Routing Management in Wireless Sensor Network

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Abstract- **Wireless Sensor Networks are networks of large number of tiny, battery powered sensor nodes having limited on-board storage, processing, and radio capabilities to monitor physical or environmental conditions, such as temperature, vibration, pressure, sound or motion, and then collectively send this information to a central computing system, called the base station or sink. Routing in sensor networks is very challenging, due to several characteristics that distinguish them from contemporary communication and wireless ad-hoc networks. Most routing protocols can be classified as data-centric, hierarchical, location-based and QoS aware.**

This paper proposed modified hierarchical binary tree (MHBT) structure to store the routing information. . The location information is stored in multiple nodes (parent and grandparent node) of the sensor, which locate the target together with the sensor, which located the information about the target object. This can enable the WSN to track the target in the event of failure of same sensor node and reduce the redundancy at most two level of the binary tree. This also improved energy efficiency, robustness, scalability and routing efficiency. We have evaluated our scheme using NS2.

Keywords:- WSN, MHBT, LEACH, DD, NS2

I. INTRODUCTION

Routing is one of the main problems in WSNs and many solutions have been developed to address this problem. Ensuring efficient routing faces many challenges due to both wireless communication effects and the peculiarities of sensor networks. These challenges preclude existing routing protocols developed for wireless ad hoc networks from being used in WSNs. Instead, novel routing protocols are required. Next, we describe these main challenges facing routing in WSNs [1].

Energy Consumption - The main objective of the routing protocols is efficient delivery of information between sensors and the sink. To this end, energy consumption is the main concern in the development of any routing protocol for WSNs. Because of the limited energy resources of sensor nodes, data need to be delivered in the most energy-efficient manner without compromising the accuracy of the information content

Scalability - WSNs usually consist of a large number of nodes. The need to observe physical phenomena in detail may also require a high-density deployment of these nodes. The large number of nodes prevents global knowledge of the network topology from being obtained at each node. Hence, fully distributed protocols, which operate with limited knowledge of the topology, need to be developed to provide scalability. In addition, since the density is high in the network, local information exchange should also be limited to improve the energy efficiency of the network.

Addressing - The large number of sensor nodes in a network prevents unique addresses from being assigned to each node. While local addressing mechanisms can still be used to facilitate communication between neighbors, address-based routing protocols are not feasible because of the large overhead required to use unique addresses for each communication. Consequently, the majority of the ad hoc routing protocols cannot be adopted for WSNs since these solutions require unique addresses for each node in the network

Robustness - WSNs rely on the nodes inside the network to deliver data in a multi-hop manner. Hence, routing protocols operate on these sensor nodes instead of dedicated routers such as in the Internet. The low cost components used in sensor nodes, however, may result in unexpected failures to such an extent that the sensor node may be non-operational. As a result, routing protocols should provide robustness to node failures and prevent single point-of-failure situations, where the information is lost if a sensor dies.

Topology - The deployment of a WSN can be either predetermined or through a random strategy. While predetermined topology can be exploited to design more efficient routing protocols, this is usually not the case for WSNs. Consequently, individual nodes are usually unaware of the initial topology of the network. However, the relative locations of the neighbors of a node and the relative location of the nodes in the network significantly affect the routing performance.

Application - The type of application is also important for the design of routing protocols. In monitoring applications, usually nodes communicate their observations to the sink in a periodic manner. As a result, static routes can be used to maintain efficient delivery of the observations throughout the lifetime of the network. In event-based applications, however, the sensor network is in sleep state most of the time.

II. ROUTING PROTOCOLS FOR WSN

The review of current approaches is based on an extensive survey of the state of-the-art in goal and data-oriented routing approaches. Firstly we begin with Data Centric Protocols, which are centered on the data itself. Secondly, we analyze, Hierarchical Routing, which consists on establishing a hierarchical route towards the data collection points. Thirdly, we use position information to relay the data to the desired regions (Location-based protocols), and lastly we consider QoS-Aware protocols, which take into account energy consumption and data quality. The network may have to satisfy certain QoS metrics (delay, energy, bandwidth) when delivering data to the base station, metrics which are used in the QoS-Aware protocols.

