A Technical Review on LEACH and DEEC for Heterogeneous Wireless Sensor Network

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Abstract—**Wireless sensor networks (WSNs) are presently equipped to handle more complex functions. The main challenges in wireless sensor network include enhancement of stability, conservation of energy, the lifetime of the node and the throughput of the network and its node. To improve the stability of the network as well as to reduce the energy consumption clustering is used. In a cluster, efficient routing protocol plays a vital role in maintaining the stability and also helps in saving energy. In heterogeneous networks the nodes with the higher energy have more chances to become cluster head than the nodes have low energy. It simply means that selection of cluster head and giving tasks to them will increase energy efficiency.**
In this paper we proposed LEACH (Low Energy Adaptive Clustering Hierarchy) and DEEC (Distributed Energy Efficient Clustering) for heterogeneous wireless sensor network. It is based on dynamically changing cluster head election probability. Various energy efficient protocols for Heterogeneous WSN have been developed in recent years and are discussed in this paper.

Index Terms—Energy Efficiency, Clustering, LEACH, DEEC

I. INTRODUCTION

Technological developments in the field of Micro Electro-Mechanical Sensors (MEMS) have enabled the development to tiny, low power, low cost sensors having limited processing, wireless communication and energy resource capabilities, with the passage of time researchers have found new applications of WSN. In many critical applications WSNs are very useful such as military surveillance, environmental, traffic, temperature, pressure, vibration monitoring and disaster areas. To achieve fault tolerance, WSN consists of hundreds or even thousands of sensors randomly deployed inside the area of interest [1]. All the nodes have to send their data towards BS often called as sink. Usually nodes in WSN are power constrained due to limited battery, it is also not possible to recharge or replace battery of already deployed nodes and nodes might be placed where they cannot be accessed. Nodes may be present far away from BS so direct communication is not feasible due to limited battery as direct communication requires high energy. Clustering is the key technique for decreasing battery consumption in which members of the cluster select a Cluster Head (CH). Many clustering protocols are designed in this regard [2]. All the nodes belonging to cluster send their data to CH, where, CH aggregates data and sends the aggregated data to BS [3]. Under aggregation, fewer messages are sent to BS and only few nodes have to transmit over large distance, so high energy is saved and over all lifetime of the network is prolonged.
Recent advances in wireless communication technologies have enabled the development of large-scale wireless sensor network that consist of many low-powers, low-cost and small-size sensor nodes. Sensor network hold the promise of facilitating large-scale and real-time data processing in complex environments. Key management is crucial to the secure operation of wireless sensor network.
Energy consumption for aggregation of data is much less as compared to energy used in data transmission. Clustering can be done in two types of networks i.e. homogenous and heterogeneous networks. Nodes having same energy level are called homogenous network and nodes having different energy levels called heterogeneous network.

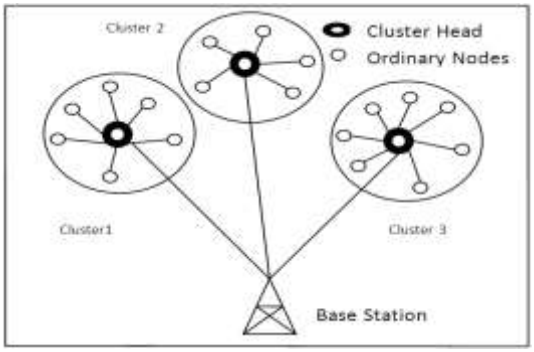

Figure 1: Clustering Based WSN

In this paper, we study performance of heterogeneous WSN protocols multi-level heterogeneous networks. We compare performance of LEACH (Low Energy Adaptive Clustering Hierarchy) and DEEC (Distributed Energy Efficient Clustering) multilevel heterogeneous WSNs. Heterogeneous networks contain normal, advanced and super nodes whereas super nodes have highest energy level as compared to normal and advanced nodes.

II. Concepts of Wireless Sensor Network

A WSN can be defined as a network of devices, denoted as *nodes*, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links. The data is forwarded, possibly via multiple hops, to a *sink* (sometimes denoted as *controller* or *monitor*) that can use it locally or is connected to other networks (e.g., the Internet) through a *gateway*. The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not.

