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Energy Preservation in Heterogeneous Wireless Sensor Networks through Zone Partitioning

Shahzad Hassan*[1], Muhammad S Nisar[2], Hongbo Jiang[3]
[1,3]Department of Electronics and Information Engineering
[2]Wuhan National Laboratory optoelectronics
HUST, Wuhan China
*Corresponding author, e-mail:shahzad@hust.edu.cn

Abstract

Energy preservation is critical task in the wireless sensor networks and the energy cost increases proportionally as the transmission distance increases. Since nodes are equipped with limited energy it is very crucial to decrease the energy consumption by decreasing the communication distance between the nodes. In clustering protocols inter-cluster and intra-cluster communication is most neglected part. We have proposed a new zone based clustering protocol which reduces the intra- clustering and inter-clustering transmission distance between the communicating nodes. Experimental results reveal that our proposed protocols have outperformed the compared protocols in terms of stability period, instability period and throughput.

Keywords: Heterogeneous, Zone, Clustering, Residual energy

1. Introduction

The term WSN can be defined as, "Incorporating simple sensing, processing, storage and communication abilities into minimal size, low price devices and combining them into so called WSN" [1]. The emerging field of WSNs fuses sensing, computation and communication on single compact chip known as sensor node. In the last two decades the WSN has attain rapid developments and has made it possible to deploy the sensor networks to monitor the physical occurrences in a variety of environment, especially in hostile locations where human intervention is not possible or may be dangerous. Since the WSN contains numerous number of nodes ranging between couple of hundreds to thousands scattered randomly throughout a geographic area or deployed closed to the phenomena. However nodes have severe constraints in terms of energy.The lifespan of the sensor networks strongly depends on the battery and in many cases the nodes may have restricted battery power.

Many novel techniques related to wireless sensor networks have been proposed by the researchers in order to minimize the node's energy consumption [2]. The function of sensor node can be divided into three major phases i.e. sensing, processing and transmission. In the sensing phase nodes sense the data and forward it for processing to perform local computation on the data, while in transmission phase the node exchanges data with its neighbors, respective cluster heads or base station as the case may be [3]. A sensor node utilizes energy during sensing, processing and transmission. Data transmission is responsible for a major chunk of energy consumption in a sensor node, consuming between 60% [4] and 80% [5]. At the same time it consumes less energy, ranging between 20%-40%, in sensing and processing. To address above mentioned issues, clustering [6-8] has been proposed by various researchers. Clustering protocols provide the solution to utilize the network energy uniformly which enhances network life time. Clustering of nodes does also avoid long distance communication between nodes and BS.

Since the nodes are have limited battery and major portion of the energy is depleted in transmission which is directly proportional to transmission distance. Thus minimizing the transmission distance between the nodes could significantly increase the network lifetime. Generally in clustering the nodes are divided into cluster heads and cluster members. The cluster members transmits their data to cluster head via intra-cluster communication while the

cluster heads perform data aggregation on the data obtained by cluster members and forwards it to the base station for further processing via inter-cluster communication.

Clustering methods offer numerous advantages over traditional routing protocols but conversely, there also exist certain drawbacks associated with clustering protocols such as number of cluster heads, high energy depletion in cluster heads which involves multiple tasks like data aggregation and long haul inter-cluster communication and the intra-cluster communication distance. Although the intra-communication distance between the cluster members and cluster heads is kept to minimum but however due to random deployment of nodes, the node may be located closer to the base station as compared to the cluster head. In this case, although the distance between node and base station is less than the distance between node and cluster head but due to clustering mechanism the node will transmits its data to the cluster head instead of transmitting it directly to the base station.

Thus prolonging the network life time in clustering does not involve efficient cluster head selection algorithms, balanced cluster head but it should also accounts for the intra-clustering and inter-cluster transmission distance.

2. Related Work

SEP [8] is a two tier heterogeneous protocol having nodes with different energy level. Some nodes have higher energy level as compared to the rest of the nodes. The nodes equipped with higher energy level are known as advance and the ones having less energy are known as normal nodes. In SEP the cluster head selection is based on the weighted probability of each node according to initial energy instead of remaining energy. The drawback of SEP is advanced nodes, which contains higher energy and there probability to become cluster head is more than the normal node. At a certain point the energy of these advance nodes becomes equal or even less than normal nodes, but they still retain the higher probability to become a cluster head. DTRE-SEP [9] is based on direct transmission and residual energy of the network nodes. The normal nodes compare its distance with the associated CH and the base station. If the CH is far away from the node, the node will directly transmit its data to the base station instead of the CH. In this way loss of extra transmission energy can be preserved. The probability of CH election is both weight and residual energy based. If the energy of advance nodes becomes less than the specified limit, both normal and advance node will have equal probability to become CH on basis of residual energy.