A. Data-Centric and Flat-Architecture Protocols

Since transmitting data from every sensor node within the deployment region might result in significant unnecessary redundancy in data and incur in unnecessary energy and traffic expenditure, routing protocols that are able to select a set of sensor nodes and utilize data aggregation during the relaying of data have been considered. In data-centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data. Sensor Protocols for Information via Negotiation (SPIN) [2,3] is the first data-centric protocol, which considers data negotiation between nodes in order to eliminate redundant data and save energy. Later, Directed Diffusion has been developed and has become a breakthrough in data-centric routing. Many other protocols have also been proposed based on Directed Diffusion, such as Energy aware routing ,Rumor routing, Minimum Cost Forwarding Algorithm and Gradient-Based Routing.

B. Hierarchical Protocols

Hierarchical or cluster-based routing methods [4,5], originally proposed in wire networks, are well-known techniques with special advantages related to scalability and efficient communication. As such, the concept of hierarchical routing is also utilized to perform energy-efficient routing in WSNs. In a hierarchical architecture, higher-energy nodes can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the proximity of the target. The creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster, performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink.

Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other for routing. However, most techniques in this category are not about routing, but rather “who and when to send or process/ aggregate” the information, channel allocation, and so on, which can be orthogonal to the multihop routing function. The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication. Cluster formation is typically based on the energy reserve of sensors and sensor’s proximity to the cluster head. LEACH is one of the first hierarchical routing approaches for sensors networks.

C. Location-Based Protocols

Most of the routing protocols for sensor networks require location information for sensor nodes. In most cases location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors. Alternatively, the location of nodes may be available directly by communicating with a satellite using GPS if nodes are equipped with a small low-power GPS receiver. To save energy, some location-based schemes demand that nodes should go to sleep if there is no activity. More energy savings can be obtained by having as many sleeping nodes in the network as possible. In this section, we review two geographic routing protocols, such as Geographic Adaptive Fidelity and Geographic and energy aware routing.

D. QoS-aware Protocols

The network needs to ensure Quality of Service (QoS) besides ease of deployment, energy efficiency and low cost. One of the major design goals of WSNs is reliable data communication under minimum energy depletion to extend the lifetime of the network. This may be achieved via aggressive energy management techniques. Owing to their poor energy conservation, traditional routing protocols are not suitable for WSN applications. It is highly desirable to employ an energy-efficient route discovery and data relaying techniques to transfer data between the sensor nodes and the base station. Some of the routing challenges and design issues that affect the routing process in WSN are: node deployment, data reporting method, node/link heterogeneity, fault tolerance, scalability, transmission media, data aggregation, connectivity, coverage and QoS. In QoS-based routing protocols, the network has to balance between energy consumption and data quality. In particular, the network has to satisfy certain QoS metrics such as delay, energy, bandwidth when delivering data to the base station. In this context, we review three routing protocols, such as SPEED, Sequential Assignment Routing and Real-time Power-Aware Routing [6, 7].

III. MODIFIED HIERARCHICAL BINARY TREE (MHBT)

The hierarchical tree structure is proposed to store the location information redundantly in multiple nodes in a controlled manner in order to reduce the tracking time. Here we have considered the routing scheme for target detection. Reduction in localization time is important, as we need to store the information before another object appear in the sensing zone of a sensor node. The location information is stored in multiple nodes (parent and grand parent node) of the sensor, which locate the target together with the sensor, which located the information about the target object. This can enable the WSN to track the target in the event of failure of same sensor node, as there will be multiple copies of the location information in the network. The number of multiple copies is restricted to only parent and grandparent node to reduce the time to store the location information [8, 9, 10].

For simulation, we are considering a three dimensional array for storing the location information at different sensor node. The array is taken to be binary which can store either '0' or '1'.

Sensor-target [i] [j] [k] = 1 denotes that sensor node 'i' stores the information that target object "j" is located by sensor node "k". Node "i" and "k" can be same. As we are considering complete binary tree, finding parent node and grand-parent node can be easily done. Every location information of target object "t" detected by sensor node "s" involves the following flag settings.

Sensor-target [s] [t] [s] = 1
Sensor-target [s/2] [t] [s] = 1 :: storing the location information in parent node.
Sensor-target [s/4] [t] [s] = 1 :: storing the location information in grand-parent node.

