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Evaluation of Various Data Aggregations Techniques for Energy Efficient Wireless Sensor Networks

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Abstract*— the quick growth in network multimedia equipments have allow additional real-time digital services such as video-conferencing, online games and distance education to develop to be the standard internet tasks. WSNs is now major part of research in computational theory because wide variety of applications. But due to limited battery power consumption has become major limitations of WSNs protocols. Though many protocols has been proposed so far to improve the energy efficiency further but still much enhancement can be done. This paper has presented various data aggregation techniques for WSNs. This paper has shown that the among others GSTEB has shown quite significant results.The general objective of this paper is to evaluate the limitations of the earlier techniques of data aggregation. This paper ends up with the suitable future directions to extend GSTEB protocol further

Index Terms*— WSNs, GSTEB, DATA AGGREGATION, ENERGY.

I. INTRODUCTION

A wireless sensor network (WSN) comprises of hundreds to thousands of low-power multi-functional sensor nodes, doing work within an unattended environment, and having sensing, computation and communication capabilities. The fundamental areas of a node certainly are a sensor unit, an ADC (Analog to Digital Converter), a CPU (Central processing unit), an energy unit and also a communication unit. Sensor nodes are micro-electro-mechanical systems (MEMS) that create calculable reaction to a modification of some physical condition like temperature and pressure. Sensor sense or measure the physical data with the area to become monitored. The repetitive analog signal sensed through the sensors is digitized by an analog-to-digital converter and delivered to controllers for further processing. Sensor nodes are of smaller size, use extremely low energy, are operated in high volumetric densities, which enable it to be independent and adaptive towards environment.

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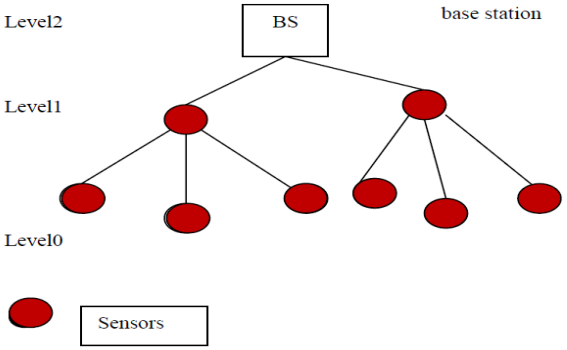

A Wireless Sensor Network structure is shown in Figure-1

The spatial density of sensor nodes within the field might be around 20 nodes/ m^3. As wireless sensor nodes are generally smaller electronic gadgets they may only be well prepared having a limited power source. Each sensor node carries a certain part of exposure for the purpose it may and properly report the specific quantity that it must be observing. Some reasons for power consumption in sensors are: (a) signal sampling and conversion of physical signals to electrical ones; (b) signal conditioning, and (c) analog-to-digital conversion.

II. DATA AGGREGATION TECHNIQUES

In typical WSNs, sensor nodes are generally resource-constrained and battery-limited. Just to save resources and energy, data have to be aggregated to prevent overwhelming variety of traffic within the network. There have been extensive concentrate on data aggregation schemes in sensor networks. The objective of data aggregation is the fact that eliminates redundant data transmission and enhances the duration of energy in wireless sensor network. Data aggregation is the procedure of just one single or several sensors then collects the detection be described as a consequence of other sensor.

It has to techniques

1. Data aggregation
2. Non data aggregation

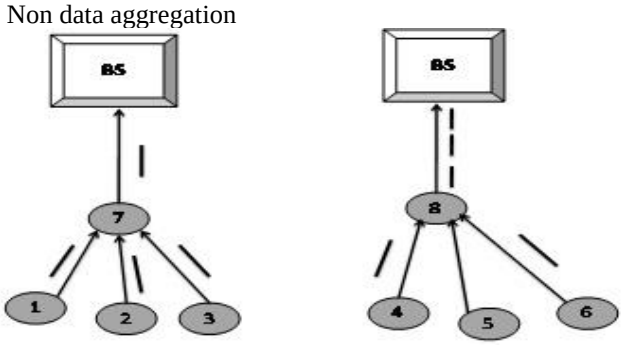

Figure.2. Data aggregation model and Non-data aggregation model

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The collected data needs to be by sensor to relieve burden before these are towards base station or sink. The wireless sensor network has consisted three different types of nodes: Simple regular sensor nodes, aggregator node and querier. Regular sensor nodes sense data packet through the environment and send towards the aggregator nodes basically these aggregator nodes collect data from multiple sensor owned by the network, aggregates the data packet with a couple of aggregation functions like sum, average, count, max min after which sends aggregates cause upper aggregator node or perhaps the querier node who generate the query.

