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A SURVEYON CLUSTERING BASED ROUTING PROTOCOLS FOR HETEROGENEOUS WIRELESS SENSOR NETWORKS

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***Abstract*—Energy consumption is major constraint in Wireless Sensor Networks (WSNs). Till now, numerous routing protocols have been investigated to achieve the energy efficiency. Earlier communication protocols were proposed, which can have large impact on the overall consumption of these networks.These conventional protocols such as direct transmission, minimum-transmission-energy, multi-hop routing, and static clustering may not be suitable for sensor networks.LEACH was proposed to overcome the problems of conventional protocols. In LEACH, cluster heads are randomly rotated in order to divide energy load among all nodes. There are so many protocols which follows the same operation as LEACH. This paper reviews on hierarchical based clustering and evolutionary protocols for heterogeneous WSNs to provide better energy efficiency.**

Keywords: ***energy consumption, clustering, heterogeneous wireless sensor networks.***

1. INTRODUCTION

Wireless sensor networks (WSNs) comprises of low power sensor nodes which have limited wireless communication capabilities and energy resources.Batteries are used to power the sensor nodes and after deployment, these sensor nodes remain unattended. WSNs are useful in various applications, such as environmental monitoring, disaster management, medical care, military applications,etc. The two protocols were proposed for energy analysis in wireless sensor networks such as direct communication and minimum transmission energy (MTE) protocols.By using direct communication protocol, each sensor node directly communicates with the BS, but this requires large transmit power to send the data from each node. If BS is located far from the nodes,direct communication will need large amount of transmit power, whereas in MTE,intermediate nodes are used to send data to the BS.These both have limitations such as in direct communication Protocol, only receptions occur at the BS,so eitherif the BS is close to the nodes,it requires large amount of energy to receive data. Hence,it will quickly drain the energy of nodes. On the other hand,MTE only considers the energy dissipation of the transmitters not of the receivers in order to determine the route [1].These drawbacks leads to the need of clustering concept.In clustering,nodes are organized into clusters that communicate with the local CH to transmit data to the sink, where end user can acquire it. In this way, communication distancebetween nodes and BS is reduced to transmit data. Thus, clustering is energy efficient communication protocol.But it also has its pros and cons. The local BS is always high energy node,if the BS is an energy constrained node, it would be die rapidly. Thus, conventional clustering performance is not suitable for micro sensor networks as cluster heads (CHs) are fixed, this can also be referred to as static clustering. Dynamic clustering protocols were proposed to deal with static clustering issues [1, 2].

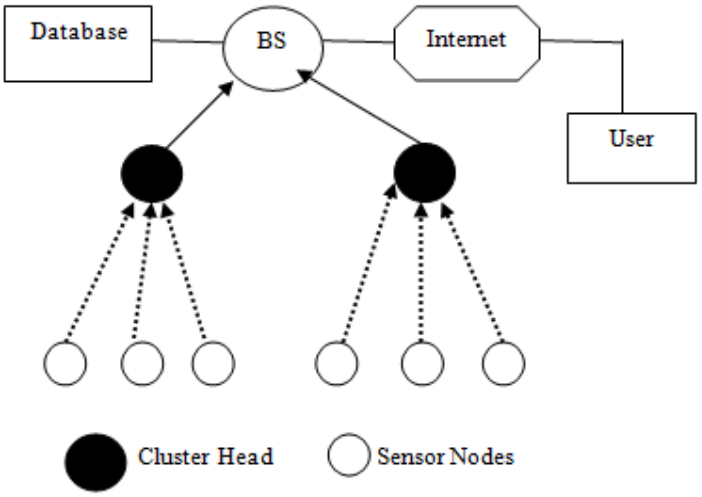

Fig. 1. Clustering technique

2. CLUSTERING BASED ROUTING PROTOCOLS

The numbers of routing protocols are proposed to enhance energy efficiency and increased lifetime.

