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Research Article

Fuzzy Based Optimal Clustering Protocol for Maximizing Lifetime in WSN

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Abstract: In Wireless Sensor Networks (WSN), the clustering protocol requires the nodes local information like energy level, distance between to BS and node density, link quality and load while estimating the cluster heads to handle network lifetime. In this study, we propose fuzzy based optimal clustering protocol for maximizing lifetime in WSN. Initially, several provisional cluster heads are elected in a random manner. The nodes other than provisional cluster heads involve in gathering the neighbor nodes local information such as residual energy, distance, node density and network load. The collected information is fuzzified using fuzzy logic technique and appropriate cluster head and size are estimated. Based on uninterrupted operational mechanism of each cluster head, the cluster heads are updated, thereby reducing the frequency of cluster head updation. By simulation results, we show that the proposed technique enhances the network lifetime.

Keywords: Cluster head updation, clustering, fuzzy logic, network lifetime, residual energy, wireless sensor networks

INTRODUCTION

Wireless Sensor Network (WSN): Wireless Sensor Network (WSN) has become a very important topic with the rapid development that is vulnerable to a wide range of attacks due to deployment in the hostile environment. A WSN is a large network of resource-constrained sensor nodes with multiple preset functions, such as sensing and processing with number of low-cost, resource limited sensor nodes to sense important data related to environment and to transmit it to sink node that provides gateway functionality to another network, or an access point for human interface. These sensor networks are composed of energy constrained nodes embedding limited transmission, processing and sensing capabilities. Therefore network lifecycle becomes short and hence maximizing lifetime technique implementation becomes an important requirement for WSN.

Security Monitoring are composed of sensor nodes that are placed at fixed locations throughout an environment that continually monitor one or more sensors to detect an anomaly. Node tracking scenarios used in tracking of a tagged object through a region of space monitored by a sensor network (Bhattasali and Chaki, 2011; Kavitha and Sridharan, 2010; Gaddour *et al*., 2009).

Application of WSN: WSN have been used in wide-range of areas like in military applications where sensor nodes include battlefield surveillance, guiding systems of intelligent missiles and detection of attack by weapons of mass destruction, in medical application where sensors can be extremely useful in patient diagnosis and monitoring, environmental monitoring, in industrial applications where sensors includes industrial sensing and diagnostics, in infrastructure protection which includes power grids monitoring, water distribution monitoring etc. and in other miscellaneous applications where sensors will soon find their way into a host of commercial applications at home and in industries, such as ovens, refrigerators and vacuum cleaners, which enable them to interact with each other and be remote-controlled.

Need for maximizing lifetime: Network lifetime can be defined as the time elapsed from the network operation starts until the first node in the network depletes its energy. Energy-efficient operation, channel contention, latency and management of WSNs are complex and critical issues that have to be addressed to facilitate large-scale deployments. Energy consumption in a node can be due to either useful or wasteful operations.

The useful energy consumption includes transmitting or receiving data messages and processing query requests.

The wasteful consumption can be due to overhearing, retransmitting because of harsh

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environment, dealing with the redundant broadcast overhead messages, as well as idle listening to the media.

In order to save the transmission power, clustering and multi-hop transmission techniques can be used. The battery replacement is not a decision for networks with thousands of physically embedded nodes, an efficient energy saving protocol is required to prolong the sensor network lifetime (Chhabra and Sharma, 2011).

Need for cluster based routing: Cluster-based organization of large sensor networks is the basis for many techniques that address these issues.

Clustering is particularly useful in mutual sensor applications that perform different tasks and deployed in the same physical area. The network is decomposed into a set of clusters, for example, for administrative or communicating purposes, with each cluster formed by grouping a set of nearby nodes. A designated node, namely, the Cluster Head (CH), manages each cluster. With many solutions based on clustering, the nodes within a cluster communicate only with their CH. The CHs are responsible for coordinating both inter-cluster and intra-cluster communication. Communication among CHs can be through either single or multiple hops (Malathi and Gnanamurthy, 2012; Chhabra and Sharma, 2011).

Problem identification: In Mina *et al*. (2009), they have proposed an energy efficient clustering algorithm with optimum parameters for reducing the energy consumption and prolonging the system lifetime. An analytical clustering model with one-hop distance and clustering angle is given. The optimum one-hop distance and clustering angle are formulated by minimizing the energy consumption between inter-cluster and intra-cluster. Furthermore, the continuous working mechanism of each cluster head which acts as the local control center and will not be replaced by the candidate cluster head until its continuous working times reach the optimum values is given. This approach will reduce the energy consumption and prolong the system lifetime. This approach will maximize the lifetime by considering the cluster heads working time but ignores the nodes local information like energy level, distance between to BS and node density, link quality and load to determine the tentative cluster heads which plays a very important role in the lifetime.

To overcome the above disadvantage, a fuzzy logic based clustering scheme utilizing the local information is proposed.

LITERATURE REVIEW

Sharma and Kumar (2012), an effort has been done to propose F-MCHEL, a homogeneous energy protocol. In LEACH protocol the clusters are formed randomly on the basis of threshold values; whereas, in the proposed protocol a fuzzy logic approach is used to elect the cluster-head based on two descriptors-energy and proximity distance. Out of these elected cluster heads one Master cluster head has been elected. The cluster head which has the maximum residual energy is elected as Master cluster head. In conventional Leach approach all the Cluster heads are used to sends the aggregated information to the base station, however in the proposed protocol only Master cluster head sends the aggregated information to the base station. Simulation results on MATLAB shows that the proposed protocol provides higher energy efficiency, better stability period and lower instability period as compared to LEACH protocol in spite of overhead of election of Master cluster head.

