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IEEMARP- a novel energy efficient multipath routing protocol based on ant Colony optimization (ACO) for dynamic sensor networks

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Abstract

In the past few years, research and development in Wireless Sensor networks (WSNs) have gained momentum due to its numerous applications in agriculture, industrial manufacturing, military surveillance, environmental monitoring, consumer electronics, medical & healthcare, disaster recovery operations etc. Dynamic WSNs offer a robust blend of distributed sensing, computing and communication. Dynamic sensor networks are characterized by large scale deployment, dynamic and unstructured topology, power limitations, less memory and limited computational capabilities. Sensor nodes deployed in real-time environment's for sensing data have power-limitations which hampers the overall performance of WSNs. So, the only obvious solution is to propose an energy efficient routing protocol to optimize WSN real-time performance. Different specialists have proposed various directing conventions for WSNs dependent on Fuzzy Logic, Genetic Algorithms, Meta-Heuristics, and other improvement strategies. However, every solution suggested till date has its advantages and limitations. In this paper, our primary objective is to utilize Swarm-Intelligence based approach i.e. "Ant Colony Optimization (ACO)", for routing protocol development. Ant colony optimization (ACO) based approach gives optimal solution in terms of efficient routing path determination, energy efficiency and delivering high performance in terms of packet delivery and throughput. In this paper, we propose a novel energy efficient ACO based multipath routing protocol for WSN i.e. IEEMARP (Improvised Energy Efficient Multipath ACO based Routing Protocol). The proposed protocol works in three phases (Neighbor Discovery via Link Knowledge, Packet Transmission via exponentially weighted moving average method and ACKR packet delivery for assuring end-to-end delivery. To validate the performance of the protocol

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proposed, extensive simulations were conducted using NS-2.35-allinone simulator on diverse parameters like (PDR), throughput, routing overhead, energy consumption and end-to-end delay. In addition to this, the performance of protocol is compared with traditional routing protocols like Basic ACO, DSDV and DSR and other ACO based WSN protocols like ACEAMR, AntChain, EMCBR, IACR, AntHQSeN, FACOR and ANTALG. Simulation based results, clearly states that as compared to Basic ACO, DSDV and DSR, the performance of WSN network is improvised to around 10% in all performance metrics via IEEMARP routing protocol. And as compared to ACEAMR, AntChain, EMCBR and IACR, IEEMARP performs 20% better in overall functionality and almost 10–12% better as compared to AntHQSeN, FACOR, ANTLAG routing protocols in varied WSN scenarios. It is also observed that IEEMARP protocol is highly efficient in TCP packet transmission from source to destination node.

Keywords Wireless sensor networks (WSN) · Ant colony optimization (ACO) · Energy efficient routing · DSDV· DSR · Basic ACO · ACEAMRA · AntChain · EMCBR · IACR · AntQHSeN · FACOR · ANTALG · Swarm intelligence · Packet delivery ratio · End-to-end delay · Throughput

1 Introduction

Recent advancements in wireless standards and Microelectromechanical Systems (MEMS) technology enhanced the technology driving Wireless Sensor Networks. Wireless Sensor networks (WSN) [1, 55, 57] are composed of few hundreds to tons of thousands of static or mobile sensors, forming a self-organized ad-hoc network [6, 13, 17, 20–22, 32, 33] in multi-hop manner. Every sensor in WSN is highly compact, tiny, and efficiently collaborate with other sensors to sense, process, compute and transfer the live sensed data back to the receiving station for further processing. Every operational sensor node can sense diverse information like temperature, humidity, pressure, vehicle movements, airflow direction, gases and other characteristics [49]. It is because of these varied sensing characteristics, sensor networks, nowadays, can be deployed in varied real-world environments like Agriculture, industry, environmental sensing, healthcare, smart homes, smart cities, military, underwater and even space explorations [23].

Sensor networks are classified into two broad categories: Structured and Unstructured. In unstructured WSN, ad-hoc deployment of sensor nodes is done and nodes can perform all tasks from monitoring, communication, sensing and computations without any sort of human intervention. In case of structured WSN, sensor nodes installed in real-time with proper planning, as sensors are comparatively less in number as compared to unstructured WSN and installation, cost of laying as well as preventive maintenance is cheap as compared to unstructured WSN.

Wireless sensor networks are equipped with an automatic network formation function, in which, the sensor nodes once deployed can start communicating with neighboring nodes forming autonomous network in an automated fashion. The main features surrounding wireless sensor networks are self-organization, scalability, dynamic topology, limited resources of sensor nodes, data-centric, robustness, flexibility and ease of installation. In this research paper, our main contribution is to work towards energy efficient routing protocol based on ACO.

1.1 Design issues and challenges of wireless sensor networks

a. Node Deployment: In WSNs, application dependent node deployment strategy is followed by either random deployment or manual deployment. All the sensor nodes are randomly scattered and forms an ad-hoc network whereas in manual deployment, nodes are places as per pre-defined paths. In order to optimize the methodology for random deployment, various techniques are useful for WSNs in terms of Swarm Intelligence like Bee Colony Optimization (BCO) [26, 52, 63], Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) or Genetic Algorithm [50].
b. Energy Conservation: In WSNs, all nodes transmit the data from one node to another and in addition to transmission, the nodes perform the task of complex computation and communication which utilizes additional energy. More energy utilization, can shorten the time span of node to operate. Researchers also concluded that strong energy utilization also occurs when nodes perform the task of data sensing, processing, route path discovery. So, efficient routing protocols are required to perform the task by consuming less energy of nodes [35, 40].
c. Fault Tolerance: Various environmental factors like Physical calamities, power lags and even interferences can damage the sensor nodes hardware characteristics, bringing the entire network to halt. It is required that routing protocols must deploy fault tolerance mechanism to keep the operations going on smoothly and WSN network operate without any faults.
d. Security: Another serious challenge concerning WSN after routing is Security. As sensors are deployed in sensitive areas like underwater, military battle stations, sensitive industrial manufacturing centers etc. Sensors requires protection from all sorts of threats/intrusions coming from outside world. So, routing protocols must be secure enough to protect the sensors from varied attacks.
e. Scalability: Sensor Networks are highly dynamic and size of network can increase from time to time. So, routing schemes deployed must be scalable enough to handle high data transmission loads and sensors to respond to all events in timely fashion irrespective of the sensor network size.
f. Link Heterogeneity: As Sensor network, may comprise of tons of heterogeneous nodes, via which routing issues can impact the overall performance. Routing protocols should be highly adaptable to handle all types of heterogeneous nodes.
g. Robustness: In order to enhance lifetime of nodes, every node must be designed to be robust as much as possible. In order to implement a real-time WSN environment, tons of nodes are deployed and has to remain operational for suitable number of years. In order to attain this, the system must be designed to tolerate and adapt to all sort of node failures. System components must be independent as possible and must be equipped with strong interfaces to handle all sorts of unexpected events. The robustness of all sorts of wireless links can be enhanced via utilization of multi-channel and spread spectrum radios to operate on varied frequencies.

The research and development of routing protocols towards less energy consumption for performing packet transmission is one of the significant issues for WSNs because sensor nodes have limited power and cannot be used for a prolonged period of time. In WSNs with the static sink node, the sensor nodes can transmit the information to the sink node in multi-hop fashion manner. So, the sensor nodes lying very close to the sink node can lose their energy faster as compared to other nodes, as more data is routed to these nodes, as these nodes are close to a sink node, and lots of routing tasks are also required to be performed by these nodes. Multi-hop routing is regarded as serious issue to be solved as this can impact the overall functionality of the network.

Considering conventional multipath routing protocols like AOMDV, which uses the same path for transmission was not efficient, as excessive energy consumption, node failures and network partitioning was there, which impacts the overall network performance.

To design, energy efficient routing protocol for WSNs, we must control overall network for optimal path discovery and energy consumption of nodes. In addition to this, routing protocol should be efficient enough to maintain throughput, routing overhead reduction, packet delivery ratio and end-to-end delay reduction in overall network. [61]

Considering the above-mentioned reasons for enhancing network lifetime, the following initial parameters are considered on top priority for development of an efficient routing protocol:

- Optimal route selection for transmission of packets from source to destination.
- Maintaining energy efficiency in sensor nodes to assure, WSN network is operational for a prolonged period of time.
- Maintaining other network parameters like: Packet delivery ratio, routing overhead, throughput and end-to-end delay.

