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A Comparative Analysis of OLSR Routing Protocol based on PSO and Cuckoo Search Optimization (CSO) in MANETs

Udaya Kumar Addanki[1], B. Hemantha Kumar[2]
Research Scholar, Department of CSE
Acharya Nagarjuna University, Guntur, A.P., India
udayaka.18@gmail.com
https://orcid.org/0000-0001-9915-3581
[2]Professor, Department of IT
RVR & JC College of Engineering, Guntur, A.P., India
bhkumar_2000@yahoo.com
https://orcid.org/0000-0002-2445-6796

Abstract— New developments in wireless communication have enabled the use of highly efficient and inexpensive wireless receivers in a variety of portable applications. Each node in a mobile network is a mobile device that independently organizes its own connection to the others and manages its own data transmissions. The adaptability, scalability, and cost reduction of mobile networks have attracted considerable attention. Because mobile networks are constantly changing, problems with routing and power usage are common. High error rates, energy limitations, and inadequate bandwidth are just a few of the issues plaguing mobile ad hoc networks. The relevance of routing protocols in dynamic multi-hop networks like Mobile Ad hoc Networks (MANET) has drawn the attention of many scholars. In this paper, we focus on implementing an OLSR(Optimised Link State Routing) protocol and evaluates its performance using two optmisation algorithm: Particle Swarm Optimization(OLSR) and Cuckoo Search Optimization (CSO). The simulation result suggests that PSO is superior to both CSO and the conventional OLSR routing technique. We implemented using NS-2 simulator for simulation and NAM for network animation.

Keywords- Wireless communication, Mobile networks, Mobile Ad hoc Networks (MANETs), Optimized Link State Routing (OLSR), Particle Swarm Optimization (PSO), Cuckoo Search Optimization (CSO), NS-2 simulator, Network Animation (NAM).

I. INTRODUCTION

A mobile ad hoc network (MANET) is a group of wireless nodes that may operate as a network without the need for permanent infrastructure or centralised management. In these networks, routers are mobile and self-coordinating. This suggests that the network's topology may change often and unexpectedly [1]. These networks may function autonomously or in conjunction with the wider web. Designing routing protocols is difficult because of characteristics like multi-hop, mobility, supporting heterogeneity, limited power, and finite bandwidth.

Because of the highly dynamic nature of these networks, some routing algorithms can need frequent exchanges of control packets in order to identify lost connections [2]. Users that are constantly moving about need to be able to connect even when there are no permanent facilities accessible. MANETs, in contrast to traditional networks, are not governed by any central authority. Because there is no centralised hub or switching facility, information must be sent between nodes by means of "forwarding" nodes. Because of this, any node in the network, with the exception of the client, has the potential to function as a router and send packets to other nodes in the network [3].

The topology of this sort of network is in a state of perpetual change as a result of the frequent migration of nodes in this form of network. There is also the possibility that some nodes may join the network, depart the network, or enter a state of inactivity. The most challenging part of MANETs is figuring out how to route data transfers in the most effective way possible due to the features described above. Another problem is the enormous amount of energy that is being used. Batteries are the primary source of power for mobile hosts, which means that their energy reserves are often limited. As a result, it is crucial to cut down on energy use by as much as is practically possible. These networks are helpful in a variety of circumstances, including crises, military operations, conferences, and other similar events, when regular networks with a permanent infrastructure would be inadequate to meet communication needs [19]. Even though there have been many different routing systems established for these kinds of networks, the vast majority of them are based on extremely basic assumptions about the mobility of users. It is possible that investigating the use of heuristic and meta-heuristic

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approaches in MANET routing could be an intriguing area of research [5]. This is due to the fact that, in a variety of situations, automaticity and informed interactions between nodes prevent link failure and cause the path reliability to tile at the conclusion of the transmission phase.

Nodes in MANETs are unable to access topological information, hence it is up to those nodes to figure out where their target nodes are located via a process of trial and error. To put it another way, the sending node has to locate the receiving node before it can start transferring data pieces. This is a prerequisite for the transmission process.

II. LITERATURE REVIEW

In recent years, a number of research on mobile ad hoc networks, have been carried out, which has led to the widespread use of these networks in analytical work.

They proposed employing a Nero-Fuzzy Adaptive Inference System (ANFIS) in their work [6], which would consist of both mobile and stationary agents. The proposed method employs three distinct agents: a stationary any-cast management agent, a stationary optimisation agent, and a mobile any-cast route design agent. Each of these agents serves a distinct purpose in the algorithm.

