Energy Efficient Data Aggregation in Wireless Sensor Networks: A Survey

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Abstract— The use of Wireless Sensor Networks (WSNs) is anticipated to bring lot of changes in data gathering, processing and dissemination for different environments and applications. However, a WSN is a power constrained system, since nodes run on limited power batteries which shorten its lifespan. Prolonging the network lifetime depends on efficient management of sensing node energy resource. Energy consumption is therefore one of the most crucial design issues in WSN. Hierarchical routing protocols are best known in regard to energy efficiency. By using a clustering technique hierarchical routing protocols greatly minimize energy consumed in collecting and disseminating data. To prolong the lifetime of the sensor nodes, designing efficient routing protocols is critical. In this paper, we have discussed various energy efficient data aggregation protocols for sensor networks.

I. INTRODUCTION

Wireless Sensor Network is an emerging field with lot of applications. Due to its wide applications in the field of defense security, civilian applications and medical research, there is lot of research going on. There are various issues like deployment and routing issues of Wireless Sensor Networks (WSNs). With rapid advancement in electronics industry, small inexpensive battery powered wireless sensors have started to hit the market for communication purpose. Nodes in WSN can be deployed in a wide geographical space to monitor the changes in the environment. The development of this technology has been due to micro electro-mechanical systems technology, wireless communication and low-cost manufacturing. Sensors are expected to be deployed randomly in the area of interest by a relatively uncontrolled means, e.g. dropped by a helicopter, and to collectively form a network in an ad-hoc manner [1, 2].

Sensors nodes are energy constrained. Therefore, designing energy-aware algorithms becomes an important factor for extending the lifetime of sensors [3].

Data aggregation in WSN is a data transfer technique where multiple data packets from sensor nodes are gathered to a certain sensor node and combined into a less number of packets. This technique is essential in the wireless sensor environment because the reduction of data packets enables less usage of wireless transmission modules, reducing energy consumption, increase network lifetime, and decrease end-to-end delay. Efficient data aggregation techniques can provide these advantages by ensuring quick and high data aggregation rates, while avoiding excessive use of control packets. Sample commercial and military applications include environmental monitoring, industrial sensing and diagnostics, battlefield awareness, context-aware computing such as intelligent home and responsive environment.

II. DESIGN CONSIDERATIONS FOR WSN

The main aim of designing the goals for WSNs is to try to prolong the lifetime of the network by using different efficient energy management techniques. The design of routing protocols in WSNs is influenced by many challenging factors. Following are some of the challenges that affect the energy efficiency of WSNs.

Node deployment in WSNs is application-dependent. It can be manual or randomized. In manual node deployment, the sensors are manually placed at preplanned locations. However, in random node deployment, the sensor nodes are scattered randomly. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy-efficient network operation. Every node in the network cannot reach the BS directly hence there is a need multiple hops. Sensor nodes use energy for performing computation and communicating information in a network. Sensor nodes lifetime is strongly dependent on battery lifetime. Each node plays as a router and sensor in a multi-hop WSN. So there is a need of change of cluster head which act as a router in each round in the network, in order to prolong the network lifetime. Data delivery method is application specific. It can be subdivided as query-driven, time driven, event-driven, or a hybrid of all these methods.

III. MOTIVATION

Routing protocols providing an optimal data transmission route from sensor nodes to sink is to save energy of nodes in the network. Data aggregation plays an important role in energy conservation of sensor network. Data aggregation methods are used not only for finding an optimal path from source to destination but also to eliminate the redundancy of data, since transmitting huge volume of raw data is an energy intensive operation, and thus minimizing the number of data transmission. Also multiple sensors may sense the same phenomenon, although from different view and if this data can be reconciled into a more meaningful form as it passes through the network, it becomes more useful to an application.

IV. RELATED WORK

In this section we will focus on the related work that has been done previously by several researchers. Energy Efficiency for prolonging the WSN has received much focused attention. Researchers have focused on Wireless

Sensor challenges that have limited resource capabilities of the hardware i.e. memory, processing power, bandwidth and energy deposits.

Much research is currently being conducted in the following areas:

1) Increasing network lifetime.
2) Improving reliability of data transfer.
3) Finding solutions to assist easy deployment and maintenance.
4) Developing techniques that will enforce secure, private and trustworthy networks.

