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Analysis of Cluster Based Anycast Routing Protocol for Wireless Sensor Network

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ABSTRACT- *A wireless sensor network is a collection of nodes organized into a cooperative network. Each node consists of processing capability, may contain multiple types of memory, have a RF transceiver, have a power source, and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion.*

Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network and have to ensure reliable multi-hop communication .The performance of the network is greatly influenced by the routing techniques. Routing is to find out the path to route the sensed data to the base station. In this paper the features of WSNs are introduced and routing protocols are reviewed for Wireless Sensor Network.

Keywords- *Wireless Sensor Networks, Routing Protocols, Hierarchical Routing Protocols*

I. Introduction

Wireless sensor networks are quickly gaining popularity due to the fact that they are potentially low cost solutions to a variety of real-world challenges [1]. Their low cost provides a means to deploy large sensor arrays in a variety of conditions capable of performing both military and civilian tasks. Wireless Sensor Network (WSN) is intended for monitoring an environment. Wireless sensor network (WSN) is widely considered as one of the most important technologies for the twenty-first century [2]. In the past decades, it has received tremendous attention from both academia and industry all over the world. A WSN typically consists of a large number of low-cost, low-power, and multifunctional wireless sensor nodes, with sensing, wireless communications and computation capabilities [3, 4]. These sensor nodes communicate over short distance via a wireless medium and collaborate to accomplish a common task, for example, environment monitoring, military surveillance, and industrial process control [5].

A sensor node, also known as a mote (chiefly in North America), is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. A mote is a node but a node is not always a mote. The wireless sensor node is used to sense and collect data from a certain domain and transmit it to the sink where application lies. Ensuring the direct communication between a sensor and the sink may lead nodes to produce their messages with such a high power that it could result resources to be quickly consumed. Therefore, the collaboration of nodes to ensure that distant nodes communicate with the sink is a requirement. In this way, messages are generated by intermediate nodes so that a route with multiple links or hops to the sink is established.

Sensor nodes use a lot of energy in sending and receiving messages in wireless sensor networks, so hierarchical routing is an efficient way to reduce energy consumption with data aggregation and fusion. Hence, we consider the approach for designing routing protocol based on the specific communication pattern and also robust to the dynamic nature of the sensor networks.

Anycast is a technique used to deliver a packet to one of many hosts. A group of possibly distributed hosts respond to the same address known as anycast address. A packet destined for an anycast address will be delivered to one of the hosts with that address which is close to the source [21]. The Anycast communications becomes quite important in a network with multiple sinks. Anycast can be an important paradigm for a wireless sensor network in terms of resource, robustness and efficiency for replicated service applications. Assuming that the sources and the sinks are distributed in the network uniformly, the sources sending the data packet to the ”nearest” sink around the area in which the events happen can reduce the hops of packets transmitting, so that it saves energy, reduces the cost of router table maintenance and extends the effect of network survival. When a sensor node produces data, it has to send it to any available sink. A sink selection strategy is to choose a sink for each source arbitrarily. This simple strategy is assumed to balance the energy consumption [22].In this paper we introduce the mechanism of Cluster Based Anycast Routing protocol (CBAR) for routing in WSN. We have tudied other energy efficient and related routing protocols used in WSN. This paper shows the design paradigm of CBAR and compared with other existing protocols in WSN.

II. Cbar: Cluster Based Anycast Routing

Cluster based anycast routing (CBAR) is a routing protocol based on clustering where “Cluster Head” are base station and root nodes. In order to minimize dissipation of energy in each cluster, CBAR elect sufficient number of cluster heads and rotate randomly which will communicate with other nodes when each node transmitted and receive data to and from cluster head node. If the cluster-head node is base station then it will not involve in inter-cluster routing otherwise base station receives data from the elected cluster-head node.

The entire protocol is divided into two processes or phases. First phase, concentrate on building the tree .So, the first phase which is known as “Building Phase” is based on building the topology and election of cluster-heads. The second phase, known as “Transmission Phase” , which is based on routing strategies for managing and transmitting data among nodes.

1.1 Building Tree

A network consists of small number of base station and a numerous number of wireless sensors distributed randomly distributed over the network. In first phase, design of topology based on cluster-head election as well as the formation of cluster with cluster-head and other nodes.

