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Hierarchical cost effective leach for wireless sensor networks

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ABSTRACT

Wireless sensor networks are those that are used for the communication between various sensor nodes to the base station. Heterogeneity in such networks are used to manage the network deployment cost and the network traffic. A hierarchical cost effective LEACH (HCEL) protocol is proposed to enhance energy efficiency of the sensor nodes thereby maximizing the network performance without increasing the network deployment cost.In this paper, a heterogeneous network that comprise three types of sensor nodes are considered. A hierarchical network structure is formed where the data are forwarded by using "aggregators". The clustering is done inorder to maximize the energy eficiency of the sensor nodes. The cost comparision is done between various protocols like seperateLEACH(SL), proposedLEACH(PL), seperateproposed(SP) and HCEL. The energy efficiency is derived by initiating the activity window interference. Simulation results show that the HCEL protocol derive a gradual decrease in the network deployment cost ratio in terms of powerful nodes and energy factor.

Introduction

A self configurable local area network (LAN) through which terminals equiped with sensor nodes, transmit the paramaters to a predetermined set of information receptacles called base station (BS) is refered as the wireless sensor network (WSN). In the present scenario, wireless sensor network (WSN) has become one of the emerging networking technologies that the sensor nodes can be deployed without communication infrastructure. It provides powerful data processing, storage center and access point to the sensor nodes in the network. A major issue in wireless sensor networks is energy efficiency [1], which is solved using energy efficient protocol.

The deployment of heterogeneous sensor nodes in wireless sensor network paves an efficient method to increase the network lifetime and reliability. The work [2], introduces an energy efficient heterogeneous clustered scheme (EEHC), for cluster head election in a distributed fashion in hierarchical networks.

When comparing technologies with deployment cost, spectrum availability etc., traditional technical metrics such as spectral efficiency are hence no longer sufficient. A methodology to evaluate the cost and capacity of different heterogeneous radio access networks are done in [3]. To deploy the sensors at minimum cost, it is equiped with small batteries that can store atmost 1Joule [4] that reduces both transmission range and the data rate. Multihop communication network are formed if the sensors do not fall within the communication range.

The clustering in sensor networks is done inorder to improve the MAC layer scalability and routing. Clustered sensor networks can be classified in to two broad types: homogeneous and heterogeneous sensor networks. In homogeneous networks all the sensor nodes will be deployed with identical battery energy, whereas in heterogeneous network, two (or) more nodes with different battery energy and functionality are used [5].

In this paper, we focus on the heterogeneous nodes in wireless sensor network, where three types of nodes type-1, type-2, type-3 are considered that are deployed with varying hardware cost, battery cost and initial energy. The sink (or) the base station (BS) is located outside the network sensing area. The HCEL protocol is proposed to make the sensor nodes energy efficient, thereby increasing the network lifetime without increasing the network deployment cost.

The rest of the paper is organised as follows. In section 2, the related works are discussed. In section 3, we define the heterogeneous model and the performance measures for heterogeneous wireless sensor network. In section 4, the network model and the assumptions consideed for network deployment are studied. In section 5, the steps followed in the proposed protocol are seen. In section 6, the simulation environment is discussed, followed by the conclusion of the proposed work.

Related work

A hierarchical clustering algorithm that introduced in sensor network is Low Energy Adaptive Cluster Hierarchy based protocol (LEACH). LEACH [6] divides each operation in to rounds; during each round a different set of nodes are cluster heads (CH). Each node can become cluster head only for one round. Thereafter, each node has probability of becoming a cluster head in each round. At the end of each round each node that is not a cluster head selects the closest cluster head and joins the cluster to transmit data. LEACH uses the concept of data fusion to reduce the data transmission between sensor nodes in a cluster to produce a single packet.

In [5] comparitive study of homogeneous and heterogeneous clusterd wireless sensor networks is made. A method to estimate the optimal distributon among different type of sensors is proposed. The overhead lies if the heterogeneity is due to the operation of the network. A concept of flooding (multihop) routing is done (MLEACH), which was restricted

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due to the cluster head election issue.

In [7] a radio access network infrastructure cost model is proposed, that includes non-uniform traffic density model. The data are transmitted to the base station of shorter range and with maximum bandwidth. This model underestimates the spatial variability in traffic demand for mobile data services. One major disadvantage of the model is that, since it utilizes only limited access point, it cannot optimize the network deployment cost.

The mathematical and simulation results of heterogeneous wireless sensor networks are analyzed based on the coverage degree and coverage area [8]. The use of inexpensive low capability devices and some expensive high capabilty devices can significantly extend the duration of a networks sensing performance.

