Intra-clustering communication enhancement in WSN by using skillful methodologies

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Abstract. Member nodes in a wireless sensor networks are split into many virtual sets called cluster. Each cluster will be formed of a cluster head and cluster members. Clustering techniques are an energy efficient process that prolong the network lifetime. Intra-cluster communication is the energy efficient major factor in clustering protocols. The dissipated energy in intra-cluster will primarily depend on the communication distance between member nodes and its cluster head. Therefore, reducing of energy that have been consumed in data transmission between ordinary nodes and its belonging cluster header, is consider as one of the important topics that have been taken into consideration by researchers. Clustering technique in WSN is one of the robust techniques that are utilizing to enhance consumed energy. Traditional clustering technique is not convenient with the animated nature of the WSN. A Fuzzy C-Mean Clustering (FCM) algorithm is proposed, this method has given momentum to improve network status and promote the state of sustainability of energy consumed by sensors nodes. Decision tree algorithm (DTA) which falls under the category of supervised machine learning algorithms is utilized to select Cluster Head (CH). The CH electing is done in such a way that reduces the intra-cluster communication distance; also, this method has limit the amount of consumed energy in the entire network.

An event driven data model that depends on FCM with DTA which is named as Voronoi Fuzzy Clustering with Decision Tree Algorithm (VFDTA) is adopted in this study. The evaluation metrics the performance of VFDTA protocol is better than well-known protocols (LEACH, SEP and Z-SEP) in terms of network stability, consumed energy and network lifetime.

Keywords: Fuzzy C-Mean Clustering, Cluster head election, intra-clustering, energy consumption, network lifetime.

1. Introduction

The cluster head in wireless sensor network, will receive sensing data that collected from monitoring area by active sensor node. The process of transferring the sensed data from active node in the monitoring area within cluster, to the CH is called intra-cluster. The intra-clustering communication is the prime factor that affects on the efficiency of energy in clustering protocols [1][2].

The sensor nodes which deployed over a geographical area will communicate wirelessly through wireless links [3]. The main task of the associated sensors is to monitoring physical phenomena like seismic events, vibrations, temperature, humidity, and more another number of applications like border surveillance or any other military applications and health related applications [4].

Since nodes in wireless sensor networks are generally small size and equipped with limited energy, because of sensor nodes commonly operate in harsh environment with small capacity of energy source. The process of changing or replacing the sensor battery is difficult if not impossible; nodes may be deployed in unfriendly or unpractical environment. [4][3].

Energy exhaustion is a vital issue in prolong the network lifetime, the draining of minimum quantity of energy is to remain the network from failure. In wireless sensor network data transferring is the most energy constraint task. The lifetime of whole component in network should be long enough to achieve the application requirements. In the past two decades there are numerous papers which offered different ways to extend the wireless network life time. By
utilizing a smart method to grouping the sensors in the monitoring area in addition to the proficient way to elect cluster head, helps a lot in reducing communication distance which effects positively on the energy that spent to transfer data in intra-clustering.

Inter-clustering communication is the connection function between CHs or between CHs and sink node. Figure 1, shows intra-clustering and inter-clustering communication between sensor nodes and sink node in wireless sensor network (WSN). Controlling the energy consumption process within each cluster has a significant impact on the total consumed energy of the wireless network.

In intra-clustering the communication processes is done through three steps:
- Active sensor node will transmit the sensed data to its CH.
- CH aggregate and process the collect data send by its associated sensor node members.
- CH then transmits data to the sink node by one hop or relay sensed data to other CH in multi-hop routing.

One of appropriate methods that manage the use of energy and improve the network lifetime in WSN is clustering. Data gathering techniques in clustering algorithms decrease the collected data by cluster head to the degree that eliminate the utilized consumed energy, cluster head also responsible to send the collected data to the sink or base station directly in one-hop routing, or relay sensed data to next hop cluster head in hierarchal routing protocol [6] [7].

In this paper, hopeful methods that distribute the sensor nodes on the sensing area through using Voronoi diagram, clustering these nodes by utilizing FCM method to reduce the intra-clustering distance and electing cluster head with high parameters by applying the DTA. All these well-built methods will effectively contribute to improved energy spend during data transmission within the cluster, which have additional benefit to improve power saving and to eliminate the consumption energy in the entire network. As a result, these three combined techniques will reduce distance within intra-cluster communication which improves the energy management of the entire network.

The experimental results present that the combination of the three methods will offer an important enhancement on the total network lifetime when utilizing in WSN.

