC.2017.8058340.
36. S. Ananthakumaran, M. Sathishkumar, R. Bhavani, R. Ravinder Reddy, **Prevention of routing attacks using trust-based multipath protocol**, International Journal of Advanced Trends in Computer Science and Engineering, Vol. 9, No. 3, pp. 4022-4029, 2020. https://doi.org/10.30534/ijatcse/2020/227932020
37. Kavitha, V., Ananthakumaran, S. **Novel energy-efficient secure routing protocol for wireless sensor networks with Mobile sink**. Peer-to-Peer Netw. Appl.12,881-892,(2019). http://doi.org/10.1007/s12083-018-0688-3