

Comparative Survey of Distributed Energy Aware Clustering Algorithm

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Abstract: *Wireless Sensor networks, a huge number of small sensors are deployed to create a network which cooperate together to set up a sensing network. To develop applications and protocols for sensor network, the maximum network lifetime and minimal energy consumption should be considered as important parameters. Improved network lifetime, scalability and load balancing are important parameters for wireless sensor networks. Clustering is very useful technique through which we can affect these factors. The method of clustering prolongs network topology by using energy, bunch and centrality factors and also the distances between nodes for formulating clusters. A supervisor node is assumed which elects new cluster head when existing cluster head fails. This property causes a raise in network lifetime. This survey compares the performance of distributed energy-aware clustering algorithm such as LEACH, FEED, HEED, EADC protocol. The report is based on energy consumption, network lifetime and scalability from the previous works that has been done.*

Keywords: LEACH, FEED, HEED, EADC, lifetime, energy, clustering.

1. Introduction

Wireless sensor networks [1-10] consist of hundreds to thousands of low-power multi functioning sensor nodes, working in an unattended environment with limited computational and sensing capabilities. In recent years, researchers have done a lot of studies and proved that clustering is an effective scheme in increasing the scalability and lifetime of wireless sensor networks. The limited energy available at the sensors makes the network lifetime one of the most critical issues in the design of WSNs. An systematic lifetime analysis can considerably help the network design.

LEACH [2-4] is a typical clustering protocol proposed for periodical data gathering applications in wireless sensor networks. In LEACH, each node alone elects itself as a cluster head with a probability. Cluster heads receive and combine data from cluster members and send the aggregated data to the BS by single-hop communication. In order to balance the energy using up, the role of cluster head is sometimes rotated among the nodes. LEACH protocol is simple and does not involve a large communication overhead. However, the performance in heterogeneous networks is not especially fit, because it elects cluster heads without considering the residual energy of nodes. To solve this problem, researchers enhanced LEACH and proposed some new algorithms. The imbalanced energy consumption exists among cluster heads due to the non-uniform node distribution.

Hybrid Energy Efficient Distributed clustering Protocol (HEED) [3-5] protocol extends the basic scheme of

LEACH by using residual energy as primary parameter and network topology features (e.g. node scale, distances to Neighbors) are only used as secondary parameters to break tie between candidate cluster heads, as a metric for cluster selection to realize power balancing. The clustering process is separated into a number of iterations, and nodes which are not covered by any cluster head double their probability of becoming a cluster head. Because these energy-efficient clustering protocols enable every node to independently and probabilistically decide on its role in the clustered network, they cannot assure optimal elected set of cluster heads.

The protocol is an extension of TEEN [2-7] aiming to capture both time-critical events and periodic data collection. The network construction is same as TEEN. After forming clusters the cluster heads broadcast attributes, the threshold value, and the broadcast schedule to all nodes. Cluster heads are also dependable for data aggregation in order to decrease the size data transmitted so energy consumed. According to energy dissipation and network lifetime, TEEN gives better performance than LEACH and APTEEN because of the decreased number of transmissions.

Proposed [6-9], non-uniform node distributions, the energy consumption among nodes are more imbalanced in cluster-based wireless sensor networks. A cluster-based routing protocol for wireless sensor networks with non-uniform node distribution is projected, which includes an energy-aware clustering algorithm EADC and a cluster-based routing algorithm. EADC uses competition choice to construct clusters of even sizes.

2. Clustering in Wireless Sensor Networks

In [9], Clustering can be defined as a pictorial arrangement of the dynamic nodes into various groups. These effective collections of nodes are grouped together regarding their relative transmission range proximity to each other that allows them to establish a bidirectional link. The diameter size of the clusters determines the control architectures as single-hop clustering and multi-hop (K-hop) clustering. In single-hop clustering each member node is never more than 1-hop from a central coordinator and the cluster head.

Thus all the member nodes remain at most two hops distance away from each other within a coherent cluster. In multi-hop clustering, the limitation or restriction of an immediate proximity to member nodes from the head is removed, allowing them to be present in serial k-hop distance to form a cluster.

