A Review on Energy Efficient Clustering Based WSNs Protocols

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Abstract:- WSNs have shown an important role in many real world applications. Due to the structures of the resource-controlled and battery-responsive sensors efficient energy consumption has found to be a major area of research in WSNs. WSNs has comprised of battery-responsive sensor nodes which are responsible for communicating with the sink (base station) for certain task. Due to limited battery life sensor nodes become dead after the consumption of the battery. First node dead time is called stability period whereas last node dead time is known as network lifetime. So using the energy in organized manner; may increase the network lifetime of the WSNs. This paper has described and explores the various energy efficient protocols to evaluate the short coming of the earlier work in WSNs.

Index terms: WSNs, LEACH, Energy consumption, SEP, Lifetime.

1. INTRODUCTION

Wireless Sensor network [1] Composed of many small distributed sensor nodes that provide the reliable monitoring in various environments such as military and civil application. In WSN every sensor node contains specific hardware receiving hardware, memory, processing unit, required. With the help of networking tiny sensor nodes, it becomes easy to acquire the data about physical phenomena which was quite difficult with conventional methods. These node process data and send it base station called as sink. For communication of data between nodes and sink many routing technologies are used initially, such as direct communication and multihop data transmission. But due to limited battery life of nodes this techniques were not so effective because early death of some node in both techniques were fail to achieve in the network suitability periods.

So to reduce energy consumption a clustering technique were introduced in which out of thousands of nodes few nodes become cluster head and they manage the entire network. Cluster head is a node which is responsible for maintain cluster, collect data from nodes in the cluster and communicating with sink. By using clustering methodology it has been observed that there is large amount of energy that has been saved. In static clustering method some rules were followed to elect a cluster head, once a cluster is formed and cluster head is elected, the cluster was statically operated until the head node dead. Because cluster head node have more responsibility so rapid decrease in energy in the Cluster head node. The death time was head node was too early in static clustering technique. So there was a need required the wenzimen proposed a protocol based on adaptive clustering technique he named it LEACH.

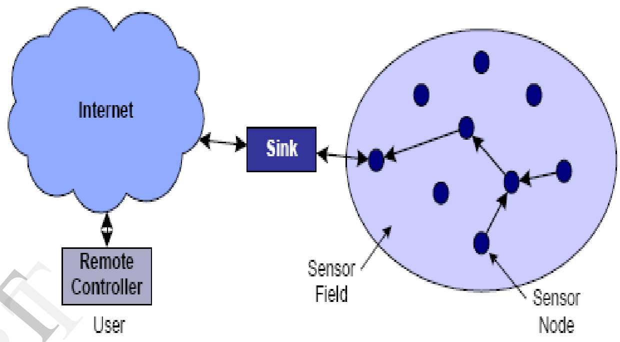

Figure 1: Architecture of wireless sensor network. (adapted from [3])

A wireless sensor network is composed of a large number of sensor nodes that are densely deployed either inside the environment or close to it. The position of sensor nodes need not be engineered or predetermined. This allows random deployment in inaccessible hazardous environments. Some of the most important application areas of sensor networks include military, natural calamities, health, and home. When compared to traditional ad hoc networks, the most noticeable point about sensor networks is that, they are limited in power, computational capacities, and memory. Hence optimizing the energy consumption in wireless sensor networks has recently become the most important performance objective.

The main task of a sensor node in a sensor network is to monitor events, i.e., collect data, perform quick local data aggregation, and then transmit the data. Sensor nodes which has limited battery power. Sensor nodes of WSN have the capability of self-organizing the network. The transmission between the sensor nodes are done through wireless medium.

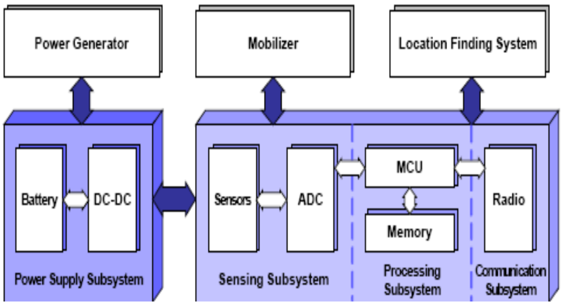

Figure 2: Internal structure of sensor node

This figure 2 redrawn from [37] shows the architecture of a typical wireless sensor node, as usually assumed in the literature. It consists of four main components: (i) a sensing subsystem including one or more sensors (with associated analog-to-digital converters) for data acquisition; (ii) a processing subsystem including a micro-controller and memory for local data processing; (iii) a radio subsystem for wireless data communication; and (iv) A power supply unit.

