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Performance Analysis on Energy Efficient and Scalable Routing Protocols of Wireless Sensor Network for Precision Agriculture

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ABSTRACT

This paper focuses on energy efficient routing protocols of wireless sensor network for the crop monitoring of precision agriculture. Precision agriculture can be defined as the advanced technology which is used the art and science to enhance crop production. In order to develop the precision agriculture, wireless sensor network technology becomes main issues in crop monitoring system. In this paper, two energy efficient and scalable routing protocols, Low Energy Adaptive Clustering Hierarchy (LEACH) and Distributed Energy Efficient Clustering (DEEC) protocols are analyzed in 100 square meters area with 100 sensor nodes. This paper mainly presents the dead nodes, alive nodes and amount of data received of routing protocols which will become main issues of crop monitoring system in precision agriculture. MATLAB software is utilized as core simulator for this research.

KEYWORDS: *energy efficient, wireless sensor network, precision agriculture, LEACH, DEEC*

I. INTRODUCTION

Precision agriculture means the use of information and control technologies in agriculture. Agricultural inputs such as irrigation and fertilizers can be applied in precise quantities as determined by modelling of crop growth patterns to maximize the crop yield and to minimize the impact on the environment [1]. Wireless sensor networks (WSN) can periodically collect and relay data to the information centre. This data can be used as inputs to the modelling software to determine the optimal quantities of the agricultural inputs (fertilizers, irrigation, pesticides etc.) required in different locations and at different times in the field.

Myanmar being an agricultural country needs some innovation in the field of agriculture. This can be achieved through modern technologies which assist communication and control within devices. WSN technologies have become a backbone for crop monitoring system [2]. WSN has provided small and low cost sensor nodes with the capability of sensing various types of environmental phenomena and wireless communication [3],[4]. Each of these sensor nodes has the capability to collect and route data either to other sensors or back to an external base station. Routing protocol is an indispensable part which ensures the normal operation of Wireless Sensor Network and the high efficient transmission of information [5]. The main objective of protocol design is to detect and collect the data provided by sensor nodes and respect their limited energy, memory, and computing capabilities. In the routing protocol of WSN, hierarchical routing protocols aim at clustering the nodes so that cluster heads can do some aggregation and reducing of data in order to save energy [6].

In this research, energy efficient and scalable routing protocols are implemented with dead nodes, alive nodes and amount of data received which are important for crop monitoring of precision agriculture. The remainder of the paper is organized as follows: In Section 2, the LEACH protocol and its working are discussed. The DEEC protocol and its working are introduced in Section 3. In section 4, simulation results and discussions of this paper have been illustrated. Finally, the paper is concluded in Section 5.

II. Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for wireless sensor network. In LEACH the nodes are partitions into clusters and in each cluster there is a dedicated node with extra privileges called Cluster Head (CH). This CH creates and manipulates a TDMA (Time division multiple access) schedule for the other nodes (cluster member) of that cluster. Those CHs aggregate and compress the sensing data and send to base Station (BS) [7].

This protocol is divided into rounds [8]; each round consists of two phases as shown in fig 1.

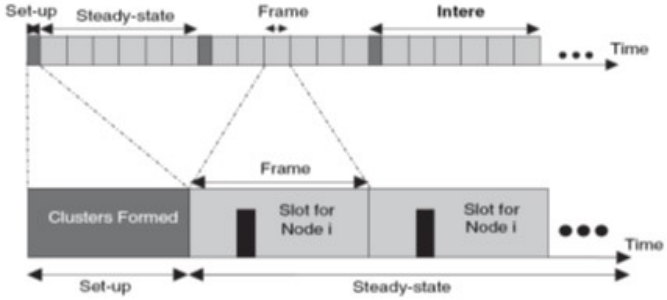

Figure1. Time line showing LEACH operation [9]

