Performance Analysis of QoS Enhanced Cluster based Routing Protocols for Wireless Sensor Networks

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***Abstract*-In this paper, the optimization strategies of routing protocols are analysed with respect to energy utilization of sensor nodes in Wireless Sensor Networks (WSNs). Routing Protocols are in charge of discovering and maintaining the routes in the network. Different routing mechanisms have been proposed to address energy optimization problem in sensor nodes. Clustering mechanism is one of the most efficient mechanisms which cater to the requirements of energy conservation in wireless sensor networks. To check the efficiency of different clustering scheme against modelled constraints, we select five cluster based routing protocols; Low Energy Adaptive Clustering Hierarchy (LEACH), Threshold Sensitive Energy Efficient sensor Network (TEEN), Stable Election Protocol (SEP), Distributed Energy Efficient Clustering (DEEC), and Hybrid Energy Efficient Distributed protocol. To validate our mathematical framework, we perform analytical simulations in MATLAB by choosing number of alive nodes, number of dead nodes, number of packets, number of cluster heads, as performance metrics.**

I. INTRODUCTION

Wireless Sensor Networks (WSN) consists with huge tiny sensors that are arranged in spatially distributed terrain. Sensors can sense, compute, store, transmit and receive data of interests from the environment in which they are deployed. The sensor nodes are small, wireless and battery powered. Due to small size of sensors, a big size battery source cannot be embedded into them therefore sensors need efficient mechanism for energy utilization. Communication protocols are used to improve the life time of the sensors in wireless sensor networks. The design objective of these protocols is to reduce unnecessary data transmission and reception. For this purpose, the nodes are switched into idle or sleep mode when there is no data to transmit or receive. Routing and Medium Access Control (MAC) layer protocols are defined for efficient utilization of energy resources.

A Sensor Node (SN) consists of processor, sensor, transceiver, and power units. Sensor nodes face energy optimization problems in wireless sensor networks. Clustering is one of the mechanisms used in WSNs, which handles these issues efficiently. Two main components of clustered network are Base Station (BS) and Cluster Head (CH). The sensor nodes are located at minimum communication distance. Each cluster has its cluster head and all the nodes in the cluster are in accessible range of their respective cluster head. The sensor nodes sense the data from the environment and transmit to the cluster head, the cluster head aggregates data and sends the aggregated data to the Base Station. In this paper, we discuss the issues related to the energy limitation constraint with respect to the maximizing the network lifetime.

We perform analytical simulations in MATLAB. Performance parameters; number of alive nodes, number of dead nodes, number of packets and number of cluster heads. All of the Clustering Techniques consist of two phases; setup phase and steady state phase. In setup phase, cluster formation and CH selection are performed, while in steady state phase the data transmissions between nodes, cluster heads and base station are performed.

II. PROBLEM FORMULATION

Let a set of sensors; S*1*, ..., S*N*, with adjustable sensing ranges are deployed in a network. These sensors are alive for a specific number of round s, r*1* , r*2* , ..., r*k*, where K denotes the index for round number. To maximize network life time, K must be maximized in such a way that each sensor appearing in the sets r1, r2, ..., rk consumes at most E energy (E is the initial energy of the sensor nodes). Maximizing K is equivalent to maximizing life time of a network. The sensing range of sensors in terms of distance, d, determines energy consumption by the sensor during activation period of sensors. If a sensor participates in more than one set, then the sum of energy spent during network life time has to be at most E. Let us consider for this example E= 2, e1= 0.2, Cluster heads c**1**, c*2* , ..., c*M*, and Z sensing ranges p*1* , p*2* , ..., p*Z* and the corresponding energy consumption e1 , e2, ..., e*Z*. Initial relationship between sensor and CH: αizj = 1, if sensor s I with radius r z covers CH c ij . Some indexes are also used which are; i, I th sensor, j, j th CH, z, zth sensing range, and k, kth round. Some variables are also defined: r k , Boolean variable, fork= 1..K; r k = 1there are still alive nodes are present, other wiser k = 0, if. X ikz is a Boolean variable, for i = 1..N, k= 1..K, z= 1, ..., Z; x ikz = 1if sensor i with range p z is in cover k, otherwise x ikz = 0.

