

An Efficient Deployment of Sensor Nodes in Wireless Sensor Networks for Agricultural Field

S. R. BARKUNAN AND V. BHANUMATHI

*Department of Electronics and Communication Engineering
Anna University Regional Campus Coimbatore
Tamilnadu, 641046 India
E-mail: barkunan@gmail.com*

Nowadays, Wireless Sensor Networks (WSNs) play a vital role in agricultural field for improving growth rate and to reduce the resource utilization like water, manpower, *etc.* WSNs are used to monitor the environmental conditions of the agricultural field to achieve the automatic irrigation for the different plants in large areas of agricultural land. WSNs include a number of inexpensive energy constrained in sensor nodes, which collects the environmental data from large scale agricultural land and transmit the data to the base station. The network lifetime and Quality of Service (QoS) should be improved in agricultural WSN for better performance. For achieving this, the node power consumption should be reduced. By introducing clustering technique for the nodes in the agricultural field, it is observed from the simulations, that the energy consumption is reduced to a considerable amount thereby increasing network lifetime. The cluster formation is done based on neighbor node and residual energy, which overcomes the drawbacks such as network early dead, excess energy consumption, poor efficiency in packet delivery, link stability problem, *etc.*, The simulation results shows that the proposed algorithm gives better performance in terms of Packet Delivery Ratio (PDR), throughput, energy consumption and network lifetime. Hence, it is understood that it is more suitable for large scale WSN installed in agricultural lands.

Keywords: EDWSN, WSN, LEACH, HEED, agriculture monitoring

1. INTRODUCTION

India is a highly populated country and having agriculture as a main sector for overall growth of the people. The scarcity of water for agricultural activities is one of the major problems in the country. For efficient water management, the irrigation should be automated by monitoring the environmental parameters of the agricultural field. The agricultural land has some important physical parameters like water level, sun light, temperature, air humidity and soil moisture. The parameters are needed to be continuously monitored for efficient utilization of resources but it is a tedious process in large scale agricultural lands. Hence, sensor nodes are placed in various places on field to collect the real time data and send to the agriculturalist through remote server. These real time data are used to control the water irrigation for the agricultural land. Fig. 1 shows the wireless agricultural sensor networks for monitoring the parameters and data transmission. WSNs are used in various applications such as environmental monitoring, industrial monitoring, diagnostics, infrastructure protection, battlefield awareness and context-aware computing [1]. WSNs have number of sensors called as nodes or motes and these nodes are used to sense the physical parameters of agricultural land for a long time. Energy efficient utili-

Received August 29, 2017; revised October 16, 2017; accepted December 15, 2017.
Communicated by Changqiao Xu.

zation is a key premise in order to increase the lifetime of WSNs. Another important quality required for WSNs is that to have a rapid query response for sensing and sending data from remote locations to base station [2, 3]. The low cost wireless monitoring network helps to control the irrigation in agricultural lands [38].

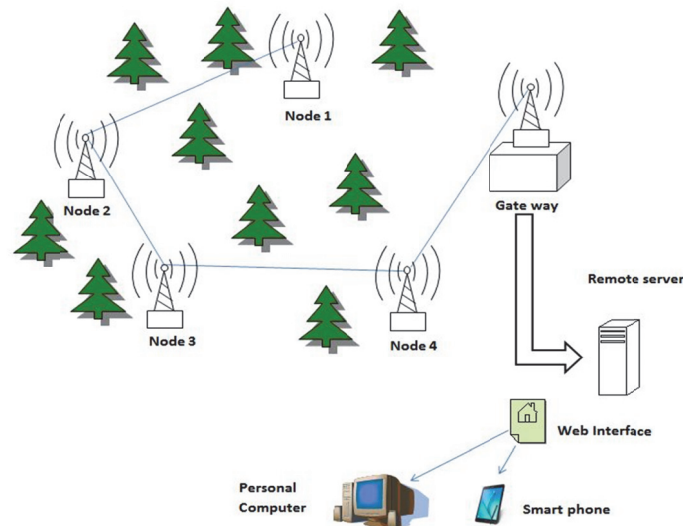


Fig. 1. Wireless agricultural sensor networks.

Real time environments offer numerous challenges to WSNs such as channel fading, interference, radio abnormality and multipath propagation. These challenges tend to complicate the design procedure further. Energy competence, reliability, QoS and security are some of the important parameters that determine the effectiveness of the WSNs. The WSNs are most involved in crop monitoring with video surveillance where the sensor transmits sensed data such as soil salinity, PH, temperature and moisture level to farmers' cooperative through the crop gateway by using 802.15.4 and internet [33]. The scalability problems in this type of networks are solved by clustering technique, which increases the overall network lifetime thereby reducing the energy consumption. However, it is very crucial to resolve the number of mandatory cluster heads and satisfy the cost of desired level of coverage to the entire WSNs. Clustering is the significant task of grouping the sensor node with neighbor sensor nodes. Each cluster has one cluster head, which controls all the functions of cluster members within a cluster and forward the packets to the BS [4]. Residual energy in the node plays an important role in electing the cluster head [5]. Network clustering and sensor scheduling increases the network lifetime and also it minimizes the node energy consumption [6].

