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Energy Efficient Clustering Method for Wireless Sensor Networks using Dynamic Power Management

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***Abstract*— A Wireless Sensor Network (WSN) comprises of many sensor nodes each one containing a processing unit, one or more sensor, a radio for data communication and power unit usually equipped with a low capacity battery. WSNs are made up of small energy constrained sensor nodes. Nodes in the same cluster send data to its own cluster-head. Cluster head selection approach is to extend network lifetime and reliability by taking obstacle-aware criteria into consideration. All sensors present in wireless sensor network are battery operated devices which have limited battery power In this an improvement has been made to energy efficient dynamic power management(DPM) technique which shuts down the sensor node when there is no work. DPM is an effective tool in reducing system power consumption without significantly degrading performance. Shut down the node when not needed and wake them up when necessary which yields better savings of energy and enhance lifetime. DPM strategy attempts to minimize the power consumption of the system by dynamically defining the most economical operation conditions.**

***Keywords*— *WSNs, sensor nodes, clusters, cluster head and Dynamic Power Management*.**

I. INTRODUCTION

A wireless sensor network (WSN) typically consists of a sink node and a large number of sensor nodes, each of which gathers information from its vicinity and delivers collected data to the sink for further processing in a possibly multihop fashion. The sensor nodes usually operate with batteries and are often deployed into a harsh environment. Once deployed, it is hard or even impossible to recharge or replace the batteries of the sensor nodes. Therefore, extending the network lifetime by efficient use of energy is a critical requirement for a WSN. The sensors lifetime depends on the energy of the sensor nodes which is limited by the battery of the node. Clustering is considered to be an energy management strategy in wireless sensor networks and Leach is one of the most well known clustering mechanisms. Clustering is one of the energy management strategies in wireless sensor networks which divides the network into a number of clusters and in each cluster a nodes is assigned as cluster head. Instead of each node sending their own data directly to the base station nodes in a cluster send their data to the cluster head, then the cluster head aggregates the received data and send it to the base station LEACH is a method that move cluster head location to central position of a local cluster for energy efficiency and load balancing after randomly selecting a cluster head. Deterministic cluster-head selection is a method which elects a cluster head using by remaining energy level of nodes as determining the threshold that is probability of a cluster head. The most clustering algorithms can cause additional energy drain as information exchange between nodes.

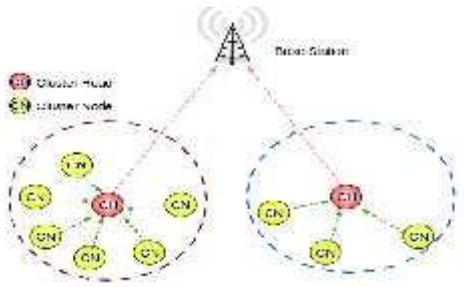

Fig 1: Cluster formation

1.1 Advantages of using DPM technique

Reducing energy consumption is one of the key challenges in sensor networks. One technique to reduce energy consumption is Dynamic Power Management.

- DPM is an effective tool in reducing system power consumption without significantly degrading performance.
- The power regulator monitors and adjusts each logical processor in a sensor network independently.
- DPM mode lets the processors operate in low power state or high power state as needed.

1.2 Architecture of WSN with DPM

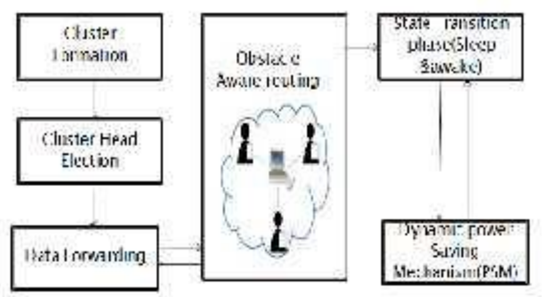

Fig 2:WSN with Dynamic Power management

The energy efficient routing scheme should guarantee uninterrupted network connectivity, which will minimize the energy consumption. In most of the remote area applications when the WSN node depletes all its energy, replacement of the power source is not possible and it may also be an inefficient one. The sensor node lifetime mainly depends on the battery lifetime in sensor networks. Nodes that are not currently needed for ensuring connectivity can go to sleep and save energy. Finding the optimal subset of nodes that guarantee connectivity, is referred to as topology control. In power management, active nodes do not need to maintain their radio continuously on. They can switch off the radio and enter into a low-power sleep mode when there is no network activity, thus alternating between sleep and wake up periods. Depending upon the application, sleep/wake up protocols could be used separately or in connection with MAC protocols.

