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A Comparative Analysis of clustering based Routing Techniques for WSN

P.Madhumathy , Dr. D.Sivakumar

ABSTRACT-In recent years, there has been a rapid proliferation of research concerning Wireless Sensor Networks (WSNs), due to the wide range of potential applications that they can be used for. Sensor nodes are typically powered by batteries with a limited lifetime, and in most cases, the batteries cannot be recharged. The energy problem in WSNs remains as one of the major barriers that prevent the complete exploitation of this technology.
Almost in all the hierarchical or cluster based protocols in the literature, the alternate Cluster Head (CH) selection or the re-clustering was done in such a way that there exist more delay and high energy consumption thereby resulting in the reduced lifetime of the network. In this paper, the focus is mainly driven over the survey of the energy-efficient hierarchical cluster-based available routings for Wireless Sensor Network

Key words: cluster architecture, WSN , cluster head(CH)

1. INTRODUCTION

1.1. Wireless Sensor Networks

Recent technological advances in Micro Electronic Mechanical Systems (MEMS) and wireless communication technologies have enabled the development of tiny, low cost, low-power, and multifunctional smart sensor nodes in a Wireless Sensor Network (WSN) [1]. WSNs have received significant attention from researchers because they find applications spanning over vast and varied areas such as habitat monitoring, object tracking, military systems, and industrial and home automation. Sensor nodes are typically powered by batteries with a limited lifetime, and in most cases, the batteries cannot be recharged. The energy problem in WSNs remains as one of the major barriers that prevent the complete exploitation of this technology. In wireless sensor networks where nodes are powered by batteries, it is critical to prolong the network lifetime by minimizing the energy consumption of each node [2]. A WSN typically consists of a large number of low cost, low power and multifunctional sensor nodes that are deployed in a region of interest. These sensor nodes are small in size, but are equipped with embedded microprocessors, radio receivers, and power components to enable sensing, computing, communication, and actuation.

*P.Madhumathy is currently pursuing Ph.D program in Anna university, India. Email:sakthi999@gmail.com

*Dr.D.Sivakumar is a Professor and Dean in Arunai college of engineering, thiruvanamalai , India
Email:dgsivakumar@sify.com

These components are integrated on a single or multiple boards, and packaged in a few cubic inches. typically powered by 2 AA batteries can last for up to three years with a 1% low duty cycle working mode [3].

1. 2. ROUTING IN WSNS

Due to the severe energy constraints of large number of densely deployed sensor nodes, it requires a suite of network protocols to implement various network control and management functions such as synchronization, node localization, and network security [4]. The traditional routing protocols have several shortcomings when applied to WSNs, which are mainly due to the energy constrained nature of such networks [5]. There are some important principles for designing WSN protocols [6]
(i) Providing data centric mechanisms for data processing and querying within the network. (ii) Using application knowledge to customize the software design and implementation. (iii) Using localized algorithms to collectively achieve a global objective while providing scalability and robustness. (iv) Lightweight middleware in terms of computation complexity and(v) communication requirements and Smartly trading Quality of Service (QoS) of various applications with each other.

2. CLUSTER BASED ROUTING IN WSN

In order to support data aggregation through efficient network organization, nodes can be partitioned into number of small groups called clusters. This phenomenon of grouping sensor nodes into clusters is called clustering. Every cluster would have a leader, called cluster head [8].

CHs consume a larger amount of energy when they are located farther away from the sink.

2.1 LEACH (Low-energy adaptive clustering hierarchy)

LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station .After a given interval of time, a randomized rotation of the role of the CH is conducted so that uniform energy dissipation in the sensor network is obtained.
The operation of LEACH is separated into two phases

i. The setup phase ii. The steady state phase

During the setup phase, a predetermined fraction of nodes, p, elect themselves as CHs as follows. A sensor node chooses a random number, r, between 0 and 1. If this random number is less than a threshold value, T(n), the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head (p), current round (r), and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G.
It is given by:

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where G is the set of nodes that are involved in the CH election.
Each elected CH broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster heads. All the non-cluster head nodes, after receiving this advertisement, decide on the cluster to which they want to belong to. This decision is based on the signal strength of the advertisement [11]. The cluster-head node, after receiving all the data, aggregates it before sending it to the base-station.
It reduces energy consumption by (a) minimizing the communication cost between sensors and their cluster heads and (b) turning off non-head nodes as much as possible [10].
The limitations of LEACH are (a) it is not applicable to networks deployed in large regions. (b) Furthermore, the idea of dynamic clustering brings extra overhead, (c) the