A. Set-up Phase

In set-up phase, CH selection is done by considering two factors. First, the desired percentage of nodes in the network

and second the history of node that has served as CH. This decision is made by each node n based on the random number (between 0 and 1) generated. If the generated random number is less than a threshold value T (n), then the corresponding nodes becomes CH for that round. The threshold value T (n) is calculated as following equation.

$$T(\mathrm{n}) = \begin{cases} \frac{P}{1-P\times\left(r \bmod \frac{1}{P}\right)} & \mathrm{n} \in \mathrm{G} \\ 0 \text{ otherwise} \end{cases} \qquad (1)$$

Where P is the desired percentage of cluster-head, r is the number of round and G is the set of nodes that have not been cluster-heads in the last 1/P rounds. Nodes that have been cluster heads cannot become cluster heads again for P rounds. Thereafter, each node has a 1/P probability of becoming a cluster head in each round. In the following advertisement phase, the CHs inform their neighborhood with an advertisement packet that they become CHs. Non-CH nodes pick the advertisement packet with the strongest received signal strength. The flowchart of LEACH protocol is shown in fig 2.

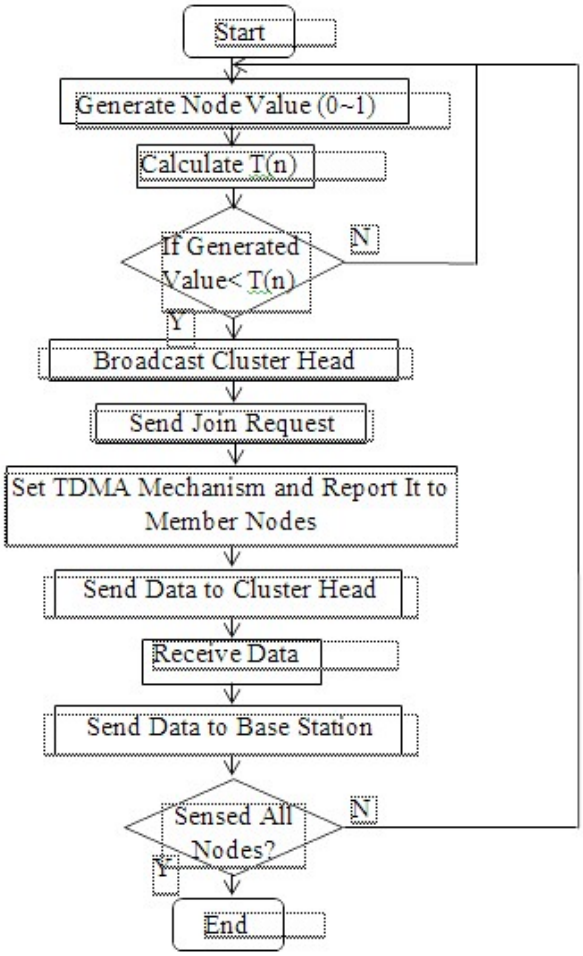

Figure2. Flowchart of LEACH protocol

Every node that has opted to become a CH broadcasts its new role to the network using a non-persistent CSMA MAC protocol. On receiving the CH broadcasts, each Non Cluster Head (NCH) node decides a cluster to join. The decision may be based on received signal strength of CH broadcast message, among other factors. The NCH, then inform selected CH their wish to become member of cluster. Once the cluster is formed, CH creates and distributes a TDMA based schedule to assign a time slot to each of its CM. To reduce inter cluster interference each CH selects a CDMA code, which is then distributed to all CMs. The completion of setup phase triggers beginning of the steady-state phase.

B. Steady-state Phase

In steady-state phase, nodes send their data during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy (chosen based on the received strength of the CH advertisement). The radio of each non-CH node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes. When all the data has been received, the CH aggregate these data and send it to the Base Station (BS).LEACH is able to perform local aggregation data in each cluster to reduce the amount of data that transmitted to the BS.