3. Design Goals of Clustering

Implementing clustering algorithms are crucial to the design if the aim to create an invisible global infrastructure is ever to be realized where mobile devices can communicate with each other effectively, efficiently, reliably and wirelessly without loss of connectivity, data or huge amounts of energy.

4. Advantages of Clustering

The cluster architecture with a large number of terminals ensures efficient performance. The cluster structure provides a certain amount of benefits, a few of which are mention below:

- Aggregation of Topology Information
- Efficiency and Stability
- Communication Coordination
- Routing Efficiency
- Spatial Reuse of Resources

5. Distributed Energy-Aware Clustering Algorithms

However, following are the protocols that are used for distributed energy-aware clustering function.

1. Low Energy Adaptive Cluster Hierarchy (LEACH) protocol
2. Fault Tolerant, Energy Efficient, Distributed Clustering (FEED) protocol
3. Hybrid, Energy-Efficient, Distributed Clustering (HEED) protocol
4. Energy aware Distributed clustering (EADC) protocol

5.1 Low Energy Adaptive Cluster Hierarchy (LEACH)

LEACH (Low Power Adaptive Clustering Hierarchy) [2-4] is an algorithm used for clustering in WSN. In this algorithm there is a probability formula for every node to be a cluster head in every round. Cluster head receive and aggregate message from cluster members and send the aggregated data to the BS by single hop communication. The clusters in the network are formed based upon the received signal power

and use local CHs as routers to the sink. At the starting of every round every node chooses a random number between 0 and 1. There is a threshold number $T(n)$ which varies in each and every round. The node can be a cluster head in the current round if the random number chosen by it is less than $T(n)$. If a node decides to be a cluster head in a definite round, it informs other nodes about this fact by broadcasting a message. Then every regular node joins the near cluster. The LEACH probability formula is:

$$T(n) = p(n) / (1 - p(n)^{r \bmod (1/p(n))}) \quad \forall n \in G$$

Where n is the number of network nodes, r is the number of the round, G is the set of nodes that haven't been cluster head in the last lip rounds and p is the desired percentage of cluster heads which equals to 0.05. This formula lets every node to have the chance of being a cluster head once in every lip rounds. LEACH enhances network lifetime and energy consumption compared with the direct algorithm. One shortcoming of LEACH is that it doesn't consider the energy factor in selecting cluster heads. Thus chosen cluster heads aren't always suitable for the network.

5.2 Fault Tolerant, Energy Efficient, Distributed Clustering (FEED)

In FEED (Fault tolerant, Energy Efficient, Distributed Clustering) [2-3] all network nodes are divided into clusters such that at the end of the algorithm there are some cluster heads (CH), some pivot cluster heads (PCH), and some supervisor nodes (SN). A CH node is a regular cluster head which is the head of its cluster. A PCH node is a pivot cluster head with additional capabilities beyond a CH node. All the PCH nodes together cover a large area of the entire network and are also the best nodes for acting as routers. A SN node is a supervisor node for its cluster head (CH or PCH) and will replace its CH or PCH when the CH or PCH fails. So, SN nodes are substitutes for their cluster heads and also try to achieve to a fault tolerant clustered network.

5.3 Hybrid, Energy-Efficient, Distributed Clustering (HEED)

In HEED (A Hybrid, Energy-Efficient, Distributed Clustering) [4] several iterations are needed to choose a Cluster head. The time slice (round trip) for each round should be long enough for a node to receive all sent messages from its neighbor nodes. All nodes assume the initial probability to become a cluster head as follows:

$$CH_{prop} = C_{prop} \times (E_{residual} / E_{max})$$

At the beginning of each round all uncovered nodes decide to be cluster heads with probability CH_{prob} . If a node decides to be a cluster head, it broadcasts a message to other nodes. In this message if CH_{prob} is less than 1, the node introduces itself as a tentative cluster head. If CH_{prob} is equal to or greater than 1, the node introduces itself as a final cluster head. At the end of each round all nodes double their CH_{prob} . A node assumes itself covered if it is covered by at least one tentative or formal cluster head. If at the end of a round, a definite node isn't covered by any tentative or final cluster head, it reveals itself as a final cluster head. Then

each node joins a cluster which generates the minimum cost for it.