2.1.1 LEACH-C (Centralized)

In LEACH-C, the base station receives information about residual node energy and node positions at the set up phase of each round. The received data can compute an average residual energy for all nodes. The nodes with less than average energy are excluded in selection of cluster heads. Among the nodes that have more than average energy, cluster heads are selected with use of the simulated annealing algorithm. The base station sends all nodes a message of the optimum cluster head IDs (Identifiers). The node, the ID of which is the same as the optimum cluster head ID, is nominated as a cluster head and prepares a TDMA schedule. LEACH-C is not feasible for larger networks because nodes far away from the base station will have problem sending their states to the base station and as the role of cluster heads rotates so every time the far nodes will not reach the base station in quick time increasing the latency and delay.

2.1.2 LEACH-E (Enhanced Low-Energy Adaptive Clustering Hierarchy)

In this protocol it is proposed to elect the cluster-heads according to the energy left in each node. E-LEACH [11] further improved in two major aspects. E-LEACH proposes a cluster head selection algorithm for sensor networks that have non-uniform starting energy level among the sensors. However, this algorithm assumes that sensors have global information about other sensors. remaining energy. E-LEACH also determines that, under certain assumptions, the required number of cluster heads has to scale as the square root of the total number of sensor nodes to minimize the total energy consumption. The drawback of LEACH-E is that it requires the assistance of routing protocol, which should allow each node to know the total energy of network.

2.1.3 LEACH-F(Fixed Cluster)

LEACH-F [12] is the further development of LEACH, which is based on clusters that are formed once and then fixed. Then, the cluster head position rotates among the nodes within the cluster. The advantage with this is that, once the clusters are formed, there is no set-up overhead at the beginning of each round. To decide clusters, LEACH-F uses the same centralized cluster formation algorithm as

LEACH-C. The fixed clusters in LEACH-F do not allow new nodes to be added to the system and do not adjust their behavior based on nodes dying.

2.2 PEGIASIS(Power- Efficient Gathering in Sensor Information Systems)

PEGASIS improves on LEACH by saving energy in several stages. First, in the local gathering, the distances that most of the nodes transmit are much less compared to transmitting to a cluster-head in LEACH. Second, only one node transmits to the BS in each round of communication. The protocol is a near optimal chain-based protocol for extending the lifetime of network. In PEGASIS[13], each node communicates only with the closest neighbour by adjusting its power signal to be only heard by this closest neighbour . Each Nodes uses signal strength to measure the distance to neighbourhood nodes in order to locate the closest nodes. After chain Formation PEGASIS elects a leader from the chain in terms of residual energy every round to be the one who collects data from the neighbours to be transmitted to the base station. As a result, the average energy spent by each node per round is reduced.

(a) Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the Base station instead of multiple nodes. (b)This approach reduces the overhead and lowers the bandwidth requirements from the BS. The limitations are (a) It still requires dynamic topology adjustment since a sensor node needs to know about energy status of its neighbours in order to know where to route its data.(b) Moreover, PEGASIS assumes that each sensor node can be able to communicate with the BS directly. In practical cases, sensor nodes use multi-hop communication to reach the BS.

2.3 TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol)

TEEN [14] is other hierarchical protocol for reactive networks that responds immediately to changes in the relevant parameters. In this protocol a clusters head (CH) sends a hard threshold value and a soft one. The nodes sense their environment continuously. The first time a parameter from the attribute set reaches its hard threshold value, the node switches on its transmitter and sends its data. The nodes then transmits data in the current cluster period if the following conditions are true: the current value of the sensed attribute is greater than the hard threshold, and the current value of the sensed attribute differs from sensed value by an amount equal to or greater than the soft threshold.

Important features of TEEN include (a) the energy consumption in this scheme is less than the proactive networks. (b) The soft threshold can be varied. The main drawback of this scheme is that (a) if the thresholds are not reached, the nodes will never communicate. (b) TEEN is not suitable for sensing applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached.