III. Distributed Energy Efficient Clustering (deec) Protocol

Distributed Energy Efficient Clustering (DEEC) is an energy aware adaptive clustering protocol used in heterogeneous wireless sensor networks. DEEC selects every sensor node as a cluster head based on its initial and residual energy. The flowchart of DEEC is shown in fig 3.

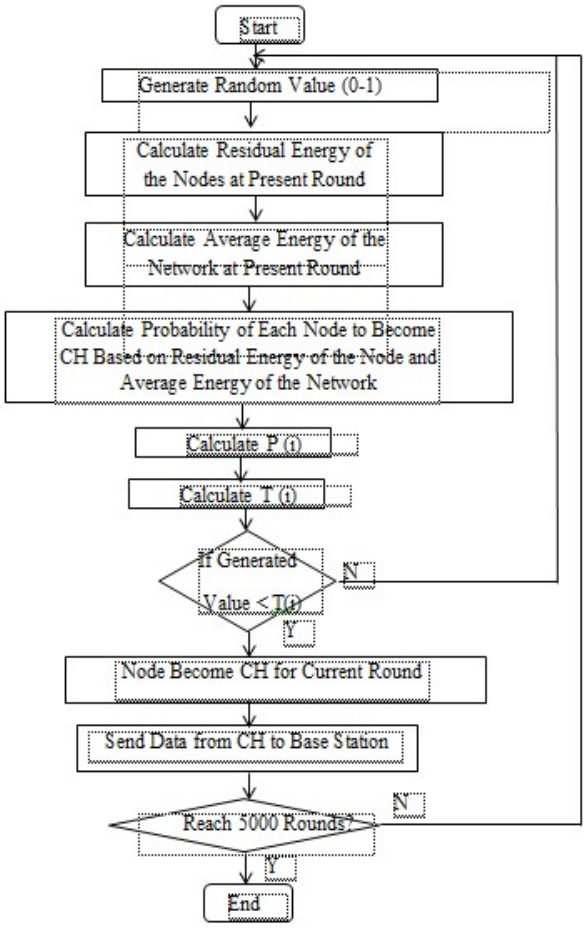

Figure3. Flowchart of DEEC protocol

A cluster head(CH) selection criterion in DEEC is focused around energy values of nodes. As in homogenous network, when nodes have equal measure of energy throughout every epoch then choosing $p_i = p_{opt}$ guarantees that p_{opt} Non CHs throughout every round. In WSNs, nodes with high energy are more reasonable to become CH than nodes with low energy but the net value of CHs throughout every round is equivalent to p_{opt} N. pi is the probability for each node s_i to become CH, so node with high energy has larger value of p_i as contrasted to the p_{opt} . P_i can be calculated as equations 3 and 4. $E_i(r)$ depicts average energy of network during round r. E_i (r) can be calculated as equation 5. When the generated value is less than the threshold value the node becomes the CH for current round. The threshold value T(n) is calculated as equation 2.

$$T(n) = \begin{cases} \frac{P_i}{1-P_i \times \left(r \bmod \frac{1}{P_i}\right)} & \text{if } S_i \in G \\ 0 \text{ otherwise} \end{cases} \quad (2)$$

$P_i = P_{opt}\,(1+a)\,E_i\,(r) / (1+a\times m)\,E\,(r)$ if normal node (3)

$P_i = P_{opt}\,E_i\,(r) / (1+a\times m)\,E\,(r)$ if advanced node (4)

Where; P_i - probability for cluster head selection
P_{opt} - optimum number of cluster heads
'm' and 'a' are variables of advanced and normal nodes

$E_i\,(r) = (1/N) \times E_{total}\,(1- R)$ (5)

$E_{total} = N\times(1-m)\times E_o + N\times m\times E_o\times(1+a)$ (6)

$R = E_{total} / E_{round}$ (7)

$E_{round} = L\times(2N\,E_{elec} + N\times EDA + k\,E_{mp}\,d\,toB\,S + N\,E_{fs}\,dtoCH)$ (8)