To achieve this, Swarm Intelligence based techniques- ACO and BCO are best for WSN [39]. But out of the two, the ACO based technique is optimal. ACO technique [3, 4, 8, 9, 11, 12, 18, 27, 29, 30, 43, 51, 65] is a metaheuristic technique inspired by foraging behavior of real-ant colonies. ACO algorithm lays the shortest path between nest and food sources. When ant roams randomly in the environment, it releases a pheromone trail which acts as a base for other ants to follow the same track from nest to food source and vice-versa. As more and more, ants pass the same path, the pheromone quantity automatically gets increased. The larger the pheromone, the more ants will follow the same path and in turn, ants construct the optimal shortest path in the environment to facilitate the food movement from source to nest. Considering the methodology of ACO, and real-time ants' inspiration, lots of researchers have proposed tons of ACO based routing protocols [41, 44] like Basic ACO, SC, EEABR, FF, ED, BABR etc. but all have issues with regard to dynamic mobility, energy and end-to-end reliability.

In this paper, we propose a novel energy efficient multipath routing protocol based on ACO, i.e. IEEMARP, efficient enough to be applied to unstructured WSNs for efficient data transmission via laying an optimal path of discovering neighboring nodes using link discovery, performing packet forwarding to avoid end-to-end delays and maintaining overall throughput and high packet delivery ratio among transmitting nodes.

Contributions in paper:

(1): An in-depth analysis of Literature concerning various techniques/protocols proposed by varied researchers based on Ant Colony Optimization (ACO) for enhancing performance parameters for Sensor network in terms of energy efficiency, throughput, packet delivery ratio, routing overhead and end-end delivery.
(2): Analysis with regard to Ant Colony Optimization (ACO) based Swarm Intelligence technique for applying in Sensor Networks to improvise sensor network performance.
(3): Design and Development of- A novel energy efficient multipath routing protocol based on ACO for dynamic sensor networks i.e. IEEMARP for better Packet delivery ratio, energy efficiency, throughput, less routing overhead and end-to-end delivery optimization.
(4): Simulation based Extensive testing of- IEEMARP with standard WSN routing protocols like DSDV, DSR, Basic ACO and novel ACO based proposed protocols, i.e. ACEAMR, AntChain, EMCBR, IACR, AntHQSeN, FACOR and ANTLAG using NS-2.35 all-in-one simulator to observe the performance achieved.

1.2 Organization of Paper

Section II outlines Literature review with regard to study of various routing protocols and techniques observed and gaps identified in existing research, acted as motivation towards design of novel multipath ACO based routing protocol. Section III enlightens the concept of "Ant Colony Optimization" and ACO algorithm, taken as base for research. Section IV discusses IEEMARP routing protocol- Design Parameters, Algorithm, Protocol steps and properties. Simulation and discussion part of the IEEMARP routing protocol is enlisted in section V. Section VI gives performance highlights of the proposed protocol in comparison with standard and other novel ACO based WSN routing protocols. Section VII concludes the paper with future scope.

2 Literature review

In this section, comprehensive literature work with regard to various routing protocols, proposed by several researchers considering ACO based technique for WSN's is elaborated stating the gaps identified.

Dorigo and Gambardella outlines Ant Colony System (ACS) [10], in which ants efficiently complete all sorts of complex tasks via mutual cooperation, which sometimes becomes tedious for a single individual to complete. When the ants move out from nest in search of food, lay a chemical trail substance called "Pheromone", [56] being highly volatile chemical substance, acting as guiding source for other ants to follow. More the ants follow the pheromone trail, the level of pheromone raises and attracts other ants to follow leading to optimal path lay from nest to food source.

Gunes et al. [14] proposed Ant Colony based Routing Algorithm (ARA). The algorithm was designed especially for Adhoc networks routing path optimization. In ARA, discovery of routing path depends on backward and forward ants. During the discovery of routing path, ARA protocol broadcasts forward ant carrying unique sequence number. On the receipt of forward ant, by new node, the reverse path is laid and broadcasted. If forward ant is received by any other node which has already received it before, the ant gets dropped. When forward ant reaches the destination, it is changed to backward ant and follows the same path back to the nest. In ARA technique, all the routing tables are created, updated and maintained by intermediate nodes. Simulation based results state that ARA protocol is highly efficient in route discovery and packet transmission as compared to traditional routing protocols like DSR, DSDV and AODV.

Shah and Rabaey [58] proposed Energy Aware Routing (EAR) technique for ad-hoc sensor networks. The protocol proposed uses very less energy of nodes to perform packet transmission from one node to another and simulation-based results stated that EAR technique not only increases the network-lifetime but is almost 40% efficient as compared to existing DD routing schemes.

Hussein and Saadawi [19] proposed Ant Routing Algorithm for Mobile Adhoc Networks (ARAMA). In this protocol, the source node transmits a forward ant to lay a routing path to the destination node instead of using flooding technique. All the information with regard to intermediate nodes is added to the forward ant in addition to other information like number of hops, pending energy, bandwidth and length of the queue. On reaching the destination, all the pheromone values are updated and forward ants are dropped and optimal track for routing the packets between source to destination node is constructed.

Ding and Liu proposed AntChain algorithm [7]. In this algorithm, the base station uses an efficient optimization method, i.e. Ant colony optimization, to form a chain. In this algorithm, the routing information is sent to sensor nodes in the form of a chain. In AntChain, three different sensor chains are used for data gathering to handle all sorts of situation. (1) Bi-Directional Ant-Chain- self adaptive to all sorts of changes made in topology; (2) Uni-direction AntChain- used for data gathering; (3) Query chain- to collect data from other sensor nodes operating in WSN. Simulation based results states that AntChain performs better in terms of data handling i.e. reliable and energy efficient transmission happens between source node to destination node and the network lifetime in AntChain is better as compared to other protocols i.e. LEACH and PEGASIS.

Camilo et al. [5] proposed Energy Efficient Ant Based routing (EEABR) protocol. In this protocol, forward ant is broadcasted by all sensor nodes at regular intervals of time to determine optimal track for routing the packets from source to destination node. Every forward ant, contains all the information of traversed nodes. When any node, receives the forward ant, it cross checks the routing table. If there is no entry, the table gets updated and ant is forwarded to the next node at 1-hop distance. On reaching the destination, the forward ant gets converted to backward ant and follows the same path back to the nest. Simulation based results prove that the EEABR routing protocol is best in maintaining the energy of nodes and performs well in packet delivery as compared to BABR and IABR routing protocols.

Patel et al. [53] proposed Energy Minimum Cost Bandwidth Constraint Routing Protocol (EMCBR). EMCBR is fast, scalable and avoids congestion cum delay and gives best QoS routing in WSN. Simulation based results prove that EMCBR protocol is efficient in terms of energy efficiency, high throughput and packet delivery transmission in sensor communications.

Xia and Xu [68] proposed ACO-EAMRA algorithm for determining the optimal path between source to the destination node. In this algorithm, two rules are optimized for routing: State transition rule and Global pheromone update rule. Two parameters q and q_o were added to the algorithm in order to improvise the state transition rule and the ant's possibility to determine the optimal path. ACO-EAMRA algorithm iterates N number of times, to get the optimal global routing path in sensor network.

Peng et al. [54] proposed IACR protocol for optimizing by using improved ant colony algorithm for meeting QoS requirements in an energy-aware fashion, and to balance the node energy utilization to maximize the network lifetime. IACR protocol is composed of two parts: Route Discovery and Route Maintenance. In this protocol, lightweight ants determine the optimal path between transmitting nodes by considering distance, delay, packet loss, bandwidth and energy levels. The IACR routing protocol was tested using OMNeT++ simulator and is compared with DD protocol on Packet Delivery ratio, average hop count and routing overhead and results state that IACR performs better as compared to DD and gives best performance in varied WSN scenarios.

Kumar et al. [25] proposed AntHQSeN, a reactive routing protocol for Sensor Networks based on Ant colony optimization for optimizing QoS. The protocol primarily works in two stages: Discovery of Routing Path and Maintenance of Routing Path. Forward Ants perform the task of determining multiple paths from source node to the destination node and forwards the data packets stochastically. Routing phase gets completed when the destination node transforms the forward ants to backward ants to update pheromone table values. Route maintenance can only occur when there is any sort of node failure. The protocol is efficient in terms of bandwidth, timestamp, energy and concentration of pheromone. Simulation based results proved that AntHQSeN protocol is energy efficient as compared to AODV and EEABR routing protocol and suitable for multimedia packets transmission.

Amiri et al. [2] proposed Fuzzy Ant Colony Optimization Routing (FACOR) protocol for sensor Networks. In this protocol, ants are used to determine existing multiple paths between source and destination. In order to determine the best path, fuzzy logic is applied. The performance of FACOR based routing protocol is tested using NS-2 simulator and is compared with AODV routing protocol. Simulation based results state that FACOR protocol is efficient in terms of energy efficiency, packet delay and overall lifetime of sensor nodes is also enhanced.

