Performance Evaluation of Multipath Ring Routing Protocol for Wireless Sensor Network

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Abstract— **In the past many years different types of routing protocols, single-path and Multipath, have been designed for wireless sensor network. We have also found various multipath routing protocols available that send similar data to base station via multiple paths to increase reliability. We have found that a new simulation environment Castalia is developed based on OMNET++. They have provided implementation of Multipath rings routing protocol. We found that it is based on technique called Synopsis Diffusion. We observed that although implementation of protocol is there, detail understanding of the technique is not available in a literature. Hence, in this paper we have discussed Multipath rings routing protocol for wireless sensor network implemented by Castalia Simulator. Here, we have also, evaluated performance (and hence verified its working) of Multipath rings routing protocol through simulation. We have taken a view that, Multipath rings routing protocol can route the packet from source to Sink via multiple path so network becomes more robust and fault tolerant than the Single path routing. Simulation results also show that Multipath rings routing protocol is more robust than Bypass routing technique.**

Keywords—**Castalia, Multipath Routing, Ring Routing.**

I.   INTRODUCTION

Wireless sensor network (WSN) is a collection of large numbers of low cost low power sensor nodes, which are responsible for sensing the environment and based on triggering condition sensor nodes are activated [1]. Each sensor node has limited transmission range so it can not send their data directly to base station. WSN uses multi-hop communication to send their data to base station. Different routing protocols are designed for routing purpose in wireless sensor network. Each sensor nodes are powered by on board battery and it cannot be replaced or recharge thus network lifetime becomes an important parameter for sensor network design and one cannot use the same routing protocol which designed for wired or wireless network [2].

Tree-based routing structures set up a single propagation path from each sensor node to the base station. They are highly susceptible to failures in wireless communication in that the data acquired by a sensor node are successfully transported to the base station only if the transmissions over all links along its propagation path succeed. In contrast, multi-path routing structures allow multiple propagation paths to be set up between each sensor node and the base station to make data collection robust against communication failures. The data acquired by a sensor node are successfully transported to the base station as long as any one of its propagation paths is failure-free [3].

II.   WORKING OF MULTIPATH RINGS ROUTING PROTOCOL

The multipath rings routing protocol is adopted from similar technique by [4]. In multipath Rings Routing, nodes do not have a specific parent. A node just gets a level ring number during topology formation. Ring number indicates the hop distance of source node from Sink node. The first topology setup packet sent from the Sink (base station) has *ring number 0*. Any node that receives this topology setup packet, it will increment ring number of received packet by *1* and rebroadcast it. This process continues until all packets get ring number. Eventually all connected nodes will have a ring number.
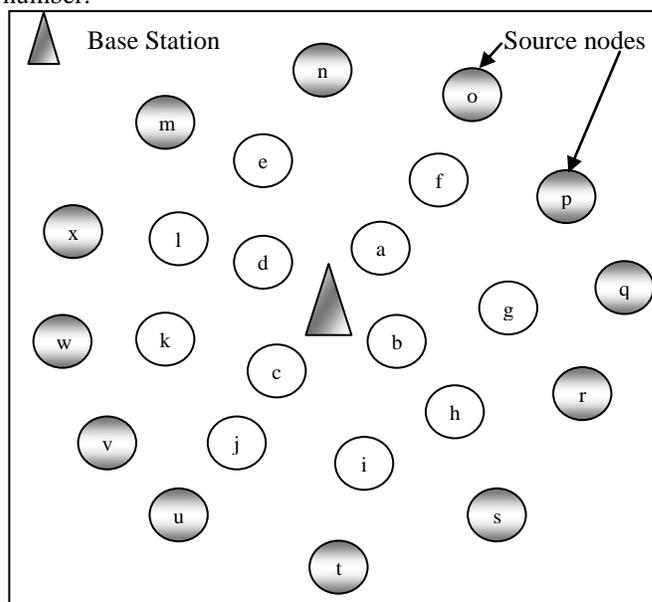

Figure 1.   Sensor nodes in sensor field before topology setup phase

After topology setup phase is completed, when a source node wants to report a data to the Sink it does not send it to a particular node but rather broadcasts it, with attaching its ring number. Any node having a smaller ring number will receive that packet and rebroadcasts it. The process continues until the packet reaches to Sink [5].

