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Resource Biased Routing (RBR) Algorithm for Energy Optimization in Wireless Sensor Networks

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Abstract: ***Energy efficiency is the major concern in the design of Wireless Sensor Network (WSN). In the traditional routing algorithms, some nodes are constantly involved in forwarding data packets, hence more energy will be depleted among those nodes and the nodes will die much earlier than others causing disconnection of the network. So it is necessary to develop algorithm to evenly distribute energy dissipation across nodes and reduces hotspots in the networks. The resource biased Routing(RBR) algorithm biases the use of resource-rich actor nodes over energy-constrained sensor nodes for packet forwarding and processing in the network .This algorithm efficiently and evenly distributes load across the nodes and thus optimizes the use of energy available at each sensor node.***

Index Terms: **Base Station, Hop Count Indicator (HCI), Node Usage Indicator (NUI), Resource Biased Routing (RBR).**

I. INTRODUCTION

Wireless sensor networks have recently come into prominence because they hold the potential to revolutionize many segments of our economy and life, from environmental monitoring and conservation, to manufacturing and business asset management, to automation in the transportation and health care industries. A wireless sensor network is a collection of nodes organized into a cooperative network. Each node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), may contain multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single Omni-directional antenna), have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators. The Figure 1 shows a simple illustration of wireless sensor networks (WSNs)

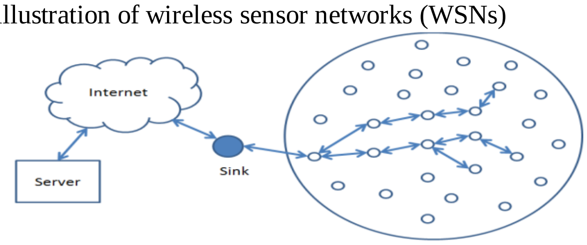

Fig. 1 Wireless Sensor Networks [1]

Since energy consumption in wireless systems is directly proportional to the square of the distance, one hop communication is expensive in terms of energy consumption. Most of the routing algorithms use either multi hop communication or clustering model since they are more energy efficient in terms of energy consumption. Efficient routing techniques play a significant role in saving the energy consumption of the network. With the energy constrained nature of sensor nodes, it is very important to make efficient use of battery power in order to increase the lifetime of network, hence it is necessary to design efficient routing protocols in WSN.

II. RELATED WORK

Energy is a factor of utmost importance in WSNs. Directed diffusion is a routing protocol which is used for collecting and publishing the information in WSNs. Its main objective is to extend the network life time by realizing the essential energy saving. The disadvantage of Directed Diffusion routing protocol is that it selects the shortest path between the source node and the sink node, which causes the early death of nodes on that route [2]. Energy-Efficient Sensor Routing (EESR) is a routing protocol [3] which is developed to reduce the energy consumption, and to provide scalability in the Wireless Sensor Network. The disadvantage of EESR algorithm is that there is no balance in the energy consumption, *i.e.*, some nodes consume their energy before other nodes. The geographic location-based routing in [4] selects the minimum energy consumption path in order to route data to minimize the end to end energy consumption. Each sensor node makes a decision on next hop in the route based on the geographic information of the destination, the neighbor nodes and itself. This algorithm does not track the energy level of each node; therefore, it does not balance energy consumption among all sensor nodes. In the energy efficient routing protocol [5], each node selects its next hop node based on the energy level of its neighbors. The node will relay data packets to its sibling node instead of its parent node if the sibling node has more energy than the parent node. This algorithm only considers energy balance of the network. It could not guarantee minimum transmission latency. Zeng [6] proposed an energy efficient geographic routing protocol which makes routing decision locally by jointly considering multiple factors - the realistic wireless channel condition, packets advancement to the destination, and the energy availability on the node with environmental energy supply. This algorithm saves nodes energy and guarantees short path transmission. But this decision has to be done by each node for every hop of the data transmission. This creates a large amount of overhead. The data transmission latency is significantly increased. The EECCR routing algorithm proposed in [7] divides sensor nodes into different scheduling sets. The sensor nodes in each set together make the monitored region *m*-covered and the network *n*-connected.