Singh et al. [64] proposed ACO based Routing Algorithm (ANTALG) for Mobile Adhoc Networks. In this protocol, random selection of source and destination nodes is performed and ants are used as an exchange between the nodes. When the ants move, pheromone tables are created to determine the time taken by packets to reach from source to destination. ANTALG protocol is tested using NS-2 simulator and is compared with varied routing protocols like AODV, ADSR, HOPNET and simulation results proved that ANTALG is better in terms of throughput, packet delay, jitter and window size.

Mondal et al. [31] proposed an energy efficient load balanced data gathering method based on rough fuzzy c-means (RFCM) and Ant Colony Optimization (ACO) i.e. RFCM-ACO for efficient load balancing and energy preservation. In the proposed protocol, the sensors are partitioned into clusters by RFCM and via ACO-based lower and upper chain formation. The proposed protocol is compared with LEACH, PEGASIS and Hybrid_FCM and it is found that RFCM-ACO outshines in performance as compared to other protocols.

Zou and Qian [69] analyzed the performance of ACO based technique for optimizing WSN and proposed an improved ant algorithm efficient to construct the sensor node transfer function and pheromone update rule and construct an optimal path considering the dynamic state of network. The proposed protocol is tested using simulation-based approach and was found, that proposed protocol yields better result in terms of delay and less packet loss and QoS is also improvised.

2.1 Literature analysis and gaps identified

From the literature review it is observed that no doubts tons of energy efficient routing protocols are proposed by several researchers and performance in terms of packet delivery, throughput, energy is optimized, but still lots of work is required in terms of routing overhead reduction, end-to-end delay. Even the energy efficiency performance is not too solid, which is required for real-time sensor network operation.

3 Ant colony optimization- computational swarm intelligence technique

Ant Colony Optimization technique [28, 36, 43, 44, 66] is based on ants i.e. how ant colonies find the efficient path between nest and food source. In search of food, ants roam randomly in the environment. On location of the food source, ant's first return back to their nest by laying a trail of chemical substance called "Pheromone" in their path. Pheromone lays the foundation for communication medium for other ants to follow the way and go to the food source. When other ants follow the path, the quantity of pheromone increases on that particular path. The rich the quantity of pheromone along the path, the more likely is that other ants will detect and follow the path. In other words, ants follow that path which is marked by strongest pheromone quantity. As pheromone evaporates over time, which in turn reduces its attractive strength? The longer the time taken by ant to travel the path from food source to nest, the quicker the pheromone will evaporate. So, the path should be shorter so that the active strength of pheromone is maintained and ants can easily transfer the food from source to nest. So, in turn of this policy the shortest path will naturally emerge.

The following algorithm explains Ant Colony Optimization:

Initialize Parameters.

Initialize pheromone trails.

Create ants.

While Stopping criteria is not reached **do.**

Let all ants construct their solution.

Update pheromone trails.

Allow Daemon Actions.

End while.

4 IEEMARP- improvised energy efficient multipath ant colony based routing protocol for wireless sensor networks

In this section, the design parameters, algorithm, phases of protocol operation as well as properties of proposed routing protocol i.e. IEEMARP are discussed. [36, 45]

4.1 Design parameters

Step 1: Consider a source node S, willing to transmit data to another node D- destination node, the source node considers all QoS parameters like rate of transmission, energy level, delay avoidance and bandwidth. All the nodes traversed by ant from S to D are termed as "Visiting Node" and list of all visited node is created in form of routing table i.e. Multipath table-Rt.

Step 2: Source node S undertakes the process of initialization and discovery of the neighboring node.

Step 3: In order to initialize the packet transmission, a Fant (Forward Ant- Route Request) is created to traverse all the nodes from S to D at 1-hop distance. The Fant carries all the significant information parameters like source node address, destination node address, hop count as well as the speed of transmission.

Step 4: The detailed evaluation of all nodes at 1-hop distance is performed on evaporation of pheromone. Every node 'i' has routing table called "*PhTab*", containing the information with regard to the availability of pheromone level on every node (*Vi*, *Vj*). The pheromone quantity is initialized to constant C.

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

$\tau_{i,\,j}\rightarrow$ is pheromone quantity available on the link.

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

α and β highlights the advantage of pheromone to calculate optimal routing paths.

M➔ denotes the node sets i.e. *Vk*, not traversed by forward ant while performing packet transmission.

Step 5: Determination of pheromone evaporation of all sensor nodes at 2-hop distance.

Step 6: Calculation of path preference probability value of every path from source S via observing the level of pheromone evaporation of every sensor node operating on the network. A node j from a set of adjacent nodes (j, k ... n) of *i* is selected as MPR node to traverse all sensor nodes at 2-hop distance in such a manner that its path preference probability is best as compared to other sensor nodes.

Step 7: After obtaining path preference probability amount, it is compared with predefined requirements. If the value is greater, then the path determined gets accepted for packet transmission otherwise, it is rejected.

Step 8: Forward ant on reaching the destination, gets transformed to backward ant and follows the same path as traversed back to the originating node.

Step 9: Only that path with higher path preference probability value is accepted and packet transmission starts between sender node to the destination node.

4.2 Algorithm

Input: Feature Matrix
Output: Fitness Value
Step 1: Population Initialization,
$P = \sqrt{(x(i) - x(j))^2 + (y(i) - y(j))^2}$ //Where, x and y – node input values; (1)

Step 2: Path Initialization i.e. R= random value for size of feature matrix

Step 3: Velocity initialization,

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) + P^{-b}*(pb(k) – x(k)) +P^{-b}* random * (Gb(k) – x(k)); //Where, pb – Path best; gb – Global Best;k-size of feature vector; b –number of updation; (2)
Pd = trial intensity (k)*Pb(path(k));

Step 4: Calculation of Optimal Path

Step 5: Updation of PBest and GBest values

Step 6: Updation of Fitness values

4.3 Phases of operation

IEEMARP Routing Protocol (Improvised Energy Efficient Multipath Ant Based Routing Protocol) operates in following three main stages:

1. Neighbor discovery via Link Knowledge
2. Packet Transmission
3. Efficient & Reliable end-to-end delivery

The detailed step by step workflow analysis of IEEMARP protocol is demonstrated in Fig. 1.

The following three points highlight the phases of the IEEMARP routing protocol proposed for optimizing energy efficiency in WSN network.

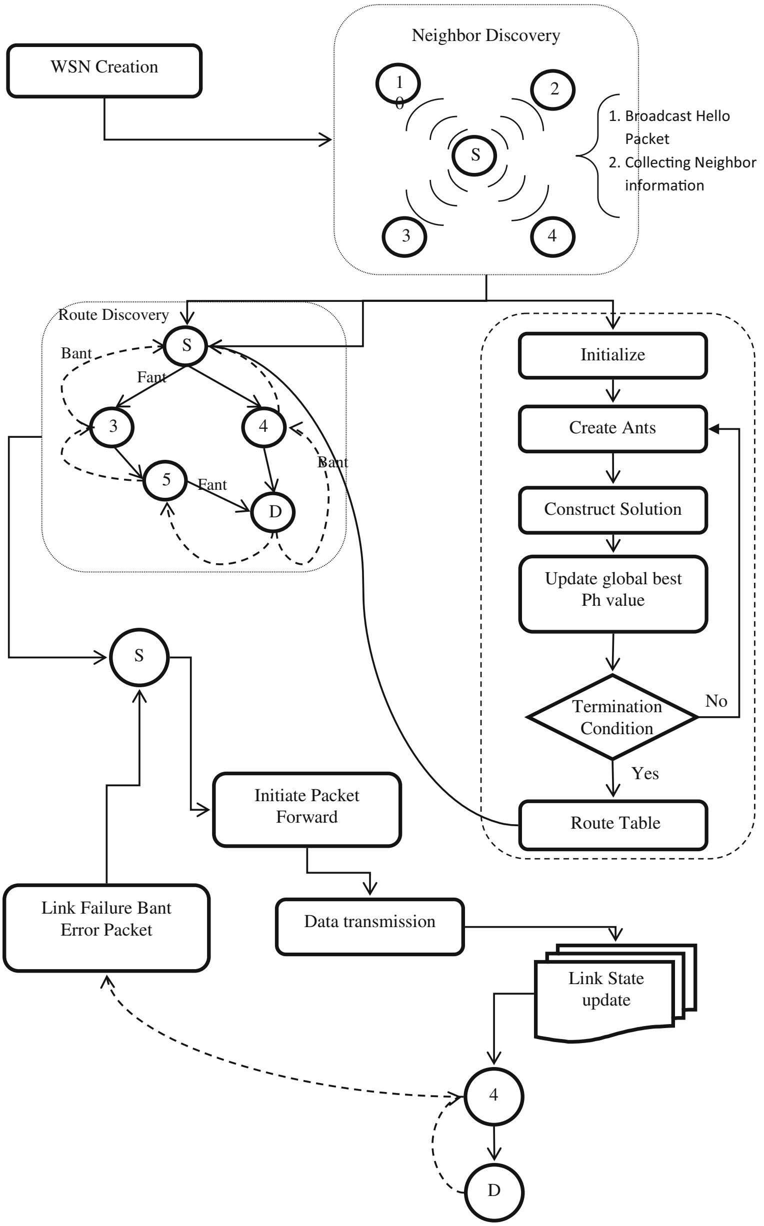

Fig. 1 IEEMARP Routing Protocol- Working scenario

4.3.1 Neighbor discovery via link knowledge

Before starting packet transmission, a sensor node transmits a HELLO message at 1-hop broadcast to mark its presence to all the sensor nodes in its range. The nodes operating in the radio range of sensor node are termed as "Neighboring nodes". The nodes follow "**sleep and wake up strategy**" to minimize energy consumption. When the node wakes up, it transmits a new "HELLO" message to all the nodes highlighting its active state. If any node doesn't want to be utilized for routing, it doesn't broadcast HELLO message. Hello message is used to keep the track of all the nodes at 1-hop distance willing for packet forwarding in addition to the knowledge of their state whether active/sleep. A node can store all the information of neighboring nodes in its memory at 1-hop distance.