Chung Zhou [9] proposed a distributed hierarchical agglomerative clustering (DHAC) algorithm for distributed environment. It forms clusters by using single hop neighbors joined with hierarchical agglomerative clustering. The model initially generates the resemblance coefficients for each node, followed by the formation of hierarchical cluster tree and then elects the cluster head. DHAC avoids unnecessary energy consumption of rescheduling by considering the network traffic load.

In work [10], the performance as well as energy consumption issues of a wireless sensor network providing periodic data from a sensing field to a remote receiver are examined. The sensors are assumed to be randomly deployed. Two types of sensor nodes are used, one with single layer of identical sensors (homogeneous) and one with an additional overlay of fewer but more powerful sensors (heterogeneous). The formulation of the energy consumption and the study on estimated lifetime is based on clustering mechanism with varying parameters related to the sensing field, example: size and distance. A clock driven communication takes place where the sensors gather and send data at constant periodic intervals. The event and query driven communications are not explored and the delay and resolution of the data are not evaluated except energy efficiency.

A heterogeneous sensor network with three types of sensor nodes are considered [11] where the clustering is done in a random manner. The energy efficiency is not attained at the complete level since the hierarchical network structure is not followed.

Heterogeneous Network Model

In this section, the performance of heterogeneous network model and the resources available are discussed.

Heterogeneous resource type

The resources of heterogeneous network can be classified as:

(i) Computational heterogeneity

The sensor nodes will be deployed with powerful microprocessor and extended memory capacity that enables complete data processing and long- term shortage.

(ii) Link heterogeneity

The node with high-bandwidth and long distance network tranceiver than the normal node provide more reliable data transmission.

(iii) Energy heterogeneity

The battery capacity of the node is replaceable.

Performance metrics

The use of heterogeneity in wireless sensor network can bring the following benefits to the network.

- Prolonging network lifetime
- Improving reliability of data transmission
- Decreasing latency of data transportation
- Increased throughput

Network Model and Assumptions

Network model

The network consists of three types of sensor nodes uniformly distributed within the sensing area. The working set of the LEACH protocol is organised in to number of rounds, where in each round the cluster head varies from one node to another. Each node has a probability of becoming the cluster head, p is the round number. The hierarchical cost effective LEACH (HCEL) protocol joins the non cluster head node with the cluster head and is arranged in a hierarchical level based on the distance between the base station and the cluster.

The sensor network consists of one hundred sensor nodes that are deployed within (200*200) square field. Each type node varies from each other according to their hardware components, battery and energy capacity. The cluster head election is based on the weighted probability of each node and compared with the random number [0, 1]. The hierarchy is formed based on the forward aggregator selection in each level and forwarding data through them. The activity window is then assigned to the member of a cluster to a time period in order to improve the energy efficiency of the sensor node.

Assumptions

The work is followed under certain assumptions that are to be adopted in the sensing area. They are

i. A heterogeneous sensor nodes and base station are considered.
ii. All the sensor nodes are static after deployment.
iii. The base station is located outside the sensing area.
iv. A hierarchical arrangement of the cluster is considered.
v. The sensor nodes will be of varied initial energy.
vi. A multihop routing is carried out.
vii. Hcel Protocol Model

(i) Level identification

It is the initial step involved in the proposed work. The sensor nodes are randomly deployed in the sensing area, the base station is deployed outside this area. Each node assigns a particular location from the assigned *number of levels*; each level is seperated by a fixed distance. The *distance calculation* for each node is done based on the distance between the sensor nodes from the base station. The level is identified for each node only if the following condition is satisfied.

dist (basestation,node) ≥ [(level_no level_dist) +base_dist]*
dist(basestation,node)<[(level_no+1 level_dist)+base_dist]
j= number of levels (1)

for each node if the above condition becomes true, then the node belongs to the current level, else the iteration is continued till the condition becomes true.