The major components of ordinary sensor node architecture will be illustrated in Figure 2. The sensing unit for data gathering from the physical environment, a microcontroller for processing the data locally, a transceiver which is a wireless communication unit that transmit and receive signals to and from other nodes, power source (a battery) for supply energy needed by the device to perform the required task, analog to digital convertor ADC and memory unit for store data locally. The sensing unit holds the information from the physical environment of network area; the sensor will activate the camera unit to capture the image of event driven and then relay the data to ADC unit to obtain digitized information. The processor unit will get the data for processing and then either transfer it to transceiver unit which contains both transmitter as well as receiver, or will transfer the process data to memory for storing. All physical components of sensor architecture based on power supply for working, this power must provide from batteries [8].

The rest of the paper are arranging as follows. Section II will present the related work. Section III will describe the Improvement of Intra-Clustering Communication. Section IV Proposed Model. Experimental results are shown in Section V. Section VI concludes the paper.

2. Related Work

Many researchers in the field of WSN have present a considerable interest in topic of CH selection. Smart election of CH from cluster nodes plays a major role for energy management of WSN. The position of CH has prime effects on the distance of intra-clustering communication and the energy consumption in intra-cluster will depends onto communication distance of intra-clustering. Therefore, for each cluster if the distance of intra-clustering communication be large the consumed energy will be more than other clusters. The following lines review what researchers have done in this topic.

In [9] the researcher offers (introduced) I-DEC protocol (improved DEC), which have a capability to improve network stability, also network lifetime will be prolong over other existing protocols. A general view of the proposed protocol with their cons, pros and present
improvements is also given in this study. From the practical results for the proposed DEC protocol will present good performance with reference to consumed energy upon existing protocols. In [10] presents a reshaped data aggregation protocol. So as to reduce the average of consumed energy for the entire network and extended the network lifetime. By utilizing fuzzy c-mean clustering algorithm to select cluster head, therefore each active node will transmit the sensed data to its belonging CH. The main job of CH is to aggregate the sensed data that send by member nodes by computing a major value and then relay the aggregated data directly or by multi-hop to sink node. From the practical results offer to us that the action of the proposed protocol is finer than LEACH protocol and the clustering algorithm K-Means.

From the paper of [11], a new smart protocol for cluster head selection (SCHS) is proposed. Mainly this protocol is focusing on the performance enhancement over LEACH protocol. This smart protocol will divide the sensed area into two regions: border or outer region and inner region. The selection of CH is bounded on inner region nodes. By calculating the distance of intra-cluster communication, the SCHS protocol will have high effect to reduces the communication distance. Therefore, if this scheme is applied on LEACH protocol the results will be significantly improved the network lifetime performance. Simulation analysis presents that the smart protocol will prolong the network lifetime as the average of node death and the average of consumed energy of nodes is lower than well-known LEACH protocol. The research paper of [12] proposed a new protocol of a Multi-Measurement based on Fuzzy Logic for intra-clustering and inter-clustering multi hop data transmission. Main job of this protocol is to give high stability among the network nodes and select nodes with high stability as cluster heads for effective data transmission. The results of simulation proven that the proposed scheme is more dynamic than state-of-art protocols. As explained from simulation results, this approach will efficiently increase the nodes residual energy, because of the CH election from nodes with more stability every round which have prime effect on network lifetime. Moreover, this protocol will have good scalability and better performance for large scale network.

The research case that present in [13] proposed algorithm with high gained energy efficient based on node ranking to select a CHs. The performance of the proposed algorithm is compared with renowned algorithms by the parameters of consumed energy and network life time. From the experimental results our protocol out performed PEGASIS protocol over 15% and well-known LEACH protocol by almost 70% mainly for the criterion of network life time. The location of base station will not affect the proposed protocol as in PEGASIS and LEACH protocols, since our protocol will have combined the distance from CH to BS and residual energy of nodes in its election criterion of CHs. The simulation results also show that the proposed protocol output high connectivity by determine more CHs that reduce the distance to base station through multi-hopping data transmission. As the base station will calculate the rounds number that a CH can be alive for in advance, from this BS function a great effect on network life time to be extended by reduces the dissipated energy on replacing CHs.

3. Improvement of Intra-Clustering Communication

Clustering is approach that divide wireless sensor networks into many virtual groups; each group is contain a number of sensor nodes. The cluster is consisting of a leader called a cluster head and members of ordinary sensor nodes. Figure 3, present the cluster structure [14].

Clustering scheme is used to minimize the consumed energy in wireless sensor networks by reducing overhearing and overhead messages, also the process of clustering will prolong network lifetime by balancing sensor energy level. The cluster head is a node with distinctive characteristics, the responsibility of CH is (i) communications with all nodes in the cluster and (ii) collect data that send from sensor members and forwarding data to other CHs or relay data to sink node [15 and 4].

