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Threshold Constrained Member Clustering-Performance Comparison against Other WSN Clustering Algorithms

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Abstract:- We have already present the new clustering algorithm named Threshold Constrained member Clustering (TcC) [8] in Wireless sensor networks (WSNs) This particular algorithms provide some solution for some of the WSN design issues and limitation like limited capacity of battery for Sensor nodes, highly costly Routing schemes etc. As a part of solution we proposed new scheme of Cluster head selection in WSN. We put constrained over the maximum number of member nodes supported by a cluster head based on a threshold value. The proposed clustering approach selects a cluster head from the available list of eligible sensors based on a new Weight function. The new weight function considers three major parameters for the selection criteria and they are as follows, residual battery level of sensor, energy consumption of communication device on sensor and distance of sensor node to the base station. We considered different existing WSN clustering algorithms like MbC, McC and MdC for comparison and then compared the performance of proposed algorithm (TcC) against these algorithms. We have performed the experiment for all these algorithms and evaluated Network lifetime, Response delay and Successful delivered packets for all these Algorithms.

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a specialized wireless network that composes of a number of Sensor nodes deployed in a specified area for monitoring environment conditions such as temperature, air pressure, humidity, light, motion or vibration, and so on. The networks consist of different components which performs different activities. Sensor Field: Sensor field are those field where the sensor nodes are scattered or deployed in randomly or deterministic manner. It is also called monitoring area. Sensor Node: Sensor node is a small hardware device. Sensor nodes detect environmental condition, processing them and transfer it into base station. Cluster Head: Cluster Heads are the organization leader of a cluster. It is a power full Node of Cluster. The Cluster heads has more battery power and hardware complexity compare to member node. Cluster head receive information from the sensor node and send it to base station. Sink: It is also called Base Station. The base station work as a gateway. It provides the communication link between the sensor network and the end-user. Internet: Through the communication Technology such as satellite, radio modems, high power Wi-Fi links etc., information broadcast to the end user. Sensors are hardware device and they measure physical data of parameter to be monitored. It is usually programmed to monitor or collect data from surrounding environment and pass the information to the base station for remote user access through various communication technologies. The main component of wireless sensor node is a sensing unit, a processing unit, a transceiver unit and a power unit. Sensing Unit: It is used to convert analog signal to digital signal which are generated by sensor node. It means sensing unit composed of two sub unit: Sensor: Sensor is a device which is used to translate physical phenomena to electrical signals. Sensors can be classified as either analog or digital devices. There exists a variety of sensors that measure environmental parameters Such as temperature, light intensity, sound, magnetic fields, image, etc. Analog to Digital converter: The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC and then fed into the processing unit. Processing Unit: The processing unit mainly provides intelligence to the sensor node. The processing unit consists of a microprocessor, which is responsible for control of the sensors, execution of communication protocols and signal processing algorithms on the gathered sensor data. Transceiver Unit: The functionality of both transmitter and receiver are combined into a single device known as a transceiver. Similar to microcontrollers, transceivers can operate in Transmit, Receive, Idle and Sleep modes. An important observation in the case of most radios is that, operating in idle mode results in significantly high power consumption, almost equal to the power consumed in the Receive mode. Thus, it is important to completely shut down the radio rather than set it in the idle mode when it is not transmitting or receiving due to the high power consumed. Battery: Sensor nodes small in size, light weight, cheap and the size of battery is very limited means low power battery. Battery plays a vital role for determining the lifetime of sensor node. The battery supplies power to the complete sensor node. The sensor node consumes power for sensing, communicating and data processing. In sensor nodes, data communication consumes more energy as compare to computation energy. The communication device on sensor has limited battery capacity and transmission range. They operate on battery and need to be recharge intermittently. Sometimes it is impractical to recharge a sensor immediately after energy depletion of the sensor's battery. An energy efficient WSNs can be developed by using energy-aware network protocol. In recent time many routing protocol have been proposed to improve the performance of route discovery. Most of them focused on finding the shortest path between the source and destination node which includes minimum number of intermediate forwarding nodes. A common problem WSNs is that the sensor node close to the sink will deplete their energy quickly because they need to forward information collected by any other