A. LEACH:LEACH stands for Low Energy Adaptive Clustering Hierarchy. This technique has proposed dynamically method to form cluster and selection of cluster head node. In this method a probability P is taken which was the percentage of node to be elected as cluster head. For communication of data there exist a number of rounds. In every round there exist two phases 1) Setup Phase 2) steady Phase.

In the setup phase the cluster head election and cluster formation two main activities were taken place. In Cluster head Election process every node is randomly assigned with a pocket value between {0, 1}, for every round a network threshold T (n) was calculated with the formula **T (n) = P/ {1-P(r mod 1/P)}** in this T (n) is the threshold of network, P is the probability percentage of cluster head and r is the current round number. Node having pocket value <T(n) select itself as cluster head and advertise a message with its node id to all other nodes in this all P nodes of this node advertise itself as cluster head now the nodes join the cluster according to the signal strength of advertise message and nodes join that message with join message along with node id. Now Cluster head node form a TDMA slot for every node of its cluster. After this Steady Phase starts in this cluster head collect the data from its native nodes compress it and send it to base station.

This way every round of LEACH works. There is a fix time of every round, once a node become cluster head it can't be elected as cluster Head for next 1/P rounds. So this way all nodes having equal opportunity to be elected as cluster head. Now all nodes randomly and almost chosen as cluster head and increase in network sustainability period. LEACH have proposed the very effective model to save energy, it was further enhanced by taking various parameters. The focus is primarily enhanced the network life time which is very important due to limited battery in sensor nodes.

B. SEP: Stability Election Protocol [2], a heterogeneous-aware protocol to prolong the time interval before the death of the first node (we refer to as stability period), which is crucial for many applications where the feedback from the sensor network must be reliable. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. Ibrahim Matta: et al [2] showed by simulation that SEP always prolongs the stability period compared to (and that the average throughput is greater than) the one obtained using current clustering protocols. SEP yields longer stability region for higher values of extra energy brought by more powerful nodes. Stable Election Protocol (SEP) is based on weighted election probabilities of each node to become cluster-head (CHs) according to their respective energy. This approach ensures that the cluster head election is randomly selected and distributed based on the fraction of energy of each node assuring a uniform use of the nodes energy. SEP also considered two types of nodes and two level hierarchies.

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 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 energy E_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:

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

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

'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:

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

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

The total energy of new heterogeneous setting will be:

$$n.\ (1\text{-}m).\ E_0 + n.m.\ E_0\ .(1+a) = n.\ E_0\ .\ (1+a.m) \qquad (5)$$

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.

C. Stable Cluster Head Election (SCHE) Protocol

It is based on LEACH architecture that uses clustering technique. Its goal is to reduce the energy consumption of each sensor node and thus minimizing the overall energy dissipation of the network. SCHE is a source driven protocol based on timely reporting. So the sensor node will always have some data to transmit to the Base station. It also makes use of data aggregation to avoid information overload.

It provides n analytical framework to attain the stable probability for a node to be a cluster-head to minimize energy consumption. It is necessary to apply suitable CH election mechanism to minimize energy consumption of each sensor node that ultimately results in reduced energy dissipation. SCHE was proposed where this mechanism was applied by obtaining the optimum value of probability for a node to become a CH and consumes significantly less energy compared to LEACH. It also reduces consumption by minimizing distance between CH and BS.7

D. Extended Stable Election Protocol (ESEP)

It is a modified SEP protocol. Instead of two types of nodes, it considers three nodes based on their energy levels. These nodes are: normal, moderate and advance nodes. The goal of ESEP is to achieve a WSN that maximizes the network lifetime and stability period. Also it must reduce the communication cost and deployment cost. The operation to become a CH is same as in SEP by generating a random number and then comparing it with the threshold. In ESEP the moderate or intermediate nodes are selected in two ways either by the relative distance of advance nodes to normal nodes or by the threshold of energy level between advance nodes and normal nodes.

