International Journal of Engineering & Technology, 7 (4) (2018) 3119-3125

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.18140
Research paper

Distributed semi-clustering protocol for large-scale wireless sensor networks

Mohanad H. Wasmi[1]*, Salah A. Aliesawi [1], Wesam M. Jasim [1]

[1] College of Computer Sciences and Information Technology, University of Anbar, Ramadi, Iraq

**Corresponding author E-mail: mohanad.h1989@gmail.com*

Abstract

Conservation of energy is one major issue in the deployment of Wireless Sensor Networks (WSNs). The power resources of the sensor nodes are significantly restricted and these nodes are deployed in remote places. Communication protocols must be designed carefully in order to achieve the efficient utilization of the limited energy of sensor nodes. Clustering the nodes is the best technique to achieve this goal and improve the lifetime of the network. Many protocols have been proposed to prolong the lifetime of the network. Low- Energy Adaptive Clustering Hierarchy (LEACH) is one of the most famous of clustering protocols. LEACH transmits data directly from Cluster Head (CH) to the Base Station (BS), thereby far away nodes from BS dies early. In this paper, we propose a new routing protocol called Distributed Semi-Clustering Protocol (DSCP), which is more suitable for long-scale transmission in WSNs. Instead of using Direct Transmission (DT) to send data of CH to BS, DSCP uses Multi-Hop (MH) communication with minimum energy cost from each CH to reach BS. Finally, the Dijkstra algorithm is employed in DSCP between CHs to efficiently search for the optimal path. The simulation results show the significant improvement of our proposal compared to other clustering protocols, and it has a longer network lifetime and more extended stability period.

Keywords: *WSNs; Semi-Clustering; Dijkstra Algorithm; Network Lifetime; Stability Period.*

1. Introduction

Nowadays, the Internet of Things (IOT) has been widely used in various fields and promoted necessary changes in social production modes. WSNs as the predecessor of IOT has become a research hotspot [1]. WSNs consist of hundreds to thousands of sensor nodes. Each node has four essential components; the sensing unit, data processing unit, power unit and the transceiver unit, to perform distributed sensing tasks. It's mainly used in applications where human intervention is not necessary, such as remote monitoring, habitat monitoring and surveillance. The sensor node has limited-energy and deployed in the remote or dangerous places where recharging is semi-impossible [2]. Energy conservation is considered as the most crucial challenge to guarantee the connectivity between nodes and prolong the lifetime of the network. This challenge becomes more critical in large-scale networks; especially, when the system carries a much bigger load and depletes its energy quickly. Hence, the network cannot be sensed anymore [3]. In recent years, several techniques for saving energy have been developed such; cross-layer design [4], clustering [5], routing protocols [6], etc. Clustering techniques are widely accepted methods that are used to improve the energy efficiency and increase the stability period. In clustering, some special nodes which have high residual energy are selected as CHs for gathering information before processing it and sending it to BS. On the other hand, low energy nodes act as normal nodes. They sense information and send the data packets to CHs. Data packets received by CHs from the various nodes, are gathered into one packet before transmitting it to BS. As result, the number of forwarded packets is decreased. Only CHs are allowed to communicate with BS. In this process, the network load is remarkably reduced, so the stability of the network is increased and the network lifetime is prolonged [3][7]. When the network is splitted into many clusters, the communication cost is divided into two main terms: Intra-cluster term which includes the energy cost of the non-CH nodes to reach their CH. While Inter-cluster term includes energy cost of CHs nodes to reach sink or BS [8]. Generally, a cluster network employs DT in each cluster [9]. In LEACH protocol, single-hop inter-cluster communications can reduce the energy consumption of communication by forwarding data of CH to BS. However, when the CHs are far away, the communication distance increases, the single-hop communication becomes less energy efficient as it consumes more energy for long distances. Based on the above, this paper proposed a hybrid technique to combine the Dijkstra algorithm with MH inter-cluster communications among CHs. The proposed protocol is called Distributed Semi-Clustering Protocol which depends on a distributed manner for choosing CHs. Our contribution is to extend the stability period and the lifetime of WSNs by employing the Dijkstra algorithm between CHs to reach BS and taking into account the energy cost in transmitting and receiving data at each CH node to discover the actual shortest path with minimum cost to reach BS.

This paper organized as follows: The related works are presented in section 2. In section 3, a brief description of the LEACH protocol, the basic idea of Dijkstra algorithm and the radio energy model are introduced. Our proposal, DSCP is illustrated in details in section 4. Then, in section 5, the simulation results of DSCP performance are indicated. Finally, section 6 presents the conclusions of this paper.

2. Related work

Many clustering protocols are developed in last years to improve the lifetime of WSNs. The first clustering protocol LEACH [10] is proposed by Heinzelman et al. It uses a distributed clustering approach in CHs selection process. CH role is rotated in every Group of Rounds (GOR) in order to balance energy load among all nodes. The received data by CHs is forwarded directly to BS. Since CHs use DT to reach BS, far CHs consumes more energy cost and dies early.