In study Kumar *et al*. (2011a), they have focused mainly on the energy efficient hierarchical clustering routing protocol. Clustering mechanism helps to reduce the complexity of network overhead that is proportional to the number of nodes in the network. The study proposed a novel approach with an energy efficient hierarchical clustering technique using the Fuzzy Logic method. The Fuzzy search algorithm applies for cluster formation and cluster head selection in the distributed hierarchical clustering environment. The fuzzification functions and rules optimize the simulation.

In study Mina *et al*. (2009) an energy efficient clustering algorithm with optimum parameters is designed for reducing the energy consumption and prolonging the system lifetime. An analytical clustering model with one-hop distance and clustering angle is given. The optimum one-hop distance and clustering angle are formulated by minimizing the energy consumption between inter-cluster and intra-cluster. Furthermore, the continuous working mechanism of each cluster head which acts as the local control center and will not be replaced by the candidate clusterhead until its continuous working times reach the optimum values is given and the optimum continuous working times of each clusterhead can be obtained through the optimum one-hop distance and the clustering angle. With the mechanism, the frequency of updating clusterhead and the energy consumption for establishing new clusterhead can be reduced.

In study Dasgupta and Dutta (2010) they present a new approach of cluster head selection strategy embedded with the traditional Fuzzy c-means algorithm with minimum distance and maximum residual energy criteria satisfied. The experimental results show that our cluster- based head selection algorithm performs better than the cluster head election strategy used in LEACH and can make the network lifetime longer.

In study Vidhya and Dananjayan (2010) a cluster-based cooperative Multi-Input and Multi-Output (MIMO) scheme is proposed as a solution for problem of reduce in the lifetime due to the adverse impacts caused by radio irregularity and fading in multihop WSN. The proposed scheme extends Low Energy

Adaptive Clustering Hierarchy (LEACH) protocol and enables multihop transmissions among the clusters by incorporating cooperative MIMO scheme through the selection of cooperative sending and receiving nodes. The performance of the proposed MIMO system is evaluated in terms of energy efficiency and reliability. Simulation results show that tremendous energy savings can be achieved by adopting cooperative MIMO scheme among the clusters. The proposed cooperative MIMO scheme prolongs the network lifetime with 75% of nodes remaining alive when compared to LEACH protocol.

Khan *et al*. (2011) developed a mechanism to increase the lifetime of homogeneous sensor nodes by controlling long distance communication, energy balancing and efficient delivery of information. Energy efficiency is a very important issue for sensor nodes which affects the lifetime of sensor networks. To achieve energy balancing and maximizing network lifetime they divide the whole network into different clusters. In cluster based architecture, the role of aggregator node is very crucial because of extra processing and long range communication. Once the aggregator node becomes non functional, it affects the whole cluster. They introduce a candidate cluster head node on the basis of node density. They introduce a modified cluster based model by using special nodes called Server Nodes (SN) that is powerful in term of resources. These server nodes are responsible for transmitting the data from cluster head to the base station. The proposed algorithm for cluster head selection is based on residual energy, distance, reliability and degree of mobility. The proposed architecture is more scalable and proposed algorithm is robustness against even/uneven node deployment.

Song and Cheng-Lin (2011) have proposed a novel energy efficient unequal clustering algorithm for large scale Wireless Sensor Network (WSN) which aims to balance the node power consumption and prolong the network lifetime as long as possible. This approach focuses on energy efficient unequal clustering scheme and inter-cluster routing protocol. On the one hand, considering each node's local information such as energy level, distance to base station and local density, they use fuzzy logic system to determine one node's chance of becoming cluster head and estimate the corresponding competence radius. On the other hand, adaptive max-min ant colony optimization is used to construct energy-aware inter-cluster routing between cluster heads and Base Station (BS), which balances the energy consumption of cluster heads and alleviates the hot spots problem that occurs in multi-hop WSN routing protocol to a large extent. The confirmation experiment results have indicated the proposed clustering algorithm has more superior performance than other methods such as Low Energy Adaptive Clustering Hierarchy (LEACH) and Energy Efficient Unequal Clustering (EEUC).

In study Alim *et al*. (2013), a fuzzy logic based energy-aware dynamic clustering technique is proposed, which increases the network lifetime in terms of LND. Here, two inputs are given in the fuzzy inference system and a node is selected as a cluster head according to the fuzzy cost (output). The main advantage of this protocol is that the optimum number of cluster is formed in every round, which is almost impossible in LEACH (low-energy adaptive clustering hierarchy). Moreover, this protocol has less computational load and complexity. The simulation result demonstrates that this approach performs better than LEACH in terms of energy saving as well as network lifetime.

Lotf and Ghazani (2011) have made an attempt to present a model based on Hopfield- fuzzy CMeans clustering algorithm. Firstly, it is capable of identifying the reasons behind the emergence of the present status. Secondly, the suggested model must represent the clustering of the WSN in different levels. Finally, it tests the validity of the suggested model with comparing by other models (Hopfield-K-Means, K-Means and fuzzyCMeans).

METHODOLOGY

Proposed solution:

Overview: In this study, we propose fuzzy based optimal clustering protocol for maximizing lifetime in WSN. Initially, several provisional cluster heads are elected in a random manner. The nodes other than provisional cluster heads involve in gathering the neighbor nodes local information such as residual energy, distance, node density and network load. The collected information is fuzzified using fuzzy logic technique and appropriate cluster head and size are estimated. Based on uninterrupted operational mechanism of each cluster head, the cluster heads are updated, thereby reducing the frequency of cluster head updation.