2.4 HEED (Hybrid, Energy-Efficient Distributed Clustering)

HEED [15] is a distributed algorithm which selects the CH based on both residual energy and communication cost. The HEED protocol gets executed in three subsequent phases: Initialization phase, repetition phase and finalization phase. Initialization phase, in which the initial CH nodes percentage will be given to the nodes. It is represented by the variable Cprob. Repetition phase, in which until the CH node was found with least transmission cost, Finalization phase, in which the selection of CH was finalized. In general, the tentative CH now becomes the final CH node. Each sensor node computes its probability to become CH using equation 2.

CHprob = Cprob * Eresidual/Emax ……… (2)

Where,
Eresidual - residual energy of the concerned node.
Emax - maximum battery energy.

In HEED, (a) the distribution of energy consumption extends the lifetime of all the nodes in the network, thus sustaining stability of the neighbor set. (b) Nodes also automatically update their neighbor sets in multi-hop networks by periodically sending and receiving messages. (c) The HEED clustering improves network lifetime over LEACH. The limitations are,(a) the cluster selection deals with only a subset of parameters, which can possibly impose constraints on the system. (b) These methods are suitable for prolonging the network lifetime rather than for the entire needs of WSN.

2.5 APTEEN (Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol)

APTEEN [16] is an improvement to TEEN to overcome its shortcomings and aims at both capturing periodic data collections (LEACH) and reacting to time-critical events (TEEN). Thus, APTEEN is a hybrid clustering-based routing protocol that allows the sensor to send their sensed data periodically and react to any sudden change in the value of the sensed attribute by reporting the corresponding values to their CHs. The architecture of APTEEN is same as in TEEN, which uses the concept hierarchical clustering for energy efficient communication between source sensors and the sink. APTEEN supports three different query types namely (i) historical query, to analyse past data values, (ii) one-time query, to take a snapshot view of the network; and

(iii) persistent queries, to monitor an event for a period of time. APTEEN guarantees lower energy dissipation and a larger number of sensors alive [16].

Experiments have demonstrated that APTEENs performance is between LEACH and TEEN in terms of energy dissipation and network lifetime. While in LEACH sensors transmit their sensed data continuously to the sink, in APTEEN sensors transmit their sensed data based on the threshold values. TEEN gives the best performance since it decreases the number of transmissions. The main drawbacks of the two approaches are the overhead and complexity of forming clusters in multiple levels, implementing threshold based functions and dealing with attribute-based naming of queries.

3. A COMPARATIVE ANALYSIS OF CLUSTER BASED ROUTING TECHNIQUES FOR WSN

TABLE 1: CLASSIFICATION AND COMPARISON OF ROUTING PROTOCOLS IN WSNS

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Protocol	Classification	Data Aggregation	Overhead	Data delivery model	Power Usage	Advantages	Disadvantages ges
LEACH	Hierarchical	yes	high	Cluster-head	high	Avoids battery depletion	Does not guarantee good CH distribution
PEGASIS	Hierarchical	no	low	Chains based	max	Avoids so much clustering	Requires dynamical topology adjustment
HEED	Hierarchical	yes	high	Cluster-head	high	achieve power balancing using residual energy and node degree	Not suitable for entire Needs of WSN
TEEN	Hierarchical	yes	high	Active threshold	high	We can control the number of Packet transmissions.	not good for applications where periodic reports are needed
AAPTEEN	Hierarchical	yes	high	Active threshold	high	PTEEN's rformance is tween LEACH and EN in terms energy dissipation	

4 CONCLUSION AND FUTURE WORK

Due to the scarce energy resources of sensors, energy efficiency is one of the main challenges in the design of protocols for WSNs. The ultimate objective behind the protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. In this paper we have surveyed and summarized recent research works focused mainly on the energy efficient hierarchical cluster-based routing protocols for WSNs. As this is a broad area, this paper has covered only few sample of routing protocols. The protocols discussed in this paper have individual advantages and pitfalls. Based on the topology, the protocol and routing strategies can be applied.Also in most of the protocols they do not taken into account of the node mobility and have not followed an appropriate location management scheme for the re-clustering which results in the wastage of energy and causing extra delay. The factors affecting cluster formation and CH communication are open issues for future research. Moreover, the process of data aggregation and fusion among clusters is also an interesting problem to explore.

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