Fan and Song proposed improved version of LEACH protocol Energy-LEACH (E-LEACH)[11]. It depends on the residual energy of nodes during CHs selection process to achieve more balance in energy consumption. All nodes must know a global information about residual energy of other nodes.

In [12], Deng and Qi proposed a technique for reducing the number of CHs that can communicate directly with BS. This method named Three-Layered LEACH (TL-LEACH), which rely on the ideas found in LEACH and PEGASIS protocols. The CHs nodes of the set-up phase in LEACH are elected to be CHs of the second CH level, only CHs in the second level have the ability to communicate directly with BS.

The proposed protocol in [13] partitions the network into different size clusters. Clusters that are far away from BS have a larger size than nearby ones. Furthermore, MH communication is employed to find the optimal path to BS. Moreover, a rotation mechanism of CH role is employed to balance energy consumption.

Arezoo et al. proposed Cell LEACH (Cell-LEACH) in [14]. It divided the network into many clusters and each cluster is divided into seven subsections (cells) that include a set of sensors. Every cluster has one CH and seven cell-heads. The sensor nodes communicate with cell-heads, then the cell-heads communicate directly to CH.

In [15], MH-Technique (MHT-LEACH) is discussed. It improves the performance of LEACH. Instead of sending data from CHs to BS directly, MHT-LEACH depends on the location and the distance of CHs from BS in data transmission. Subsequently, MHT-LEACH aims to distribute all CHs into two levels and direct data to BS over these levels. Hence, balancing energy load through all parts of the network is achieved.

New clustering approach is introduced in [16]. LEACH and Minimum Transmission Energy (MTE) protocols are combined in single protocol. This approach employs a MH intra-cluster data transmission rather than single hop in clustered architecture, to mainly save transmission.

Authors in [17]proposed a new version of MHT-LEACH protocol called Improved MH Technique (IMHT-LEACH), for routing data to BS through multi-levels. Instead of using two levels to distribute CHs in the network as in MHT-LEACH, IMHT-LEACH uses more than two levels for distributing CHs in the network and classifying all CHs based on the distance from BS, In order to distribute the energy load through all parts of the network and increase the lifetime. Hence, this technique is more suitable for large networks.

3. Preliminaries

3.1. Basic idea of dijkstra algorithm

Dijkstra algorithm is a search graph algorithm. It is the best-known algorithm to obtain the shortest-paths from given source to all vertices in the graph. This algorithm is applied in many fields such as graph theory, a data structures, and flight agenda. Dijkstra's algorithm detects the shortest path from the source to a vertex or node nearest to it based on distance, then to a second closer node, and so on[18].

3.2. LEACH Protocol

LEACH [10] is one of the most prominent clustering mechanisms that achieves the energy saving in the sensor network. In LEACH, sensor nodes organize itself as CHs and non-CHs (normal nodes) through a certain period called round. Each round has two phases: the setup phase and the steady state phase. The round begins with a setup phase as shown in figure 1.

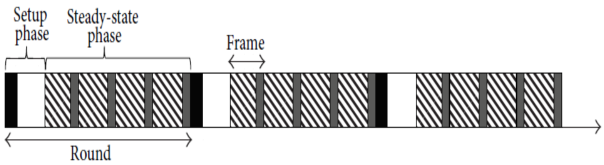

Fig. 1: Operation of LEACH Protocol.

This phase is concerned with CHs selection and cluster formation based on the probabilistic model and the received signal strength. Each sensor node makes an independent decision by using a fully distributed algorithm to decide to be a CH or not; without any centralized control. Therefore, every node chooses a random number between 0 and 1. If the selected number by the node is less than a threshold value *T(ni)* as referred in equation (1). The node becomes CH in the current round and broadcasts its decision. The role of CH is rotated among the nodes in every GOR to distribute energy cost evenly. Non-CH nodes choose closer CHs to access them using minimum communication energy. Hence, all sensor nodes can determine their related cluster.

$$T(ni)=\begin{cases}\dfrac{p}{1-p(r \bmod 1/p)} & , if\ in \in G \\ 0 & , otherwise\end{cases} \qquad (1)$$

Where *p* is the desired percentage of nodes to be selected as CHs in the sensor population, *r* represents the current round number, if a node $ni \in G$, this means that node has not been selected as a CH in the recent rounds *(1/p)*. This guarantees the rotation role of CH periodically between all nodes. The setup phase is followed by a steady-state phase, this phase is concerned with data transmission between the network nodes. The communication between normal nodes and their CH is established using Time Division Multiple Access (TDMA). Non-CHs nodes send their data to their CH and then to BS as shown in the figure 2.

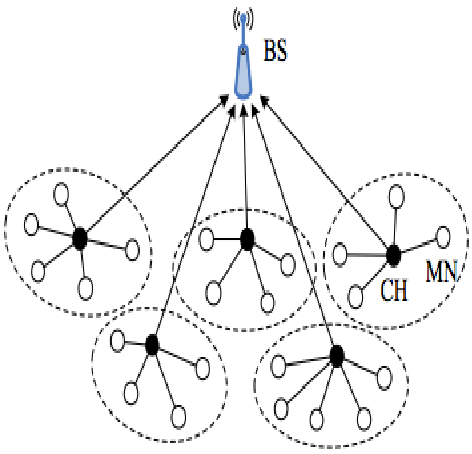

Fig. 2: Basic Structure of LEACH [19].

