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Enhancing The Lifetime of Heterogeneous Wireless Sensor Networks (Hwsns) By Distributed Clustering Mechanism

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ABSTRACT

A Wireless Sensor Network (WSN) is a group of specialized transducers with a communications infrastructure that uses radio to monitor and record physical or environmental conditions. A Heterogeneous Wireless Sensor Network (HWSN) is a network of sensors that uses wireless links with different communication range or those sensors may be used in a number of applications. Owing to the limited and non rechargeable energy supply, WSN has a rigid requirement regarding its power consumption. Clustering can be considered as an effective way that improves the energy efficiency. Large sized clusters consumes more energy than small sized clusters, because it has long intra cluster distance, i.e., the distance between the cluster members and the cluster head. In this paper, an improvised technique Distributed Energy Efficient Mechanism (DEEM), that uses multi hop communication links between the cluster members and the cluster heads is proposed here. Moreover, cluster heads communicate with the base stations in a multi hop manner. So energy is distributed equally among the nodes and this result in considerable conservation of energy. The simulated result shows considerable increase in lifetime of sensor nodes by using the proposed technique.

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INTRODUCTION

Wireless sensor network (WSN) signify a group of spatially spread and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSNs measures environmental conditions like temperature, sound, pollution levels, humidity, wind speed and direction, pressure, etc. WSNs were initially designed to facilitate military operations but its application has since been extended to health, traffic, and many other consumer and industrial areas. A WSN consists of anywhere from a few hundreds to thousands of sensor nodes. The sensor node equipment includes a radio transceiver along with an antenna, a microcontroller, an interfacing electronic circuit, and an energy source, usually a battery. The size of the sensor nodes can also range from the size of a shoe box to as small as the size of a grain of dust. As such, their prices also vary from a few pennies to hundreds of dollars depending on the functionality parameters of a sensor like energy consumption, computational speed rate, bandwidth, and memory (Ameer Ahmed Abbasi, Mohamed Younis, 2007; Mhatre, V., C. Rosenberg, 2004).

Clustered sensor networks can be classified in to two broad types they are, homogeneous and heterogeneous sensor networks. In homogeneous networks all the sensor nodes are identical in terms of battery energy and hardware complexity. Heterogeneous sensor networks, has two or more different types of nodes with dissimilar battery energy and different functionality are used. By embedding a more complex hardware and extended battery energy in a few cluster head nodes, it is able to reduce the hardware cost for rest of the network. But here, the role rotation of cluster nodes is not possible, as the cluster heads are fixed. When the nodes in the network communicate with the cluster head by a single hop, the nodes that are farer from the cluster heads tend to spend more energy than those of which are closer to the cluster heads (Ameer Ahmed Abbasi, Mohamed Younis, 2007). On the other hand, when the nodes uses multi-hop to communicate with the cluster head, the nodes that are nearest to the cluster head have a burden of highest energy due to relaying. Hence there exists a non-

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uniform energy drainage pattern in the network. Hence there are two desirable characteristics for a sensor network, viz. lower hardware cost, and uniform energy drainage. While heterogeneous networks are able in achieving the former, the homogeneous networks have the capability of achieving the latter. However both these features cannot be incorporated in the same network (Mhatre, V., C. Rosenberg, 2004).

Energy conservation is an important aspect in WSNs. When the sensors are deployed in hostile environments, replacing or recharging their batteries won't prove as a desirable option. In general, a major part of the energy is utilized by the communication electronics in the sensor node. Clustering is considered as an important energy saving method in WSN, and the efficiency of the WSN mainly relies on the energy-efficient clustering routing algorithm (Kumar, D., 2009; Dilip kumar, 2013). The clustering structure aggregates data efficiently and achieves network load balance. Clustering algorithm selects a part of the nodes in WSN as cluster heads and classifies all other nodes reasonably. While clustering nodes in WSN, a single cluster must neither be too big nor be too small. Clustering proves to be an effective method for extending the lifetime of wireless sensor networks. Current clustering algorithms use two approaches; selecting cluster heads with higher residual energy and rotating the cluster heads in a periodic fashion to distribute the energy consumed among the nodes within each cluster and extend the network lifetime (Li Qing, Qingxin Zhu, Mingwen Wang, 2006).

