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Research Article

Energy efficient hybrid AOMDV-SSPSO protocol for improvement of MANET network lifetime

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Abstract
Mobile adhoc network (MANET) contributes to a variety of applications due to its optimum design and capacity to be used in situations where establishing a physical network is not feasible. MANET consists of nodes that use routing protocols to send packets from source to sink using the store-and-forward technique. Data packet transit from source to sink is a relatively expensive procedure because these packets are delivered through each intermediate node. MANET has a number of issues, one of which being high energy consumption (EC). The wireless mobile nodes in MANET does not have a reliable power source as the nodes in this network are battery-powered. As a result, the network's lifespan is decreased by the quick battery depletion. However, when determining a path from a source to a sink node, traditional protocols also neglect the consumption of energy by the nodes. Therefore, to enhance the performance of MANET routing performance, we proposed an optimized routing protocol named as adhoc on-demand multipath distance vector sleep scheduling particle swarm optimization (AOMDV-SSPSO) which is based on the concept of Swarm intelligence (SI). SI approaches are based on the concept of optimization and provides the best solution in MANET to resolve computational challenges i.e., routing of data using these optimization techniques improves the route optimization and quality of services. The objective of the proposed research work is achieved by three vital steps which are route establishment phase, optimal path selection and sleep scheduling mechanism. The route establishment phase is based on an AOMDV routing protocol which can be used to identify multiple routes for data transfer from source to destination. Out of all the possible routes the optimal path will be selected with the help of particle swarm optimization (PSO). The sleep scheduling technique places nodes in a sleep state when they are not in use and their absence does not result in partition in their immediate area. The effectiveness of the suggested algorithm is examined and compared against the existing approaches in terms of end-to-end (E2E) delay, energy consumption (EC), network lifetime and throughput (TH). The simulation results generated by the network simulator (NS 2.35) software indicate the effectiveness of the proposed technique. According to the simulation results, AOMDV-SSPSO offers greater TH and is more energy efficient, resulting in a longer network lifespan. However, because of the nodes transition from one state to another, the E2E delay in AOMDV-SSPSO is high. In general, it is observed that the proposed technique AOMDV-SSPSO outperforms than other existing protocols.

Keywords
AOMDV, EC, Energy efficiency, E2E delay, MANET, Network lifetime, NS 2.35, PSO, Throughput.

1.Introduction
In this era of wireless technology, people want to communicate anywhere and at any time. Through wireless networks, people can communicate with one another at high data speed and low cost. There are two distinct communication approaches for wireless mobile nodes: infrastructure-oriented and infrastructure-less.

While nodes in the former approach link to a base station or other access point via fixed infrastructure and nodes in the latter approach communicate without the aid of any pre-existing network infrastructure.

Mobile adhoc network (MANET) consists of wireless mobile devices that are disseminated without the requirement for specified infrastructure therefore any node can behave as a client or a server [1]. Like an infrastructure-oriented network, MANET will not have a centralized authority, therefore it is difficult to

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implement security of nodes without centralized control [2]. In an adhoc network, a mobile node's physical position is continually changing, which has more unpredictability effects on the network structure. Due to the creation of such a dynamic topology, the link state and connectivity with nearby mobile nodes changes. The mobile node must decide whether to execute routing in order to remain in the network or to get separated from the network when a new link is introduced or an existing link is disconnected.

In a MANET, the receiving node may have left the transmission range of the sending node during packet forwarding since nodes are mobile. As a result, the packets could be lost during transmission [3]. However, if these nodes are used continuously without being charged their batteries run out in a short period of time. Therefore, dynamic topology and routing are the challenging issues with this type of network. Researchers presented several routing protocols which aimed at increasing network efficiency, lowering power consumption, and reducing delays. However, establishing, maintaining and performing route repair when links breaks are the primary responsibilities of MANET routing protocols. Routing is a technique for deciding which paths in a network to use to send data, and routing protocols are the set of rules that specify how routers interact with one another and share information that enables them to decide which paths to take between any two nodes in a network. There are three different routing protocols used in the MANET that are proactive, reactive, and hybrid routing protocol [4].

Proactive routing protocols, often known as table driven routing protocols because they save the data of all nearby nodes in the form of tables. In this protocol, each node has a separate routing table that maintains a list of all possible routes to every destination. Since the topology of MANET is dynamic, it results in the frequent update of the routing tables [5]. Its disadvantage is that they are failing to operate well in large networks because the routing table entries reach too large as they must store route information for all accessible nodes. Proactive protocols include global state routing (GSR) and destination sequenced distance vector (DSDV) routing protocols. In DSDV, even if the routes aren't required, each node works as a router, maintaining a routing table and sending out periodic routing updates. Each route or path to the destination is assigned a sequence number to avoid routing loops. Even if the network is idle, routing updates are exchanged. Therefore, it is not ideal for networks with a lot of movement. In GSR the source node uses Dijkstra's algorithm to find the shortest path to the sink. It calculates the distance between the source and the intermediary nodes where data will be sent. The routes are only discovered in reactive or on-demand protocols when they are required [6]. Route establishment is achieved through the mobile network by broadcasting route request (RREQ) packet. Reactive protocols include dynamic source routing (DSR), adhoc on-demand distance vector (AODV) and adhoc on-demand multipath distance vector (AOMDV) routing protocol [7]. DSR does not make use of periodic advertisements. It computes the routes as needed and then keeps track of them. The sender of a packet chooses the entire network of nodes that the packet must traverse, and the sender explicitly specifies this route in the packet's header by referencing each forwarding hop with the address of the subsequent node that the packet must transmit to on its way to the destination host.

The four types of control messages that are utilized in AODV are RREQ, route reply (RREP) route error (RERR), and route-reply acknowledgment (RREP-ACK). When data packets need to be transferred, the source node uses AODV to construct a route to an unknown destination [8]. Path construction is accomplished by broadcasting a RREQ message to its neighbors while keeping a new sequence number to preserve updated data. The intermediate node receives a request and looks up a route to the requested destination in its routing table. As a result, it may send a RREP message to the origin node with the whole route. The sender node sends a RREP-ACK message to the sink to ensure bidirectional link. When a node loses a link to its destination, it must send a RERR message to its neighbors to alert them that the present route is no longer available [9]. In AOMDV, multiple paths are generated between the source and destination and when any route fails it uses alternate routes. When all routes fail in AOMDV protocol then the new route discovery phase is required. Hybrid routing protocol combines the features of proactive and reactive protocols [10]. Due to the adaptability of these protocols, they change the zone and location of mobile nodes depending on the source and sink. A popular hybrid protocol is called zone routing protocol (ZRP). ZRP was proposed to minimize the control overhead and route discovery delay of proactive and reactive routing protocol [11]. The MANET routing protocol taxonomy is shown in *Figure 1*.