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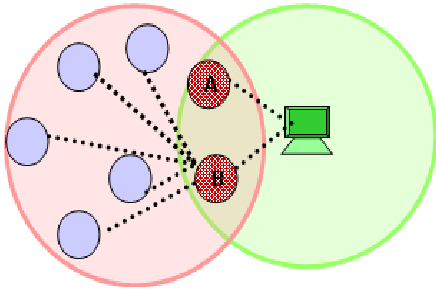
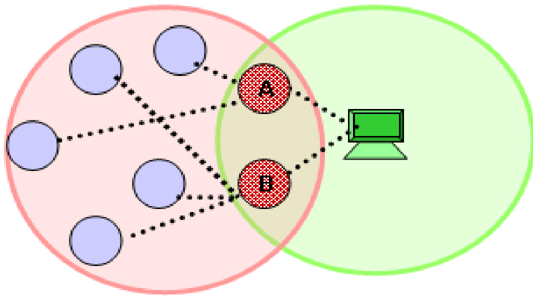
node. Therefore authors in [1] proposed a Local Update based Routing Protocol (LURP) that allows the sink node to move an update its location information. A cluster based routing protocol will group sensor node to efficiently forward the collected information to the sink. There are many hierarchical cluster based routing protocol proposed for wireless sensor network such as Hybrid Energy Efficient Distributed(HEED) Clustering Algorithm [2] and Low Energy Adaptive Clustering Hierarchical(LEACH) [3]. The authors proposed the cluster head selection approach based on weight function which includes energy and distance uses. In clustering algorithm the cluster head is selected based on some parameter value or constraints. There are some more clustering algorithms like Maximum Battery Clustering(MbC) [10] where Cluster Head selected based on the residual battery level, Minimum communication Cost Clustering(McC) [4] where cluster head selection based on minimum communication cost and Minimum distance Clustering(MdC) [9] where Cluster Head selected based on minimum distance with respect to each node. Authors in [6] proposed a protocol to increase the network lifetime in Wireless Sensors Networks by having uniform distribution of Cluster. Authors in [7] also proposed a new scheme of maximum lifetime of Wireless Sensor Networks using fuzzy analysis. In our proposed algorithm called Threshold constraint member algorithm (TcC). This put constraint over the maximum number of member node of each cluster head as shown in fig 1(b). In the old scheme a single cluster head overloaded with many sensor nodes to monitor and collects the information. Fig 1.a shows that cluster head B is overloaded with support responsibilities of multiple sensors. Fig 1.b shows the new scheme proposed in the TcC algorithm. It restricts the number of member nodes of each cluster head to be less than a threshold value. This way each cluster head will have a maximum set of member node which it can support without much burden. In our proposed algorithm each sensor node selects a cluster head from the eligible candidate list of cluster heads based on a Weight function. Weight function considers three parameters of sensor to select it as cluster head. These parameters are distance of sensor node to the base station, energy consumption of communication device on sensor and battery level of sensor. The next few section of the paper contains of the following section 2 present the energy model for each node's energy consumption. In this also have description our proposed clustering algorithm. Section 3 presents performance result of our proposed algorithm over other different algorithm. We also study a transmission range control in WSNs. In this section we compared and evaluated the performance of our proposed clustering algorithm and other clustering algorithm. Section 4 contains the summary of our work in this paper.



(a) A Cluster-Head and Member Links In Typical Schemes.



(b) A Cluster-Head and Member Links In The Proposed Scheme.

Fig 1. A Cluster-Head And Member Links In Wsns.