Estimation of metrics:

Nodes residual energy: The total energy spent by the transmitter for transmitting z bits message through distance d is given using Eq. (1):

$$E_{tx}(z, d) = E_{tx\cdot e} + E_{tx\cdot a}(x, d) \quad (1)$$

$$= \begin{cases} z.E_e + z\lambda_t d^2, & d < d_0 \\ z.E_e + z\lambda_a d^4, & d \geq d_0 \end{cases} \quad (2)$$

where,

$E_{tx\cdot e}$ = Electronics energy

$E_{tx\cdot a}$ = Amplifier energy

E_e = Energy dissipated per bit to run the transmitter or receiver

$\lambda_t d^2$, $\lambda_a d^4$ = The amplifier energy that depends on transmitter distance

The total energy consumed by the receiver is given using Eq. (3):

$$E_{rx}(z) = E_{rx\text{-}e}(z) = zE_e \quad (3)$$

The residual energy of each node (E_{res}) following one data communication is estimated using Eq. (4) (Peng *et al*., 2013):

$$E_{res} = [E_i - (E_{tx}(z, d) + E_{rx}(z))] \quad (4)$$

where,
E_i = Initial energy of the node

Distance: Each sensor node estimates the distance to BS based on the Received Signal Strength (RSS). RSS is estimated by the Friis Eq. (5). (Kumar *et al*., 2011b):

$$\text{RSS} = \frac{P_{tx} * \alpha * \beta * h_{tx} * h_{rx} * \mu^2}{(4 * \mu * d)^2 * x} \quad (5)$$

where,
P_{tx} = Transmission power
α = Transmitter gain
β = Receiver gain
μ = Wavelength
d = Distance among the transmitter and sink
x = System loss

Thus the distance is defined using the following Eq. (6) (Khan *et al*., 2011):

$$d = \sum_{i=1}^{k} (f_1 + f_2 + ... + f_i) \text{ i.e., d} = \sum_{i=1}^{k} (f_i) \quad (6)$$

where,
f_i = Sum of distance from N_i to BS

Node density: The node density of node (N_i) is estimated in terms of the node degree. It represents the total of number of nodes linked to it (Saxena *et al*., 2013):

$$ND_i = cnt(N_j) \,|d_{i,j}) < R_{tx};\ i \in N_i \text{ and } j \in N_j \quad (7)$$

where,
$d_{i,j}$ = Distance among N_i and N_j
R_{tx} = Node's transmission range
cnt = Node count

Network load: The network load is estimated based on the nodes load in terms of the queue length. It is estimated using the following Eq. (8) (Basaran *et al*., 2011):

$$QL_j = P_i + P_{quej} + (\mu * P_{dropi}) \quad (8)$$

where,
P_i = Number of packets in N_i's queue
P_{quej} = Number of packets in N_j's queue
μ = Re-transmitting limit of a single packet
P_{dropi} = Packets dropped by N_i due to excessive re-transmissions

Thus, each node performs the load balancing among the nodes based on queue length.

Table 1: Fuzzy interference system

Node ID	Residual Energy (E_{res})	Distance (d)	Node Density (ND_i)	Load

Optimal clustering protocol: Let % H be the pre-defined threshold percentage of provisional cluster heads.

The steps involved in this clustering protocol is as follows:

- At time t, several Provisional Cluster Heads (PCH) are elected in a random manner to compete for final cluster heads.
- Excluding the chosen PCH, the remaining nodes broadcasts a HELLO message at fixed power level.
- Each PCH which receives HELLO message estimates the distance (shown in section (Distance)) and appends the node ID to its route cache.
- Finally, for each PCH, the parameters such as Residual Energy (E_{res}), Node Density (ND_i) and Load are gathered (Estimated in sections (Nodes residual energy), (Node density) and (Network load)).
  The format of HELLO message is as follows:
  The Table 1 includes the parameters such as Residual Energy (E_{res}), Distance (d), Node Density (ND_i) and Load (Estimated in section (Nodes residual energy)-(Network load)).
- Utilizing the estimated parameter values, each node analyzes the parameters condition using fuzzy logic technique (The fuzzy logic technique is demonstrated in next subsection (Fuzzy based cluster head selection)). Fuzzy logic handles the uncertainties in electing cluster heads and determining the cluster size.
- When a PCH estimates its possibility to become the cluster head, broadcasts a desire message (D_Mes) establishing its desire to become CH.
- However, when PCH finds that there is another PCH with the greater criteria to get selected as CH, it just declaration its Desire Cancellation (DCL_Mes) message.
- After CH election, each CH broadcasts a cluster advertisement (CL_ADV) message through the network. Ordinary sensors nodes in the network join the nearby CH.

Fuzzy based cluster head selection: The cluster head selection is performed using the fuzzy logic technique.

The parameters residual energy, distance to sink, node density and load are taken as input for the fuzzy member ship functions and based on the fuzzy rules, the possibility for the node being the cluster head and cluster size is estimated as output.

The steps that determine the fuzzy rule based interference are as follows.

Fuzzification: This involves obtaining the crisp inputs from the selected input variables and estimating the degree to which the inputs belong to each of the suitable fuzzy set.

