IEEMARP: Improvised Energy Efficient Multipath Ant Colony Optimization (ACO) Routing Protocol for Wireless Sensor Networks

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Abstract. Wireless Sensor Networks (WSNs) being special type of wireless communication networks, characterized via various specific features like Limited Memory, Energy, Less Processing power. In Wireless Sensor Networks, every sensor node actively participates in routing work by forwarding the packets from sender to receiver and the packet forwarding is entirely based on network topology. One of the most important issue surrounding WSNs is Energy Efficiency and Efficient Routing mechanism which should be dynamic and efficient enough to handle changing topologies. So, there is utmost need for optimization techniques which can lay the foundation of development of suitable routing protocol to attain energy efficiency and routing in sensor networks. Swarm Intelligence is one the most important technique which is highly considered for developing energy efficient routing protocols. Considering Swarm Intelligence, Ant Colony Optimization (ACO) technique is utilized to propose Energy Efficient protocol for WSN. In this paper, a Novel Energy Efficient Routing Protocol based on ACO for WSN is proposed i.e. IEEMARP (Improvised Energy Efficient Multipath Ant Based Routing Protocol). Hardcore testing of protocol proposed i.e. IEEMARP is done in different simulation scenarios using NS-2 simulator on varied parameters like Packet Delivery Ratio, Throughput, Routing Overhead, Energy Consumption and End-To-End Delay and performance is compared with other routing protocols like Basic ACO, DSDV, DSR, ACEAMR, Ant Chain, EMCBR and IACR. The results states that IEEMARP is almost 7 to 10 times better in different parameters. It has also been observed that IEEMARP routing protocol is also efficient in transmitting TCP packets.

Keywords: Sensor networks · Wireless Sensor Networks · ACO
Routing · Pheromone table · IEEMARP · Energy Efficiency · NS-2
ACEAMRA · IACR · EMCBR · Ant chain · DSDV · DSR · AODV
Routing protocol

1 Introduction

Wireless Sensor Networks (WSN) [1–3] are sophisticated next generation sensor networks, integrating various technologies like Sensors, Wireless Communication Network, MEMS technology [4, 5]. WSNs encourage tons of novel and existing applications like Environmental Monitoring, Military, Health-care, industrial production, safe public transportation, smart homes and space technology [6]. Wireless Sensor Networks have enabled highly compact and self-autonomous sensor nodes, each node containing different sensors and have additional functionalities in terms of computation, communication and limited power supply [7]. Conserving energy and balancing power consumption among sensor nodes in entire network is the first and foremost goal to improve overall lifetime of sensor network.

Wireless Sensor Networks (WSNs) consists of few to tons of hundreds and thousands of sensors working cooperatively in particular geographic area to get live data from surroundings. Particularly, two types of sensor networks exist: Structured and Unstructured. In Unstructured WSN, nodes are installed in ad-hoc fashion and once deployed the network can perform monitoring and communication operations without any interference. This network face limitation in terms of failure detection as numbers of nodes is very large. In Structured WSN, few sensor nodes are installed after proper planning and the overall cost and maintenance of this type of network is usually very small.

WSN Technology offers unique advantages as compared to traditional networks in terms of less costs, scalability, efficiency, accuracy, robustness, flexibility and above all ease of deployment. WSN being promising technology to bring revolution in near future especially in terms of Medical technology, Smart Cities development in order to transform the world. Research in WSN aims to meet various limitations in terms of designing new concepts, improvising or developing new routing protocols, new applications development and innovating new algorithms.

WSN networks are highly mobile and dynamic, so finding the optimal path in terms of energy efficiency becomes highly complex. Every sensor node performs the task of routing the packets between source to destination node. As the network packets travel in network, various issues in terms of Packet Delay (Time taken by network packets to reach destination), Energy Efficiency (Battery consumed by sensor nodes to transport the packets), Packet Loss (Dropping of packets in transmission process), Latency and other issues occur which impacts the overall performance and reliability of network. So, sophisticated methodologies and measures are required to combat these issues to make WSN network overall dynamic, robust, energy efficient and highly scalable.

Routing is one of the central issues to be addressed and lots of researchers have proposed novel routing protocols. Data flow between sensor nodes is basically performed via conventional multipath routing protocols like AOMDV which uses same path for transmission in all scenarios. The shortcoming for using AOMDV routing protocol is excessive energy utilization, failure of nodes and partitioning of network which impacts the overall network. Todays, WSN network demand optimal paths changing as per transmission requirements, energy efficiency, less packet loss and proper load balancing. Swarm Intelligence oriented routing protocols [18, 19, 31, 32] -

Ant Colony Optimization, Bee Colony Optimization are best in terms of energy efficiency, packet transfer and load balancing. Ant Colony Optimization based techniques and methodologies [8] are used in several domains cum disciplines to find solutions to tough problems. ACO technique [10–12] basically revolves around studying the behavior and pattern of biological ants to search for food stuff roaming randomly in the environment and their collective behavior to transport the food from source to nest in optimal manner via Pheromone trail based technique.

Ant Colony Optimization (ACO) [9, 13, 14, 19, 29, 30, 39] is based on ants foraging behavior roaming arbitrarily in environment in search for food and upon discovering the food source, returning back to nest leaving behind a trail of chemical substance called "Pheromone" [15–17] for other ants to follow. As, other ants start moving, the routes longer from nest to source loose pheromone as pheromone evaporates guiding the ants to choose the best shortest path.

Stigmergy [20–22] is associated with two common words: "Stigma" and "Ergon" meaning "Stimulation by work". It is combination of Positive and Negative feedback, Multiple Interactions and Randomness.