The base station initiates the tree construction by broad-casting a child request (CREQ) packets to discover the child nodes. The child nodes send a child reply (CREP) to the required cluster-head for joining the cluster and become the member of the tree. After choosing a parent, the nonmember sends a child reply (CREP) packet to the selected parent so as to in-form that it will be a child node. Upon receiving the CREP packet, the parent node confirms an acceptance of a new child node by replying with a child acceptance (CACP) packet. So, finally the ACK packet from child to parent in reply to the CACP packet completes the binding in the cluster.

The election algorithm based select a node based on value generated by the node as the overhead of cluster-head is higher than other nodes. Then each elected node broadcast a message to each node in the network to join it. Based upon the strength of the CREQ signal, nodes send CREP packet to join the cluster.

When a node moves from one region to another region it will join the cluster accordingly and then send information to the respective cluster-head. In this protocol the tree formation is hierarchical, where each cluster-head (CH) is connected to base station (BS) and also each cluster-head is connected to the nodes in cluster to complete the tree structure formation.

1.2 Adding the Nodes

Using the joining mechanism, a newly created node finds a parent as follow. A joining node broadcast the parent request (PREQ) packet for making their neighboring nodes to known about its presence. Any nodes of the tree which hear this request reply by sending unicast CREQ packet to joining nodes. Note that this CREQ packet is same as described in Section 3.1 except that we use unicast instead of broadcasting. Then, the processes will follow the tree construction phase, *i.e.*, the joining node sends a CREP packet to a selected parent and waits for a CACP packet as a confirmation of their relation. If the joining node does not receive any CREQ packet after broadcasting the PREQ packet, it infers that no any node is within its radio cover-age or all of its neighboring nodes do not attach to the tree yet. In this case, it waits for an incoming CREQ packet after one of its neighbors has attached to the tree. As an option, joining node can broadcast the PREQ packet periodically until receiving the CREQ packets.

A sensor node can join in an anycast tree through the following process:

1) Every sink node broadcasts a query CRQ to its neighbor nodes within small range. The CRQ contains the location information of some one sink node, the ID of Anycast group, the path cost φ from a sink to the node that has sent the CRQ. If the CRQ comes from a sink node directly, the value of φ is zero and Next node’s ID is zero.
2) If a neighbor node receives the CRQ and it hasn’t joined in any anycast tree. The node accepts the CRQ and checks if it comes from a tree’s node through checking the id that identifying anycast group, if it is, it appends the CRQ into its father node table and records the father node's relevant parameters including location information, the path cost φ and anycast id it is requested to join. If the id in the CRQ was not belonging to any anycast tree’s node, the node discards the CRQ.
3) After receiving a CRQ, the node set a timer whose time interval may be decided by the current network status. The node may receive more than one CRQ in the time interval. After the timer expires, the node selects the neighbor node with the minimum path cost φ as its father node through comparing the size of the path cost φ in the CRQ, records the information on its father node and returns a RREP to its father node. If more than one the path cost φ of the CRQ received is equal, the node selects a

neighbor node as its father node randomly.

4) After the father node receives the joining message, it will return an ACK message to this child node. Due to the characteristics of the algorithm, each node only needs to retain the information of his father node. The father node doesn't need to record the relevant information of the child node. This is different from the TCP/IP which will record the child's IP. The child node replaces Next node's ID in the CRQ with it's the father ID, recalculate the path cost φ from the sink to this node and replaces the path cost φ in the CRQ with the new φ . At the same time, updates the relevant parameters (position, etc) and broadcasts the CRQ to the next hop until all node join in an anycast tree, just as it is shown in fig. 1.

