MRRP: Multihop Reliable Routing Protocol for Wireless Sensor Network

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ABSTRACT In Wireless sensor networks, sensor nodes sense the data from environment according to its functionality and forwards to its base station. This process is called Data collection and it is done either direct or multi-hop routing. In direct routing, every sensor node directly transfers its sensed data to base station which influences the energy consumption from sensor node due to the far distance between the sensor node and base station. In multi-hop routing, the sensed data is relayed through multiple nodes to the base station, it uses less energy. This paper introduces a new mechanism for data collection and routing based on biased back off scheme. The proposed algorithm is termed as MRRP: Multihop Reliable Routing Protocol. This algorithm is explained and implemented using MATLAB. The performance results are compared with LEACH. The comparison reveals that the proposed algorithm performs better than LEACH.

Key words— Wireless sensor networks, Reliable forwarding, Data collection, back off scheme, Routing Protocol, Energy Efficiency.

I. Introduction

Wireless Sensor Networks (WSNs) are extensively used in numerous real time applications such as military, medical, disaster detection, structural monitoring, etc. These WSNs contains huge set of small sensor nodes, deployed in the environment for monitoring environmental parameters such as humidity, temperature, pressure, etc. The wireless sensor nodes sense the data from environment based on the application and forwards to the central base station or sink for further processing. This process is called data collection, which is the primary task of the WSNs. In data collection process, the sensor nodes forward the data to the central base station either by direct communication or by multi-hop communication. The direct communication from sensor nodes to base station is energy expensive due the distance between sensor nodes and base station is more, this reduces the lifetime of the network. Alternatively, Multi-hop communication schemes are used for better network lifetime and performance due to its effective utilization of resources. In multi-hop communication, every sensor node is busy in forwarding the sensed/received data to nearest intermediate (neighbor) nodes or to the base station using multi-hop routing paths.

In this process, selection of next (neighbor)node in routing path is very important for forwarding data. Then next node or forwarding node in the routing path is not only meant for relaying the data, but also useful for aggregating the data. Data aggregation or Data fusion techniques are used to shrink the size of the data packet to be transmitted to next node by aggregating the data or by eliminating similar data, received from previous nodes. Multi-hop techniques improve the energy conservation of node and the lifetime of the network.

II. Related work

Heinzelman et al. [13] proposed LEACH, a hierarchical cluster based routing algorithm for enhancing the lifetime of the network and reducing the energy usage. In this protocol, the network is managed in the form of clusters. Each cluster consists a set of cluster members that are organized by a Cluster Head (CH). The cluster member forwards the data to respective CH and CHs forward this data to base station. CHs are selected randomly in a distributed manner.

Later, LEACH was modified to LEACH-C [12], where the CH selection process was based on a centralized process, i.e., CHs are elected by the base station based on their residual energy. Mahmood et al. [14] proposed an MODLEACH, modified version of LEACH. In MODLEACH, a CH replacement technique and dual transmitting power levels were proposed to improve the performance based on the metrics such as throughput and lifetime.

Reactive routing protocols [4], [5], [17] are designed to reduce the bandwidth and storage cost consumed in table driven protocols. These protocols apply the on-demand procedures to dynamically build the route between a source and a destination. Routes are generally created and maintained by two different phases, namely: route discovery and route maintenance. Route discovery usually occurs on-demand by flooding an RREQ (Route Request) through the network, i.e., when a node has data to send, it broadcasts an RREQ. When a route is found, the destination returns an RREP (Route Reply), which contains the route information (either the hop-by-hop information [4] or complete addresses from the source to the destination [6]) traversed by the RREQ.

III. BACKGROUND

An overview of the functional architecture of Reliable Routing Enhancement is illustrated in Fig.1, which is a middle-ware design across the MAC and the network layers to increase the resilience to link dynamics for WSNs/IWSNs. The Reliable routing enhancement layer consists of three main modules, the reliable route discovery module, the potential forwarder selection and prioritization module, and the forwarding decision module. The helper node and potential forwarder are interchangeable in this work. The reliable route discovery module finds and maintains the route information for each node. During the route discovery phase, each node involved in the cooperative forwarding process stores the downstream neighborhood information, that is to say, when a node serves as a forwarder, it already knows the next-hop forwarding candidates along the discovered path.