The contents are as follows: in section II described as the related work. In section III explained as proposed scheme, in section IV the results of proposed approach are given and section V contains the conclusion.

I. Related Work:

SEP (Stable Election Protocol) is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. There are two classical approaches are present, they are direct transmission and minimum transmission energy (MTE). In direct transmission method, sensor nodes are directly communicated with sink by single-hop communication. In MTE, the data is routed over minimum cost routes. Nodes that are near the sink act as relays with higher probability than nodes that is far from the sink (Smaragdakis, G., 2004).

HEED (Hybrid Energy Efficient Distribution) was designed to select different cluster heads in a field according to the amount of energy that is distributed in relation to a neighboring node. In HEED sensors are quasi-stationary and links between nodes are symmetric. Energy consumption is non-uniform among all nodes. Same or different power levels are used for intra-cluster communication. HEED distribution of energy extends the lifetime of the nodes within the network thus stabilizing the neighboring node. Only two level hierarchies provided but can be extended to multilevel hierarchy (Dilip kumar, C., 2007).

EEHC (Energy Efficient Hierarchical Clustering) for electing cluster heads in a distributed fashion in hierarchical wireless sensor networks. The election probabilities of cluster heads are weighted by the residual energy of a node relative to that of other nodes in the network. The algorithm is based on LEACH and works on the election processes of the cluster head in presence of heterogeneity of nodes. Simulations results show that EEHC is more effective in prolonging the network lifetime compared with LEACH (Smaragdakis, G., 2004; Kumar, D., 2009)[4] & [8].

DEBC (Distributed Energy Based Clustering) protocol for heterogeneous wireless sensor networks Cluster heads are selected by a probability depending on the ratio between remaining energy of node and the average energy of network. The high initial and remaining energy nodes have more chances to be the cluster heads than the low energy nodes. This protocol also considers two-level heterogeneity and then it extends the results for multi-level heterogeneity. DEBC is different from LEACH, which make sure each node can be cluster head in each n=1/p rounds (Jin Yan, 2008).

DDAEE (Distributed Data Aggregated Energy Efficient), clustering protocol also fit for the multilevel heterogeneous wireless sensor networks. Here, all the nodes use the initial and residual energy level to define the cluster heads. It does not require any global knowledge of energy at every election round. This DDAEEC algorithm allows a more number of data to send from cluster head to a base station in a certain time interval. It improves the life time of WSNs.

S-EECP (Single-hop Energy Efficient Clustering Protocol), the CHs are elected based on different weighted probabilities (Fig. 1). The weighted probability is evaluated based on the ratio between residual energy of each node and average energy of network. The nodes with high initial and residual energy will have more chances to become CHs per round per epoch. In M-EECP (Multi-hop Energy Efficient Clustering Protocol), after the election of CHs, the member node communicates directly with the CH using a single-hop communication (Fig. 1). On the other hand, CHs use multi-hopping to reach the BS (Dilip kumar, 2013; Bandyopadhyay, S., E.J. Coyle, 2003).

II. Proposed Protocols:

There are various approaches proposed for energy efficient clustering mechanism in heterogeneous wireless sensor networks. In order to reduce the energy consumption, cluster formation and cluster head selection is introduced. A distributed energy efficient mechanism required for cluster formation and energy efficiency. In this paper the proposed new cluster head selection mechanism to increase the life time of WSN and a reconfiguration approach to optimize the energy consumption in inter cluster communication.

