IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

LOW ENERGY CLUSTERING HIERARCHY (LECH) PROTOCOL FOR STATIC WIRELESS SENSOR NETWORKS

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***Abstract*—**Network lifetime is the major constraint in the design of the wireless sensor network. Designing an energy efficient routing algorithm to increase the network lifetime is one of the most significant design criteria of wireless sensor networks. Various clustering techniques are used previously to augment the network lifetime. A novel routing protocol, Fixed Low Energy Clustering Hierarchy (FLECH) is proposed to achieve the increased gross lifetime of the wireless sensor network. FLECH is a hierarchical based routing that has fixed clusters and heterogeneous nodes. A cluster head is elected in each of the fixed clusters based on two attributes of nodes, energy and distance from the base station. As the event occurs the member nodes communicate the message to its respective clusters heads using Adaptive on Demand Distance Vector (AODV) algorithm. Then the cluster heads aggregate the received data and transmit it to the base station.

Keywords*— *AODV, FLECH

I. Introduction

The advancement in the technology has afforded us to manufacture small and low cost sensors that are economically and technically feasible. The sensing element senses the ambient conditions of the area where it is deployed and converts that physical signal into an electrical signal. The converted electrical signal is processed and studied to learn about the properties of object located and /or events happening around the sensor. A network of these disposable sensors is used in several applications in which human intervention is nearly impossible. A wireless sensor network consists of a large number of sensing units. Each of these sensors can communicate either amongst each other or with the base-station (BS). The ambient conditions of a large geographical area can be monitored with the help of large number of sensors nodes. Each sensing unit performs various operations. They are sensing, processing and transmitting. Host of wireless sensor nodes are deployed aerially over a field in a random fashion. These sensor nodes measure and monitor field ambient conditions of interest. The quality of information
about the physical environment produced depends on the efficacy of the sensing unit. It makes decision based on its mission, attribute value table and its communication, computing and battery capacity.

In the recent years, researchers are intensively exploring the potential of networked sensor nodes in information collecting and processing and the possible ways of establishing co – ordination amongst them. The major roadblock researchers are facing in sensor network design is limited supply of energy and bandwidth. Thus, innovative techniques that eliminate energy inefficiencies that would shorten the lifetime of the network are highly required.

Hence in an effort to address these inefficiencies, an efficient data routing protocol has been proposed. The network structure is devised based on hierarchical network structure where in the sensor nodes are clustered and cluster heads performs data aggregation and transmission in order to reduce energy consumption. Within the cluster multi- hoping shortest path finding technique is used to relay data from source node to cluster head. It is a data centric, event based routing protocol in which data transmission occurs only when the sensor node detects the occurrence of an event. Various techniques have been adopted to increase the network lifetime. The proposed routing protocol is simulated using NS2, network simulator. Network simulator is a discrete event network simulator. It is used by the researchers in researching computer networks. Simulator basically uses TCL language for simulation. The output of simulation contains all the information about communication that is how the packet is forwarded. Here it also shows the animation of the experiment result.

II. Literature Survey

LEACH was devised by W.B.Heinzelman. LEACH protocol was the resolution for the limited energy problem. In this protocol, nodes are arranged in smaller groups in order to create a cluster. These clusters organise themselves and a cluster head is elected for each of the clusters among the member nodes by randomised method. The role of the cluster heads are rotated among the cluster member nodes in a random fashion. Nevertheless, this protocol produces a good result. LEACH protocol operates in rounds. Each round consists of two phases. One set up phase and another steady state phase [1].

In order to eliminate the inefficiency incurred due to randomised method used for cluster head selection, Fuzzy Inference System (FIS) is made use of. It comprises three parts: fuzzier, inference engine and defuzzifer [2].

The normal sensor nodes on receiving advertisements from many cluster heads takes a call as to which cluster head to join for cluster formation based on the signal strength of the received advertisements. In order to reduce the transmission overhead on cluster heads gateway nodes have been placed around the periphery of the area. These nodes act as a gateway to the base station. Hence reducing the transmission overhead on cluster heads and increasing the network lifetime [3].

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MHRP is a combination of both multi-chaining and chain leader selection concepts. It is an optimised version of PEGASIS. It has been largely successful in cutting down the energy consumption and increasing the network lifetime. It comprises two stages. At the first stage, the entire area under supervision is divided into four equal regions. Each region contains equal number of nodes. It makes use of greedy algorithm for chain formation in each region. In the second stage, the chain leader is elected based on which node responds first to the message broadcasted by sink. Once after the election of chain leader data transmission occurs and after certain number of transmissions cycle repeats [5].