II. DESIGN AND ALGORITHM

A. Energy Design

In our research we have considered the "radio model" proposed in [4] for the energy consumption of each sensor node in wireless sensor networks. For data transmission between two nodes situated at transmission range of d meters. The transmitting and receiving energy can be defined as

$$E_{TOT}(i) = E_{TX} + E_{RX}, \qquad (1)$$

Where $E_{TOT}(i)$ is the energy consumption at node i, E_{TX} is the energy dissipated in the transmitter of the sending node given by

$$E_{TX}(b,d) = (E_{elec} \times b) + (\in_{fs} \times b \times d^2), \quad (2)$$

Term E_{RX} is the energy consumption at the receiving node given by

$$E_{RX}(b) = (E_{elec} \times b), \qquad (3)$$

Where E_{elec} the energy is expended in the radio electronics which is equal to 50nj/bits. $\in_{fs}$ = 10pj/bits/m is the energy consumed in free space at the output transmitter antenna for a transmitting range of one meter in wireless sensor networks.

B. Clustering Algorithm

This section contains our new cluster head selection algorithm. First phase is the Community Creation phase which covers complete monitored area with well distributed and compact manner. This leads in circular Community creation with equal numbers of sensor nodes deployment. Base station proposed some fix numbers of

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Sensor nodes in each community. These Sensor nodes are called Eligible Candidate and they get selected based on the distance from the Base station. In next phase, each Sensor nodes in each community approach these Eligible Candidates after receiving their advertisement message. Each Sensor node select one of the Eligible Candidate as its Cluster Head based on some selection criteria. In our case it is the Cost function value mentioned in next section. While one of the Eligible Candidate selected as Cluster Head, rest other nodes from Eligible candidate list get selected as Backup cluster heads. These backup Heads will own the responsibilities of Cluster Head in a situation where primary Cluster Head failed. Once Cluster Head selection phase is over, each sensor nodes will have Cluster Head and backup cluster Head allocated list. Next important phase is Cluster Formation phase. Each sensor nodes transmits its advertisement message and join request in the WSN and attached to the Cluster Head directly. When any nodes attached to a Cluster Head, then it's Node Degree incremented by one. When any cluster Head exhausted with more number of member nodes then, the corresponding sensor nodes attach to its backup head. This maintains the perfect load balancing across the complete the WSN. Last important phase in WSN is Routing Configuration phase. In this phase, each node will form a data forwarding path from Node to base station. Each sensor node first forwards its data to its Cluster Head and then Cluster Head will forward it to Base station using single hop routing. If Cluster Head belongs to any higher level will forward it to low level cluster head using multi-hop routing. In typical WSNs, a clustering algorithm selects a cluster head with minimum distance or minimum residual battery level. A weight function is commonly used or cluster head selection in a clustering algorithm. We consider a cost function presented in [5]

1 Minimum Cost Function

The minimum cost function combining both energy consumption and battery level for cluster head selection can be given as [5]:

$$C(i) = \left(E_{TOT}(i)\right)\left(B_{init}\right)^{1}\left(B(i)\right)^{-1}, \qquad (4)$$

Where B_{init} is initial battery level of sensor node and $B(i)$ is residual battery at node i. In order to increase the network lifetime, the minimum cost function algorithm will select a cluster head with minimum cost. As a result, the selected cluster head has high residual battery level and low energy consumption.

2 Threshold constrained member node clustering

A cluster head gets selected based on the value of cost function 2.2.1. Then member nodes of cluster head get selected. In our proposed algorithm we are using a threshold value put a constraint over a maximum number of member node supported by the cluster head. We have investigated different approaches to find the appropriate threshold value by varying the percentages of the total number of sensor network, we found that the appropriate threshold value in around 10 percentages. We divide sensor node into the groups where nodes within the base station's transmission range are defined in "layer 1" and nodes far from the base station defined in higher layer depending on the distance to the base station.

