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An Energy-Efficient Routing Protocol for Wireless Sensor Networks Using AI Techniques

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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 networks. We have also found various multipath routing protocols available that send similar data to the 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 a technique called Synopsis Diffusion. We observed that although the implementation of the protocol is there, a detailed understanding of the technique is not available in the literature. Hence, in this paper, we have discussed the Multipath rings routing protocol for wireless sensor networks implemented by Castalia Simulator. Here, we have also, evaluated the performance (and hence verified its working) of the Multipath rings routing protocol through simulation. We have taken a view that the Multipath rings routing protocol can route the packet from source to Sink via multiple paths so the network becomes more robust and fault tolerant than the Single path routing. Simulation results also show that the Multipath rings routing protocol is more robust than the Proposed EE routing technique.

Keywords—Castalia, Multipath Routing, Ring Routing.

I. INTRODUCTION

A wireless sensor network (WSN) is a collection of large numbers of low-cost low-power sensor nodes responsible for sensing the environment and activated based on triggering condition sensor nodes [1]. Each sensor node has a limited transmission range so it can not send its data directly to the base station. WSN uses multi-hop communication to send its data to the base station. Different routing protocols are designed for routing purposes in the wireless sensor network. Each sensor node are powered by on board battery and it cannot be replaced or recharged thus network lifetime becomes an important parameter for sensor network design and one cannot use the same routing protocol 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. The ring number indicates the hop distance of the source node from the 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 the ring number of the received packet by 1 and rebroadcast it. This process continues until all packets get thering number. Eventually, all connected nodes will have a ring number.

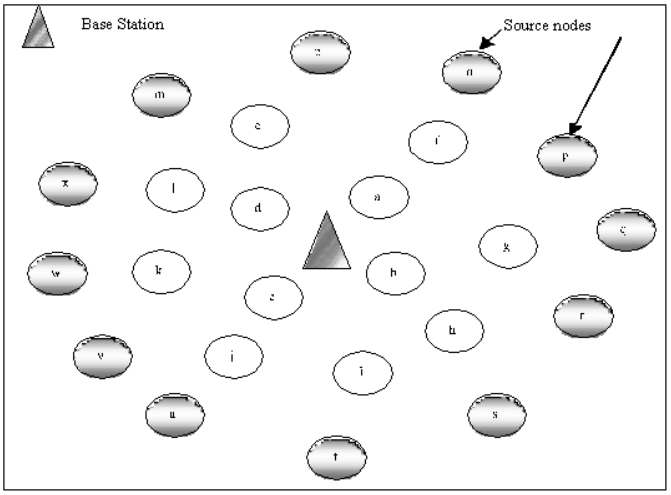


Figure 1. Sensor nodes in the sensor field before the topology setup phase

After topology setup phase is completed, when a source node wants to report data to the Sink it does not send it to a particular node but rather broadcasts it, 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 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 the 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 the data gathering station. It is also assumed that each sensor node has its own power supply battery and 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 the Topology setup phase is to organize the network according to each node's hop distance from the Sink node i.e. at the end of this phase each node will come to knowhow many hops, Sink is away from it.

In the Topology setup phase base station broadcast network setup packet with the current ring number set to Zero. The ring number parameter is used to define hop distance. The nodes which are in direct proximity to the base station can receive this topology setup packet. Upon receiving this packet, the receiver node will increment the ring number of the packet by 1 and rebroadcasts the packet and it will also set its own ring number equal to the received packet ring number plus one. So all the nodes which are the direct neighbor of the Sink node will fall under ring 1 and the direct

neighbor 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-NodeID	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.