LEACH can aggregate and fuse data locally in each cluster to reduce the transmission cost to BS. Although LEACH acts in an effective manner, it suffers from significant drawbacks. One of these drawbacks is the direct transmission of CHs to BS using single-hop. Hence, it is not applicable to large scale networks

3.3. Radio energy model

Each sensing node can perform multiple tasks such as; sensing, processing, transmitting and receiving data. Every one of these tasks exhausts a specific amount of node energy [20]. The first order radio energy model in [21]], is used to estimate the energy consumption of the node and the total network lifetime. This model is depicted in figure 3.

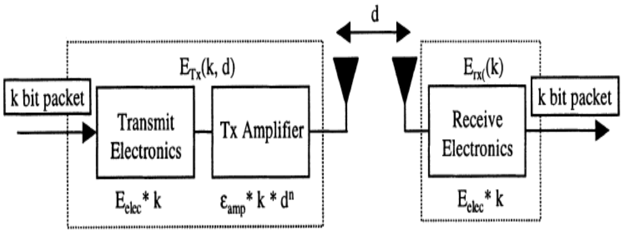

Fig. 3: Radio Energy Dissipation Model.

The radio model takes into account the free space and multipath fading models when a node wants to transmit *k-bit* data to a destination through distance *d*. If the transmission distance *d* is less than or equal to a threshold value d_0, the transmission energy in free space model (d^2 power loss) is used. Otherwise, the transmission energy in multipath fading model (d^4 power loss) is employed. The amount of energy consumption by transmitter E_{TX} for sending *k-bit* data through a distance *d* is given in equation (2). E_{TX} consists of two terms are the component cost term which concerned with operation the electrical circuits, and the amplification cost term which makes the transmitted signal has the capacity to overcome noise in its path.

$$E_{TX}(k,d)=\underbrace{K*E_{TX\_elec}}_{ComponentCost}+\underbrace{K*\varepsilon_{amp}*d^{n}}_{Amplification\ Cost} \qquad (2)$$

$$=\begin{cases} K*E_{TX\_elec}+K*\varepsilon_{fs}*d^{2} & ,if\ d\le d_0 \\ K*E_{TX\_elec}+K*\varepsilon_{mp}*d^{4} & ,if\ d>d_0 \end{cases}$$

On the other side, the amount of energy consumed by receiver E_{RX} for receiving *k-bit* data is given in equation below.

$$E_{RX}(k)=\underbrace{K*E_{RX\_elec}}_{ComponentCost} \qquad (3)$$

Where E_{TX_elec} and E_{RX_elec} are the required energy to operate the electronic circuit per *bit* in both transmitter and receiver. The amplifier parameters ε_{fs} and ε_{mp} are the amplification energy per bit over a distance d^2 for free space model and d^4 for multipath fading model, respectively. The threshold value d_0 denoted as:

$$d_0=\sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \qquad (4)$$

If a node works as an intermediate node to relay data from source to destination, its radio expands:

$$E_{Relay}(k,d)=E_{RX}(k)+E_{TX}(k,d) \qquad (5)$$

$$=\begin{cases} 2*K*E_{\substack{RX\_elec\\TX\_elec}}+K*\varepsilon_{fs}*d^{2} & ,if\ d\le d_o \\ 2*K*E_{\substack{RX\_elec\\TX\_elec}}+K*\varepsilon_{mp}*d^{4} & ,if\ d>d_o \end{cases}$$

The description of these parameters are given in table 1

Table 1: Parameters Description

Operation	description	Dissipated energy
K	Packet length	4000 *bits*
E_{Tx_elec} / E_{Rx_elec}	Energy spent to operate the electronic circuit	50 *nJ/bit*
E_{Tx-amp}	Energy of transmission amplifier	ε_{fs} or ε_{mp}
d_0	Threshold distance	$\sqrt{\varepsilon_{fs}/\varepsilon_{mp}}$
ε_{fs}	free space model ($_{fs}$) is used, if $d \le do$	10 *pJ/ bit/m2*
ε_{mp}	multipath model ($_{mp}$) is used, if $d > do$	0.0013 *pJ/ bit/m4*

4. Distributed semi-clustering protocol

Our proposal DSCP aims to find an effective way to save the energy consumption and prolong the network lifetime. DSCP combines single-hop intra-cluster and MH inter-cluster communication techniques into a single protocol.

