Energy Aware Data Aggregation in Wireless Sensor Network

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***Abstract*— Wireless sensor networks (WSNs) have attracted many researcher due to its wide range of application and benefits. Most of researchers take care about energy parameter of WSNs. To increase life time and for saving energy, Data aggregation plays very important role. Many data aggregation approaches are introduced but cluster-based data aggregation protocols are most popular because of its benefits. This paper address the unbalanced energy dissipation in cluster based homogeneous, reactive WSNs in which Cluster heads (CHs) transmits data to Base Station (BS) via multi-hop, proposes an energy aware data aggregation. Algorithm also introduce some technics which save the energy of sensor nods. We simulate our protocol and it give better performance than LEACH, TEEN and WB-TEEN in terms of energy consumption, network life time and energy dissipation.**

Keywords—wireless sensor network; data aggregation; clustering; energy-efficient; network lifetime; balanced energy dissipation

I. INTRODUCTION

Collection of hundreds or thousands of sensor node is known as sensor network[1], which is communicate to gather to achieve particular task. Advance research in Micro-Electro-Mechanical Systems (MEMS) provides the mechanism for development of smart sensors. Sensor nodes are tiny in size, have limited processing and computing power, very low communication and storage capabilities. We have variety of sensors which are capable to measure properties of the environment. One or more sensors are attached with WSNs node. WSNs nodes are deployed in the remote area through wireless links. Today many applications are use WSNs for security, monitoring and other purpose [2].

According to their operating mechanism and targeting application, sensor networks are classified in to two types [3].

(1) *Proactive Networks*: It is fishable for the applications which require monitoring the environment at regular interval because in this type of network, the sensor nodes, at regular interval, sense the environment of interest, switch on the transmitter and transmit the data of interest.

(2) *Reactive Networks:* It is fishable for the application which is time critical because in this type of sensor network, nodes react immediately to sudden and drastic changes in the environment of interest.

For creation of wireless sensor network, we first deploy the nodes as required by application and nodes form a network using short–range wireless communication. Generally WSNs are used in a harsh environment and so generally we can't have deployment control over it. Given large area to be covered, the small battery life, and possibility of having damage during deployment, hundreds or thousands of sensors are expected in WSNs. Most of applications of WSNs is attribute gathering, i.e. sensor node sense environment and transmit required attribute in single or multi-hope manner to Base station. Most of applications are interested in correlated data of the sensor measurements at BS instead of collecting attributes from all nodes. As we stated above there is high density of nodes are present in WSNs, it is likely that information are co-related or redundant. Due to this type of data, in a WSNs data aggregation plays a major role. By data aggregation one can combine the data at intermediate node and can present high quality of information. Such kinds of capability of WSNs are known as aggregation capacity for WSNs [4].

We can categorize routing protocols that support data aggregation in two categories Based on network structure. (1) Hierarchical routing: In this topology, based on requirement, nodes form a cluster. Each cluster has CH which act as leader and that CH perform the collection and aggregating the data packet and forward that packet to BS. (2) Flat routing: In this topology data transmission is done hope by hope, in the form of flooding. Flooding and Gossiping, Direct Diffusion is examples of a flat routing.

The organization of the paper is as follows: section II elaborates the related work. In section III, we present problem statement and objective followed by propose protocol. Section IV discusses simulation results and analysis, and finally we present our conclusion in section V.

II. RELATED WORK

Previous research shows that Hierarchical routing protocols are more energy efficient protocols than flat base routing. Data aggregation methods in hierarchical routing are

A. Chain based data Aggregation [11]

In this method energy efficient chain is created for data transmission. Different researchers have proposed different algorithm for chain based data aggregation. For chain based data aggregation algorithm, all nodes in network must know the location of other nodes in the network. In this technique data is transmitted to its near neighbor. To determine the nearest neighbor, signal strength is used. Collected data travels

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on network, aggregated at each node and only chosen nodes transmit data to a base station. All nodes periodically get turn on for transmit the data to base station so that power consumption for transmitting the data is distributed among the all nodes.