$$Max\ r1 + \cdots + rK \quad (1)$$

Subject to,

$$\sum_{k=1}^{k}\left(\sum_{z=1}^{z} XikzEz \leq E\right) \forall i = 1, \dots, N$$

$$\sum_{z=1}^{z} Xikz \leq Ck\ \forall i = 1, \dots, N \text{ and } \forall k = 1, \dots, k$$

$$\sum_{i=1}^{N}\left(\sum_{z=1}^{z} Xikz * \alpha izj \geq rk\right) \forall k = 1, \dots, k \text{ and } \forall j = 1, \dots, M$$

K represents an upper bound for the number of rounds. The first constraint assures that the energy consumed by each sensor i is less than or equal initial energy of each sensor. K, guarantees that, if sensor i is part of any round k then exactly one of its Z sensing ranges are set.

III.CLUSTER FORMATION IN PROTOCOLS

Clustering process consists of two phases.

***Setup state*:** In this state, cluster head selection is based on different parameters like initial energy of the node, remaining energy of the node, and the total network average energy. After CH selected that node advertises its status to the member nodes in the cluster using CSMA/CA MAC protocol. After receiving the status details from the member nodes the CH allotted TDMA based time slots to the non-CH nodes, so that they can communicate to their respective cluster heads.

Steady state: In this state, the non-CH nodes sense the data from the environment and transmit the data to CH, during allocated time slots by the CH. A Ch aggregates the data and sends to Base Station.

IV.CH Selection in Protocols

In Wireless Sensor Networks, cluster heads are used for data aggregation and transmission in such a way that more energy is conserved. With the help of CH selection criterion in protocols (homogenous or heterogeneous) may enhance the stability region and lifetime of the network.

A. LEACH

LEACH is a single hierarchical level protocol for homogenous networks. All the nodes in the network have same initial energy. LEACH follows the self organizing and adaptive CH selection criteria. In setup phase, CH is selected based on the following threshold equation,

$$T(n) = \begin{cases} \frac{P}{1-p\left(r*mod\,(1/p)\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (2)$$

Where, P is the desired number of CHs, r is the current round and G is the set of nodes that have not been CH in the current epoch. Epoch is the number of rounds for a CH, after which again it become eligible to become a CH.

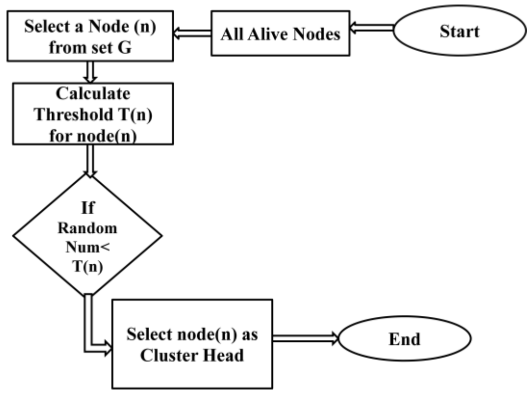

Fig 1. Flow chart of CH selection in LEACH protocol

Each node generates a random number between 0 and 1, if the number is less than the node's threshold, then the node becomes a CH. Each CH advertise its status using CSMA-CA MAC protocol. All nodes send their membership willingness message to the suitable CH. Then CHs schedule all nodes using TDMA for data transmission. In steady state phase, the transmissions are performed.

B. TEEN

TEEN is targeted at reactive networks. The CH selection in TEEN is based on two threshold values;

Hard Threshold: This is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report its cluster head.

Soft Threshold: This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit.

Closer nodes from clusters, with a cluster heads to transmit the collected data to one upper layer. Forming the clusters, cluster heads broadcast two threshold values. First one is hard threshold, it allows nodes transmit the event, if the event occurs in the range of interest. Therefore a significant reduction of the transmission delay occurs. Unless a change of minimum soft threshold occurs, the nodes don't send a new data packet. Employing soft threshold prevents from the redundant data transmission. Since the protocol is to be responsive to the sudden changes in the sensed attribute, it is suitable for time-critical applications.

C. SEP

SEP improves the stable region of the clustering hierarchy process using the characteristic of heterogeneity; fraction of advanced nodes and the additional energy factor between advanced and normal nodes.