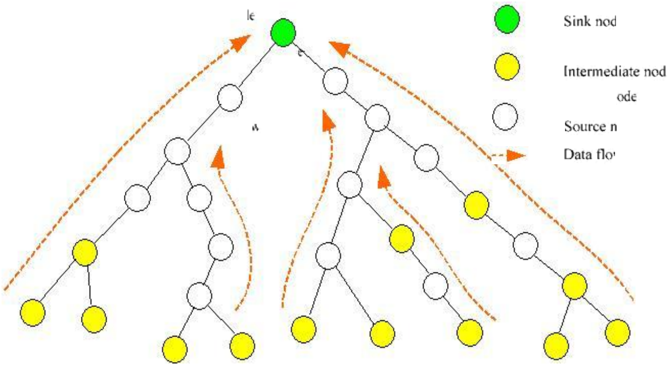


Figure.1: Anycast tree is establish from all sensor to a sink

1.3 Clustering

First of all we need to elect the cluster-head from each cluster before routing depending uSpon the election algorithm which may vary for every round of election. Each cluster on the network has the unique cluster id. These cluster-heads takes part in data transmission by transmitting data from nodes to the respective cluster-heads and then finally transmitting it to the sink. In each cluster rest of the nodes are in the sleep mode to save energy. Only cluster-heads takes part in routing, all other nodes sends their data to their respective cluster-heads in each round. Various considerations are followed to proposed the network model and placement of sensor nodes.

1. The sink and source are placed at opposite ends
2. The sensor nodes are randomly deployed in cluster
3. All nodes are of same types of sensor node
4. Data need to be collected together for sending it to cluster-head

The election of a CH among the fellow nodes for a cycle is based on battery power and the distance from the sink of each node. After one round again the same selection process is being executed for a new cluste-head. Usually the battery assigned to each node is being consumed with every action of transmission or sleeping but the one with the highest value and distance from the sink gets the chance to be a cluster head,as the weight age sum method is used gving more weight age to power over distance, the actual election process is being executed keeping in mind the criteria of energy efficiency. Weighted sum is the method for solving optimization which seeks solution by systematically varying weights among the objective conditions under given constraints this is the way to achieve high performance. The weights are assigned to the battery and distance from the sink, as keeping in mind the equation they must satisfy;

Σ Wi Ji = 1 and W1 J1 + W2 J2 = 1 (1)

Where, W1 = Wb is the weight given to the battery of the node and W2 = Wd is the weight given to the distance; Ji is the quantity multiplied to the weights of i-th factor.

1.4 Anycast Routing

It is impossible to use only base station when the network size is too large because the traffic will concentrate around the base station which has high loss. Thus, the user can deploy the base station a some ratio compared to the number of sensor in a network , in order to distribute the load. Without any change in the routing protocol , multiple base station can operate independently. Each node needed to be attached to the tree created by a nearest base station because a CREQ packet from the that base station arrives first. The Node can use the group ID to distinguish different base stations. Thereby, they can attach to multiple trees in order to achieve the robustness against failed nodes, i.e., multipath routing is supported. To collect the data, each node just forwards its sensed data and all of received data to its parent. If it does not attach to the tree yet, it keeps such data in the buffer and send them later.

III. Cluster Based Anycast Routing (Cbar) Algorithm

The algorithm is explained in the following steps:

Step 1: Initialization

Set number of CREP = 0 and status of parent node, CREP send and received, CREQ send and receive as NULL. Choose BS as parent (node), BS broadcasts CREQ packets, Sensor broadcasts PREQ packets, call election algorithm to select cluster-head (CH).

Step 2: Formation of tree

Select cluster-head (CH) near the sink (BS) and if node elected as CH connect to BS and send request to nodes else node will join CH as leaf in the tree as source node

Step 3: Topology model

- All sensor nodes are started with same initial energy with transmission distance d0
- Each sensor node can compute the distance d of the source based on the received location information
- Transmitting power of a sensor node is controllable, i.e., transmitting power of a sensor node can be modulated according to the transmitting distance
- Change the flag values accordingly as per transmission and buffer the packets for transmission

Step 4: Update energy of each sensor node

The transmission depends on the energy of the node and distance between CH and BS with nodes depending on the following factor on a weighted basis.

Tc = W1 * D + W2 * Ef (2)

where Tc is transmission criterion, W1 and W2 are the weight factors; D is the proximity factor on the given distances of the node with BS and CH whose Tc will be calculated.