DERP a chained based protocol which improvises PEGASIS [6].

Problem Statement

The wireless sensor networks deployed in a remote region for sensing certain ambient conditions vital for certain applications are power constrained. The batteries of the nodes forming the sensor network are irreplaceable or not feasible to replace as they are deployed in a remote location. For the network to be cost worthy, it should have a longer network lifetime. Network lifetime can be enhanced with an energy efficient routing protocol.

The proposed system focuses on one aspect of the wireless sensor network i.e. data routing. Data transmission incurs a major cost on the energy of the nodes. Several different routing protocols have been proposed until now by researchers in order to achieve effective and efficient data transmission. A novel routing protocol, FLECH (fixed low energy clustering hierarchy) has been designed to enhance the network lifetime by consuming lesser energy for data transmission.

IV. System design and Implementation

LECH Method

Low Energy Clustering Hierarchy is a novel routing protocol whose sole objective is to increase the network lifetime. This routing technique has been devised after a tedious research in pursuance of the set objective. It is an on-demand reactive protocol having a hierarchical network structure. The deployment of sensor nodes over a field is randomised. Multi-hoping technique is being used. There each node plays a dual role as data router and data sender. The sensor nodes deployed are homogenous i.e. having equal capacity in terms of power, transmission, processing and communication. The network is scalable. The routing has two layers where one layer is used for the selection of cluster-heads and the other layer is used for routing and packet transmission. A detailed description of all the stages involved is given below.

Fragmentation of Area into Fixed Clusters

The sensor nodes deployed area is at the outset fragmented into four segments or quadrants. The fragmentation is performed by taking the base station as the reference that is the point of origin; the field is fragmented into four different regions or quadrants. The decision as to which fragment or quadrant the node belongs to is made based on the distance (distance with respect to base station) and the orientation with reference to the base station. The four quadrants or fragments that are formed are taken to be clusters. The clusters that are formed are fixed throughout the network lifetime as opposed to the dynamic clusters in LEACH protocol.

Election of Cluster-Head

Once after the formation of fixed clusters, election of cluster head takes place in each cluster. The role of cluster head rotates after the occurrence of every 15 events. Cluster head has dual task. One, it acts as the nodal centre for data transmission and two; it aggregates the received data and eliminates redundant data packets.

Each of the fixed clusters contains homogenous nodes as opposed to the SEP protocol where the deployed nodes are heterogeneous. The cluster head is elected amongst the homogenous sensor nodes in each of the fixed clusters based on the distance from the base station and the residual energy. The node having highest residual energy and shortest distance from the base station gets elected as the cluster head.

Data routing

Now the actual data transmission takes place. The proposed routing protocol is an event driven routing technique. The sensor nodes in each of the fixed clusters on sensing the event flags the respective cluster-heads as to the availability of data. AODV routing technique is used to route the sensed data from source node to the cluster head (sink node). Cluster head acts as a gateway to the base station. The role of cluster head rotates within the cluster after every 15 events. The cluster head is elected amongst the homogenous sensor nodes in each of the fixed clusters based on the distance from the base station and the residual energy. The node having highest residual energy and shortest distance from the base station gets elected as the cluster head.

AODV

Ad Hoc networks have lots of routing protocols to establish the routes from source to destination. These routing protocols are mainly classified into two type's viz. Proactive and reactive routing protocols. Ad hoc On-Demand Distance Vector (AODV) Routing is a reactive routing protocol for mobile ad hoc networks (MANETs) and other wireless ad hoc networks.

AODV Operation

In AODV, the network is silent until a connection is needed. At that point the AODV nodes forward this message, and record the node that they heard it from, creating an explosion of temporary routes back to the needy node. Whena node receives such a message and already has a route to the desired node, it sends a message backwards through a temporary route to the requesting node. The needy node then begins using the route that has the least number of hops through other nodes. Unused entries in the routing tables are recycled after a time. Network node that needs a connection broadcasts a request for connection. When a link fails, a routing error is passed back to a transmitting node, and the process repeats. The flowachart of the AODV protocol is as shown in figure 1. The AODV Routing Protocol uses an on-demand approach for finding routes, that is, a route is established only when it is required by a source node for transmitting data packets. It employs destination sequence numbers to identify the most recent path. The major difference between AODV and Dynamic Source Routing (DSR) stems out from the fact that DSR uses source routing in which a data packet carries the complete path to be traversed.

