A REVIEW ON SELF-ORGANIZING CLUSTERING METHODS FOR ENERGY-EFFICIENT DATA GATHERING IN SENSOR NETWORKS

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ABSTRACT

Wireless sensor networks are self-organizing low cost and low power utilizing network. It can sense, calculate and communicate the data. Collection of data at sensor nodes consumes a lot of energy and sensor nodes have limited energy. Especially, energy consumption in data transmission scales proportionally to the n^{th}power of the radius of the radio signal. Therefore, cluster-based data gathering mechanisms effectively save energy. In cluster-based data gathering, since each node can save transmission power and the number of collisions is also reduced sensor networks can live for longer period. In clustering, however, we need to consider that the other nodes in receiving data from cluster members, fusing data to reduce the size and sending the aggregated data to a base station.

This synthesizes existing clustering algorithms in wireless sensor networks and compare them in terms of their stable operation period(SOP) and highlights the challenges in clustering.

Keywords: Wireless Sensor Networks, Data Gathering Protocols, Energy-Efficient Operation, Clustering

I INTRODUCTION

Recent advances in Micro-electromechanical-systems(MEMS) based sensor technology, low-power digital electronics, and low-power radio frequency(RF) design have enabled the development of relatively inexpensive and low-power wireless micro sensors. Wireless sensor networks(WSNs) have given rise to many applications including environmental monitoring and military surveillance. In these applications sensors are usually remotely deployed in large numbers and operated autonomously. In these unattended environments, the sensors cannot be charged, so energy constraints is the most critical problem that must be considered. In large WSNs sensors are often grouped into clusters. Clustering is essential for sensor network applications where a large number of ad-hoc sensors are deployed for sensing purposes. If each and every sensor starts to communicate and engage in data transmission in

the network, great data congestion and collisions will be experienced. This will drain energy quickly from the sensor network. Clustering is a method used to overcome these issues.

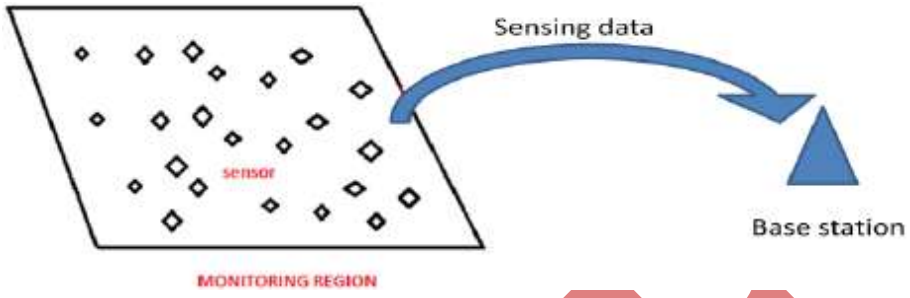

Figure 1 : Sensor Network

In Clustered networks, some sensors are elected as Cluster-Heads(CHs) for each cluster created. Sensor nodes in each cluster transmit their data to the respective CH and the CH aggregates data and forwards them to central Base-Station (BS). Clustering facilitates efficient utilization of limited energy of sensor nodes and hence extends network lifetime. Although sensor nodes in clusters transmit messages over a short distance(within clusters), more energy is drained from CHs due to message transmission over long distances(CHs to the base station) compared to other sensor nodes in the cluster periodic re-election of CHs within clusters based on their residual energy is possible solution to balance the power consumption of each cluster. Clustering increases the efficiency of data transmission by reducing the number of sensors attempting to transmit data to the base station. Aggregating data at CHs via in intra-cluster communication also helps in eradicating data duplication. Clustering is proposed because of its network scalability, energy saving and network topology stability. Clustering scheme reduce the communication overheads among the sensor nodes.