2.1. LEACH

The main clustering protocol exists for increasing energy efficiency is Low energy adaptive clustering hierarchy protocol (LEACH) [2].It is self configuring, randomization based protocol to distribute the energy load among nodes evenly. In this protocol every node has equal chance to become cluster head (CH).High energy node can take as CH. It does not expend the energy of single sensor because rotates among all sensors. It also perform the function of data fusion in order to reduce the data packet size which is being sent from the clusters to the BS, further reducing energy consumption and extending the network lifetimeOperation of LEACH is divided into rounds which is followed by set up and steady phase. In set up phase, clusters are organized while in steady phase, data transmission takes place. Steady phase has longer session than set up phase. Instead of these two phases, one more phase is Advertisement phase. During advertisement phase, nodes decides itself whether to be cluster head or not for current round. This decision is based upon node n by selecting random number between 0 and 1.If the chosen number is less than threshold T (n), then the node becomes a CH for the round. The threshold is calculated as-

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$$T(n) = \frac{p}{1-p*[r \bmod \left(\frac{1}{p}\right)]} \text{ if } n \in G$$

Otherwise 0

Where P is the desired percentage of CH candidates, r is the current round and G is the set of nodes that have not been CH so far for the last 1/p rounds. It has drawback that all nodes in the sensor network are homogeneous.

2.2 SEP

In 2004,Stable Election Protocol(SEP) was introduced for clustered heterogeneous wireless sensor networks [3].It is proposed to prolong the stability period(time interval before the first node dies(FND) essential for some applications whose feedback from the sensor network must be required. This protocol helps to improve the stability period of hierarchical clustering process. In order to achieve the increased stability period, SEP tries to balance energy consumption. In this, out of whole population some sensor nodes are provided with more energy than that of rest nodes (normal nodes) on the same network. Most probably, advance nodes become CH which is good fairness constraint. It ensures stability by using heterogeneity factors like fraction of advanced nodes and additional energy factor among advanced and normal nodes. This protocol has improvement over the existing LEACH as it increases the Epoch (optimal probability) of the wireless sensor network in proportion to energy augmentation. Initial energy is not considered for heterogeneity of nodes in case of LEACH. Consequently, energy consumption of resources in sensor network is not optimized in the presence of such heterogeneity.SEP protocol ensures that the CH election process suitably adapted to deal with heterogeneity of nodes. LEACH is not efficient in heterogeneity of nodes, therefore, SEP is used to increase stability region in case of heterogeneous networks.

2.3 LEACH-EP

It is extension of LEACH protocol. Traditional protocol does not consider energy parameter to select the cluster head, but LEACH-EP [4] takes energy into account. In this protocol, higher residual energy node has more opportunities to become CH.Energy based threshold is calculated as T ep (n)

$$p * \frac{E(n)}{Ech - av(r-1)} if\ E(n) \geq 0.5 * Ech\_av(r-1)$$

0 if E (n) <0.5*Ech_av(r-1)

Where E (n) is current residual energy of node n. Ech_av (r-1) is average residual energy of all CHs in previous round.

2.4 *LEACH-DT*

In [5], the authors proposed a distance based algorithm which is known as LEACH-DT to balance energy consumption among all nodes. This protocol self elects the CH based on probabilities that their distance to the sink. LEACH makes use of the same formula as original LEACH. This protocol forms the different sensor groups depending upon their distance to the BS. Each sensor group works for CH selection and then data is relayed from the sensor groups at larger distance to the nearer ones on hop by hop basis. But this protocol has some drawbacks such as it is unable to balance energy consumption among sensors within cluster and therefore, node at larger distance will die out early.