II. RELATED WORK

Tapan Kumar Jain et.al [1] proposed a "cluster head selection algorithm" for a wireless sensor network that a node can be a cluster head if it is connected to at least one unique neighbor node where the unique neighbor is the one that is not connected to any other node. If there is no connected unique node then the CH is selected on the basis of residual energy and the number of neighbor nodes. With the increase in number of clusters, the processing energy of the network increases; hence, this algorithm proposes minimum number of clusters which further leads to increased network lifetime. The major novel contribution of the proposed work is an algorithm that ensures a completely connected network with minimum number of isolated nodes. An isolated node will remain only if it is not within the transmission range of any other node. With the maximum connectivity, the coverage of the network is automatically maximized.

Muhammad Imran and Asfandyar khan et.al [2] proposed a "homogeneous wireless sensor networks (WSNs)"to minimizing long range communication. Sensor nodes are resource constrained particularly with limited energy that is difficult or impossible to replenish. LEACH (Low Energy Adaptive Clustering Hierarchy) is most well -known cluster based architecture for WSN that aims to evenly dissipate energy among all sensor nodes. In cluster based architecture, the role of cluster head is very crucial for the successful operation of WSN because once the cluster head becomes nonfunctional, the whole cluster becomes dysfunctional. A coordinator node (CN) is rich in terms of resources. This CN take up the responsibility of transmitting data to the base station over longer distances from cluster heads. The K theorem is used to select candidate cluster heads based on bunch of sensor nodes in a cluster.

Anitha and Kamalakkannan et.al [3] proposed energy efficient routing algorithms to forward the incoming packet when the sensor nodes are stationary. Some of the applications in WSN must combine with both mobile sensor nodes and fixed sensor nodes in the same networks. When mobility is functioned there should be performance degradation. Because these nodes are equipped with a lesser amount of memory, restricted battery power, little computation capability, and small range of communication. So there is a need for energy efficient routing protocol to forward the incoming packet. Energy Efficient Cluster Head Selection Protocol in Mobile Wireless Sensor Network (EECHS-MWSN) is used. The cluster-head nodes are selected from the residual energy, lowest mobility factor and density of the node. It is also used that the Gateway nodes are act as an intermediate node to transfer the data to the Base station.

Muhammad Aslam and Ehsan et.al [4] proposed development of energy effective path planning algorithm in order to tackle the issues of limited life-time for Wireless Sensor Networks (WSNs). Overall advancement in routing protocols prove that clustering is much better approach as compared to flat and location-based energy efficient routing protocols. HADCC model is fascinated with hybrid cluster head selection algorithm. This hybrid algorithm makes decision of cluster head selection of nodes. In order to execute proposed model an advance network topology, in which the whole network region is divided into two physical levels. First physical level consists of a circular region, containing homogeneous normal nodes and all important Base Station. While, second physical level is outer region of the circle that contains advanced heterogeneous nodes.

Basavaraj and Siddarama et.al [5] proposed a method to develop a data aggregation technique which is energy efficient and reliable. Initially a cluster is formed and the cluster head is selected based upon the cost value. The nodes in the cluster maintain a Neighbor information table (NIT) containing Node id, Distance and Cost. This NIT information is sent to the cluster head. Each cluster selects a coordinator node (CN) randomly in the network which is closer to the cluster and monitors the operations of the sensor nodes and commands them for specific operations. The cluster head aggregates the data and sends it to the CN. The CN calculates the loss ratio which is the ratio of number of packets dropped and total packets broadcast from the source. Based upon the loss ratio, the cluster size can be modified and the forward node count of each node can be incremented or decremented. Once the cluster size is changed, the CN gathers the information again from the cluster head compresses it and sends it to the sink. Since the loss ratio is measured at the CN itself, the energy consumption can be effectively reduced. Also the reliability can be increased due to altering the cluster size before the data is transmitted to the sink.

III. PROPOSED WORK

The WSN architecture, as well as the energy efficient routing scheme should guarantee uninterrupted network connectivity, which will minimize the energy consumption. To reduce energy consumption, Obstacle aware criteria is used. The paths between the Gateway nodes and the Sink are strictly monitored by the supervisors because they are the critical elements. If suppose there is no obstacle in these paths. The appearance of obstacles is possibly in the paths between the cluster-head candidates and the Sink during network operation. These obstacles may highly damage the communication link between the clusters and the Sink if these candidate nodes are promoted to become cluster-head nodes. Nodes that are not currently needed for ensuring connectivity can go to sleep and save energy. In power management, active nodes do not need to maintain their radio continuously on. Depending upon the application, sleep/wake up protocols could be used separately or in connection with MAC protocols.