Swarm Intelligence [19, 23–25] lays the strong foundation of algorithms for distributed optimization and control which ultimately leads to design and development of various routing algorithms/protocols for WSN.

Considering Swarm Intelligence based technique Ant Colony Optimization as prime source of motivation, we propose IEEMARP- ACO based routing protocol for sensor networks. The protocol is suitably evaluated in diverse scenarios using various simulation parameters. The results obtained via novel proposed protocol i.e. IEEMARP is compared with other existing novel routing protocols like Basic ACO, Ant Chain, EMCBR, ACEAMR, IACR protocol on various parameters. The results obtained show the proposed protocol i.e. IEEMARP is quite effective as compared to other protocols in selected schemes.

The Research paper is drafted in following sequence: Sect. 2 presents Literature Review. Section 3 underlines the Design Parameters, Algorithm & Overall scenario flow of IEEMARP Routing Protocol. Section 4 outlines Simulation based results and protocol performance analysis on diverse parameters. Section 5 is devoted to conclusion and future directions.

2 Literature Review

Ant Colony Optimization [14] is completely laid on Ant foraging. Ant Colony System [26–28] is strong example of distributed biological system by which ants via mutual cooperation complete complex tasks which a single individual is almost incompetent to complete. When ants move out from nest in real world environment, in search for food release chemical substance called "Pheromone" [33–35] which is highly volatile. The path is followed by large number of ants which raises the pheromone level and majority of ants follow the same path. Finally, ants will determine the optimal path via cooperation.

Gunes et al. [36] proposed Ant Colony Based Routing Algorithm (ARA). ARA, on-demand algorithm to Adhoc networks in which routing discovery totally relies on

forward and backward ants. In Route discovery, ARA protocol broadcasts forward ants which carries a unique sequence number. If a node receives forward ant that it has never got, it creates a reverse path and rebroadcasts the ant to its neighbors. If the node has received duplicate ant, it will drop the ant. On reaching the destination, the forward ant transforms itself to backward ant and traverses the path to nest backwards. If the intermediate node receives the backward ant, it creates a path to destination node (including next hop, destination and pheromone) and continues the transmission along with reverse path. The intermediate nodes create the respective routing tables. The multipath to the destination node can be formed. Simulation results showed that ARA protocol is efficient as compared to DSR, AODV and DSDV routing protocol.

Shah and Rabaey [37] proposed Energy Aware Routing. The approach is highly useful for less energy and low bit rate networks. Simulation results presents EAR scheme produces an increase of overall 40% network lifetime increase as compared to DD routing scheme.

Hussein and Saadawi [38] proposed Ant Routing Algorithm for Mobile Adhoc Networks (ARAMA). When a node needs to establish a path to destination node, it transmits a forward ant to a neighbor node rather than flooding. Intermediate Node ID's are appended to forward ant along with other information like hops, energy left over, bandwidth, queue length. ARAMA is based on grade and the value is calculated by backward ant and saved in nodes. The formula of grade lies on link information such as energy. When backward ant reaches intermediate node, the pheromone values are updated. The backward ants are dropped on reaching the destination. The data gets transmitted in optimal path.

Camilo et al. [40] proposed Energy Efficient Ant Based routing (EEABR) protocol. Every sensor node in the network launches a forward ant at regular intervals to determine optimal route. Every ant carries the address of the last visited nodes. Every time, a node receives ant, it looks up the entry in routing table. If no loop exists, it adds the entry to the table the information of ant and timer restarts and forwards the ant to next hop. When the forward ant reaches the destination, it is converted to backward ant and lay the pheromone trail on every hop till reaches the nest. EEABR protocol is compared by author with BABR and IABR and results show EEABR is efficient in maintaining energy level of nodes in overall network.

Patel et al. [41] proposed EMCBR protocol. EMCBR is fast, scalable and avoids congestion, delay and improves overall QoS of routing in WSN.

Xia and Wu [42] proposed ACO-EAMRA. In this algorithm, the authors optimized state transition rule and global pheromone update rule. Two parameters q and qo were added in the algorithm to improvise the state transition rule and ants possibility to determine best route. The protocol modifies the pheromone of each edge. ACO-EAMRA Algorithm will repeat N number of times to get optimal global routing path.

Peng et at. [43] proposed IACR protocol. The protocol considers QoS along with balancing energy level of nodes. The protocol constitutes two parts: Route Discovery and Route Maintenance. The algorithm is preferred for performing real-time multi-media activities like Voice Streaming, Video Streaming.

3 IEEEMARP- Improved Energy Efficient Multipath Ant Colony Based Routing Protocol for Wireless Sensor Networks

In this section, IEEMARP- Energy Efficient Multipath Ant Colony Based Routing Protocol for Wireless Sensor Networks will be covered- Design Parameters, Algorithm, Protocol phases and Properties of protocol proposed.

3.1 Design Parameter

STEP 1: Suppose S being the source node want to transmit some data D being destination node with considering all QoS parameters like Energy Efficiency, faster transmission rate, avoidance of delay and quality bandwidth. The nodes visited by ants following the path from Node S to Node D are called Visiting nodes and list of visiting nodes is prepared. Visiting nodes list takes the form of multipath route table Rt.

STEP 2: Node S is taken as initial node from where the transmission will start and will also initialize neighbor discovery process.

STEP 3: Node S will initialize and transmit a Fant (Forward Ant- Route Request) to reach node D through via all path nodes at 1-hop distance from Node S. The Fant contains various parameters like address of source node, address of destination node, hop count and network speed.