Multipath rings routing protocol is a kind of proactive routing protocol because in multipath ring routing protocol network initialization is done prior to the data dissemination and route discovery is also not required before data transmission [3]. In Multipath rings routing protocol it is assumed that all nodes are distributed randomly to sense the sensor field and base station which is responsible to gather data from all sensor nodes and report to data gathering station. It is also assumed that each sensor nodes has own battery for power supply and it cannot be replaced or recharged. Multipath ring routing protocol can be divided into two basic steps 1. Topology setup phase, 2. Data Dissemination phase .

A. Topology Setup Phase

The basic idea of Topology setup phase is to organize network according to each node's hop distance from Sink node i.e. at the end of this phase each node will come to know that how many hop, Sink is away from it.

In Topology setup phase base station broadcast network setup packet with current ring number set to *Zero*. Ring number parameter is used to define hop distance. The nodes which are in direct proximity of the base station can receive this topology setup packet. Upon receiving this packet, receiver node will increment ring number of packet by *1* and rebroadcasts the packet and it will also set its own ring number equals to received packet ring number plus *one*. So all the nodes which are direct neighbour of Sink node will fall under *ring 1* and the direct neighbour of nodes within *ring 1* will fall in *ring 2* and so on. In general if the node is *n* hop away from Sink node then that node will fall under *ring n*.

Self-Node ID	Destination Node ID	Current SinkID	Packet Type	Current Ring Number

Figure 2. Packet Format

Fig. 2 defines the packet format for topology setup phase. This packet contains five basic fields. The first field is ID of the node which is broadcasting the packet, Second field contains the ID of destination node, which is generally broadcast address for topology setup phase, third field is Current SinkID; this field is useful when network is dealing with multiple Sink nodes. The forth field is a flag to define packet type, for Multipath rings routing protocol this flag contains either multipath rings routing topology setup packet or multipath rings routing control packet or multipath rings routing data packet value, while the fifth field indicates the current ring number. During topology setup phase base station will broadcast topology setup packet with current ring number value equals to zero. The process shown in fig. 3 will continue until all nodes will get their ring numbers. Once this phase completed the whole network is divided into set of rings. Each ring represents the hop distance from the base station. In

scenario shown in fig. 4 the network is divided into three rings as R1, R2 and R3 respectively.

There may be chance that some node may join the network after topology setup phase is completed so that node may broadcast join network request. Upon receiving this request, receiver node will send their current ring number to sender node so sender node can set their current ring number equals to one more than received packet's ring number.
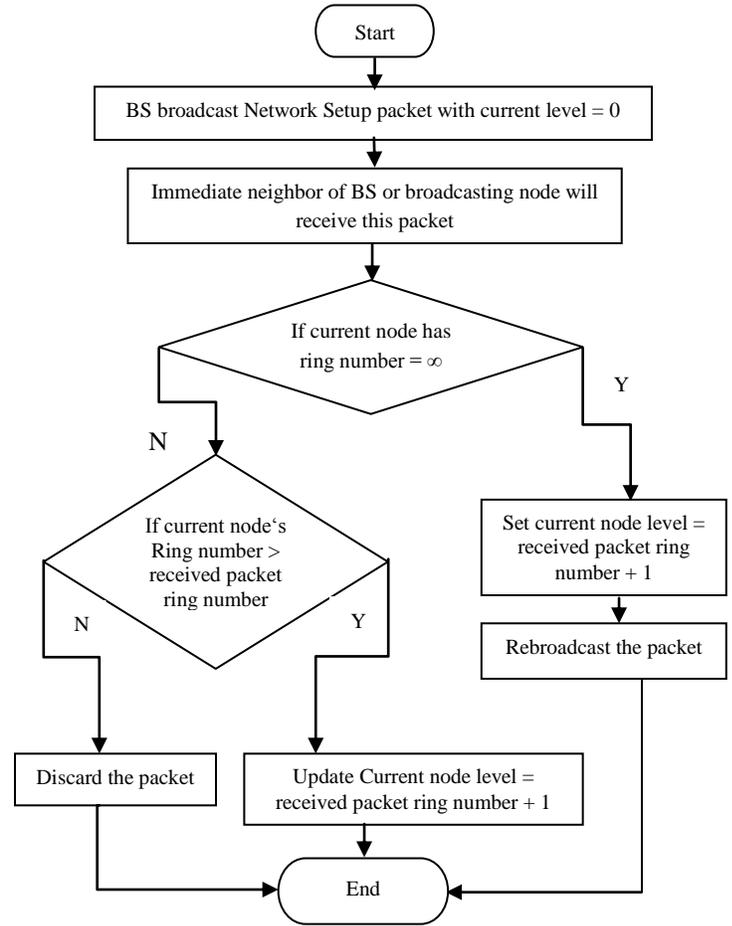