The Z-SEP [10] is based on zone partitioning. The zones are divided into multiple zone namely zone O, 1, and 2. The normal node is deployed in zone 0 while the advance nodes are deployed in Zone 1 and 2. The normal nodes directly transmit to the base station and does not take part in cluster formation and cluster head selection. The cluster formation and cluster head selection takes place only in the advance nodes. Although this scheme has significantly enhance the stable region of the network and decrease the unstable region but due to direct transmission the energy of the normal nodes drains out very quickly leaving a huge coverage area uncovered. In another approach [11] the author has divided the network region mainly into two areas (i) Non- clustered region. The non-clustered region is further divided into two regions. The nodes which are deployed close to base station, transmits directly to the base station while the nodes near to the gateway transmits directly to the gateway, (ii) Clustered region, the clustered region refers to that area, in which nodes are deployed far from the base station as compared to direct transmission area. In this scheme the complexity of the network is increased as every region performs different operations. Moreover the aggregated data is from the cluster heads is again forwarded to the gateway for aggregation increasing risk of data loss.

We propose Zone Based Heterogeneous Clustering Protocol (ZBHCP) which aims to prolong the network life time by zone partitioning which leads to uniform energy utilization in the network and decreasing the intra-cluster and inter-cluster communication distance by computing the transmission distance between the cluster member node and the base station and as selecting the cluster heads from their respective zones.

3. Zone Based Heterogeneous Clustering Protocol (ZBHCP)

In the proposed protocol the network region is equally divided into four equal rectangular zones and equal numbers of nodes are randomly deployed in each zone. To limit

the energy wastage due to long distance between cluster head and and cluster member, each cluster head is selected from the respective zone by compairing its residual energy with the zone nodes.

3.1. HWSN and Energy Consumption Model

The HWSN model consists of n number of nodes randomly deployed in m x m region. Two types of nodes have been deployed in the region advance nodes m and normal nodes n. The advance nodes are equipped with α times more energy than the normal nodes which is (1 − m) × n. This research reflects the energy consumption model proposed in [6] to measure energy consumption for proposed protocol, To transmit a P-bit Packet across a distance d_{TX}, the energy expended by the system is given below,

$$E_{Tx}(P, d_{TX}) = \begin{cases} P.E_{Ckt} + P.\varepsilon_{fs}.d_{TX}^2 & \text{if } d_{TX} < d_{NS} \\ P.E_{Ckt} + P.\varepsilon_{mp}.d_{TX}^4 & \text{if } d_{TX} \geq d_{NS} \end{cases} \tag{1}$$

$E_{Tx}(P, d_{TX})$ is the energy consumed by the transmitting node that forwards the P bits of data with a transmission distance 'd' to the receiver. E_{Ckt} =50nJ is the energy dissipated per bit to run the transmitter or the receiver circuit. Free space (ε_{fs}) and multipath (ε_{mp}) depends distance (d_{NS}) between transmitter and receiver. $d_{TX}$is the distance between the T_x (transmitter) and R_x (receiver) while the distance between the network nodes and the BS is at all times less than or equal to d_{NS}. By equating the two expressions at $d_{TX} = d_{NS}$, we have "$d_{NS=}\sqrt{\varepsilon_{fs}/\varepsilon_{mp.}}$"To receive P−bit message the systems utilizes energy equal to $E_{RX=}P.E_{Ckt}$

3.2. Cluster Head Selection and Cluster Formation

The cluster head selection process is similar to [6] and cluster heads are randomly selected for each round. Initially the selection process of cluster head is probabilistic [5]. The cluster heads are selected independently from each zone. A random number is generated between 0 and 1, if the generated number is greater than a certain previously set threshold the node becomes cluster head in that round. The threshold for normal and advance node is:

$$T_{NN} \begin{cases} \left(\dfrac{P_{NN}}{1 - P_{NN} * (r * mod(\frac{1}{P_{NN}}))} \right) & if \ S_N \in Y' \end{cases} \tag{2}$$

$$T_{AN} = \begin{cases} \left(\dfrac{P_{AN}}{1 - P_{AN*} * (r * mod(\frac{1}{P_{AN}}))} \right) & if \ S_A \in Y'' \end{cases} \tag{3}$$

