Lifetime Improvement of DEEC and DDEEC Protocols using Sleep Awake Mechanism in Wireless Sensor Networks

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***Abstract* - Wireless Sensor Networks (WSNs) is an emerging technology nowadays. With its increasing demand, they are designed in such a way to perform more complex functions. But they still require the battery operated sensors to perform the various tasks. In WSNs, due to non uniform distribution of energy nodes in the network, some of the nodes drain out energy very quickly and consequently energy holes are created at few places in the network. These energy holes become the cause for data routing failure. In this paper, Sleep Awake Mechanism is applied to eradicate the energy holes. The sleep awake mechanism is applied on two heterogeneous protocols namely Distributed Energy Efficient Clustering (DEEC) and Developed DEEC (DDEEC) and then results are compared. Simulations results show that modified DEEC (mDEEC) and modified (DDEEC) enhance the network lifetime by 25.69% and 18.50% respectively as compared to DEEC and DDEEC and the throughput by 32.81% and 35.80% respectively.**

***Index Terms* - Wireless Sensor Networks (WSNs), Distributed Energy Efficient Clustering (DEEC), Developed DEEC (DDEEC).**

I. INTRODUCTION

WSN is an emerging technology of 21st century which is predicted to change the human life in future. It basically consists of a Base Station (BS) and several sensor nodes (SNs) scattered in the desired area. Sensor nodes gather the desired information from the area of interest and send it to the BS. The gathered information can be temperature, pressure, humidity, pollution content etc. From BS, the information is sent to the user using satellite or internet link. The small sized SNs are mainly used because of their low power, low cost and multifunctionality. The life of a WSN depends on its SNs. Research is made in this field to design the routing protocols to improve the lifetime of sensor nodes. Apart from limited battery power sensor nodes, the other issue attached with WSN is that these wireless networks work in dynamic environments. As a result, there is loss of nodes which may cause degradation of the performance of the network.

Wireless Networks are classified into two types depending on the energy level of the nodes- Homogeneous Network and Heterogeneous Network. In Homogeneous Networks, all the nodes have same battery energy and same hardware complexity. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol works well in homogeneous networks. In Heterogeneous Networks, nodes have different battery energy and hardware complexity. Stable Election Protocol (SEP), Distributed Energy Efficient Clustering (DEEC) protocols are the examples of heterogeneous protocols.

Efficient use of energy is a challenging task for researchers nowadays. Due to non uniform distribution of energy nodes in the network, some of the nodes drain out energy very quickly and consequently energy holes are created at few places in the network. These energy holes become the cause for data routing failure. Due to these holes, some of the areas in Wireless Sensor Networks remain unattended. This makes WSN an un-effective network. Use of sleep nodes in the network can help to reduce the energy holes to large extent. When any node is in sleep node, then its communication with the cluster head is ceased for some time. This may help the node to save its energy.

Sleep Awake mechanism defines a threshold value for all the sensor nodes in the network. This threshold value decides that when the node will be in sleep mode and when it will be in awake mode. Utilizing the concept of sleep awake mechanism can help to reduce the energy consumption of the nodes and consequently can improve the parameters like lifetime of the network and no. of data packets sent to the base station.

In this paper, sleep awake mechanism is applied on DEEC and DDEEC protocols and results are analyzed in terms of network lifetime, stability period, instability period and throughput.

II. ENERGY HOLE PROBLEM IN WIRELESS SENSOR NETWORKS

Energy holes are created when some of the nodes drain out their energy very quickly. This may be due to the non uniform distribution of nodes in the network. This unbalanced distribution of energy causes some of the nodes to die early, thus becoming the cause for data failure at that area of the network. The sensor nodes near the sink have a greater load. They have to send their

own data to the BS as well as the data which is routed from the distant nodes. This also results in major consumption of energy by the nodes near the sink, thus creating energy holes in the network.

III. SLEEP AWAKE MECHANISM

In this mechanism, some of the sensor nodes are in sleep mode while the others remain in the active mode for every round of communication. The active nodes are used for communication purpose while sleep nodes are used for maintaining sensing, coverage and connectivity. The sink is placed at the center of the field. All the nodes have different energies as they belong to the heterogeneous network. The information is sent to the BS on the basis of residual energy.
In this mechanism, four stages are defined-

- Initializing Stage
- Sleep/Awake Mechanism Scheduling Stage
- Threshold Calculating Stage
- Cluster Forming Stage

Formula to calculate the threshold value E_{th} is given by –

$$E_{th} = (ETX + EDA) * (E_{amp} * D * d^4) \quad (1)$$

ETX is the transmission energy. *EDA* is the data aggregation energy. E_{amp} is the energy of the amplifier. D is the length of the packet of data. d is the distance between sink and its maximum distance node.
The following procedure is carried out after calculating the E_{th} value.
For every node, the below written cases are carried out.