4.3.2 Packet transmission

Let's consider N, as a subset of neighbors tracked by the source node. If source node S, wants to route a packet, transmitted by any other node to destination node d. For each neighbor node n ε N, the node s maintains a metric Rn,d, that specifies a reliable end-to-end delivery of packet to the destination node.

The initialization and maintenance of the Rn,d value are done by exponentially weighted moving average method. If any situation occurs, where destination node is not able to reach in direct order, the node performs packet forwarding to other active or willing neighboring node. The node to which the packet is forwarded is regarded as "Next-Hop" node. The next-hop node is selected on the basis of R value, which is higher as compared to other neighboring nodes. The packet will not be transmitted to two nodes: Destination node and source node. The packet gets dropped, if the hop count value exceeds a certain limit, in order to avoid the issue of infinite looping in WSN network.

The major advantage of the IEEMARP routing protocol is that the entire traffic load is distributed throughout the network, when high quality multiple path exists between the operational nodes in the network.

4.3.3 Efficient and reliable end-to-end reliability

In order to assure, packets get reached safely from source node to a destination node, the source node receives a special packet from the destination node, after packet transfer gets completed i.e. ACK packet. The packets soliciting acknowledgement are termed as "ACKR" packets. All the ACKR packets are forwarded in round robin manner by the source node to all active nodes in WSN network. All the ACKR packets are treated in similar fashion as normal data packets. The ACKR packets are forwarded to those nodes having high R values among all the other subset of nodes. On receipt of ACKR packet, the destination node transmits ACK packets in reverse manner 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 original source node, the final destination node, the sequence number of the packet, the previous node and the next hop node. The signature plays an important role to forward the ACK packet to the neighbor node from where the ACKR packet is received. The signature also enables the node to keep track of ACKR packets for deleting all duplicate packets to prevent flooding in the network. A node periodically checks the number of signatures it stores and deletes part of the old signatures if this number exceeds a certain threshold.

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 can minimize the probability of their loss by making use of the highest reliability service that is provided by the MAC layer such as acknowledged transmission.

4.3.4 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 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. A node needs to maintain the following things in its memory.

- The set N of one-hop neighbors that the node tracks.
- $R_{n,d}$, ∀ n ε N and ∀ d ε D, will require O(η) 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(η). Thus, the memory requirement of the routing protocol is O(η) or O( ) as η can be considered a constant.

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, every 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.

Since the node A does not receive the ACK packets in response to the ACKR packets, it reduces the R value for node B. Therefore, no routing loops are permanent in nature.

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.

5 Simulation results & discussion

5.1 Simulation Assumptions

In order to test the performance of IEEMARP routing protocol proposed, ns-2.35 all-in-one simulator is used [37, 42]. In order to perform simulation, the following assumptions with regard to Network Model and Network protocol.

A Sensor network with N number of nodes are deployed in random fashion in environment.

Network Model Assumptions:

- All the nodes are homogeneous and are of equal size when deployed initially.
- All the sensor nodes have the same amount of initial energy.
- In the initial status, nodes don't have any information of any other neighboring nodes like Location.
- Every node in the sensor network acts as Router, and has the capability to efficiently sense the surrounding nodes.
- The speed of mobile nodes is random.
- As the sensor network has issues with regard to energy, it forces to use the energy efficient algorithms to maximize the network lifetime.
- WSN nodes transceivers use single channel and omni-directional antenna, and propagate isotropic signals in all directions.
- WSN routing protocols makes a clear assumption to have in-advance knowledge of destination address.

Network Protocol Assumptions:

- The protocol doesn't make use of broadcasting for any sort of route discovery and maintenance.
- The protocol can have routing loops, but not persistent loops.
- Energy Variations and Packet Delivery Ratio may occur in routing protocol as compared to other routing protocols i.e. ACEAMR, IACR, AntChain, EMCBR, AntHQSeN, FACOR, ANTLAG depending on applications and packet size.
- Basic Ant Colony Routing Protocol is utilized for basic routing, energy maintenance and scenario working for sensor network.

5.2 Simulation parameters

The performance of IEEMARP protocol is evaluated via simulations. IEEMARP protocol is compared with standard routing protocols as well as other proposed ACO based routing protocols for WSNs [36, 44, 45]. It is assumed that all the sensor nodes (50, 150, 200, 800) in different simulation scenarios are uniformly deployed in the 3000 m × 1000 m area. The simulation ran for 150 s/300 s and 500 s.

Extensive simulations are conducted to determine the efficiency of routing protocol proposed in terms of the packet delivery ratio, throughput, routing overhead, energy efficiency and end-to-end delay.

The following Table 1 enlists simulation parameters considered for testing IEEMARP protocol on ns-allinone-2.35 simulator.

IEEMARP is tested on following performance metrics:

- Packet Delivery Ratio (PDR): It is defined as ratio between the packets generated at the source nodes as compared to the packets received at the destination node. Considering mathematically, PDR can be formulated as:

$$\text{PDR} = \text{S1}\%\text{S2}$$

Table 1 Simulation Parameters

Parameters	Values
Simulator	ns-allinone-2.35
Operating System	Ubuntu 16.04
Routing Protocol	Basic ACO
Dimension of Topology	3000 m × 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	10,000 mJ
Number of Nodes	100, 150, 200…800 (Max)
Queue Length	64
Data Rate	Variable
Type of Interface	Wireless Physical Interface
Node's Radio Range	~250 m
Mobility Speed	1….15 m/s
MAC Type	IEEE 802.11
Mobility Model	Random way Point

Where S1 is aggregation of packets received by the destination node and S2 is total packets generated by the source node.

Or

$$\text{Packet Delivery Ratio} = (\text{Total Packets Sent–Total Packet Loss})^{*}\ 100/\text{No.of Packets transmitted}$$

- Throughput: It is termed as total number of packets delivered over physical or logical link during simulation time. Throughout can be formulated as:

  Throughput = Total Packets Transmitted during Simulation / Total Simulation Time.
- Routing Overhead: It is termed as number of routing packets required for communication. In order to determine routing overhead, AWK script is utilized which processes the trace file and gives precision result.
- Energy Consumption: It is regarded as utilization of energy level by sensor nodes to perform varied networking tasks like: Routing of packets, Clustering, path selection or routing table updates. It is measured in Joules.
- End-to-End Delay: It is the termed as common wait between information delivery bundled by CBR resource and its transmission to receiver node. It contains all the setbacks during transmission like path determination, streaming, handling of advanced nodes and re-transmission of packets etc.

  It is calculated as:

$$\text{End–to–End delay} = \text{Transmission Time }(\text{Hop }1 + \text{Hop }2 + \ldots\text{Hop n})$$

5.3 Simulation scenario

In this part, we highlight simulation screenshots, specifying the working of the IEEMARP routing protocol.