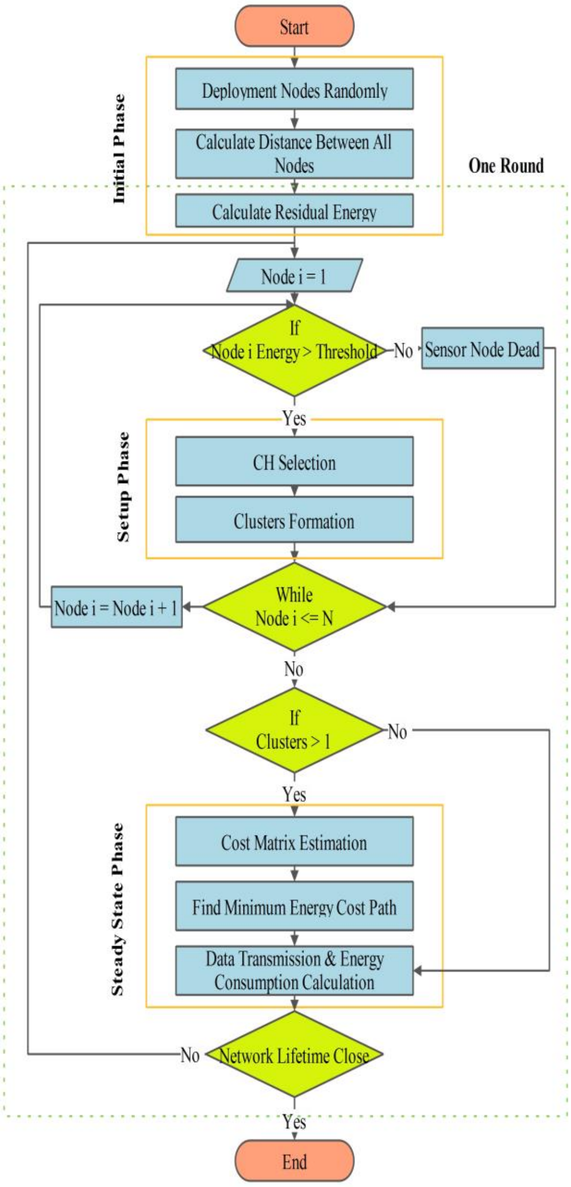

Fig. 4: Flowchart of Proposed DSCP.

The operation of DSCP is similar to LEACH protocol in many ways; it's mainly divided into three phases: the initial phase, the set-up phase and the steady-state phase. In the first one, the distance between all nodes and their residual energy are calculated after the random deployment of the nodes through the sensing field. In the second phase, CHs selection and clusters formation are performed consequently. The steady state phase interested in finding the optimal path between CHs to reach BS and data transmission process.
DSCP differs from LEACH in terms of sending the aggregated data by CHs to BS not directly but in MH manner. Each CH sends its data to the nearest CH and so on until reaching to BS. MH manner in DSCP relays on using a hybrid method for finding the optimal path before transmission process. No doubt that, finding the least cost between CHs affect significantly on enhancing the network lifetime and stability period. Hence, the energy required for sending data over the long distances is minimized. DSCP flowchart is illustrated in figure 4 and explained in details in the next subsection.

4.1. Initial phase

In this phase, the sensor nodes are deployed randomly inside M×M square field (intended area or target area) to cover the total area as the first step. Let these nodes assumed to be homogenous and each one has a unique Id. BS and all the sensor nodes are stationary after deployment. Moreover, they can determine their location using Global Positioning System (GPS), then they calculates the inter-distance between them based on Euclidean distance equation

$$d = \sqrt{(x2\_x1)^2 + (y2\_y1)^2} \qquad (6)$$

The energy cost exhausted by each node is directly proportional to the transmission distance to reach BS. Thus, closest nodes to the sink, will consume a much lower amount of energy than farther ones.

The final step in the initial phase is checking the residual energy of nodes; if node's energy is lower than a threshold, this node is considered a dead node otherwise the node is marked as a live node and becomes eligible to be CH in the next phase.

4.2. Setup phase

During this phase, many clusters are going to be established. It's divided into two sub-phases; CHs selection and cluster formation

4.2.1. CHs selection

At this stage, each live node can make its independent decision to be CH or not, in distributed manner. The node takes its decision based on a probabilistic model similar to that is used in LEACH. Each node broadcasts its decision with other nodes

4.2.2. Clusters formations

By the end of CHs selection process, cluster formation begins. CH-nodes broadcasts advertisement message to neighbors' nodes. Based on the Received Signal Strength Indication (RSSI) of the advertisement message, the non-CH nodes determine their nearest CH. Then, each node sends a Join-REQ message that contains its id to its CH. Each CH creates nodes schedule list according to the received Join-REQ messages and broadcasts this list to its cluster members.
This list is used for telling the nodes related with the cluster, so they can transmit their data to the CH regularly to reduce the consumed energy.

4.3. Steady-state phase

As soon as CHs selection and clusters formation sub-phases are completed, the steady state phase starts. As shown in figure 5.