Algorithm- Target Detection

Step 1 : Define a two dimensional grid.
Step 2 : Generate position of the sensor nodes at the different grid position randomly.
Step 3 : Define a/ multiple path in terms of serial location.
Step 4 : Initiate the object at a random position on the path.
Step 5 : With every iteration, find the location of the object in the path.
Step 6 : Find the nearest sensor node 'A', which can detect the object 'X'.
Step 7 : Let sensor node 's', locate the target 't'
Sensor-target [s] [t] [s] = 1
Sensor-target [s/2] [t] [s] = 1
Sensor-target [s/4] [t] [s] = 1
Step 8 : Repeat step 3 through 7 for the entire moving target object in the system.
Step 9 : end Target Detection

Algorithm: Trajectory

Step 1 : Let the target object to be tracked is "t".
Step 2 : Start from the root node (any node)
Repeat step 3 & 4 until node = Null
Step 3 : Varying node-1 from 1 to no of sensor
If sensor-target [node] [t] [node-1] = 1
Then store node-1 in tracking.
Step 4 : Node = Lchild [node] i.e. left child
Start from the next node (say node)
Repeat step 5 & 6 until node = Null
Step 5 : Same as step 3
Step 6 : Node = Rchild [node] i.e. right child
Step 7 : Display path
Step 8 : Trajectory

IV. SIMULATION ENVIORMENT

A. Performance Metrics

We evaluated the following performance metrics:

Network lifetime: The network lifetime is directly proportional to the number of live nodes in the network after during the simulation time.

Average energy consumption: The average energy consumed by the nodes in receiving and sending the packets. The average energy consumption is calculated across the entire networks. It measures the average difference between the initial level of energy and the final level of energy that is left in each sensor node.

Scalability - A protocol is scalable if it is applicable to large as well as small populations. A crucial issue for WSN is the handling of a large number of nodes.

Routing Overhead - The routing protocol overhead describes how many control packets (or in terms of bytes) for route discovery and route maintenance need to be sent in order to propagate the packets. The bandwidth consumed by all the control packets of the routing protocol is measured as control packet overhead. we have normalized the routing overhead between 0 to 1.

B. Simulation Parameters

MHBT is evaluated through Network Simulator (NS-2). We used a bounded region of 1000 x1000 sqm, in which 500 sensor nodes are randomly placed and a sink node is located in the center of the network. The simulated traffic is Constant Bit Rate (CBR). We vary the transmission range as 250, 300, 350, 400 and 450 m. Some important simulation parameters are summarized in table I.

Table I: Network configuration parameters

Parameter	**Value**
Simulator	NS-2
WSN protocols	MHBT, LEACH, DD
MAC type	IEEE 802.11
Application	Location estimation
Antenna type	Omni directional
Simulation time	100 seconds
Grid size (mxm)	500X500, 1000X1000, 1500X1500, 2000X2000
BS Location	Mid of the grid (m/2, m/2)
Transmission range	100m to 400m
Node speed	0 – 40 m/s in steps of 5 m/s
Number of sensors	10, 20, 30, … 500
Traffic type	CBR (UDP)
Data payload	512 bytes/packet
Transmit Power Receiving Power Idle Power Initial Energy	360 mw 395 mw 335 mw 12 J
Propagation model	Two-ray ground reflection
Bandwidth	2 Mbps

Sensor radius (m)	50, 100, 200, 300
Channel type	Channel/ Wireless Channel
Energy Model	Battery
Interface queue type	Queue/Drop tail/ Priqueue
Link layer type	LL
Communication model	Bi-direction

V. RESULTS AND DISCUSSION

Figure 1 shows the initial field distribution of the network. A 1000m*1000m field is taken and nodes are randomly placed in it. The sink/base station (BS), which is denoted by x, is placed at the center of the field (500, 500). Placing the base station at the center is convenient so that no node founds it out of its transmission range. Here, the advanced nodes are shown by a plus symbol (+) and the normal nodes by a circle (0). In Figure 1, all the nodes are alive in the network.
The performance of our proposed MHBT is compared with the DD -Directed Diffusion, LEACH – Low Energy Adaptive Clustering Hierarchy protocol.
Network lifetime: When more sensors are deployed, each target is covered by more sensors, thus more set covers can be formed. Also considering the same number of sensors for a smaller number of targets the lifetime increases. The network lifetime increases with number of sensors and sensing range as shown in figure 2. The MHBT has 10-20% higher network lifetime as compared to LEACH and DD even when sensing range is higher.
The network lifetime is directly proportional to the number of nodes in the network. Initially figure 3 show the increase in the network lifetime as number of nodes in the increase. But after 300 nodes (in 1000m x1000m) both protocols network lifetime (number of rounds) decreases. MHBT performs better in terms of number of rounds (i.e. measure in time).