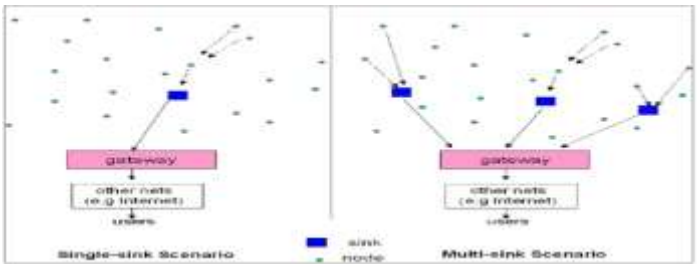

Figure 1: Left part: single-sink WSN. Right part: multi-sink scenario.

This is a traditional single-sink WSN (see Figure 1, left part). Almost all scientific papers in the literature deal with such a definition. This single-sink scenario suffers from the lack of scalability: by increasing the number of nodes, the amount of data gathered by the sink increases and once its capacity is reached; the network size cannot be augmented. Moreover, for reasons related to MAC and routing aspects, network performance cannot be considered independent from the network size.

From this definition, main characteristics of the Wireless Sensor Network can be defined:

- Power consumption constraints for nodes using batteries or energy harvesting
- Ability to cope with node failures (resilience)
- Some mobility of nodes (for highly mobile nodes see MWSNs)
- Heterogeneity of nodes
- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions
- Ease of use
- Cross-layer design

Cross-layer is becoming an important studying area for wireless communications. In addition, the traditional layered approach presents three main problems:

1. Traditional layered approach cannot share different information among different layers, which leads to each layer not having complete information. The traditional layered approach cannot guarantee the optimization of the entire network.
2. The traditional layered approach does not have the ability to adapt to the environmental change.
3. Because of the interference between the different users, access conflicts, fading, and the change of environment in the wireless sensor networks, traditional layered approach for wired networks is not applicable to wireless networks.

So the cross-layer can be used to make the optimal modulation to improve the transmission performance, such as data rate, energy efficiency, QOS (Quality of Service), etc. Sensor nodes can be imagined as small computers which are extremely basic in terms of their interfaces and their components. They usually consist of a *processing unit* with limited computational power and limited memory, *sensors* or MEMS (including specific conditioning circuitry), a *communication device* (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery. Other possible inclusions are energy harvesting modules, secondary ASICs, and possibly secondary communication interface (e.g. RS-232 or USB).

The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Other special components in routing based networks are routers, designed to compute, calculate and distribute the routing tables.

III. Literature Review

B. Baranidharan and B. Santhi, "An Evolutionary Approach to improve the life time of the Wireless sensor network". In this paper, they worked on the approach that how energy efficiency in the wireless sensor is increased by Genetic algorithm approach? Genetics operators are applied in such a way to reduce the redundant information to the sink and conserve its energy reserves, thereby, increasing the life time of nodes.

Sujee et al (2015) proposed that Wireless Sensor Network (WSN) technology used to sense various types of physical and environmental conditions with the availability of small and low-cost sensor nodes. Main drawback in WSN is limited battery power in the sensor nodes. Here, first analyzed the basic distributed clustering routing protocol LEACH, which is in a homogeneous environment, then analyzed with the heterogeneity concept in nodes to increase the life of WSN. Simulation results were obtained using MATLAB that shows the LEACH heterogeneous environment significantly reduces energy consumption and increases the total lifetime of the WSN than LEACH homogeneous environment.

Amit Sharma et al (2014) said that In WSN, it is too difficult to initialize the sensor nodes and manage the sensor networks due to the large number of sensor nodes, which may number tens of thousands. Moreover, in order to save energy, sensor nodes carry out data aggregation and compression before sending data to the base station, and execute energy efficient routing. So in this research work amit Sharma Dr. S. N. Panda et al analyzed that cluster based routing technique is the best energy efficient routing technique comparing to any other techniques.

In [3], authors introduce first time reactive protocol Threshold Sensitive Energy Efficient sensor network protocol (TEEN). The sensed attribute is temperature, which is divided into two categories; Hard Threshold (HT) and Soft Threshold (ST). HT is the value of the attribute beyond which the node senses this value must switch on its transmitter and report to its CH. On the other hand, ST is the small sensed value after HT which further reduce the energy consumption.