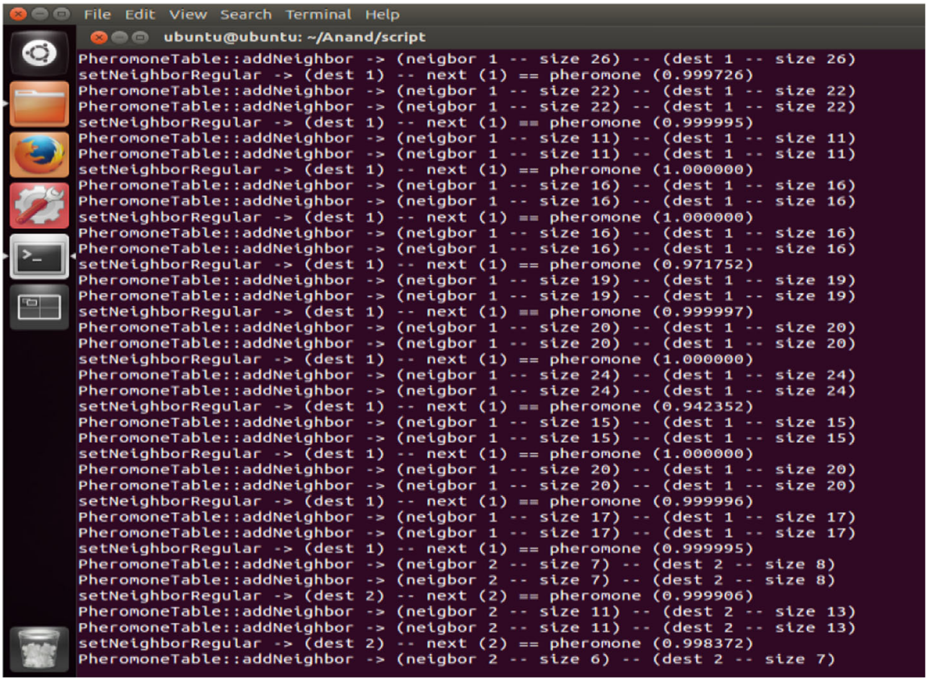

Fig. 2 Simulation Sceanrio- Updating of Pheromone values of neigboring nodes

Figure 2 demonstrates the start of the simulation and updating of information regarding neighboring nodes, i.e. Pheromone values in routing table using a basic ACO algorithm.

Figure 3 highlights the NAM (Network Animator) window regarding initialization of the IEEMARP routing protocol to perform the preliminary task of Route discovery to determine neighboring nodes within the radio range.

Figure 4 demonstrates that after neighboring nodes determine the neighbors and optimal routing paths, the sensor nodes start packet transmission to the base station (Node 0). TCP protocol is used for packet transmission for maintaining efficient end-to-end communication.

As TCP packets are received from the transmitting nodes, the base station node transmits an ACK packet (Acknowledgement packet) to the sensor nodes validating the delivery. Figure 5 highlights the ACK packet transmission from base node to transmitter node.

Sensor networks are always surrounded by issues concerning congestion [60], packet dropping and overhead. If any case of fault tolerance occurs, the packets get dropped due to routing overhead. IEEMARP routing protocol performs well and maintains less overhead in the network using an Ant colony optimization scenario. Figure 6 highlights packet dropping scenario in the network.

Figure 7 gives the link status between base station 0 and sensor node 3 by 10 Mbits/Sec with delay in 10 ms. IEEMARP routing protocol is considered highly successful in packet transmission and suitable for reliable communication in wireless sensor networks.