The precision irrigation using the autonomous Wireless Sensor Agricultural Networks (WSAN) based system has the soil specific sensors for collecting real time information about soil and environments [29]. These collected data send to remote station via IEEE 802.15.2. The sensor node energy optimization is mostly required to extend the lifetime of agricultural WSN. The wireless integrated frequency domain soil sensor is

used to monitor the paddy field. This soil sensor measures soil moisture content and water depth and able to send the collected data to a remote station through IEEE802.15.4. The sensor node continuously provides reliable information about paddy field with minimum battery power [30]. The various real time parameters are monitored using RFID and Quick Response codes in [41] are implemented through WSN for irrigation management in agricultural land. From the literatures, as far as we have analyzed, no one have concentrated on implementing the clustering for an agricultural field in order to improve the performance. Hence an efficient deployment of nodes based on clustering is detailed in this paper. This paper is organized as follows: Section 2 presents the related works of WSN in agricultural monitoring and the clustering methods used to improve the network lifetime and QoS. Section 3 explains the proposed clustering protocol for agricultural monitoring WSN. Section 4 describes the experimental details and simulation results. Finally, we conclude the paper in Section 5.

2. RELATED WORK

The wireless sensor networks are designed to improve the growth rate by monitoring and controlling the environmental data such as temperature and humidity in green house management system. It also monitors the crop diseases and crop productivity through measuring the leaf temperature and humidity [31]. The communication module Zigbee is used in WSN which covers small agricultural area monitoring. The environmental data like illumination, temperature, humidity are continuously monitored for improving quality of crop productivity [32]. In [34] the author introduced WSNs with four types of sensor motes which include soil moisture motes, environmental motes, water level motes and gateway motes, where each sensor node is connected to one another through 802.15.4. The soil moisture motes are used for measuring the temperature, salinity and soil moisture content, the environmental motes for relative humidity and temperature, the water level motes for electrical conductivity and water temperature. The gateway motes are used to transmit the collected data to a central computer. The sensor node periodically transmits the sensed data to BS and stored in its database. The Graphical User Interface will read the data from a database which visualize them graphically and also shows the node's location with the help of Google map. A web application based automated irrigation system is detailed in [35] uses WSN to monitor and control the agricultural irrigation by sensing the soil moisture and temperature in remote land. A remote terminal unit collects the soil moisture data, field temperature and humidity from different fields which are sensed by TDR-3A sensor and then sent through the gateway. The SCADA server system analyzed and compared the real time field data with reference values and issue the corresponding control signal to the NPN transistor based controlling relay to close or open the solenoid valve [36]. In [37] the author proposed a wireless sensor network based pesticide drift controlling to reduce the environmental contamination and monitor after and before the spraying. The sensor networks provide necessary information to crop spraying support and control system to measure the environmental conditions like humidity, temperature and wind speed. This information can be used to evaluate the moving path of the spraying vehicle, analyze the crop spraying quality through measuring the deposition of pesticide over the crop leaf. In agricultural monitor-

ing and controlling systems, the WSN plays an important role. For energy efficient node deployment in agricultural WSN, the clustering approaches are used as a technique for electing cluster heads with high residual energy and periodically rotate the cluster heads for maintaining the balanced energy consumption throughout the entire network thereby prolonging the network lifetime. In [39] the authors describe various routing protocols and selection of a particular protocol for wireless sensor network application. In [7] the authors proposed a distributed clustering protocol LEACH (Low Energy Adaptive Clustering Hierarchy). It is a self-organizing cluster formation protocol, which uses distributed algorithm to form a cluster that means the cluster head and non-cluster head (cluster members) are in one hop transmission range. In LEACH protocol, the threshold value has been calculated as

$$U(n) = \frac{1}{m - [r \bmod m]}. \quad (1)$$

Where, r is the index of the current round, m is the expected number of sensor nodes in each cluster $m = \frac{N_n}{CH}$, N_n denotes total number of sensor nodes, CH is the total expected number of cluster heads. HEED (Hybrid Energy-Efficient Distributed clustering) [8], LEACH and LEACH-C, protocols are not suitable for sensor nodes deployed in a large network region and leads to more control overhead, redundant message, acknowledgement packets and more retransmission. In [9] the authors developed a load balanced clustering algorithm on the basis of their distance from the base station and density of sensor node distribution for wireless sensor network. The authors [10] proposed the energy aware clustering algorithm EADC and cluster based routing to provide a load balancing among the cluster head. In CBR, the cluster head not only receives data from its cluster member nodes by direct hopping, but also collects data from other sensor nodes when it is from other clusters [11].

In cluster based routing protocol, the cluster head consumes more energy than other nodes, so the cluster head drain their battery energy very quickly, which leads to link break that diminish the network lifetime and network efficiency [12]. In [13] the authors proposed a Link-Aware Clustering Mechanism (LCM) for Energy-Efficient Routing in Wireless Sensor Networks. The authors [14] proposed Cluster head Gateway Switch Routing (CGSR) protocol. Least Cluster Change (LCC) algorithm is used to form a cluster and distributed algorithm elects the cluster head in WSNs. These protocols use gateway nodes in the routing path. The cluster gateway locates the common node of the communication range of two or more cluster heads and it reduces the workload of cluster head by avoiding a direct hopping between the cluster head and provides high link stability, reliable path between the cluster head. In [40] the authors proposed Scalable Energy Efficient Clustering Hierarchy (SEECH) protocol for saving node power in distributed wireless sensor networks during the real time monitoring and data collection in smart space and large scale environments. In [15] authors proposed a positioning system based on landmark graph and two tier wireless Received Signal Strength Information (RSSI) for finding the current position of the sensor node. The authors [16] proposed a method using local information and neighbors aggregated up through the spatial boundary formation, which create the global topological information about the sensor spreading re-

gion. The authors [17] discussed about the routing through asymmetric links to reach the destination with assured packet delivery rate with minimum control overhead for wireless heterogeneous sensor networks.