A. Distributed Energy Efficient Mechanism:

There are two phases that are accomplished in DEEM: setup phase and steady state phase. In the setup phase, cluster head selection and cluster formation process is completed. In the steady state phase, selected cluster head is identified and the selected cluster head uses the inter cluster communication. Owing to randomness property of WSN; cluster can be small or large in their deployed region. Large sized clusters consumes more energy than small sized clusters, because it has long intra cluster distance, i.e., the distance between the cluster members and the cluster head. In this paper, an improvised technique that uses multi hop communication links between the cluster members and the cluster heads is proposed here (Fig. 2). Moreover, cluster heads communicate with the base stations in a multi hop manner. So energy is distributed equally among the nodes and this result in considerable conservation of energy. The distance based probability is a function of the distance of the normal sensor to the advanced sensor. The proposed system develop distributed algorithm which addresses the energy-efficient clustering under the joint coverage and routing constraint.

There are some assumptions for our protocol as given below;

- Base station should be known to all cluster members.
- Base station should be independent of energy resources.
- Sensor nodes are static.
- Sensor nodes locations are not known.

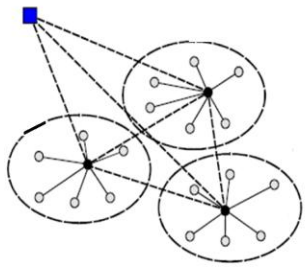

Fig. 1: S-EECP and M-EECP.

B. Cluster Head Selection:

Cluster head selection and cluster formation processes are completed in the setup phase. The cluster head aggregate the data and send to base station.

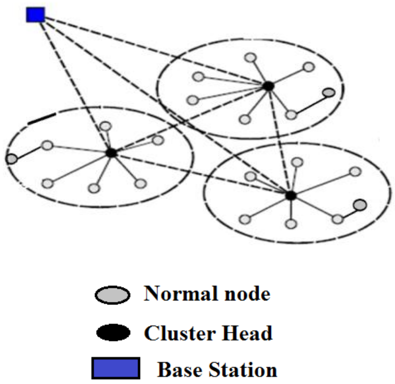

Fig. 2: M-DEEM.

Each sensor node computes its approximate distance according to the strength of receiving signals. The sensor nodes elect the cluster head according to high energy or threshold. At initial, advanced node is elected as a cluster head which consists of high threshold value. Each sensor nodes chooses a random number between 0 and 1 individually. If this is lower than the calculated threshold T(i) for node i, then it becomes a cluster head. Each node becomes a cluster head in one epoch. An epoch is defined as,

$$epoch = \frac{1}{Popt} \quad (1)$$

In the three level heterogeneous nodes (normal nodes, advanced nodes, and super nodes), a reference value P_{opt} has been replaced by weighted probabilities. The advanced node (m) has α amount of more energy than normal nodes.

$$Pnorm = \frac{Popt}{1+\alpha m} \quad (2)$$

$$Padvanced = \frac{Popt}{1+\propto m}\ (1+\propto) \quad (3)$$

$$Psuper = \frac{Popt}{1+\beta m}\ (1+\beta) \quad (4)$$

The total initial energy of the new heterogeneous network setting is given by the following equations,

$$E\ total = N\ \times Eo\ \times (1+m\ \times S) \quad (5)$$

Where,

$S = (\alpha - m_o \times (\alpha - \beta))$

The CHs are elected periodically by different weighted probability. Each member node communicates with their respective CHs by using, multi-hop communication (i.e. inter-cluster communication) when the distance between normal node to base station is greater. Then CHs collect the data from the normal nodes in their respective clusters, aggregate it and transmit it to the BS using multi-hop communication.