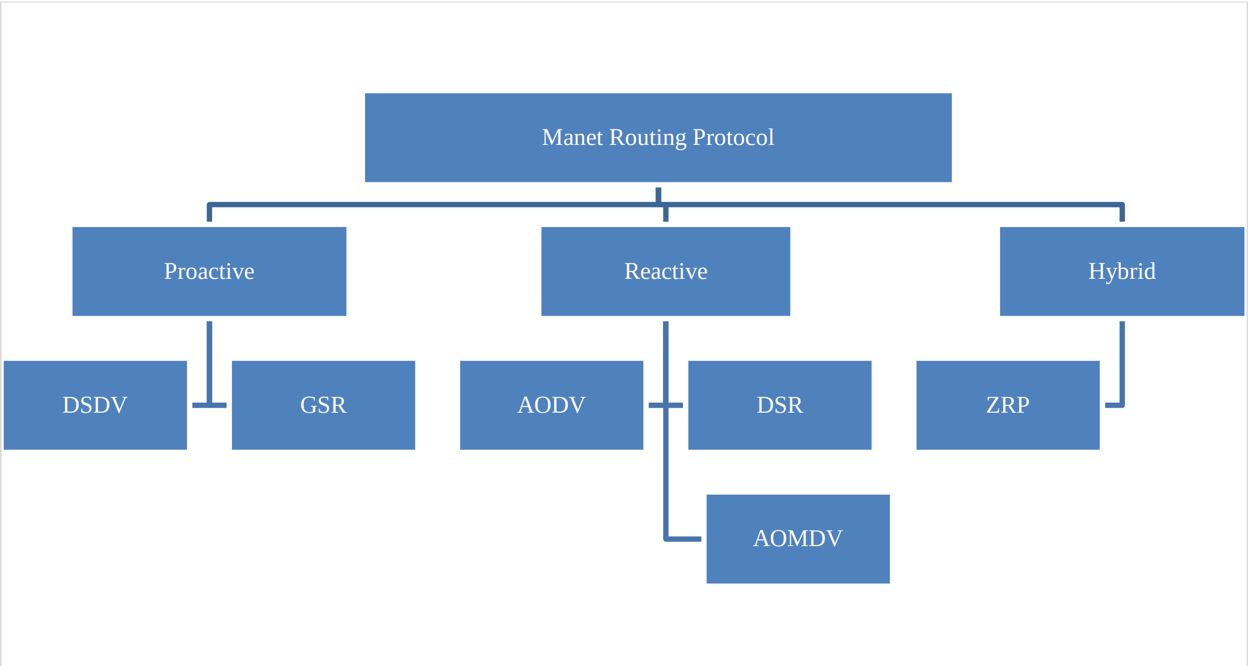

Figure 1 Taxonomy of MANET routing protocol

As all nodes in a MANET are battery-powered and have limited power, more attention must be paid to each node in order to reduce energy consumption (EC). When a node is in idle state or sending and receiving packets, it consumes more energy. Energy usage in all aspects of mobile nodes will necessitate a significant amount of effort. To deal with energy efficiency issues a swarm intelligence (SI) or nature-inspired algorithms has proven the efficient solution to reduce energy usage [12]. SI is a computational intelligence technique that relies on the cooperative behavior of intelligent agents interacting in a distributed environment to solve a problem and find a comprehensive solution. Self-organization and the division of labour are two key ideas that are regarded as vital aspects of the SI. Division of labour is the simultaneous completion of a number of easy and manageable tasks by individuals, while self-organization refers to a network's capacity to develop its agents or components into a suitable form without the need of outside intervention. Because of this split, the swarm can work cooperatively to solve complicated issues. The ant colony bird flocking, elephant herding, and fish schooling features in nature serve as inspiration for SI approaches. Ant colony optimization (ACO) and particle swarm optimization (PSO) are two of the most widely used SI techniques for optimal path discovery in MANET [13]. These techniques are based on the evolutionary process, in which various particles work together to choose the optimum route. The basic idea underlying these methods is to first identify the fitness function over an initial population and then iteratively calculate the fitness value (FV) on a new population. [14]. This research work incorporates the features of SI and proposed an optimized energy efficient routing algorithm named as adhoc on-demand multipath distance vector sleep scheduling particle swarm optimization (AOMDV-SSPSO) which uses AOMDV routing protocol for multiple path selection and among these multipath, optimal path will be selected with the help of SSPSO.

The summary of work contributions is as follows.

- The proposed routing algorithm improves the node efficiency by choosing the optimal route between the source and sink.
- The choice of optimal path is done by using the concept of PSO along with sleep scheduling mechanism.
- The proposed routing algorithm provides higher throughput (TH) and is more energy efficient, which leads to increase the network lifetime.
- It has been found that the suggested approach has increased the satisfactory level of energy efficiency of the network.

The structure of research work is as follows: Section 2 outline the related work based on routing protocols and optimization techniques. Section 3 includes proposed methodology; section 4 includes the result and discussion and at last section 5 elaborate the discussion and limitation of study. Finally, the research conclusion in section 6.

2.Literature survey

Since the analyses of routing protocols and optimization approaches in MANET have been the focus of much research, thus it is crucial to conduct a thorough review and analysis of the existing literature. Bai et al. [6] evaluated and analyzed the performance of proactive and reactive routing protocols. Simulation findings will be justified in terms of performance measures that are routing overhead TH packet delivery ratio (PDR) and end-to-end (E2E) delay. Experimental findings showed that AODV algorithm performs better in terms of TH and E2E delay, whereas the DSR algorithm performs slightly better among routing algorithms in terms of PDR. For addressing real-time quality of service (QoS) needs, Agbaria et al. [15] presented a routing protocol named as real time unicast mobile adhoc network that considers dynamic scheduling, resource management, and multipath search. The proposed solution combines proactive and location-based features, in which each node retains a global perspective that is updated on a regular basis through state interchange among all nodes. Node can extrapolate the position of a single node at any time based on its velocity vector. Author presents this technique by introducing a real-time and QoS routing mechanism. The protocol performance is evaluated, and its results are compared with AODV, DSR and optimized link state routing (OLSR) routing protocols. The simulation results reveal that suggested protocol achieved the lowest latency and offers excellent reliability in sending messages as comparison to AODV, DSR and OLSR routing protocols. Sivakumar and Duraiswamy [16] presented an effective routing protocol named as Load distribution based routing protocol (LDR) for supporting QoS through the adoption of load distribution and traffic avoidance techniques. Two types of traffic were discussed in research work that are real-time traffic and regular traffic. Normal traffic is regarded as low priority while real-time traffic is given high priority. The cost parameters are calculated using the mentioned approach depending on the link loads. Congestion is minimized by transmitting traffic across lines with lower loads. The LDR protocol performs better than the other existing protocols for both real-time traffic and regular traffic.

Since underutilized nodes often have more energy than utilized nodes, Srivastava et al. [17] proposed method that chooses a route that contains underutilized nodes in order to balance the energy usage across all nodes. The suggested method examines not only energy but also bandwidth, load, and hop count while choosing a route, which can lead to shorter, better, and energy-rich paths for routing packets and ensures the network lifetime's longevity. The simulation results demonstrate that the suggested protocol succeeds in eliminating overheads, accelerating convergence, ensuring high dependability, and providing better outcomes than earlier methods like DSR. A multi-path routing system known as Multi-Route AODV Ant routing was suggested by Abd et al. [18] and is based on AODV and ACO. The author also suggested a load-balancing technique that transmits data simultaneously over all found paths. In this approach, EC is divided across numerous nodes via the network, and data packets are balanced via paths that have been found. This protocol is referred to as using the AODV ant load balanced multi-route algorithm. The analysis of the route is completed when the link is established utilizing the resource scheduling issue. This approach adjusts the size based on the mobility of the nodes which results in minimizing the time it takes to get a message. According to the results of the simulation, the load balancing technique produces greater performance than the ordinary multi-route algorithm.

For the detection of link breakdowns and route repairs in AODV, Azzuhri et al. [19] suggested a better method. The HELLO message is used by the researcher to identify connection failure and to improve AODV performance. The second function is the link break location parameter for detecting AODV local route repair. The results of the simulation study for the route repairing method demonstrate that the fixed setting of the AODV, using a fixed local route repairing threshold, did not generate the optimal PDR value. It also showed how strongly the network load affects the best techniques.
Gautam et al. [20] explores the concept of MANET and find out that EC is the major concern in wireless network. Authors suggested a routing protocol named as energy efficient dynamic state (EEDS). By continuously monitoring each node on the network, this approach tries to extend the network lifespan, thereby increasing the network QoS. In EEDS, when every node in the network is able to actively participate in sending and receiving packets after a predetermined timestamp, the packet drop ratio is drastically lowered. Additionally, the TH results

indicate that the findings are superior to other existing studies.

Alinci et al. [21] explores that in MANET due to multi hop infrastructure less network, it has minimum battery power and a limited bandwidth due to data packet are lost. To overcome the problem mobile nodes could be combined in clusters so that wireless network achieves better stability and scalability. In this, researchers analyze different mechanism for clustering considering various performance parameters. Priyadharshini and Selvan [22] proposed that in MANET, energy of nodes may drain due to nodes mobility and infrastructure less network. Due to this performance of routing will decrease. To overcome this problem, researchers developed mechanism that is using the forecast metrics which are using fuzzy rules to choose the node whose energy is going to be exhausted. In order to avoid data loss and transmission overhead, the route recovery mechanism is designed so that corresponding routes are diverted to active nodes. The suggested protocol reduces congestion delay and extends the network lifetime since simulation results demonstrate that it performs better than the other protocols.

Bhardwaj [23] discussed that the restricted power supply is a challenge in MANET. Either charge the current network wirelessly or utilize an efficient energy protocol is the only solution to overcome the problem, therefore author suggested an Energy Efficient Position Based Routing Protocol method for charging current wireless network. The suggested protocol considers four factors that are route findings, residual energy, bandwidth, load and hop count. Degradation of the QoS is consequently caused by the issue of the channel link failure during an active call. According to the simulation findings, the overheads can be reduced, route reliability can be preserved, and link utilization can be increased by using proposed approach.

Saxena et al. [24] proposed that the MANET is a infrastructure less network with nodes are connected by wireless links. As routing and energy efficiency are primary issues in MANET due to dynamic topology, therefore the researcher considered energy aware mechanism depending on clustering to enhance MANET life. The network is broken into manageable tiny groups in this method to extend the network lifetime. The suggested approach would be a clustering algorithm that is both scalable and energy-efficient in terms of how the clusters are placed. The cluster head (CH) is chosen using maxheap and the node in the cluster with the highest energy level will act as a cluster. Since the CH battery will never run out, the functioning of the cluster won't degrade as a result of CH services, which will allow the network to last longer.

Singh and Chadha [25] studied that batteries contains limited energy and battery replacement or reload cannot be done at any moment. This makes electricity consumption the primary issue, and the lack of power among MANET nodes leads to egoistic behavior of the hops. Hence researchers analyze the previous work of protocols and their effect on selfish behavior of node in detail. Mohammed et al. [26] provide a cluster optimization technique to achieve energy efficiency in a network. This method considers fuzzy properties when calculating the FV of the nodes, which tends to handle the unknown events such CH failure, topological changes, and CH energy depletion. The suggested method is compared with four existing protocols, and the comparison shows that the proposed method gives optimal results than existing approaches.