Many protocols are constructed to minimize battery energy consumption by reducing the active time of the sensor nodes. In order to reduce the collision and redundant packet transmission, overhearing of request and acknowledge messages are avoided [18]. The energy required for transmitting and receiving an ' l ' bit message is determined by using Radio Energy Dissipation model that is also called as radio model [7, 19-22]. The total energy consumed by each node is calculated as the sum of transmitted and received energy for all data and control packets. The transmitting and receiving cost of ' l ' bit messages through a distance ' d ' between the transmitter and receiver can be calculated as

$$E_t = \frac{(P_t \times l + e_{amp} \times l \times d^\alpha)}{2 \times 10^6} \text{ (joules),} \quad (2)$$

$$E_r = \frac{P_r \times l}{2 \times 10^6} \text{ (joules).} \quad (3)$$

Now, E_t and E_r are the transmitting and receiving energy cost, P_t and P_r are the transmitting and the receiving powers, α is an exponential fading factor, e_{amp} is an amplifying energy. Now, $\alpha = 2$ for free space fading, $\alpha = 4$ for multipath fading [23, 24]. For each round the residual energy of the sensor node is estimated as

$$E_R = E_T - E_t - E_r. \quad (4)$$

E_R is the residual energy of each sensor node, E_T is the total energy of the sensor node.

3. PROTOCOL DESIGN

The proposed Efficient Deployment of Wireless Sensor Network (EDWSN) algorithm takes care about first round too. In the initial stage (first round), after sensor node deployment, any one of the sensor nodes cannot declare itself as a cluster head. This is because, all sensor nodes have identical energy level and are uniformly distributed in a remote location. Most of the clustering protocols like LEACH, MBC does not work properly under the initial stage. The cluster formation using distributed algorithm in WSNs does not guarantee the cluster head placement and number of cluster heads in a large agricultural land monitoring environment. A distributed algorithm has knowledge only about the neighbor nodes [7, 25, 26]. While forming a cluster by using distributed algorithm, those sensor nodes having one hop distance may join with corresponding cluster head. Nevertheless, some of the sensor nodes even in one hop distance cannot join to any one of cluster head, because the hop distance may be high. These nodes are living alone and are called as spontaneous nodes. All spontaneous nodes try to communicate with nearest cluster head, in order to participate as a cluster member in any cluster. During connection failure, they may lose the residual energy due to excess control packet overhead, delay in packet transmission and unwanted resource usage.

3.1 EDWSN Algorithm

In EDWSN, after the sensor node's deployment, each sensor node has the same residual energy. In this condition, *CH* election based on the residual energy is very difficult. Hence we consider the number of neighbor nodes for identifying the *CH*. Therefore, the intended algorithm provides the best method to elect the *CH* throughout the entire network lifetime. Fig. 2 shows the flowchart of EDWSN algorithm for node deployment of WSN for agricultural environmental monitoring.

Assumptions:

1. All sensor nodes must have homogeneous characteristics (*i.e.* All the nodes having a same physical property).
2. Each sensor node must know its own location and residual energy.
3. All sensor nodes may possibly have a unique packet size; and time slots are time synchronized as they start the setup phase at the same time.
4. Base Station (BS) is fixed and situated outside the supervised area.

These assumptions have been achieved by using location and synchronization methods [7, 19, 27, 28]. In setup phase, the cluster head is elected and cluster is formed. It is followed by the steady state phase. Each cycle has set of rounds that should be used to elect the cluster head and maintain them so as to avoid election of a cluster head of the previous round in the same cycle. If the same node repeatedly elected as a cluster head, then it loses its energy very quickly. To avoid this situation, the previous round cluster head is not elected as a current cycle cluster head. At the end of each cycle, the entire sensor nodes may once again be eligible to be elected as a cluster head which maintains the energy balancing throughout the network. The protocol operation can be divided into rounds. Each round has two phases, *i.e.* Setup phase and Steady state phase, which is similar to LEACH [7] and MBC [19].

(A) Setup Phase

(i) Cluster Head Election

In the proposed model, the threshold value $T(n)$ has been calculated by multiplying the factors such as the total number of neighbor nodes and the residual energy of the sensor node. Where F_{CH} is the flag (set $F_{CH} = 1$ for previous round *CH* and $F_{CH} = 0$ for sensor node having a chance to act as current or next round *CH* based on $T(n)$), $N_{j-current}$ is total number of current neighbor nodes, $E_{n-current}$ is the current sensor node energy, E_{max} is the initial energy. The expected number of sensor nodes in each cluster is $m = \frac{N_n}{CH}$. If the sensor node lost its energy more quickly the coverage distance may get reduced, thus giving rise to the connectivity problem causing low packet retransmission and network lifetime. After node deployment, initially the node shares the awareness message to neighbor nodes. Each and every node calculates its threshold value and broadcast to the neighbor node and updates the threshold value in the table. The node compares its threshold value with the table. If the threshold value of the node is the maximum value in threshold table, then it act as a cluster head and broadcast the message to the neighbor nodes. Otherwise it reset F_{CH} and goes to next cycle.