Assume that the distance between transmitter and receiver is d, the energy consumed for transmitting L bits data from transmitter to the receiver is given by the following equation,

$$Etx\ (L,d) = \frac{L \times Eelec + L \times \varepsilon_{fs} \times d^2}{L \times Ed + L \times \varepsilon_{mp} \times d^4} \quad (6)$$

Where, E_{elec} is the amount of energy consumption of the wireless circuit for sending and receiving data. The energy require for receiving the data is given by the following equation,

$$E_{rx} = L \times E_{elec} \quad (7)$$

The probability of a node to become a cluster head, P_{opt} which can be calculated by the equation,

$$K_{opt} = \sqrt{\frac{N}{2\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}\frac{M}{d_{BS}^2} \quad (8)$$

Where, $d_{BS} = 0.765 * \frac{M}{2}$

By using (8), the optimal probability of a node to become a cluster head is constructed. The average energy E_{avg} of the network at i^{th},

$$E_{avg}(i) = \frac{1}{N}\ E(1-\frac{i}{R}) \quad (9)$$

Where, R is the total number of rounds of the network lifetime. Therefore, every node consumes the same amount of energy at each epoch.

$$R = \frac{E_{total}}{E_{round}} \quad (10)$$

The average energy for the different epoch based on residual energy $E_i(r)$ of each node per round can be obtained as,

$$E_{avg}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i\ (r) \quad (11)$$

C. Multi-Hop Communication Mechanism:

Two major communication patterns are single-hop and multi-hop which is mostly used in WSNs. Single-hop communication transmits the data directly to the BS without any relay, thus the node located away from the BS will consume more energy than the other nodes and drains faster, die out first. To conquer this problem, we use shortest path algorithm

Directed weighted graph for direct communication G = {V, E}, where V is a set of nodes and E is a set of edges. Each edge is a pair (v, w), where v, w ∈ V. Edges are sometimes referred to as arcs. If the pair is ordered, then the graph is directed. Vertex w is adjacent to v if and only if (v, w) ∈ E. In an undirected graph with edge (v, w), and hence (w, v), w is adjacent to v and v is adjacent to w. Sometimes an edge has a third component, known as either a weight or a cost.

A cycle in a directed graph is a path of length at least 1 such that $w_1 = w_n$; this cycle is simple if the path is simple. For undirected graphs, we require that the edges be distinct. The logic of these requirements is that the path u, v, u in an undirected graph should not be considered a cycle, because (u, v) and (v, u) are the same edge. In a directed graph, these are different edges, so it makes sense to call this a cycle. A directed graph is acyclic if it has no cycles. A directed acyclic graph is sometimes referred to by its abbreviation, DAG.

An undirected graph is connected if there is a path from every vertex to every other vertex. A directed graph with this property is called strongly connected. If a directed graph is not strongly connected, but the underlying graph (without direction to the arcs) is connected, then the graph is said to be weakly connected. A complete graph is a graph in which there is an edge between every pair of vertices.

D. Data Communication Phase:

Formerly the clusters are formed and the TDMA plan is set, the data communication phase can begin. The active node periodically collects and transmits the data on the basis of allocated time to the CH, where the remaining node are turned off to minimize the energy consumption. After collecting information from all the nodes, CH aggregate the data and route that to BS via multi-hop communication.

RESULTS AND DISCUSSION

A heterogeneous clustered WSN has been simulated with 100 sensor nodes. The normal nodes, advanced nodes and super nodes are randomly distributed over the remote control area. Therefore the horizontal and vertical coordinates of sensor node is selected randomly. The base station considered to be in center of the sensing field. The simulation parameters are tabulated in table1.

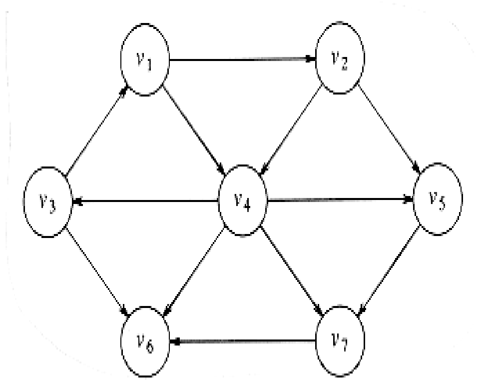

Fig. 3: Directed weighted graph.

Table 1: Simulation Parameters.