In Threshold constraint member node clustering (TcC) algorithm each sensor node within the "layer 1" he selects a cluster head from the candidate list using the new cost function given as

$$E_{avg} = \frac{1}{N}\sum_{i=1}^{N} E_{TOT}(i), \qquad (5)$$

Where $T_{BS}(i)$ is the distance between node i and base station and $T_{\max}$ is the maximum transmission range. The other node in the higher level which are not able to contact the node in "layer 1", selects the cluster head from other lower layer closer to the base station. The cost function for such nodes given as

$$C(i) = E_{TOT}(i)\frac{B_{init}}{B(i)} + \frac{T_{BS}(i)}{T_{\max}}, \qquad (6)$$

Once a cluster head is selected, and its number of member node reach to maximum threshold then any other node will not be added to the same cluster head even though it has low cost function value. This way threshold constrained member cluster node algorithm can distribute the member nodes to each cluster head. This approach have many benefits as, less burden on the cluster head to support limited member node, reduces the time to send packets to the base station etc. since the proposed algorithm selects a cluster head based on the cost function, the selected cluster head can keep high residual battery level and short distance to the base station. The threshold constrained member node clustering is a design approach to enhance network lifetime and reduce communication delay.

III. RESULT

We compared the performance of our proposed algorithm Threshold constrained Member node Clustering (TcC) with other existing algorithms like Maximum battery Clustering (MbC), Minimum cost function Clustering (McC), and Minimum distance Clustering (MdC). We consider a wireless sensor network of 100 nodes randomly distributed in a square area. We also have following assumptions, each sensor node has initial battery level of 500 Joule (J) and any node after complete energy depletion will disconnect from the network automatically. In our study, the length of datagram packet is fixed at 500 Kbits. The data rate for communications is 250 Kbps. We assume that the period of sensing devices to monitor or collect environmental data is 1 day. Each algorithm executes for 10 runs using randomly generated network topologies. We use following performance metrics to evaluate and compare among routing algorithms.

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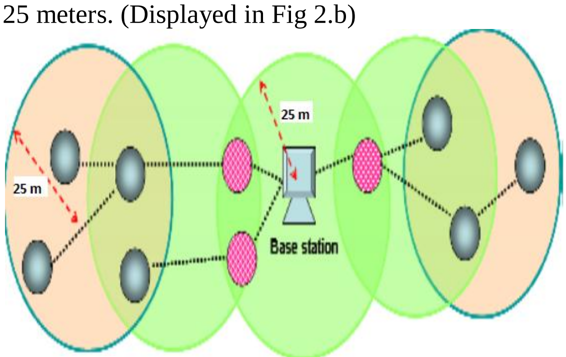
1. Number of successfully delivered packets is the number of times that packets can be successfully delivered to the base station more than 80% of total packets sent by all sensor node in network.
2. Network lifetime is the duration from the start up time until the first node is disconnected from the network due to it run out of battery.
3. Delay time is the period of time that the base station takes to receive packets successfully.
4. Average network energy consumption per node $E_{avg} = \frac{1}{N}\sum_{i=1}^{N} E_{TOT}(i),$ Where N is the number of sensor nodes and $E_{TOT}(i)$ is defined as equation (1) in section 2.

A. Transmission range impact:

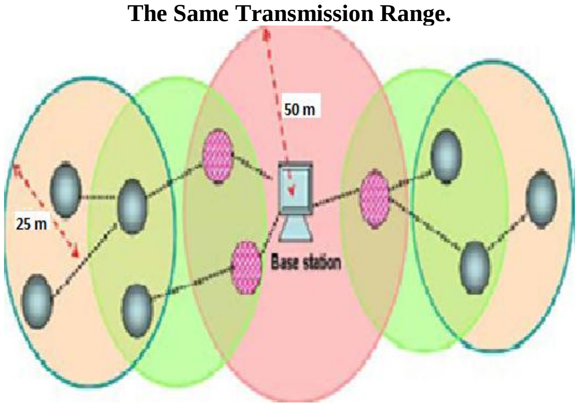
In our experiment, the base station is located in the center of the area. To evaluate the impact of transmission range, we consider two scenarios:

1) Both the base station and each sensor node has a transmission range of 25 meters (displayed in Fig 2.a)

2) The base station extends its transmission range to 50 meters while each sensor node has a transmission range of 25 meters. (Displayed in Fig 2.b)



(A) Scenario1: The Base Station and All Sensor Nodes Have The Same Transmission Range.