2.5 DEEC

LEACH, PEGASIS, HEED [2, 6, 7] all are assumed to be best and suitable for homogeneous sensor networks. The performance of these protocols will be poor in heterogeneous environments. It may be possible that nodes having energy will die out more quickly as compared to the nodes having high energy. Distributed EnergyEfficient Clustering protocol (DEEC) [8] is developed for heterogeneous sensor networks. It not only prolongs the network lifetime but also stability period.SEP is proposed for two level hierarchical heterogeneous networks, which consists of two nodes of different types according to the initial energy. The advanced nodes are high energy nodes than normal nodes.SEP only increases the stability period. It is not fit for multilevel heterogeneous (WSNs), which includes nodes of more than two types. On the other hand, DEEC is well suited for two level heterogeneous networks as well as fit for multilevel hierarchical networks. Like LEACH, DEEC also does rotation of Cluster Head among all the nodes.CH selection process is based on the probability of ratio between the remaining energy of each node and the total energy of the network. Thus, round number for the rotation of each node is varied according to its initial and remaining energy.

2.6 NEAP

As we know that clustering schemes are not effective for the heterogeneous WSNs. A novel energy adaptive protocol (NEAP) is introduced to reduce overall power consumption and to prolong the lifetime of the network in a Heterogeneous WSNs. In NEAP [9] protocol, CH is selected based on threshold probability and it also considers certain parameters in order to form clusters such as nodes current battery power and number of current CH members, distance between CHs and nodes .It overcomes from LEACH limitations by considering sensor node concepts and some sensor node assumptions.

2.7 ERP

It is new evolutionary based routing protocol [10] for clustered heterogeneous WSNs. Bio inspired algorithms are the algorithms which extend the network lifetime but at the cost of reduction in stability period. This presents tradeoff between lifetime and stability period. This is due to the one common parameter i.e. transmission distance which is not considered while designing fitness function. The motive of ERP protocol is to reduce the unwanted behavior of Evolutionary Algorithm. It deals with clustered routing problem by designing new fitness function which considers parameters like cohesion (intra-distance) and separation error (inter-distance). This protocol helps in increasing stability period as well as stability period in heterogeneous wireless sensor networks. This protocol basically refines the fitness function by redefining the distance function in order to serve two clustering purpose such as intra-distance and inter-distance.

2.8 SAERP

A new stable aware evolutionary routing protocol (SAERP) is proposed for both homogeneous and heterogeneous wireless sensor networks in order to ensure maximum stability and minimum instability periods [11]. It uses evolutionary modeling where cluster heads are selected in a more energy efficient way for well maintain balanced energy consumption. It uses energy based heuristics for initializing the individual solutions, evaluating the fitness and mutation to maintain longer stable and shorter instable regions. To deal with routing problems, no attempt has been made to investigate meta-heuristics techniques such as evolutionary algorithms (EA's). Still EA's has been used in handling various WSNs challenges but the development of EA based stable aware routing is not explored yet. In

SAERP, the robust performance is obtained by introducing energy aware heuristics for population initialization and mutation operator while designing a suitable fitness function.SAERP outperforms LEACH and SEP as both considers homogeneous and heterogeneous environments. It is reliable as data transmission takes place in this protocol is single hop.

2.9 ASLPR

In order to reduce energy consumption and to prolong network lifetime, optimal CH selection is necessary. Conventional and clustering protocols (LEACH,PEGASIS etc) does not considers the sensor node parameters for CH selection, Ali jalali et al.[12] Proposed a new evolutionary based application specific low power routing protocol(ASLPR) which considers some sensor node concepts such as residual energy of each node, distance between the nodes and CH etc. ASLPR is said to be modified LEACH protocol as it overcomes the limitations of LEACH.ASLPR increases the stability period and enhances the network lifetime. Network lifetime is defined based on the application that means sensor nodes dies out according to the application. There are some applications which require increased network lifetime until first node dies (FND).for example health monitoring networks. Like LEACH, CH selection process is based on probability model. Operation is same as LEACH. We know that each and every node has equal chances to become CH in every round as CH role is randomly rotated. It may be possible that a node with less energy and larger distance from BS become CH, nodes will die out rapidly. These drawbacks are getting eliminated with the use of ASLPR as it considers energy and distance parameter too for CH selection.