Where;
R - total rounds of the network lifetime
E_{round} - total energy dissipated in the network
E_{elec} - energy dissipated to run the electronics circuits
E_{fs} - free space loss
E_{mp} - multipath loss
E_{total} - total initial energy
EDA - compression energy
d_{toCH} - average distance between the cluster member and the cluster head
d_{toBS} - average distance between the cluster head and the base station
N - numbers of sensor node
L - message size
k - numbers of clusters

Moreover, in DEEC the residual energy can be calculated as equation 9.

$$E_{Tx}(l,d) = \begin{cases} l \times E_{elec} + l \times E_{fs} \times d^2 \text{ if } d \le d_o \\ l \times E_{elec} + l \times E_{mp} \times d^4 \text{ if } d > d_o \end{cases} \quad (9)$$

Where;
$E_{Tx}\,(l,d)$ - residual energy of sensor nodes over distance 'd' with message 'l'
d - distance between the two communicating ends
d_o - initial distance

In the precision agriculture, wireless sensor network routing techniques are used for the purpose of crop monitoring. The research area is 100m x 100m and 100 sensor nodes are randomly deployed in the field. LEACH and DEEC protocols are comparatively analysed for routing protocol of the network. Number of alive nodes, dead nodes and amount of data received will be discussed in next section with research parameters.

IV. Simulation Results AND Discussions

In this section, LEACH and DEEC protocols are comparatively studied in the 100 square meters field with 100 sensor nodes. As crop monitoring is one of the important issues in precision agriculture, the situations of crop have to get precisely. And in order to prolong the network lifetime, the sensor nodes have to active for a long time. So in this research, alive nodes, dead nodes and amount of data received of two energy efficient routing protocols are simulated with MATLAB software.

Firstly, LEACH protocol is with the network lifetime and amount of data received over 5000 rounds. This experiment was simulated with 100 sensor nodes in the 100 square meters area. The simulation parameters are described in table 1.

Table1. Parameters and Values of Simulation Environment for LEACH protocol

Parameters	Values
Simulator	MATLAB
Routing Protocol	LEACH
Numbers of Sensor Nodes	100
Network Size	100m x 100m
Initial Energy	0.5J
Packet Size	4000 bits

The result of network lifetime (dead nodes) and amount of data received for the 100m x 100m network over 5000 rounds for LEACH protocol is illustrated in fig 4.