In order to prolong the stable region, SEP attempts to maintain the constraint of well balanced energy consumption. Advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. For this purpose, a weight is assigned for individual probabilities for election of CHs for advance and normal nodes. Therefore SEP gives two different threshold formulae,

$$T(Snrm) = \begin{cases} \frac{Pnrm}{1-Pnrm\,(r*mod\,(1|Pnrm\,))} & if\ Snrm \in G' \\ 0 & otherwise \end{cases} \quad (3)$$

where, *G'* is the set of normal nodes which can become CH.

$$T(Sadv) = \begin{cases} \frac{Padv}{1-Padv\,(r*mod\,(1|Pnrm\,))} & if\ Sadv \in G'' \\ 0 & otherwise \end{cases} \quad (4)$$

Where, G'' is set of advance nodes, which can become CH.

D. HEED

Hybrid Energy Efficient Distributed clustering protocol extends the basic scheme of LEACH by using residual energy as primary parameter and network topology features are only used as secondary parameters to break tie between candidate cluster heads, as a metric for cluster selection to achieve power balancing. The clustering process is divided into a number of iterations, and in each iterations, nodes which are not covered by any cluster head double their probability of becoming a cluster head. Since these energy-efficient clustering protocols enable every node to independently and probabilistically decide on its role in the clustered network, they cannot guarantee optimal elected set of cluster heads.

Each node perform neighbour discovery, and broad casts its cost to the detected neighbours. Each node sets its probability of becoming a cluster head, CH*prob*, as follows:

CH*prob*= max(C*prob(E*residal*/E*max*), P*min*)(5)**

Where, C*prob* is the initial percentage of cluster heads, While E*residual* and E*max* are the residual and the maximum energy of a node (corresponding to the fully charged battery), respectively. The value of CH*prob* is not allowed to fall below the threshold P*min*.

E. DEEC

DEEC is a distributed clustering scheme for heterogeneous wireless sensor networks. In DEEC the cluster heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster-heads for nodes are different according to their initial and residual energy. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the nodes with low energy. DEEC introduces multi-level heterogeneity for maximizing K. The nodes having greater residual energy have more right to become a CH. Therefore, CH formation in DEEC is based on residual energy of entire network and residual energy of the node that wants to become a CH.

Therefore, DEEC calculate optimum number of CHs for each round from the following two equations.

$$P(i) = \begin{cases} \frac{PoptEi\,(r)}{(1+am\,)E'(r)} & if\ Si\ is\ normal\ node \\ \frac{Popt\,(1+a)Ei(r)}{(1+am\,)E'(r)} & if\ Si\ is\ advanced\ node \end{cases} \quad (6)$$

Where, E (r) is the average energy of the network at round r and is given by

$$E^{'}(r) = \frac{1}{N}\sum_{i=1}^{N} Ei(r)$$

Ei(r) is the residual energy of the node at round r.

V.SIMULATION RESULTS

To evaluate the performance of the selected protocols against maximizing objective function K, analytical simulation were performed in MATLAB. For N, 100 nodes are randomly scattered in network field of 100mm area. BS is placed at the centre of the network field. In order to obtain more realistic results, we adjust the heterogeneity level for different routing protocols according to their proposed model. For energy dissipation characteristics, adopted first order radio model.

Fig.2 shows stability period and network lifetime of the network for all routing protocols with respect to dead nodes in r*k* number of nodes. Results show the instability and value of k of the network. The instability faced by routing protocols SEP has minimum and TEEN has maximum unstable region. Successful data delivery at base station is an important factor to analyze quality of routing protocol and it depends upon value of initial energy. If base station is receiving high data means routing protocols working properly.

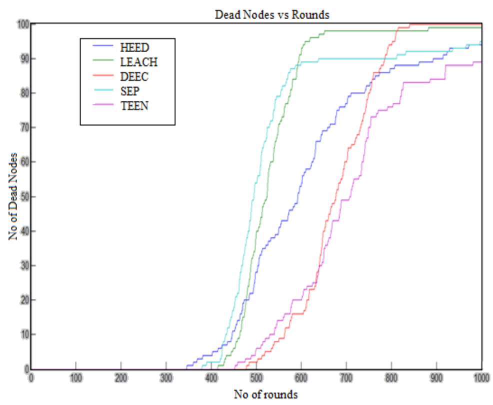

Fig.2 Dead Nodes vs Rounds

Fig.3 shows the comparison of every protocol for number of packets that are sent to base station. Result shows that DEEC has highest successful data rate, as compare to other routing protocols. It is because of shorter value of K in LEACH and SEP, as compare to DEEC. However, TEEN has better network lifetime, as compare to DEEC. However its execution provides low data delivery, as compared to DEEC. Reason behind this unusual result is limited transmissions of TEEN. DEEC, is time based routing protocol and it has to transmit data continuously. While TEEN is threshold based and have limited information to share with base station.