Figure 3. Flow chart of Topology setup phase

B. Data Disseminiation Phase

After completion of topology setup phase data transmission from source node to sink node can take place. In Wireless sensor network as the sensor nodes do not have global address so when any node wants to send its data to sink it won't send to particular node but rather it broadcasts the packet with its current ring number. If any node having current ring number value lower than the received packet's ring number receives, then it can rebroadcast that packet. This process will continue until packet reaches to base station.

Fig. 5 shows the flows of data transfer phase in Multipath ring routing protocol. In this phase when any node wants to send data to sink node it will broadcast the data with its current ring number. So all neighbour of source node can hear that packet and check ring level of that packet if the packet has

higher ring number than the receiving node then only node will further process that packet otherwise it will directly discard that packet. If the receiving node is sink node then it will receive that packet and process it but if the receiving node is not sink node then receiving node will set the ring number of packet equals to its own ring number and rebroadcast the packet.
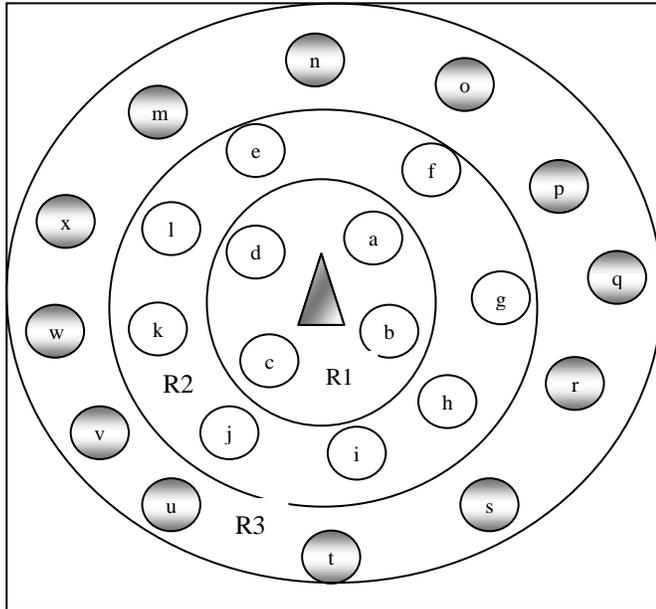

Figure 4. Sensor nodes in sensor sield after topology setup phase

In fig. 6 we have explained data transmission in Multipath rings routing protocol with example. As shown in fig. 6 *node p* and *node q* within ring R3 wants to send their data to sink node, so, it will broadcast their data with its current ring number i.e. *3*. All the neighbour nodes of *node p* and *node q* can receive this packet. Upon receiving the packet, receiver node compares its current ring number with received packet's Ring number and if received packet's ring number is higher than receiving node's ring number then receiving node will decrement current ring number of packet by *1*, and rebroadcast that packet.