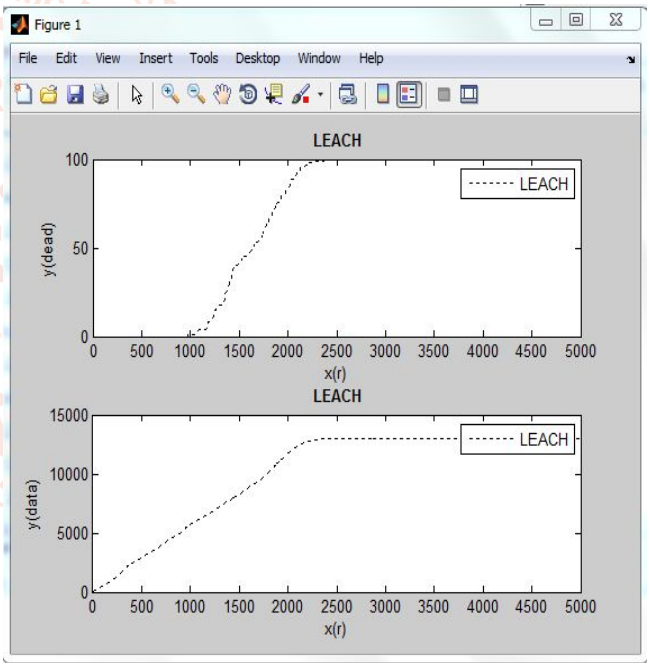

Figure4. LEACH Protocol Network Lifetime and Amount of Data Received

In LEACH protocol, sensor nodes starts to dead when the numbers sensing round of 1000 rounds. Dead nodes are gradually more and more and all the 100 sensor nodes dead at 2200 sensing rounds of the network. This means that the network lifetime of LEACH protocol is only 2200 sensing rounds of the network. When the first node dead of 1000 rounds, the amount of data received at the base station is about 5000 kbps. Data received increase when the numbers of sensing rounds increase. The maximum kbps received is about 14000 kbps when the sensing round is 2200 rounds. And then DEEC protocol simulation over 5000 rounds was simulated with 100 sensor nodes in the 100 square meters area. The simulation parameters are described in table 2 with detail expressions.

Table2. Parameters and Values of Simulation Environment for DEEC protocol

Parameters	Values
Simulator	MATLAB
Routing Protocol	DEEC
Numbers of Sensor Nodes	100
Network Size	100m x 100m
E_{elec}	50nJ/bits
Initial Energy	0.5J
E_{fs}	10pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
Packet Size	4000 bits
Numbers of Round	5000

The investigation of this experiment is simulation of dead nodes, alive nodes, amount of data received and counts of cluster head over 5000 rounds for the DEEC protocol in the selected network. The result of dead nodes, alive nodes, amount of data received and count of cluster heads for the 100m x 100m network over 5000 rounds is illustrated in fig. 5, 6,7 and 8.