Rule evaluation: The fuzzified inputs are taken and applied to the antecedents of the fuzzy rules. It is then applied to the consequent membership function.

Aggregation of the rule outputs: This involves merging of the output of all rules.

Defuzzification: The merged output of the aggregate output fuzzy set is the input for the defuzzification process and a single crisp number is obtained as output.

The fuzzy inference system is illustrated using Fig. 1.

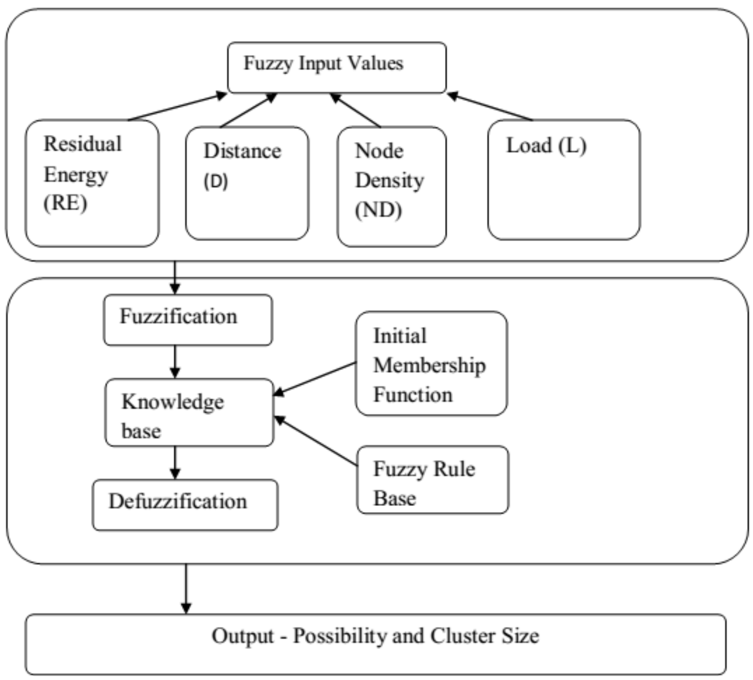

Fig. 1: Fuzzy interference system

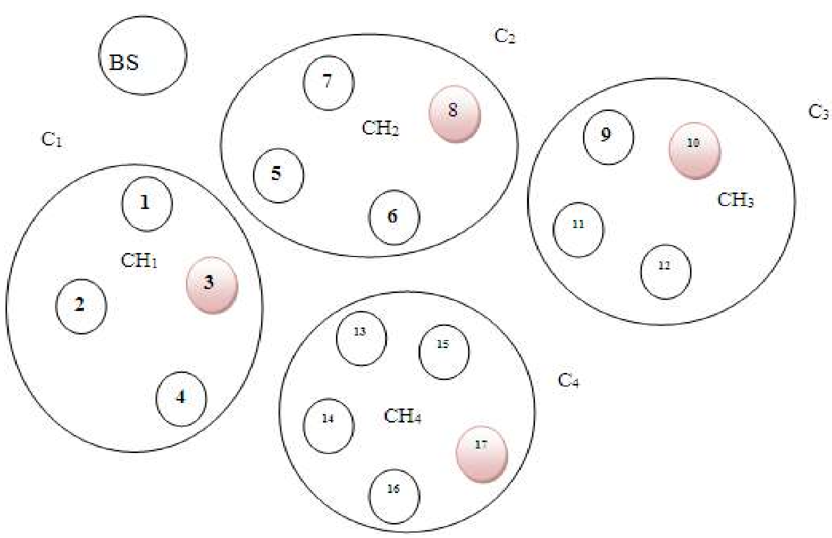

Fig. 2: Cluster formation

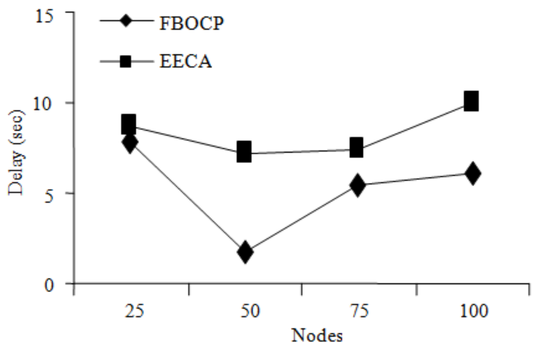

Fig. 3: Nodes vs. delay

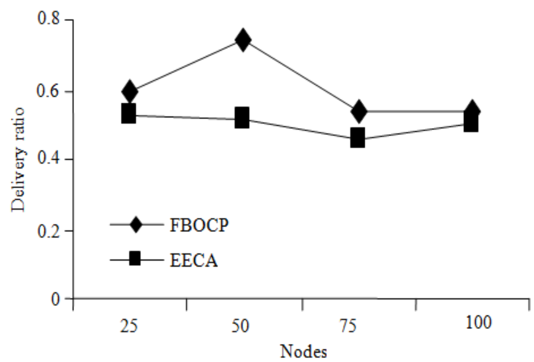

Fig. 4: Nodes vs. delivery ratio

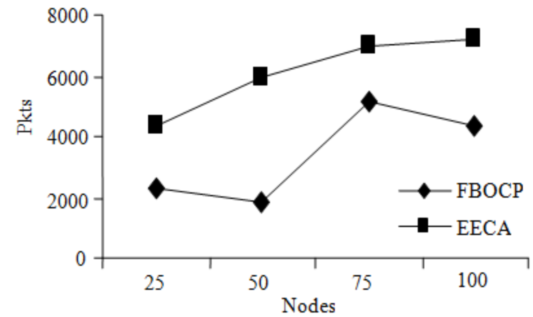

Fig. 5: Nodes vs. drop

Fuzzification: This involves fuzzification of input variables such as Residual Energy (RE), Distance to sink (D), Node Density (ND), Load (L) and Link Quality (LQ) (Estimated in sections (Nodes residual energy)-(Network load)) and these inputs are gives a degree to appropriate fuzzy sets. The crisp inputs are combination of RE, D, ND, L and LQ. We take two possibilities, high and low for RE, D, ND, L and LQ.