Parameter		Value
Network size		100m × 100m
Node number *(n)*		100
Base station position		50 m, 50m
Initial energy	Normal node *(m)*	1nJ
	Advanced node *(α)*	2nJ
	Super node *(β)*	3nJ
Transmitter/Receiver electronics E_{elec}		50 nJ/bit
Data aggregation (E_{DA})		5 nJ/bit/report
Reference distance		90m
Transmit amplifier $\in_{fs}$ if $d_{BS} \leq d_0$		10pJ/bit/m^2
Transmit amplifier $\in_{fs}$ if $d_{BS} \geq d_0$		0.0013pJ/bit/m^4
Energy dissipated per bit		50nJ
Message size *(l)*		6400 bits

In this section, we constructed 100 heterogeneous nodes in 100 × 100 region and one BS.

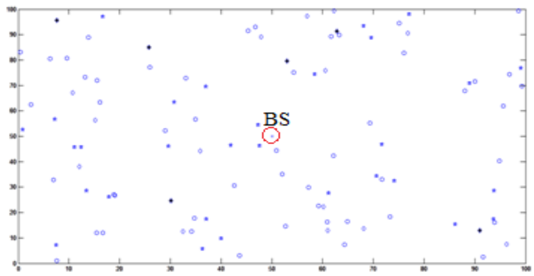

Fig. 4: Heterogeneous wireless sensor nodes in 100 × 100 regions.

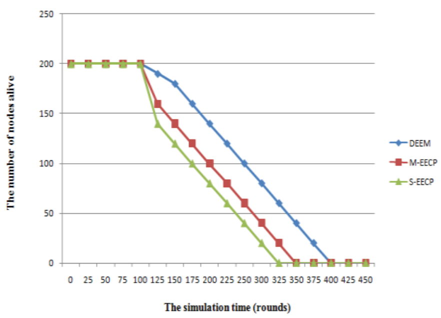

Fig. 5: Number of alive nodes per round over an area of size 100×100 m^2.

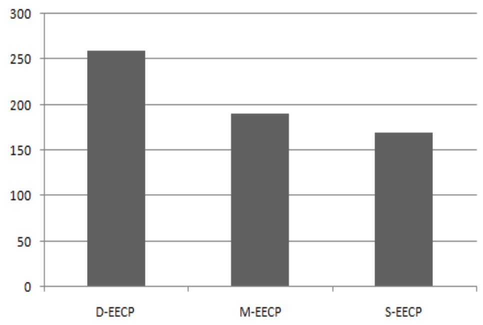

Fig. 6: Network lifetime as a function of first dead node.

Experiment:

In the experiment, the cluster members i.e., normal nodes use multi-hopping to communicate with the elected CH. CHs use multi-hopping to communicate with the BS. Comparing the performance of DEEM with the S-EECP and M-EECP, when the first node is dead can be clearly seen in Fig. 5 and Fig. 6. DEEM extends the network lifetime by 65, 70 and 21% against S-EECP and M-EECP. Because in S-EECP, data packets are directly transmitted for long distance (CHs and BS) without relay, hence, the nodes located farther away have high energy burden because of communication long range communication and they die earlier. Therefore DEEM overcomes the imbalance energy consumption problem by using multi-hop communication among all nodes. It achieves balance of energy consumption among all nodes and enhances the network lifetime.

III. ***Conclusion:***

An attempt has been made through this paper, to suggest an improvised technique that further enhances the conservation of energy than the existing methods. A new method is designed, that uses multi hop communication links between the cluster members and the cluster heads. Further the cluster heads communicate with the base stations in a multi hop manner. WSN has a rigid requirement regarding its power consumption due to the limited and non rechargeable energy supply. So by employing this new improvised technique, the energy is distributed equally among the nodes and this brings about a considerable conservation of energy. This method is helpful when the clusters far from base stations need to communicate with these base stations and they communicate using multi hop links thereby reducing the energy consumed. Furthermore, the intra cluster communications using multi hop links distributes the energy among the nodes within the cluster thereby further reduction of energy consumed. Hence this method provides an efficient way of conserving energy in wireless sensor networks and thus increasing the lifetime of wireless sensor nodes within a network.

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