There are numerous kind of data aggregation approaches to WSN:

2.1. Cluster-Based Approach: In energy-constrained sensor networks of enormous size, it could be inefficient for sensors to supply the data straight away to the sink. Cluster based approach is hierarchical approach. In cluster-based approach, whole network is divided in to many clusters. Each cluster possesses a cluster-head which is obviously selected among cluster members. Cluster-heads do the role of aggregator which aggregate data received from cluster members locally after which transmit the cause base station (sink). Recently, several cluster-based network organization and data-aggregation protocols have already been completely proposed for anyone wireless sensor network. Figure 3 shows a cluster-based sensor network organization. The cluster heads can communicating with the sink directly via long range transmissions or multi hopping through other cluster heads.

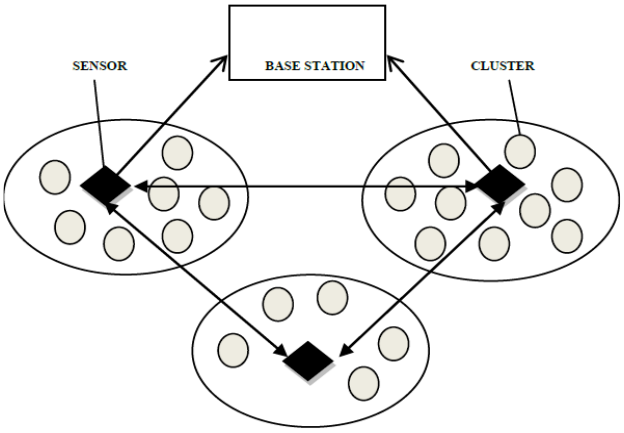


Figure.3 Cluster based sensor network.
The arrows indicate wireless communication links.

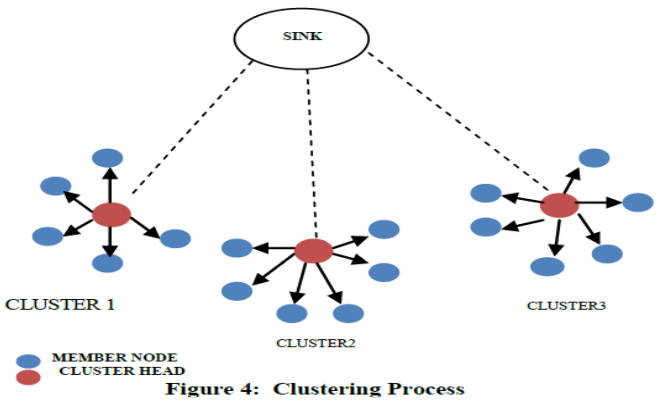
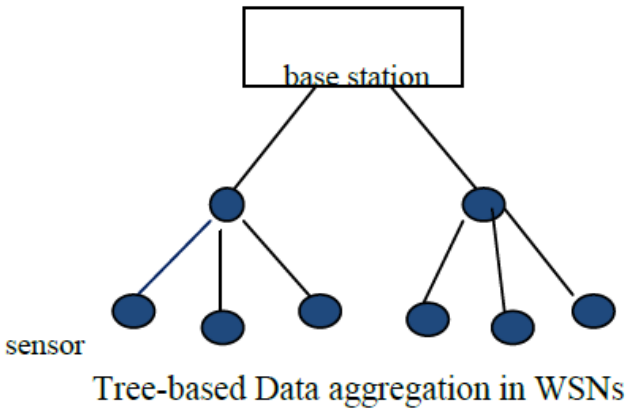


Figure 4: Clustering Process

The advantages with this scheme is so it reduces energy usage of each node and communication cost. The clustering algorithms which are made are derived from homogeneity and heterogeneity of nodes. Among the earliest works proposing this approach in WSNs is LEACH (Low Energy Adaptive Clustering Hierarchy). Recently, there have been a lot of other clustering techniques which are generally variants of LEACH protocol with slight improvement and different application scenarios. DEEC (Design of a distributed energy-efficient clustering), EDACH (Energy-Driven Adaptive Clustering Hierarchy) and EEUC (An Energy-Efficient Unequal Clustering Mechanism) are typical clustering techniques proposed with the aim of minimizing energy usage, while extending network life time. Clustered sensor network can be classified into two main types: homogeneous and heterogeneous sensor network. While energy efficiency in WSNs remains a function of uniform distribution of energy among sensor nodes, classifying clustering techniques depends on the objectives in mind. The Optimal clustering technique could be the technique for the heterogeneity nodes.