B. Grid based Data Aggregation

In grid based data aggregation, network is divided in the grid and each grid has fixed aggregator node and that node performs the data aggregation. Based on the geographical position, an aggregator is selected. In this type of network node does not communicated with each other, only communicate whit aggregator node [6].

C. Tree based Data Aggregation

In tree based data aggregation, tree is form to aggregate the data. This type of aggregation technique is used when we want combine data from all nodes like radiation effected area and other application. In this concept, tree is formed and data aggregation is done at each intermediate note and aggregated data is transfer toward the root node [5 original and 14-15/04062839].

D. Cluster based data Aggregation

In Cluster based data aggregation technique, group of node form a cluster and one leader node, known as cluster head, aggregate the data and transmit it to base station. Usage of this method reduces the amount of data transmitted to base station and so it increase the life time of network. Clustering routing protocol become popular due to its grate advantage like data aggregation/fusion, robust, more scalability, energy friendly etc.

Manly two phase are present in each round of clustering process. Two rounds are 1 cluster set up phase and 2 steady phase. In cluster set up phase, in centralized or distributed manner, the CHs are elected and then clusters are formed. In steady phase, member nodes send their measurements to CH, CH perform aggregation function and then they transmit aggregate information to BS.

LEACH [6] is most benchmark clustering protocol for homogeneous network. In leach protocol, cluster heads are elected in a distributed manner based on the number of times the node has been a CH so far and the random number which is known as probability. In leach nodes directly communicate with base station. . In EEBCDA [7], for CHs selection, residual energy level is consider. This protocol solve the problem of unbalanced energy dissipation. The network is divided into unequal size rectangular grids and CH rotate among the node in each grid respectively. The CH transmits data to BS in single hop communication. In GCEDA [8], BS selects the CHs based on the parameter like highest energy, node with highest neighbor, and small distance with BS. The nodes are uniformly distributed in this protocol. In this protocol, further, CHs are grouped according to available data from each CH to perform the further aggregation. This task is done to reduce the data and so small amount of packet sent to BS and which lead to low energy consumption, and due to this network life time will increase. In CEEC [9], the network model contains nodes which are heterogeneous in terms of energy. The energy level of the nodes is increases with increase in the distance of nodes from BS. BS selects optimum number of CHs based on four parameters initial energy of node, residual energy of nodes, average energy of each region and location of nodes. The CHs directly communicate to BS by one hop communication. In TEEN [2], Sensor node sense their environment rapidly, but it also check some condition over sense data and transmit sense data if certain condition full fill by data so the energy usage is less than that in the proactive network, because data transmission in some conation only. The CHs are selected same as LEACH protocol and they transmit the data to BS in multihop fashion for homogeneous network. APTEEN [10] is improvement of TEEN protocol. APTEEN is suitable for both proactive and reactive environments. WB-TEEN [11] is an improvement of protocol TEEN which enables clusters balancing; it avoids clusters formation with a significant difference in size. All clusters have almost the same number of member nodes. The CHs directly communicate to BS by one hop communication.

III. PRAPOSED PROTOCOL

A. Problem Statement and Objective

The Algorithms that are exists in literature have following drawbacks.

1) In above protocol, All nodes are raise there hand to become CHs and due to this high compitition occurs and it leads to high energy dissipation.

2) All CHs communicate with base station in a single hope manner and due to this more energy is used. For large seneore network it's a big disavantage.

3) All CHs has not same members, some CHs has more member nodes and some CHs has less member nodes which leads to unbalanced energy consumption.

4) There is unbalanced energy dissipation because the distances of transmitted data of CHs in different region are different and due to that stability period is less.

So, our goal to devlop a neew protocol is to develop cluster based data aggregation protocols in which there is no compitition among the nodes to become a clustere head. Second, the CHs communicates with BS in a multihope so that it is also suatable for large network. Third, All CHs has aproximatelly same number of member. It should be have high stability period.