Where, T_{NN}, $T_{AN}$are threshold for normal and advance nodes,P_{NN} and P_{AN} are the normal and advance nodes, r is the round,Y' and Y'' are the set of normal and advance nodes that have not become CHs within the last 1/P_{NN} and 1/P_{AN}, rounds of the epoch. The probability for advance and normal nodes to become CH is,

$$P_{NN} = \frac{P_{opt}}{(1 + \alpha * m)} * \frac{NE_{RES}}{Zone\ Nodes} \tag{4}$$

$$P_{AN} = \frac{P_{opt}(1 + \alpha)}{(1 + \alpha * m)} * \frac{AE_{RES}}{Zone\ Nodes} \tag{5}$$

Where NE and AE is normal and advance nodes residual energy, onaverage n*P_{opt} nodes must become CHs per round per epoch. Once the cluster head selection process is completed, the selected cluster heads, advertise message to the cluster members to join. Based on the RSSI value the cluster members join the nearest cluster head thus forming a cluster. Moreover the

nodes also take part into direction communication to the base station only in that case when the transmission distance of their respective cluster head is maximum as compared to the base station. The total energy expanded by the cluster head is given by,

$$E_{CH=}P \cdot \left(E_{Ckt} \left(\frac{n}{C} - 1 \right) + E_{AD} \frac{n}{C} + E_{Ckt} + \epsilon_{fs} d_{TX}^2 \right)$$
(6)

Where C is the number of clusters, E_{AD} aggregated data and d_{TX} is the distance between the associated CH and the sink. The energy used in a non CH is as follow,

$$E_{NCH} = \begin{cases} P.E_{Ckt} + P.\varepsilon_{fs}.d_{CH}^2 \ \ if \ \ d_{CH} < d_{BS} \\ P.E_{Ckt} + P.\varepsilon_{mp}.d_{BS}^2 \ \ if \ \ d_{CH} > d_{BS} \end{cases}$$
(7)

Where d_{CH} is the distance from each member node to their respective CHs and d_{BS} is the distance between nearest node and the base station. The overall energy expended in the network is equal to,

$$E_{TOT} = E_{CH} + E_{NCH}$$
(8)

The optimal probability of each node to become CH is "$P_{opt}=C_{opt}/n$", where C_{opt} is the optimal number of clusters per round

3.3. Performance Measures
- Stability Period: Stability Period or stable region is known as the time elapsed since the network became operational till the time first node dies,
- Instability Period: Instability Period or unstable region is the time interval starting from death of first node till the last node of the network dies out
- Network lifetime: is the measure of time period since the network becomes operational till the last active nodes becomes inactive,
- Number of active nodes: is the overall number of nodes that are still active and are part of the network,
- Number of dead nodes: is the number of inactive nodes which have utilized there all energy.
- Throughput: is total number of packets transmitted from cluster heads to the base station.

4. Simulations and Results
In simulations 100 nodes are randomly deployed equally in four zones having both normal and advance nodes. The base station is deployed in the center of the network. The packet size used for intra-cluster and inter-cluster communication and data aggregation is set to 500 bytes. The simulations are performed in MATLAB. Individual simulations were run for each protocol in their original. Rest of the parameters is given in Table 1.

Table 1. Network Parameters

Parameter	Value
Area	100*100
N	100
E_{AD}	5nJ/bit/message
E_0	0.5J
Packet Size	500 bytes
P_{opt}	0.1
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4