The threshold is found as follows,

$$T(n) = \left[F_{CH} + \left[\frac{N_{j-current}}{m} \times \frac{E_{n-current}}{E_{max}} \right] \right]. \quad (5)$$

Pseudo code for EDWSN algorithm

$T(n)$: Threshold value
 CH : Cluster Head
 CM : Cluster Member

Initialization:

- 1: Node discovery message (residual energy, node ID)
- 2: Calculate $T(n)$
- 3: **If** ($0 < T(n) \leq 1$)
- 4: Go to Cluster Head election phase
- 5: **Else**
- 6: It can act as a CH in next cycle

Cluster Head election phase:

- 7: Broadcast $T(n)$ to neighbor nodes
 - 8: Update $T(n)$ value in table
 - 9: **For** ($0 < T(n) \leq 1$)
 - 10: Compare $T(n)$ value with table
 - 11: **If** $T(n)$ is maximum value
 - 12: Broadcast CH awareness message
 - 13: **Else**
 - 14: Act as CM
 - 15: Wait until CH awareness message is received
-

(ii) Cluster Formation

After the cluster head election, the cluster head announces CH awareness message to its neighbor nodes. After receiving cluster head announcement, the nearest sensor nodes send the joint request message to the chosen cluster head. Then the cluster head creates the TDMA schedule and sends it to the corresponding cluster members. The cluster members use a Carrier Sense Multiple Access Collision Avoidance (CSMA/CA) Medium Access Control (MAC) protocol. Cluster using a Direct Sequence Spread Spectrum (DSSS) technique establishes the communication with the cluster member node, thus reducing the interference with adjacent cluster.

(iii) Connection Time Estimation

Now, we consider all the sensor nodes in a cluster receives an advertisement message from corresponding cluster head at time instance t_0 and send back the information to the cluster head at time t_1 .

For 2-D, we consider (x, y) coordinates.

$$R_i \geq ((X_j - X_i)^2 + (Y_j - Y_i))^{\frac{1}{2}} \quad (6)$$

Where, R_i is distance between the sensor nodes.

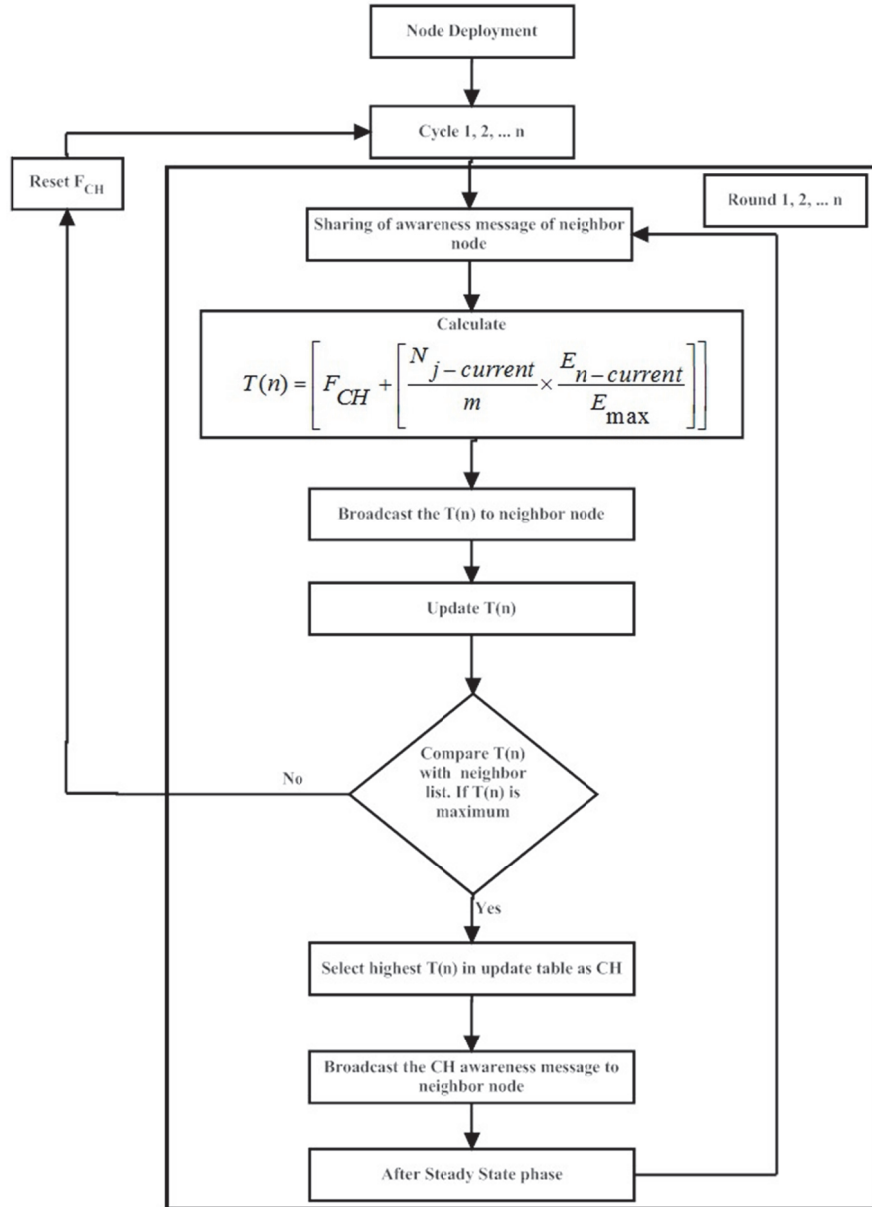


Fig. 2. Flowchart of EDWSN algorithm.

The Round Trip Time (RTT) is used for allocating the TDMA time slot to the cluster member node. The processing delay and propagation delay majorly influence the round RTT. The propagation delay is the ratio of distance between the nodes to speed of the data packet. The RTT can be computed by using Eq. (7)

$$RTT = t_1 - t_0. \quad (7)$$

Where t_0 is the sending time and t_1 is the receiving time. This TDMA allocation provides the enhanced data collection from member node with reduced interference and collision.