Authors in this work [4] propose a Chain-Cluster based Mixed routing protocol (CCM) which makes full use of the advantages of LEACH and Power-Efficient Gathering in Sensor Information Systems (PEGASIS), and provides improved performance. It divides the network into few chains and executes in two stages. In the first stage, sensor nodes in each chain transmit data to their own chain head node in parallel, using an improved chain routing protocol. In the second stage, all chain head nodes group as a cluster in a self-organized manner, where they transmit fused data to a voted CH using the cluster based routing. Experimental results demonstrate that CCM protocol outperforms both LEACH and PEGASIS in terms of the energy consumption and delay.

Georgious et al. [5], propose Stable Election Protocol (SEP), a heterogeneous-aware protocol to prolong the stability period and average throughput. SEP is based on weighted election probabilities of nodes to become CH according to the residual energy. Nodes are divided into two categories; based on their energy one are advanced nodes and other are normal nodes advanced node have more energy than normal nodes. The probability to become cluster head of advanced node is more than normal nodes.

W. Heinzelman, introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH arranges the nodes in the network into small clusters and chooses one of them as the cluster-head. Node first senses its target and then sends the relevant information to its cluster-head. Then the cluster head aggregates and compresses the information received from all the nodes and sends it to the base station. The nodes chosen as the cluster head drain out more energy as compared to the other nodes as it is required to send data to the base station which may be far located. Hence LEACH uses random rotation of the nodes required to be the cluster-heads to evenly distribute energy consumption in the network. After a number of simulations by the author, it was found that only 5 percent of the total number of nodes needs to act as the cluster-heads. TDMA/CDMA MAC is used to reduce inter-cluster and intra-cluster collisions. This protocol is used were a constant monitoring by the sensor nodes are required as data collection is centralized (at the base station) and is performed periodically.

It has been concluded that in LEACH, number of cluster heads are presumed and increase/ decrease in number of cluster heads can increase the energy consumption. LEACH has not considered the optimal selection of cluster heads. Optimal selection of CH minimizes the energy consumption and increase the network life span. Since LEACH does not consider the residual energy for CH selection, therefore the residual energy as well as the cluster head selection becomes the basis of our research.

Table 2.1: Energy-Efficient Based Clustering Protocols

Routing Protocol	Classification	Clustering Technique	Outcome/Limitations
LEACH(Heinzelman,2000)	Classical	Distributed	Random selection of CH, used for small Networks
BCDCP(Muruganathan,2005)	Classical	Centralized	Low energy consumption, but Limited Scalability
PEGASIS (Lindsey, 2002)	Classical	Distributed	Single CH forms bottleneck
TEEN (Manjeshwar, 2001)	Classical	Distributed	Not good for periodic data & large network
HEED (Younis, 2004)	Classical	Distributed	Cluster head selectionoverhead, uncovered node issues
APTEEN (Manjeshwar, 2002)	Classical	Distributed	Longer time delay and intricacy issue
ELCH (Lotf, 2008)	Classical	Distributed	Adverse effects on network op. if cluster size increases
SHPER (Kandris,2009)	Classical	Distributed	Mobility is not supported
DEEC (Qing,2006)	Classical	Distributed	Scalable but advanced nodes punished as CHcontinuously