2.10 MBC protocol

As discussed earlier, most of the protocols are developed for stationary environment, but there are certain protocols designed for mobile sensor nodes. One of the most famous protocols is Mobility Based Clustering (MBC) protocol [13] for mobile wireless sensor networks. In the proposed protocol ,the sensor nodes elects itself as cluster head based on parameters such as its residual energy and mobility. A non CH node establishes a stable data link with CH node during clustering within the pre-specified connection time.CH nodes provides the TDMA schedule to each non CH node for data transmission in ascending order within pre-assigned connection time. During steady state phase, the leaf sensor nodes sends sensed information to the CH according to its allocated time schedule and then sends join request message to new cluster in case of failure of the connection with previous CH. In this way, the protocol reduces the overhead and packet loss rate.

3. OPTIMIZATION STRATEGIES

Over the last decades, many researchers have concentrated their research work on WSNs. The various issues like energy minimization, quality of service, security management etc have been widely explored. There are critical issues such as energy efficiency, quality of service, and security. Optimization is basic necessityto obtain better results in one of any these issues. Moreover in number of applications such as health monitoring networks, vehicular ad-hoc networks (VANET's) these issues might contradict and require tradeoff between them. The use of traditional algorithms was not suitable regarding it due to the high energy harvesting and data processing requirements. Regarding this, the researchers started using bio mimic optimization strategies in WSNs. These techniques are adverse and include many various optimization algorithms. The most commonly used bio-mimic algorithms are particle swarm optimization, genetic algorithms, ant colony optimization. Optimization refers to applied sciencein which parameters values are obtained that facilitates an objective function so that some minimum as well as maximum values can be produced [14].

3.1Particle swarm optimization in WSNs

PSO comprises of a swarm of candidate solutions known as particles. Many revised versions of PSO have come into existence by introducing new parameters and factors [15].The three steps that define the PSO technique are generation of particles velocity and position, update of velocity and position update. Nodes can be positioned static or mobile. The researchers tried to minimize the hole coverage area by using PSO – Voronoi algorithm for static positioning of nodes. The fitness of WSN's coveragecan be assessed by using Voronoi diagram. Depending upon the fitness, PSO looks for the most suitable location of the sensors. Instead of static node positioning, a hybrid approach is also used in mobile nodes. A modified PSO which is known as particle swarm genetic optimization (PSGO) is used to serve this purpose in order to improve the QOS in sensing the coverage area. Besides nodes positioning, the node localization is another one optimization problem which can be handled by PSO. In this PSO-based distributed localization scheme beacons are not used for node localization.

3.2 Ant colony Optimization

Social behavior of ants also inspired a number of techniques and methods like other swarm intelligence methods that also inspired from animals and insects behaviour.ACO is based upon foraging behavior of some ants species.ACO is helpful in many engineering domains for solving discrete optimization problems. The basic foraging behavior of ants is presented as [17].

1. In first step, food source will find out by the ants, and then return back to the nest and leave behind a pheromone trail.
2. Ants will follow all possible routes.

3. Ants will take the shortest route.

For energy efficient clustering in WSN's, the ACO method makes use of two levels such as inter-cluster and intra-cluster. The sensor nodes sends data directly to their cluster head in the first level while second level uses ACO method in order to find the suitable route to the sink. This method provides smooth and efficient operation for inter-cluster operation. ACO method named Ant Chain is proposed which uses centralized approaching order to gather data in sensor networks. This method apparently divides the work among sensor nodes and the BS. In this way, the algorithm makes the working of sensor nodes simple. The areas that are covered by
ACO are stationary node deployment, data aggregation and fusion, cross layer optimization.

3.3 Genetic Algorithm

GA is evolutionary type of algorithm based on the abstraction of biological systems.GA can be characterized as a global search heuristic. It makes use of selection, crossover and mutation operators for getting suitable global answer. Another one elitism operator is used to store the best chromosomes for the next generation. Here population is termed as chromosomes and the candidate solutions are termed as individuals.GA has two mainly merits over conventional algorithms .The first one is capability of handlingcomplex problems. Another one is that it can deal with all types of objective functions such as linear or non linear, continuous or discontinuous, stationary or transient. Some authors investigated energy efficient spanning trees for data aggregation based on GA approach. Commonly, spanning tree for data aggregation is widely accepted in WSN area, but fair load sharing is still missing.GA also considers areas like positioning of base station and nodes.