The selection of CH is an important issue in wireless sensor network, the improper selection of CH wills dramatically effects on the consumed energy in clustering scheme. For this reason, the selection of CH is vital issue to minimize intra-cluster communication [1], therefore the utilizing of powerful technique like DTA in this paper will have a major effect on nodes lifetime. CHs election is based primary on two parameters: firstly is the residual energy of node. Therefore, high residual energy node has high probability of selection as a CH. Secondly
is communication cost of intra-cluster, which is a function of the following metrics: (i) cluster features, like cluster size or the distance between cluster head and the closet sensor nodes; (ii) each node try to connect to its CH, must utilize minimum power level or must use the same power level for all intra-cluster communication [4].

For simplify, the intra-clustering communication between active nodes and CHs is done directly or through the hierarchical scheme [2]. On the other hand, inter-cluster communications are established when the connection between CH and base station or between two CHs, which is one of CHs responsibility [16].

Moreover, CH will manage the communication process through: (i) collect the transmitting data from active nodes, sends the aggregate data to the CH in upper level in multi-hop routing. (ii) A CH will forward the receive data from another CH to top level [17 and 2].

The energy dissipation of CHs in multi-hop routing algorithms is divided into two types (i) intra-cluster energy dissipation and (ii) inter-cluster energy dissipation between more than one CH. But in one-hop communication clustering algorithms only inter-cluster energy dissipation between the individual CH and sink node [2]. One of the most important jobs in our consideration is the management of consumed energy in intra-clustering communication in order to extend the network lifetime as long as possible.

Briefly, the main task of this paper is how to prolong entire network lifetime through reducing the intra-clustering communication energy, via reducing distance between active node to its belonging cluster head, and between CHs and base station or sink node. Figure 4 shows the structure of intra-clustering data gathering scheme.

4. Proposed Model

The proposed model architecture is consisting of one sink node and a number of homogenous nodes. Each cluster contains sensor member nodes and an elected cluster head, the cluster head will collect the sensing data from member nodes and forward the sensed data to sink directly or by multi-hop. Figure 5 present the flow chart of the proposed model.

In our proposed system the following presumption must be considered:

- All nodes in WSN are homogenous.
- All nodes position is fixed when deployed in observation area.
- Sensor nodes are randomly distributed.
- Each node has an ID number.
- Single sink node which positioned out of the scope field.
- All sensors nodes in the field must have data to be transmitted.
- Each individual cluster consists of a member of nodes.
- Node with high energy and closet distance to base station is select as cluster head.
- The initialized energy is same for all sensor nodes.
- Intra-clustering links are symmetric.
- Sensor node equipped with camera that sense the monitoring area.
- Each send packet has same size which equal to 4000 bits.
- The node is considered to die only when their energy is exhausted.
4.1 Energy Model

Generally, sensor nodes in WSNs are distributed randomly. The energy is exhausted mainly within communication in WSN as it depends mainly on the distance between each dual node [14]. The energy consumption model can be seen in Figure 6.

The calculation of consumed energy by transceiver unit and the entire consumed energy for intra-clustering communication by radio unit are as follow:

- The sensor member consumed energy through data transmission by its radio electronics.
- The amplifier circuitry of sensors also dissipates a considered energy.
- The cluster head receiver consumed energy through data receiving by its radio electronics.
- Data gathering and processing in cluster head consumed considering energy.
- The transmission and amplification energy by radio electronics of cluster head node to sink.

According to proposed energy model, the total consumed energy in transmission case is compute by collect the consumed energy from ordinary nodes and cluster head node. The consumed energy in receiving case is determined by the consumed energy from cluster head to collect data.

4.2 Energy Computation

The radio circuitry of member node will spend energy \( E_{elec} \) through data transmission, and \( E_{amp} \) energy for radio amplifier. Therefore, the gross energy for transmission m-bits packet data from member node to cluster head node with distance equal to \( d \) is given by:

\[
E_{Tx}(m,d) = mE_{elec} + mE_{amp} \times d^2
\]  

Where \( E_{elec} \) is the consumed energy per bit to run the transceiver circuit, \( E_{amp} \) is energy dissipated by amplifier to transmit single bit. \( d^2 \) is the distance between ordinary node and commander node, for free space model (less than the crossover distance).

