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Independent hierarchical cluster using stable election protocol for wireless sensor networks

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ABSTRACT

Wireless sensor networks (WSN) processing require the battery powered sensors so as to prolong the effective network life time. The basic goals of wireless sensor network are to enhance the lifetime of the network and also to use the energy of the network nodes efficiently. There are so many traditional approaches or techniques available in wireless sensor network (WSN) to achieve the above goals. But, they are not so efficient and reliable in terms of utilization of energy of the nodes in the network. Thus, Clustering is one of the key techniques to achieve the above goals in wireless sensor network with less energy consumption. The main objective of the Stable election protocol is to extend the stable region of wireless sensor nodes, which finally increases the life time of the network with efficient energy usage. The protocol classified the nodes into different types in term of their energy levels.The Stable Election Protocol is a heterogeneous aware protocol to prolong the time interval before the death of the first node, which is crucial for many applications where the feedback from the sensor network must be reliable. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node.We show by simulation that SEP always prolongs the stability period compared DECP protocols. We found that SEP yields longer stability region for higher values of extra energy brought by more powerful nodes.

Keyword: Wireless Sensor Networks, Network Life Time, Clustering Protocol, Heterogeneity.

1. INTRODUCTION

The wireless sensor networks have been used in a wide range of both civilian and military applications and the sensor nodes limited capacity has posed many challenges in the design issues. The resources such as communication bandwidth and the energy are more limited than those in a traditional wireless sensor network. This limitation requires any design protocols and technique to use the resources available effectively and efficiently. In this thesis, we described about the design of clustering protocol for wireless sensor networks considering the energy consumption issues as the main constraint. Various clustering techniques have been designed for wireless sensor networks in the past. Although many of these techniques performed effectively in many aspects, there are still some areas which are to be addressed in these techniques.

The goals of this thesis are:

1. To design an energy efficient clustering technique for wireless sensor networks
2. To verify the correctness of the designed clustering technique on a competent simulation platform.

1.1. Objective

1. To identify the existing clustering techniques in wireless sensor network and implement at least some of them

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2. To design and develop a new proposed clustering technique which helps to extend the stable region of the wireless sensor nodes which finally increases the life time of the network and the efficient energy usage.
3. To analyse and verify the performance of the proposed clustering protocol using a simulator Matlab.
4. To compare the proposed method with the existing algorithms based on the number of nodes alive in each of the rounds of the network.

2. CLUSTERING

Clustering is an energy efficient protocol that has been implemented in many communication protocols for wireless networks. In a clustering-based protocol, nodes are being classified into several clusters. Each cluster is constituted by one cluster head and numbers of member nodes. In this protocol, all the member nodes of the cluster send their data to their respective cluster head which then forwards the aggregated data to the base station. The base station then interacts with outside world through Internet or satellite links. The cluster head performs data processing such as data aggregation, before forwarding the processed data. Clustering helps to reuse bandwidth and thus increases the system capacity. In addition, the clustering method helps to obtain the hierarchical structure which enable to manage energy efficiently of the network as well as to manage topology of the network with large numbers of nodes. In clustering-based protocol of wireless sensor networks, network nodes are classified into various clusters. Then the members node transfer their data to the cluster heads at the time of each frame of data transfer, and then the cluster heads relay the data to the base station. Since data located at nodes which are very close to each other are highly correlated, the cluster head aggregates the data from each member node to reduce the amount of data that must be transmitted to the base station. As a result, the energy required for data transmission can be decrease. Since the cluster heads are to transmit the data to the base station through the shared wireless channel, if the cluster heads cannot aggregate the data, and then there will be no benefits to use this approach over another traditional approach where each node transmits its data directly to the sink or the base station.

2.1. Cluster Head Selection Algorithm

In the clustering-based protocol, the nodes are arranged into local clusters. Each cluster consists of one cluster head and number of member nodes which belongs to the same cluster. All non-cluster head nodes should transmit their data to the cluster head, while the cluster head must forward the received data from all the cluster members to the remote base station after performing data aggregation.Therefore, being a cluster head is much more energy consuming than being a non-cluster-head member node.