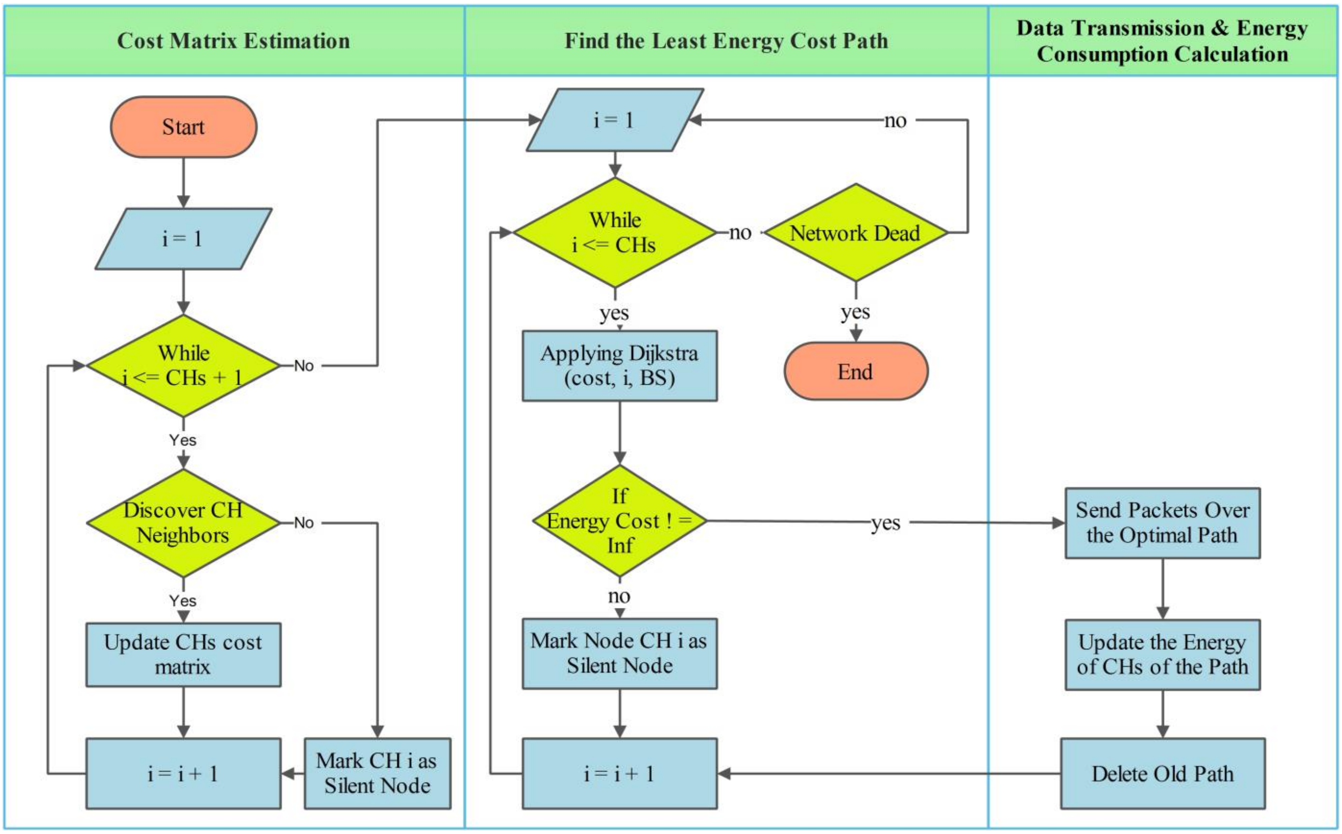

Fig. 5: Steady-State Phase.

Steady state phase is portioned into three sub-phases. The transmission of data through the long distances between CHs consume the most of nodes energy. Therefore, finding the optimal path between clusters is one of the solutions that would help in achieving energy efficiency of DSCP.

Steady-state phase begins to find an economical way to transmit the aggregated data to BS. Each CH has to paid energy cost for sending and receiving data. These costs have to be considered before estimating the minimum cost path using the Dijkstra algorithm. First of all, all cost between CHs and BS is estimated. Then, the Dijkstra algorithm starts to determine the least energy consumed path depending on the energy cost.

We consider the energy cost as weights for edges between CHs instead of depending on the distance as weights between them. Hence, the Dijkstra algorithm assigns initial energy cost and try to improve them gradually until reach to BS with the best route which achieves the least cost. Accordingly, each CH routes packets via the best path found. The energy of CHs of the path is updated in each round until the network dies. At the start of each round, the old path is deleted and a new operation is repeated

5. Performance evaluation

Now, we are interested in estimating the performance of proposed DSCP with other traditional protocols. The performance metrics are necessary for evaluating the performance of the clustering protocols. There are many metrics can be used in this evaluation such as:

a) Network lifetime: the time duration from begin of the network operation until the last sensor node dead.
b) First Dead Node (FDN): denotes the elapsed time duration in which the first node (1%) dies (stability period)
c) Half Dead Node (HDN): refers to the elapsed time duration in which half of the nodes (50%) are dead
d) Last Dead Node (LDN): indicates the elapsed time duration in which last node (100%) dies
e) Un-Stability period: Duration of elapsed time after FND until LND in the network.
f) Throughput: refers to number of packets received at BS during the network operation

In most of the high-density networks with homogeneous nodes, the death of the first node (FDN) or even some of the nodes is not critical in these types of applications or networks. It's not a hindrance to prevent the network from performing its duty correctly. The network is trustable and performing the needed task as long as more than the half of the number of nodes will be remained alive. Therefore, FDN may be considered based on network specifications, node density and distribution of nodes within the network. Furthermore, before the network reaches LDN, the network structure is bad. Hence, the network reliability is not satisfying and it's become useless. So, most researchers believed that LDN isn't accurate parameter about the validity of the network. On the other hand, HDN gives considerable attention as the estimated value for the average of the lifetime and performance of the network.