B. Assumptions

To build a proposed network model for cluster based data aggregation the node and network level assumptions are

1) Node Assumptions

- Initially all the nodes are homogeneous in terms of energy.
- CH decides the matter of concerned value from data packets coming from the nodes.

2) Network Assumptions

- The BS, CH and nodes are static after deployment.

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- The Links between CH and nodes are unidirectional.

C. Network Model

Normally, in sensor network nodes are randomly dispersed without any deployment management in network area. The node deployment is very promising task but we can solve this problem by dividing whole network area in to multiple logical regions. The proposed network model contains nodes which are homogenerous in terms of energy.

Total N nodes are dispersed in the whole network. The BS is above the deployment area along Y-axis. Figure 1 shows the network model.

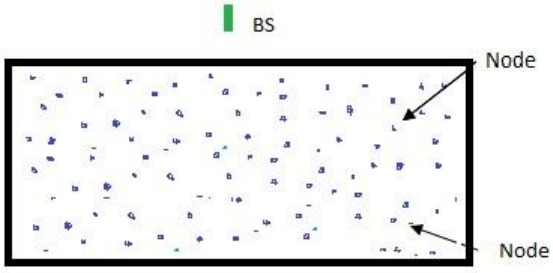

Figure 1. Network Model

The energy assigned to nodes is E. So, the total number of node in network is

$$N \quad (1)$$

The total Energy of all nodes E_n is

$$E_n = N \times E \quad (2)$$

In this way, Total energy of network E_t is

$$E_t = N \times E \quad (3)$$

D. Set-up Phase

In set-up phase, main task is selection of CHs and formation of clusters. In our proposed protocol, BS selects the CHs in initial round as it has information about initial energy and location of all nodes.

In our proposed clustering algorithm, three factors are keep in mind to select CHs which are: initial energy of nodes, remaining energy of nodes, and location of nodes for selection of CHs. Initially, BS knows the initial energy and location of all nodes so it randomly selects the nodes as CHs based on location. These CHs are selected in such way that they are apart from each other. The total numbers of CHs are determined as 8 to 12 % of total number of nodes N. BS selects Head of CH (HCH) from the CH who have high energy and almost equal distance from other near CH. The total numbers of HCHs are determined as 32 to 36 % of total number of CH nodes. Now, BS broadcast the CHs and HCHs id to all other sensor nodes. The other node will join the closest CH. The CH will join the HCH which is near to it.

After the initial round, for each subsequent round the CHs and HCHs are selected by the cooperative work of the last round CH (LR_CH) and last round HCH (LR_HCH). While at the last time of data gathering round, every member node transmit its residual energy information along with its data to CH. All the LR_CH sorts all nodes according to its remaining energy in its cluster and chooses the CH which has highest energy for the next round. So LR_CH chooses CH for next round called as Next round CH (NR_CH). Once the CHs have been selected, each CH broadcasts message to inform other nodes.

Similarly, the HCHs for the next round (NR_HCH) will be selected by the cooperative work of the HCDs of last round (LR_HCH). While at the last time of data gathering round, every CH has already information about node which has highest energy level so they send this remaining energy level along with aggregated packet to HCH. Now, HCH sorts remaining energy level of NR_CH and chooses the NR_HCH which has highest energy for the next round. So LR_HCH chooses HCH for next round. Once the HCH is selected, they unicast message to CH.

For becoming a member, node sends the request to nearest CHs. If CH has no more members than it rejects the request and that node join another CH.

E. Data transmission Phase

In This phase we use concept of hard threshold and soft threshold which is similar to TEEN protocol. In this concept, the CH broadcasts two threshold values Hard Threshold (HT) and Soft Threshold (ST). If sense value is greater than soft threshold and difference between previous sense value and current sense value is greater than soft threshold then only, sensor send the data to the CHs. So, ST threshold further reduce the number of transmissions. For the first round, if the sensed value is greater than HT then it is stored in an internal variable called as sensed value (SV). Whenever node transmits the data, SV is set equal to the current value of the sensed attribute. Thresholds value are determine according to application. Depending upon application to application, values of HT and ST are varies.