The weighted election probabilities are given by:

$$p_{nrm} = \frac{p_{opt}}{1+p.a+k.b}$$

$$p_{mod} = \frac{p_{opt}}{1+p.a+k.b}.\ (1+a)$$

$$p_{adv} = \frac{p_{opt}}{1+p.a+k.b}.\ (1+b)$$

And the total initial energy of heterogeneous network is given by:

E_t= n. E_0.(*1-p-k*) + n.p.E_0.(*1+a*)+ n.k.E_0.(*1+b*)

E_t= n.E_0.(*1+p.a+k.b*)

The results show that ESEP outperforms SEP and LEACH in terms of stability because of three levels of heterogeneity. However, additional energy factor between advance and normal nodes and *b* additional energy factor between advance, normal and moderate nodes due to three types of nodes in ESEP, it has different energy levels.

E. Threshold-sensitive Stable Election Protocol (TSEP)

The early protocols SEP and ESEP were heterogeneity-aware protocols that improve the stability period and network lifetime but a major drawback of heterogeneity is that the increased throughput eventually decreases the network lifetime. Therefore, to control the trade-off between the efficiency, accuracy and network lifetime, a new protocol TSEP was proposed. It is a reactive routing protocol that senses data continuously over the network but transmits only when there is a drastic change in the value of sensed attributes. The transmission takes place only when a specific level of threshold is reached. It uses three levels of heterogeneity by considering three types of nodes: normal, intermediate and advance nodes. The highest energy nodes are advance nodes followed by intermediate and normal nodes. The intermediate nodes are selected by using a fraction *b* of intermediate nodes. The energy of intermediate nodes is assumed to be μtimes more than that of normal nodes. So, the energy of intermediate nodes is calculated as:

$E_{INT} = E_0(1 +$ ⍰)where μ=$\frac{\alpha}{2}$

So, total energy of normal, advance and intermediate nodes is *n.b(1+α), n*E_0*.(1-m-bn),* and *n.m.*E_0*(1+ α)*respectively. So total energy of all nodes becomes *n* E_0 *.(1-m-bn)* + *n.m.*E_0*.(1+ α) + n.b.(1+ ⍰) = n.*E_0*.(1+ mα +b ⍰).*

The optimum probability of nodes to be elected CHs is calculated by:

$p_{nrm} = \frac{p_{opt}}{1+m\alpha+b⍰}$

$p_{int} = \frac{p_{opt}}{1+m.a+b⍰}.$ (1+ ⍰)

$p_{adv} = \frac{p_{opt}}{1+m.a+b.⍰}.$ (1+*α*)

To make sure that the CH is selected in the assumed way, a new parameter threshold, is considered. If the generated random number by the nodes is less than the threshold then that node becomes the CH for the current round. The threshold is calculated by the following formulae:

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

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

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

Where G', G'' and G''' are the set of normal, intermediate and advance nodes that have not been elected the CH.
Average number of CHs per round will be:

$n.(1\text{-}m\text{-}b).p_{nrm} + n.b.p_{int} + n.m.p_{adv} = n.p_{opt}$

This shows that due to energy heterogeneity, the energy dissipation is reduced in the network. At the start of each round, the process of cluster change takes place in which the CH broadcasts some parameters to the other nodes. These parameters are the report time, attributes, soft threshold (ST) and hard threshold (HT). the nodes keep sensing the environment for change in the values of attributes. When the values of attribute set reaches the hard threshold, the radio is turned on and the data is transmitted to the CH. This sensed value is stored in a variable called Sensed Value (SV). The next time the nodes transmit data only when the sensed value is greater than the hard threshold or if the difference between the sensed value and the value in SV is equal to or greater than the soft threshold.

2. RELATED WORK

[Bit et al. 2013]has investigated the problem for enhancing network lifetime using homogeneous sensor nodes. It was revealed that energy imbalance in WSN occurs due to relaying of data from different parts of the network towards sink. So for improved energy balance instead confusing only sensor nodes it is desirable to deploy relay nodes in addition to sensor nodes to manage such imbalance. Allocation-wise pre-determined heterogeneous node deployment strategy based on the principle of energy balancing derived from this analysis, leading to an enhancement of network lifetime was developed.