In example shown in fig. 6 packet broadcasted by *node p* and *node q* are received by *node f* and *node g* of ring R2. Upon receiving this packet receiver node checks that this packet is not destine to it but it is destined to sink, so, *node f* and *node g* will decrement current ring number packet by *1* and rebroadcasts it. Now this broadcasted packet reaches to ring R1, so, *node a* and *node b* will receive that packet, these node will also check that this packet is not destined to it so again it will decrement current ring number of packet by *1* and rebroadcasts the packet. Now this broadcasted packet reaches to base station and it is also destined to base station only so packet will be given to application layer. In this phase as shown in fig. 6 when nodes of ring R3 wants to send their data to sink node it will broadcast it with its current level. This broadcasted data can be received by many lower level ring's node that's why this protocol is known as Multipath. Because same data is transmitted via multiple paths so robust data

delivery and fault tolerance is also achieved in Multipath ring routing protocol. In data dissemination phase when any node within *ring n* broadcast their data, all the neighbour node of source node within *ring n-1*, *ring n* and *ring n+1* can receive that data but as the Sink node is within *ring 0*, and the aim of algorithm is to route packet from source node to sink node, only nodes of *ring n-1* will process that packet while nodes of *ring n* and *ring n+1* will discard that packet.
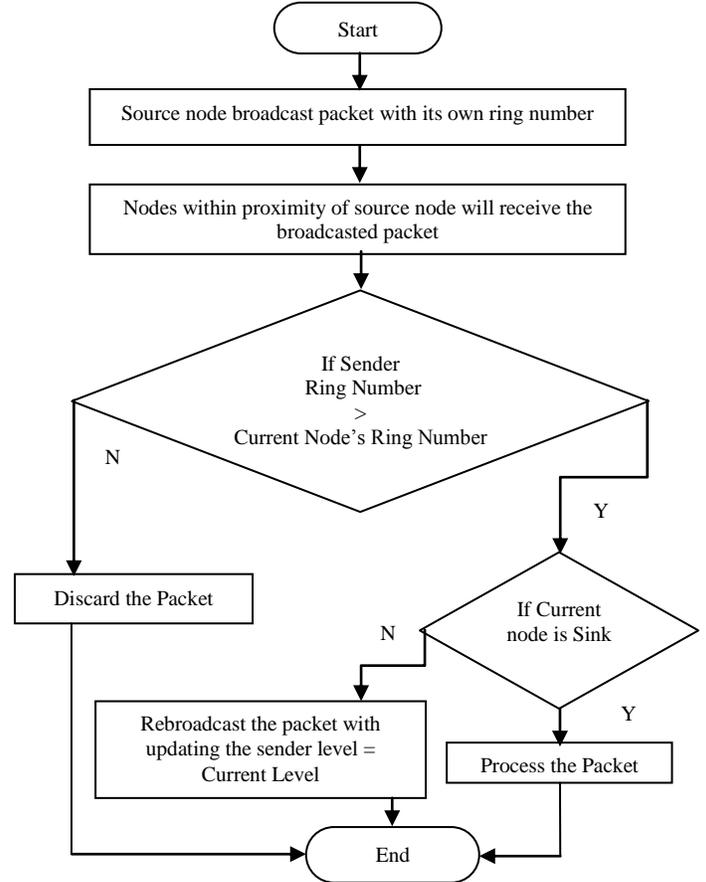

Figure 5. Execution of data disseminiation phase in Multipath rings routng protocol.

III. ENERGY MODEL

The resource manager module of Castalia is responsible to calculate amount of energy used in different operations like transmission, reception etc. The default value is 18720 joules. It is a typical energy of AA battery. Energy is linearly subtracted based on overall power drawn and time passed. Modules that model hardware devices (i.e., the radio and the sensor manager) send messages to the resource manager in order to signal how much power they currently draw. Energy consumption by radio module is separately defined by Castalia [6]. To define the main operating parameters of a radio, Castalia follows a specific format. Castalia defines 2 radios: CC1000 and CC2420. CC2420 and CC1000 define the real radios of the same name by Texas Instruments. For evaluating Multipath rings routing protocol we have used CC2420 radio.