5.1. Simulation environment

Matlab 2016a is used as a simulation platform to evaluate the performance of DSCP. Our network model consists of 200 nodes in 250*250 m^2 and all nodes are homogeneous. Hence, the nodes have the same initial energy 0.5 J. Our proposal interests in either large-scale networks or long-distance transmission cases, hence two scenarios of BS location are considered during simulation. The first scenario, BS located at the border (125, 0) m. While the second scenario, BS located far away from the sensor area, at (125, -125) m. Other simulation parameters are mentioned previously in table 1.

5.2. Simulation results

- **BS at border**

Figure 6 shows the total number of nodes alive versus 1500 rounds. E-LEACH is more stable than LEACH because it depends on the residual energy of nodes during CHs selection. Hence, the stability period of E-LEACH is relatively larger than LEACH. TL-LEACH uses two level of CHs and only CHs in the 2nd level can communicate directly with BS. Therefore, the transmission distance to reach BS from CHs of the 1st level is divided and energy cost is minimized. Hence, TL-LEACH performs better than either LEACH or E-LEACH. DSCP achieves the best number of rounds compared with all the above protocols.

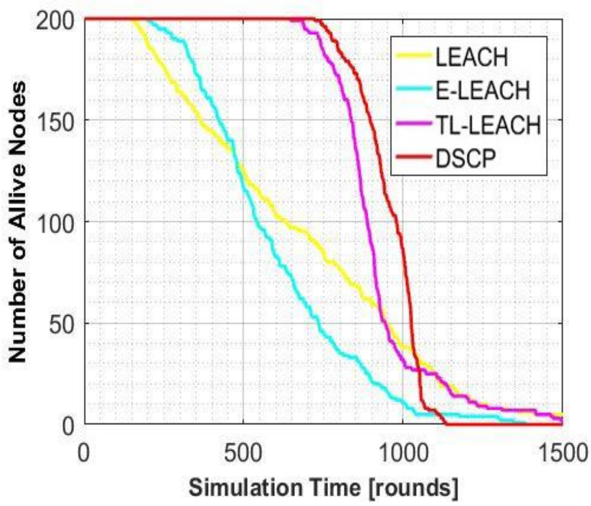

Fig. 6: Number of Alive Nodes when BS at (125, 0).

Fig. 7: Comparison for FDN, HDN, and LDN for LEACH, E_LEACH, TL_LEACH and DSCP when BS at (125, 0).

DSCP is not only depended on MH communication but also on using Dijkstra Algorithm to find the least cost path to reach BS. Moreover, it considers the energy cost of the CHs. This of course, will balance the inter-term energy cost between CHs. Hence, the transmission distance and communication cost are decreased.

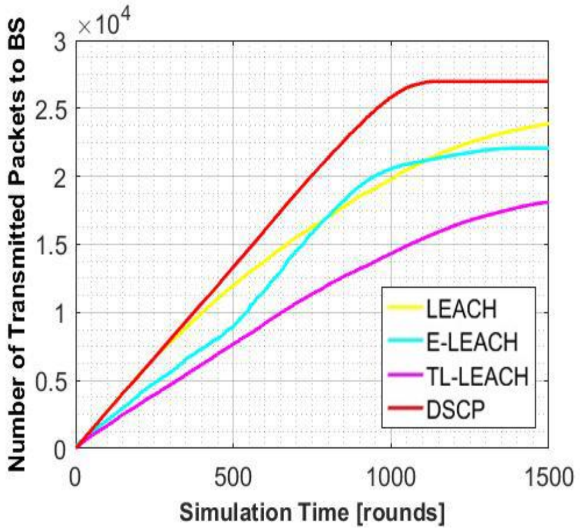

Fig. 8: The Total Number of Received Packets at BS (125, 0)

Figure 7 shows FDN, HDN, and LDN for LEACH, E_LEACH, TL_LEACH and DSCP respectively. It's obvious that DSCP achieved the highest number of FDN (stability period) and HDN in comparison with others. In terms of FDN, proposed DSCP is more efficient than LEACH, E-LEACH, and TL-LEACH by 79%, 72%, and 10%, respectively. LEACH performance is the worst one regarding FDN, because the far away CHs consumed much more energy in sending its data directly to BS, hence they die early. Either concerning HDN, DSCP also outperforms LEACH, E-LEACH, and TL-LEACH by 36%, 45%, and 9% respectively. Due it chooses the least cost path; therefore, the nodes conserve its energy for a longer period.