II CHALLENGES FOR CLUSTERING ALGORITHMS [1]

Clustering schemes play an important role in WSN; these can effectively improve the network performance. There are several key limitations in WSNs that clustering schemes must consider:

a) **Limited Energy: Wireless** sensor nodes are small size battery operated sensors, so they have limited energy storage. It is not practicable to recharge or replace their batteries after exhaustion. The clustering algorithms are more energy-efficient compared to the direct routing algorithms. This can be achieved by balancing the energy consumption in sensor nodes by optimizing the cluster formation, periodically re-electing CHs based on their residual energy and efficient intra-cluster and inter-cluster communication.

b) **Network Lifetime :**The energy limitation on nodes results in a limited network lifetime for nodes in a network. Clustering schemes help to prolong the network lifetime of WSNs by reducing the energy usage in the communication within and outside clusters.

c) **Limited Abilities :**The small physical size and small amount of stored energy in a sensor node limits many of the abilities of nodes in terms of processing, memory, storage and communication.

d) **Secure Communication :**The ability of a WSN to provide secure communication is ever more important when considering these networks for military applications. The self-organization of a network has a huge dependence on the application, it is required for,An establishment of secure and energy efficient intra-cluster and inter-cluster communication is one of the important challenges in designing clustering algorithms since these tiny nodes when deployed are unattended to in most cases.

e) **Quality of Service(QoS) :** From an overall network standpoint, we can look at QoS requirements in WSNs. Many of these requirements are application dependent such as acceptable delay and packet loss tolerance, etc.

III CLUSTERING PROCESS

There are two main steps in clustering, which are CH selection and cluster formation. CH selection could be classified into three types, centralization by the BS, decentralization by the sensor nodes or hybrid selection by some information provided by the BS and some by the nodes themselves.

3.1 The Main Concerns in Selecting CH_S Are:

Distance between CHs and the BS to ensure that CHs are not too far from the BS, making inter-cluster communication or communication between CH and BS expensive Uniform CH distribution so that CHs are not cluttered. Cluttered CHs can cause long distance between non-CH nodes and their corresponding CH. In other words causing high energy consumption for intra-cluster communication CHs perform extra tasks for WSNs such as: data aggregation and forwarding therefore energy at the CHs might be depleted quickly. CH re-selection or rotation is another concern in clustering. In reselecting a CH, one must consider how much overhead in terms of energy consumption and time it takes. Residual Energy in a sensor node to be elected as a CH.

Time delay: how long it takes to select a CH and to form a cluster. This parameter could mean the communication disruption during that period.

3.2 The Main Concerns in Joining a CH For A Sensor Node Are:

Distance between a node and a CH. This is often presented as signal strength between CHs and the node itself.

Number of hops from a node to its CH

Cluster size: the decision whether or not a node joins a cluster also depends on the size of a cluster. The number of nodes in a cluster represents the accumulated energy in a cluster and also extra energy consumption for the CH to serve its cluster.

IV CLUSTERING ALGORITHMS FOR WIRELESS SENSOR NETWORKS

4.1 Low-Energy Adaptive Clustering Hierarchy(LEACH) [2]

LEACH is a protocol architecture for sensor networks that combines the ideas of energy efficient cluster-based routing and media access together with application specific data-aggregation to achieve good performance in terms of system lifetime, latency and application perceived quality. The operation of LEACH is divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase when data are transferred from the nodes to the cluster head and on to the BS, as shown in fig 2.

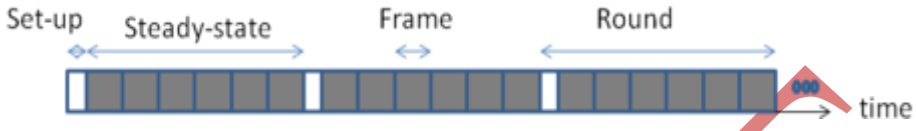

Fig 2: Time line showing LEACH operation. Adaptive clusters are formed during the set-up Phase and data transfers occur during the steady-state phase

LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control.