4. OPTIMIZATION CHALLENGES

Though the bio-mimic strategies are very helpful in addressing WSNs issues such as designing and deployment of nodes, energy efficiency, localization, security management etc, but still it poses some research challenges which are listed below.

TABLE I. COMPARSION BETWEEN CLUSTERING BASED ROUTING PROTOCOLS

Protocol	Prediction related	Data transmission	Evolutionary related	Energy efficiency
LEACH	No	Single hop	No	Poor
SEP	No	Single hop	No	Good
DEEC	Yes	Single hop	No	Good
HEED	No	Single hop	No	Good
NEAP	No	Multi-hop	No	Good
ERP	No	Single hop	Yes	Good
SAERP	No	Singe hop	Yes	Good

Uncertainty

The uncertainty is the main characteristic which has not been so much considered until now. It is due to the situations such as delivery of data, monitoring of some events etc of the sensor networks.The attempts which are modeled to tackle with these situations are based upon probabilities associated with events. Instead of advances in optimization dealing with such probabilistic problems are still hard.

B Dynamicity

It is another one important challenge which is of major concern. It refers to the terms such as failure of nodes, attacks on nodes, mobility of nodes etc.It is still main challenge in optimization problem models.

C. Scalability of data

Scalability issue occurs due to the changes in dimensions of the networks. These issues are particularly related to designing of multi-sink and cross layer. Sometimes, these optimization strategies are unable to cope up with changes in network size, density and topology .

D.Deployment problem

There are various coverage problems which have still unexplored such as not considering obstacles while deploying the nodes. The three optimization strategies mainly used for this purpose are ACO, PSO and GA. Although PSO and GA have addressedhybrid and dynamic deployment yet these are not addressed by ACO. There are some other areas which are covered by ACO, but not covered by GA and PSO.

TABLE II. FUNCTIONAL COMPARSION BETWEEN OPTIMIZATION STRATEGIES

Algorithm name	Merits	Demerits
PSO	• Implementation is easy • Only few parameters are required to be adjusted • Effective global searching	• Can't used for high speed real time applications • It fails in case of frequently optimization
ACO	• Can be dynamically adapted in some applications • Fast discovery of best solutions results from positive feedback	• Tough theoretical analysis • Straightforward coding doesn't exist
GA	• Not dependent • Each optimization problem having chromosome can be solved with encoding • Easily transferrable to other existing models.	• Running times are more • Optimization response time is not constant • Stop criterion is not clear in every problem

5. CONCLUSION AND FUTURE WORK

Over the last few years, Wireless Sensor Networks have attracted greater attention in various fields of applications. Examples include battlefield surveillance, remote monitoring etc. In these applications, energy consumption is major issue. In order to deal with this severe issue, researchers explored many clustering routing protocols. LEACH is the representative one. Though, LEACH outperforms the static clustering and traditional protocols but it is not suitable for heterogeneous wireless sensor networks. Various heterogeneous aware protocols such as SEP, NEAP are introduced to deal with such heterogeneity of nodes. This paper also has presented review on evolutionary algorithms like ERP, SAERP which are developed to overcome the clustering problems. In this paper, we have presented the latest clustering protocols in WSNs and classified the schemes according to the single hop, multi-hop categories and homogeneous and heterogeneous networks. Most commonly issues for such protocols are how to select and form CHs so that less energy can be consumed due to the redundant messages sent to the BS. Many of the recent researches focuses on homogeneous type of wireless sensor networks while there are few researches on the heterogeneous which are more appropriate for real life applications. It was seen that most of the recent routing protocols presume that the sensor nodes and sink are stationary not mobile. However, there are some situations or applications which require being sensor nodes and sink mobile not stationary. In this survey, we have given complete overview of the three important methods namely PSO, ACO and GA.Hybrid approaches can also be adopted such as combination of genetic algorithm and simulated annealing for better results in optimization.

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