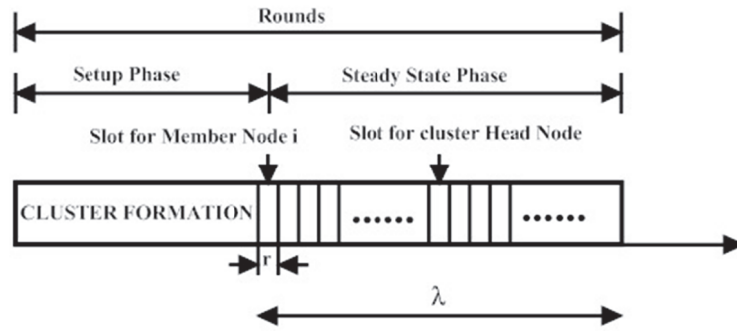


Fig. 3. Time slot.

(iv) Time Scheduling

Fig. 3 shows the time slot diagram of cluster formation in agriculture WSN. Each cluster head itself allocates a time slot to the cluster member based on control packet information. The member node sends the data to the cluster head through a direct hopping during the allocated time slot in ascending order based on connection time between cluster head and member nodes (calculated by using RSSI). The cluster head access the allocated time slot based on the hop counts between cluster head to base station in ascending order to avoid the collision and packet retransmission. We can analytically determine the value of the total number of cluster head (C) by using the computation and communication energy. So, the number of cluster member in each cluster is $M = (\frac{N_n}{CH} - 1)$. We assume that M number of member nodes send the data packets consecutively during the steady state phase. λ is the constant total time duration for steady state phase and this will be divided into the ratio of $(Mnr : MnrC)$ where the total time duration of sending a data packets for cluster member to cluster head and cluster head to base station is (Mnr) and $(MnrC)$. Node i begin its transmission at (nrM_i) . Here, M_i denotes the sequence number of member node ' i ' in the transmission schedule. The cluster head node j begins its transmission at $(\frac{N_n}{CH} - 1)nr + C_j(\frac{N_n}{CH} - 1)nr$. Where, C_j denotes the sequence number of cluster head node ' j ' in the transmission schedule.

(v) Tree Formation

The minimum spanning tree algorithm is used to construct the tree topology between the cluster heads. This tree construction process is initiated by the base station.

(vi) Computational Complexity

Let the total number of sensor nodes as N_T , the total number of cluster heads as N_{CH} and total number of Cluster members as $N_{CM}(N_T - N_{CH})$. Every sensor node in the network starts exchange their information to discover the neighbor node. $C_{ND} = N_T \times CP_{ND}$, where CP_{ND} (Neighbor Node Discovery) contains Node ID, Residual energy level. All the nodes broadcast their threshold value through C_{TH} . It is obtained by $C_{TH} = N_T \times CP_{TH}$, where CP_{TH} is the control packet that contains node ID and threshold value of the particular node. The cluster head awareness message is $C_{CHA} = N_{CH} \times CP_{CHA}$ where CP_{CHA} (Cluster Head Awareness) contains Node ID and cluster head information. Based on RSSI, each node sends join request to cluster head. It is obtained from $C_{CMI} = N_{CM} \times CP_{NJR}$ where CP_{NJR} (Node Join Request) contains Node ID and cluster head ID. The cluster head sends TDMA schedule to cluster member, it is calculated by using $C_{TDMA} = N_{CH} \times CP_{TDMA}$ where CP_{TDMA} (TDMA schedule) contains cluster head ID and time scheduling information. Total number of control packets exchanged during the setup phase of each round is

$$\begin{aligned}
 C_{PT} &= C_{ND} + C_{TH} + C_{CHA} + C_{CMI} + C_{TDMA} \\
 &= N_T + N_T + N_{CH} + N_{CM} + N_{CH} \\
 &= 2N_T + 2N_{CH} + N_{CM} \\
 &= 2(N_T + N_{CH}) + N_{CM} \\
 &\cong O(n).
 \end{aligned} \tag{8}$$

(B) Steady State Phase

The steady state phase has two stages of packet transmission. First, cluster members send the data packets to corresponding cluster heads by means of one hop transmission in a particular time slot using TDMA time scheduling. Next, the cluster head transfers the received packets to base station through intermediate cluster heads using minimum spanning tree technique. Fig. 4 shows Inter cluster communication for data transmission from source CH to BS.

The proposed protocol considers the distance and energy to find the shortest path to reach the destination. This algorithm is used in between the source cluster head to base station through an intermediate cluster head. A cluster head sends the data to the nearest cluster head towards the base station. In order to avoid the interference and collision the CSMA/CA technique is used for data communication.

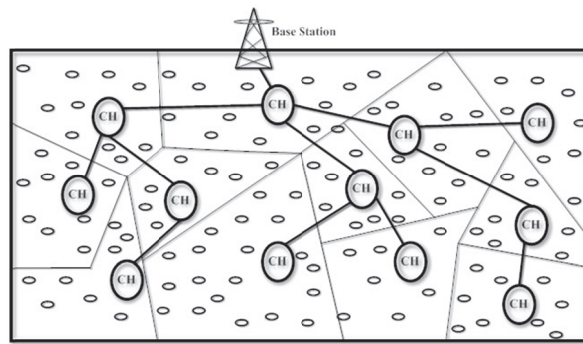


Fig. 4. Inter cluster communication.