4.2 Hybrid Energy-Efficient Distributed Clustering (HEED) [3]

HEED considers a hybrid of energy and communication cost when selecting cluster heads. Unlike LEACH, it does not select cluster heads randomly. Only sensor nodes that have a high residual energy can become cluster heads.

In HEED residual energy is used as a primary parameter to probabilistically select an initial set of cluster heads, and the secondary parameter ,intra-cluster communication cost, to "break ties" among them.
The secondary clustering parameter, intra-cluster communication cost, is a function of
1) Cluster properties, such as cluster size, and
2) Whether or not variable power levels are permissible for intra-cluster communication.
If the power level used for intra-cluster communication is fixed for all nodes, then the cost can be proportional to
1) node degree, if the requirement is to distribute load among cluster heads, or
2) 1 /node degree , if the requirement is to create dense clusters.
This means that a node joins the cluster head with minimum degree to distribute cluster head load (possibly at the expense of increased interference and reduced spatial reuse), or joins the one with maximum to create dense clusters. We use the terms minimum degree cost and maximum degree cost to denote these cost types. Observe that inter-cluster communication is not incorporated in the cost function since local information is insufficient in this case.

4.3 Multihop Routing Protocol With Unequal Clustering (MRPUC) [4]

This method creates unequal size clusters in sensor network to avoid hot-spot problem, which arises near base-station area, when multi-hop data transmission protocol is used.
MRPUC uses many measures to balance the energy of nodes.
First, it selects the nodes with more residual energy as cluster heads, and clusters closer to the base station have smaller sizes to preserve some energy during intra-cluster communication for inter-cluster packets forwarding.

Second, when regular nodes join clusters, they consider not only the distance to cluster heads but also the residual energy of cluster heads.

4.4 An Energy-Efficient Unequal Clustering Mechanism For Wireless Sensor Networks(EEUC) [7]

This method of unequal clustering wisely cluster the network into unequal size clusters. EEUC is a distributed competitive algorithm, cluster heads here are selected by localized competition, which is unlike LEACH, and there is no iteration, which differs it from HEED. The node's competition range decreases as node's distance from the base station decreases. This results in clusters closer to the base station have smaller cluster sizes, thus these small size clusters will consume lower energy during the intra-cluster data processing, and can preserve some more energy for the inter-cluster relay traffic.

EEUC is a distributed clustering algorithm, where cluster head selection is based on residual energy of each node. The algorithm begins with the selection of several tentative cluster heads to compete for final cluster heads. Every node becomes a tentative cluster head with the same probability T which is a predefined threshold. Other nodes stay in sleep mode until the cluster head selection process ends. Suppose node i becomes a tentative cluster head, i has a competition range R_{comp} , this competition range is a function of its distance from the base station.

4.4 Energy Efficient Clustering (EC) [6]

To address the hot-spot issue, UCR, EEUC, MRPUC, EEDUC and UCS propose using multi-hop routes to the sink and conclude that cluster sizes should be smaller as clusters approach the sink. The small size clusters near the sink region is to compensate for the inter-cluster energy consumption by reducing the intra cluster energy consumption with smaller cluster sizes.

Unequal Clustering techniques which we discussed in last two sections have some deficiencies. For example both MRPUC and EEUC assume network-wide announcements during cluster formation process.However; such an assumption not only reduces energy efficiency, but also limits the applicability to small-scale networks only.

EC algorithm focuses on balancing energy consumption within the network and also avoid network wide broadcasting of control packets.