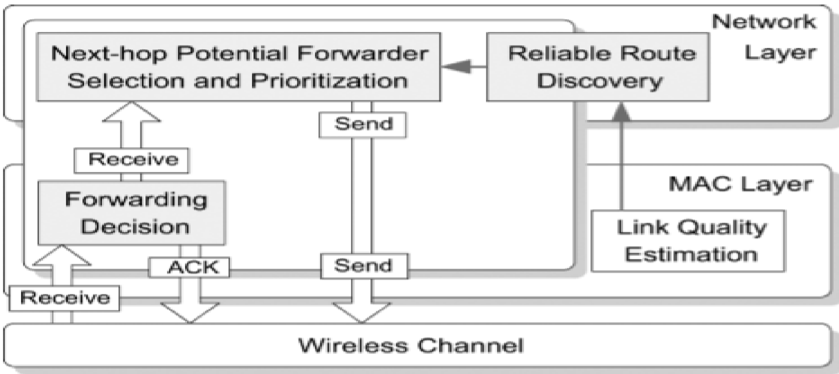

Fig.1 Architectural view of Reliable Routing Enhancement

The other two modules are responsible for the run time forwarding phase. When a node successfully receives a data packet, the forwarding decision module checks whether it is one of the intended receivers. If yes, this node will cache the incoming packet and start a back off timer to return an ACK message, where the timer value is related with its ranking in the intended receiver list (called forwarding candidate list). If there is no other forwarder candidate with higher priority transmitting an ACK before its back off timer expires, it will broadcast an ACK and deliver the packet to the upper layer, i.e., trigger a receiving event in the network layer. Then, the potential forwarder selection and prioritization module attaches the ordered forwarder list in the data packet header for the next hop. Finally, the outgoing packet will be submitted to the MAC layer and forwarded towards the destination.

IV MULTIHOP RELIABLE ROUTING PROTOCOL(MRRP)

A Multi-hop reliable routing protocol, is proposed for data collection in WSN.We consider a dense multihop static WSN deployed in the sensing Fields. Since opportunistic routing is normally effective for wireless networks with higher node densities (e.g., more than ten neighbors per node), we assume that each node has plenty of neighbors. When a node has packets to send to the destination, it launches the on-demand route discovery to find a route if there is not a recent route to a destination.
The proposed MRRP algorithm is explained in Fig.2. This algorithm consists of two stages: Initialization stage and Path Selection and Data Relay stage. These stages are explained in the section given below.

4.1 Initialization stage.

Initially, in this stage, all the sensor nodes are randomly placed in the environment depends on the application. All nodes in the network computes its hop count distance from the BS. For calculation of hop count, BS broadcasts the Beacon message containing its identity.

```
Procedure MRRP ( )
    //Stage I: Intitialization Stage
    node Deployment( )
    // Stage II:Path Selection and Data Relay
    While (not all nodes are dead) do
        Repeat
                Forward_Node_Selection( )
                Forward_Data( )
                Update_Energy( )
                Update_NNtable( )
            Until data reaches to BS
        End
End Procedure
```

Fig.2 MRRP Algorithm

The node, which receives the Beacon signal responds with its id and its location coordinates. BS calculate the hop count from each node using the node coordinates and send the hop count value to nodes .Each sensor node stores hop count value in Neighbor Node information table (NN table). The NN table consist of Next−Node, Hop Count between Next node and BS (HC−BS), Neighbor Node Remaining Energy (NNRE), Distance (Distance between source node and next node), and Distance from next node to BS (D−to−BS).

4..2.1 Forward node selection.

If a node has data packets to send to a destination, it initiates a route discovery by flooding an RREQ message. When a node receives a non-duplicate RREQ, it stores the upstream node id and RREQ's sequence number for reverse route learning. Instead of rebroadcasting the RREQ immediately in existing reactive routing protocols, we introduce a biased back off scheme at the current RREQ forwarding node. The aim of this operation is to intentionally amplify the differences of RREQ's traversing delays along different paths. This operation enables the RREQ to travel faster along the preferred path according to a certain defined metric. Let and denote the last-hop node and current forwarding node of an RREQ, respectively. Let *vi* and *vj* denote the set of vi's one-hop neighbors, and *C (i, j)* denote the common neighbor set between *vi* and *vj*. We define a helper vk between vi and vj as the common neighbor of *vi* and *vj*, satisfying *Pik* > *Pij* and *Pkj* > *Pij*, where *Pij* is the PRR between *vi* and *vj*. For cooperative routing, there exists an implicit constraint, that is, the nodes in the helper set should be able to hear from each other