4. SIMULATION RESULTS

In this section, the proposed EDWSN algorithm and existing algorithms such as SEECH, MBC, HEED and LEACH were simulated using NS-2 simulator and its performance were compared. For the experimental purpose, a range of 20-100 sensor nodes are randomly deployed in the area of $100 \times 100 \text{ m}^2$ using random topology. The initial energy of individual sensor nodes is 10 joules with homogeneous property and uniformly distributed in network area $100 \times 100 \text{ m}^2$. The parameters and values used for simulation are given in Table 1. Based on the parameters, the network performance such as PDR, delay, total energy, speed, throughput and number of cycles of proposed algorithm is obtained and compared with the existing algorithms.

Table 1. Simulation parameters and values.

Parameter	Value
Network field	$100 \times 100 \text{ m}^2$
Number of nodes	20-100
Transmission distance	30m
Size of Control packet	25 bytes
Size of Data packet	512 bytes
No. of Cluster head per rounds	5
Base station	(50,100)
Antenna type	Omni-directional
$E_{threshold}$	0.01 J
E_{elec}	50 nJ/bit/m ²
E_{DA}	5 nJ/bits/signal
E_{amp}	0.0013 pJ/bit/m ⁴

Fig. 5 shows the performance of a PDR with different number of sensor nodes for proposed EDWSN algorithm and existing algorithms. From the figure, the PDR decreases as the sensor node increase because the growth of the network causes every node to take additional time (*i.e.* causes more delay in the network) to form a cluster. Hence the sensed data waits in sensor node buffer till it gets the time slot to transmit the data to base station. Here, the proposed EDWSN algorithm provides more stable link in the network that avoids the spontaneous node problem, link failure, congestion and delay.

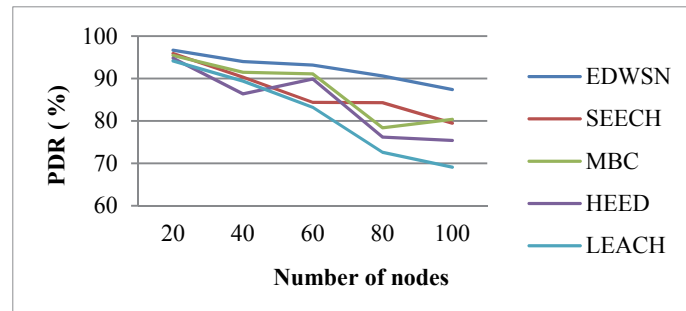


Fig. 5. PDR vs. number of nodes.

Fig. 6 shows the delay analysis for varying sensor nodes in the network. It is seen that the proposed algorithm consumes less delay compared to the existing algorithms. This is because of the selection of shortest path for data transmission.

Fig. 7 shows the throughput analysis. It is observed that the proposed minimizes the interferences and collisions in the data path. EDWSN is found to be better compared to the existing works.

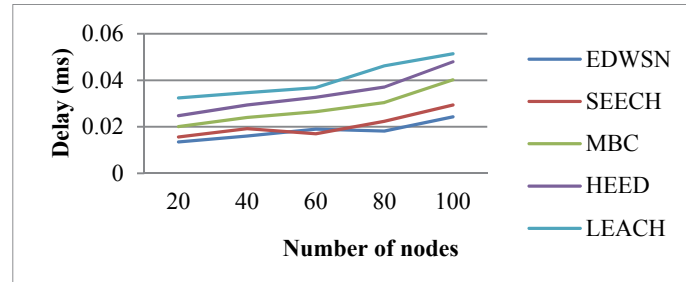


Fig. 6. Delay vs. number of nodes.

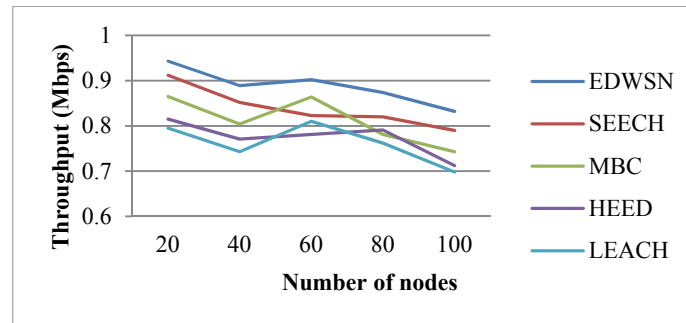


Fig. 7. Throughput vs. number of nodes.

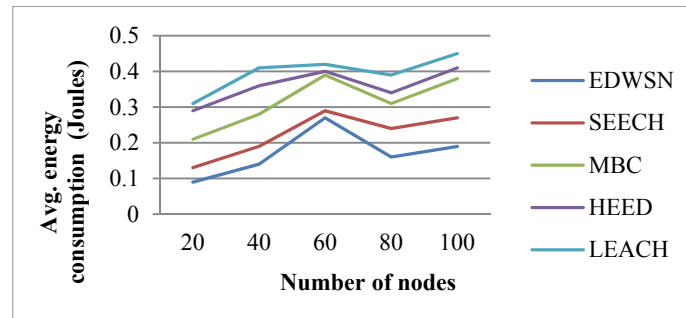


Fig. 8. Average energy consumption vs. number of nodes.

Fig. 8 shows that EDWSN algorithm grants best cluster formation and pivots upon the cluster head in each round that preserves the average energy level throughout the network. And also provides a superior way in stable links than other clustering algo-

rithms. It is observed that the clustering method based on neighbor node and residual energy provides an increase in PDR of 6%, 10%, 21% and 25% when compared with SEECH, MBC, HEED and LEACH respectively. The average power consumption in the proposed is reduced to 24%, 26%, 20% and 31% in comparison with the existing. The above results show that the proposed method gives better performance compared to existing algorithms.