A. Low Energy Adaptive Clustering Hierarchy [5]

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol has attracted intensive attention because of its energy efficient, simplicity and load balancing properties. LEACH is a cluster based protocol. The numbers of cluster heads and cluster members generated by LEACH are important parameters for achieving better performance. LEACH organizes nodes into clusters with one node from each cluster serving as a cluster-head (CH). It randomly selects some predetermined number of nodes as cluster heads. CHs then advertise themselves and other nodes join one of those cluster heads whose signal they found strongest (i.e. the CH which is nearest to them). In this way a cluster is formed. The CH then makes a Time Division Multiple Access (TDMA) schedule for the nodes under its cluster. The communication between different clusters is done through CHs in a Code Division Multiple Access (CDMA) manner. The CHs collect the data from their clusters and aggregate it before sending it to the other CHs or base station (BS). After a predetermined time lapse, the cluster formation step is repeated so that different nodes are given a chance to become CHs and energy consumption is thus uniformly distributed.

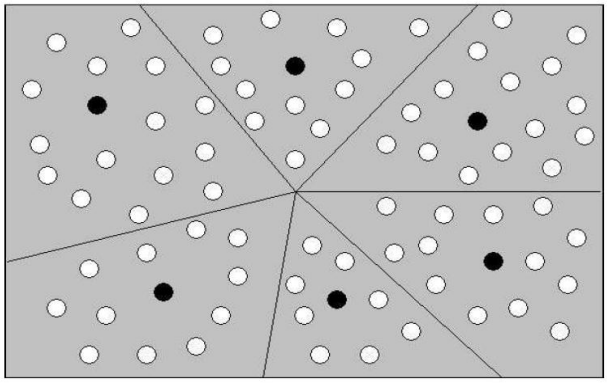

Figure: 1 Cluster head formation

Figure 1 is examples of the clusters constructed in which cluster heads are evenly distribute the energy load among the sensor nodes in a network. Black nodes represent cluster heads.

Operation: LEACH operation is broken into rounds, with each round having a set-up phase and a steady state phase.

Set-up phase: Each node decides whether or not to be a cluster-head based on its remaining energy and a globally known desired percentage of cluster heads. Each node electing itself as a cluster-head broadcasts an advertisement message announcing its intention. Non cluster head nodes receive possibly several advertisements and pick one cluster to join based on the signal strength of the advertisement received from the corresponding cluster-head

Steady-state phase: Each cluster-head waits to receive data from all nodes in its cluster and then sends the aggregated or compressed result back to a BS.

Weaknesses: Clustering is a good approach which, if implemented properly, can lead to energy efficient networking in WSNs. Despite the significant overall energy savings, however, the assumptions made by the protocol raise a number of issues as explained in [4]: LEACH assumes that all nodes can communicate with each other and are able to reach the sink (therefore, it is only suitable for small size networks), LEACH assumes that all nodes have data to send and so assign a time slot for a node even though some nodes might not have data to transmit, LEACH assumes that all nearby nodes have correlated data which is not always true, LEACH requires that all nodes are continuously listening (this is not realistic in a random distribution of the sensor nodes, for example, where cluster-heads would be located at the edge of the network), there is no mechanism to ensure that the elected cluster-heads will be uniformly distributed over the network (hence, there is the possibility that all cluster heads will be concentrated in one part of the network), periodic dynamic clustering carries significant overhead which may off-set energy gains derived by the clustering option.

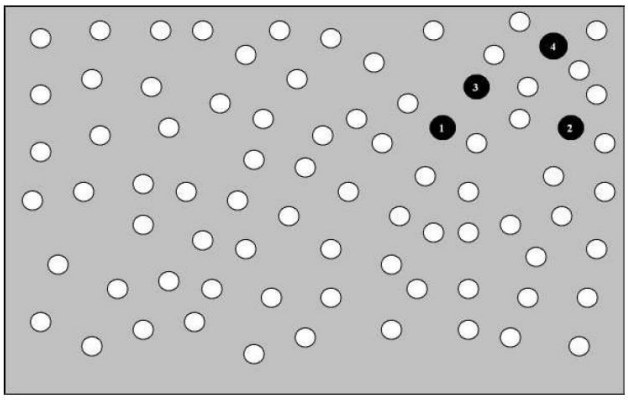

Figure: 2 50 Random nodes distribution in LEACH

Figure 2 is an example of the clusters constructed by LEACH. All the cluster-heads are distributed on the upper right corner. Thus the nodes in the left side will consume much energy to communicate with those cluster heads. In Figure 3.2, cluster head 4 contains no more than 6 cluster members. However, cluster-head 1 contains 30 cluster members at least. The power of Cluster-head 1 will be drained quickly. The nodes far away from cluster head 1 will also consume much energy to transmit data. After cluster head gathers all the data from cluster members, it forwards the data to the sink directly.