5.4 Energy Aware Distributed Clustering (EADC)

This process is similar to the cluster set-up phase in EADUC [6]. The whole process is divided into three phases: information gathering phase, whose duration is T1; cluster head election phase, whose duration is T2; cluster forming phase, whose duration is T3.

5.4.1 Information Gathering Phase

The duration of the phase is defined as T1, during which each node broadcasts a Node Msg with the following two values: one is the node id, and the other is the residual energy of this node within radio range r. At the same time, it receives the Node Msg messages from its neighbor nodes, according to which, each node s_i calculates the average residual energy $E_{i,r}$ of its neighbor nodes by using the following formula.

$$E_{i,r} = \frac{1}{d} \sum_{j=1}^d E_{j,r}$$

Where, $E_{j,r}$ denotes the residual energy of s_j , one neighbor node of s_i , and d is the number of all neighbor nodes of s_i . For each node, we give the following formula using which to calculate its waiting time for broadcasting Head Msg message.

$$t_i = \begin{cases} \frac{E_{i,r}}{E_{i,r}} T2V_r, & E_{i,r} \geq E_{i,r} \\ T2V_r, & E_{i,r} < E_{i,r} \end{cases}$$

Where, t_i denotes the waiting time of s_i , and $E_{i,r}$ is the residual energy of s_i , V_r in the formula is a real value uniformly distributed in [0.9, 1] which is introduced to reduce the probability that two nodes send Head Msg s at the same time.

5.4.2 Cluster Head Election Phase

When T1 has expired, EADC begins the cluster head competition phase whose duration is T2. In this phase, if node s_i receives no Head Msg when timer t_i expires, it broadcasts the Head Msg within radio range R_c to advertise that it will be a cluster head. Or else, it gives up the competition.

5.4.3 Cluster Forming Phase

After T2 expires, the last phase of EADC is the cluster formation phase; we define the duration as T3. In this phase, each non-cluster head node chooses the nearest cluster head and sends the Join Msg which contains the id and residual energy of this node. According to the received Join Msgs, each cluster head creates a node schedule list including the Schedule Msg for its cluster members, the Schedule Msg is used for telling the cluster members when they can transmit their message to the cluster head and in other time interval they can alter their state to a sleep to reduce the energy consumption. At this point, the entire process of EADC is completed. Each cluster is composed of the nodes in the Voronoi cell around the cluster head. EADC works according to the following five phases.

Density - This factor for every node reveals the number of nodes around that node such that their distances are less than a threshold Distance. It'll be very good if we choose cluster heads from nodes that have the greatest density factors.

Centrality - Sometimes a node has a good density factor meaning that there are lots of near nodes around it but they are all on one side of that node. It is enviable to choose cluster heads from those nodes at the center of their neighbors.

Energy - It is clear that cluster heads should be chosen from those nodes with enough remaining energy.

Near to other nodes - As mentioned, all nodes contribute to choosing cluster heads. A node that is going to be a cluster head is called a Volunteer. All nodes vote for volunteers. A regular node tries to vote for the near volunteer. Cluster heads should be selected from the nodes that many nodes elect as their nearest one.

Not being in border - Cluster heads shouldn't be chosen from nodes at the border of the network because border cluster heads. Create problems for their members during communication.

6. Performance Analysis

We compare the distributed clustering protocol LEACH, FEED, HEED, EADC based upon the following metrics like scalability, remaining energy and topology lifetime. We analyzed these from various works that have been already done in various papers.

Scalability

A WSN can consist of thousands of sensor nodes, compactly deployed in an local area. Protocols must thus degree well with the number of nodes. This is often attained by using distributed and contained algorithms, where sensor nodes only communicate with nodes in their zone. Centralized approaches are not related, especially because of the single point of failure problem.

Remaining Energy

One of the most significant research interests is energy efficiency in wireless sensor networks because it settles the lifetime of the sensor network. Residual energy is critical to cluster heads because cluster heads suffer heavier burden than general cluster members. The energy will drain quickly as cluster head needs to not only collect data from its cluster members but also process, data aggregation and then transmit message to the sink. To ensure that the cluster heads perform their task without interrupt, the nodes are more eligible than the others nodes in terms of residual energy that have the maximum remaining energy. The remaining energy is calculated up to 50 cycles.