Although the time of the LDN of LEACH, E-LEACH, and TL-LEACH is longer than that of DSCP, it implies that the energy consumption of these protocols is not so well balanced, thus some sensor nodes have more residual energy to live longer.

Moreover, DSCP has the successive death of nodes in a comparatively short period (un-stability period). By comparing elapsed time from FND to LND in the network, it's found that DSCP has a smaller un-stability period than LEACH, E-LEACH, and TL-LEACH as shown in table 2. There is no doubt, the proposed DSCP performs much better in balance energy consumption and more stable than LEACH, E-LEACH, and TL-LEACH, since nodes deaths begin later in DSCP and continue until all nodes die.

Table 2: In-Stability Period

Protocol	In-Stability Period (Rounds)
DSCP	356
TL-LEACH	421
E-LEACH	450
LEACH	722

Figure 8 shows the throughput. In TL-LEACH, only CHs of the 2^{nd} level have the right to send data packets to BS. Hence, the number of the received packet is strictly related to their numbers. On the other hand, in DSCP, all near CHs to BS can relay data. Hence, the throughput is higher than that of TL-LEACH. As result, DSCP has the better performance, since BS receives much more packets from CHs during the network lifetime.

- **Far away BS**

As BS has placed far away from the sensing field, at (125, -125), the transmission distance to reach BS becomes longer, the impact of DSCP in improving the stability period and prolonging network lifetime appears in a clearer manner. This is illustrated during comparison of figure 9 and 10 with figure 6 and 7, respectively. We conclude from this result, DSCP is maintaining its performance when BS far away, while LEACH, E-LEACH, and TL-LEACH are fading in a relatively short time.

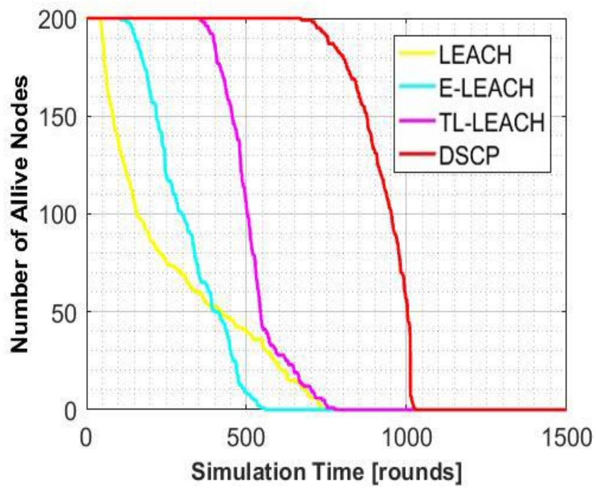

Fig. 9: Number of Alive Nodes when BS at (125, -125).

Fig. 10: Comparison for FDN, HDN, and LDN for LEACH, E_LEACH, TL_LEACH and DSCP when BS at (125, -125).

Therefore, proposed DSCP is more efficient than LEACH, E-LEACH, and TL-LEACH by 93%, 84%, and 47%, respectively regarding FDN. Either In terms of HDN, DSCP also outperforms LEACH, E-LEACH, and TL-LEACH by 83%, 69%, and 47% respectively. It implies, our protocol is more efficient than others in large-scale networks or when BS moved away from CHs, where the impact of employing MH communication in long-distance transmission appears on the lifetime and stability of the network. Hence, DSCP achieves lower energy consumption and becomes more stable.

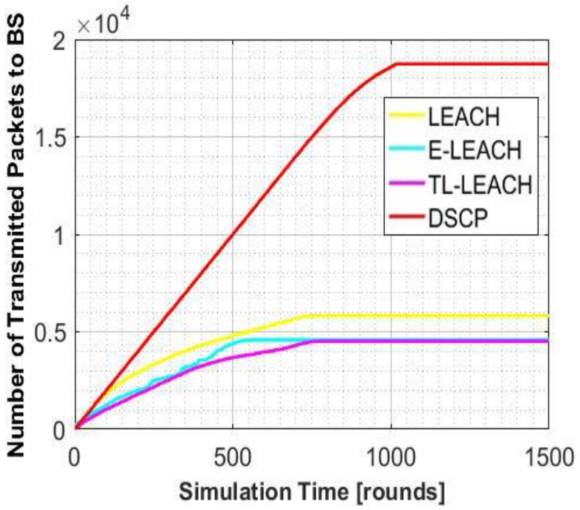

Fig. 11: The Total Number of Received Packets at BS (125, -125).

The total number of the received packet at BS over the simulation time is given in figure 11. DSCP achieves the highest throughput of received packets compared with LEACH, E-LEACH, and TL-LEACH; due to the lifetime of DSCP is larger than others. Thus, a larger number of nodes still able to send their packets to BS duly

6. Conclusions

In this paper, we seek to reduce data transmission cost of CHs to reach BS by using MH communication between clusters. Our main idea is to avoid DT in long distances and minimize the power consumption as much as possible. Besides MH communication, the Dijkstra algorithm is the cornerstone of our proposal. Dijkstra algorithm helps not only in finding a low-cost path but also in balancing energy cost through the path. As future extensions to this work, it is interesting for determining optimal cluster size and reduce intra-cluster communication to improve balancing load and more saving energy.