Joshi and Biradar [27] proposed a technique for reducing overhead and EC among nodes. In MANET, mobile nodes are infrastructure-free, and researcher consider the presence of auxiliary nodes. Auxiliary nodes do not participate in the data distribution process, but they do assist in routing decision. The suggested method does not examine a normal cluster-based communication, rather assumes that all nodes are in a simulated region defined by a specific radius called a communication district. Each communication district is subdivided into smaller sections known as sub-districts. The suggested system may successfully reduce the routing overhead due to the bidirectional and perimetric beacon production, which guarantees that the proposed system will reach the destination node regardless of mobility. The retransmission energy in MANET is greatly reduced by these phenomena. The results of simulation were evaluated using routing overhead, PDR, and EC performance measures, and it was discovered that they outperformed than the reactive and proactive routing techniques.

Shashidhara et al.[28] suggested a location-aware content prefetching (LACP) mechanism. Prefetching data based on user access patterns reduces total processing time. The model is made up of a grid of heterogeneous nodes arranged in a square shape. These nodes have a dynamic nature and are connected to the network and each node has the same bandwidth, cache and computing power. The outcome demonstrates that, when compared to existing content prefetching (ECP), the suggested content prefetching strategy minimizes latency and achieves higher TH i.e., LACP uses resources more effectively when compared to ECP.

By combining the multi-criteria algorithm and the Cuckoo optimization algorithm (COA), Tabatabaei [29] develop a new routing protocol which is used to select the shortest path between nodes. The proposed method considers four key factors: the available bandwidth, the remaining energy, speed of movement, and the number of rounds in the routing process. To analyze the effectiveness of the suggested technique, the proposed algorithms from Tabatabaei (2021) were used to simulate the proposed method using OPNET simulator. The simulation findings demonstrated that the process of choosing a stable route using multi-criteria approach and COA has a significant impact on the performance of network, and in terms of TH and E2E delay, the proposed strategy outperforms the existing methods.

Sarhan and Sarhan [30] offered an optimized routing protocol named as elephant herd optimization (EHO-AOMDV) for the node energy conservation. The proposed EHO-AOMDV optimizes node EC by categorizing nodes into groups, which reduces the likelihood of path failure as data loads rise. The EHO updating operator evaluates nodes based on residual energy after each transmission round, then updates classes in accordance with that evaluation. Experiment was conducted with Ns-3 simulator, having five performance metrics that are routing overhead, PDR, EC, E2E delay, and number of dead nodes. Results indicate that the suggested EHO-AOMDV achieved a higher PDR while consuming less energy on average and having fewer dead nodes, while AOMDV performed better in terms of E2E delay.

Kumaran and Ramasamy [31] introduced a hybrid ACO and Genetic Algorithm (GA) algorithm, which is a metaheuristic technique aimed at combining the advantages of both to reduce the routing problems. The benefits of metaheuristic approaches like ACO and the GA are combined in the suggested method to improve the network's performance and efficiency. The network is simulated with various node counts and node pause intervals. When the network node pause duration is less than 120s, this approach still has significant routing inefficiency even if it performs better than the pure ACO and GA models. In situations where the node pause duration is quite long, the algorithm performs better. Through analysis, it was discovered that the suggested hybrid strategy increases MANET routing performance while meeting QoS criteria.

A fuzzy logic based AODV algorithm was proposed by Li et al. [32] to increase the route's reliability in MANET. The most reliable relay node is chosen during the route discovery phase, and the most reliable route is set aside for data transmission. Simulation findings demonstrate that the proposed routing protocol delivers higher reliability without requiring more time, and it provides better link connectivity, and a longer route life when compared to the conventional AODV protocol and the fuzzy logic routing method. Even the average delay is low when there are more than 70 nodes, and the average routing efficiency is almost 18% higher than AODV.
Jubair et al. [33] evaluated and compared the performance of two routing protocols which are AODV and OLSR in MANET. The research utilized a simulation to assess the effectiveness of the routing protocols based on the quantity and size of nodes in the network. The evaluation results show that the AODV outperforms the OLSR in the majority of the simulated scenarios. The findings also demonstrate that the TH, PDR, and E2E delay of the network are significantly influenced by the number of nodes and network size.

To maintain balance during data transmission, Venkatasubramanian [34] introduces the multipath routing protocol, which creates several paths with optimal routing. Fruit fly algorithm (FFA) is used to address high EC and discover the best values for objective parameters (i.e., energy). Based on the fruit fly tendency to seek for food in FFA-DSR, the fitness value (FV) for each possible path is determined and arranged in the most efficient order. FFA-based DSR performed better than existing routing protocols when it was implemented using the NS-2 simulator. The experimental results show that the suggested approach minimizes energy by over 20% when compared to the ACO.

For an optimal load-balancing energy-efficient routing protocol, Alghamdi [35] presented a meta-heuristic technique inspired by cuckoo search. In order to divide the routing overhead across the participating nodes, the proposed protocol employs the cuckoo search approach to choose the best routing path based on each node's remaining energy.

The novel protocol has been assessed and compared with other protocols, including Ant HocNet routing protocol, load-balancing AOMDV protocol, enhanced AODV protocol, and on-demand multipath distance vector protocol. After analyzing the simulation findings, the proposed routing technique showed considerable improvements in PDR, longer battery life, and low packet delay time.

Suresh et al. [36] proposed the routing protocol known as optimal route selection (ORS), which is used to choose a CH and a backup CH, generate the best path between the CH and each member node, and establish the best path based on the maximum energy and number of hops between the nodes. The member node between the base station and the CH is given by an ORS which is more energy efficient than existing techniques. The proposed ORS routing protocol outperforms the existing approaches in terms of TH, minimal jitter and latency, and maximum PDR.

After studying the existing literature, the following observation are identified:

- Due to the MANETs changing topology, weak wireless links, and mobile environment, security issues arise. Some mechanism is needed which prevents a node to learn the identity or the credentials of other nodes.
- Few of the researchers used optimization algorithms to select the optimal path for transferring packets from source to destination, however choosing an efficient optimization algorithm is a big challenge because such algorithms face several issues like low convergence speed.
- Nodes are equipped with small non-rechargeable batteries. Therefore, the efficient battery usage of a node is very important aspect to support the extended operational lifetime of network.
- In mobile adhoc network mobility has often induce several issues related to accessibility, connectivity, packet loss etc. A network with better stability and longer lifetime is need of today's era, but along with this providing desired coverage and connectivity with limited resources is also one of major challenge.

It is clear by analyzing the literature that the high EC of mobile devices results in a reduction in network lifetime in MANETs, which is the most challenging problem. As a result, the primary issue that needs to be solved in this research work is the efficient use of nodes energy in MANET.

3.Proposed methodology

MANET, one of the rising domains in the wireless sector, faces numerous challenges, particularly in the field of its applications. After reviewing the existing literature, it is clear that the most difficult problem with MANETs is the high EC of mobile devices. A network may have challenges with continuous transmission as well as excessive EC during high data rate transmission due to a lack of infrastructure, low resource usage, dynamic topology, and node coordination failure. Therefore, efficient use of energy in MANET can be considered as the primary issue to be solved in this research work. With the suggested approach, this problem can be reduced, and it leads to increased energy efficiency in terms of various performance metrics. We proposed an energy efficient, optimized routing protocol named as AOMDV-SSPSO which helps to reduce EC in MANETs. The objective of the proposed research work is achieved by three vital steps which are route establishment phase, optimal path selection and sleep scheduling mechanism. The proposed protocol minimizes the EC of nodes by integrating the optimization concept with the sleep scheduling technique. *Figure 2* shows the systematic diagram of the suggested approach.

The route establishment phase is based on an AOMDV routing protocol which can be used to identify multiple routes for data transfer from source to destination. Out of all the possible routes the optimal path will be selected with the help of PSO. The sleep scheduling technique places nodes in a sleep state when they are not in use and their absence does not result in local partition in their immediate area. All the phases of the suggested approach are described in detail in the following subsections.