STEP 4: On pheromone evaporation, evaluation of 1-hop distance nodes will be performed. Each node 'i' maintains a table called "Pheromone Table", specifying the amount of available pheromone on every link (). This quantity is initialized to constant C.

$$\mathrm{Ph(i,j)} = Ph(i,j) = \frac{[\tau_{i,j}]^{\alpha}.[\eta_{i,j}]^{\beta}}{\sum_{k \in M}[\tau_{i,k}]^{\alpha}.[\eta_{i,k}]^{\beta}} \tag{1}$$

$\tau_{i,j} \rightarrow i_{s}$ the amount of pheromone on the link.

$\eta_{i,j} \rightarrow$ link visibility.

α and β states the importance of pheromone to determine efficient route paths.

$M \rightarrow$ regarded as the set of nodes Vk, not traversed by ant during packet transmission.

STEP 5: Calculation of pheromone evaporation of all 2-hop distance sensor nodes in the network.

STEP 6: The path preference probability value of each path from source S with the help of pheromone evaporation of every node. A node j from a set of adjacent nodes (j, k … n) of i is selected as MPR node such that it covers all the 2-hop distance nodes and its path preference probability is better than others.

STEP 7: If, path preference probability amount is higher as compared to predefined requirements, the path gets accepted and proceed with memory storage for effective utilization.

STEP 8: On reaching the destination Fant gets converted to Bant. The Bant will take the same path like Fant in opposite way.

STEP 9: The path having higher path preference probability will be considered as the optimal path for transmission of data packets from S source node to D destination node.

3.2   IEEMARP Routing Protocol- Algorithm

Input: Feature Matrix
Output: Fitness Value
STEP 1: Initialize Population,
 //Where, x and y - input features of node;   (2)

STEP 2: Initialize path, R = random value for size of feature matrix
STEP 3: Initialize Velocity,

For i=1,
$$V(i) = V + P (R(i), R(j));$$
        End loop

For k = 1 to number of cluster
Omega, O(K+1) = max(omega) – (max(omega) – min(omega). max(R));
V (k+1) = O(k) * v(k) + *(pb(k) – x(k)) + * random * (Gb(k) – x(k)); //Where, pb – Path best; gb – Global Best; k- size of feature vector; b –number of updation;   (3)
Pd = trial intensity (k)*Pb(path(k));

STEP 4: Distance Calculation
STEP 5: Update PBest and GBest
STEP 6: Fitness value updating

Detailed step by step work-flow analysis of IEEMARP protocol is demonstrated in Fig. 1.

3.3   IEEMARP Routing Protocol – Phase of Operation

IEEMARP Routing Protocol (Improvised Energy Efficient Multipath Ant Based Routing Protocol) consists of three phases as: Link Knowledge Based Neighbor Discovery, Packet Forwarding/Fault localization and Reliable End-to-End Communication.

Detailed work of each phase in the designed algorithm i.e. IEEMARP Protocol is described as follows
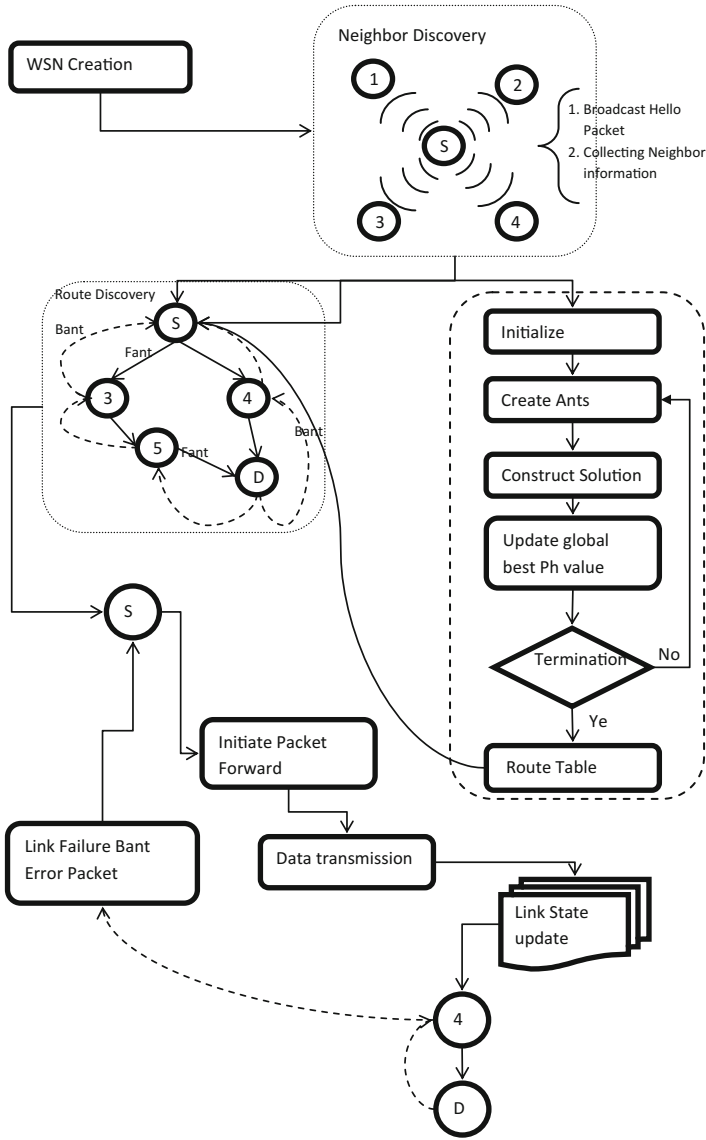
Fig. 1. IEEMARP routing protocol-working

1. Link Knowledge Based Neighbor Discovery

A sensor node sends a Hello message via one-hop broadcast to make its presence known to present nodes in its radio range. Nodes which are in the radio range are called neighbor nodes. A node may go to sleep mode to conserve energy level. When a node wakes up, it sends new hello packet to all the neighbor nodes along with the duration of time it will be in active state in the message. If a node does not wish to be used for

packet forwarding, then it need not send a Hello message to its neighbors. Hello message allows the node to track of all its one-hop neighbors that are willing to forward packets and the duration the node is in active or awake state. The protocol doesn't enforce the node to monitor entire one-hop neighbors.