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III. PROPOSED WSN MODEL

We consider a WSN that consists of large number of sensors that are uniformly distributed and a base station to collects data from other sensor nodes. The proposed system model has the following assumptions:

1. Each node performs sensing task periodically and always has some data to send to the base station.
2. All nodes are stationary and energy constrained.
3. Geographic Location of each node is known.
4. There is no energy hole in the network.
5. Base station is externally powered and has high storage and computation capability
6. All the nodes use multi-hop routing method to forward the data to the closest relay node.
7. Relay nodes carry the sensory data to the base station.
8. There is only one transmission range fixed for all the nodes.
9. Each node has a data rate to carry all the data traffic.

The proposed system consists of a network model consisting of source node S, a number of intermediate nodes and a destination base station D. All the intermediate nodes have limited energy. Each sensor node consists of a set of 3 parameters representing (Available Energy Indicator, Hop Count Indicator, Node Usage Indicator). The Node Usages indicator (NUI) specifies how many times a specific sensor node has been used during the routing purpose. Available Energy indicator (AEI) specifies the remaining available energy at the node. Hop Count Indicator (HCI) specifies the distance of a specific sensor node from the base station in terms of Hops. The base station is initialized with the hop value "0" while all other sensor nodes are initialized with infinite hop value. The base station is also has unlimited energy available as it is externally powered. All the other nodes have an initial energy level $E_{initial}$(in Joule). All the sensor nodes in the proposed network are assigned with a unique ID and all the nodes are participating in the network and forward the given data. The sensor nodes are also assumed to be fixed for their lifetimes.

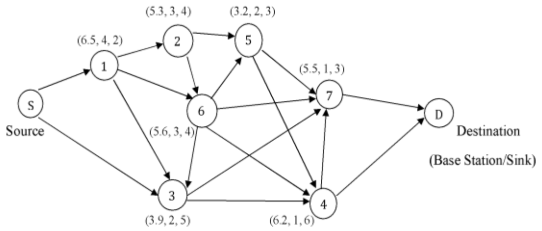

Fig. 2 Proposed Sample WSN Model at Arbitrary Time t

IV. PROPOSED RESOURCE BIASED ROUTING (RBR) ALGORITHM

A. Overview

The proposed Resource Biased Routing (RBR) algorithm is used for selecting the neighbor nodes to which the data is to be forwarded. The next node is selected based on the following parameters:

1. Available Energy Indicator (AEI)
2. Hop Count Indicator (HCI)
3. Node Usage Indicator (NUI)

According to the proposed algorithm, ideally a sensor node is selected as next hop in which the available energy level indicator is high, having low value of hop count indicator as well as having the low value of node usage indicator. Each node maintains a Sensor Node Information (SNI) table for the routing function to perform. The SNI table consists of entries of all the neighbor nodes through which the node can transfer data. A minimum Energy threshold level (E_{th}) will be required to be maintained at each sensor nodes, and if due to any reason the energy threshold value will drop below $E_{th,}$ the node will die.

There are mainly three phases in the proposed routing algorithm.

1. Neighbor discovery Broadcast Phase.
2. Route formation Phase
3. Data Transfer phase

A. Neighbor Discovery Broadcast phase:

In the wireless sensor network initialization, the base station starts a network discovery process for the entire network to create a set of neighbors & creation of neighbor tables.

The base station broadcasts a setup message to all the sensor nodes. The format of the setup message is as given:

Sender ID	Node Usage Indicator(NUI)	Hop Count Indicator(HCI)	Available Energy Indicator(AEI)	Base Station ID