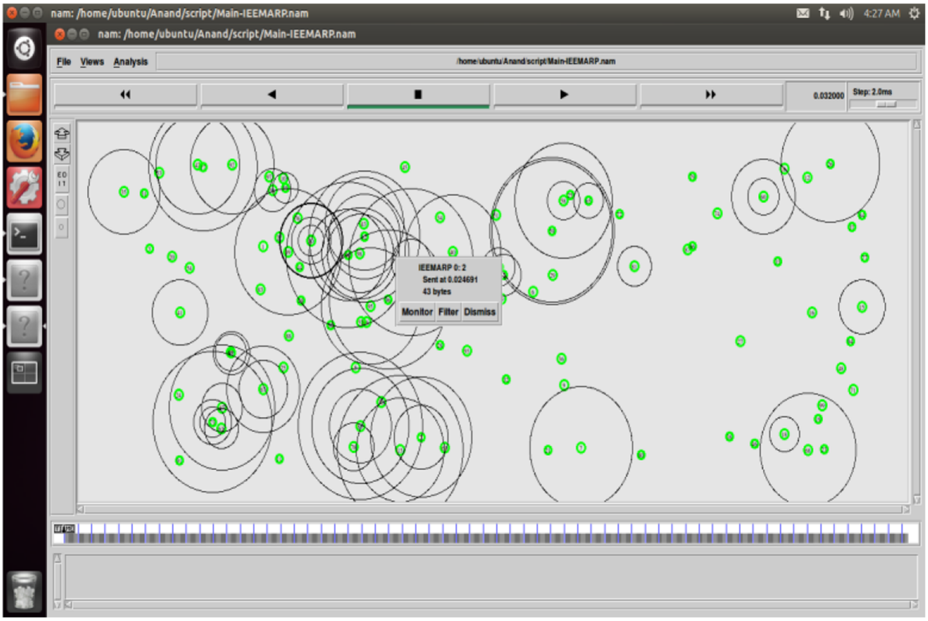

Fig. 3 IEEMARP protocol- Route discovery

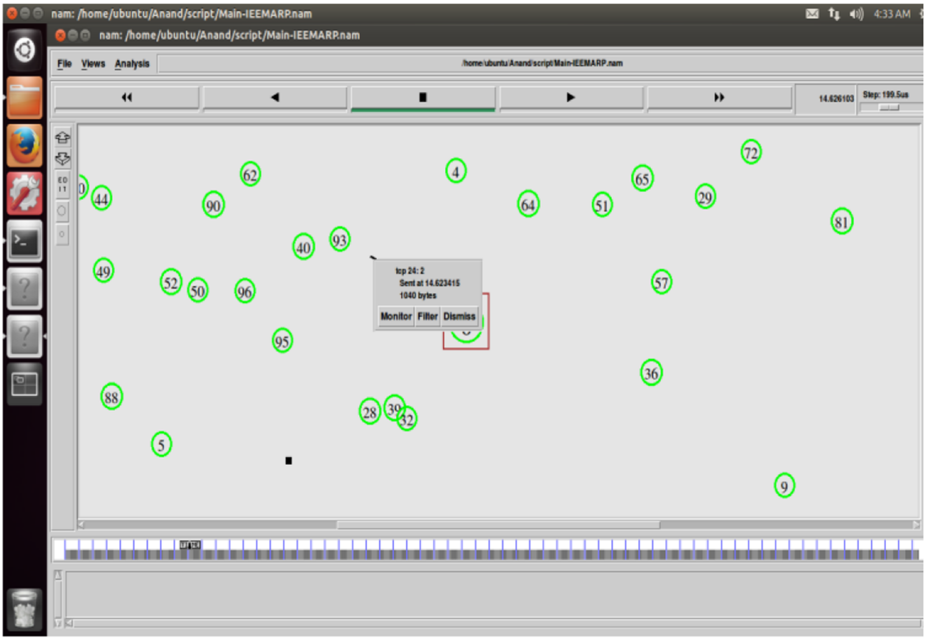

Fig. 4 Packets Transmission to Base Station

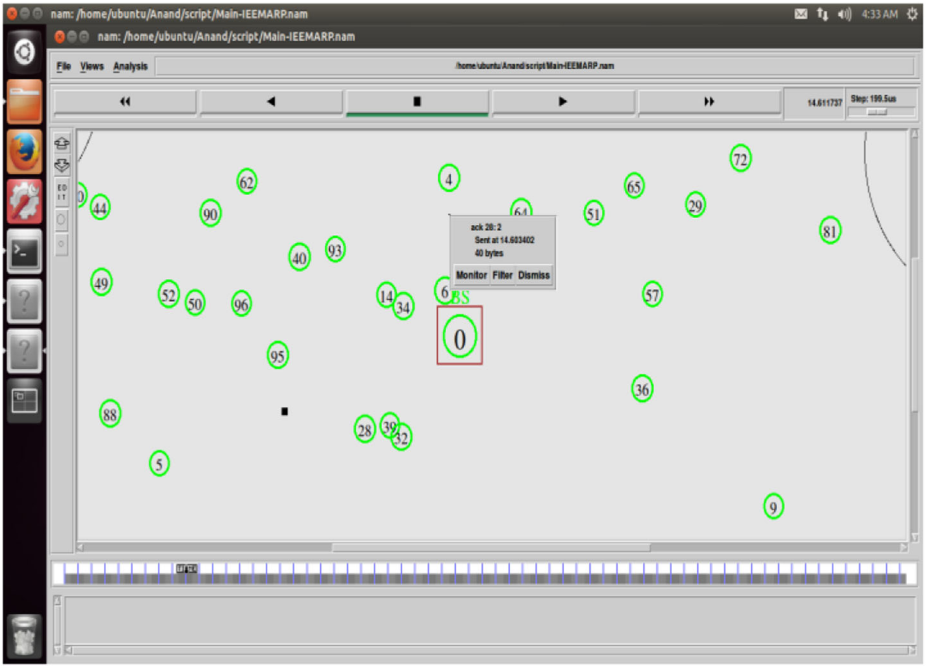

Fig. 5 ACK Packet transmission

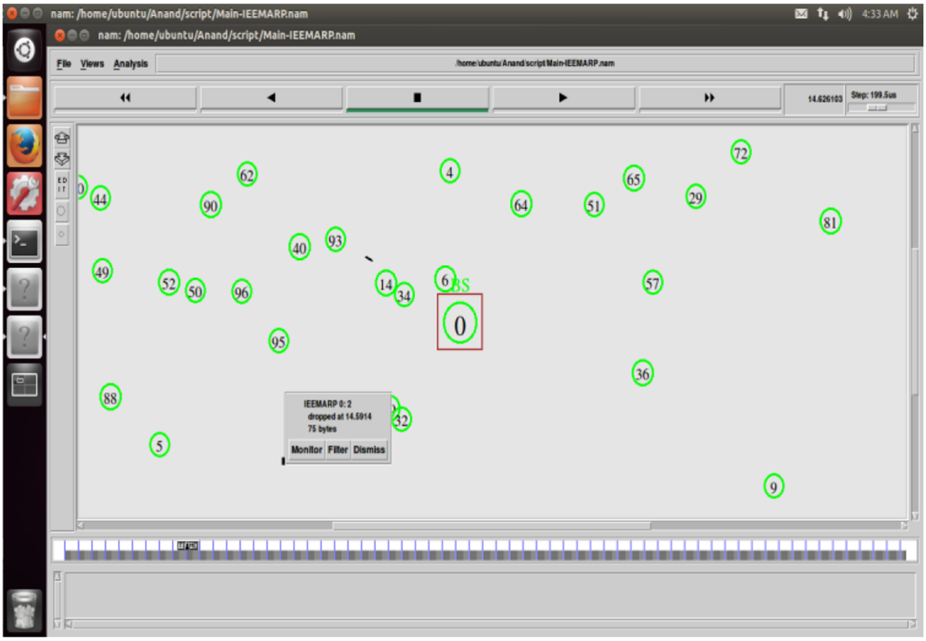

Fig. 6 Packet Dropping due to Routing Overhead

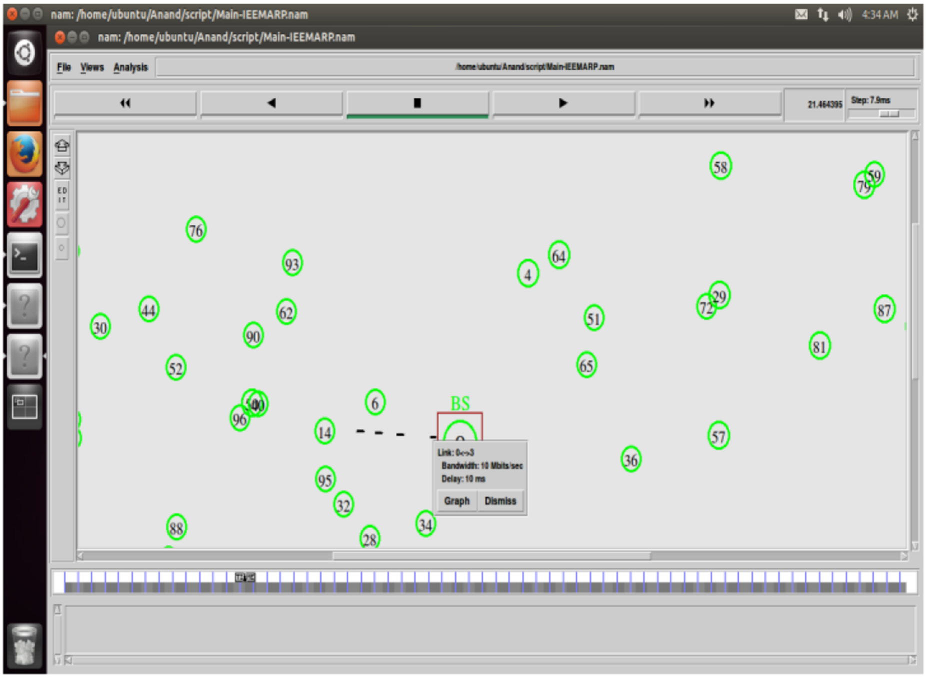

Fig. 7 Link Status between Nodes

5.4 Results and performance comparison

In this section, IEEMARP routing protocol performance is measured as compared to various standard and diverse ACO based WSN routing protocols proposed by various researchers.

A. Performance comparison of IEEMARP routing protocol with Basic ACO, DSDV and DSR protocols

The IEEMARP routing protocol is tested on varied performance parameters and compared with Basic ACO, DSDV and DSR protocol on the basis of the packet delivery ratio, end-to-end delay, average number of hops, control packet overhead, dropped reply messages and overall throughput.

Table 2 enlists results of performance of IEEMARP routing protocol as compared to standard routing protocols. [15, 16, 34, 46, 62, 67].

Simulation based analysis, clearly states, that as compared to Basic ACO, DSDV and DSR routing protocols, IEEMARP performs better, almost 9% better in packet delivery ratio, 15%

Table 2 Basic ACO V/s DSDV v/s DSR v/s IEEMARP performance comparison

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

Table 3 Packet Delivery Ratio- Data Analysis

Time	Packet Delivery Ratio (%)				
	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

better as compared to End-to-end delay, number of hop count is significantly improvised, less control packet overhead is observed close to around 6%, packet drops are reduced to significant level and overall increase in throughput is also observed.

B. Performance comparison of IEEMARP Protocol with- ACEAMR, AntChain, EMCBR, IACR, AntHQSeN, FACOR and ANTALG protocols

In this part, IEEMARP protocol is compared with other ACO based WSN protocols like ACEAMR, AntChain, EMCBR, IACR, AntHQSeN, FACOR and ANTALG protocols [24, 38, 47, 48, 59].

- Packet Delivery Ratio

The following Table 3 and Fig. 8 illustrates Packet Delivery Ratio (PDR) of IEEMARP routing protocol observed in varied simulation scenarios as compared to other protocols- ACEAMR, AntChain, EMCBR, IACR.

From the tabular analysis, by taking average rate of performance and comparing the values of IEEMARP with other protocols, it is evident that IEEMARP is almost 22% efficient as compared to ACEAMR, 16% as compared to AntChain, 19% as compared to EMCBR and 8% as compared to IACR protocol in Packet delivery ratio.

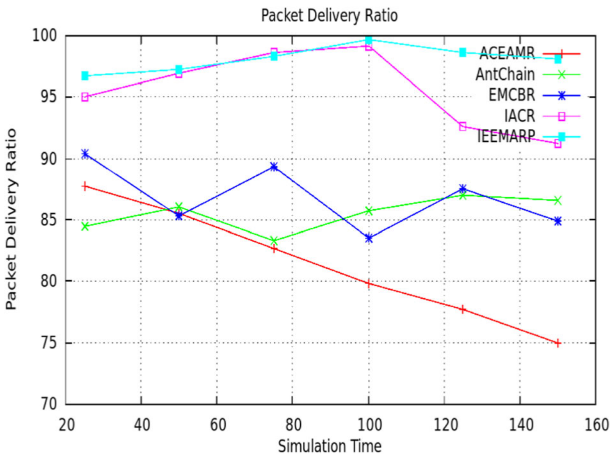

Fig. 8 Xgraph based results demonstrating PDR performance of IEEMARP protocol

Table 4 Packet Delivery Ratio- Data Analysis

Time	Packet Delivery Ratio (%)			
	AntHQSeN	FACOR	ANTALG	IEEMARP
25	87.76	85.41	90.64	93.93
50	85.50	83.01	89.69	93.27
75	82.70	80.13	82.26	85.60
100	79.87	77.23	82.81	86.84
125	77.73	75.08	80.30	84.31
150	74.97	73.06	78.66	82.84

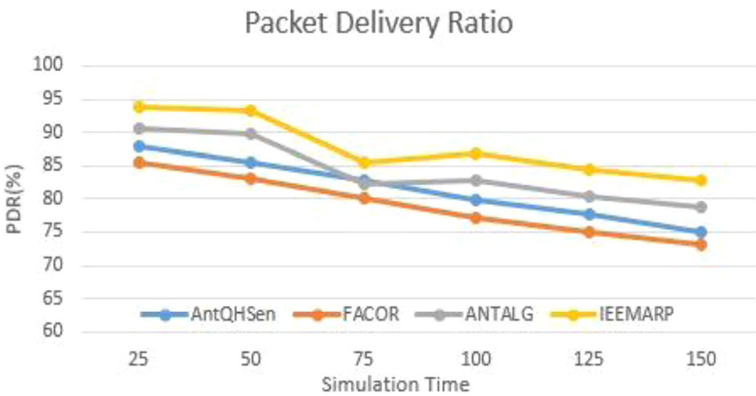

Fig. 9 Results demonstrating PDR performance of IEEMARP protocol

The following Table 4 and Fig. 9 demonstrates Packet Delivery Ratio (PDR) of Routing Protocols- AntHQSeN, FACOR and ANTALG compared with IEEMARP on varied simulation scenarios.