2.2. Tree-Based Approach: The tree based approach is defining aggregation from constructing an aggregation tree. The type of tree is minimum spanning tree, sink node consider to be a root and Source node consider as leaves. Information flowing of information begin with leaves node as many as root means sink (base station). Drawback to this strategy, like wireless sensor network usually are not clear of totally failure, in case there is data packet loss at any higher level of tree, the results will probably be lost not limited to single level however for whole related sub tree as well. This strategy is acceptable for designing optimal aggregation techniques GSTEB is simply self-organizing protocol to create a routing tree for prolonging the network lifetime in a variety of applications. Each round, BS assigns a root node and broadcasts the ID and coordinate of the main node along with other nodes. Then each node selects its parent in parallel using local information of their own as well as neighbors. Because nodes don't use anything but local information to decide on their parents, GSTEB is usually an energetic and parallel protocol, that may change the main and reconstruct routing tree with shorter delay and much less overhead. Therefore an even better balanced load is achieved, especially for dense nodes deployed.



Tree-based Data aggregation in WSNs

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2.3. Hybrid-Based Approach: Hybrid approach followed between tree and cluster based scheme. Within this, the details aggregation structure can adjusted in accordance with specific network situation and by some performance statistics.

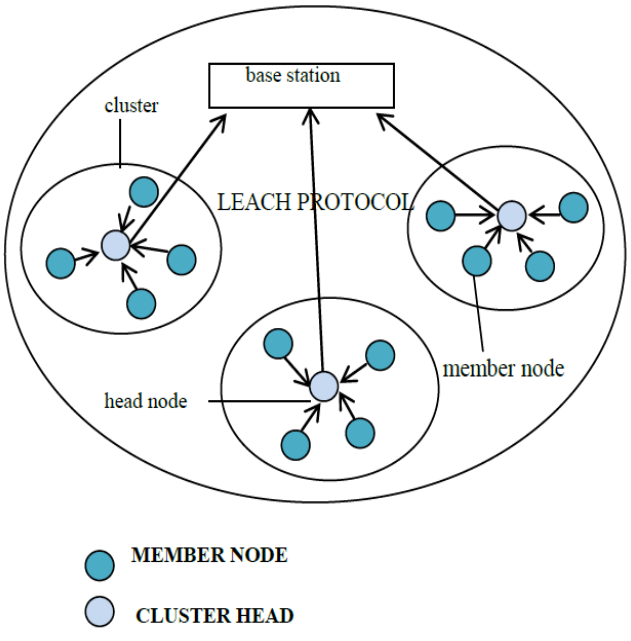
LEACH

WSNs are micro sensor systems that are spatially distributed. WSN is a power constrained system as the sensor nodes have limited battery life that shortens the network lifetime. Maximizing the network lifetime depends upon an efficient communication protocol. Energy consumption is, therefore, a critical design issue in WSN. A cluster-based technique is the basic method to increase the scalability, performance, efficiency and lifetime of the network. LEACH [11], a hierarchical clustering routing protocol, was proposed by Chandrakasan, Heinemann and Balakrishnan, in MIT. Leach is a protocol that works well in homogenous networks. In a homogenous network, all nodes have equal amount of initial energy. Basically there are two types of routing protocols in WSNs: Flat routing protocols are those in which the routing condition of each node in the network is the same. There are no special nodes in network and each node has equal status. So, the network traffic is distributed equally among all nodes. Comparatively, hierarchical routing protocols make use of the concept of clusters that divides all nodes into groups or clusters. Nodes in this type of network have different levels. A CH is selected among all the nodes and different hierarchical routing protocols may use different methods of selecting CHs.

LEACH is a low energy protocol that may adapt clustering. It is a cluster-based protocol that utilizes the concept of randomized rotation of local cluster-heads and distributes the energy load evenly among all the sensor nodes in the sensing field of the network.

Characteristics of LEACH:

- Set up of clusters through local collaboration and control.
- To reduce the Data aggregation in network traffic.
- Local compression to scale back world communication.
- Randomized rotation of the cluster heads and also the corresponding clusters.
- Random Death of nodes.



LEACH protocol

Setup Phase:

In the foundation or setup phase, each node decides whether to become a cluster-head (CH) in the present round. To be selected a CH; each node generates a random number between 0 and 1. The threshold is set up for the current round and the generated random number is compared to the threshold of the given round. If the number is less than threshold T(n), that particular node will be selected the CH for that round.

The threshold is set up as:

$$T(n) = \begin{cases} \dfrac{p}{1-p*\left(r \bmod \frac{1}{p}\right)} & \\ 0, \quad \text{otherwise} & \end{cases}, \; n \in G$$

Here p is the ratio of cluster-head nodes in the total number of nodes.

r is the current round number. G is the set of nodes that have not been selected as CH nodes in the former $\frac{1}{p}$ rounds.