(ii) Cost computation

In this section the deployment cost of each node is computed [11], in a heterogeneous network. Three types of node type-1, type-2 and type-3, where the battery energy of type-1 is lower than the other two nodes. Hence type-2 and type-3 are considered as the powerful nodes. The generalized deployment cost model of type *i* node is given as follows.

$$C_i = \alpha i + \beta_i * E_i \quad i = \text{ node type} \quad (2)$$

Where , is the hardware cost given by the circuit energy consumption and antenna energy consumption [10], β is the battery energy of the node and E is the energy of the node. The energy of the powerful nodes are calculated by using

$$E_3 = E_1 * (1+\mu) \quad (3)$$

$$E_2 = E_1 * (1+\lambda) \quad (4)$$

The deployment cost of each node is calculated with respect to LEACH protocol as below

$$C_{DL} = C_{DIRECT} - C_{LEACH} / C_{DIRECT} \quad (5)$$

$$C_{HL} = C_{HETEROLEACH} - C_{LEACH} / C_{HETEROLEACH} \quad (6)$$

$C_{SL}=C_{SEP}-C_{LEACH}/C_{SEP}$ (7)

$C_{SP}=C_{SEP}-C_{PROPOSED}/C_{SEP}$ (8)

$C_{PL}=C_{PROPOSED}-C_{LEACH}/C_{PROPOSED}$ (9)

Where (5),(6),(7),(8) and (9) represent the cost ratio of dirct transmission with respect to LEACH, deployment cost ratio of heteroLEACH with respect to LEACH, the deployment cost ratio of SEP with respect to LEACH, deployment cost ratio of SEP with respect to PROPOSED and deployment cost ratio of PROPOSED with respect to LEACH.

The deployment cost ratio with respect to HCEL is given by

$C_{HCEL}= C_{SP}$ *level count[i] / nodes[i]* (10)

i=level hierarchy number

(iii) Cluster head election

The cluster head election in a heterogeneous network for each round is done based on the weighted probability of type-, type-2 and type-3 sensor nodes.

(i) Weighted probability for type-1 node

$\Gamma_{ai}=P_{opt}/1+\gamma*\Delta$ (11)

$\Delta= \lambda- \chi*(\lambda- \mu)$

(ii) Weighted probability for type-2 node

$\Gamma_{bi}=P_{opt}\,(1+\lambda)/1+\gamma*\Delta$ (12)

(iii) Weighted probability for type-3 node

$\Gamma_{ci}=P_{opt}\,(1+ \mu)\,/1+\gamma*\Delta$ (13)

The probability value is then compared with the random number [0, 1] for each node and the cluster head is elected.

(iv) Clustering

The cluster head election is followed by the clustering technique where the neighbor nodes that fall with the communication range of a particular cluster head will be clustered.

(v) Forward Aggregator Selection

When the clustering of the sensor nodes are completed, followed by is the forward aggregator selection. The forward aggregator of a particular node in the next higher level is selected based on the comparision between the node to the base station and next level node to the base station. The one with the minimum distance will be taken as the forward aggregator.

Consider a sensor network and begin with level-0 of the hierarchy. From those sensors, we select a subset as aggregator for level-1. From level-1 aggregator, a subset is selected as an aggregator for level-2. Finally the sink (which cannot be the aggregator for anyother level) is the only agregator of level h+1. These selected aggregators are used to forward the data from each sensor node to the base station.

(vi) Route discovery

Once the forward aggregator is selected for each node, the route to forward the data to the base station is identified. It works, by periodic broadcasting of the route update message by the sink, which discovers the primary route to the sink. Each node, when receiving the update for the first time marks the node from which it received the message as its parent and rebroadcasts the message, Followed by is the transmission of messages by the sensing node to share with its neighbor and by receiving the route-update message from a node different from its parent (or) by receiving message from one of its neighbors. At the end of this phase each node would have calculated the minimum cost routes to the sink.

***(vii)* Weight assignment**

When the route to the base station from each node is detected, each path is assigned with the weight. The base station sends a probe message to all the nodes through the discovered path. Once when the sensing node receives the message, it will forward the message after tagging it with the proper value in the load and energy bottleneck [6]. When all the probe message have been responded or a timer has expired, a sensing node will assign each of its N routes the weight is given by

$P_i = \epsilon_i/\lambda_i\,(h_i)^{\beta}$ for i=1….N (14)

Where ϵ_i = energy bottleneck of route *i* received in related probe response message, λ_i load bottleneck of route *i* received in related probe response message, h_i number of hops in route *i* and β (0,1) which is the factor defining the desired impact of the number of hops on the weight.

(viii) Optimal route selection

The optimal route selection includes the selection of the path from the sensor node to the base station which attains a minimum cost. The selected route has to be capable of satisfying the QOS requirements of the traffic that will be generated. The optimal route is selected in a link-by-link fashion.