Total energy consumption: In the proposed algorithm MHBT the energy consumed is reduced since only activated nodes in the network is involved in network and rest of nodes remain in standby mode. Figure 4 shows the graph comparing the energy consumption between DD, LEACH and MHBT. Energy consumption increases for all routing scheme as number of nodes increase. But MHBT has 20% less consumption because its uses two level hierarchy of binary tree to store the redundant information.

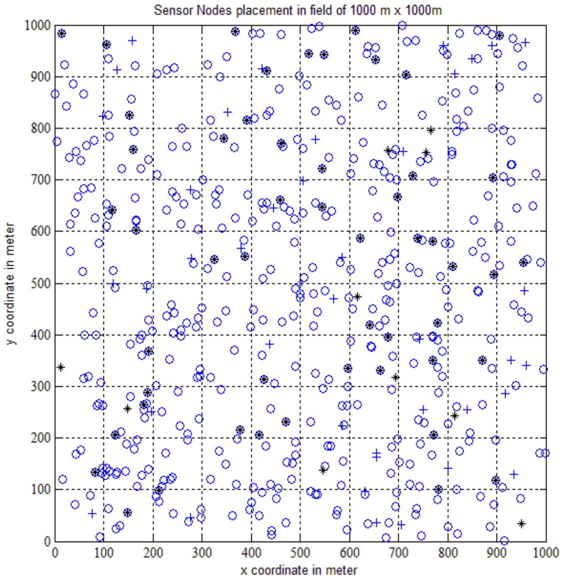

Figure 1: Sensor nodes distribution in 1000m x 1000m field

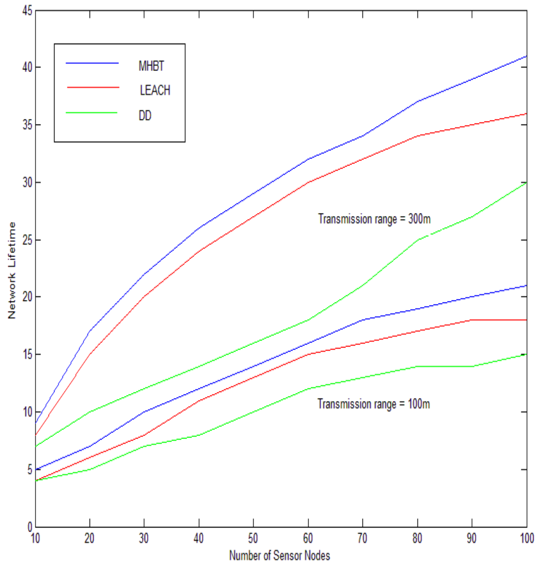

Figure 2: Network Lifetime vs. transmission range

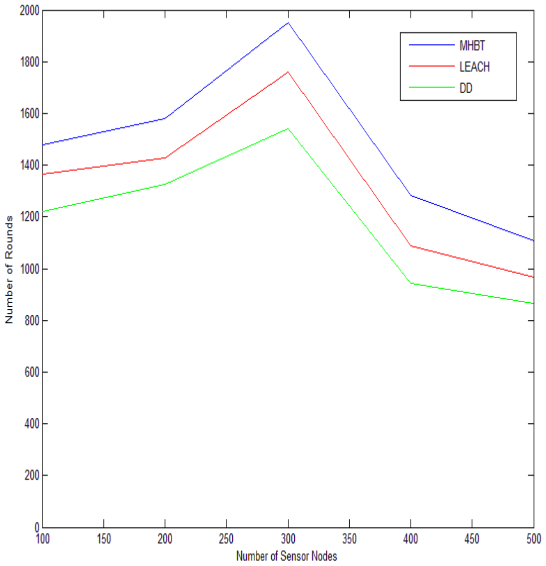

Figure 3: Network Lifetime vs. Number of Sensor Nodes

Scalability: The routing protocol is said well scaled when it experiences minimal performance degradation when used in increasingly large networks. The scalability is a measure against the data delivery ratio by varying the number of nodes. MHBT, DD and LEACH routing scheme well scale up for 300 nodes in transmission range of 1000x1000m. But after that LEACH and DD performance is degrade sharply as compared to proposed MHBT scheme while increasing the number of nodes.