with a reasonably high probability. Let *H (i, j)* denote the set of helpers between and. In other words, *H (i, j)* is the common neighbor set between *v*i and vj on the premise that any two nodes in *H (i, j)* can overhear each other, and *H* (*i*, *j*), *Pik>Pij*, *Pkj > Pij*.
Let *bij* denote the back off delay at the current forwarding node *vj*, which receives an RREQ from *vi.bij* is calculated as defined in

$$b_{ij} = \frac{Hopcount}{\sum_{k} P_{ik} P_{kj} + 1} . \alpha \quad (1)$$

where α is a time slot unit; the HopCount is the RREQ's hop distance from the source node thus far. The rationale is that, the neighbor by more forwarding candidates, better link qualities, as well as shorter hop-count will have a shorter back off delay to rebroadcast the RREQ.

4.2.2 Aggregate and forward the data.

Forward nodes perform data aggregation on receiving and/or sensed data and then forward to the next selected forward node towards the BS. The energy consumption for data aggregations calculated using the Equation 4

$$EF(b)=bEDA \quad (2)$$

where EDA is the energy needed for Data Fusion or Aggregation of sensor data. b is the data packet size.

4.2.3 Update energy of each node and NN information table.

The first order radio energy model of sensor node considered for this work is discussed in [12]is used to calculate the RE (Residual Energy) of a node i, when it transmits or receives the data packet as follows:

$$RE(i)= RE(i)-(ETX (b, d) + ERX (b, d) +EF(b)) \quad (3)$$

where ETX (b, d) is the energy consumption for transmitting b bit of data in d distance. ERX(b) is the energy expenditure for receiving bit of data.

V SIMULATION RESULTS AND ANALYSIS

The proposed RFDMRP routing algorithm is developed and tested using the MATLAB (2012b). The algorithm is simulated using100sensornodes were randomly deployed in 100m×100marea along with BS. The BS was located in (50,50) position. The transmission range (Tr) of every sensor node in one hop was fixed at 20m. The initial energy (Eo) for the sensor node was set as 0.5J. The value of Electronic amplification(Eelec)for transmitting and receiving the data was set as 50nJ/bit. The packet size of data was 4KB. The energy consumption of a sensor node for transmitting data using free space model (εfs) and multi-path model (εmp) were set as 10pJ/bit/m2,0 .0013pJ/bit/m4 respectively.

5.1 Result analysis

In this Section the performance of proposed algorithm MRR protocol is analyzed and compared with LEACH protocol. For comparison important performance parameters are considered such as
• The Numbers of nodes alive over stimulation time (rounds)
• The numbers of nodes dead over the simulation rounds
• The Remaining Energy over simulation rounds
• The data packets reached to the BS over simulation rounds.