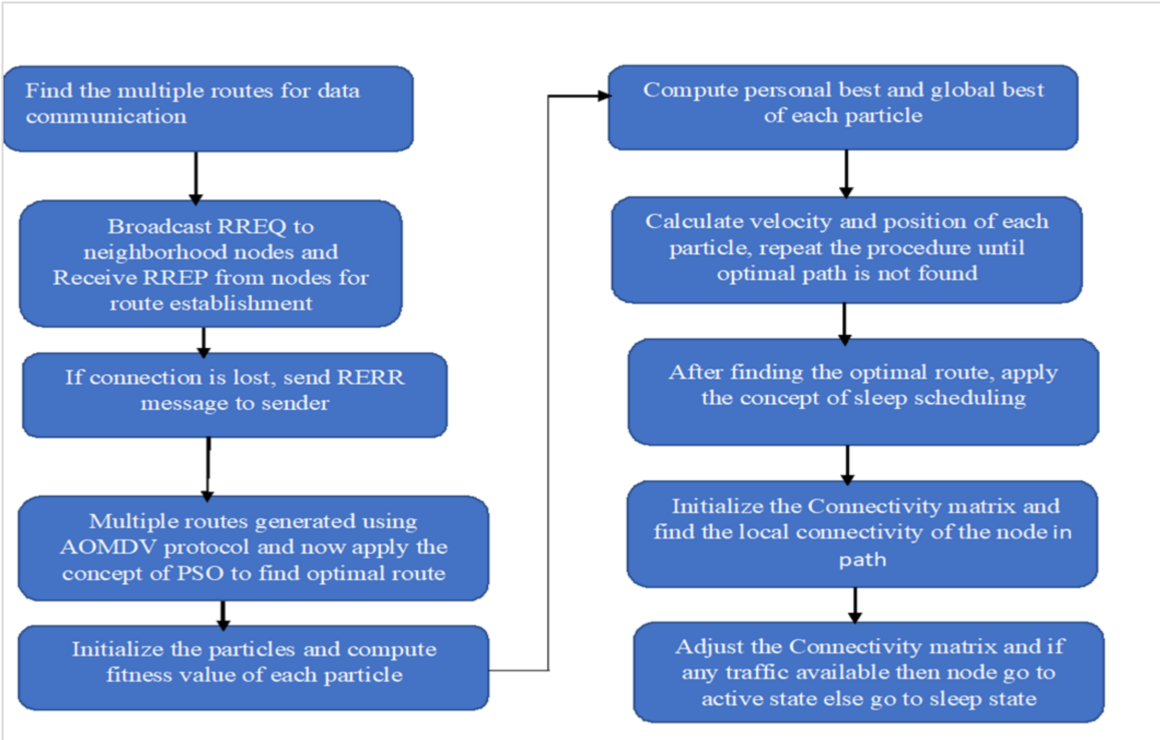

Figure 2 Illustration of Proposed routing protocol

3.1Route establishment phase

In a dynamic network, when connection failure and route breakdowns occur, AOMDV protocols are useful. If AODV is utilized in this scenario, each path failure causes a new path discovery which increases the overhead and latency. This limitation can be avoided if numerous different paths are available. AOMDV only initiates new path discovery after all previous routes to the destination have failed. During the route discovery phase, each copy of a RREQ packet received by a node represents a different reverse path. Routing loops will emerge if a node accepts all of these unnecessary RREQ packets. AOMDV utilizes the concept of advertised hop count to prevent such loops forming. The hop count advertised is the highest of all routes reachable at that node. For the same sequence number, it will never change. The advertised hop count is updated as the sequence number changes. RREQ, RREP, RERR and RREP-ACK are the four control packets used by AOMDV. By flooding RREQ packets, the source node will start a route discovery process. Because of flooding, an intermediate node may get redundant copies of the same RREQ packets. The reverse pathways of these duplicate packets are checked and is chosen on the basis of RREP packets, which it generates and delivers back to the sender through these paths. The sink node creates a reverse route and generates the RREP message in response to each RREQ arriving at the destination just like intermediate nodes. When a connection is lost, a RERR message is sent to the sender to maintain the route. When the intermediate node receives this error message along the route, it examines to see if the node transmits the RERR as its next hop. The sender node sends a RREP-ACK message to the sink to ensure bidirectional link. If this is the case, the route table will become invalid, and the source node will receive the error message. The path establishment method is depicted in *Figure 3* and *4*.

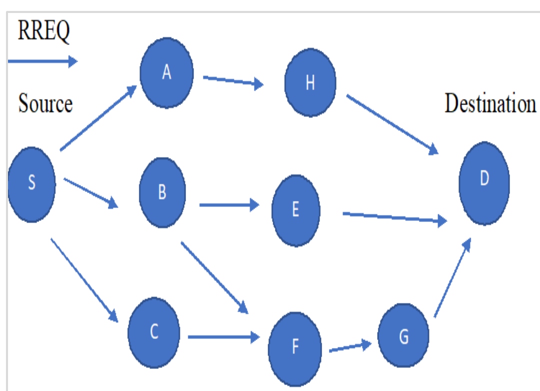

Figure 3 RREQ broadcast

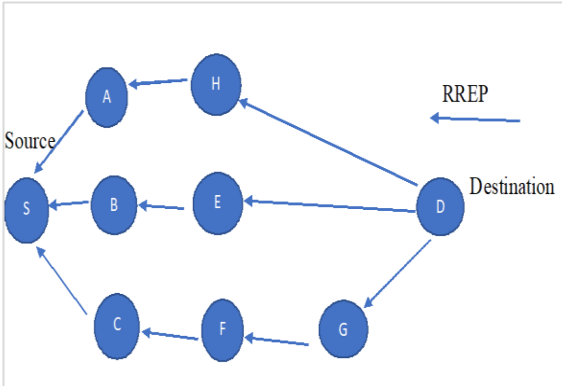

Figure 4 RREP broadcast

In *Figure 3*, source broadcasts the RREQ message to all nodes, including intermediate nodes and the sink node and in *Figure 4*, the destination node creates a reverse route and generates a RREP packet, which it then broadcasts to all nodes through the path. AOMDV can be configured to either a link or a node-disjoint route. In node-disjoint route, the source and sink nodes are the only nodes that share a common node, whereas, in a link-disjoint path, there is no shared link.

Figure 5 depicts the concept of node-disjoint or a link-disjoint. As seen in *Figure 5(a)*, the routes SBD, SCD, and SED have no common node or link, therefore these are node-disjoint or a link-disjoint pathways. *Figure 5(b)* shows that the routes SBCED and SCD which share node C, but not a link, resulting in a link-disjoint path. Finally, *Figure 5(c)* depicts the routes SBCD and SBD, which share both the link SB and the node B, indicating that they are not disjoint. Disjoint alternate paths are preferable to overlapping alternate paths since the risk of interconnected and contemporaneous failure is lower.

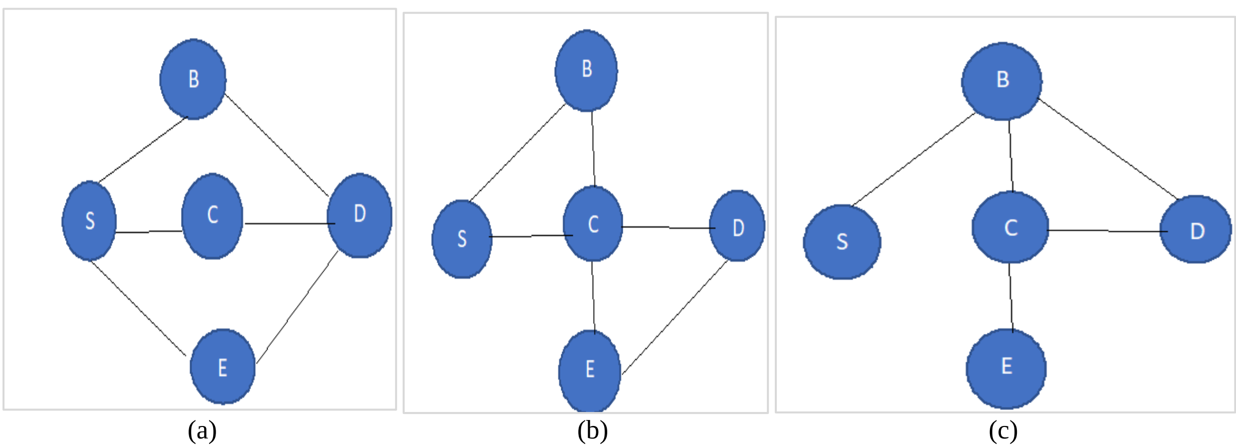

Figure 5 Link and node-disjoint routes

3.2Optimal path selection

The AOMDV routing protocol provides multiple routes for transferring the information from source to sink. Now the optimal path is selected with the help of PSO. PSO is an algorithm based on optimization and it always chooses the optimal path in a search space by predicting social behavior of flocking birds or fish schooling, where each bird or fish is treated as a particle in a hyper-dimensional search space. The movement of the particles in space is distributed at random. In every iteration, individuals evaluate their own fitness and that of their neighbors, and they move toward successful neighbors (those whose current position offers a more effective solution to the situation than their own) to benefit from them. In PSO the optimal solution is obtained when the algorithm reaches convergence. If the algorithm has attained convergence, it is influenced by the velocity and position of the particle. Mathematically, in PSO, each particle has a corresponding position, velocity, and FV. Each particle maintains and stores a record of its position and best FV.

In PSO, there are two optimum values for every node in each iteration. The first value is the one that has already been determined, whereas, Particle swarm optimizer finds the second one. Particle maintains the record of its coordinates in the solution space that are then connected to the best possible value achieved so far, and this value is called personal best (pBest). Another value that is tracked by the particle is the best value obtained so far by any particle in the nearby area of that particle. This value is called global best (gBest). It is constrained by the inertial range to provide an acceptable solution. The fundamental principle of PSO is to force each particle toward its local and global optimal positions. The particle adjusts its velocity and positions using Equations 1 and 2 after finding the pBest and gBest value.

$$V(t+1) = wV(t) + C1r1\,(pBest(t) - X(t)) + C2r2(gBest(t) - X(t)) \quad (1)$$

$$X(t+1) = X(t) + V(t+1) \quad (2)$$

Where, V (t + 1) and X (t + 1) are the velocity and position of particle.
t = Count of iterations
w = Inertia range
C1, C2 = Learning factor
r1, r2 = a random number with values ranging from 0 to 1

Repeat the above steps until the optimal path is obtained. PSO proves its effectiveness and superiority in the solution of high-complexity optimization issues. After selecting the optimal path through PSO, the proposed work uses the concept of sleep scheduling which enhances the further lifetime of the network.