The high energy cluster head position rotates among the various sensors in order to not to drain the battery of a single sensor. Sensors elect themselves to be the local cluster heads at any given time with a certain probability, and broadcast their status to other sensors each sensor node choosing the cluster-head with strongest signal. Each node takes the decision independent of the other nodes to become cluster head. Then cluster head creates a TDMA schedule for all nodes within its cluster telling each node when it can transmit. It allows radio component of each non cluster head to be turned off at all times except during its transitions time, thus minimizing the energy dissipation in the individual sensors and their receivers on during set up phase to hear the advertisements of all cluster heads.

Steady phase:

This operation is divided into frames where the nodes send their data to CH at most one frame during their transmission time slot. The CH transmits the aggregated data to the Base station (BS).

This protocol selects the CH randomly and the total energy load of the network is equally distributed to each sensor node by which it can consume less energy and thereby improving the network lifetime. LEACH outperforms conventional routing protocols like direct transmission, minimum-transmission-energy, in the static clustering algorithms. LEACH is distributed and nodes do not require control information from the base station nor knowledge of the global network.

The LEACH protocol carries out energy optimization and also reduces the amount of data transmitted to prolong the network lifetime. However, it has some drawbacks:

- It may happen that the same CH node is selected CH again in some other round as it has more energy.
- It has a hotspot problem, i.e. the CH uses more energy than normal sensor nodes
- The normal sensor nodes that overlap their sensing fields generate duplicate data that create unnecessary load on other CHs

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- The CHs are selected randomly, so if the node with low energy is selected CH, then that node may be heavily loaded and more energy will be consumed that results in early death of these nodes and ultimately reduce the network ml=olifetime.

SEP

There are some drawbacks associated with LEACH such as: single hop routing is used where each node can transmit directly to CH and sink. CHs are elected randomly. Therefore there is a possibility that all CHs will be concentrated in the same area. The concept of dynamic clustering is used which leads to unnecessary overhead due to cluster changes. The protocol also assumes that all nodes have amount of energy for each node.

But recent protocols like SEP[9] is opposite to that of LEACH as it considers energy heterogeneity where the factors mentioned are just a possibility. WSNs have assumed homogenous nodes for most of the time. But these nodes also differ in initial amount of energy and also in depletion rate. This leads to the heterogeneous networks where we consider two or more types of nodes. SEP is proposed for two-level heterogeneous networks that has two types of nodes according to their initial energy. The nodes that have higher amount of energy than the other nodes are called advance nodes and the other nodes are the normal nodes.

In SEP the election probabilities of nodes are weighted by the initial energy of each node to become the cluster-head relative to the other nodes in a network. This prolongs the time period before the death of first node in the system. SEP approach makes sure that CH election is done randomly and is distributed based on the energy of each node assuring the uniform utilization of the nodes energy. SEP consists of advance nodes that carry more energy than the normal nodes at the beginning, so it enhances the stability period of the network.

Normal nodes have initial energyE_0, and advance nodes have initial energy (1+a)E_0.Where (a) is the percentage of energy higher than normal nodes. Each node has a probability to become a CH and each node generates a random number between 0 and 1 just like in LEACH. If the number is less than threshold T(s), then that node becomes CH in the current round. With increase in number of rounds, the T(s) also increases and reaches 1 only in the last round.

Let p_{nrm} be the weighted election probability of normal nodes and p_{adv} be the weighted election probability of advance nodes. Optimum probability of each node to become CH can be calculated by:

$$p_{nrm} = \frac{p_{opt}}{1+am} \quad (1)$$

$$p_{adv} = \frac{p_{opt}}{1+am} * (1+a) \quad (2)$$

'm' denotes the fraction of advance nodes and 'a' is the additional energy factor between advance and normal nodes. The threshold is given by the formula:

$$T_{nrm} = \begin{cases} \frac{p_{nrm}}{1-p_{nrm}\left[r.mod\ \frac{1}{p_{nrm}}\right]} & \text{if} n_{nrm} \in G \\ 0 \quad otherwise \end{cases} \quad (3)$$

$$T_{adv} = \begin{cases} \frac{p_{adv}}{1-p_{adv}\left[r.mod\ \frac{1}{p_{adv}}\right]} & \text{if } n_{adv} \in G \\ 0 \ otherwise \end{cases} \quad (4)$$

The total energy of new heterogeneous setting will be:

n.(1-*m*). E_0 +n.*m*. E_0 .(1+*a*)=n. E_0 .(1+*a.m*) (5)

so the total energy of the system is increased by (1+*a.m*) times.