Fig 3 Format of the Setup Message

Each intermediate node after receiving the packet updates and stores all the necessary information (Node Usage Indicator, Hop Count Indicator and available energy Indicator) in the Sensor Node Information (SNI) Table. Sender ID specifies the node id of the message sender. Initially the message sender is base station but after that any intermediate node can work as a message sender. Base station ID is the node id of the base station. Initially Node Usage Indicator is set to '0' for each sensor node. For the setup packet broadcasted by base station node, the hop count value is set to '0'. After receiving the setup packet, all the receiving nodes within one hop from the base station node set their hop counts with increment 1 and mark the base station node as their parent node by recording its hop count. Then, each node with hop count l, called a relaying node, in turn broadcast a newly constructed setup packet. The new setup packet has the same format as that was sent by the base station node, but with the relaying node's ID number and the hop count is now set to 1. If the same message is received again by an intermediate node, it neglects the message .This broadcasting process repeats hop-by-hop until all the nodes in the network have been notified. B. Route formation Phase:

In the route formation phase, the source node sends the data to the base station by the formation of route using the proposed RBR routing algorithm. The energy consumed by a specific sensor node depends upon the amount of data transfer by that node. If there is a high volume of data, the energy depleted on that node is high and if the amount of data transfer through that node is low then there is low degradation of energy through that node. Initially the source node determines the size of data that is to be transfer to the base station. The size of data will depends upon the number of data packets transferred. After that it calculates the amount of energy required by each intermediate node depending upon the data size. The amount of energy required will vary during each iteration as the total number of data packet will vary. The energy required for transmission of data (E_{tr}) as well as the energy required for receiving of data (E_{re}) at a specific node can be determined using the first order radio model[8]. In this model, a radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and E_{amp} = 100 pJ/bit/m2 for the transmitter amplifier. The radios have power control and can expand the minimum energy required to reach the intended recipients. The radios can be turned off to avoid receiving unintended transmissions.

The transmitting Node Energy is given by

$E_{tr}(m, d) = E_{elec}(m) + E_{amp}(m, d)$

$E_{tr}(m,d)=(E_{elec}+E_{amp}*d^2)*m$ (1)

Where m=no of bits in the data packet and

d= distance between any two nodes (assumed to be same for all nodes.)

The receiving node energy is given by

$E_{re}(m) = E_{elec}(m)$

$E_{re}(m)=E_{elec}*m$ (2)

The amount of energy required $E_{rq}(m)$ for a specific node to transfer data of size m is given by

$E_{rq}(m) = E_{tr}(m) + E_{re}(m)$ (3)

Where $E_{tr}(m)$ = Energy required for transmission of data.

$E_{re}(m)$ = Energy required for receiving of data

The current remaining energy level of a sensor node after relaying one packet of m bits can be calculated by deducting the initial or previous energy value from the value of the energy dissipated by the sensor node.

The format of the route formation packet send by the source node to a specific intermediate neighbor node is as given:

Source ID	Base Station ID	E_{rq} (D)	E_{th}	Present Node ID	Next Node ID	Count Indicator Hop

Fig 4 Format of the Route Formation Packet

Where Source ID is the node ID of the sensor node who wants to transfer data. Base Station ID is the node ID of the sensor node where the data will be received. $E_{rq}(m)$ is the amount of energy required by each intermediate node for transferring data of size m. E_{th} is the minimum energy threshold level required by each intermediate node to live. Present Node ID is the ID of the current Node and the Next Node ID is the ID of the next hop. As soon as the next hop is selected, its ID will be written in the Next Node ID field of the route formation packet .The source will write its ID in the source ID field and in the present Node ID field, just as information for the node that detected the event, after which the source ID field will be fixed, but the present Node ID field will change according to the present node. The Hop Count of the next node will be written in the Hop Count Indicator Field. RBR algorithm finds the best possible route from the source node to the base station through a no of intermediate nodes.

The various steps of proposed RBR algorithms are as given.

1. First of all, find all the neighbor nodes having AEI >= ($E_{rq}(m)$ + E_{th}) using SNI table of the sensor nodes. If there is no node having AEI> ($E_{rq}(m)$ + E_{th}), then drop the data packet as the transfer of packet is not possible, else add all such sensor nodes having AEI>= ($E_{rq}(m)$ + E_{th}) to the present Neighbor list and go to step 2.

2. Now from all the neighbor nodes, find the node having highest value of Available Energy Indicator (AEI) and consider it as next hop node. However if there are more than one nodes having the same highest value of AEI, then go to step 3.