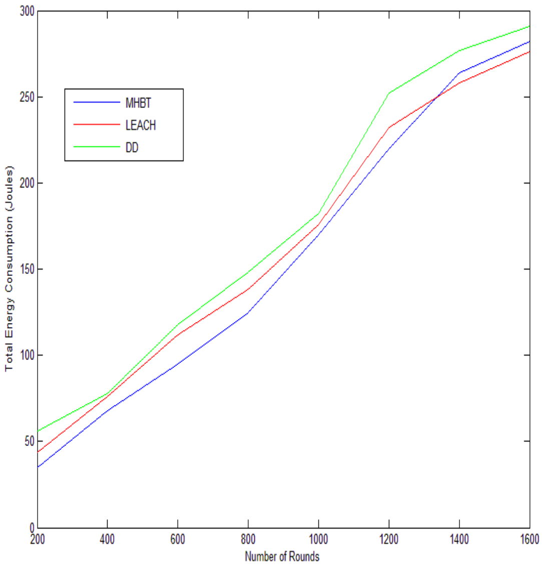

Figure 4: Total energy consumption vs. number of rounds

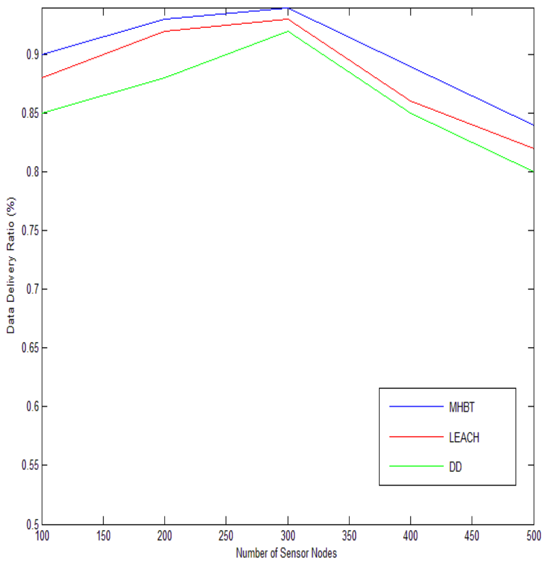

Figure 5: Data Delivery Ratio vs. Number of Nodes

***Routing overhead*:** To find routes, routing protocols used to send control information (packets). These control information along includes basically route request sent, route reply send and route error sent packets. Routing overhead can be define as a ratio of total number of control packets sent to the total number of data packets delivered successful. It is measured between 0 to 1. As the number of nodes increased, normalized routing overhead increased sharply especially when number of nodes is high. DD suffer highest routing overhead as its nature is flooding, while leach has moderate routing overhead. MHBT has higher overhead but it is 20-30% less as compared to these two routing schemes.

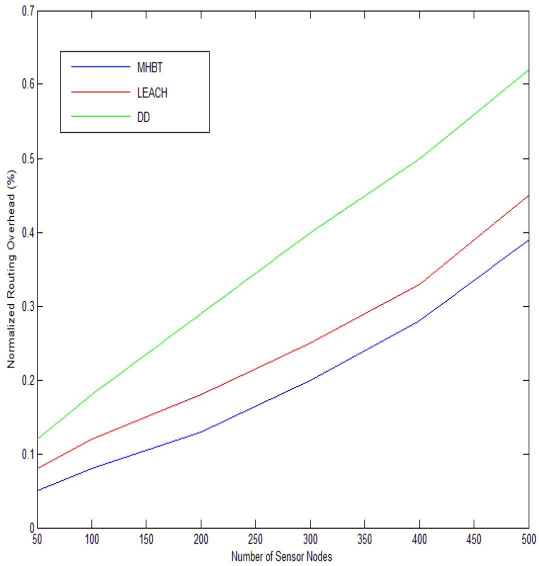

Figure 6: Normalized Routing Overhead vs. Number of Nodes

CONCLUSIONS

Simulation result shows MHBT perform well over LEACH and DD protocol. This routing management guaranteed network connectivity, efficient routing and good target detection probability in WSN with low energy consumption. The MHBT suffer initial setup delay but after that it outperform over many hierarchy routing scheme for WSN especially well even for large networks.

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