Each member node always transmit the control packet to CHs. For next round CH selection, there is information regarding remaining energy of node in control packet and according to that remaining energy CH is selected. Even if thresholds are not satisfied, the nodes send only remaining energy level to CH. Similarly, for next round HCH selection, each CH has information about which node has highest residual energy and they will send this information along with the data packets to HCH of last round.

The CHs aggregate the data from all sensor nodes which are in cluster. The CH applies average function if sense values are same. If values are different then it may apply maximum, minimum or sum aggregation function. So, depending upon the application the matter of concerned value is transmitted. Now, to further perform inter cluster aggregation, the CH send the aggregated data to their HCH. The HCH collect data from all CHs, aggregate it and send fused information directly to BS.

Along with the data, the HCH also send residual energy information so that the user can know the status of the

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network. So even if thresholds are not reached the BS will get at least energy level of network. From this information the user can ensure that the nodes are alive.

F. Energy Consumption Model

We have used first order radio model for energy calculation. If the distance between the transmitter and receiver sensor node is less than a threshold distance d_0, the free space model is used as shown in (5), if not the multipath model is used as shown in (6). So, the energy spent for transmitting a k-bit message over distance d is,

$$ETX(k,d) = kE_{elec} + kE_{fs}d^2, \text{ if } d<d_0 \quad (5)$$

$$ETX(k,d) = kE_{elec} + kE_{mp}d^4, \text{ if } d>=d_0 \quad (6)$$

Where E_{elec} is the per bit energy dissipated to run the transmitter or the receiver circuit, E_{fs} or E_{mp} is the energy dissipated per bit to run the transmit amplifier. To receive this message, the energy used is as shown in (7),

$$ERX(d) = kE_{elec} \quad (7)$$

The consumed energy for aggregating m messages with k-bit is as shown in (8),

$$EA(m, k) = m \times k \times EDA \quad (8)$$

Where EDA is the energy required to aggregate message signal per bit.

IV. Simulation and Analysis

The proposed algorithm introduces a novel CHs selection scheme in which for the initial round the CHs and HCHs are selected by the BS and for the subsequent round the CHs and HCHs are selected by the cooperative work of sensor nodes.

The propose algorithm adopts following measures to enhance energy efficiency.

- First, except the first round, CHs and HCHs are selected by the LR_CHs and LR_HCHs, so there is no more competition of nodes to become CH.
- Second, the necessary parameters for selecting CHs and HCHs like residual energy of node are transmitted along with sensed measurements.
- Third, each member node join to the closest CH and CH join to the closest HCH. If CH or HCH has more than certain number of members than it rejects node and that node join with another CH.
- We perform two level of data aggregation 1 at CH and another at HCH so that number of packets which sends to BS is reduce and energy can be saved. Also we perform two hope communication and node does not communicate with BS directly which also useful to reduce the energy consumption.
- Fifth, the HCH which are far away from the BS drain more energy as compare to the HCH which are near to BS. So in order to balance the energy dissipation, the proposed heterogeneous network model dispersed the nodes with increasing order of energy in network. So, it brings the equal distribution of resources with respect to responsibility of nodes.
- Sixth, In reactive protocol with the concept of threshold, if threshold is not satisfied than node will note communicate with BS and so this reason BS does not know about the state f nodes. The proposed algorithm, solve this problem by sending energy level to BS even if thresholds are not reached. So the user can ensure that the nodes are alive.

For the simulation, we have used MALAB simulator. Table 1 shows the simulation parameters. We take 100 sensor nodes.