3. Find the node having lowest value of HCI (Hop Count Indicator) and consider it as next hop node. If there are more than one node having same highest value of AEI and same lowest value of HCI, then go to step 4.

4. Find the node in which the value of NUI (Node Usage Indicator) is lowest and use it as next hop node.

5. If there are more than one node having same highest value of AEI and same lowest value of HCI and same lowest value of NUI, then go to step 6.

6. Consider any neighbor node as next hop node randomly.

7. Repeat from step 1 to step 6 till all the data packets either reaches to the base station or data packet finally being dropped due to not satisfying the condition given in step 1 by all the neighbor nodes.

Each node will re-calculate the value of AEI after the data transfer. Similarly the value of NUI will be increased by one each time a specific node will be used for data transfer. The same algorithm will be used for all the source nodes interested to send data to the base station. The uniform energy level degradation among all sensor nodes causes an enhancement in the lifetime of the sensor nodes.

C. Data Transfer phase:

After the route establishment, the source node starts transferring the data through the specified route to the base station.

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V. SIMULATION MODEL

A. Simulation Tool (Castalia)

We simulate RBR routing algorithm on Castalia, which is a simulator for Wireless Sensor Networks (WSN). It is based on the OMNeT++ platform. This software provides a high fidelity simulation for wireless communication with detailed propagation, radio and MAC layers. We have compared the proposed RBR routing algorithm with two popular sensor networks routing protocols – directed diffusion and flooding.

B. Performance Matrices

Average Energy Consumption: The average energy consumption can be defined as the average amount of energy dissipated by the sensor node to transmit and/or receive a data packet from the source sensor node to the base station. It can be calculated as

$$E_{avg} = (E_{i,\, initial} - E_{i,\, res})/M*N \qquad (4)$$

Where M is the number of nodes, $E_{i,\, initial}$ is the initial energy level, $E_{i,\, res}$ is the remaining energy levels of node and N is the no of data packets received by the base station.

C. Simulation Parameters

No of sensor nodes: 100
No of packets/sec = 5
Packet size =2KB
Initial Energy level =7 Joule
Energy Threshold Level = 0.5 Joule
Node Placement = Uniform
E_{elec} = 50 nJ/bit
E_{amp} = 100 pJ/bit/m2

VI. RESULTS & DISCUSSIONS

The results obtained after a simulation time of 125,175,200,250 sec are compared with flooding and directed diffusion routing protocols. The comparative average energy consumption graph of all three routing algorithm is as shown in the figure 1.

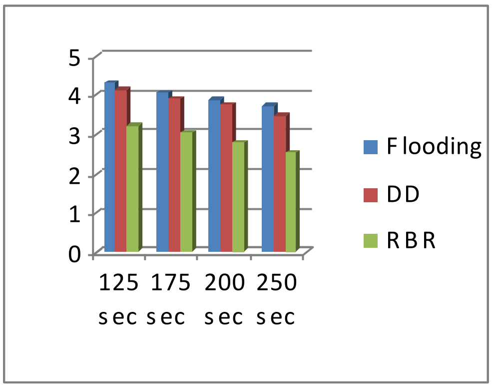

Fig. 5 Avearge Energy Consumption(In Joule) Per Node at Different Simulation Time

From the figure 1 it is clear that at different simulation time intervals, the average energy consumption at a specific sensor node is less in proposed RBR routing algorithm as compared to Flooding and Directed Diffusion(DD) protocols.

VII. CONCLUSIONS & FUTURE WORK

Routing algorithm is an important research topic in wireless sensor networks. Its performance directly affects the energy efficiency and network efficiency. We have proposed an energy-efficient routing algorithm RBR for the wireless sensor networks. It is a decentralized energy aware routing algorithm. This algorithm uses available energy, hop count along with node usage counter. From the simulation results, it can be concluded that proposed RBR algorithm optimize the energy available at a specific node in a much better way as compared to Flooding and Directed Diffusion. In this paper we have considered Flooding and Directed Diffusion, which is an existing energy efficient routing protocol. In future various other Energy Efficient routing algorithms could be taken into consideration while analyzing the performance of our proposed algorithm.

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