References

[1] X. Yulong, W. Xiaopeng, and Z. Han, "Comparative study on the optimal path problem of wireless sensor networks," *2016 IEEE Int. Conf. Mechatronics Autom.*, pp. 2234–2239, 2016.

[2] F. Shemim and S. Shajahan, "Enhanced Energy Aware Multi-Hop Hierarchical Routing Algorithm for Wireless Sensor Networks," *IEEE.* Conf. (ICECTA),2017. pp. 2–5, 2017.

[3] H. Lin, L. Wang, and R. Kong, "Energy Efficient Clustering Protocol for Large-Scale Sensor Networks," *IEEE Sens. J.*, vol. 15, no. 12, pp. 7150–7160, 2015.

[4] A. Ben Ammar, A. DZIRI, M. TERRE, and H. YOUSSEF, "Multi-Hop LEACH Based Cross-Layer Design for Large Scale Wireless Sensor Networks," *Wirel. Commun. Mob. Comput. Conf. (IWCMC), 2016 Int. IEEE*, pp. 763–768, 2016.

[5] O. Younis, M. Krunz, and S. Ramasubramanian, "Node clustering in wireless sensor networks: Recent developments and deployment challenges," *IEEE Netw.*, vol. 20, no. 3, pp. 20–25, 2006.

[6] C. Cirstea, "Energy efficient routing protocols for Wireless Sensor Networks: A survey," *2011 IEEE 17th Int. Conf. (SIITME).* pp. 277–282, 2011.

[7] R. S. S. Kumari, A. Chithra, and M. B. Devi, "Efficient 2-level energy heterogeneity clustering protocols for wireless sensor network," *Indian J. Sci. Technol.*, vol. 9, no. 8, pp. 2–7, 2016.

[8] P. Ding, J. Holliday, and A. Celik, "Distributed Energy-Efficient Hierarchical Clustering for Wireless Sensor Networks," *IEEE Int. Conf. Distrib. Comput. Sens. Syst.*, vol. 356, pp. 322–339, 2005.

[9] S. Taruna, "Multi-Hop Clustering Protocol using Gateway Nodes in Wireless Sensor Network," *Int. J. Wirel. Mob. Networks*, vol. 4, no. 4, pp. 169–180, 2012.

[10] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," *System Sciences, 2000. Proceeding of the 33rd Annual Hawaii International Conference on,2000,* pp. 10. vol.2.

[11] F. Xiangning and S. Yulin, "Improvement on LEACH Protocol of Wireless Sensor Network," *2007 Int. Conf. Sens. Technol. Appl.*, vol. 9, no. 2, pp. 260–264, 2007.

[12] Z. Deng and B. Qi, "Three-layered routing protocol for WSN based on LEACH algorithm," *Wireless, Mob. Sens. Networks, 2007. (CCWMSN07). IET Conf.*, pp. 72–75, 2007.

[13] W. J. Y. Liu, "Energy efficient clustering and routing scheme for Wireless Sensor Networks," *978-1-4244-4738-1/09/$25.00 ©2009 IEEE*, 2009.

[14] A. Yektaparast, F. Nabavi, and A. Sarmast, "An improvement on LEACH protocol07436173," pp. 992–996, 2012.

[15] E. Alnawafa and I. Marghescu, "MHT: Multi-hop technique for the improvement of leach protocol," *Netw. Educ. Res. RoEduNet Int. Conf. 15th Ed. RoEduNet 2016 - Proc.*, pp. 3–7, 2016.

[16] M. Arioua, Y. El Assari, I. Ez-Zazi, and A. El Oualkadi, "Multi-hop Cluster Based Routing Approach for Wireless Sensor Networks," *Procedia Comput. Sci.*, vol. 83, no. Ant, pp. 584–591, 2016.

[17] E. Alnawafa and I. Marghescu, "IMHT: Improved MHT-LEACH protocol for wireless sensor networks," *2017 8th Int. Conf. Inf. Commun. Syst. ICICS 2017*, pp. 246–251, 2017.

[18] L. A, Introduction to the design & analysis of algorithms. Boston: Pearson, 2012

[19] X. Liu, *A survey on clustering routing protocols in wireless sensor networks*, vol. 12, no. 8. 2012.

[20] A. Bachir, M. Dohler, T. Watteyne, I. Member, and I. S. Member, "MAC Essentials for Wireless Sensor Networks MAC Essentials for Wireless Sensor Networks," *Commun. Surv. {&} Tutorials*, vol. 12, no. 2, pp. 222–248, 2010.

[21] W. B. Heinzelman, A. P. Chandrakasan, S. Member, and H. Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks," vol. 1, no. 4, pp. 660–670, 2002.