Case 1 - $E_r > E_{th}$:
The node is considered to be in the active mode if energy value of the sensor node is greater than the threshold value and this node is ready for communication.

Case 2 - $E_r < E_{th}$:
The node moves to the sleep mode if energy of the node is less than the threshold value of the energy.

IV. HETEROGENEOUS PROTOCOLS

1. DEEC Protocol

DEEC is defined for two level heterogeneous network. Its Cluster Head (CH) selection method is based on the concept of initial energy and residual energy.
For every round in a network, p_i is the probability of each sensor node to become a cluster head. G is defined as the set of sensor nodes which are eligible to become a CH in round r. In each round, a random number is selected by every node. If that random number is less than the threshold value as given in eq. (2), then that node is considered as a CH.

$$T_{(Si)} = \begin{cases} \frac{pi}{1 - pi\,(r \bmod \frac{1}{pi})} & \text{if Si } \in \text{ G} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Two types of nodes are present in DEEC – Normal nodes and Advance nodes. Therefore, value of probability to be selected as CH is changed accordingly for normal and advance nodes as shown in eq. (3).

$$p_i = \begin{cases} \frac{p_{opt}\, Ei(r)}{(1+am)E'(r)} & \text{if Si is normal node} \\ \frac{p_{opt(1+a)}\, Ei(r)}{(1+am)E'(r)} & \text{if Si is advance node} \end{cases} \quad (3)$$

$Ei(r)$ is the energy of the node at round r. $E'(r)$ is the average energy of the network at round r. P_{opt} is the reference probability. There are m fraction of advance nodes in the network which have α times more energy than advance nodes.

2. DDEEC Protocol

It has same CH selection method as DEEC. The only difference lies in expression defining the probability of normal and advance nodes. As advance nodes have more probability to be selected as CHs but if these are elected as CH again and again, then they will drain energy very quickly and will consequently die very soon. DDEEC has proposed a technique to balance the cluster head election criteria. The value of threshold energy Th_{REV} is given by-

$$Th_{REV} = \text{Eo}\,(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disAN}}) \quad (4)$$

Th_{REV} is the threshold value at which the normal and advance nodes have same CH election expression. Eo is initial energy of the node. E_{disNN} and E_{disAN} is the energy dissipated by normal node and advance node respectively in each round.
The SN's average probability to be CHs is given by –

$$p_i = \begin{cases} \frac{p_{opt}\, Ei(r)}{(1+am)E'(r)} & \text{for normal nodes, } Ei(r) > Th_{REV} \\ \frac{(1+a)p_{opt}\, Ei(r)}{(1+am)E'(r)} & \text{for advance nodes, } Ei(r) > Th_{REV} \\ \frac{c(1+a)p_{opt}\, Ei(r)}{(1+am)E'(r)} & \text{for advance, normal nodes, } Ei(r) \leq Th_{REV} \end{cases} \quad (5)$$

c is a positive number which controls the CH number.

V. NETWORK MODEL

- The sensor nodes are randomly distributed across the network.
- The BS is deployed at the center of the network.
- All the sensor nodes are stationary.
- The energy of the sink is unlimited.
- The energy of all the nodes is not the same, i.e. heterogeneous nodes are present.
- Sleep nodes are selected from the network on the basis of defined threshold value, i.e. there is no fixed place for the existence of sleep nodes across the network.

VI. RESULTS AND DISCUSSION

In this section, we simulate two heterogeneous clustering protocols namely mDEEC and mDDEEC which are modified versions of DEEC and DDEEC respectively after applying sleep awake mechanism. Simulation is done using MATLAB. For this purpose, 100 nodes are randomly distributed over the entire Wireless Sensor Network in the field with dimensions 100m × 100m.

Table 1. Simulation Parameters

Parameters	Representation	Values
N	No. of Sensor Nodes	100
Xm × Ym	Network Size	100m × 100m
Sink(x,y)	Sink Node	50,50
Eo	Initial Energy of Sensor Nodes	0.5 J
L	Packet Length	4000 bits
P_{opt}	Probability	0.1
E_{elec}	Transmitter/Receiver Electronics Energy	50nJ/bit
E_{DA}	Data Aggregation Energy	5nJ/bit/signal
ϵ_{fs}	Energy Consumed by Amplifier at Shorter Distance	10pJ/bit/m^2
ϵ_{mp}	Energy Consumed by Amplifier at Longer Distance	0.0013pJ/bit/ m^4
do	Distance	70m
N	No. of sleep nodes	10
Rmax	No. of rounds	10,000

After applying the sleep awake mechanism, these modified versions are compared with their basic protocols in terms of below mentioned simulation parameters.

Network Lifetime – The main purpose of designing the routing protocols is to increase the lifetime of the Wireless Sensor Network. Network Lifetime is the time span from start of the first round to the last node dead.