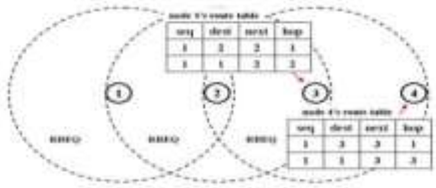

Figure 1: AODV Routing table entries

In AODV, the source node and the intermediate nodes store the next-hop information corresponding to each it employs destination sequence numbers to identify the most recent path. The major difference between AODV and Dynamic Source Routing (DSR) stems out from the fact that DSR uses source routing in which a data packet carries the complete path to be traversed. In AODV, the source node and the intermediate nodes store the next-hop information corresponding to each flow for data packet transmission. In an on-demand routing protocol, the source node floods the Route Request packet in the network when a route is not available for the desired destination. It may obtain multiple routes to different destinations from a single RouteRequest. The major difference between AODV and other on-demand routing protocols is that it uses a destination sequence number (DestSeqNum) to determine an up-to-date path to the destination. A node updates its path information only if the DestSeqNum of the current packet received is greater or equal than the last DestSeqNum stored at the node with smaller hop coun

System Implementation

Step 1: Aerial deployment of homogenous nodes in a remote two dimensional field with an area of 100sqmts, whose certain ambient conditions are to be measured in the interest of an application.

Step 2: Fragmentation of the field into four fixed clusters with each cluster having 15 nodes and the base station at the centre for simulation purpose.

Step 3: Soon after the fragmentation election of the cluster heads takes place. Each of the nodes in the network has the knowledge of its co-ordinate values. Cluster head is elected based on the root mean square value of a node's distance from the base station and its residual energy. Distance from the base station is calculated using the distance formula. Node with the highest RMS value gets elected as the cluster head. The formulae for calculating distance and the RMS value is given below.

Step 4: Data routing starts when the event occurs. The following are the stages for an actual data transmission to transpire.

1. Path finding

The process of path finding is initiated as and when the source node wants to communicate with another node for which its routing table has no information. Each node consists of two separate counters: a node sequence number and a broadcast id.

The source node in order to find the path broadcasts route request packet (RREQ) to all its neighbours. Source address and broadcast id is unique in each node. Broadcast id gets incremented whenever a new route request (RREQ) is issued by the source node. Each neighbour either satisfies the RREQ by sending a route reply (RREP) back to the source or rebroadcasts the RREQ to its own neighboursaafter increasing theahop_cnt []. If a node receives multiple copies of the same RREQ packet, it discards the extra RREQ and does not rebroadcast it. Nodes in order to establish the forward path as well as the reverse path keeps track of the certain information when it cannot satisfy the route request (RREQ).

Destination IP address , Source IP address,Broadcast id, Expiration time for reverse path route entry

Source node's sequence number The RREQ packet contains the following fields:

<src_addr,src_seq_#,brdcst_id,dest_addr,adest_seq_#,ahop_cnt>

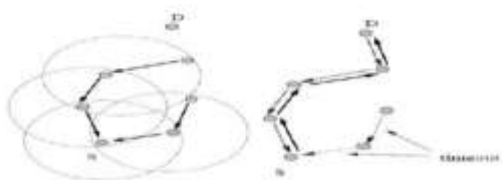

Figure 2: Representation of formation of forward path and reverse path

2. Establishing reverse path

The route request packet consists of other than broadcast id, the source sequence number and the last destination sequence number. The source sequence signifies and maintains freshness information about the reverse path to the source.

The destination sequence number specifies certain conditions for the path to destination to be acceptable to source. As the RREQ travels from a source node to different destination nodes, it parallelly establishes the reverse route from all nodes back to the source. To establish a reverse path, a node registers the address of the neighbouring node from which it has first received the route request (RREQ). The recorded reverse path route entries are preserved for the time until the RREQ could travel across the network and produce a route reply to the sender.

Establishing forward path

Finally, a route request packet (RREQ) would reach a node that holds a current route to the destination. The receiving node prior to all verifies that the route request packet was received over a duplex link. If an intermediate node possesses in its record a route entry for the expected destination, it determines whether the route entry found in its register is stale or valid by comparing the destination sequence number of its own route entry with the destination sequence number in the RREQ. If the RREQ destination sequence number is greater than the one found in the intermediate node's register, then the intermediate node must treat that recorded route as stale and should not use it to respond to the RREQ. In that case the intermediate node has to rebroadcast the RREQ. The intermediate node can respond only when the destination sequence number found in its register is greater than or equal to the destination sequence number contained in the route request packet. Once confirming the desired destination, the node unicasts the route reply packet back to its neighbour from which it has received the route request packet.