(B) Scenario2: The Base Station Has Extended Transmission Range.

Fig 2 Transmission range in Wireless sensor Network

A link formed between any pair within the transmission range. Each node selects a cluster head and form a cluster according to the self-organized manner. The communication process in WSNs is described in [5].

The results of the two scenarios with transmission range constrains are compared and discussed as the following.

1. The transmission delay time

Figure 3 compares the delay time of different scenarios for all algorithms. The result show that the extended transmission range of the base station to the node in “layer 1” (scenario2) gives shorter delay time than the limited transmission range (scenario1). This is quite obvious as Extension of transmission range will increase the number of nodes in “layer1” which connect with the base station directly and reduce the number of member nodes in higher layer. We can see that TcC stand really well against all the algorithms in both the scenarios.

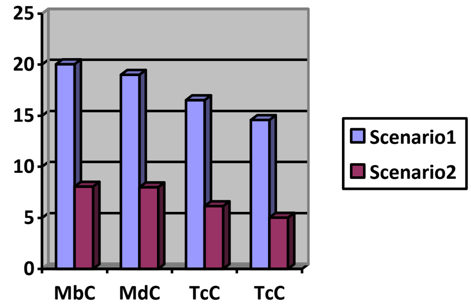


Fig 3 Algorithms(Horizontal) Vs Delay Time in Seconds(Vertical)

2 The network lifetime

Figure 4 shows the network lifetime of different scenario for all clustering algorithms. It can be observed in scenario2 have longer network lifetime than scenario1.The reason is because expanding the transmission range will also increase the number of nodes within the base station’s transmission range. Therefore, it reduces the amount f aggregated data packets which are forwarded to the base station since nodes can connect with the base station directly. TcC has the longest network Lifetime as compared to all the algorithms in both scenarios.

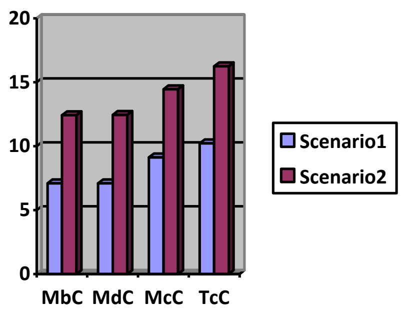


Fig 4 Algorithms (horizontal) vs. Network lifetime in hours (vertical)

3 Successful delivered packet

We compare the number of successfully delivered packets for all clustering Figure 5 shows this comparison for different scenario using transmission range constrains. It can be seen that all algorithms in scenario2 allow more

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sensor nodes to have direct connectivity with the base station. Therefore, the number of successful packets delivered in the network increases. TcC has best case of Successful delivered packets.

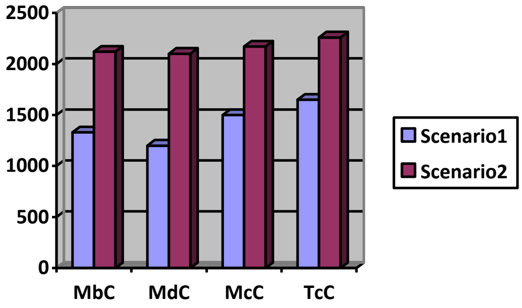

Fig 5 Algorithms (Horizontal) Vs. Successful Delivered Packet (Vertical)

IV. CONCLUSION

We propose a new clustering approach called the threshold constrained member node clustering algorithm for wireless sensor networks in this paper. A new cost function is also presented for the cluster head selection algorithm. We also study the impact of transmission range in wireless sensor networks. We found that the performances of clustering algorithms improve when we extend the transmission range of a base station. Simulation results show that the proposed algorithm (TcC) performed really well in Network Lifetime, Response Delay and Successful delivered packet in WSN as compared to other existing WSN clustering algorithms.

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