TABLE I. Simulation Parameters

Parameters	Values
Surface of deployment	(0,0)*(100,100)
Position of the base station	(50,175)
Number of sensors	100
Initial Energy of sensors	0.5 J
Size of control Package	8 bytes
Size of data Package	512 bytes
Transmitter/Receiver Electronics Eelec = Etx = Erx	50nJ/bit
Data Aggregation Energy EDA	5nJ/bit/signal
Transmit amplifier ($d<d_0$) E_{fs}	10pJ/bit/m^2
Transmit amplifier ($d>=d_0$) E_{mp}	0.0013pJ/bit/m^4

First of all, we measure the lifetime of the network. Figure 2 gives the number of alive nodes over rounds. As evident from the figure, EACAD has a longer network lifetime than LEACH and WB-TEEN. The first node of LEACH, WB-TEEN and EECAD dies in the 273rd round, 290th and 1483th round and the last node dies in 1427th round, 1481th and 1557th round, respectively. After 1205 rounds the numbers of alive nodes of LEACH, WB-TEEN and EECAD protocols are 19, 35 and 100 respectively. In EACAD protocol, the energy used by all nodes in every round is nearly same. So when the first node is die, all nodes are die within less number of rounds. There is higher improvement in stability period of EACAD protocol compare to LEACH and WB-TEEN.

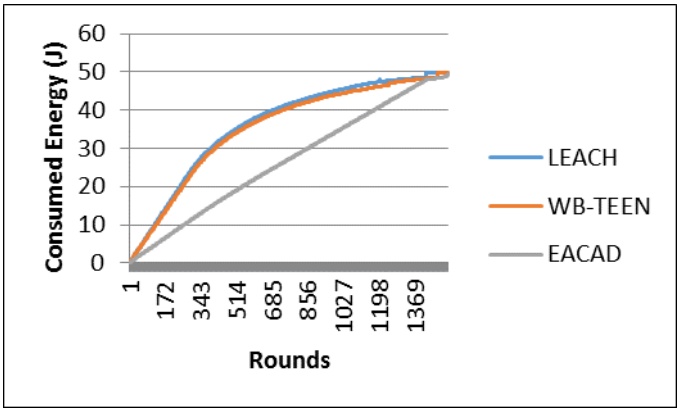

Figure 2. Number of Alive nodes in Various Protocols

Secondly, we compare the energy dissipation of LEACH, WB-TEEN and EACAD protocols. We take statistics of the

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total consumed energy of whole network over rounds, as shown in Fig 3. It is explicit that EACAD has more residual energy than LEACH and WB-TEEN in every same round, which shows that EACAD is more energy efficient than LEACH and WB-TEEN. The total consumed energy of LEACH, WB-TEEN and EACAD protocols after 1205 rounds are 48.1513 J, 46.1945 J and 38.5896 J respectively. EACAD algorithm provides an improvement of 15.10% and 11.80% in energy consumption as compared with primary cluster based protocol LEACH and WB-TEEN respectively. We have calculated the ratio of time interval between the time when the first node dies and the time when the last node dies to the full time of network. It indicates the balanced extent of energy dissipation, and the protocol with smaller ratio has a better performance in balancing energy dissipation. The values of this ratio of LEACH, WB-TEEN and EACAD are 0.81,0.8 and 0.1, the result of contrast shows that EACAD is able to achieve more balanced energy dissipation than LEACH and WB-TEEN.