5. CONCLUSION

From the literature review, it is understood that most of the systems deal with WSN to make automatic agricultural monitoring, but the network life time and QoS parameters are not considered. The energy efficiency is attained by making clustering among the nodes in agricultural WSN. Simulation result demonstrates that the proposed EDWSN algorithm offers a best cluster head election and cluster formation, that makes the overall performance better than other cluster formation techniques like HEED, LEACH, protocol and it also provides satisfactory result in terms of PDR, network lifetime, energy consumption, balanced control overhead which are important for mission critical application. In WSN, EDWSN algorithm can be used efficiently in large agriculture land for environmental monitoring. In future, the proposed algorithm will be implemented in real time to monitor agriculture environment through WSN.

REFERENCES

1. F. Zhao and L. Guibas, *Wireless Sensor Networks*, Elsevier, India, 2004.
2. B. Li, W. Wang, Q. Yin, R. Yang, Y. Li, and C. Wang, "A new cooperative transmission metric in wireless sensor networks to minimize energy consumption per unit transmit distance," *IEEE Communications Letters*, Vol. 16, 2012, pp. 626-629.
3. S. D. Muruganathan, A. B. Sesay, and W. A. Krzymien, "Analytical query response time evaluation for a two-level clustering hierarchy based wireless sensor network routing protocol," *IEEE Communications Letters*, Vol. 14, 2010, pp. 486-488.
4. P. Guo, T. Jiang, K. Zhang, and H. H. Chen, "Clustering algorithm in initialization of multi-hop wireless sensor networks," *IEEE Transactions on Wireless Communications*, Vol. 8, 2009, pp. 5713-5717.
5. A. Wang, D. Yang, and D. Sun, "A clustering algorithm based on energy information and cluster heads expectation for wireless sensor networks," *Computer and Electrical Engineering*, Vol. 38, 2012, pp. 662-671.
6. B. Wang, H. B. Lim, and D. Ma, "A coverage-aware clustering protocol for wireless sensor networks," *Computer Networks*, Vol. 56, 2012, pp. 1599-1611.
7. W. R. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application specific protocol architecture for wireless microsensor networks," *IEEE Transactions on Wireless Communication*, Vol. 1, 2002, pp. 660-670.
8. O. Younis and S. Fahmy, "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," *IEEE Transactions on Mobile Computing*, Vol. 3, 2004, pp. 366-379.

9. Y. Liao, H. Qi, and W. Li, "Load-Balanced clustering algorithm with distributed self-organization for wireless sensor networks," *IEEE Sensor Journal*, Vol. 13, 2013, pp. 1498-1506.
10. J. Yu and Y. Qi, "A cluster based routing protocol for wireless sensor network with non uniform node distribution," *International Journal of Electronics and Communications*, Vol. 66, 2012, pp. 54-61.
11. S. A. B. Awwad, C. K. Ng, N. K. Noordin, and M. F. A. Rasid, "Cluster based routing protocol for mobile nodes in wireless sensor networks," in *Proceedings of IEEE International Symposium on Collaborative Technologies and Systems*, 2009, pp. 233-241.
12. G. Chen, C. Li, M. Ye, and J. Wu, "An unequal cluster-based routing protocol in wireless sensor networks," *Wireless Network*, Vol. 15, 2009, pp. 193-207.
13. S. S. Wang and Z. P. Chen, "LCM: A link-aware clustering mechanism for energy-efficient routing in wireless sensor networks," *IEEE Sensors Journal*, Vol. 13, 2013, pp. 728-736.
14. H. Raza, P. Nandal, and S. Makker, "Selection of cluster head using PSO in CGSR protocol," in *Proceedings of IEEE International Conference on Methods and Models in Computer Science*, 2010, pp. 91-94.
15. K. Li and D. Guo, "Position and movement detection of wireless sensor network devices relative to the landmark graph," *IEEE Transactions on Mobile Computing*, Vol. 11, 2012, pp. 1970-1982.
16. M. Duckham and D. Nussbaum, "Efficient, decentralized computation of the topology of spatial region," *IEEE Transactions on Computers*, Vol. 60, 2011, pp. 1100-1113.
17. X. Chen and Z. Dai, "ProHet: A probabilistic routing protocol with assured delivery rate in wireless heterogeneous sensor networks," *IEEE Transactions on Wireless Communications*, Vol. 12, 2013, pp. 1524-1531.
18. I. Jang, S. Yang, H. Yoon, and D. Kim, "EMBA: An efficient multihop broadcast protocol for asynchronous duty-cycled wireless sensor networks," *IEEE Transactions on Wireless Communications*, Vol. 12, 2013, pp. 1640-1650.
19. S. Deng, J. Li, and L. Shen, "Mobility Based clustering protocol for wireless sensor networks with mobile nodes," *IET Wireless Sensor Systems*, Vol. 1, 2011, pp. 39-47.
20. M. Ettus, "System capacity, latency and power consumption in multi-hop routed SS-CDMA wireless network," in *Proceedings of IEEE International Conference on Radio and Wireless*, 1998, pp. 55-58.
21. Y. Yuan, M. Chen, and T. Kwon, "A novel cluster based cooperative MIMO scheme for multi hop wireless sensor networks," *EURASIP Journal on Wireless Communications and Networking*, 2006, pp. 38-47.
22. S. Dabey and R. Shrivastava, "Energy consumption using traffic models for MANET routing protocol," *International Journal of Smart Sensor and Ad-hoc Network*, Vol. 1, 2011, pp. 84-89.
23. T. Rappaport, *Wireless Communication – Principles and Practice*, Prentice Hall, Englewood Cliffs, NJ, 1996.
24. K. Pahalavan and A. Levesque, *Wireless Information Networks*, Wiley, NY, 1995.
25. V. D. Park and M. S. Corson, "A highly adaptive distributed routing algorithm for mobile wireless networks," in *Proceedings of the 16th Conference on IEEE Computer and Communications Society*, Vol. 3, 1997, pp. 1405-1413.