2. Packet Forwarding/Fault Localization

Let the subset of neighbors that the node keeps track be represented as N. Suppose a node s wants to transmit a packet, transmitted by another node, to a destination node d. For each neighbor node $n \varepsilon N$, the node s maintains a metric $R_{n,d}$, which represents the end to end reliability of forwarding a packet, going to destination node d through the neighbor node n. Initialization and updation of the $R_{n,d}$ value are done by exponentially weighted moving average method which is discussed in the later section.

If the destination node cannot be reached directly, then the node forwards the packet to an active and willing neighbor node. This neighbor node to which the data packet is forwarded to will be henceforth referred to as the next-hop node. The next-hop node is chosen among the set of neighbors with highest R value. The data packets are not forwarded to the node from which it received the packet or to the source node which originated the packet. Every node in the network increments the hop-count value present in the header by one. The packet is discarded if the value of the hop-count exceeds a certain value, avoiding infinite loops in the network.

3. Maintaining End-to-End Reliability of Reaching the Destination

The source node solicits an end to end acknowledgement packet known as ACK packet from destination node for packets that it transmits. The packets soliciting acknowledgement are called as ACK Request (ACKR) packets. The source node forwards these ACKR packets in a round robin fashion to all active and willing nodes. However, the ACKR packets are subsequently treated in the same manner as data packets by all the other nodes to forward them to the next- hop node.i.e. the ACKR packets are treated similar to those of the data packets by being forwarded to the node with the highest R value. When the ACKR packet is received, the destination node sends ACK packet to the source node.

For every ACKR packet p a node generates or forwards, it needs to remember the packet's signature, sig(p), consisting of the source node, destination node, sequence number of the packet, the previous node and next hop node. The signature helps the ACK packet to be forwarded to the neighbor node from which it received the ACKR packet. The signature also helps the node to keep track of ACKR packets it received and eliminate any duplicate ACKR packets by discarding them. Every node after regular intervals of time, checks the quantity of signatures and removes signatures only if threshold value increases.

Each ACK packet carries the current value of end-to-end reliability of reaching the destination node d through the neighbor node n along the route taken by the corresponding ACKR packet. The loss of a huge portion of the ACK packets by these transmissions is still acceptable as long as at least one ACK packet reaches the source node within a reasonable amount of time t (e.g. every 10 min). If no ACK packets are received in response to the ACKR packets forwarded to neighbor node n in time interval t.

The ACKR/ACK packets makes use of the highest reliability service that is provided by the MAC layer such as acknowledged transmission.

3.4   IEEMARP Routing Protocol – Properties

Let N be the set of all the nodes in the network and D be the set of all the destination nodes in the network. Let η and Θ denote the cardinality of the sets N and D respectively.

As the node need not keep track of all its one-hop neighbor nodes, η would be the upper limit of the number of neighbor nodes a node keeps track. The following things are required to be stored in node's memory:

- A set N of one-hop neighbors that the node tracks.
- Rn, d, $\forall$ n ε N and $\forall$ d ε D, will require $O(\eta\Theta)$ memory.
- {sig(p), n}, where sig(p) is the signature of an ACKR packet p forwarded to node n that has not yet reached the destination node and acknowledged.

Each node restricts the number of packet signatures that it can store to some threshold value. Therefore, the total memory requirement of the node to store the packet signatures is $O(\eta)$.

The IEEMARP protocol can have routing loops, but these loops are not persistent. Suppose, we consider a scenario where a node A forwards a packet to another node B. Node B forwards this packet to node C, which in turn forwards this packet back to node A. By imposing the limit on the hop count value ensures that the packet will ultimately be discarded sometime once the hop count exceeds the limit. Also each node keeps track of the signature for the ACKR packet that it has forwarded to its neighbor nodes and has not yet been acknowledged yet. The node uses these signatures to discard any of the duplicate ACKR packets that might be travelling in the loop.

Packets forwarded via broadcast/multicast cannot utilize the MAC-level acknowledgements and they are prone to loss due to collision at MAC-level and PHY-level noise. The IEEMARP protocol avoids broadcast/multicast for data packets forwarding or routing monitoring/discovery.

The protocol does not make use of broadcasting for route discovery and maintenance as it hinders the scalability of the network.

One-hop broadcast is used for route discovery by sending hello packets to neighboring nodes.

4   IEEMARP Simulation

4.1   Parameters of Simulations

See Table 1.

Table 1. Enlists simulation parameters considered for testing IEEMARP protocol

Parameter name	Values
Simulator name and version	ns-allinone-2.35
Base protocol for routing	Ant Colony Optimization (ACO) based routing
Dimension of topology	3000 m x 1000 m
Network type	Wireless
Simulation time	150 s, 300 s, 500 s
Antenna type	Omni antenna
Simulation model	Energy model
Initial energy of nodes	10000 mJ
Number of nodes	100, 150, 200…800 (Max)
Queue length	64
Data rate	Variable
Interface type	Wireless physical interface
Radio range for node	~250 m
Mobility speed	1….15 m/s
MAC type	IEEE 802.11
Mobility model	Random way point

4.2   Metrics Used

To determine the novelty of the proposed protocol the following metrics are used:

- Packet Delivery Overhead
  Packet Delivery is regarded as the total number of packets successful transmitted at destination node.