From the Tabular Analysis, it is observed that IEEMARP protocol is almost 9% efficient as compared to AntHQSeN, 8% as compared to FACOR and near to about 5% as compared to ANTALG in terms of packet delivery ratio.

- Throughput

Table 5 and Fig. 10 illustrates simulation based data values in lieu of Throughput performance of IEEMARP protocol as compared to other routing protocols - ACEAMR, AntChain, EMCBR, IACR on varied simulation times.

Table 5 Throughput—Data Analysis

Time	Throughput (Mbps)				
	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

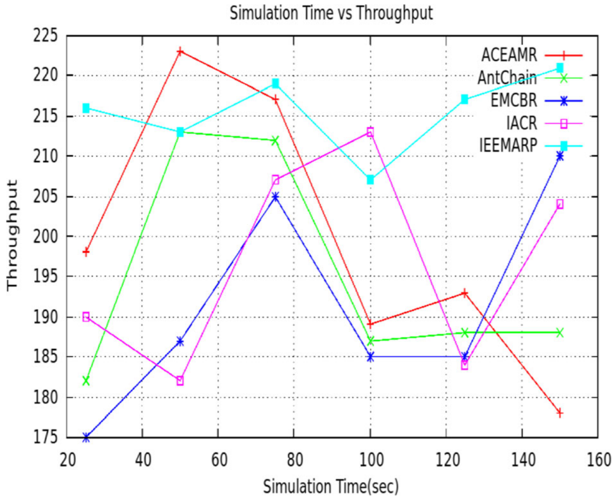

Fig. 10 Xgraph based results demonstrating Throughput performance of IEEMARP protocol

From the Tabular analysis, it is observed that, IEEMARP routing protocol outshines in Throughput, to almost 26% better as compared to ACEAMR, 19% as compared to Ant Chain, 8% as compared to EMCBR and 5% as compared to IACR.

Simulation based data values are enlisted on Table 6 with regard to Throughput performance comparison of routing Protocols- AntHQSeN, FACOR and ANTALG compared with IEEMARP on varied simulation scenarios.

From Table 6 simulation-based data analysis, it is observed that IEEMARP performs close to around 6% as compared to AntHQSeN, 4% as compared to FACOR and near to about 3% as compared to ANTLAG in throughput performance as highlighted in Fig. 11.

- Routing Overhead

The following Table 7 gives clear picture with regard to Routing Overhead performance of IEEMARP protocol on varied simulation times as compared to other routing protocols- ACEAMR, AntChain, EMCBR, IACR.

Simulation based analysis, highlights that, in terms of Routing overhead performance, IEEMARP protocol faces less routing overhead as compared to other protocols in terms of nearly 1% as compared to ACEAMR, 4% as compared to AntChain, 2% as compared to EMCBR and 1% as compared to IACR. Figure 12.

Table 6 Data Values- Throughput

Time	Throughput (Bytes/Sec)			
	AntHQSeN	FACOR	ANTLAG	IEEMARP
25	85.136	85.551	86.271	90.574
50	88.460	85.983	84.862	89.695
75	86.293	85.179	86.167	90.694
100	85.863	84.530	86.433	89.913
125	88.350	84.049	84.826	89.582
150	83.968	81.914	86.662	89.612

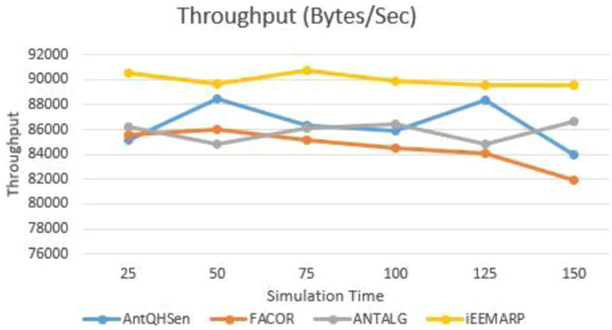

Fig. 11 Results demonstrating Throughput performance of IEEMARP routing protocol

The following Table 8 and Fig. 13 gives performance comparison of IEEMARP routing protocol in terms of routing overhead performance as compared to other Protocols-AntHQSeN, FACOR and ANTALG on varied simulation scenarios.

From Table 8, it is evident that IEEMARP outshines in routing overhead performance near to about 7% as compared to AntHQSeN, 5% as compared to FACOR and 1% as compared to ANTLAG.

Table 7 Routing Overhead–Data Values

Time	Routing Overhead (%)				
	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

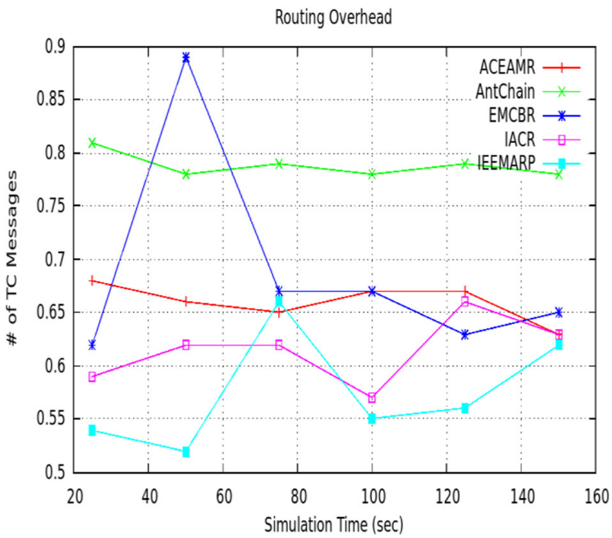

Fig. 12 Xgraph based results demonstrating Routing Overhead performance of IEEMARP protocol

Table 8 Data Values—Routing Overhead

Time	Routing Overhead (%)			
	AntHQSeN	FACOR	ANTLAG	IEEMARP
25	9.55	7.27	5.03	5.42
50	7.42	6.19	6.70	5.29
75	6.33	6.11	7.46	6.68
100	9.86	6.43	7.74	5.51
125	6.16	8.25	7.14	5.61
150	9.43	8.94	6.62	6.33

- Energy Consumption

The following Table 9 and Fig. 14 gives detailed description with regard to energy utilization of IEEMARP routing protocol on varied simulation times as compared to other routing protocols- ACEAMR, AntChain, EMCBR, IACR.

Energy consumption is regarded as the most vital parameter for any routing protocol in WSN for long term performance. From Table 9 it is evident that IEEMARP performs better and saves tons of energy of sensor nodes making them operational for prolonged period of time. Simulation based data analysis, highlight that IEEMARP routing protocol conserves energy near to about 8% as compared to ACEAMR, 5% as compared to AntChain and nearly 4% as compared to IACR.

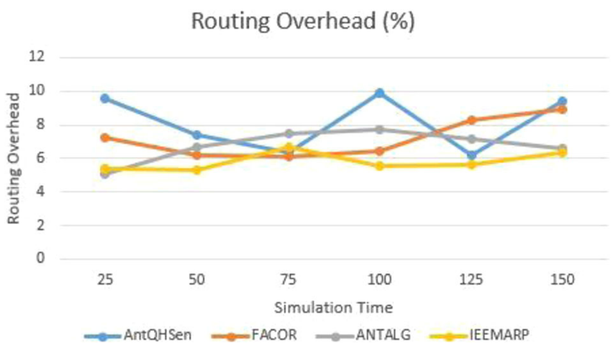

Fig. 13 Results demonstrating Routing Overhead performance comparison of IEEMARP routing protocol

Table 9 Data Values—Energy Consumption

Time	Energy Consumption (Joules)				
	ACEAMR	AntChain	EMCBR	IACR	IEEMARP
25	98.21	98.2	98.81	99.42	99.52
50	97.23	97.25	97.785	98.32	98.21
75	85.05	86.335	86.9525	87.59	89.065
100	81.179	82.798	83.5495	84.30	86.202
125	77.308	79.261	80.1365	81.01	83.339
150	73.437	75.724	76.7235	77.72	80.479

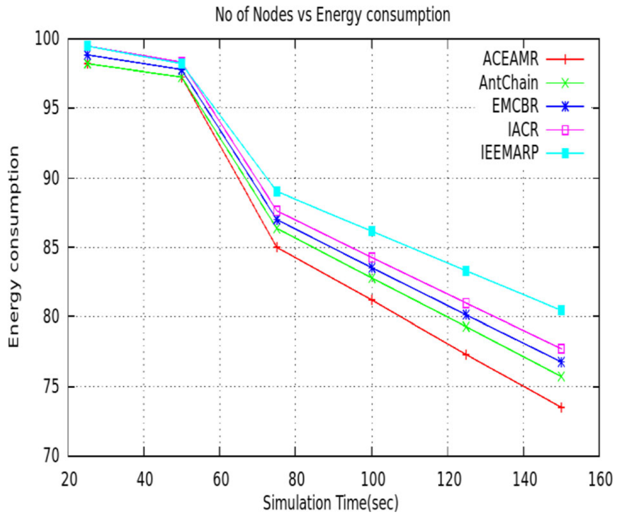

Fig. 14 Xgraph based results demonstrating Energy Consumption performance of IEEMARP protocol

Table 10 gives clear data analysis picture with regard to energy consumption of IEEMARP routing protocol as compared to - AntHQSeN, FACOR and ANTALG protocols on varied simulation scenarios.