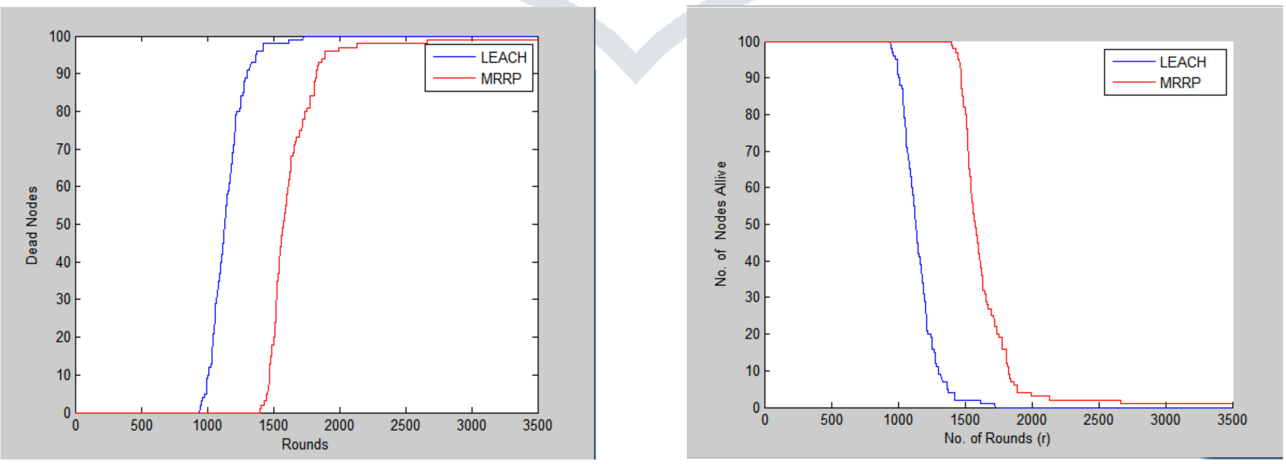

Fig. 3 (a) Dead Nodes vs Round (b) Alive Nodes vs Round

Figure 3(a) shows the graph plotted for the dead nodes over simulation rounds. The first node died earlier in MRRP than The Other Two approaches due to multi-hop transmission of data packets. However, the last node expired earlier in existing approaches than the MRRP. This shows the lifetime is extended in the proposed approach due to the biased back off scheme is used for selection of the next hop node. Similarly, the graph plotted for number of alive nodes over simulation rounds is shown in Fig. 3(b). Figure4(a)shows the graph plotted for remaining energy of each round. MRRP consumed less energy compared to the existing algorithms. This is due to the nodes in the MRRP forward the data to the nearest (less distance) node with less energy. Figure 4(b) shows the graph plotted between data packets forwarded to base station and simulation rounds. More data packets are relayed to the Base station in MRRP when compared to the existing approach.

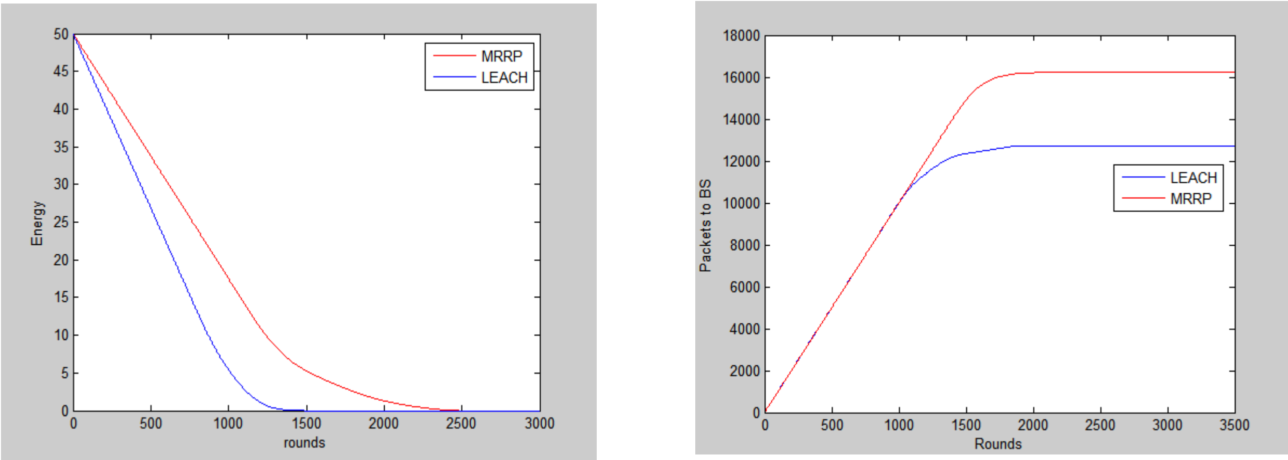

Fig.4 (a) Remaining energy vs Round (b) Number of data packets sent to BS vs Round

VI CONCLUSION

In WSN, Multihop routing is an effective mechanism for data collection. In multi-hop routing, the selection of forward node for relaying data plays a vital role. In this paper, biased back off scheme, is used to propose MRRP.an MRRP is reliable multi-hop routing protocol for data collection in WSN to conserve energy and expand the network lifetime. In MRRP, the hop count value and PRR (packet reception ratio) is considered as parameters for forward node selection. Finally, proposed work was compared with LEACH by considering the performance metric such as network lifetime and energy consumption. From the results, it is observed that MRRP performs better than the existing algorithm.

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