2.2. Cluster Formation

The cluster formation of this protocol targeted at balancing the energy load of cluster heads. Once the nodes have been elected as cluster heads, they will invite the other non-cluster head member nodes in the network to join the clusters. To achieve this, each cluster head broadcasts an invitation message to all other members' nodes using a non-persistent carrier sense multiple access multiple access clustering protocol. The cluster head selection technique used in our protocol ensures that the non-cluster head members nodes do not need to send their data to the long distance remote base station node. Instead, they will send the data to the nearest cluster head. Then the cluster heads will take care tofurther forward the aggregated data to the base station. Since some member nodes may reside in more than one neighbourhood of cluster heads, they will receive more than one invitation messages. The dissipation energy mainly depends on the distance between thetwo nodes and the data transmission within the cluster follows the free space energy model.

Therefore, the node degree is a measurement of the intra-cluster communication cost of a cluster head. To balance the energy dissipation among the cluster heads, non-cluster head member's nodes will select the cluster head with minimum node degree as their cluster head in the current round. The member's node must inform the cluster head that it will be a member of that cluster head once if that node has decided that it belongs to that cluster. Then each node transmits a joining message to the chosen cluster head using a carrier sense multiple access multiple access protocol.

3. THE PROPOSED MODEL INCLUSTERING PROTOCOL

This chapter introduces a new energy efficient clustering protocol. It has the cluster head selection algorithm, a cluster formation phase and finally the data transmission phase.

3.1. System Model

We described here about the system model including network model and energy model used in the introduction of our new protocol. The initial energy level of nodes is considered as different;

1. All nodes are fixed and immobile.
2. The base station is fixed at the centre of the network. We also assume that network nodes are not location aware. In addition, each node has equal processing power to enable the different protocols and data processing tasks. The nodes in the network are left unattended after deployment. As a result, battery recharging of nodes in the network is not possible.

3.2. Network model

To develop the new protocol, the network model consists of the operating environment which consists of N number of nodes and one base station. Nodes are randomly installed in a 100 × 100 area with the base station assumed to be located at the centre of the network area. The sensor nodes periodically sense the environment and send the sensed data to the base station. And on the other hand, the base station is responsible for getting data from the sensor nodes and then presented the user a condition of the environment where the nodes are sensing.

Some of the characteristics of the network model are as follows:

1. All nodes have the equal capabilities of sensing, processing and communicating data;
2. The nodes are energy constrained;

3.3. Energy model

We considered the first order radio communication model introduced in as the radio energy module to assess the energy dissipation. This radio model has the following three modules i.e. the transmitter, the power amplifier, and the receiver. The transmitter dissipates energy to function the transmitter circuitry. The power amplifier dissipates energy for transmitting data and the receiver module dissipates energy to run the receiver circuitry for receiving data. There are basically two propagation models-

1. Free space propagation model and
2. Two-ray ground propagation model.

The free space propagation model is the propagation model where there is direct line of sight path between the transmitter and the receiver. The two ray ground propagation model is the model where the propagation between the transmitter and the receiver is not direct and the electromagnetic wave will bounce off the ground and arrive at the receiver from different paths at different instant of time.

3.4. Operation of the SEP Protocol

The operation of SEP protocol is divided into rounds. Where the clusters are created and organised, and then being followed by a transmission phase, where the data transmissions between the nodes and the base station occur. The procedure of the protocol operation is as follows:

1. Network initialisation.
2. Cluster heads are selected on the basis of residual energy of nodes and its minimum transmission cost.
3. Clusters are created or formed by organising non cluster head nodes into clusters.
4. Cluster member nodes are allowed only to transmit data to their associated cluster heads rather than directly to the base station
5. Cluster heads then forward the processed data to the base station.
6. After the base station received the data from all the cluster heads, a round of the network is complete and the next round will begins immediately.

4. PERFORMANCE EVALUATION

We implemented the Deterministic Efficient Clustering Protocol and finally our proposed protocol Stable Election Protocol. The proposed protocol is compared with the existing system using the performance parameter called the network life time. The network operation of DECP and SEP are all divided into rounds. One round is the time period from the set-up phase starting time to the completion time of the data transmission phase when by the time, all the nodes send data at the base station. Network life time is the time period up to which a certain amount of nodes are still survived or all the nodes are survived.For a certain application, every node is required to work in order to ensure good coverage of the network. Thus the network life time is measured by the life time of the shortest living node. Therefore, the number of rounds until the first node die or until some fixed present of nodes dies are used to evaluate the performance of the system in term of network life time in our protocols.