DDEEC (Elbhiri, 2010)	Classical	Distributed	Equal probability of CHselection below a threshold value, only effective for two level heterogeneous N/W
EDEEC (Saini,2010)	Classical	Distributed	Different type of nodes(normal, advanced & super nodes) increase the complexity
DEECIC (Liu, 2012)	Classical	Distributed	Coverage preservation, complex as unique ID for nodes is required
TADEEC (Chauhan, 2014)	Classical	Distributed	Four level-super advanced nodes added toEDEEC, TEEN incorporated, missed time critical data due tothreshold condition
Modified DEEC (Tiwari, 2015)	Classical	Distributed	Scaling factor only consider cluster size notnumber of nodes in cluster
EDDEEC (Javaid, 2015)	Classical	Distributed	Threshold value(absolute) for three level heterogeneous n/w
H-DEEC (Khan, 2013)	Classical	Distributed	Beta nodes for multi-hopping scheme with PEGASIS
HetDEEC (Singh, 2016)	Classical	Distributed	Three level heterogeneity, HetDEEC 1,2,3
(Badyopadhay, 2003)	Classical	Distributed	Suitable for large networks, hierarchy of clusters, algorithm complexity
EADC (YU, 2012)	Classical	Distributed	Clustering and routing protocol, load balancing achieved
DECSA (Yong, 2012)	Classical	Distributed	Not possible to add or remove nodes, only for static network
ECHERP (Nikolidakis, 2013)	Classical	Distributed	Design complexity dueto multi-hop CH selection by BS and application of Gaussian elimination algorithm
EECT (Thayananthan, 2014)	Classical	Distributed	Combines solar power &routing algorithm, limited to available sunlight space
LEACH-SM (Bakr, 2014)	Classical	Distributed	Race conditions and dead-locks occur during spare selection process.
O-LEACH (Khediri, 2014)	Classical	Distributed	Cluster head are selectedif energy is greater than 10 % of residual value at each node
DL-LEACH (Lee, 2016)	Classical	Distributed	Multi-hop, but short node lifespan in large network

CHSCDP (Qiang, 2015)	Classical	Distributed	More energy is consumed in cluster formation phase
LEACH -CC (Dutta, 2014)	Classical	Centralized	Cluster head are selectedby BS based on simulated annealing
Yuan, 2016	Meta-Heuristic	Distributed	PSO based CH selection,Fitness function is not based on overall energy consumption factor
PSO-ECHS (Banka, 2016)	Meta-Heuristic	Distributed	Intra-cluster energy consumption as well as the energy consumed inCH to BS transmissions is not considered
ICSCA (Gupta, 2018)	Meta-Heuristic	Distributed	Cluster head selects on avg. Euclidian distance & ratio of total energy to total energy of CH
Yadav, 2015	Meta-Heuristic	Distributed	Cluster head selection protocol based on PSO based on residual energyand transmission distance
EPSO-CEO (Vimalarani, 2016)	Meta-Heuristic	Distributed	Centralized algorithm forCH selection, CH selection based on fitness function
Singh ,2017	Meta-Heuristic	Distributed	The energy of nodes has not been considered while selecting the CH
EBAB (Wang, 2009)	Meta-Heuristic	Distributed	The intra-cluster uses an improved ACO algorithm, where clustersare formed in the initial routing process and is followed by the development of CH which engages to the nodes based on their dominance with the base station
PZSWiD (Ramachandran, 2008)	Meta-Heuristic	Distributed	Vague description of the parameters used
WEI, 2011	Meta-Heuristic	Distributed	Analyzed the size of the clusters using EC at various hop distance (a cluster distribution algorithm)
Wang, 2010	Meta-Heuristic	Distributed	It used minimum spanning tree algorithm to develop intra-cluster routing and used the treeroot as a CH
Jing, 2012	Meta-Heuristic	Distributed	ACO to manage the load of the network
Syed, 2013	Meta-Heuristic	Distributed	Efficient route paths anda potent multi path for transmitting the data in case of faulty nodes
Soumitra, 2014	Meta-Heuristic	Distributed	Use GA and ACO to improve network life, GA for clustering and CH selection and ACO for routing

IV. Low-Energy Adaptive Clustering Hierarchy (LEACH)

Low-Energy Adaptive Clustering Hierarchy is one of the most popular clustering approaches for WSN. It is an application specific architecture. In LEACH, the nodes organize themselves into local clusters, with one node acting as the cluster head and others as member nodes. All member nodes transmit their data to their respective CH, and on receiving data from all member nodes the cluster head performs signal processing functions on the data (e.g., data aggregation),and transmits data to the remote BS. Therefore, being a CH node is much more energy intensive than being a member node.