Stability Period – It is time interval from the beginning of the network to the death of the first node.

Instability Period – It is the time interval from the first node dead to the last node dead.

Packets sent to BS – This parameter defines the no. of data packets sent to the BS till the last node dies.

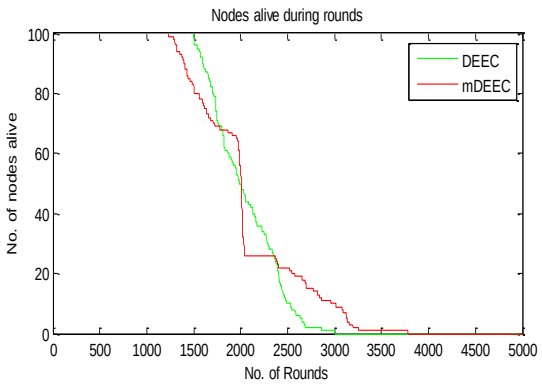

Figure 1. No. of nodes alive for DEEC and mDEEC

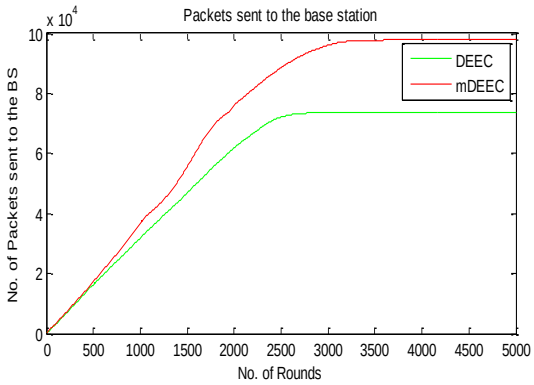

Figure 2. Packets sent to BS for DEEC and mDEEC

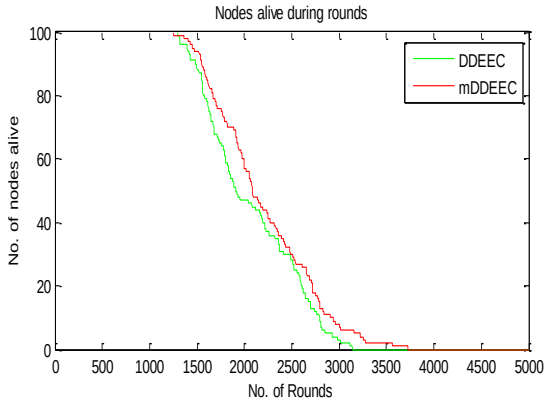

Figure 3. No. of nodes alive for DDEEC and mDDEEC

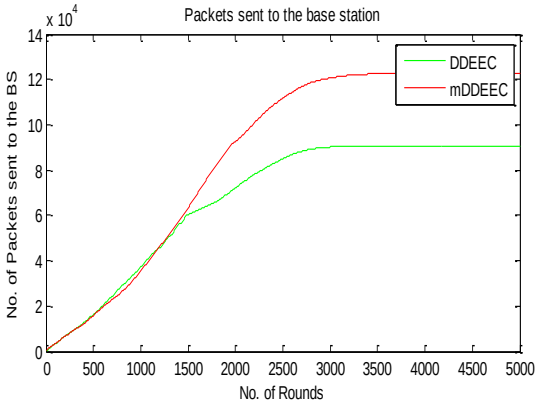

Figure 4. Packets sent to BS for DDEEC and mDDEEC

Simulation Results show that in DEEC, all the nodes die at 3008 rounds and in mDEEC, all the nodes die at 3781 rounds. Hence network lifetime is improved by 25.69 %. Packets sent to the BS are 73741 and 97939 in DEEC and mDEEC respectively. Therefore, the sleep awake mechanism improves the throughput by 32.81%. From the results, it has been proved that the stability period is more in DEEC while the instability period is greater in case of mDEEC.

In DDEEC, all the nodes die at 3141 rounds and in mDDEEC, all the nodes die at 3722 rounds. Hence network lifetime is improved by 18.50 %. Packets sent to the BS are 90452 and 122839 in DDEEC and mDDEEC respectively. Therefore, the sleep awake mechanism improves the throughput by 35.80 %. From the results, it has been proved that the stability period is more in DDEEC while the instability period is greater in case of mDDEEC.

VII. CONCLUSION

In this work, energy hole problem is focused. Sensor Nodes have limited battery life, and their energy consumption may lead to creation of energy holes in the network. Sleep awake mechanism has been introduced to improve the lifetime of the network. This mechanism has been applied to Heterogeneous protocols namely DEEC and DDEEC. It is observed that better energy consumption has been achieved after applying this approach. This work is analyzed in terms network lifetime and the packets sent to the base station.

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