A reverse path would be established to the source of RREQ parallelly along the forward path. As the RREP travels back to the source, each node along the path sets up a forward pointer to the node from which the RREP came, updates its timeout information for route entries to the source and destination, and records the latest destination sequence number for the requested destination.

A node on receiving a route reply packet (RREP) forwards the first RREP towards the given source node. If it further gets route reply packets, it updates its routing table and forwards only if the received route reply packet's destination sequence number is greater or have lesser hop count. The source node would start data transmission on receiving the first route reply packet (RREP).

The RREP packet contains the followingafields:

< src_addr,adest_addr, dest_seq_#, hop_cnt,alifetime >

Route table maintenance:

Other than destination and source sequence numbers, routing table also consists of several useful information called soft state information. Every reverse path routing entries come associated with a timer called expiration timer. The task of this timer is to eliminate reverse path routing entries from such nodes that do not lie on the route from source to the destination. Another significant factor associated with routing entries is the route caching timeout. In each routing table address of the currently participating nodes in information transmission is maintained. Such neighbors are called active neighbors.

RESULTS AND DISCUSSIONS

Figure 3 shows the initialised network with the requisite parameters and the base station. The base station node is marked by a red rectangle. For simulation purpose 61 nodes are considered. Out of that one node is base station. Base station node is placed at the centre. After the network initialization the whole area is fragmented into four fixed clusters having 15 nodes each.

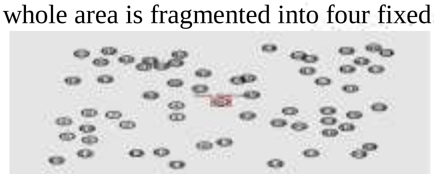

Figure 3: Network initialization and the creation of base station

Figure 4 shows the election of cluster head in each of the fixed clusters. The elected cluster heads are marked with pink rectangles. The node having highest residual energy and shortest distance from the base station gets elected as the cluster-head.

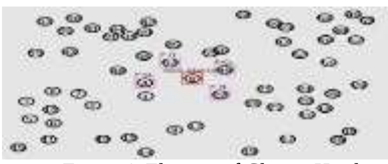

Figure 4: Election of Cluster-Head

Figure 5 shows the occurrence of event and detection by sensor nodes. After the detection of event, sensor nodes discover the shortest route to cluster head using AODV routing technique to transmit the message packet. Transmission of message packets from source to cluster-head (sink) occurs through multi-hoping. Cluster-head after receiving the data packets from its slave nodes aggregates it and transmits it to the base-station.

Figure 5: Event Sensing, Route Discovery and Data Routing

Figure 6 shows the rotation of the role of cluster head within each of the fixed clusters after occurrence of 15 events. The new elected cluster-heads are marked by pink rectangle.

Figure 6: Rotation of the role of cluster-head

As seen in the figure the average energy consumption of DSR algorithm to transmit 100 events is 6500 NJ and the average energy consumption of AODV algorithm is 4000 NJ. The average energy consumption of the proposed routing protocol FLECH is 2000NJ.

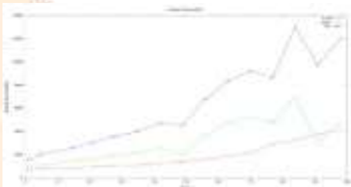

Figure 7: Graph of energy consumption vs events

As the number of events increases the packet loss in DSR and AODV algorithm also increases. But the packet loss in the proposed routing algorithm FLECH is lesser when compared to the other two algorithms.

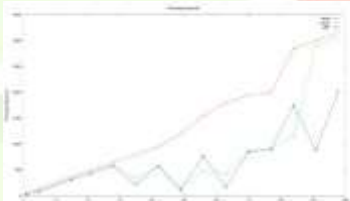

Figure 8: The graph of message vs event (packet loss)

VI. Conclusion

In the proposed routing protocol, Low Energy Clustering Hierarchy (LECH), the lifetime of the wireless sensor network has been enhanced to a larger extent by reducing the energy consumption for data transmission and packet loss during data transmission. As LECH is a hierarchical network, it has a special advantage of scalability and elimination of redundant data by the cluster head. This improves the overall network lifetime in comparison to the existing routing protocols.

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