5. SIMULATION RESULTS

We consider an area of 100m × 100m. In this area, $N = 100$ sensor nodes are randomly deployed with three levels of energy. Different symbols indicate different levels of sensor nodes. We assumed that all the sensor

Table 1
Parameter Settings

Parameter	*Description*	*Value*
Xm × Ym	Dimensions of field	100m × 100m
N	Number of nodes	100
R_{max}	Maximum number of rounds	2000
P	Probability of node to become CH	0.1
E_0	Initial energy node	0.5J
E_{elec}	Electronics energy	10^{-9}J
EDA	Data aggregation energy	10^{-9}J
ε_{fs}	Energy dissipation for free space	10^{-12}J
ε_{mp}	Energy dissipation for multipath	10^{-16}J
M	Packet size	50

nodes are either fixed or micro-mobile and ignored all the energy losses which are caused due to collision of various signals and interference caused due to signals of different sensor nodes as these nodes are randomly distributed inside the sensor field. We also assumed that the position of BS is at the centre of the wireless senor field. Sensor nodes with different levels of energy.

The energy level is divided into three groups namely: normal, advanced, intermediate nodes respectively. The sensor nodes with highest amount of energy have more chances of being selected as CH as compared to low energy sensor nodes. The sensor nodes participate in sensing the information and transmitting it to the CHs. The CH performs data aggregation and forwards the data to the BS. In this way the process is continued till the time all the sensor nodes are dead in wireless sensor field. Some sensor nodes which have been participated in the sensing process and some sensor nodes are in ideal mode whereas some nodes are dead which cannot participate in further sensing process. The nodes which are dead are represented by red colour. The nodes which have been participated in sensing and transmission are represented by pink colour whereas the ideal nodes are represented by symbols. All sensor nodes are dead. And no further sensing can be performed after this.

For our simulations, we started with the nodes classifying into some groups in which each group nodes have initial distinct energy level in term of joules. We recorded the number of dead nodes in each round of the network so that we can calculate the number of alive nodes in each round. This finally helps to evaluate the performance of the system. Stable Election Protocol outperformed better as compared to the DECP protocol in term of stable region and network life time. The number of alive nodes against the number of rounds in each of the proposed model is higher than the DECP protocol. SEP protocol increases the ratio of stable region in network lifetime. Stable selection protocol select high energy nodes to be the cluster-head