IV. PERFORMANCE EVALUATION THROUGH SIMULATION

To verify working of Multipath ring routing protocol we have used OMNET++ based Castalia simulator and evaluated performance of this protocol. Currently many wireless sensor network simulator are available but Castalia provides realistic and modular environment for radio and channel model. Also Castalia is open source simulator so researcher may also implement their own algorithms and validate it [6].
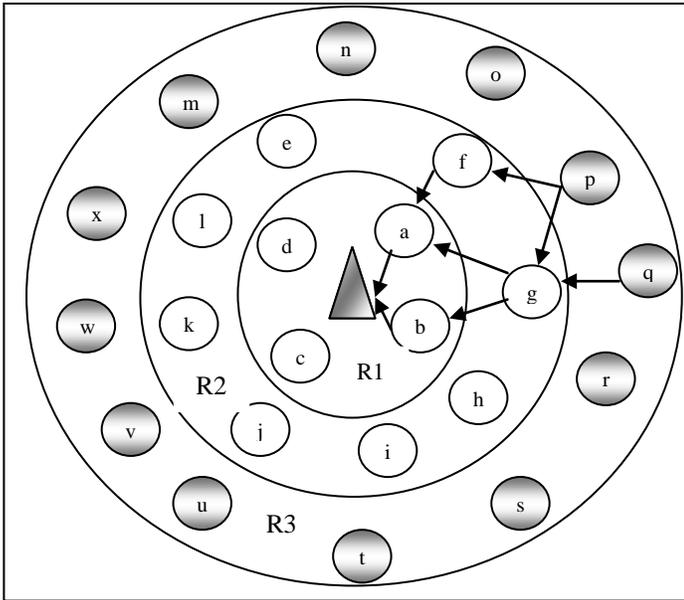

Figure 6. Data transmission in Multipath rings routing

To evaluate the performance of Multipath rings routing protocol we have simulated it with different numbers of nodes and compared its performance with Bypass routing protocol. Bypass routing is a kind of flooding protocol in which there is no specific routing algorithm is implemented. In Bypass routing when any node received packet from other node and it is not destined to that node then receiver node simply rebroadcasts it. Table 1 gives comparison between Bypass routing protocol and Multipath ring routing protocol in terms of numbers of packet successfully delivered to the Sink node.

TABLE I. NUMBER OF PACKETS RECEIVED ON SINK NODE

Numbers of node	Bypass Routing	Multipath Ring Routing
50	335	729
100	715	1447
150	1028	2254
200	1350	3365

From table I we can conclude that as in Bypass routing there is no mechanism to route the data from source to sink node, so only those node can send their packet to base station successfully which are one hop away from base station that's why fewer packets are delivered by Bypass routing protocol compare to Multipath ring routing protocol. Using Multipath rings routing data delivery improves as an average of 122% for the results shown in table I. Fig. 7 shows the graphs of

number of node's participating in the simulation w.r.t number of packets received on sink node for both protocols.

Execution of Multipath rings routing protocol can be verified by debugging simulation. Here we have put several check points to determining that how packet reaches from source node to sink node. We have done two different experiments to debug the Multipath ring routing protocol. In *experiment I* we have run simulation multiple times while varying transmit (Tx) Power of node and we have analysed the impact of Tx power in topology setup.

Where as in *experiment II* we have traced the route of the packet so that we can determine that how packet is routed from higher level ring to sink node.
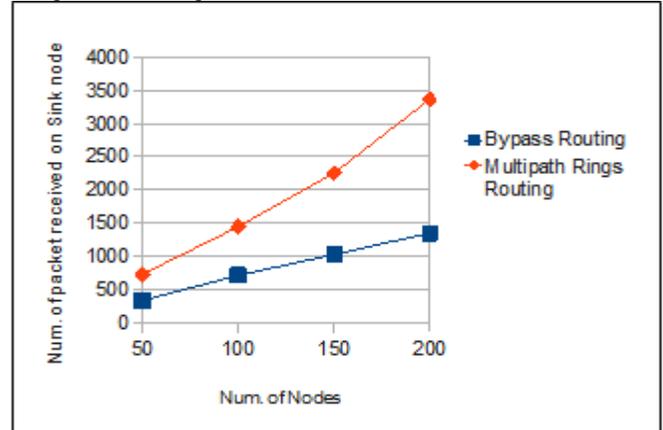

Figure 7. Comparision between Multipath rings routing and Bypass routing.

Table II shows simulation parameters used to verify Multipath rings routing protocol.