[Sabarish et al. 2012] proposed an algorithm to collect data values both at node and cluster level and find the principal component using PCA techniques. Using Data Mining Technique data discrimination is done at node and cluster level leading to a comparison made in the Statistical and Bucket-width outlier detection algorithm that improves efficiency

[Walravens et al. 2012] anticipated an architecture to calculated energy-efficiency consisting of several parallel processing elements (PEs) structured as a folded tree. Profiling SystemC models of the design with ActiveSC helps to improve data-locality resulting in an improvement in terms of energy as compared with traditional MCUs found in sensor nodes. An alternative low power ASIC approach for WSN data processing in sensor nodes without sacrificing too much of the flexibility found in traditional MCUs is introduced.

[Liu et al. 2012] A balance-aware energy-efficient geographic routing protocol (BEGR) is proposed. Both energy consumption in communication and residual energy at nodes are considered in BEGR. Liu proved that their protocol is loop-free and can adapt to dynamic scenarios resulting in prolonging network lifetime greatly based on first-dead time.

[Kansal 2012] which maximizes the network lifetime by reducing the number of communication among sensor nodes and base station. This algorithm includes new distributed cluster formation technique that enables self-organization of large number of nodes, algorithm for maintaining constant number of clusters by prior selection of cluster head and rotating the role of cluster head to distribute the energy load among all sensor nodes.

[Kauret al.2012] proposed an optimization of energy consumption in wireless sensor networks. Genetic algorithm is used to optimize this problem which reduces the energy consumption in wireless sensor networks.

[Aderohunmuet al.2011] proposed a deterministic energy-efficient clustering protocol that is dynamic, distributive, self-organizing and more energy efficient than the existing protocols. It utilizes a simplified approach which minimizes computational overhead-cost to self-organize the sensor network.

[Chuang et al 2011] An efficient compression mechanism for WSN by treating sensing data as the raw data of an image for compression has been proposed. Chuang also introduced the user-acceptable data error which can be defined by a user to enhance the compression efficiency. Experimental results show that their mechanism can reach a better compression ratio compared with other approaches in either higher or lower correlated data scenario.

[Chou et al 2011] that a distributed dead-end free topology maintenance protocol, designated as DFTM, for the construction of dead-end free networks using a minimum number of active nodes. DFTM also successfully constructed a dead-end free topology in most of the simulated scenarios. Additionally, even when the locations of the sensors were not precisely known, DFTM still ensured that no more than a very few dead-end events occurred during packet forwarding.

[Aioffi et al. 2011] has introduced a network model for inherent multi-objective optimization problem and optimization algorithms are used to define optimal (or near-optimal) density control policies, sensors clustering and sink routes to collect sensed data resulting a good balance among conflicting parameters like message delivery latency, network lifetime and rate of messages received.

3. GAPS IN LITERATURE

The survey on different WSNs has been done by considering the various stable election based protocols etc.

a) The time duration of the setup phase is non-deterministic and the collisions will cause the time duration too long and hence the sensing services are interrupted. Due to that Leach may be unstable during the setup phase that depends on the density of sensors.
b) Leach is not applicable to networks that are deployed in large region as it uses single hop routing where each node can transmit directly to the cluster head and the sink
c) The cluster heads used in the LEACH will consume a large amount of energy if they are located farther away from the sink.
d) Leach does not guarantee good cluster head distribution and it involves the assumption of uniform energy consumption for the cluster heads.
e) Leach uses dynamic clustering which results in extra overhead such as the head changes ,advertisement that reduces the energy consumption gain

4. CONCLUSION AND FUTURE WORK

Wireless Sensor Network is a network of sensor nodes without having any central controller. Its growth is continuously increasing, thus resulting huge field of research in this area. Sensors depend entirely on the trust of their battery for power, which cannot be regenerated or substituted. So the design of energy aware protocol is indispensable in respect to enhance the network lifetime. LEACH is energy-efficient hierarchical based protocol that balances the energy expense, saves the node energy and sustains the lifetime of the network. This work has evaluated the shortcomings of earlier work no modification is done. In near future a new integrated data aggregation based clustering protocol will be proposed to improve the results of existing clustering protocol further.

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