26. K. Akkaya and M. Younis, "A survey on routing protocols for wireless sensor networks," *Ad Hoc Networks*, Vol. 3, 2005, pp. 325-349.
27. X. Zhang, H. Wang, and A. Khokhar, "An energy efficient data collection protocol for mobile sensor networks," in *Proceedings of IEEE Conference on Vehicular Technology*, 2006, pp. 1-5.
28. W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy efficient communication protocol for wireless microsensor networks," in *Proceedings of the 33rd Hawaii International Conference on System Sciences*, 2000, pp. 1-10.
29. C. Goumopoulos, B. O. Flynn, and A. Kameas, "Automated zone-specific irrigation with wireless sensor/actuator network and adaptable decision support," *Computers and Electronics in Agriculture*, Vol. 105, 2014, pp. 20-33.
30. D. Xiao, J. Feng, N. Wang, X. Luo, and Y. Hu, "Integrated soil moisture and water depth sensor for paddy fields," *Computers and Electronics in Agriculture*, Vol. 98, 2013, pp. 214-221.
31. D. H. Park, B. J. Kang, K. R. Cho, C. S. Shin, S. E. Cho, J. W. Park, and W. M. Yang, "A study on greenhouse automatic control system based on wireless sensor network," *Wireless Personal Communications*, Vol. 56, 2011, pp. 117-130.
32. M. Srbinovska, C. Gavrovski, V. Dimcev, A. Krkoleva, and V. Borozan, "Environmental parameters monitoring in precision agriculture using wireless sensor networks," *Journal of Cleaner Production*, Vol. 88, 2015, pp. 297-307.
33. A. J. G. Sanchez, F. G. Sanchez, and J. G. Haro, "Wireless sensor network deployment for integrating video-surveillance and data-monitoring in precision agriculture over distributed crops," *Computers and Electronics in Agriculture*, Vol. 75, 2011, pp. 288-303.
34. J. A. L. Riquelme, F. Soto, J. Suardiaz, P. Sanchez, A. Iborra, and J. A. Vera, "Wireless sensor networks for precision horticulture in southern Spain," *Computers and Electronics in Agriculture*, Vol. 68, 2009, pp. 25-35.
35. J. Gutierrez, J. F. V. Medina, A. N. Garibay, and M. A. P. Gandara, "Automated irrigation system using a wireless sensor network and GPRS module," *IEEE Transactions on Instrumentation and Measurement*, Vol. 63, 2014, pp. 166-176.
36. S. Katyara, M. A. Shah, S. Zardari, B. S. Chowdhry, and W. Kumar, "WSN Based smart control and remote field monitoring of Pakistan's irrigation system using SCADA applications," *Wireless Personal Communications*, Vol. 95, 2017, pp. 491-504.
37. I. M. Santos, F. G. D. Costa, C. E. Cugnasca, and J. Ueyama, "Computational simulation of wireless sensor networks for pesticide drift control," *Precision Agriculture*, Vol. 15, 2014, pp. 290-303.
38. F. Viani, M. Bertolli, M. Salucci, and A. Polo, "Low-cost wireless monitoring and decision support for water saving in agriculture," *IEEE Sensors Journal*, Vol. 17, 2017, pp. 4299-4309.
39. V. Bhanumathi and C. P. Sangeetha, "A guide for the selection of routing protocols in WBAN for health care applications," *Human Centric Computing and Information Sciences*, 2017, pp. 7-24.
40. M. Tarhani, Y. S. Kaviani, and S. Siavoshi, "SEECH: Scalable energy efficient clustering hierarchy protocol in wireless sensor networks," *IEEE Sensors Journal*, 2014, Vol. 14, pp. 3944-3954.

41. W. H. Nam, T. Kim, E. M. Hong, J. Y. Choi, and J. T. Kim, "A wireless sensor network (WSN) application for irrigation facilities management based on information and communication technologies (ICTs)," *Computers and Electronics in Agriculture*, Vol. 143, 2017, pp. 185-192.



S. R. Barkunan received the B.E. degree in Electronics and Communication Engineering from Anna University, Chennai, M.E. degree in Embedded System Technologies from Anna University, Coimbatore. He is currently doing his Ph.D. in Information and Communication Engineering in Anna University, Chennai. He is currently working as a Teaching Fellow in the Department of Electronics and Communication Engineering, Anna University, Regional Campus, Coimbatore. He has published his works in various international journals and conferences. His areas of interest are embedded systems, real time systems, and wireless sensor networks.



V. Bhanumathi received the B.E. degree in Electronics and Communication Engineering from Madras University, M.E. degree in Communication Systems from Anna University, Chennai and Ph.D. in Information and Communication Engineering from Anna University, Chennai. She is currently working as an Assistant Professor in the Department of Electronics and Communication Engineering, Anna University, Regional Campus, Coimbatore. She has published her works in various international journals and conferences. Her areas of interest are wireless communication, VLSI design, network security, and digital communication.