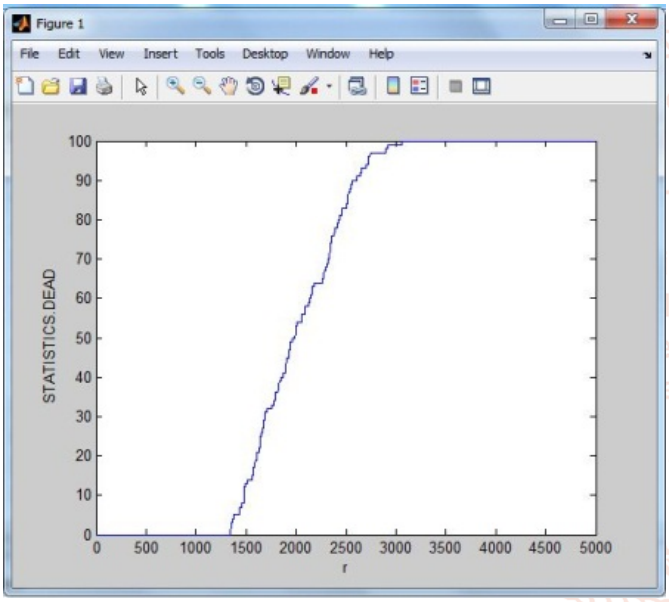

Figure5. Numbers of Dead Node over 5000 Rounds with 100 Sensor Nodes

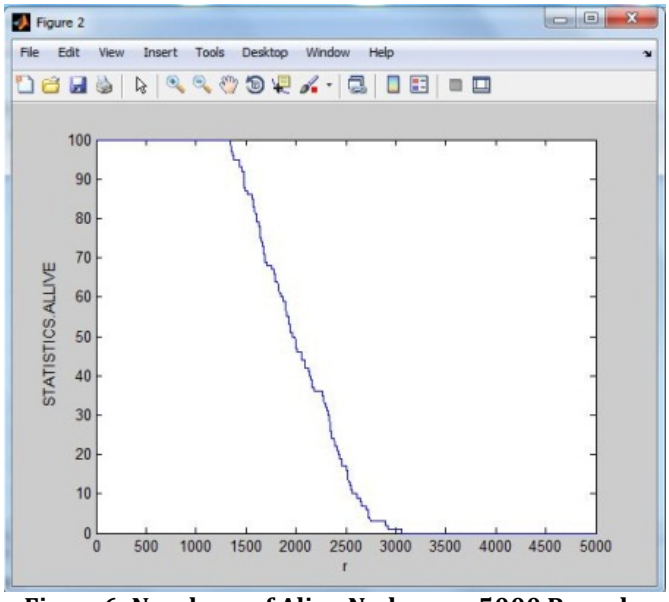

Figure6. Numbers of Alive Node over 5000 Rounds with 100 Sensor Nodes

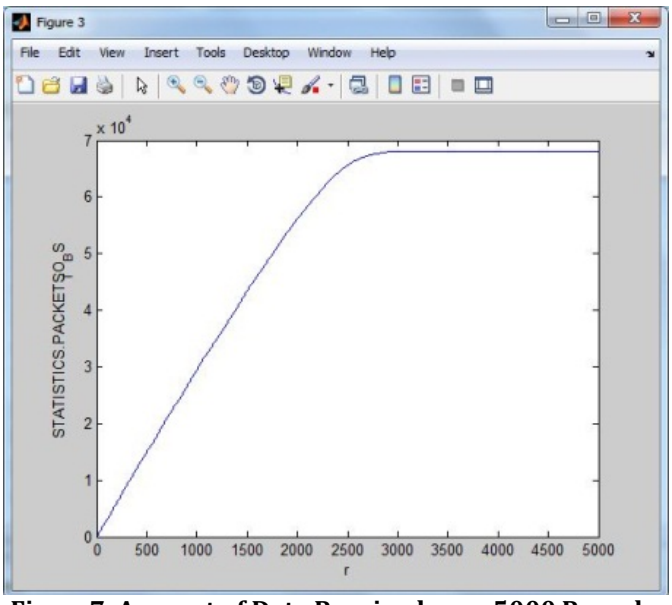

Figure7. Amount of Data Received over 5000 Rounds with 100 Sensor Nodes

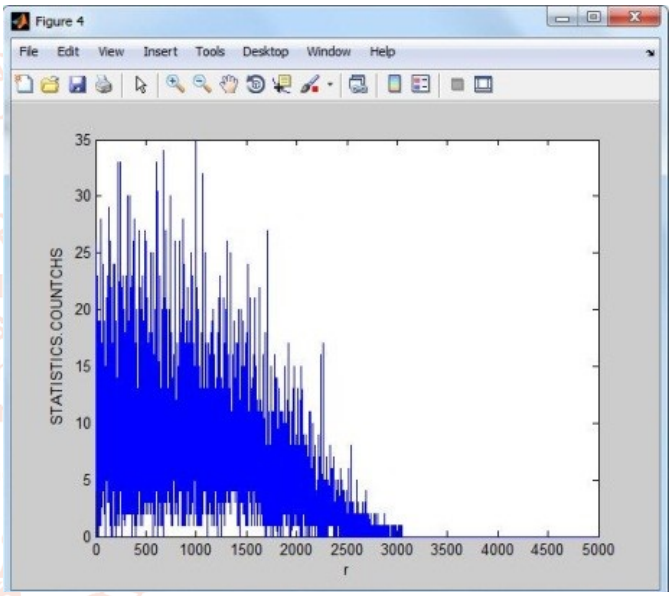

Figure 8. Counts of Cluster Heads over 5000 Rounds with 100 Sensor Nodes

From the results of DEEC protocol simulation, first node dead at the sensing round of 1300 rounds. All the sensor nodes become dead at sensing round of 3000 rounds. This means that the network lifetime for DEEC protocol is 3000 sensing rounds of the network. Amount of data received at the base station is 10000 kbps when the sensing round reaches 500 rounds. Amount of data received is increased gradually and peak at about 70000 kbps when the sensing rounds of 3000 rounds. Count of cluster heads varies when the numbers of sensing round increase because the DEEC protocol considers both residual energy of sensor nodes and average energy of the network in cluster head selection. Counts of cluster head over 5000 rounds reach peak at 1200 rounds with the numbers of cluster head of 35. Cluster head of DEEC protocol does not exit also at sensing rounds of 3000 rounds.