A. Clusture Structure

During this phase, all the sensor nodes in the Wireless Sensor Networks are divided into smaller groups known as clusters. These groups are then involved in cluster head selection. Clusters are formed by the Base station (BS) in the basis of geographical locations of the sensors. During the first round, the base station first splits the network into two sub clusters, and proceeds further by splitting the sub clusters into smaller clusters. The base station repeats the cluster splitting process until the desired number of clusters is reached. When the splitting algorithm is completed, the base station will select a cluster head for each cluster. But nodes formed in the clusters are not an equal number in each of the cluster.

B. Cluster Head Selection

In this phase, Base station broadcasts a request message to all the nodes in the clusters using a non-persistent carrier-sense multiple access (CSMA) MAC protocol. After received the request message each node responds with current information messages which includes its basic information like node's ID, node category and also about the residual energy, Mobility factor and density of the node. The remaining energy of the mobile node is considered by subtracting the total energy dissipated during the transmission from initial energy of the mobile node. Mobility is calculated based on the number of times a node changes from one cluster to another or on the basis of remoteness. Density of the node is calculated from ratio of Average distance from other nodes in same cluster and inter-node distance. These factors ensure that whether the node, to be selected as CH, belongs to a density popular area as well as the residual energy and mobility of the node within the cluster is on average. After the selection of the CH node, it should inform their role to the other nodes in the networks. To do this, each Cluster head node broadcasts an advertisement message (ADV) using a non persistent CSMA MAC protocol to other nodes. This message is a small message containing the node's ID and a header that differentiate this message as an announcement message. After received the message from CH, each node transmits a join-request message (Join-REQ) back to the cluster head. This message is again a short message, consisting of the node's ID and the cluster head's ID. If all nodes have the same initial energy then the CH is selected on a basis of random number i.e., between 0 and 1 and CH probability, which is similar to the LEACH protocol. The cluster head node sets up a TDMA schedule and transmits this schedule to the nodes in the cluster. This schedule ensures that there are no collisions among data messages. After the TDMA schedule is known by all nodes in the cluster, the set-up phase is complete and the data transmission can begin.

C. Obstacle Aware Cluster Head Selection Approach

All the sensor nodes in the network can monitor their remaining energy by themselves. In our study, the paths between the Gateway nodes and the Sink are strictly monitored by the supervisors because they are the critical elements. If suppose there is no obstacle in these paths. However, the appearance of obstacles is possibly in the paths between the cluster-head candidates and the Sink during network operation. Obstacles may highly damage the communication link between the clusters and the Sink if these candidate nodes are promoted to become cluster-head nodes. As a result, that diminishes packet delivery ratio and throughput of the network, and increases energy dissipation due to data retransmission.

In this, our cluster structure has consider four types of sensor :

• Normal nodes capture and deliver data directly to the Gateway.

• A set of cluster-head candidate nodes (CH-Can) that are selected during network deployment, these nodes are similar to normal node. Their location is much closer to the Sink than the normal nodes, because transmitting cost is more expensive when the cluster-head is far from the Sink.

• Temporary Cluster-head (Tempo-CH) is similar to normal node, it will replace temporarily cluster head role if the Gateway is suddenly down due to energy depletion or hardware-failure. Then it launches selection mechanism to find future cluster head in the candidate set. The Tempo-CH node itself is also a cluster-head candidate.

• Gateway or cluster head of cluster is responsible for receiving and aggregating data, then transmitting it directly to the Sink.

Step 1: When the Gateway detects its energy level lesser than an energy threshold (EGateway < ElowerBound), it sends notification packet to Tempo-CH. This packet includes the number of transmission to Sink per hour NbTxToSink.h−1 and the number of reception per hour NbRx.h−1, which are used for cluster-head selection.

Step 2: After receiving notification from Gateway, Tempo- CH launches cluster-head selection by sending the request of operating energy level (OEL) value to all cluster-head candidates (CH-Can). The NbTxToSink.h−1 and NbRx.h−1 values are included in sending packets.

Step 3: After receiving OEL request from Tempo-CH, CHCan node saves the values of NbTxToSink.h−1 and NbRx.h−1, and then sends a beacon signal to the Sink to verify if there is an obstacle in their path. The Tempo-CH also sends a beacon signal to the Sink.

Step 4: Based on the power strength of received beacon signal RSSI (Received Signal Strength Indicator), the Sink provides received power level (RPL) value, and sends it back to sender node (CH-Can node). The smaller RPL value is, the greater possibility an obstacle appears in the communication path.

Step 5: After receiving the RPL value from the Sink, CHCan node computes its OEL value following the Equation and sends this value to the Tempo-CH node.

$$OEL = \frac{Eresidual}{ETxToSink * NbTxToSink.h-1 + ERx * NbRx.h-1} * RPL$$

Where $E_{TxToSink}$ is dissipated energy to transmit data packet to Sink, and E_{Rx} is receiving energy of a data packet.