Figure 1 to 5 shows the membership function for the input and output variables. Due to the computational efficiency and uncomplicated formulas, the triangulation functions are utilized which are widely utilized in real-time applications. Also a positive impact is offered by this design of membership function (Fig. 6 to 11).

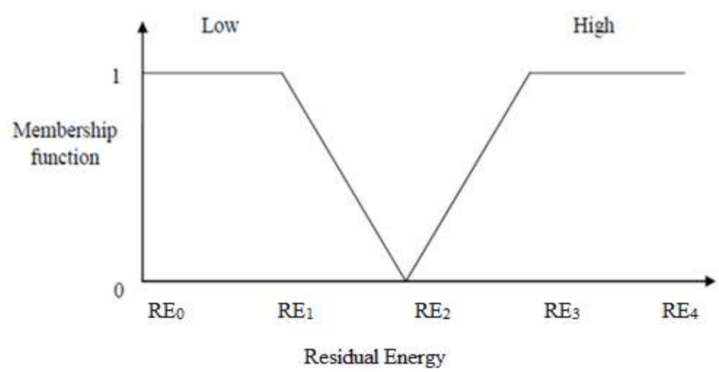

Fig. 6: Membership function for residual energy

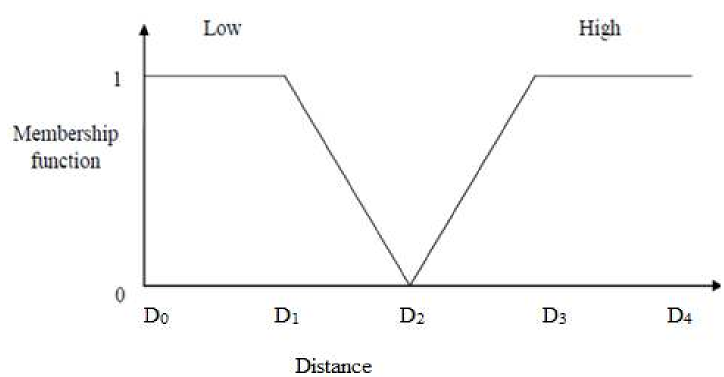

Fig. 7: Membership function for distance

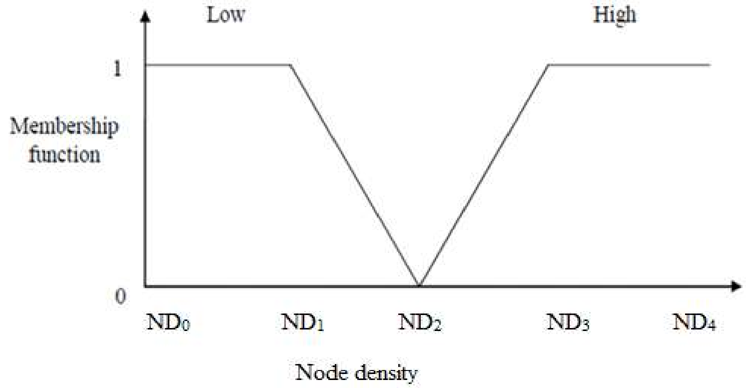

Fig. 8: Membership function for node density

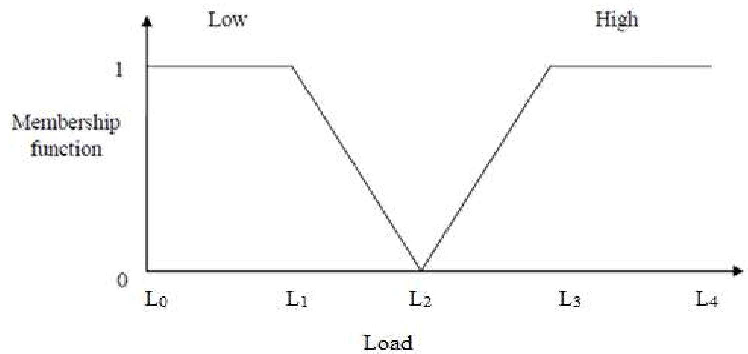

Fig. 9: Membership function for load

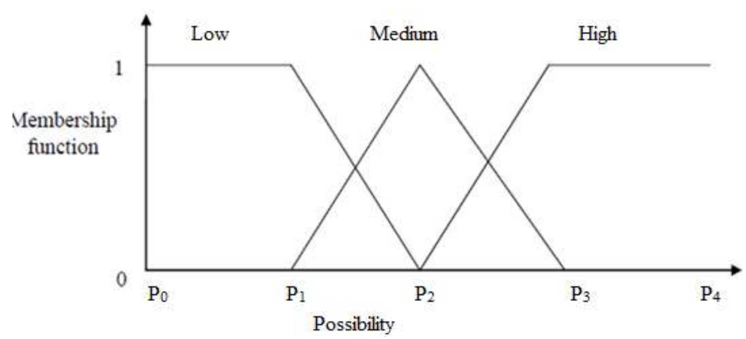

Fig. 10: Membership function for clusterhead selection possibility

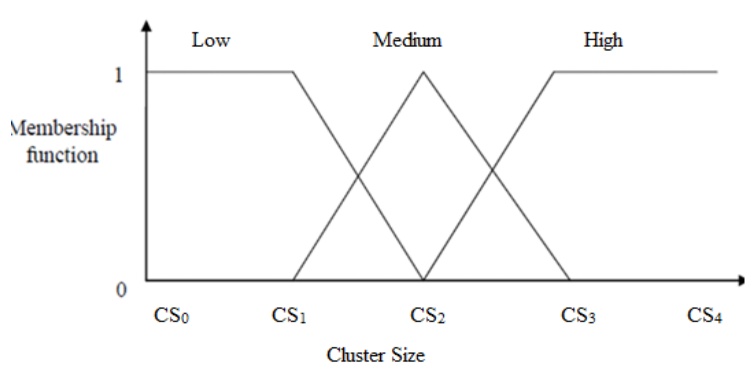

Fig. 11: Membership function for cluster size

Table 2: Fuzzy decision rules

Residual Energy (RE)	Distance (D)	Node Density (ND)	Load (L)	Possibility (P)	Cluster Size (CS)
Low	Low	Low	Low	Low	Low
Low	Low	Low	High	Low	Low
Low	Low	High	Low	Medium	Medium
Low	Low	High	High	Low	Low
Low	High	Low	Low	Medium	Medium
Low	High	Low	High	Low	Low
Low	High	High	Low	High	High
Low	High	High	High	Medium	Medium
High	Low	Low	Low	Medium	Medium
High	Low	Low	High	Low	Low
High	Low	High	Low	High	High
High	Low	High	High	Medium	Medium
High	High	Low	Low	High	High
High	High	Low	High	Medium	Medium
High	High	High	Low	High	High
High	High	High	High	High	High

In Table 2, RE, D, ND and L are given as inputs and the output represents the possibility for the node to be cluster head and cluster size. The fuzzy sets are defined with the combinations presented in Table 2.

Table 2 demonstrates the designed fuzzy inference system. This illustrates the function of the inference engine and method by which the outputs of each rule are combined to generate the fuzzy decision:

For example
Let us consider Rule 15.
If (RE, D and ND = High) and (L = Low)
Then
The respective node is chosen as the cluster head.
The estimated cluster size is high.
End if

Defuzzification: The technique by which a crisp values is extracted from a fuzzy set as a representation value is referred to as defuzzification. The centroid of area scheme is taken into consideration for defuzzification during fuzzy decision making process. The formula (9) describes the defuzzifier method:

$$\text{Fuzzy\_cost} = [\textstyle\sum_{allrules} f_i * \alpha(\text{fi})]/[\sum_{allrules} \alpha(f_i)] \quad (9)$$

where,
fuzzy_cost = Used to specify the degree of decision making
f_i = The fuzzy all rules and variable
$\alpha(f_i)$ = Its membership function

The output of the fuzzy cost function is modified to crisp value as per this defuzzification method.

Figure 2 demonstrates the cluster formation phase. CH_1, CH_2, CH_3 and CH_4 selected as cluster heads acts as aggregator nodes in our approach.

Cluster head updation: The lifetime of the network is estimated based on the operation time of the cluster head. This is directly proportional to the cluster head functionality and energy consumed. In order to minimize the frequency of cluster head updation, we utilize Best Uninterrupted Operational mechanism (BUO) of each cluster head.

As each node within the Cluster (C) functions as the cluster head once, the total energy consumption at time t is estimated using the following Eq. (10):

$$\mathrm{E}_t \approx x[(2x-1)(E_e+E_c)+E_{tx-a}(d_{avg}^2+(x-1)d^2)]z \quad (10)$$

where,
E_c = Energy dissipation for processing per bit
x = Number of nodes within the clusters (estimated based on Cluster size in section (Fuzzy based cluster head selection))
d_{avg} = Average distance from CH to BS

Thus lifetime of the cluster is estimated using the following Eq. (11):

$$\mathrm{LT}_c \approx \frac{E_i}{\left\{\left(2-\frac{1}{x}\right)(E_e+E_c)+E_{tx-a}\left[\frac{1}{x}d_{avg}^2+\left(1-\frac{1}{x}\right)d^2\right]z\right\}} \quad (11)$$

In order to maintain the balance in energy consumption, the uninterrupted operation time of each node which is acting as the cluster head needs to be equal. Thus the average uninterrupted operation time of each node is expressed using the following Eq. (12):

$$\mathrm{U}_{avg} \approx LT_c/x = \frac{E_i}{\{(2x-1)(E_e+E_c)+E_{tx-a}[d_{avg}^2+(x-1)d^2]\}z} \quad (12)$$

where,
E_i = Initial energy of the sensor node

In case a CH continuously functions till its energy supply gets exhausted, then the uninterrupted operation time U_t of the CH is given using the following Eq. (13):

$$\mathrm{U}_t \approx \frac{E_i}{\{(2x)(E_e+E_c)+E_{tx-a}*d_{avg}^2]\}z} \quad (13)$$

As per Eq. (12) and (13), $U_t > U_{avg}$ (x>1)

If (uninterrupted operation time of first CH≈U_t)
Then
E_{res} (CH) is low and it will expire.
LT≈U_t
End if