Topology Lifetime

In this paper, we define three metrics to quantify the network stability in the hierarchical architecture: the cluster lifetime, the inter-cluster link lifetime, and the end-to end path lifetime. These three correlated metrics measure

Table 1: Comparative Survey

	SCALABILITY	REMAINING ENERGY	TOPOLOGY LIFETIME
LEACH	Medium	Dry	Low
FEED	Medium	Highly stable	High
HEED	Low	Dry	Medium
EADC	High	Highly stable	High

different stability aspects of the hierarchical structure. The cluster lifetime indicates how often the nodes change their - Cluster memberships, the inter-cluster link lifetime assesses how long neighbor clusters remain connected, and the path lifetime evaluates how stable an end-to-end communication path can be. It is obvious that long lifetime implies stable architecture and good communication performance.

According to the comparative survey shown in Table 1, the scalability of EADC is high compared to other protocols, HEED suffers from low scalability. The remaining energy of FEED and EADC is highly stable but LEACH and HEED protocol's remaining energy dries as the number of cycles increase. The topology lifetime of FEED and EADC is high compared to other protocols.

7. Conclusion And Future Work

A comparison between LEACH, FEED, HEED and EADC clustering protocol has been made in this report based on scalability, remaining energy, and topology lifetime. We propose a cluster-based routing protocol for wireless sensor networks with which contains an energy-aware of maximal lifetime of clustering algorithm. The clustering algorithm balances the energy consumption among cluster members by constructing equal clusters and unequal clusters. In addition an algorithm for border node detection proposed which used to prevent boundary node become cluster head. Performance evaluation showed that our algorithm provides a better network lifetime and a better ratio "Number of CHs/Total number of sensors" than LEACH, FEED, HEED and EADC a recently published clustering protocol for wireless sensor networks.

References

- [1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: a survey", Elsevier Science, December 2002.
- [2] Mohammad Mehrani, Jamshid Shanbehzadeh, Abdolhossein Sarrafzadeh, Seyed Javad Mirabedini, Chris Manford, "FEED: Fault Tolerant, Energy Efficient, Distributed Clustering for WSN", Global Journal of Computer Science and Technology, Volume 11 Issue 2 Version 1.0 February 2011
- [3] Javad memariani, Zurati Ahmad Zukarnain, Azizol Abdullah and Zurina Mohd, "A distributed energy-aware clustering algorithm for life time enhancement of wireless sensor network", Journal of Applied sciences 12(14):1432-1444,2012
- [4] Jau-Yang Chang* and Pei-Hao Ju, "An efficient cluster-based power saving scheme for wireless sensor networks", EURASIP Journal on Wireless Communications and Networking 2012, 2012:172
- [5] Bo-Chao Cheng, Hsi-Hsun Yeh, and Ping-Hai Hsu, "Schedulability Analysis for Hard Network Lifetime Wireless Sensor Networks with High Energy First Clustering", IEEE TRANSACTIONS ON RELIABILITY
- [6] Jiguo Yu, Yingying Qi, Guanghui Wang, XinGui (2012), "A cluster-based routing protocol for wireless sensor networks with nonuniform node distribution", International Journal of Electronics and Communications (AEÜ).
- [7] AbhishekMajumderandNityanandaSarma (Sep. 2010), "DEMAC: A Cluster-Based Topology Control for Ad Hoc Networks," IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 5.
- [8] Abdel Rahman H. Hussein, SufianYousef, and Omar Arabiyat (2007), "A Load-Balancing and Weighted Clustering Algorithm in Mobile Ad-Hoc Network". Journal of Software; 18: 1092-109.
- [9] Tao Liu, Qingrui Li, Ping Liang ((2012), "An energy-balancing clustering approach for gradient-based routing in wireless sensor networks". Computer Communications xxx.
- [10] Yu.C.W, Chang.C.Cand Chou.J.H (2009), "Minimizing the number of clusters in IEEE 802.15.4 wireless sensor networks", in ProcWiMoN.