From Table 10, it is observed that on an average, IEEMARP routing protocol performs better and outshines in saving energy capacity of the nodes in varied simulation times. IEEMARP is about 7% efficient in energy saving as compared to AntHQSeN, 5% as compared to FACOR and 4% as compared to ANTLAG. Results are enlisted in Fig. 15.

Table 10 Data Values—Energy Consumption

Time	Energy Consumption (Joules)			
	AntHQSeN	FACOR	ANTLAG	IEEMARP
25	97.21	96.2	98.42	99.16
50	96.67	95.4	97.22	98.06
75	92.26	93.16	96.14	95.11
100	87.36	88.91	91.25	92.39
125	79.56	81.26	85.34	87.06
200	72.22	73.43	76.32	81.22

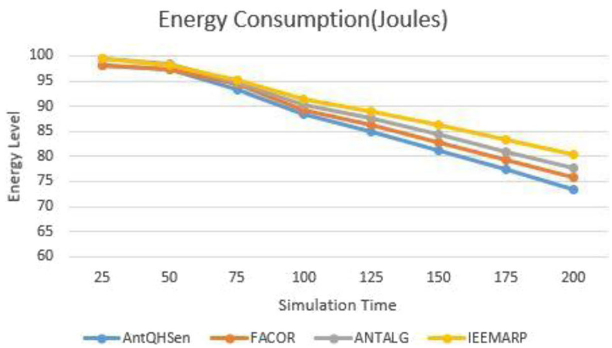

Fig. 15 Results demonstrating Energy Consumption performance comparison of IEEMARP routing protocol

Table 11 Data Values—End-to-End Delay

Time	End-To-End Delay (Seconds)				
	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

- End-To-End Delay

The following Table 11 and Fig. 16 enlists End-to-end delay performance values of IEEMARP routing protocol on varied simulation times in comparison to other routing protocols- ACEAMR, AntChain, EMCBR, IACR.

Considering End-to-End delay, it is clearly observed that IEEMARP performs better as compared to other protocols i.e. Almost 16% better as compared to ACEAMR, 7% as compared to AntChain, 3% as compared to EMCBR and about 18% as compared to IACR.

Table 12 enlists end-to-end delay of Routing Protocols- AntHQSeN, FACOR and ANTALG as compared to IEEMARP on varied simulation scenarios.

From Table 12 it is clearly observed that IEEMARP outshines in end-to-end delay performance to near 11% as compared to AntHQSeN, 10% as compared to FACOR and 2% as compared to ANTLAG. Results are highlighted in Fig. 17.

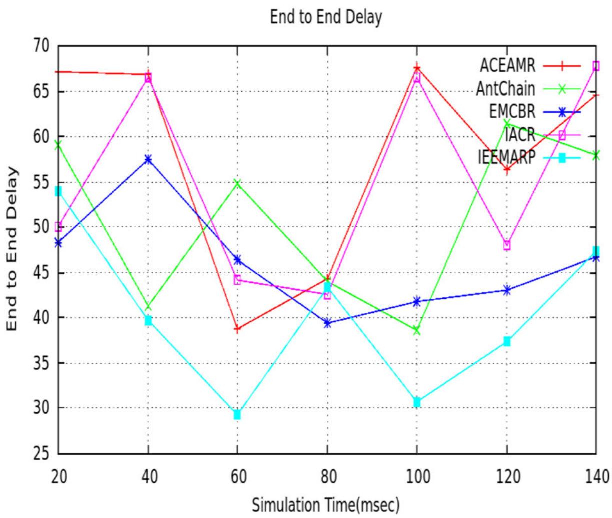

Fig. 16 Xgraph based results demonstrating End-to-end performance of IEEMARP protocol

Table 12 Data Values—End-to-End Delay

Time	End-To-End Delay (Seconds)			
	AntHQSeN	FACOR	ANTLAG	IEEMARP
20	6.32	4.24	2.36	2.13
40	8.16	5.98	3.42	3.02
60	9.68	8.24	4.16	3.56
80	11.41	10.15	5.11	4.33
100	13.09	12.15	6.01	5.05
120	14.77	14.15	6.91	5.76
140	16.45	16.15	7.81	6.48

5.5 Discussion

From the Simulation based results, and data analysis it is observed that IEEMARP is efficient in performance in WSN based scenarios and provides fast delivery of packets from source to destination nodes, maintains high energy in nodes, reduces overall routing overhead and end-to-end delay and maintains high throughput.

But IEEMARP still needs work in terms of Security and robustness.

6 Conclusion and future scope

Nowadays, WSNs play a significant tole towards data selection, sensing and delivery. WSNs are utilized in wide zones of uses like calamity the board, natural observing, military, horticulture and so forth. Due to constant topology changes, it is quite a tedious cum challenging task to routing the packets to final destination by maintaining overall performance in network with regard to throughput, energy efficiency, routing overhead, packet delivery ratio and above all end-to-end delivery. So, keeping in mind of the same, we have proposed, a novel energy efficient multipath routing protocol based on ACO technique i.e. IEEMARP is proposed. In this protocol, packet transmission from source to destination is done as per ant-based control. The main objective behind the development of routing protocol to determine optimal track for doing routing tasks from source to destination by considering multipath links

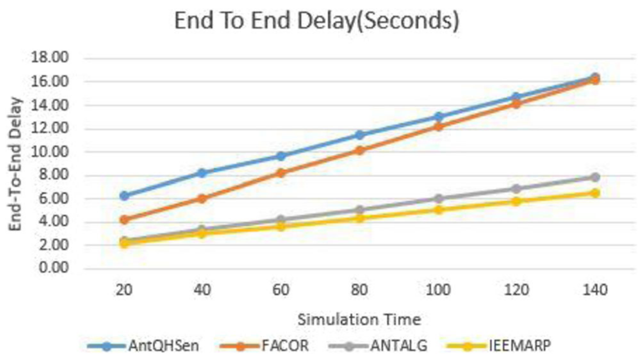

Fig. 17 Results demonstrating End-to-end delay performance comparison of IEEMARP routing protocol

and maintaining overall efficiency and high throughput in WSN. The protocol is properly simulated on the NS-2 simulator and compared with standard routing protocols like Basic ACO, DSDV, DSR and with other novel proposed ACO based WSN routing protocols like ACEAMR, AntChain, EMCBR, IACR, AntHQSeN, FACOR and ANTLAG.

Simulation based results state that IEEMARP protocol is almost 9–10% efficient in terms of performance towards packet delivery, overall throughput, packet overhead and end to end delay as compared to Basic ACO, DSDV and DSR.

On an Average, as compared to ACEAMR, AntChain, EMCBR and IACR, IEEMARP is almost 20% efficient in all performance parameters observed in WSN scenarios and almost 10–12% better as compared to AntHQSeN, FACOR, ANTLAG. Till date, as compared to standard routing protocols and even other novel proposed routing protocols, IEEMARP stands highly efficient in overall performance especially Energy Efficiency and Throughput.

6.1 Future scope

In the near future, we like to extend the technical functionalities of IEEMARP routing protocol in terms of- Security-making it highly hack-proof to defend against almost all sorts of attacks like Blackhole attack, Denial of Service Attack, Wormhole attack, Grayhole attack and above all unauthorized access via intruders from the outside world. In addition to this, stress would be to make it more scalable to facilitate additional number of nodes deployment in real-time WSN scenarios to maintain high-performance in terms of throughput and end-to-end delay, as well as adding fault tolerant mechanisms in IEEMARP to make it compatible with heterogeneous nodes based WSN network. In addition to this, our focus will be to design an ARM based WSN kit to monitor environment in terms of Temperature, Humidity and Events where IEEMARP routing protocol can be implemented in sensor memory chips.

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