The energy dissipated during transmission and reception using the following formula:

$$E_{Tx}(k,d) = \begin{cases} E_{elec} * k + \xi_{fs} * k * d^2, & d < d_0 \\ E_{elec} * k + \xi_{mp} * d^4, & d \geq d_0 \end{cases}$$

$$E_{R_x}(k,d) = E_{elec} * k \quad (3)$$

where ETx is the amount of energy consumed by each node, ERx is the amount of energy for receiving k bit packet, Eelec is the energy dissipated, ξfs is the free space propagation, ξmp is the multiple fading channel parameter, d is the transmission distance and k is message length and d0 is the initial value of d.

Step 5: Each node transmit data during their allocated time slot t and finally data will be transmitted to BS via CH

A simple combination of different routing metrics [9] used to determine the path cost using following equations:

$$\phi = \phi' + \Sigma\, \alpha_i * metric_i \quad (4)$$

$$\phi = \phi' + \alpha_1 * hop_i + \alpha_2 * w_i + \alpha_3 * delay + \alpha_4 * E_i$$

Where ϕ' is the accumulated cost along the path with different path cost metrics, metric is scaled value from (0, 1) and α1 is the weight factor for metric to calculate the cost. Here, Hopi is hop count set to 1 initially, Ei denotes the surplus energy, αi values are different sets of weight factors set as per requirements as per applications. w_i is calculated as per the energy consumption of node i and calculated as per following:

$$w_i = e_s + e_g + e_r + e_{ij}$$

where eij calculated as per the power consumption of node i transmitting data to node j where eg is the value of generating data, er is the value of receiving data and es is the value of idle power consumption of node.

Step 6: After completion of one round repeat step 2 to 5

Step 7: Stop

Each time after selection of cluster-heads (CH) the information will broadcast in the cluster so that each node can send PREQ to establish connection with CH but in CBAR the broadcast process will be once to minimize the overhead and utilize less energy. CBAR also reduce the overhead by minimizing the hop in routing and avoid periodic update to reduce the traffic in the network.