$$Packet\,Delivery\,Ratio = (Total\,Packets\,Sent - Total\,Packets\,Lost)$$
$$* \; 100/no.\,of\,packets\,sent.$$

- Throughput
  Throughput, is defined as the quantity of data delivered over physical or logical link at particular amount of time. It is determined in bits per second.

$$Throughput = Successful\,transmission\,of\,Total\,Packets/Total\,Transmission\,Time$$

- Routing Overhead
  Routing overhead is regarded as total number of packets required for communication. It is determined via awk script taking input from trace file and giving the end results.
- Energy Consumption
  Energy consumption is measured in Joules. It is defined as the rate of consuming the power from energy source by sensors during various types of works: Packet Transmission, Clustering etc.
- End to End Delay
  End-To-End delay is the duration taken by the packet to be transferred from source to destination.

$$\text{End-To-End Delay} = \text{Transmission time}(\text{Hop }1 + \text{Hop }2 + \ldots + \text{Hop n}).$$

4.3 Simulation Results (Compared with ACO, DSDV and DSR)

Table 2 states performance comparison of protocols: Basic ACO, DSDV, DSR and IEEMARP with respect to various parameters [44–46].

Table 2. ACO V/s DSDV v/s DSR v/s IEEMARP

Parameters	Basic ACO	DSDV	DSR	IEEMARP
Packet Delivery Ratio	94.58	95.96	88.12	97.73
Average End to End Delay	0.21	0.19	0.15	0.58
Average number of hops	1.67	1.092	1.04	8.21
Control packet overhead	9589	4809	5409	6090
Dropped reply messages	44	0	0	1
Throughput (byes/s)	3012	2651	3094	3795

The Results states that IEEMARP Routing Protocol is almost 9–10% efficient in terms of performance as compared to Basic ACO, DSDV, DSR routing protocols.

4.4 Simulation Scenario, Comparison with Other Routing Protocols and Results

Simulation Scenario of IEEMARP routing protocol is demonstrated via NS-2 simulator [47] working and comparison with other routing protocols- ACEAMR, Ant Chain, EMCBR and IACR and results are produced via Data Values and graphs via XGraph.

1. Simulation Scenario
   In Fig. 2, simulation is started demonstrating the updating of neighbors with pheromone values using basic ACO algorithm
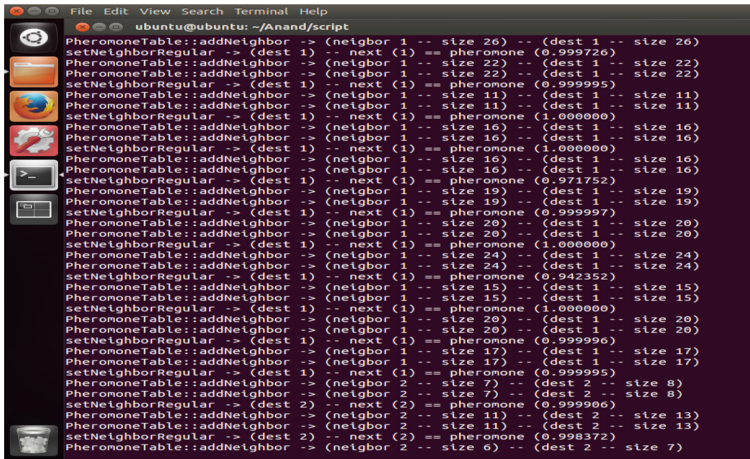
Fig. 2. Simulation scenario started

In Fig. 3, Network Animator window shows the initial stage of IEEMARP routing protocol- Route Discovery in which protocol finds the neighboring sensor node.
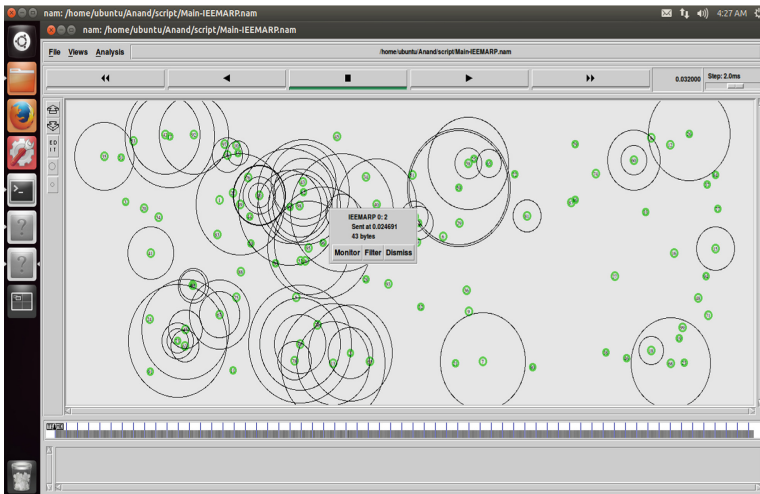

Fig. 3. Route discovery by IEEMARP routing protocol

In Fig. 4, after determining the neighbors and best routing paths, the sensor nodes will send the packets to Base Station (Node 0). The TCP protocol is utilized to send packets for reliable end-end communication.
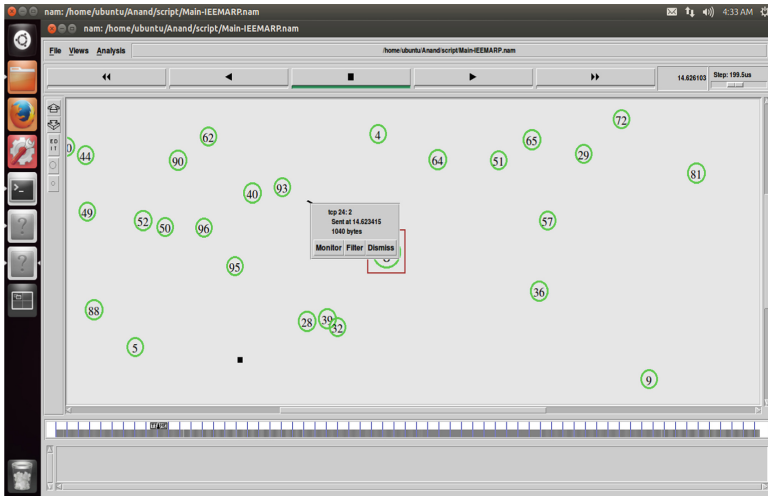
Fig. 4. Packets transmission to base station