3.3Sleep scheduling (SS) phase

During the SS phase, a node chooses whether or not to enter the sleep state based on the volume of traffic at that moment and the connections of its neighbors. Only when a node is satisfied that its neighbors may be reached for one another without requiring its active involvement, it enters the sleep state. Nodes send out a Hi message on a regular basis to other nodes which includes the sender information. When the other nodes receive a Hi message, it calculates the transmitting power needed to communicate the message and changes its vicinity table, which is kept at each node. A node can only stay in one of three states: active, idle or sleep state. Active nodes participate in data communication and send out messages on a regular basis to other nodes. A node enters an idle state when the broadcast message period has expired. A node in the idle state must choose one between active and sleep mode. The radio transceiver of a node is turned on in the active and idle states, but it is shut off in the sleep state. When a node wakes up from its sleep state, it enters the idle state and if there is any pending traffic, the node switches back to active mode; otherwise, it performs a sleep eligibility procedure to determine whether it is eligible to sleep. A node in the idle state must choose one between active and sleep mode. A local partition in a node immediate vicinity may be created when it goes to sleep. This is because when a crucial node goes to sleep, all of its paths are destroyed, and any traffic that is passing through that node is disrupted. As a result, a node checks to determine if its absence will result in a local partition before going to sleep. The node enters in the sleep mode only when there is no traffic for it to participate in and its absence does not result in a local partition. *Figure 6* depicts the state transition diagram between states.

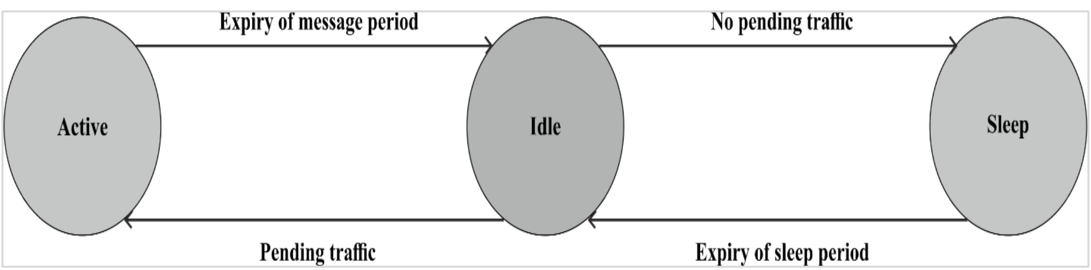

Figure 6 Transition of states in sleep scheduling

The output from the first phase of the proposed approach serves as the input for the second phase, and the output from the second phase serves as the input for the third phase, i.e., the output from the route establishment phase provides the input to the optimal path selection phase and the output from the optimal path selection phase serves as the input for the sleep scheduling phase. The proposed algorithm's pseudo code is as follows: -

Input: Nodes
Output: Set of Energy Efficient nodes
Start
for communication, choose a source and sink node.
Start the route-finding process
For each source node
Broadcast RREQ to neighborhood nodes
Receive RREP from nodes
Send RERR message to sender if connection is lost

Detect all possible routes from source to destination
End for
After receiving multiple paths choose the optimal path by applying PSO
for every particle
do initialization
compute fitness value
if calculated value is superior to previous pBest, then set current value= pBest
compute gBest as the best F.V among all the particles
end
for every particle
Compute velocity and position of each particle from eq. 1 and 2
End
Repeat the procedure until terminating criteria is not attained
After finding the optimal path, apply the sleep scheduling mechanism
Let S: number of neighbors of node u, where u runs the algorithm.
Let (n): set for node n and CM: Connectivity matrix of S×S order
Set CM for all x,y equals to false and $X(n) = 0$
Establish the local connectivity for all nodes
Adjust the CM as **if** CM $[x][y]$ = CM $[y][z]$ = TRUE **then** Set CM $[x][z]$ = TRUE
if pending traffic in network, then
Nodes will go to active state
else
Nodes will go to sleep state

4.Result

The network simulator tool (NS 2.35) is used for simulation since it offers accurate implementations of a number of network protocols. NS 2.35 uses an object-oriented extension of tool command language (TCL) where TCL is also a scripting programming language. Input files that are necessary for simulation are depicted in *Figure 7*. Here we have a scenario file that contains the number of nodes and the packet size on which the simulation is done. The output files known as the trace file and network animator are produced by using these files in the simulation. AWK programming is used to work on the output files during the study of the performance measures. Performance metrics considered in the proposed routing protocol include E2E delay, TH, EC and network lifetime.

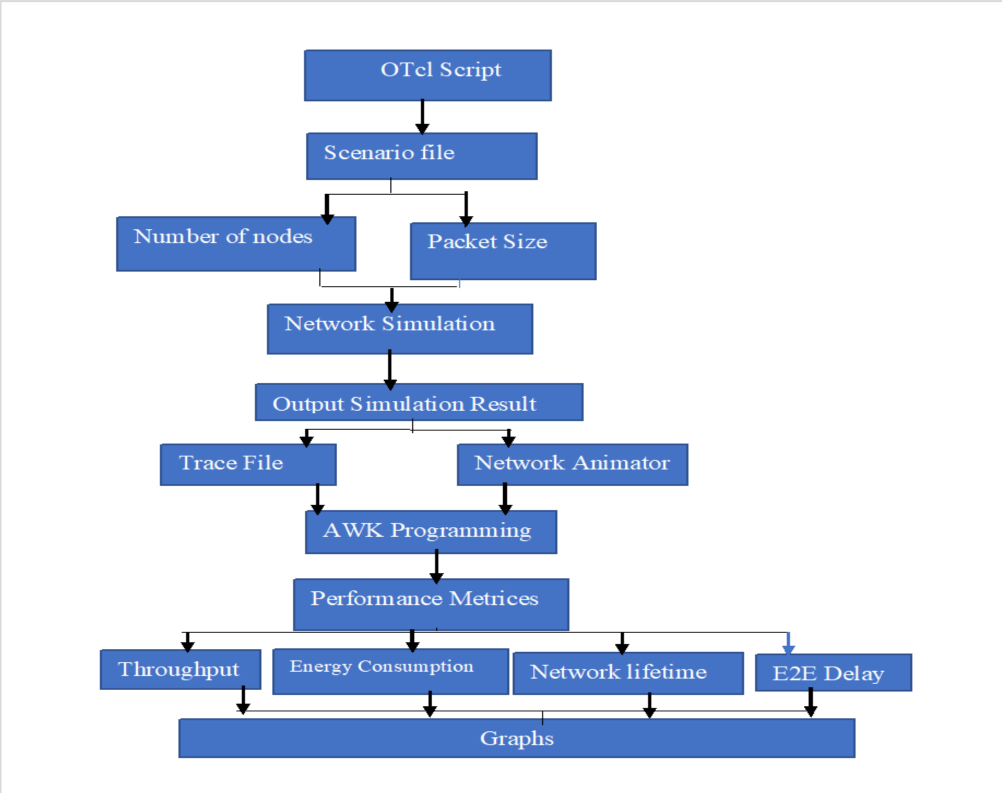

Figure 7 Experimental setup on NS2

NS 2.35 simulator simulates the suggested technique and compare it with existing protocols named as AOMDV and particle swarm optimization, adhoc on-demand multipath distance vector (PSO-AOMDV). The performance of the suggested algorithm is analyzed in terms of E2E delay, TH, EC, and network lifetime. Two different scenarios, such as the number of nodes and packet size are chosen to assess the performance of the proposed protocol. Experimental parameters for the suggested method include a node count from 20 to 120, deployment area of 1000m ×1000m, packet sizes of 200 to 1200 bytes, and pause time is 5s. The simulation parameters of proposed algorithm are listed in the *Table 1*.

Table 1 Simulation parameters and range

Parameters	**Value**
Type of Channel	Wireless
Radio Propagation model	Two-way Ground
Antenna model	Omni Antenna
Queue Length	50
Nodes no.	20,40,60,80,100,120
Nodes Speed	20
Area	1000m * 1000m
Type of traffic	CBR
Time of simulation	80s
Protocols used	AOMDV, AOMDV-PSO and AOMDV-SSPSO
Speed Type	Uniform
Pause duration	5s
Pause Type	Uniform

4.1Performance metrices

Performance metrics are high-level measurements used to evaluate the network overall performance. It should be designed to enhance improvement of the network in terms of node energy efficiency and effectiveness. The metrics that are used to compare and analyze the performance of the suggested approach with the existing protocols in this research work are E2E delay, TH, EC, and network lifetime.