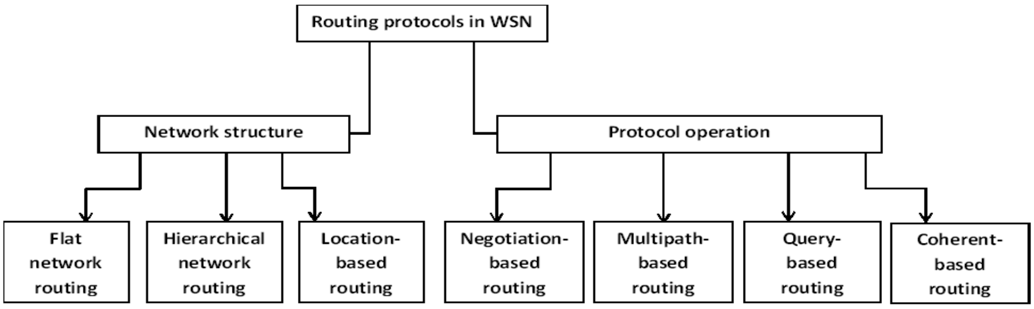


Figure 2: Routing Protocols in WSN

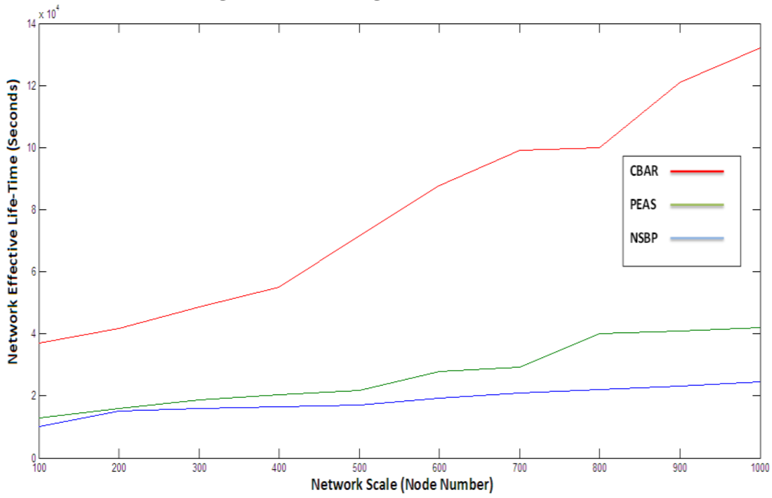


Figure 3: Network Effective Lifetime vs. Network Scale

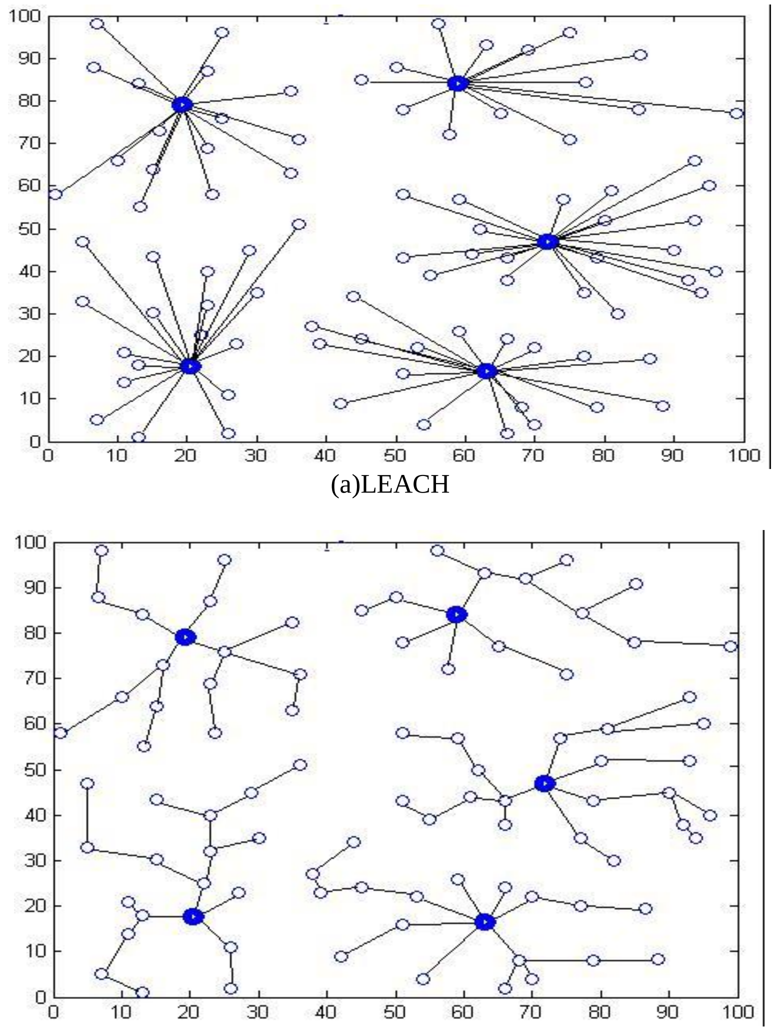
IV. Simulation Result

In this section the performance of the Cluster based anycast routing (CBAR) protocol is evaluated via computer simulation and is compared with other available schemes. Assume that there are 100 sensor nodes distributed randomly in 100×100 region , where 5 are sink nodes and 95 are sensor nodes. The simulation parameters are given in Table 1. All nodes' transmission power is adjustable and they adjust transmission power to communicate with other nodes according to actual need. Every two nodes can communicate directly with each other in the transmission range.

CBAR compared with modified LEACH, HAR, Node Scheduling based Routing protocols, GAF, PEAS, NSBP protocol. Network effective lifetime states that the data efficiently can be transmitted back to sink. This is calculated for the network scale of 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 nodes shown in horizontal direction. Fig. 3 shows the performance of CBAR compared with NSBP, PEAS and for comparison between the effective lifetimes, Nodes death time and effective lifetime compared taking scale of 1000 nodes. Fig4. Shows the resultant network topology obtained by different schemes for a network. The topology of LEACH is shown in Fig4 (a).The topology of anycast routing protocol of our paper is shown in Fig4 (b). Every sensor node joins in an anycast tree according to the path cost and data is transmitted along the tree from sensor leaves to root sink. Observe that the proposed scheme display more balanced and distributed pattern of network.