$E_{Tx} = E_{elec} * k + \alpha_{amp} * k * d^2$

$E_{Rx} = E_{elec} * k$

Step 6: After receiving OEL values from all CH-Can nodes, Tempo-CH selects the node with the highest OEL value to become future cluster-head. Tempo-CH also participates in this selection.

Step 7: When the selection is complete, Tempo-CH sends selection result to all the nodes in the cluster in order to update their routing table. The Gateway leaves cluster-head role after receiving this result.

After leaving cluster-head role, the Gateway still operates normally such as data sensing, data transmission to actual cluster-head, in order to maintain the reliability of the network. When recharging energy level of Gateway node reaches to 10% of battery capacity, it retakes the cluster-head role by transmitting notification message to all sensor nodes in the cluster, in order to update their routing table. The case of failed Gateway due to hard-failure is also considered. To detect this problem, Tempo-CH sends periodically a beacon message to Gateway, if it does not receive any feedback from Gateway, Gateway is considered as failed. Tempo-CH replaces immediately cluster-head role, and then executes cluster-head selection from second step to seventh step. In this case, Gateway only rejoins in cluster operation after being repaired by technician.

D. Dynamic Power Management

DPM is an effective tool in reducing system power consumption without significantly degrading performance. The basic idea is to shut down devices when not needed and wake them up when necessary. The shutdown techniques can yield substantial energy savings in idle system states, additional energy savings are possible by optimizing the sensor node performance in the active state. Dynamic voltage scaling (DVS) is an effective technique for reducing CPU (central processing unit) energy. Once the system has been designed additional energy saving can be done using Dynamic Power Management. However, it is not easy to decide which nodes should sleep and which should be active at in given time. Dynamic operation mode technique can be discussed through two policies Power-Aware sensor node model and Sleep state transition policy.

E. Power Aware sensor node model

Every sensor node consists different components like processor to process the incoming data, memory in order to store the data, sensor component to sense the data from environment and radio in order to transmit or receive or for both transmission and receive purpose. Depending on the different states of components there exist different states that are shown in table1. If all the components are in active state, that state is called active state which is represented as S0.In order to reduce the power consumption some of the components should be turn off. In sleep state S4,all the components kept into off state. So this state is called as deepest sleep state. Deepest sleep state takes very less power compare with all other sleep states because all components in off state in this.

State	***Processor***	***Memory***	***Sensor***	***Radio***
S0	Active	Active	On	
S1	Idle	Sleep	On	RX
S2	Sleep	Sleep	On	RX
S3	Sleep	Sleep	On	Off
S4	Sleep	Sleep	Off	Off

Table 1- Different State of Component.

F. Sleep State Transition Policy

In this how and when the sleep states will be selected to save the energy and also we will see at what value of threshold, transition from one sleep state to another sleep state happens. Assume an event is detected by node k at some time. The node finishes processing the event at t1 and the next event occurs at a time t2=t1+ti, where ti is idle time. At time t1, node k decides to transition to sleep state Sk from the active state S0. Each state Sk has power consumption Pk,and the transition times to it from the active state. By definition of node sleep state, P*j*> P*i*,(d,i) >(d,j) and (u,i) > for any i>j. Now we derive a set of sleep time thresholds{T(th,k)} corresponding to states{Sk}, where k lies between 0 to N,for N sleep states. Transitioning to sleep state Sk from state S0 will result in a net energy lose if idle time *ti*< T(th,k) because of the transition energy overhead. The energy saving from a state transition to sleep state is given by Esave,k= P0ti-{(P0+Pk)/2} {(d,k)+k(ti-) Such a transition is only justified when *E*save,k>0.The transition from one state to another is useful when energy saved must be greater than energy consumed. So the energy saving must be greater than energy expended by the sensor node for certain threshold value of time. T(th,i)=[+{(P0+Pi)/(P0-Pi)} An accurate event arrival model enables a DPM strategy to decide for the right configuration that has a long duration and minimal power consumption.

IV. CONCLUSION

In this paper, when the sensor nodes are deployed in the harsh environment there is possibility of conserving more energy because of obstacles appears in the network. This problem can be solved using Obstacle aware Cluster head selection algorithm. This algorithm will improve the network lifetime and reliability. The energy-efficient Method Dynamic Power Management (DPM) is also applied to reduce the energy consumption inside the sensor nodes, in order to increase their lifetime. In future, we can also apply compressive sensing technique to reduce the number of data transmissions and to balance the traffic load throughout networks.

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