In Fig. 5, on the successful receipt of TCP packets from the transmitting node, the base station will send the ACK packet to the sensor nodes confirming the delivery which makes the IEEMARP routing protocol a highly reliable communication protocol.
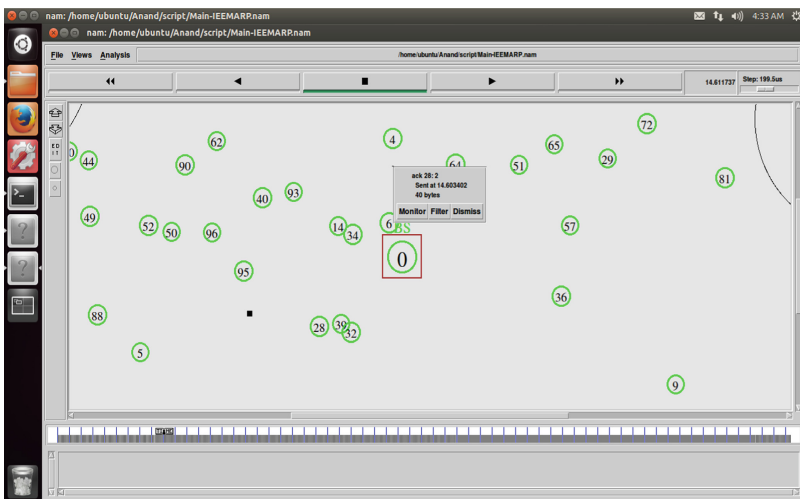

Fig. 5. ACK packet transmission

In Fig. 6, in case of any fault tolerance route discovery process, the packet is dropping due to routing overhead.
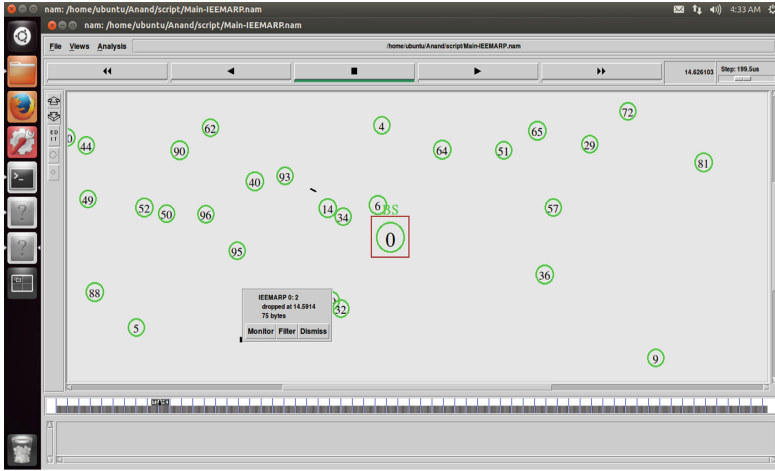
Fig. 6. Packet dropping due to routing overhead

Figure 7, demonstrates the link status between base station 0 and sensor node 3 by 10 Mbits/Sec with delay in 10 s.
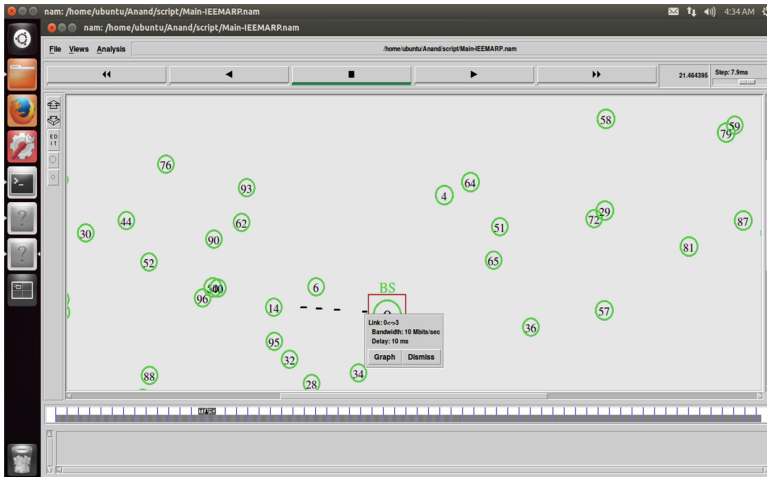

Fig. 7. Link status between nodes

2. Comparison with Other Routing Protocols- ACEAMR, AntChain, EMCBR and IACR

In this part, novel routing Protocol i.e. IEEMARP is compared with other routing protocols (Table 3). In order to prove improvements in Routing protocol, the results are compared with ACEAMR, AntChain, EMCBR and IACR Routing Protocol [47] on varied parameters like: Packet Delivery Ratio, Throughput, Routing Overhead, Energy Consumption, End-to-End Delay.

- Packet Delivery Ratio
  Data values
  Results show that IEEMARP routing protocol is almost 15% more efficient in PACKET DELIVERY as compared to other routing protocols (Fig. 8).