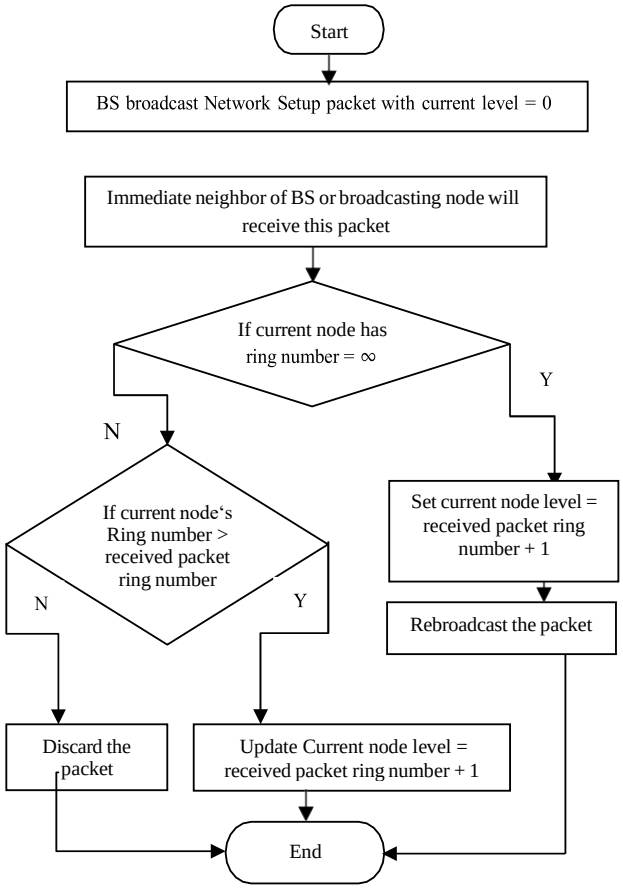


Figure 3. Flow chart of Topology setup phase

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.

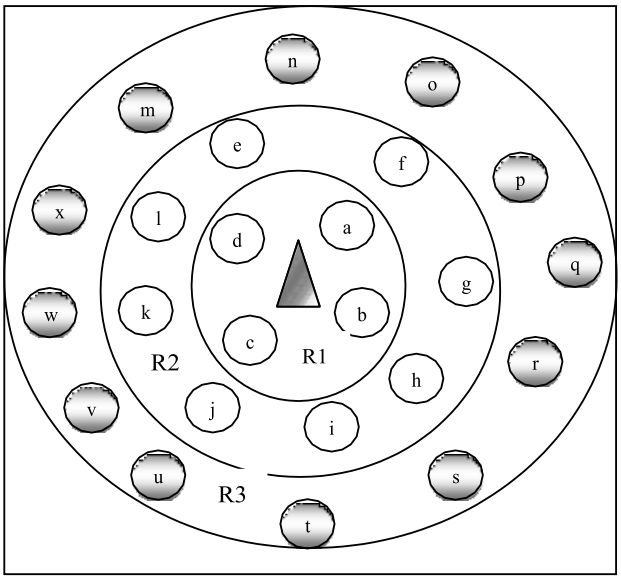


Figure 4. Sensor nodes in sensor shield after the topology setup phase

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

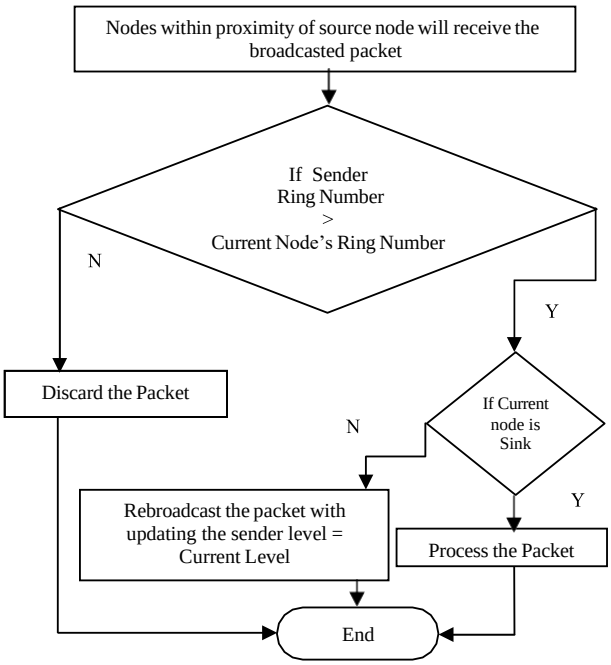


Figure 5. Execution of data dissemination phase in Multipath rings routing protocol.