E2E delay: It measures how long it actually takes for data transfer from a source to a sink. E2E delay is calculated using Equation 3:

$$\text{E2E delay} = \sum_{j=1}^{n} ((Dj - Sj))/n \qquad (3)$$

In Equation 3, n denotes the number of successful packets that are collected by destination nodes, j is the unique packet identity, Sj represents the time at which the packet with index number j was sent, and Dj represent the time at which data was received at the sink node.

Throughput: It is number of bits received by the destination in given time. It is computed using Equation 4 and measured in kilobits per second (kbps).

$$\text{Throughput (TH)} = (\text{number of bytes received} \times 8 / \text{simulation time}) \times 1000 \qquad (4)$$

Network lifetime: It is the time required to drain the battery of all nodes in the network and is computed using Equation 5.

$$\text{Network Lifetime} = \sum_{j=1}^{n} (ener(j) = 0) \qquad (5)$$

Here ener(j) represent the energy of all the nodes in the network where the value of j varies from 1 to n.

EC: EC is defined as the amount of energy consumed by nodes throughout the simulation period. It is calculated using Equation 6.

$$\text{EC} = \sum_{j=1}^{n} (init(j) - ener(j)) \qquad (6)$$

In Equation (6), n denotes the node number, the counter is denoted by j, init represents the initial energy level for each node, and ener refers to the node energy level after the simulation.

4.2Simulation results

Throughput (TH)

TH is the most important performance metric for any routing technique. X-axis in *Figure 8* shows packet size in bytes and Y-axis reflects TH whereas *Figure 9* depict the number of nodes on the X-axis and TH on Y-axis.

Figure 8 shows that for all existing and proposed protocols, the TH value increases in accordance with packet size. The simulation obtained the highest TH with packet sizes of 1200 bytes, and the lowest TH with packet sizes of 200 bytes. After a certain threshold, TH values become constant for all protocols, especially from 800 to 1200 byes which indicates that more data can be transmitted as packet sizes increase. The findings of *Figure 9* reveals that as count of nodes in the network gradually increases from 20 to 120, the suggested technique achieves a higher TH as compared to the AOMDV and PSO-AOMDV. When the network size increases from 20 to 120 nodes then AOMDV achieves 0.29% of TH, PSO-AOMDV attains 0.32% of TH and AOMDV-SSPSO achieves 0.34% of TH. TH increases in AOMDV-SSPSO because of optimal path selection among the multiple pathways and the node turns off its radio signal when there is no packet to send which results in the improvement of the TH of proposed protocol. However, the PSO-AOMDV protocol also chooses the best path out of all the available paths, therefore the TH obtained is quite acceptable. On the other hand, the TH of AOMDV is very less because nodes may have to wait longer for the route to be discovered which result in a delay for successful transmission of packets from source to sink node.

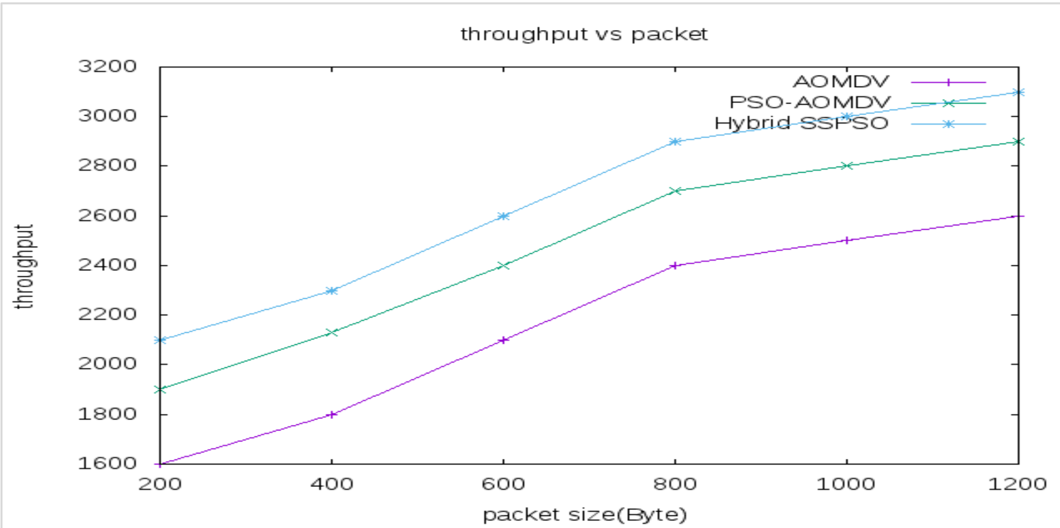

Figure 8 Throughput vs. packet size

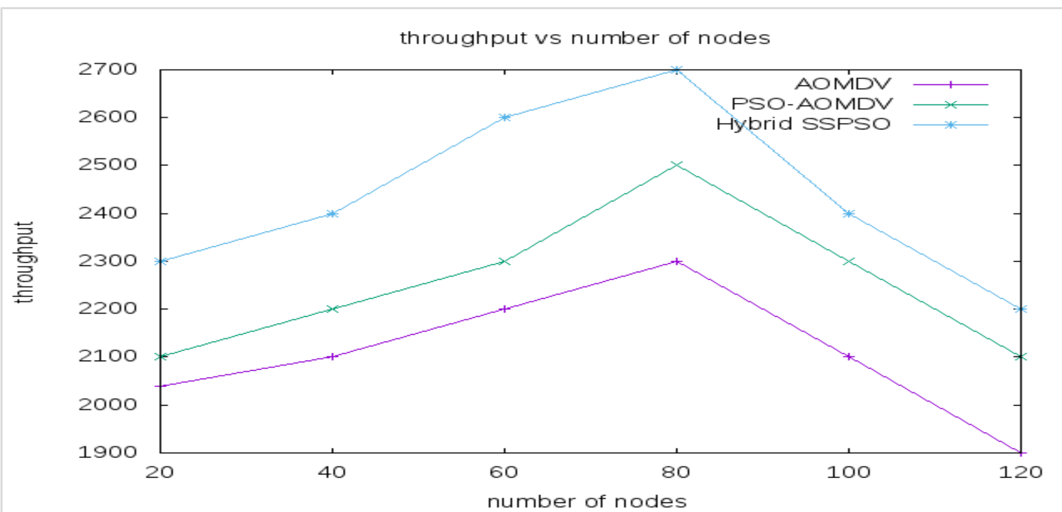

Figure 9 Throughput vs. number of nodes

Energy consumption

EC of a node is determined by how much energy it consumes for transferring the packet among nodes. Below *Figure 10* and *11* shows the plot for EC versus packet size in bytes and number of nodes respectively. X-axis in *Figure 10* shows the packet size in bytes and the Y-axis represent the EC, whereas *Figure 11* shows the number of nodes on X-axis and EC on Y-axis. *Figure 10* shows the EC for three protocols when the packet size is increased from 200 to 1200 bytes. It is clearly seen that when packet size increases from 1000 bytes to 1200 bytes then the proposed protocol consumes less energy as compared to existing techniques because it always chooses an optimized path for transferring data from source to destination and further EC of the node is reduced by allowing a node to go to sleep state when not in use. However, PSO-AOMDV also consumes slightly less energy as compared to AOMDV because PSO-AOMDV protocol uses the concept of PSO, which selects the optimal route for transferring data from source to sink. AOMDV have larger EC when the size of packet increases because AOMDV tend to establish multipath routes and to find node disjoint and link disjoint routes as possible in a route discovery phase.

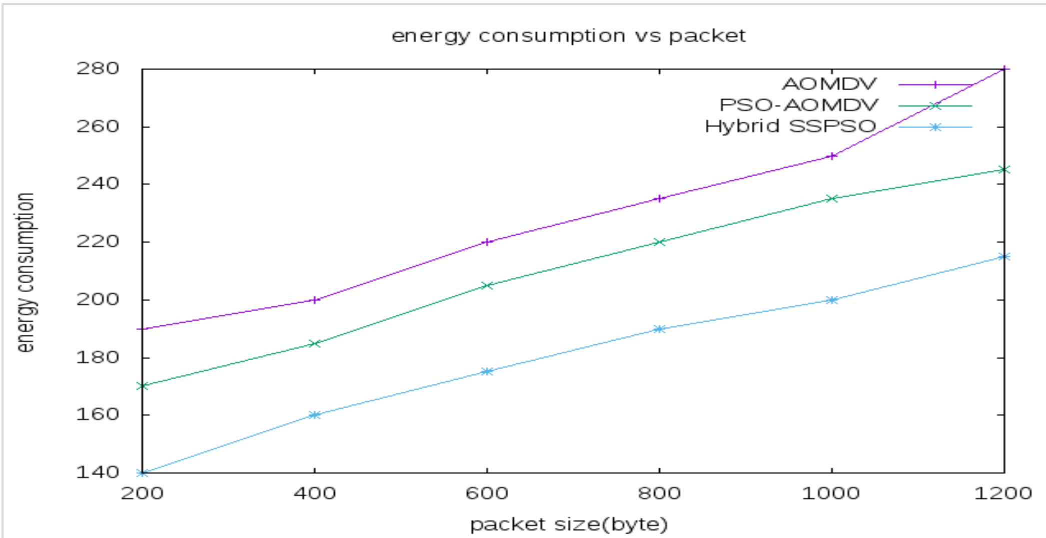

Figure 10 EC vs. packet size

The proposed method offers a lower EC when the number of nodes increases from 20 to 120 as shown in *Figure 11*. This is because AOMDV-SSPSO selects the energy efficient routes and turns off the nodes transceivers that are not actively engaged in transmitting data. In proposed approach only active nodes participate in data communication and send out messages on a regular basis. The EC by AOMDV protocol is very high because AOMDV protocol consumes lots of energy during route discovery phase and route maintenance phase.