***(*ix) Collection of cluster interference**

In formation relative to the potential interference among neighboring clusters has to be collected to allow the possibility of scheduling the waking times of clusters without damaging overlaps. The sink will broad cast a cluster interference message that will be flooded over the network so that all nodes know that this new phase has started. Nodes that are not cluster heads, which will be referred to leaf nodes since they are at the end of a routing branch, will be the ones starting the collection of cluster interference information. (13)

Each of these nodes will send a cluster information message to its respective cluster head containing, in the *local interf* field, a list of the interfering clusters it detected, a zero in the cluster depth field and empty fiels. When the cluster head receives a cluster interference information generated by one of its cluster members, it will update a list of interfering clusters detected by the members of its own cluster and will update its own depth as the largest depth of its cluster members plus one: it will add its own ID to the path and forward the message towards the sink.

(x) Assignment of activity windows

At the end of the process described in the previous section, the sink will have enough information to assign sufficiently long activity window to the different clusters in such a way that they do not interfere with eachother. The assignment of activity windows to the clusters is the last stage of what will be referred to as the setup process. It is important to mention that the setup process will be repeated periodically, with a relative low frequency that depends on the size and density of the network, on the residual energy of nodes, on the traffic intensity, and other factors, with the goal of reassigning the responsibility of frame forwarding, hence redistributing the energy consumption to extend the system lifetime.

(xi) Data collection and forwarding

The non cluster head nodes then sends data to cluster head which is then forwarded to the base station.

Validation of analysis

In this section, we validate our analysis using simulations. We have also compared the performance of different protocols under the network parameter settings.

Simulation environment

The simulation is carried out in ns-2.32 platform. A heterogeneous sensor network is considered containing 100 number of sensor nodes of type-1, type-2 and type-3 randomly distributed in the sensing area of (200*200) square field. The base station is located outside the sensing area located at the point (100,350).the values of various parameters used in the simulation process are defined in Table 1. The size of each data packets that the nodes send to the cluster head a well as the size of the message that a cluster head sends to the base station is assigned to be 500bytes. The clusters are arranged in five levels of hierarchy.

Table 1

Parameters	Values
Network Span	(0,0) to (200,200)
Number of nodes	100
BS position	(100,350)
Packet size	500 bytes
E1	1J
X(proportion of type-3 nodes)	0.5
γ	0.3

Simulation Results

In this section, the performance of the proposed protocol is evaluated. It involves how deployment cost analysis can be used to determine the performance of the network. The network deployment cost and performance of the proposed prtocol system with various protocols and the proposed protocol is compared.

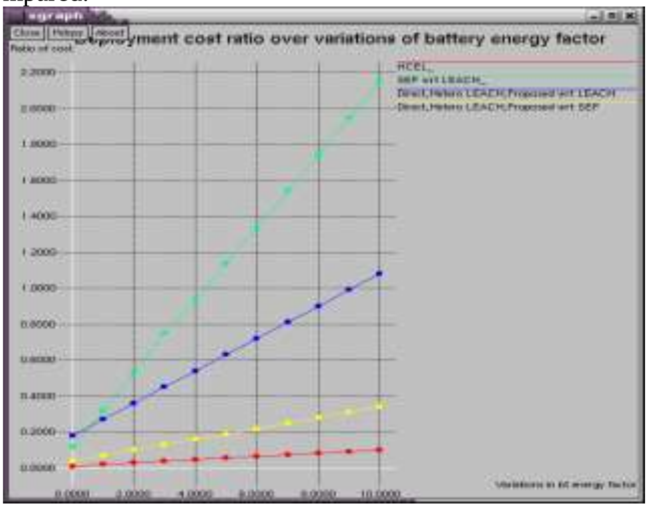

Fig .1. Cost ratio Vs variation in battery energy factor

In the above graph the cost ratio and the energy factors are compared for SEPLEACH, direct, heteroLEACH and SEP and LEACH and the HCEL protocol. The proposed HCEL protocol shows a gradual decrease in the cost ratio with the increasing valus of the energy factor thereby incresing the network lifetime.

Fig.2. Cost ratio Vs variation in number of powerful nodes

Fig.2. shows the performance of the powerful nodes type2 and type 3. As the number of powerfull nodes increases in the network the deployment cost of the network will defenitely increase and also the weight of the system will increase.The HCEL protocol decreases the cost ratio wen compared to other protocols.

Conclusion

The deployment cost ratio computation is reduced by using the hierarchical cost effective LEACH protocol (HCEL). A hierarchical network structure is formed inorder to improve the energy efficiency of the sensor nodes. The performance of the existing and the proposed protocol are compared in the ns-2 environment. The proposed protocol decreases the network deployment cost without decreasing the network lifetime.

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