And finally the performance comparison of LEACH protocol and DEEC protocol was simulated with 100 sensor nodes in the 100 square meters area. The simulation parameters are described in table 3 with detail expressions.

Table3. Parameters and Values of Simulation Environment for comparison of LEACH protocol and DEEC protocol

Parameters	Values
Simulator	MATLAB
Routing Protocols	LEACH,DEEC
Numbers of Sensor Nodes	100
Network Size	100m x 100m
E_{elec}	50nJ/bits
Initial Energy	0.5J
E_{fs}	10pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
Packet size	4000 bits
Numbers of round	5000

The investigation of this experiment was simulation of dead nodes and amount of data received over 5000 rounds in the selected network. The result of dead nodes and amount of data received for the 100m x 100m network over 5000 rounds is illustrated in fig 9.

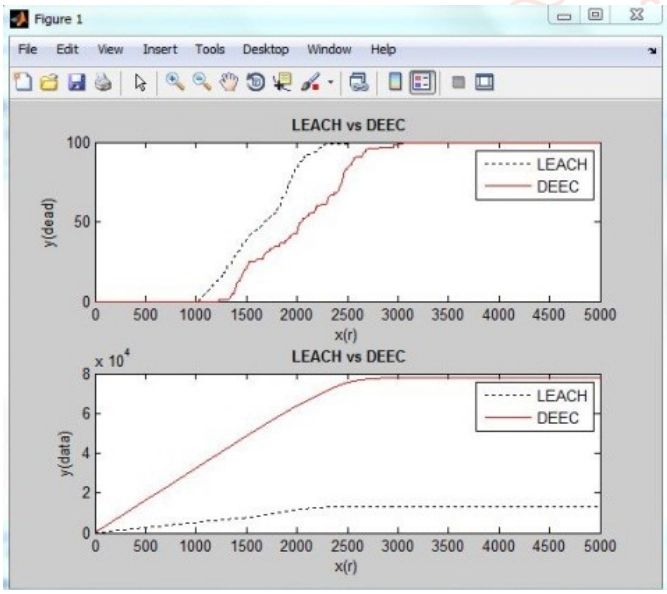

Figure9. Performance Comparison of LEACH Protocol and DEEC Protocol

The results show that sensor nodes of LEACH protocol starts to dead at 1000 sensing rounds and DEEC protocol start to dead at 1300 sensing rounds. This means that the network lifetime of DEEC protocol is better than LEACH protocol because network lifetime depends on dead nodes of the network. All the sensor nodes are dead at 2200 sensing round in LEACH protocol and at 3000 sensing round in DEEC protocol. So DEEC protocol prolong network lifetime than LEACH protocol.

In LEACH protocol, amount of data received is about 1400 kbps when the all nodes are dead. But in DEEC protocol, amount of data received is about 70000 kbps when all nodes are dead. So amount of data received by DEEC protocol is about four times more than LEACH protocol.

V. Conclusion

Precision agriculture is the use of technology to enhance the crop production. The Technological development in wireless sensor network made it possible to use in monitoring of crops situation in precision agriculture. As routing is the new challenge of wireless sensor network technology, the simulation results of this research have shown that there is an energy efficient and scalable property of routing protocol for crop monitoring of precision agriculture. Low Energy Adaptive Clustering Hierarchy (LEACH) and Distributed Energy Efficient Clustering (DEEC) protocols are the energy efficient and scalable routing protocols of wireless sensor network. Under the proposed network of 100 m x 100 m DEEC protocol and LEACH protocol were tested with network lifetime and amount of data received at the base station. From the simulation results, DEEC protocol is more energy efficient than LEACH protocol because of their network lifetime and also DEEC protocol is more scalable than LEACH protocol because of amount of data received is four times more than that of LEACH protocol.

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