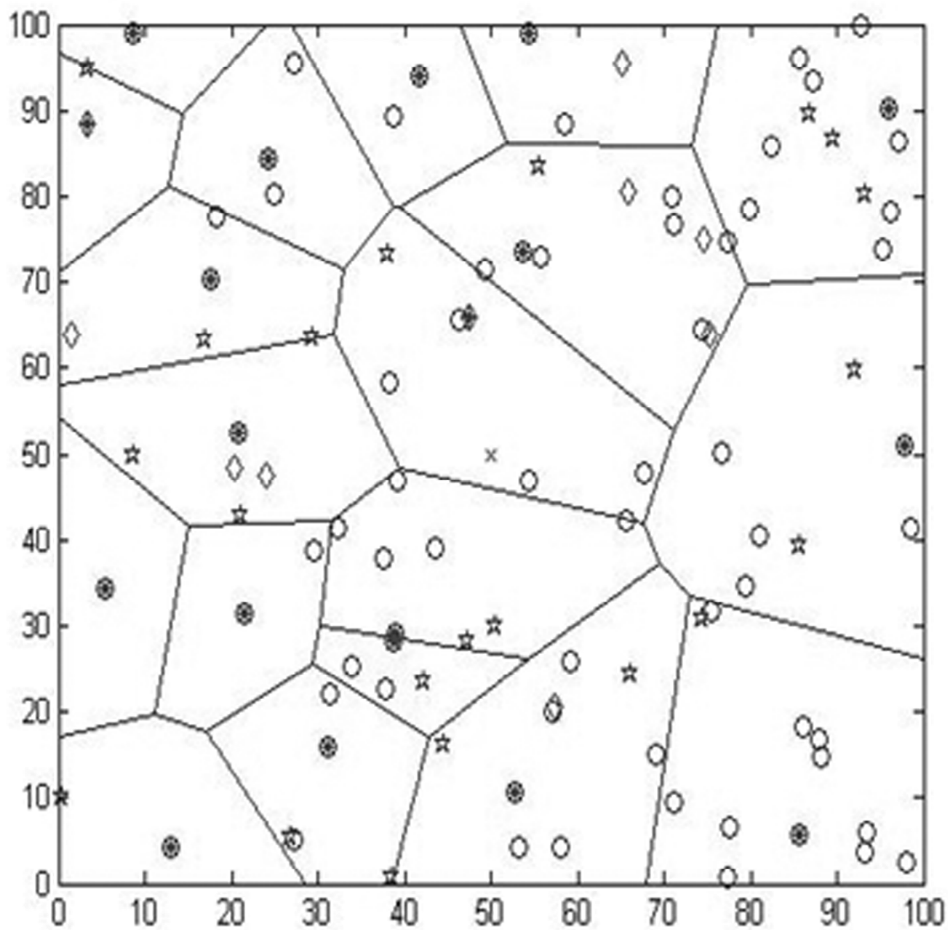

Figure 1: Wireless Sensor Networks

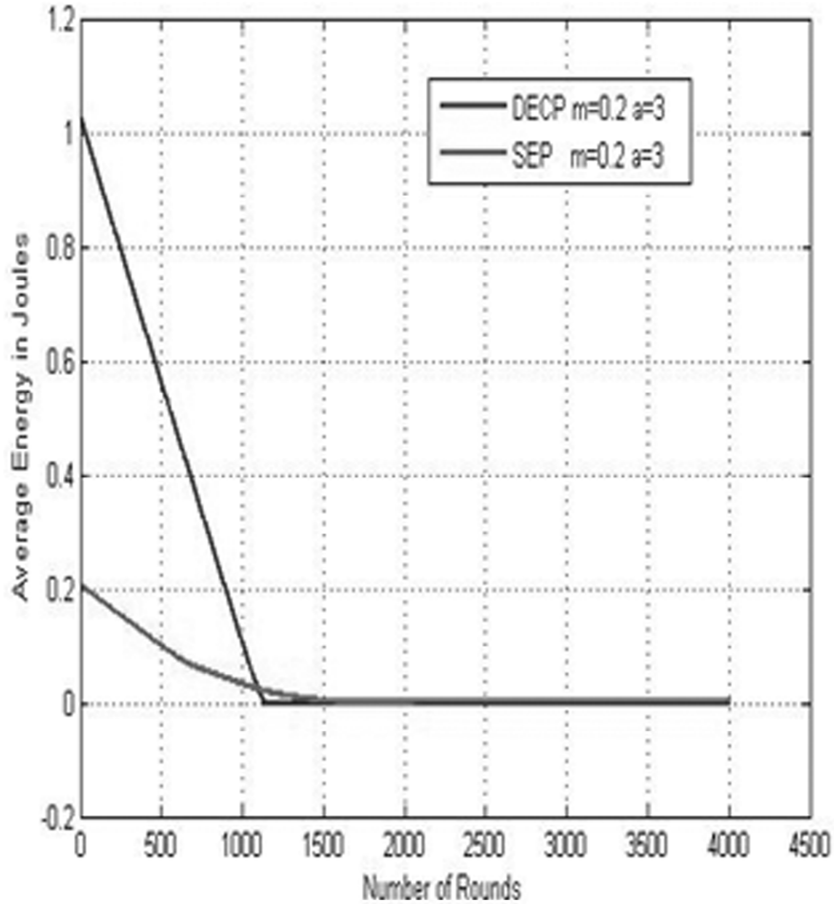

Figure 2: Number of Average Energy using the presence of heterogeneity: *m* = 0.2 and α = 3.