TABLE II. SIMULATION PARAMETERS

Parameters Name	Value
Simulation Time	3600 sec.
X axis	100 meters.
Y axis	100 meters
Numbers of Sensor nodes	36
Deployment Type	6x6 Grid
Routing Protocol	Multipath Ring Routing
Application Name	Value reporting
Sink node	Node 3
Radio Type	CC2420

Experiment I: Varying Tx Power

Table III shows the impact of transmission power on topology setup. As we are keeping transmission power high node can send data to longer distance, in the first case we have kept Tx Power = 0 dBm. During this scenario the whole network is divided into three rings i.e. Each packet reaches to sink by travelling maximum three hops.

In second case we have kept Tx Power = -5 dBm. As we are reducing Tx Power node's transmission range decreases. In this case the whole network is divided into 7 rings i.e. any packet in the network can reaches to Sink node by travelling maximum 7 hops. Here we are also concluding one more thing that is as we are reducing Tx Power more numbers of

node are responsible to route the packet so average energy consumption of the network will increase.

In third case we have keep Tx power = -10 dBm. In this case no ring is formed i.e. Tx power of sink node is such a low that no node in the network is able to receive network setup packet broadcasted by sink node. So, communication link set up cannot be possible with such low Tx Power.

TABLE III.   IMPACT OF TX POWER IN TOPOLOGY SETUP PHASE

TX Power	Nos. of Ring formed in Network
0 dBm	3 Rings
-5 dBm	7 Rings
-10 dBm	0 Rings

Experiment II: Trace route

To determine the route taken by the packet to reach from source node to sink node we have put several check points within source code of Multipath rings routing protocol which displays the packet's information at various layer of OSI model. In table IV, we show packet information i.e. sequence number of the packet, at which layer this trace is executed, source address, destination address, ring number of current node and current node at which this trace is generated. From the table IV we can say that when any node generates the packet it will broadcast the packet with its ring number. When this packet is broadcasted in the network, intermediate nodes are just responsible to forward the packet. Hence, at the intermediate node packet is reached to only MAC layer, and on the MAC layer it is verified that this packet is not destine to itself. Therefore it simply rebroadcasts the packet by decrementing ring number of packet by *1*.

Seq. Num.	Layer	Source	Dest.	Sender Ring Num.	Current Node
28	APP	34	SINK	4	34
28	MAC	34	SINK	3	32
28	MAC	34	SINK	2	7
28	MAC	34	SINK	1	3
37	APP	27	SINK	4	37
37	MAC	27	SINK	3	25
37	MAC	27	SINK	2	7
37	MAC	27	SINK	1	3

TABLE IV.   PACKET TRACE INFORMATION

In table IV, *node 34* is generating the packet with *sequence number 28* and packet is destined to SINK node so it broadcasts the packet with its current ring number value *4*. This broadcasted packet is received at *node 32* having current ring number value *3*. As *node32* is not Sink node it will decrement current ring number of packet by *1* and rebroadcast the packet. Now this broadcasted packet by *ring 3* node can be received at ring *2* as well as at *ring 4* but as per the algorithm design this packet will only processed by lower level ring. So the packet processed by *node 7 of ring 2*. Further, *node 7* is not a sink node   and current ring number is not equals to *0* so *node 7* will again decrement the current ring of packet by *1* and rebroadcasts it. This time packet successfully reaches to

sink node that is in our case *node 3* so packet will be de-capsulated and given to the application layer. This way Multipath ring routing protocol can relay the packet from source to sink by using hop distance of the source node to sink node. Here, we are referring it as a ring number of the nodes. Using this algorithm unnecessary flooding in the network is prevented at a same time no explicit route information is require to route the packet.

V.   CONCLUSION

In this paper we have discussed the Multipath rings routing protocol for Wireless sensor network to route the packet from source to sink node. We have also evaluated performance of it and compared it with Bypass routing protocol. We have verified that more numbers of packet are successfully delivered using Multipath routing protocol instead of Bypass routing protocol so we can say that Multipath ring routing protocol is also more robust in terms of data delivery. We have also measured the energy consumption of the network in Bypass routing as well as in Multipath routing and we got almost same energy consumption in both protocol so we can justify that though there is addition overhead of network setup phase in Multipath rings routing protocol, overall energy consumption of both the routing protocol during simulation is same.

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