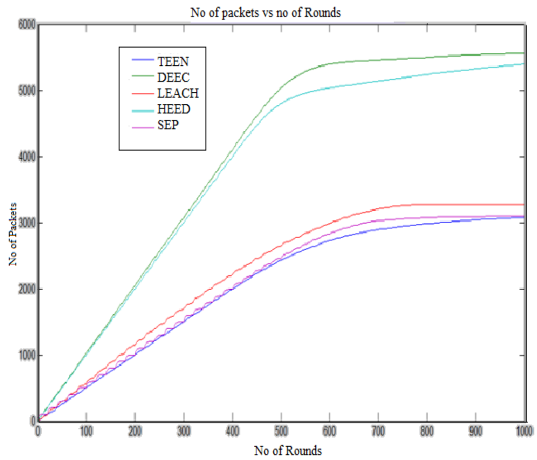

Fig.3 No of packets vs Rounds

Fig.4 depicts the number of cluster head which are selected in each round. These all routing protocols are utilizing distributed algorithm for selection of CHs. A main challenge faced by clustering routing protocols is their un-reliable distributed algorithm of selection of cluster heads. DEEC and TEEN mostly generate CHs above required average of CHs. Distributed algorithm generate un-even number of CHs for every round that can be disturb performance of network where optimal number of cluster heads are necessary enhance network's life.

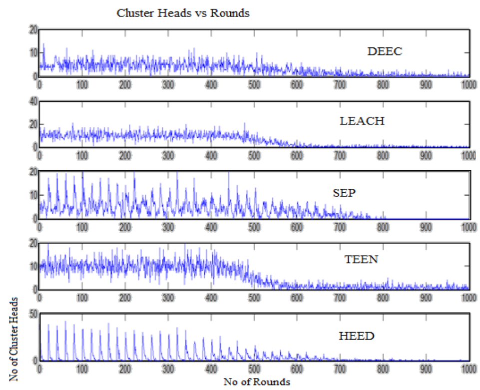

Fig.4 Cluster Heads vs Rounds

Aggregation efficiency is known as the Cluster Head collected the data from the nodes which are placed within its coverage region are processed and then transmitted to Base Station. If the aggregation efficiency is higher than the lifetime of the network will be considerably lower. TEEN has a very good lifetime but its aggregation efficiency is less. In the case of DEEC the aggregation efficiency is high but the lifetime of the network is less than TEEN.

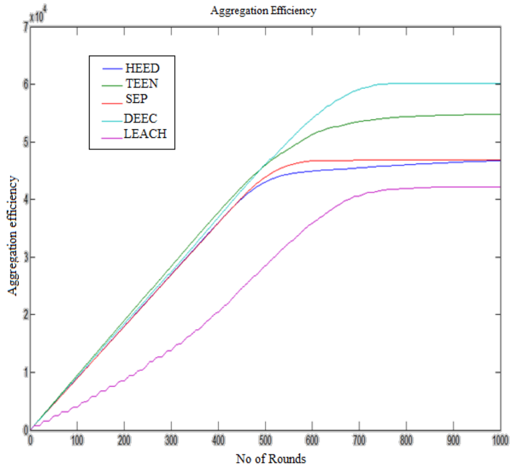

Fig.5 Aggregation Efficiency

VI. CONCLUSION

Energy optimization and efficient route discovery are challenging issues in Wireless Sensor Networks. To check the feasibility of different clustering techniques against modelled framework, select LEACH, TEEN, SEP, DEEC and HEED. It is concluded from our analytical simulation results that DEEC is the most energy efficient protocol for heterogeneous node energy network. However TEEN is more energy efficient and attain highest value of K due to its hard and soft threshold based communication. The energy consumption of TEEN is better than others due to its less data transmission to BS. In HEED all nodes are equipped with same initial energy. As the lifetime of sensor networks is limited there is a need to re-energize the sensor network by adding more nodes. Whereas, DEEC is efficient in sending maximum information to BS.

SEP is good in selection of optimum number of CHs, and therefore produces small variations in CH selection. Thus overall DEEC outperforms among selected protocols by providing feasible optimum solutions against constraints of modelled frame work.

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