B. Random competition based clustering (RCC) [6]

Although RCC is designed for mobile ad hoc networks, it is also applicable to WSNs. RCC mainly focuses at cluster stability in order to support mobile nodes. The RCC

algorithm applies the First Declaration Wins rule, in which any node can ‘‘govern’’ the rest of the nodes in its radio coverage if it is the first to claim being a CH. After hearing the claim which is broadcasted by the first node, neighboring nodes join its cluster as member and give up their right to be a CH. To maintain clusters, every CH in the network broadcast a CH claim packet periodically. Since there is a time delay between broadcasting a claim packet and receiving it, concurrent broadcast can possibly create a conflict. Being unaware of on-going claims, many neighboring nodes may broadcast CH claim packets concurrently. To avoid such a problem RCC explicitly employs a random timer and uses the node ID for arbitration. Each node in the network reset its random time value, every time before broadcasting its CH claim packet. During this random time if it receives a broadcast message carrying CH claim packet from another node, it simply ceases the transmission of its CH claim. Since random timer is not a complete solution, RCC resolve further the concurrent broadcast problems by using the node ID. If the conflict persists, node having lower ID will become the CH. Although frequent node mobility still has direct effect, RCC is shown to be more stable than conventional clustering schemes.

C. PEGASIS: Power-Efficient Gathering in Sensor Information System [7]

By this author proposed algorithm PEGASIS that is a chain based protocol provide improvement over LEACH algorithms. In PEGASIS, each node communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round. Using greedy algorithm, the nodes will be organized to form a chain, after that BS can compute this chain and broadcast it to all the sensor nodes. Energy saving in PEGASIS over LEACH takes place by many stages: First, in the local data gathering, the distances that most of the sensor 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. PEGASIS outperforms LEACH by limiting the number of transmissions, eliminating the overhead of dynamic.

D. EECS: Energy Efficient Clustering Schemes [8]

Authors proposed an algorithm in which cluster formation is different from LEACH protocol. In LEACH protocol cluster formation takes place on the basis of a minimum distance of nodes to their corresponding cluster head. In EECS, dynamic sizing of clusters takes place which is based on cluster distance from the base station. The results are an algorithm that addresses the problem that clusters at a greater distance from the sink requires more energy for transmission than those that are closer. Ultimately it provides equal distribution of energy in the networks, resulting in network lifetime. Thus main advantage of this algorithm is the full connectivity can be achieved for a longer duration. So we can say it provides reliable sensing capabilities at a larger range of networks for a longer period of time. It provides a 35 percent improvement in network life time over LEACH algorithm.

E. MST-PSO: Minimum Spanning Tree-PSO [9]

Authors proposed a minimum spanning tree-PSO based clustering algorithm of the weighted graph of the WSNs. The optimized route between the nodes and its cluster heads is searched from the entire optimal tree on the basis of energy consumption. Election of cluster head is based on the energy available to nodes and Euclidean distance to its neighbor node in the optimal tree. Others have concluded that network life time does not depend on the base station location or residual energy of the node. Once the topology decided to then network life time becomes almost settled. Author’s shows two techniques for improving network life time: reduce the startup energy consumption of the transmitter and receiver, and optimized the network topology.

F. GROUP [10]

GROUP clustering algorithms based on clustering algorithm that provides scalable and efficient packet routing for large-scale WSNs. Only some parts of total number of sensor nodes participate in formation of cluster heads (CHs). In this, cluster heads are arranged in a grid manner and primary sink (One of the sink), dynamically and randomly builds the cluster grid. Greed Seed (GS) is a node within a given radius from the primary sink. Any queries from sink to nodes are propagated from greed seed to its cluster heads and so on.

V. CONCLUSION

Energy efficiency for prolonging the WSN has received much focused attention. Data aggregation plays an important role in energy conservation of sensor network. Data aggregation methods are used not only for finding an optimal path from source to destination but also to eliminate the redundancy of data. In this paper, we have discussed various existing energy efficient data aggregation techniques for wireless sensor networks.

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