Network lifetime

It is the period of time during which a MANET network would be completely functional. *Figure 12* and *13* shows the plot of network lifetime versus packet size and no. of nodes. In *Figure 12*, X-axis shows the packet size in bytes, whereas in *Figure 13*, the X-axis represents the number of nodes and Y-axis represents the network lifetime in both figures.

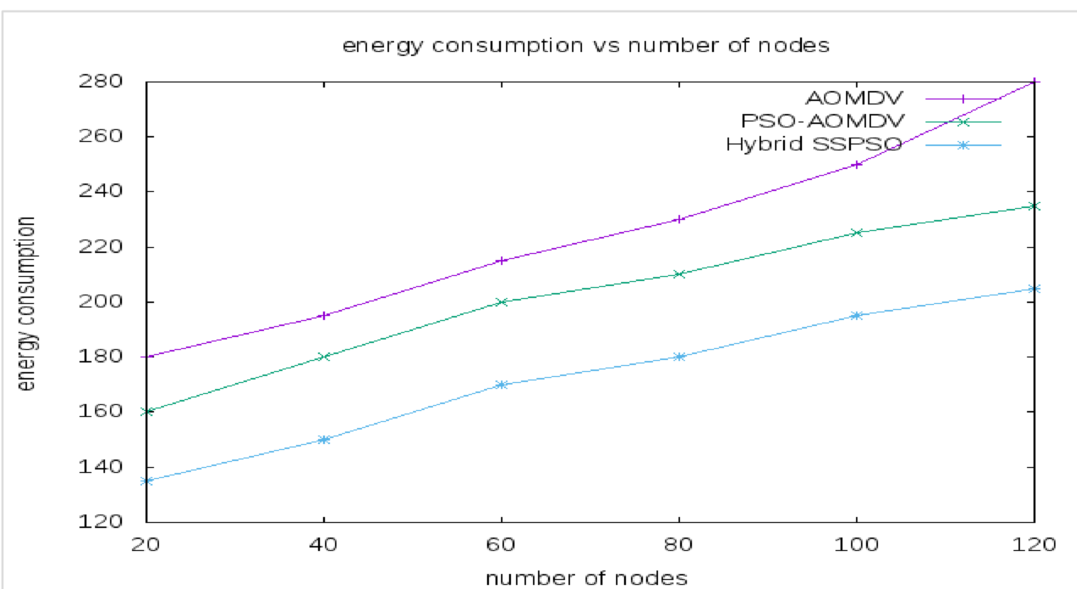

Figure 11 EC vs. number of nodes

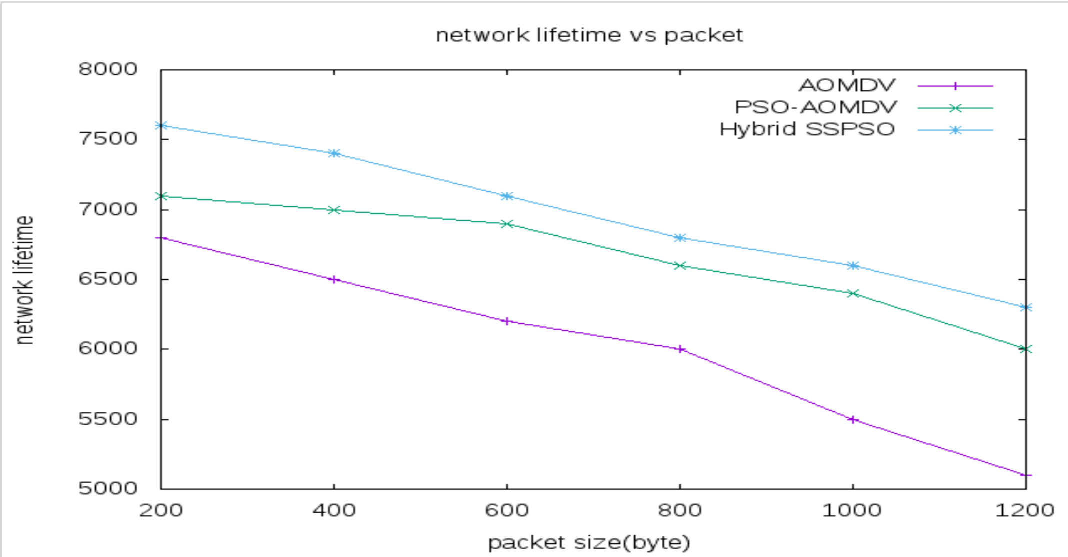

Figure 12 Network lifetime vs packet size

Figure 12 shows the plot of network lifetime for three said techniques when the packet size varies from 200 to 1200 bytes. It is clear from the simulation findings of above Figure that initially, the proposed technique achieves a highest network lifetime as compared to other existing protocol (AOMDV and PSO-AOMDV). But as the size of packet increases gradually i.e., from 400 to 1200 bytes, the network lifetime of AOMDV-SSPSO starts decreasing, but still it is significantly better than the AOMDV and PSO-AOMDV. When the packet size varies from 600 to 1200, there is a slight variation between the proposed approach network lifetime and the PSO-AOMDV network lifetime. Out of the three above discussed protocols the network lifetime of AOMDV protocol is very less because AOMDV protocol consumes lots of energy during route establishment phase and route maintenance phase and once the energy of all the nodes gets exhausted it results in the reduction of network lifetime.

Simulation findings of *Figure 13* reveals that when the number of nodes increases from 20 to 120 nodes, then AOMDV-SSPSO gives a best network lifetime as compared to AOMDV and PSO-AOMDV because it chooses the optimal route for data transmission and node went to sleep state when there is no traffic encountered which results in less EC. The network's energy usage and longevity are intertwined. The network's lifetime can be extended if the energy usage is reduced. In contrast to other techniques, AODMV uses a lot of energy since nodes may have to wait longer for route setup and maintenance, which increases node EC and shortens the network lifespan.

E2E delay

One of the key goals of MANET routing protocols is to reduce the E2E delay for transferring data from one node to another. The plot for E2E delay versus packet size and number of nodes is shown in *Figures 14* and *15*, respectively.

In *Figure 14*, X-axis shows the packet size in bytes and Y-axis represents the E2E delay. The delay times for each approach rise as the number of data packets increases. For instance, when the size of the data packet is about 1000 bytes, then PSO-AOMDV has an E2E delay of 0.25s, AOMDV has 0.28s and AOMDV-SSPSO has a delay time of 0.35s. As the size of the data packets varies from 200 to 1200, the proposed technique has a large delay time as compared to all other techniques. The proposed protocol low rate of convergence throughout the iterative process and nodes transitions from the active to idle state and idle to sleep state and vice versa, contribute to the delay in packet transmission over the network. *Figure 15* shows the E2E delay on the Y axis and number of nodes in the network on the X axis. From above figure, it is examined that when the node count is 20, then AOMDV-SSPSO has a higher E2E delay as compared to other discussed protocols, but as the node size further increases, the E2E delay is little less. When the count of nodes goes beyond 50, E2E delay again increases because in proposed routing protocol, nodes move from one state to another state to reduce the EC which tends to the delay in transferring packets over the network. However, the PSO-AOMDV protocol has less delay because of choosing the optimal path for transferring packets and AOMDV exhibits higher delay when the node count lies between 40 to 70 nodes, but as the network size increases further E2E delay is comparatively less in AOMDV as compared to AOMDV-SSPSO.