TABLE I.THE PARAMETERS USED IN THE SIMULATION

Parameter	***Value***	***Parameter***	***Value***
Size of target area	100×100	Data packet size	512 bytes
Number of sink nodes	5	Metadata packet size	25 bytes
Number of sensor nodes	95	Maximum radius ,R	20m
Initial energy	10J	α_1	1
$^{\varepsilon}elec$	50 nJ/bit	α_2	1
$^{\varepsilon}amp$	50 nj/bti/m2	$^{\alpha}3$	1
$_s$	100 nJ/s	α_4	1



(a)LEACH

(b) Anycast routing protocol

Figure 4: The network topology with different protocols

Fig. 5 shows the performance of the nodes in terms of number of sensor nodes alive per round which has not yet depleted all the energy and still involve in data dissemination and Fig. 6 shows the energy consumption of the nodes after each round and it increases as number of packet transfer also increase with time.

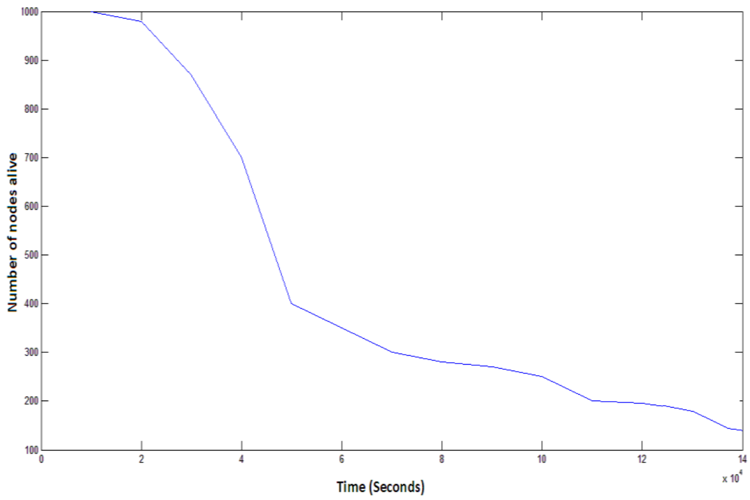


Figure 5: Number of nodes alive after each round

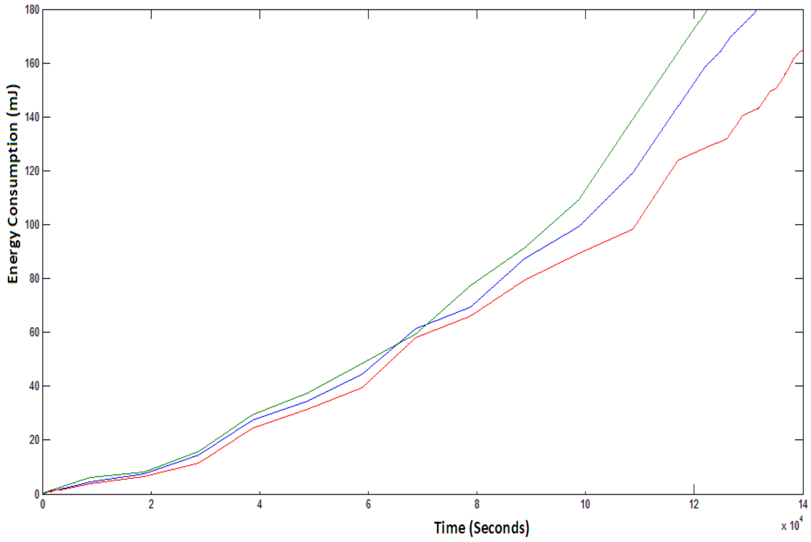


Figure 6: Energy consumption after each round

V. Conclusion

This paper is the demonstration of routing strategy of CBAR protocol and also it show how it provides the solution against the dynamic nature of wireless sensor network. It also tries to overcome the shortcoming of other protocols in terms of scalability for enhancing network life-time .Energy is one of the most important parameter in wireless sensor network. Routing consumes the larger amount of energy in WSN in terms of achieving efficient routing mechanism for collecting data packet. However, we have not explored all required performance matrices which is one of our future work.

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