Table 3. Demonstrates Packet Delivery Ratio of routing protocols compared with IEEMARP on varied simulation times.

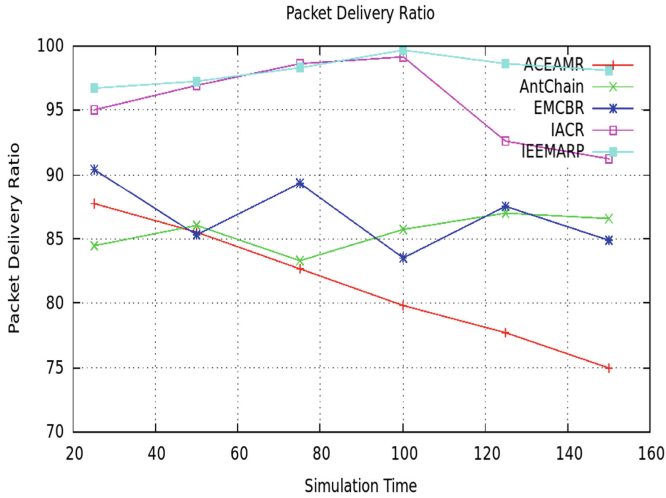| Packet Delivery Ratio					
Time	ACEAMR	AntChain	EMCBR	IACR	IEEMARP
25	87.76	84.51	90.40	95.03	96.68
50	85.5	86.02	85.30	96.94	97.26
75	82.7	83.31	89.32	98.65	98.36
100	79.87	85.77	83.53	99.13	99.65
125	77.73	87	87.49	92.56	98.65
150	74.97	86.56	84.91	91.26	98.14

- Throughput
  Data Values
  The following Table 4 shows the Throughput of Routing Protocols compared with IEEMARP on varied simulation times.

Table 4. Performance based on Throughput

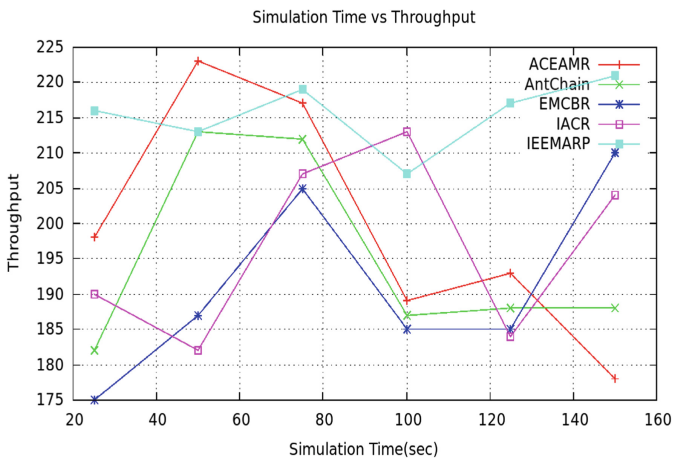| Throughput (Mbps)					
Time	ACEAMR	AntChain	EMCBR	IACR	IEEMARP
25	198	182	175	190	216
50	223	213	187	182	213
75	217	212	205	207	219
100	189	187	185	213	207
125	193	188	185	184	217
150	178	188	210	204	221

Results show that IEEMARP routing protocol is almost 22% more efficient in THROUGHPUT as compared to other routing protocols (Fig. 9).

Fig. 8. Xgraph based results demonstrating performance comparison on basis of Packet Delivery Ratio of IEEMARP routing protocol with other routing protocols.
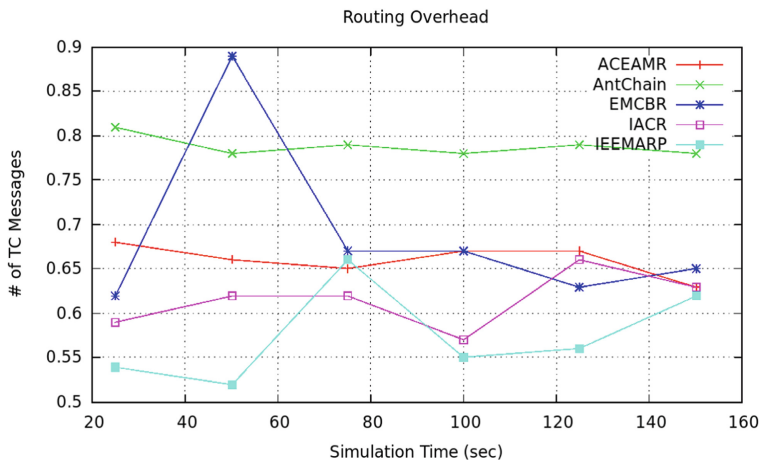
Table 5. Performance based on Routing Overhead

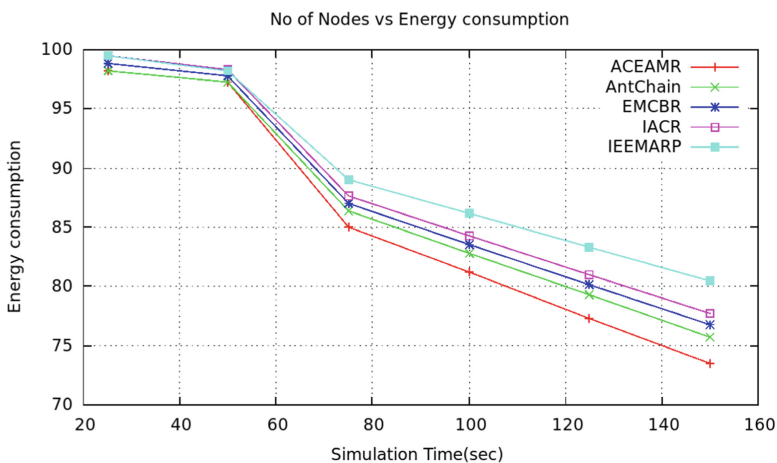| Routing Overhead					
Time	ACEAMR	AntChain	EMCBR	IACR	IEEMARP
25	0.68	0.81	0.62	0.59	0.54
50	0.66	0.78	0.89	0.62	0.52
75	0.65	0.79	0.67	0.62	0.66
100	0.67	0.78	0.67	0.57	0.55
125	0.67	0.79	0.63	0.66	0.56
150	0.63	0.78	0.65	0.63	0.62

Fig. 9. Xgraph based results demonstrating performance comparison on basis of throughout of IEEMARP routing protocol with other routing protocols.