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

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].

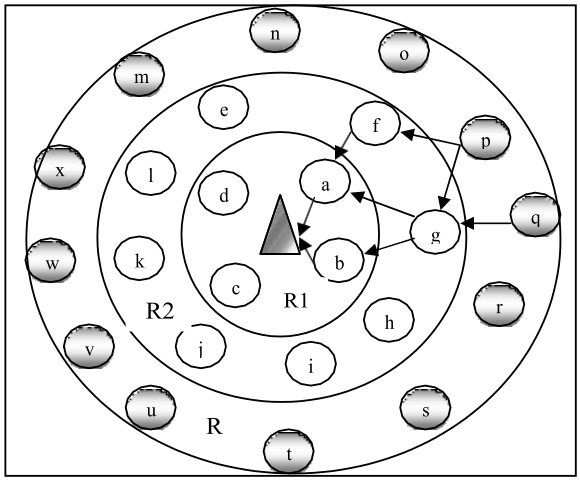


Figure 6. Data transmission in Multipath rings routing

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

TABLE I. NUMBER OF PACKETS FAILED DUE TO INTERFERENCE

Numbers of node	Proposed EE Routing	Multipath Ring Routing
100	20399	23189
200	45164	68043
300	80941	95519
400	123349	140876
500	145440	166783

From table I we can conclude that as in Proposed EE routing there is no mechanism to route the data from source to sink node, so only those node can send their packet to the base station successfully which are one hop away from the base station that's why fewer packets are delivered by Proposed EE 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 the number of nodes participating in the simulation w.r.t number of packets received on the 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.

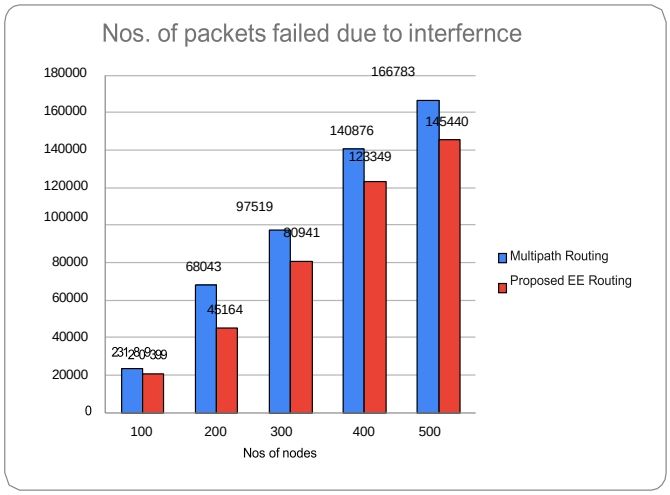


Figure 7. The number of packets failed due to interference How many numbers of packets can be failed due to

interference? To compare v.original and v.proposed. First of all check for 100 sensor nodes and then 200, 300, 400, 500. First of all check for 500 sensors node-related network Consumption. And Comparison of v.proposed and v.original. So, for 500 sensor odes in v.proposed 145410.302, no of packets failed due to interference. And for 500 sensor nodes in v.original 167783.332, no of packets failed due to interference. So, the Total saved packets are 22,373.0272.

