Cluster-based Routing in Wireless Sensor Networks: A Comparative Study

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ABSTRACT

Text Wireless sensor networks (WSNs) have emerged as an important application area resulting from the advancement of efficient short-range radio communication and miniaturization of computing devices. In a WSN, the nodes are deployed with limited battery energy and therefore enhancement of network lifetime by minimizing energy-usage is of utmost importance. One of the solutions to reduce such energy-usage is clustering of network nodes. This paper discusses the clustering approach used differently in different protocols from generic form (LEACH) to more refined form (ACM, ESDP) . Various protocols have refined this approach to utilize the overall energy consumption and prolong the network lifetime.

1. INTRODUCTION

The advent of short range radio communication and miniaturization of computing devices has given rise to strong interest in Wireless Sensor Networks [1], [2]. The definition of wireless sensor networks (WSN) is composition of hundreds or thousands of MEMS-based sensor nodes capable of communicating to the external world via base station either directly (single hop) or via other nodes (multi hop) corporately. The limitations of such type of networks are resource-constrained (limited-battery) nodes, random node deployment in unattended open field etc. There are critical situations in real world such as military system where it is very difficult to replace/recharge battery. Thus, concentration on the overall consumption of energy in the network has to be regulated enabling untethered and unattended operation for an extended period of time.

Routing in WSNs is complex, because it is impossible to define a global addressing scheme for deployed sensor nodes therefore IP-based protocols are not applicable. Secondly, the redundancy needs to be exploited by the routing protocols since multiple sensors may generate same data within same condition. And the

protocol are required to efficiently manage the resources considering limited transmission power, storage and energy. The routing scheme for sensor networks can be broadly categorized into (1) Data-centric or Query-based, (2) Hierarchical and (3) Location-based protocols. Clustering approach falls under Hierarchical category where the network is divided into hierarchies with the definition of Cluster-Heads (CH). The CH aggregates the data and compresses before sending it to the Sink. This approach efficiently maintains the energy consumption of sensor nodes using multi-hop communication.

The sensor networks can also be defined on the basis when the data is delivered to the Sink. If the sensed data is forwarded to Sink periodically then it's a Time-Driven protocol (such as LEACH, EEPSC) and when the sensed data is forwarded only if an event occurs then it's Event-Driven protocol (ACM, ESDP). The clustering scheme varies with the respective protocols.

Clustering is defined [3] as the grouping of similar objects or the process of finding a natural association among some specific objects or data. It is used in WSN to transmit processed data to base station minimizing the number of nodes that take part in long distance communication leading to lowering of total energy consumption of the system.

The LEACH[4], introduced by Heinzelman et al .,is one of the most popular clustering based routing protocols. It determines a fraction of nodes which may become cluster heads . The selection of nodes to be CH is made probabilistically, so we cannot determine the number of clusters to be formed at any particular round or efficiency of clusters. After LEACH various protocols have been developed on Clustering either by altering one phase or defining clusters to different levels.

At present, the protocols defined are still using the Clustering approach with the change in time, numbers and direction of the clusters being formed. In the paper we are going to briefly overview the different protocols based on clustering approach starting from LEACH. The paper concludes with the possibilities in clustering for future.

2. RELATED WORK

2.1 Time Driven Protocols

The data is forwarded to the sink periodically. This results in redundant data generated at Sink with useless consumption of node's energy.

2.1.1 LEACH (*Low Energy Adaptive Clustering Hierarchy)*

The LEACH uses dynamic clustering, where different clusters are formed for each round. Based on the received signal strength of sensor nodes the clusters are formed and use local cluster head as routers to the sink. The data aggregation and compression is done within a cluster. The selection of a node as cluster-head is based on a random number between 0 and 1, and this number is compared with following threshold:

$$T(n) = p/(1 - p * \left(r \, mod \, \tfrac{1}{p}\right)) \ \text{ if n} \epsilon \text{G ,otherwise 0.}$$

where p is desired percentage of cluster heads (e.g. 0.05), r is current round and G is the set of nodes that have not been cluster heads in last 1/p rounds.

LEACH achieves factor 7 reduction in energy dissipation compared to direct communication. But due to single-hop routing (node-CH or CH-Sink transmission), a significant amount of energy is consumed by the nodes. Thus it is not applicable for networks in large regions.

2.1.2 HEED (Hybrid Energy-Efficient Distributed Clustering)
The cluster heads are elected[5] based on the residual energy of each node and neighbor proximity or node density. This helps in reducing excessive loss of energy while communicating with the nearest nodes only. The assumption with HEED is it considers quasi-stationary networks where nodes are location-unaware and have equal significance. This unawareness results in transmission delay since for each transmission the location is to be generated for neighboring nodes. It is also not suitable for a network with varied sensor nodes (heterogeneous).

The Dynamic clustering scheme has overhead of head-changes, advertisements etc, which exploits the limited energy of sensor nodes. The alternate to this scheme comes with only single cluster during network operation known as Static Clustering.

2.1.3 EEPSC (Energy- Efficient Protocol with Static Clustering)
For Static clustering, EEPSC [6] was defined. The clusters are formed only once during network action. The operation is defined in three phases, (A). Depending upon the reply of each node for the broadcast messages (k) from Sink, the nodes join the clusters. (B). The energy levels of each node in different clusters help in electing CH. (C). Data transmission, aggregation starts.

2.1.4 EEEPSC (Enhanced Energy Efficient Protocol with Static clustering)
It partitions the network into distance based static clusters depending upon the strength of the broadcasted messages from the Sink. The CH is selected based on spatial distribution and the residual energy of nodes. The nodes eligible for CH were defined apriori which was not possible in LEACH.

EEEPSC has a definite number cluster-heads unlike LEACH. The CH distribution was only known here. The problem with the static clustering protocols is due to same clusters the CHs loose energy fast in comparison to other nodes resulting in loss of that cluster. The energy distribution is uneven.

2.2 Event- Driven Protocols
The sensed data is forwarded to Sink only when a certain event occurs, preventing unnecessary bandwidth and energy consumption. The main issue is accurate event detection and reliable data transmission.

2.2.1 ACM (Assured Corridor Mechanism)
This protocol [7] utilizes the aspect of both periodic and event data. When a certain event takes place then the priority flat is set for the packet (emergency packets) and transmission of normal packets is paused. Also the frequency of emergency packet is

increased resulting in timely delivery to Sink. A corridor is generated from the event-location to the Sink. All the nodes within the corridor are kept awake while the rest sleep. This reduces the delay caused by the sleep-awake cycle.

It is efficient for few distant events only where the corridors have less common region. The nodes surrounding any frequent event occurring area become dead faster than others, so not proper utilization of energy.

2.2.2 ESDP (Event-Sink Directed Protocol)

This EWSN protocol [8], forms the cluster only upon occurrence of an event and only in the direction of data flow from event region to the data sink. ESDC adapts directed clustering notion and chooses the cluster-head in the direction of the Sink to minimize the delay of event flow. Shortest path is computed from the event in the direction of Sink. The main assumption is the consideration of single event in the entire network which is not practical. Also for a single event it generates different cluster but resolves the link failure issues in networks using the BackUp nodes.

3.CONCLUSIONS

The LEACH is origin of the Clustering scheme with overhead of cluster changes, advertisements. But it is efficient with respect to proper energy distribution in comparison to static counterparts.

The EWSNs are efficient to Time-driven but the later has the real and accurate data at the Sink. The applications needing real time data have to rely on the Time-driven for periodic updates.

4.REFERENCES

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