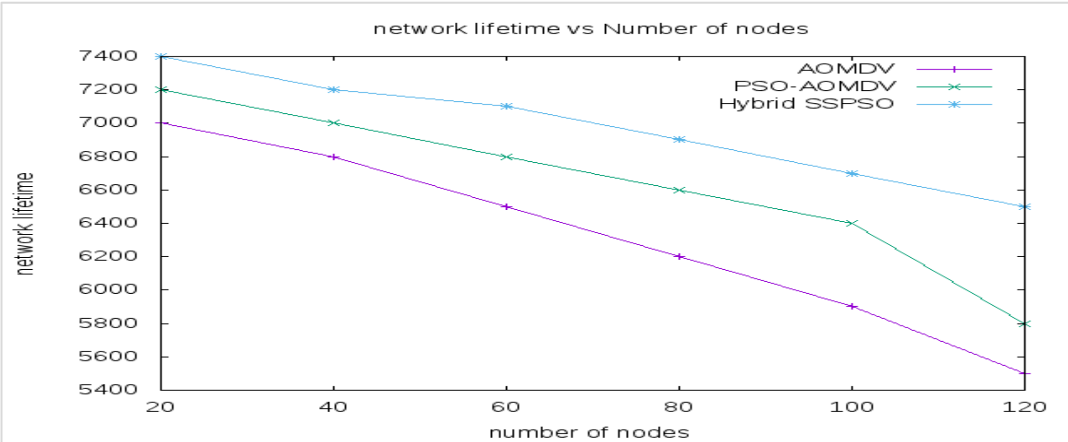

Figure 13 Network lifetime vs. number of nodes

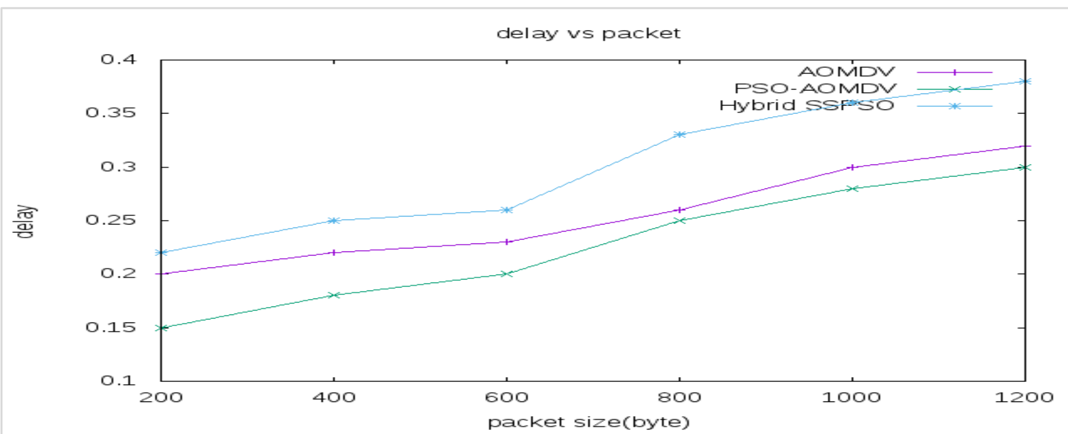

Figure 14 E2E delay vs. Packet Size

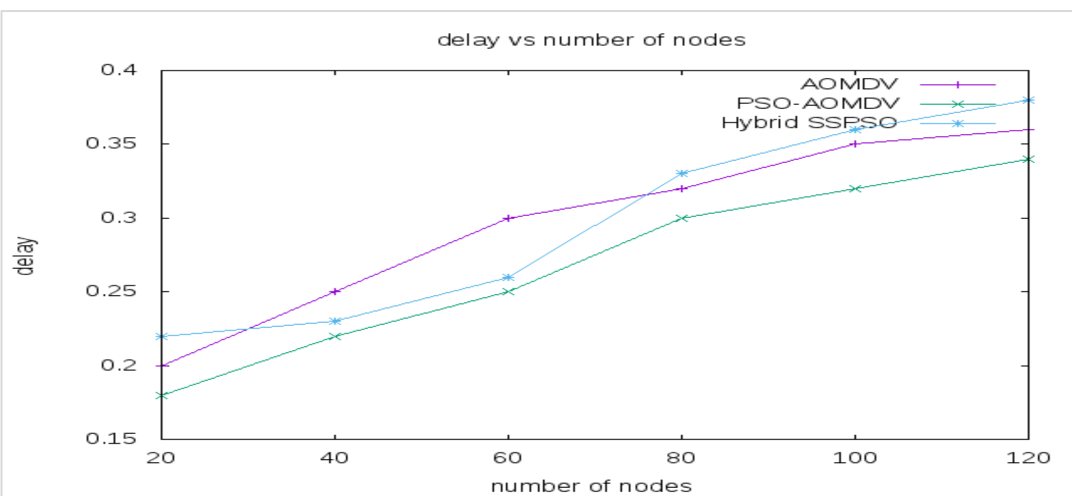

Figure 15 E2E delay vs. number of nodes

5.Discussion

The effective usage of the node's energy in MANET can be considered as the main problem that needs to be resolved in this research work. On the basis of simulation results, the following observations are obtained:

- TH value for all above-mentioned protocols become constant after a certain threshold, especially between 800 and 1200 bytes, which shows that more data can be sent as packet sizes increases.
- When the number of nodes increases, AOMDV-SSPSO offers high TH and is more energy efficient, resulting in a longer network lifetime whereas, the TH of AOMDV is very less because nodes may have to wait longer for route establishment and maintenance at the time of link breakage which result in a delay for successful transmission of packets from source to sink node.
- AOMDV exhibits higher delay when the node count is between 40 and 70 nodes, however when the network size goes further, E2E delay is comparatively less in AOMDV as compared to AOMDV-SSPSO whereas, PSO-AOMDV protocol exhibits lower delay when compared with above mentioned protocols because it chooses the best path to transfer packets from source to sink.
- AODMV consumes more energy than other mentioned protocols because nodes must wait longer for route setup and maintenance, resulting in increase of node's EC and shortens their network lifetime however, AOMDV-SSPSO gives a best network lifetime among all protocols because it chooses the optimal route for data transmission and node went to sleep state when there is no traffic encountered which results in less EC by nodes.

Limitation of study

It is observed that the proposed technique AOMDV-SSPSO outperforms than other existing protocols in terms of TH, EC and network lifetime but as the size of the data packets varies from 200 to 1200, AOMDV-SSPSO has a large delay time as compared to all other techniques because of its low rate of convergence throughout the iterative process and nodes transitions from the active to idle state and idle to sleep state and vice versa, contribute to the delay in packet transmission over the network.

A complete list of abbreviations is shown in *Appendix I.*

6.Conclusion

Due to the frequently changing topology, MANET poses a significant to the battery life of mobile devices connected to the network. However, by using the energy efficient routing protocols, network energy usage can be reduced to some extent. In order to increase the energy efficiency and network lifespan of MANET networks, there has been an increase in interest in utilizing SI or nature-inspired techniques. In this work, we provide AOMDV-SSPSO, a hybrid optimization routing protocol that always selects the optimal path for data transfer rather than the shorter one. The objective of the proposed research work is achieved by three vital steps named as: route establishment phase, optimal path selection and sleep scheduling phase. The route establishment phase is based on an AOMDV routing protocol which can be used to identify multiple routes for data transfer from source to destination. With the use of PSO, the optimal path will be chosen out of all possible paths. After selecting the optimal path through PSO, the proposed work uses the concept of sleep scheduling which enhances the further lifetime of the network. When nodes are not in use, the sleep scheduling technique puts them in a sleep state such that their absence does not cause local partition in the neighborhood. In terms of E2E delay, EC, network lifespan, and TH, the performance of the proposed algorithm is examined and compared with that of the existing techniques named as AOMDV and PSO-AOMDV. The efficiency of the proposed approach is demonstrated by the simulation results produced by the NS 2.35 software. According to the simulation results, AOMDV-SSPSO offers greater TH and is more energy efficient, which results in extending the lifespan of the network. The E2E delay in AOMDV-SSPSO is high due to the node's movement from one state to another. Overall, it has been observed that the proposed method, AOMDV-SSPSO, performs better than other existing protocols.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

Author's contribution statement

Veepin Kumar: Conception and design of the work, Data collection and analysis, study of simulation tools, writing the research paper, interpretation of results. **Sanjay Singla:** Study conception, supervision and investigation on challenges and draft manuscript preparation.

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Appendix I

S. No.	Abbreviation	Description
1	ACO	Ant colony optimization
2	AOMDV	Adhoc On-Demand Multipath Distance Vector
3	AOMDV-ACOPSO	Adhoc On-Demand Multipath Distance Vector Ant Colony Particle Swarm Optimization
4	AOMDV-SSPSO	Adhoc On-Demand Multipath Distance Vector Sleep Scheduling Particle Swarm Optimization
5	AODV	Adhoc On-Demand Distance Vector
6	CH	Cluster Head
7	COA	Cuckoo Optimization Algorithm
8	DSDV	Destination Sequenced Distance Vector
9	DSR	Dynamic Source Routing
10	EC	Energy Consumption
11	EEDS	Energy Efficient Dynamic State
12	E2E	End-to-End
13	FV	Fitness Value
14	FFA	Fruit Fly Algorithm
15	GA	Genetic Algorithm
16	GSR	Global State Routing
17	LACP	Location-Aware Content Prefetching
18	LDR	Load Distribution-Based Routing Protocol
19	MANET	Mobile Adhoc Network
20	NS 2.35	Network Simulator 2.35
21	OLSR	Optimized Link State Routing Protocol
22	ORS	Optimal Route Selection
23	PDR	Packet Delivery Ratio
24	PSO	Particle Swarm Optimization
25	QoS	Quality of Service
26	RREQ	Route Request
27	RREP	Route Reply
28	RERR	Route Error
29	RREP-ACK	Route-Reply Acknowledgment
30	SI	Swarm Intelligence
31	TH	Throughput
32	TCL	Tool Command Language
33	ZRP	Zone Routing Protocol