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

Parameters Name	Value
Simulation Time	10000 sec.
X-axis	150 meters.
Y-axis	150 meters
Number of Sensor nodes	100,200,300,400,500
MAC Protocol	T(time)-MAC
Routing Protocol	Multipath Ring Routing Vs Proposed Approach
Node Deployment	Uniform
Sink node	Node 0
Sink Position	0,0
Initial Energy	18,720 joule(Equivalent to AA size battery)

Table II. SIMULATION PARAMETERS

Experiment I : performance evolution of proposedrouting protocol

Table III COMPARISON OF MULTIPATH VS PROPOSED ROUTING FORENERGY CONSUMPTION

Numbers of node	Proposed EE Routing	Multipath Ring Routing
100	127	139
200	191	235
300	169	188
400	206	224
500	245	258

First of all, I have two Simulators used in my project related first is OMNET++ and Second is Castalia. I have done my code implementation in v.original and v.proposed. so, v.proposed in multipath ring routing related code available. So I have applied to in CastaliaResults in total 500 Sensor nodes. then I applied how many data packets can be the breakdown. How much was consumed Energy and what remaining energy?

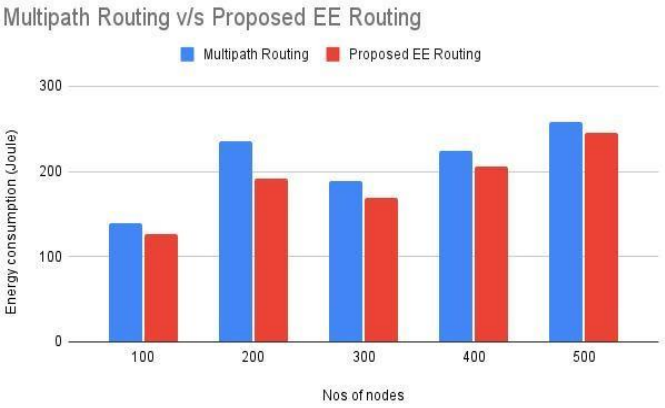


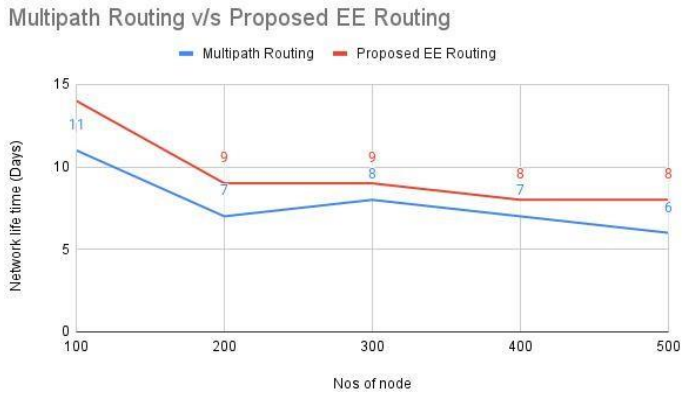
Figure 7. Comparison of Multipath vs Proposed EE Routing for Energy Consumption

So, I have a Comparison of V.original and V.proposed, and then I have found to V.original related Consumed energy is 258.83292 and the remaining energy is 18461.168. and then V.proposed related Consumed energy is 245.1043 and remaining energy 18474.8962. So, the total Save Consumed energy is 13.72862. So, this kind of comparison of multipath routing and proposed routing.

Table III Comparison of Multipath Vs Proposed Routing for network lifetime.

Numbers of node	Proposed EE Routing	Multipath Ring Routing
100	14	11
200	9	7
300	9	8
400	8	7
500	8	6

First of all, How many days for the possible network lifetime to compare 100 sensor nodes,200, 300,400, and 500 to use by proposed EE routing and multipath routing. To minimize quick energy drain and increase WSN lifespan, each active sensor is classified as either a sensing or a relay node based on its coverage capabilities [11]. The sensing node is responsible for all sensing operations. The relay nodes will not perceive the surroundings and transfer sensory information to the washbasin. Furthermore, various techniques were proposed in the literature to reduce energy consumption and thus improve the lifetime of the WSN.



This section describes the models used in this investigation. The system model is provided first, along with the required assumptions that have been established. In addition, the energy consumption model for transmission and reception based on the first-order radio model is described. Following that, the proposed network model is presented.

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 pointswithin 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.

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

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

Broadcast 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 isrequire to route the packet.

V. CONCLUSION

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

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