Fig. 10. Xgraph based results demonstrating performance comparison on basis of Routing Overhead of IEEMARP routing protocol with other routing protocols.

Fig. 11. Xgraph based results demonstrating performance comparison on basis of Energy Consumption of IEEMARP routing protocol.

- Routing Overhead
  Data Values
  The following Table 5 shows the Routing Overhead of Routing Protocols compared with IEEMARP on varied simulation times.
  Results show that IEEMARP routing protocol is almost 13% more efficient in ROUTING OVERHEAD as compared to other routing protocols (Fig. 10).

- Energy Consumption
  Data Values
  Table 6 shows the Energy Efficiency of Routing Protocols compared with IEE-MARP on varied simulation times.

Table 6. Performance Based on Energy Consumption

Energy Consumption (Joules)				
Time	ACEAMR	AntChain	EMCBR	IACR	IEEMARP
25	98.21	98.2	98.81	99.42	99.52
50	97.23	97.25	97.78	98.32	98.21
75	85.05	86.33	86.95	87.59	89.06
100	81.17	82.79	83.54	84.30	86.20
125	77.30	79.26	80.13	81.01	83.33
150	73.43	75.72	76.72	77.72	80.47

IEEMARP routing protocol is almost 8% efficient in ENERGY CONSUMPTION as compared to other protocols (Fig. 11).
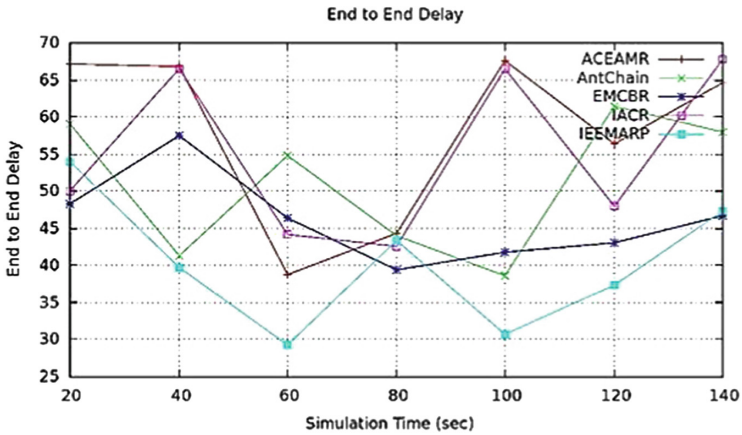
- End-To-End Delay
  Data Values
  The following Table 7 shows End-To-End Delay of IEEMARP protocol compared with other protocols on varied simulation times.

Table 7. Performance based on End-To-End Delay

End-To-End Delay (Seconds)				
Time	ACEAMR	AntChain	EMCBR	IACR	IEEMARP
20	67.12	51.99	48.28	50.10	53.97
40	66.89	42.06	57.53	66.47	39.72
60	38.82	67.35	46.39	44.24	29.22
80	44.25	65.30	39.43	42.59	43.41
100	67.55	55.11	41.77	66.52	30.74
120	56.37	60.95	43.03	47.98	37.28
140	64.67	49.13	46.78	67.75	44.34

IEEMARP routing protocol is almost 16% more efficient in END-TO-END DELAY.

Fig. 12. Xgraph based results demonstrating performance comparison on basis of End to End Delay of IEEMARP routing protocol with other routing protocols.

5 Conclusion and Future Scope

Wireless Sensor Networks are used in real time applications like Environmental Monitoring, Agriculture fields monitoring, battlefields monitoring, industrial and production control based monitoring. Due to topological changes which are highly dynamic in nature, it becomes a challenging task to route the packets efficiency considering varied parameters like Energy, Routing Overhead, End to End delay etc. to final destination in Wireless Sensor Networks. Keeping in view of the same, we proposed a new Novel ACO Based Routing Protocol i.e. IEEMARP (Improvised Energy Efficient Multipath Ant Based Routing Protocol) which considers the real-time Ant based control for movement of packets efficiently from source to destination. In the protocol, the main aim is to search for neighbor and determine optimal shortest paths between transmitting nodes, but also considers multipath links and quality in terms of throughput which makes us the paths. The protocol is properly simulated on NS-2 simulator and compared with various routing protocols like Basic ACO, DSDV, DSR and even other protocols being proposed by other researchers like ACEAMR, Ant Chain, EMCBR and IACR. We have found IEEMARP better in performance i.e. Packet Delivery, Throughput, Energy Efficiency, Routing Overhead and End-to-End delay. The performance is determined via varied simulation scenarios, simulation time and number of nodes and properly analyzed and presented via Graphs in this paper.

Future Scope
We try to compare the proposed routing protocol i.e. IEEMARP with other routing protocols like AntQHSen, FACOR, ANTALG etc. Other features like security enhancement can be considered in near future to make IEEMARP a secure WSN routing protocol.

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