The dissipate energy by cluster head receiver circuitry for receiving m-bit message from associated node is:

\[
E_{Rx}(m,d) = E_{elec} \times m
\]

The cluster consists of \( N \) nodes distributed in area of \( M \times M \). Each dissipate energy for cluster head will comes from two ways, by aggregation data from active nodes and by forwarding the collected data to the sink node. Thus, the energy consumed by cluster head is calculated by:

\[
E_{ch} = N \times E_{Rx}(m,d) + N \times E_{dc} + E_{Rx}(m,d)
\]

Where \( E_{dc} \) is the data collecting energy. For multi path model the distance from CH to sink node is greater than the radio distance of coverage area in each cluster. Therefore, the distance for multi path power loss is \( d^4 \). The overall energy dissipated by the CH is given by:

\[
E_{ch} = N \times E_{Rx}(m,d) + N \times E_{dc} + mE_{elec} + mE_{tran} \times d^4
\]

Where \( E_{tran} \) is the transmitter amplifier energy for multi path model.

4.3 The Proposition of Energy Values

- Initial energy supplied to each node (unit in Joules): \( E_0 = 0.5 \)
- Energy required to run circuitry (both for transmitter and receiver), \( E_{elec} = E_{Rx} = E_{Rr} \) (in nJoules/bit):
  \( E_{elec} = 50*10^{-9} \) (units in nJoules/bit)
  \( E_{Rx} = 50*10^{-9} \) is the transmitter energy per node (units in nJoules/bit)
  \( E_{Rr} = 50*10^{-9} \) is the receiver energy per node (units in nJoules/bit)
- Energy spent by the amplifier to transmit one bit is:
  \( E_{amp} = 100*10^{-12} \) units in (nJoules/bit/m^2)

The amplification energy in (nJ/bit/m^2), when \( d \) is less than \( d_0 \) (threshold distance) for free space is:

\[
E_d = 10^8 \times 0.000000000001
\]
The amplification energy in (pJ/bit/m^4), when \( d \) is greater than \( d_0 \) in multi path channel is:

\[
E_{mp} = 0.0013 * 0.000000000001
\]

Distance between cluster head and base station:

\[
d_s = \sqrt{\frac{E_d}{E_{mp}}} = 87.7m
\]

- Data collecting energy from cluster head node 
  \( E_{dc} = 5*10^{-9} \) (units in nJoules/bit)

5. **Simulation and Experimental Result**

The computation of energy dissipation in intra-clustering communication for transmission of sensed data by utilizing triple combined techniques is presented in this paper. Reducing the distance of transmitting data by intra-clustering communication is considered as a means to improve nodes energy exhausting, in order to conserve the network stability as long as possible and prolong the entire network lifetime. The format of the sensed data proposed to be sent by the active sensor nodes was assumed in this paper as images taken by a camera that was equipped to sensor nodes that have been deployed in the monitoring region.

The purpose of using the simulation experiment is to serve as a guide to the robustness of the designed protocol. The simulation will determine whether our designed protocol may maintain the specified criteria and requirements. Through the use of simulations, it is possible to determine whether the designed protocol complies with the specified standards and requirements. Therefore, by this section we can observe the performance of the proposed protocol and its superiority as compared with well-known protocols like LEACH, SEP and Z-SEP. MATLAB 2018b is the simulation platform to validate our protocol and explain its durability over the tested protocols. The simulations are achieved with the proposed parameters that are listed in Table 1.

100 sensor nodes are deployed randomly in network area of 100 x 100 meter with flat monitoring region. To evaluated the performance of the proposed protocol there are many metrics must be considered, the following sections will explain some of these measurement.

5.

5.1 **System Evaluation Practical Example**

An experimental example of 100 sensors that randomly distributed by using Voronoi diagram with 5 number of clusters, where the Voronoi diagram which partitioned the monitoring region into 100 objects of Voronoi cells is present in Figure 7. Clustered Voronoi cells by utilizing FCM clustering algorithm is illustrated in Figure 8. The cluster heads reconstruction by utilizing DTA method, also the distance between all elements of the CHs within the proposed network is shown in Figure 9.

5.2 **Residual Energy Computation**

The comparison of the residual energy in each round for VFDTA protocol and the three tested protocols, will be seen in Figure 7. The experimental results are done with 100 nodes and maximum rounds of about 3500.

The graph shows the residual energy in network at each round, we can clearly illustrate from the figure bellow that the residual energy for the VFDTA will be more than the residual energy of Z-SEP protocol and the result are better when compared with well-known protocols like LEACH and SEP protocols.