The above condition reveals that, if the uninterrupted operation time of first CH approaches U_t, the residual energy of CH is low and it will expire first. Using Eq. (11) and (13):

$$\nu = \frac{LT_c}{U_t} = \frac{x(E_e + E_c) + E_{tx-a} * d_{avg}^2}{\left(2 - \frac{1}{x}\right)(E_e + E_c) + E_{tx-a}\left[\frac{1}{x} d_{avg}^2 + \left(1 - \frac{1}{x}\right) d^2\right]} \quad (14)$$

If x>1, Eq. (14) becomes:

$$\nu \approx \frac{x(E_e + E_c) + E_{tx-a} * d_{avg}^2}{2(E_e + E_c) + E_{tx-a} * d_{avg}^2} \approx \frac{x}{2} \quad (15)$$

From Eq. (15), as ν increases, x also increases.

The above estimated equations give the following results:

- If n x>>1,
  Then
  $LT_c > U_t$
  End if
- If (uninterrupted operation time of first CH ≈ U_{avg})
  Then
  Each node will contain enough E_{res} for function as the normal node and remains alive till $U_t < U_{avg}$
  End if
- As the sensor nodes are randomly deployed, the distance among the nodes also varies in the random manner. Hence there is possibility that certain nodes may be alive and contains residual energy when the $U_t > U_{avg}$. Then E_i is replaced with E_{res} of the alive nodes. Thus a new U_{avg} is estimated using Eq. (12)
- When $U_{avg} \approx 1$, then the node with maximum E_{res} acts as the cluster head in the next cycle. Thus the LT_c becomes maximum
- If E_{res} of existing CH cannot function as CH in the next cycle, then it needs to be replaced by another cluster head. Then the existing CH functions as the normal node in the next cycle. This prevents network partitioning

This method of uninterrupted operational mechanism, the repeated updates of the cluster head and energy consumption for setting up the cluster head is minimized effectively. Also the network lifetime is maximized.

Table 3: Simulation parameters

No. of nodes	25, 50, 75 and 100
Area size	500×500
Mac	IEEE 802.11
Transmission range	250 m
Simulation time	50 sec
Traffic source	CBR
Packet size	512
Initial energy	10.3 J
Receiving power	0.395
Transmission power	0.660
Rate	50, 100, 150, 200 and 250 Kb

Advantages of this approach:

- It maximizes the lifetime by considering the cluster head assignment.
- This approach also considers the nodes local information like energy level and the distance between the node and the sink, node density during clustering.
- It focuses on energy efficient unequal clustering scheme and inter-cluster routing protocol which will maximize the lifetime.
- It performs load balanced clustering.

SIMULATION RESULTS

Simulation model and parameters: The Network Simulator (NS2 (Network Simulator: http:///www.isi.edu/nsnam/ns)) is used to simulate the proposed architecture. In the simulation, 50 mobile nodes move in a 500×500 m region for 50 sec of simulation time. All nodes have the same transmission range of 40 m. The simulated traffic is Constant Bit Rate (CBR).

The simulation settings and parameters are summarized in Table 3.

Performance metrics: The proposed Fuzzy Based Optimal Clustering Protocol (FBOCP) is compared with the EECA technique (Mina *et al*., 2009).

The performance is evaluated mainly, according to the following metrics.

Packet delivery ratio: It is the ratio between the number of packets received and the number of packets sent.

Packet drop: It refers the average number of packets dropped during the transmission.

Energy consumption: It is the amount of energy consumed by the nodes to transmit the data packets to the receiver.

Delay: It is the amount of time taken by the nodes to transmit the data packets.

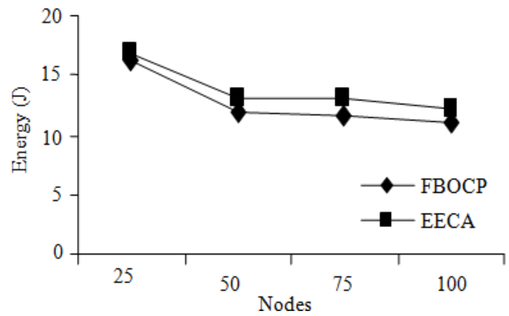

Fig. 12: Nodes vs. energy consumption

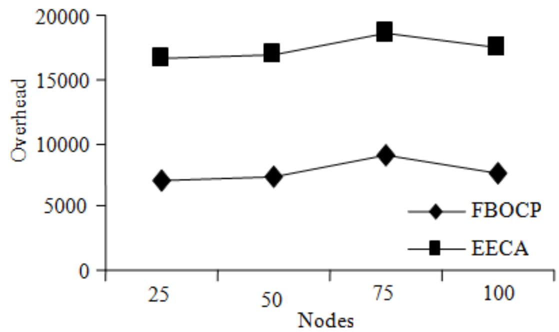

Fig. 13: Nodes vs. overhead

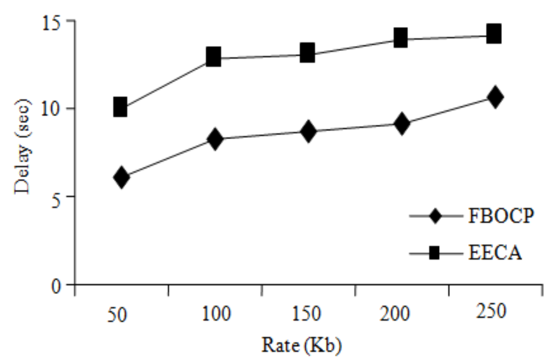

Fig. 14: Rate vs. delay

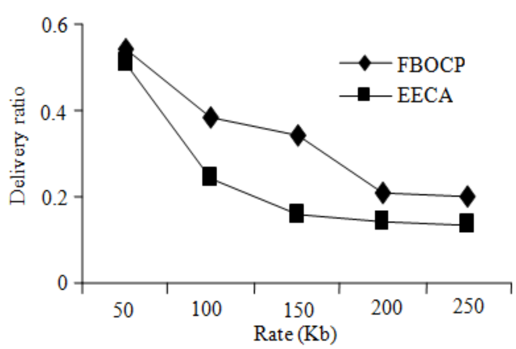

Fig. 15: Rate vs. delivery ratio

Overhead: It is the number of routing packets delivered by the receiver.