The main objective of leach is to select sensor nodes as cluster heads by rotation. In this way, the energy load of being a cluster head is evenly distributed among the nodes. The operation of LEACH is divided into rounds. Each round begins with a set-up phase followed by steady state phase. In the set-up phase the clusters are organized, while in the steady-state phase data is delivered to the BS. Initially CH is selected, based on the signal energy of nodes. The nodes with higher energy are selected as CH. Each sensor node n generates a random number between 0 and 1 and compares it to a pre-defined threshold T (n). If random<T (n), the sensor node becomes CH in that round, otherwise it is member node. Where P is the desired percentage of CHs, *r* is the current round, and *G* is the set of nodes that have not been elected as CHs in the last 1/ *P* rounds.

LEACH is a completely distributed approach and requires no global information of network. LEACH can guarantee not only the equal probability of each node as CH, but also relatively balanced energy consumption of the network nodes.

However, there exist a few disadvantages in LEACH as follows:

1) LEACH assumes a homogenous distribution of sensor nodes in given scenario, which is not very realistic
2) Some clusters will be assigned with more number of nodes; this could makes CH nodes run out of energy quickly.
3) CH has the extra burden of performing long range transmission to the distant BS, which results in too much energy consumption.
Various modifications have been made to the LEACH protocol, which form LEACH family, such as TL-LEACH, E-LEACH, M-LEACH, LEACH-C, V-LEACH, etc

Advantages in the LEACH protocol are:

1. It is one of the mostly used hierarchical routing algorithms in sensor networks.
2. LEACH protocol erstwhile divides the total wireless sensor network into many clusters. Any node that act as a CH in present round cannot be selected as the CH again; therefore each node can share the load equally which is imposed on Cluster heads [9].
3. The cluster head node is selected randomly and chance of every node to be selected as cluster head is equally attributable to which energy consumption of whole network is averaged [18]. Thus LEACH will extend the network life cycle.

Problems within the LEACH protocol are:

1) The cluster head node is randomly selected in LEACH protocol [10]. There are some drawbacks attributable to the likelihood of every node to be selected as cluster head is same. After numerous rounds, the node with greater remaining energy and the node with smaller remaining energy have same probability to be chosen as cluster head. If the node which has smaller remaining energy is chosen as cluster head, it'll run out of the energy and die more quickly, due to which network's robustness can be affected and life of the network become short.
2) The standard LEACH Protocol divides clusters randomly, additionally results in uneven distribution of clusters simply [12]. Finally, the divided clusters might not be the simplest or best. As an example some clusters have large number of nodes than others whereas some clusters have fewer nodes. Some cluster heads may be within the relatively central of clusters whereas some clusters heads may be in the edge of clusters far away from members. These phenomena will enhance the energy consumption and make harsh impact on the total performance of the network.
3) In steady state, cluster head usually transmit information to the sink or base station directly. Cluster head that is farther from the sink communicate with the sink directly mostly spend a plenty of energy. Thus it'll crash earlier as a result of it runs out of energy. Particularly in the midst of the enlargement of the dimensions of the network, these effects have an impact on the network life seriously.

V. Distributed Energy Efficient Clustering Protocol (DEEC)

In 2006, Q. Li, Z. Qingxin and W. Mingwen [21] projected DEEC protocol. DEEC protocol is a cluster based method for multi-level and 2 level energy heterogeneous wireless sensor networks. In this scheme, the cluster heads are chosen using the probability based on the ratio between residual energy of every node and the average energy of the network. The era of being cluster-heads for nodes are entirely different according to their initial and residual energy. The nodes with more initial and remaining energy have greater chances of the becoming cluster heads compared to nodes with low energy.

Advantages of DEEC:

1. DEEC doesn't need any universal knowledge of energy at each election round.
2. In contrast to SEP and LEACH, DEEC will perform well in multi-level heterogeneous wireless network.

Disadvantages of DEEC:

Advanced nodes always punish in the DEEC, particularly when their residual energy reduced and when they come in the range of the normal nodes. During this position, the advanced nodes die rapidly than the others.

VI. Conclusion

In this paper we discuss the heterogeneous wireless sensor networks protocols. All these protocols are developed to increase energy efficiency, network lifetime, stability and instability of network. Some of the protocols have certain deficiencies while others are best suited in order to save the energy. In this paper LEACH and DEEC protocols used in heterogeneous WSN have been compared.

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