In order to optimize the stable region of the system the new epoch must become $\frac{1}{p_{opt}}$.(1+a.m) as the system has *a.m* times more energy and *a.m* times more nodes.

DEEC

DEEC is designed to deal with nodes of heterogeneous WSNs. For CH selection, DEEC uses initial and residual energy level of nodes. Let ni denote the number of rounds to be a CH for node si. PoptN is the optimum number of CHs in our network during each round. CH selection criteria in DEEC are based on energy level of nodes. As in homogenous network, when nodes have same amount of energy during each epoch then choosing pi = popt assures that poptN CHs during each round. In WSNs, nodes with high energy are more probable to become CH than nodes with low energy but the net value of CHs during each round is equal to poptN. Pi is the probability for each node si to become CH, so, node with high energy has larger value of pi as compared to the popt. $\bar{E}(r)$ denotesaverage energy of network during round r which can be given as in [10]:

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

Probability for CH selection in DEEC is given as in [10]:

$$p_i = p_{opt}\left[1 - \frac{\bar{E}(r) - E_i(r)}{\bar{E}(r)}\right] = p_{opt}\frac{E_i(r)}{\bar{E}(r)}$$

In DEEC the average total number of CH during each roundis given as in [10]:

$$\sum_{i=1}^{N} p_i = \sum_{i=1}^{N} p_{opt}\frac{E_i(r)}{\bar{E}(r)} = p_{opt}\sum_{i=1}^{N}\frac{E_i(r)}{\bar{E}(r)} = Np_{opt}$$

piis probability of each node to become CH in a round. Where G is the set of nodes eligible to become CH at roundr. If node becomes CH in recent rounds then it belongs to G. During each round each node chooses a random number between 0 and 1. If number is less than threshold as defined in equation as in [10], it is eligible to become a CH else not.

$$T(s_i) = \begin{cases} \frac{p_i}{1 - p_i(rmod\frac{1}{p_i})} & if\ s_i \in G \\ 0 & otherwise \end{cases}$$

As popt is reference value of average probability pi. In homogenous networks, all nodes have same initial energy so they use popt to be the reference energy for probability pi. However in heterogeneous networks, the value of popt is different according to the initial energy of the node. In two level heterogenous network the value of popt is given by as in[10]:

$$p_{adv} = \frac{p_{opt}}{1+am}, p_{nrm} = \frac{p_{opt}(1+am)}{(1+am)}$$

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Then use the above p advand pnrm instead of popt in equation 10 for two level heterogeneous networks as supposed in [10]:

$$p_i = \begin{cases} \dfrac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ the\ normal\ node \\ \dfrac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ the\ advanced\ node \end{cases}$$

Above model can also be extended to multi level heterogeneous network given below as in [10]:

$$p_{multi} = \frac{p_{opt}N(1+a_i)}{(N+\sum_{i=1}^{N}a_i)}$$

Above pmultiin equation 10 instead of poptto get pifor heterogeneous node. pifor the multilevel heterogeneous network is given by as in [10]:

$$p_{multi} = \frac{p_{opt}N(1+a_i)}{(N+\sum_{i=1}^{N}a_i)}$$

In DEEC they estimated average energy E(r) of the networkfor any round r as in [10]:

$$\bar{E}(r) = \frac{1}{N}E_{total}(1-\frac{r}{R})$$

R denotes total rounds of network lifetime and is estimated as follows:

$$R = \frac{E_{total}}{E_{round}}$$

Etotal is total energy of the network where Eround is energy expenditure during each round.

III. GAPS IN LITERATURE

The review has shown that the majority of algorithms has the following limitations.

1. **Clustering:** In recent work clustering based protocols has shown quite significant improvement in terms of energy efficiency thus has ability to increase network lifetime a lot. Although GSTEB has quite significant results but still one can improve its results by using the clustering.
2. **Reactivity:** The GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between the sink and the member nodes.
3. **Mobile sink:** The effect of the mobile sink on the GSTEB has been neglected.

IV. CONCLUSION AND FUTURE SCOPE

GSTEB has shown quite significant results over the available WSNs protocols. But it has neglected the use of the three things:- The effect of the mobile sink has also been neglected by the most of the existing researchers The clustering has also been neglected, one can offer level wise clustering to enhance the results further. The effect of the reactivity has also been neglected as the GSTEB is proactive routing protocol. In order to overcome the constraints of the earlier work a new improved technique will be proposed in near research on GSTEB which will use clustering, reactivity and mobile sink based environment. The proposed technique has the ability to overcome the limitations of the existing protocols and GSTEB routing protocol.

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