Figure (1) shows the comparison of active nodes. It has been verified that our proposed protocol has significantly increased the stable region 197 % as compared to M-GEAR and 18% compared to Z-SEP. In Z-SEP the normal nodes are deployed between the advance nodes and normal nodes do not take part in cluster formation and cluster head selection. The normal nodes adopt direct transmission to the base station due to which their energy is depleted very rapidly. It cannot be concluded from the figure (1) the percentage of stable region of our proposed protocol is not very high as compared to Z-SEP. The increased stable region in Z-SEP is being compromised at a cost of coverage area. Since the normal nodes transmits data directly to the base station, and all of the normal nodes drains energy at 2268th round leaving 60% coverage area uncovered. While in case of M-GEAR the author has used four different scenarios but overall network stable region still is very low and the first node drains out its energy in 623th round.
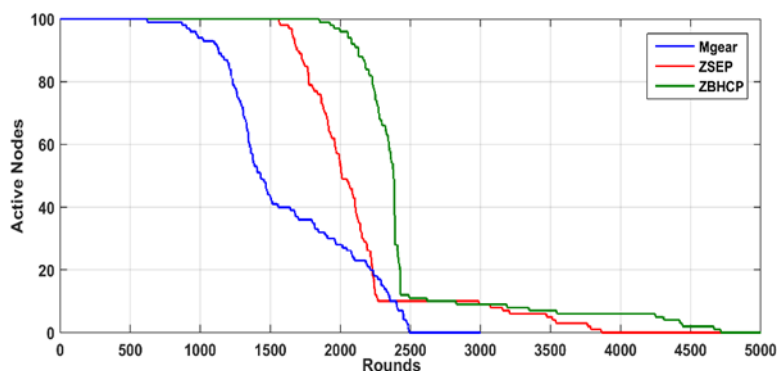

Figure 1. Comparison of Active Nodes

Figure (2) presents the comparison of dead nodes. It can be concluded that our proposed protocol has decrease the unstable region 89 % as compared to M-GEAR and 19 % with respect to Z-SEP. In Z-SEP the network energy utilization is not uniform as the normal nodes dies out at higher probability leaving behind advance nodes in the last rounds. Similarly the decreased stable region is sacrificed at the cost the uncovered region. Meanwhile in case of M-GEAR the last network node dies out 2490th round.
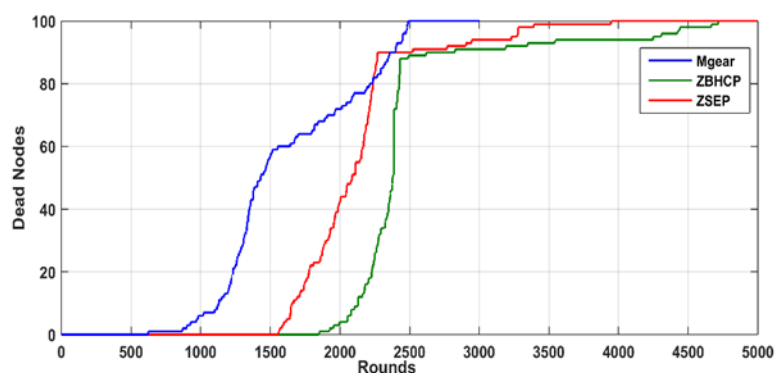

Figure 2: Comparison of Dead Nodes

Figure (3) illustrates the simulation results of throughput. The throughput of the ZBHCP seems to be comparatively very low as compared to the Z-SEP and M-GEAR. The reason behind this is the data aggregation process in ZBHCP. Due to random deployment of the nodes, the coverage area of nodes overlaps with each other and highly correlated data is gathered which is eliminated by the data aggregation and only aggregated data is transmitted to base

station for end user processing. As explained earlier the other two protocols adopt direct transmission. In Z-SEP 90% of the nodes communicate with the base station while in M-GEAR 40% of the nodes transmit directly to base station which results in redundant data being collected by base station which also increases the load and processing power required at base station. The throughput of these is protocol is therefore very high but it does not guarantee reliability of the data sent to base station.
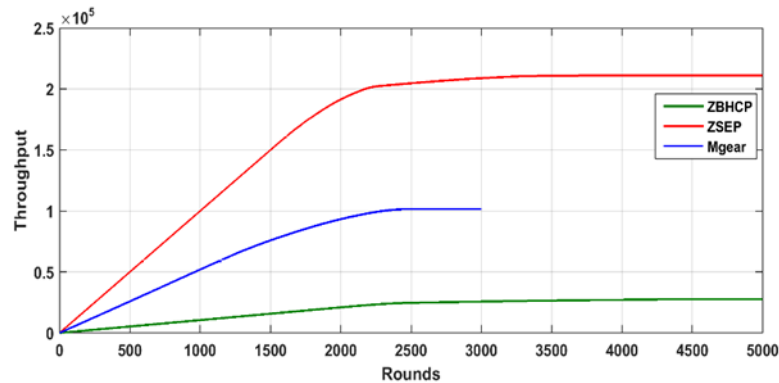

Figure 3. Comparison of Throughput

5. Conclusion

It can be concluded from the simulation results that network life time can be significantly prolonged by reducing the energy wastage in intra-clustering and inter-clustering communication due to long transmission distances by dividing the network area into equal zones.

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