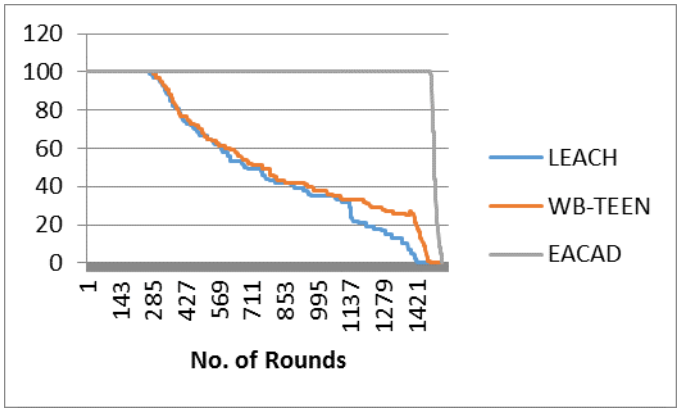

Figure 3. Energy Consumption by Various Protocols

The Figure 4 and 5 shows the comparison graphs of three protocols LEACH, WB-TEEN and EACAD with increase in network diameters from 100 to 200 meters with fixed number of nodes. As shown in Figure 4, the first node of LEACH, WB-TEEN and EACAD dies in the 51st round, 55th and 1005th round and the last node dies in 851th round, 882th and 1125th round, respectively. After 700 rounds the numbers of alive nodes of LEACH, WB-TEEN and EACAD protocols are 01, 26 and 100 respectively.

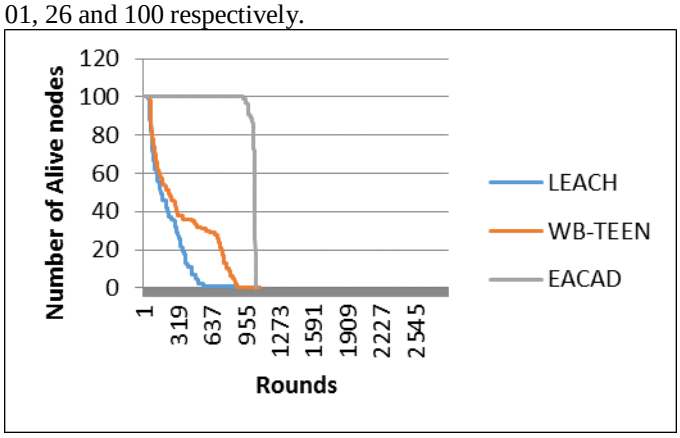

Figure 4. Number of Alive nodes in Various Protocols with increase in Network Diameter

The number of packets transmitted to BS in LEACH and WB-TEEN protocols are less compare to EACAD protocol due to early expiration of nodes with increase in distance between them. As shown in Figure 5, the total consumed energy of LEACH, WB-TEEN and EACAD protocols after 700 rounds are 49.6434 J, 45.5924 J and 33.6274 J respectively. So with increase in the network diameter, our proposed EACAD algorithm provides an improvement of 29.57 % and 24.06 % in energy consumption as compared with LEACH and WB-TEEN protocols respectively. The values of balanced expenditure ratio of LEACH, WB-TEEN and EACAD are 0.94, 0.93 and 0.12. So, EACAD is able to achieve more balanced energy dissipation than LEACH and WB-TEEN with increase in network diameter.

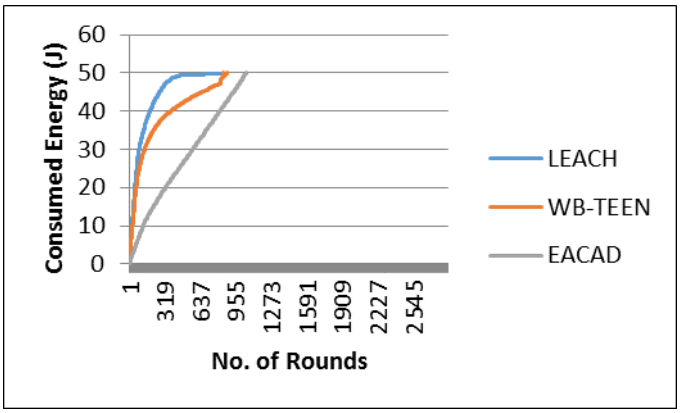

Figure 5. Consumed Energy in Various Protocols with increase in Network Diameter

V. Conclusion

We focused on Energy consumption and mainly on problem of unbalanced energy dissipation in cluster based WSNs. Simulation result shows that our proposed algorithm are better in terms of energy consumption as compared with other WSNs cluster based protocol. Our proposed protocol has high stability period. We found that proposed protocol is also give better performance with respect to existing protocol with increase diameter.

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