first for load balancing in the network and as a result, low energy nodes spend less energy than high energy nodes. So Stable selection protocol helps tosustain the survival of low energy nodes more longer time and hence prolongs the stable region of the wireless sensor networks and finally increase the life time of the network. The number of alive nodes against the number of rounds in each of the proposed model is higher than the existing system. Obviously, the node with higher more remaining energy given the opportunity to become cluster head will help to increase the stable region of the network by making the low energy nodes to survive for a longer period of time and hence finally, increased the overall life time of the network. SEP protocol also balances the energy consumption of nodes by distributing the CH selection of a node randomly for every round. As a result, it outperforms better as compared to homogeneous DECP protocol. But, the concept of remaining energy to select CH in this case has no role at all where the advance nodes have more opportunity to be the cluster-head. SEP has the best performance in term of remaining energy criteria to select CH, because SEP do not use random mechanism for cluster-head selection, thus SEP could accurately select the high energy node with very low communication cost to be the cluster-head, and implement the load balancing in WSN.

The Power Consumption of DECP and SEP protocols for varying number of nodes. Their comparison is given by the superimposed plot. We can observe from the graph that the Power Consumption of DECP is much higher than SEP. Hence SEP is more energy efficient than DECP protocol because of it consumes less power than DECP protocol by varying number of nodes.

We observed from the graph that the number of alive nodes of SEP is always lower than that of DECP which makes it more desirable for increasing the network lifetime is always higher in SEP than DECP protocol by varied number of node in wireless sensor network. The transmission from sensors nodes to sink node happens either between cluster node and its head or between cluster head and sink node.

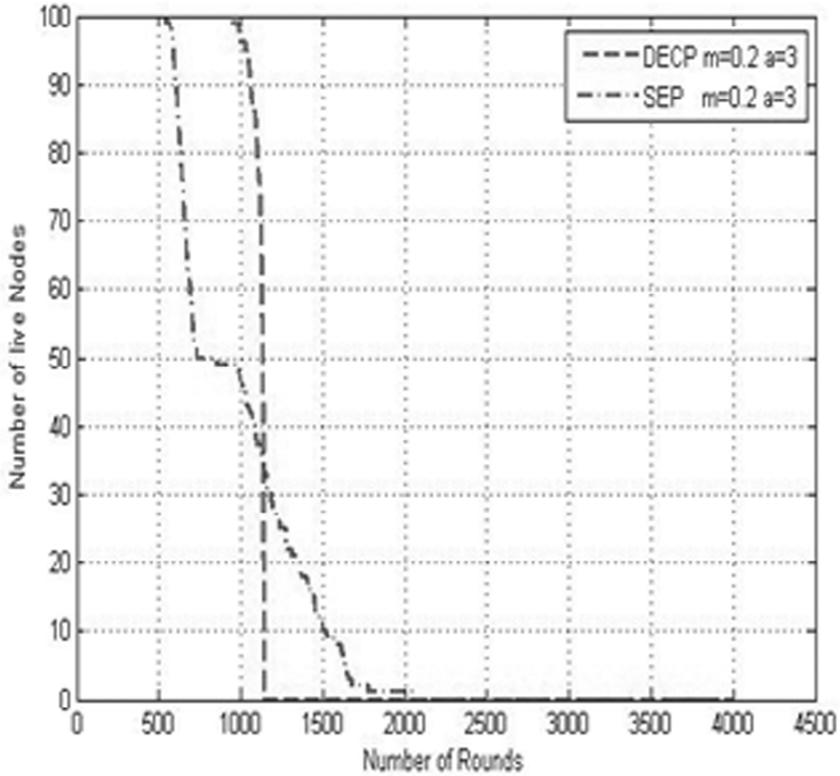

Figure 3: Number of alive nodes using the presence of heterogeneity: *m* = 0.2 and $\alpha = 3$

6. CONCLUSIONS AND FUTURE WORK

In this paper, we have presented clustered heterogeneous wireless sensor networks where more powerful sensor nodes act as cluster heads for more number of rounds.SEP protocol increases the stable period of the sensor network by assigning a three level of energy to the sensors. SEP is compared with the DECP protocol by using performance parameters, Average energy and alive node with respect to number of nodes and life time of network. The simulation results, the proposed protocol has confirmed that it provides a longer network lifetime as compared to DECP protocol and direct transmission. When increasing nodes SEP protocol for given better performance than DECP.One of our future works will include multihop clustering and fault tolerant mechanism in heterogeneous sensor networks.

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