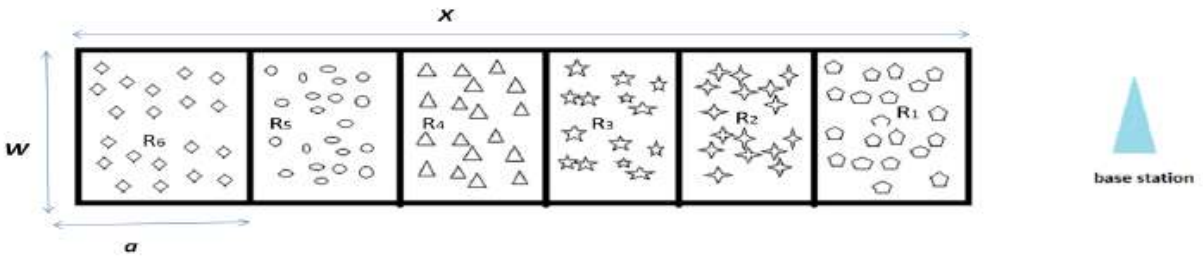

Figure 3: Network Is Divided Into Rectangular Region

The rate of energy consumption of nodes in a particular region is approximately equal with this the lifetime of nodes in a particular region same and is denoted by τ(i).EC algorithm targets to equalize the lifetime of all regions and to maintain equal energy levels at all regions throughout the lifetime of WSN.

How to iterate L:

The equation (i) = L turns into a second order polynomial $AP_i^2 + BP_i + C = 0$, of $P_i$when P_K, P_{K-1}, . . . , P_{i+1} are considered constant. Now becauseP_i's are probability values, the roots of this polynomial should be positive real and have values between 0 and 1. To satisfy this condition the equation $B \leq 2\sqrt{AC}$ must hold by constant coefficients A,B and C. it means, the value of L is iteratively increased in $\tau(i)$ = L for all i's until we start to get imaginary solutions of $P_i's$ and stop at the largest non-imaginary set of solutions.

Cluster head selection:

After the calculation of CH probabilities for each region the cluster head selection process begins.Cluster formation is performed as a distributed algorithm at the beginning of each data collection round, DCR. This involves election of CH nodes among a set of candidates followed by node-CH associations.

V ADVANTAGES

Open space can provide community members with larger recreation areas and create a sense of openness that many people desire. Open space can benefit the environment by providing habitat for wildlife, naturally filtering storm water, reducing storm water runoff from impervious surfaces and protecting the natural features of site. Linking the open space of several conservation design subdivisions can help develop larger and more effective "environmental corridors" within and between communities. Developers may benefit because these designs usually reduce the costs of site development and increase the market price of individual plots in comparison with traditional subdivisions. These designs can benefit rural areas by reinforcing the policy of maintaining the local rural character that is included in many comprehensive land use plans.

VI DISADVANTAGES

Perhaps most important, local officials, developers and the community may be predisposed toward. Traditional development designs because they are familiar and well understood. An education effort may be necessary to help these groups understand the goals and advantages of cluster development. During the planning phases, lot and home layout may take extra work to ensure that while homes are – Cluster/Conservation development land use planning – Local community located closer together, they still take advantage of the open-space goals of the design. Methods to protect and maintain the open space must be carefully developed, implemented and monitored. Although not necessarily a restricting disadvantages the management of waste water must be carefully, designed for smaller lots. While these disadvantages should be acknowledged and addressed, none should preclude the use of cluster development.

VII CONCLUSION

Clustering is widely used approach for large scale sensor networks for the efficient management of topology of the network and to reduce the communication overhead. clustering exploit data aggregation which reduces the amount of data for transmission and consequently increases the lifetime of the network. A number of clustering algorithms have been devised and some are reviewed in this review paper. This paper focused mostly on distributed unequal clustering algorithms, because they are more suitable for large-scale sensor networks. However, the energy consumption in forming clusters and maintaining them is still high; the compelling challenges for existing clustering algorithms are how to schedule intra-cluster and inter-cluster communication so that the resulting data communication overhead could be reduced, how to compute the optimal cluster size, how to calculate the optimal frequency for rotating the role of cluster head among nodes in order to maximize lifetime of the sensor network.

In this paper, first we discussed an energy efficient multi-hop data routing mechanism also known as reactive routing. Second, we discussed the clustering mechanism of some well-known clustering approaches. Finally, a comparison is carried out among these algorithms, in terms of their SOP, no of messages transmitted and effect of varying node density and network parameters.

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