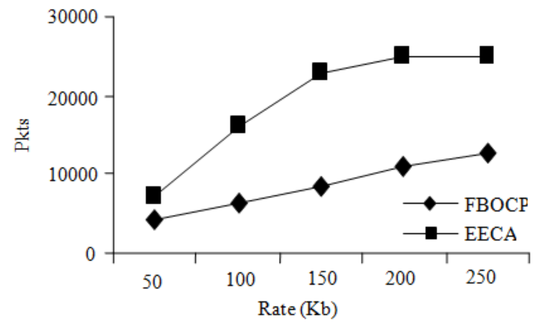

Fig. 16: Rate vs. drop

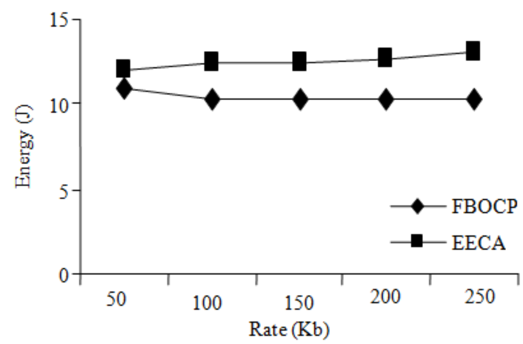

Fig. 17: Rate vs. energy consumption

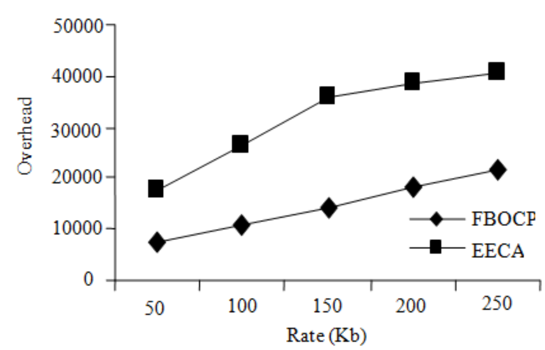

Fig. 18: Rate vs. overhead

Results:

Based on nodes: In our first experiment we vary the number of nodes as 25, 50, 75 and 100, respectively.

Figure 3 shows the end-to-end delay of FBOCP and EECA techniques for different number of nodes scenario. We can conclude that the delay of our proposed FBOCP approach has 38% of less than EECA approach.

Figure 4 shows the delivery ratio of FBOCP and EECA techniques for different number of nodes scenario. We can conclude that the delivery ratio proposed FBOCP approach has 16% of higher than EECA approach.

Figure 5 shows the packet drop of FBOCP and EECA techniques for different number of nodes scenario. We can conclude that the drop of our proposed FBOCP approach has 45% of less than EECA approach.

Figure 12 shows the energy consumption of FBOCP and EECA techniques for different number of nodes scenario. We can conclude that the energy consumption of our proposed FBOCP approach has 9% of less than EECA approach.

Figure 13 shows the overhead of FBOCP and EECA techniques for different number of nodes scenario. We can conclude that the overhead of our proposed FBOCP approach has 56% of less than EECA approach.

Based on rate: In our second experiment we vary the transmission rate as 50, 100, 150, 200 and 250 Kb, respectively.

Figure 14 shows the end-to-end delay of FBOCP and EECA techniques for different rate scenario. We can conclude that the delay of our proposed FBOCP approach has 33% of less than EECA approach.

Figure 15 shows the delivery ratio of FBOCP and EECA techniques for different rate scenario. We can conclude that the delivery ratio proposed FBOCP approach has 33% of higher than EECA approach.

Figure 16 shows the packet drop of FBOCP and EECA techniques for different rate scenario. We can conclude that the drop of our proposed FBOCP approach has 54% of less than EECA approach.

Figure 17 shows the energy consumption of FBOCP and EECA techniques for different rate scenario. We can conclude that the energy consumption of our proposed FBOCP approach has 21% of less than EECA approach.

Figure 18 shows the overhead of FBOCP and EECA techniques for different rate scenario. We can conclude that the overhead of our proposed FBOCP approach has 55% of less than EECA approach.

CONCLUSION

In this study, we have proposed fuzzy based optimal clustering protocol for maximizing lifetime in WSN. Initially, several provisional cluster heads are elected in a random manner. The nodes other than provisional cluster heads involve in gathering the neighbor nodes local information such as residual energy, distance, node density and network load. The collected information is fuzzified using fuzzy logic technique and appropriate cluster head and size are estimated. Based on uninterrupted operational mechanism of each cluster head, the cluster heads are updated, thereby reducing the frequency of cluster head updation. By simulation results, we have shown that the proposed technique enhances the network lifetime.

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