5.3 **The Period of Stability**

The period of stability will have explained the duration until the first node in the network will dies. This measure is a good factor to indicate the efficiency of any data transmission protocol. Therefore, long period of stability means that a large node number be alive for long duration. From Figure 8, we can see that the proposed protocol has long stable period than other tested protocols. Due to first node will die at later round than LEACH, SEP and Z-SEP protocols, this indicator shows that the VFDTA protocol is more stable because the network nodes be alive for a longer period of time.
5.4 Alive Nodes Number
This measure is utilizing to explain the network lifetime. The network is called high reliability if the nodes death rate is low. Network lifetime is the period of time that permits sensors nodes to transmit the most amounts of sensed data to the sink node or base station directly or by multi-hop.

The performance of the VFDTA protocol can be evaluated by make a comparison of network lifetime for the VFDTA and (LEACH, SEP and Z-SEP) protocols will be done. Simulation results is achieved by implementing the factor of a live nodes number with the rounds number, as explained in Figure 9. This graph will show the relation between alive nodes at each round of network lifetime, also illustrated that VFDTA protocol will clearly prolong the network lifetime.

5.5 Dead Nodes Number
From this metric the researchers in the field of wireless networks have introduced new sub-metrics from this title including, for example, the first node dies (FND), the half node dies (HND) and last node die (LND) to evaluate the performance of WSN in the terms of energy consumption, network stability and network lifetime. Figure 10, illustrates a bar chart for the first die node for each of the four tested protocols, we can see that our proposed protocol results are better than other tested protocols, due to the energy of nodes will be consumed after rounds number more than other tested protocols.

An extra comparison study of the FND and LND for different nodes number (50, 75 and 100) nodes, have been considered in this research. The simulation results are done between our proposed protocol (VFDTA) and the other tested protocols (LEACH, SEP and Z-SEP), will be shown in Figure 11 and Figure 12. The experimental results are done with three different nodes number and maximum rounds of about 3500. The Figure 11 shows the first node death for the three well-known protocols and our proposed protocol. The Figure 12 illustrates the last node death for the three protocols with VFDTA protocol.

6. Conclusion
A robust VFDTA protocol for data collection and transmission in limited resources wireless sensor network is being considered in this research. In order to overcome the limitation of energy resources for individual nodes and reduce the in intra-clustering communication distance, which have high effects on the consumed energy and network lifetime, the VFDTA is proposed. Firstly, Voronoi diagram could be utilized as prime sampling method for determining the WSN coverage area based on nodes energy.

Accordingly, the nodes are grouped by utilizing FCM clustering algorithm and cluster head nodes are elected by utilizing DTA method. The sensed data is transmitted from active nodes to its belonging CH, then CH collected sensed data and relay it to sink node or base station by directly or by multi-hop.

The main goal of VFDTA protocol is to reduce the intra-clustering distance, and evaluate its effects on the life of the network by distributing power consumption evenly through a more stable cluster heads. From the simulation results we can observe that the proposed protocol will promote the nodes residual energy because of smart election of CHs. Finally, from the evaluation metrics the performance of VFDTA protocol is better than well-known protocols (LEACH, SEP and Z-SEP) in terms of network stability, consumed energy and network lifetime.

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7. Appendix

Figure 1. Present intra and inter-clustering communication [5]

Figure 2. Architecture of sensing node [8]

Figure 3. Cluster structure [14]
Figure 4. The intra-clustering data gathering scheme

Figure 5. The flow chart of the proposed model
Figure 6. Radio energy dissipation model [14]

Table 1. Simulation parameters

| Parameter                     | Value                      |
|-------------------------------|----------------------------|
| Network size                  | 100 m x 100 m              |
| Monitoring Area Nature        | Flat                       |
| Nodes Number                  | 100                        |
| sinks Number                  | 1                          |
| Behavior of nodes             | Static                     |
| Sink node position            | [50, 100]                  |
| Clusters Number               | 5                          |
| Termination condition         | 0.00001                    |
| CH node Buffer size           | 35 packet                  |
| Sink Buffer size              | 100 packet                 |
| $E_i$ = initial energy for node | 2J                         |
| $E_{CH}$ = initial energy for CH node | 2J                        |
| $E_{elec}$                    | 50 nJ/bit                  |

Figure 7. 100 sensors that randomly distributed by using Voronoi diagram
Figure 8. Construction of 5 clusters by using FCM

Figure 9. The CHs reconstruction by utilizing DTA and distance between all elements of the CHs within the proposed network.

Figure 10: Residual energy for different protocols
Figure 11. Stability period for the four protocols

Figure 12. Alive nodes period for the four protocols

Figure 13. Bar chart of first die node for the four protocols
Figure 14. Bar chart of first die node for the four protocols

Figure 15. Bar chart of last die node for the four protocols