In [7], the authors provide a novel approach they call Multi-Channel On-Demand Routing with Coordinate Awareness (MCORCA). This approach, which makes use of numerous wireless channels, may increase the efficiency of MANETs. Channel assignment and collision avoidance algorithms are crucial components of the proposed cross-layer approach. This method makes use of not one but two channels: a control channel for scheduling and a data channel for actual information transfer. When applied to two-channel networks, MCORCA improves upon ORCA, a previous request-based routing method.

In [8] presented a multipath routing system for OSDM-TDMA mesh networks, which takes use of many pathways to the same destination. Should problems arise along one of these lines of travel, a swift switch to the backup plan is available. After various changes were made to MMQR in [9], the network's adaptive ordering now considers the route that alternatives travel while moving through it. They suggest a heuristic approach to picking attractors that living things could use in order to distinguish one another in a constantly shifting environment.

Quality of Service (QoS), self-organization, and self-healing are three capabilities required by the majority of wireless applications in use today. In view of these issues, the authors of [10] propose an innovative cross-layer technique for enhancing existing routing protocols. Every network layer has been updated with new decision metrics, and imprecise logic has been incorporated into the overall design. The Energy-Aware Span Routing Protocol (EASRP) was a novel approach proposed by the authors of [11]. This protocol would employ both Span and Adaptive Fidelity Energy Conservation Technique (AFECA) strategies. It is feasible that a hardware circuit known as the Remotely Activated Switch (RAS) for reviving nodes in slumber mode could significantly reduce power consumption. In certain circumstances, more active, energy-efficient protocols may be preferable to passive, conventional routing strategies. Nonetheless, in order to whiten a hybrid protocol, the EASRP algorithm must first address a number of identified issues.

As a new routing protocol, [12] presented QoS Routing Protocol Based on AODV (AQA-AODV), a novel AODV-based routing approach. The application's Quality of Service (QoS) requirements were considered when determining the routes to take using this technique. The bandwidth of a route can be estimated using an adaptive method that, in addition to providing useful real-time network status data, can also estimate the route's bandwidth. This allowed highly specialised applications to fine-tune their data transmission rates. As part of a plan for recovering (retrieving) a route, it has been suggested that a system for detecting defects in path connections and a method for restoring communication be implemented.

The multi-path technique proposed by the authors [13] is efficient in terms of energy consumption and is based on the trustworthy Markova Chain. The proposed protocol determines all potential routes between the origin and the destination, and then randomly selects the one that requires the least quantity of energy. Another factor contributing to the protocol's high level of security is the random paths taken by data packets during transmission.

The authors [14] of propose a fuzzy logic based routing solution for MANETs. The proposed method uses fuzzy logic to take into consideration mobile nodes' energy levels and transit durations to identify the optimal route to take. In OPNET simulator 10.5 simulations, we monitored a variety of metrics associated with the proposed method's use of the AODV protocol, including throughput, data loss, packet delivery rate, and hop count. The simulation results demonstrated that the proposed protocol significantly outperformed the AODV method.

The authors of [15] presented an ingenious method for selecting the optimal route through an ad hoc network to maximise its utility. To achieve this goal, the proposed protocol would use the Cuckoo Search (CS) algorithm to determine the greatest fitness value based on three variables: routing burden, remaining energy, and hop count. This will enable it to select the QoS route within a MANET. Using simulations of the Ant Colony Optimisation protocol, the Particle Swarm Optimisation protocol, and the AODV protocol, the proposed method was evaluated based on key factors including mobility, scalability, and congestion. Accordingly, the results were analysed and ranked. The analysis of simulation data demonstrates that the recommended approach is preferable in every way to the

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alternatives cited, as demonstrated by the simulation results. Using a zone-based strategy, the authors of the article [16] proposed a new routing protocol for use in Manet networks that would concurrently increase power utilisation and network efficacy. This would be accomplished by modifying the AOMDV protocol for multipath directing. Labelling, node tracking, and power analysis are the three methods used to select the optimal route from the multipath, and they all depend on parameters such as battery life and network longevity. The power-saving method is incorporated into the proposed routing protocol. It was determined through simulation that the recommended method is more reliable than the AOMDV and AODV protocols, respectively.

In the OLSR protocol, the authors [17] determined the best multi-point relay node for packet control forwarding. This strategy improved link QoS during routing. Changing the node stop time, simulation length, and simulation speed in NS-2 allowed testing the recommended procedure. Simulations determined throughput, end-to-end delay, energy cost per packet, and average node energy. This was done to test the specified methods. The protocol improves routing and solves MANET throughput problems, according to experiments.

III. METHODOLOGY

A. Cuckoo Search Optimization (CSO)

The Cuckoo Search Algorithm is a recently developed algorithm that is used for solving optimization problems. This algorithm takes its inspiration from brood parasitism in the natural world. Here, the host, a cuckoo bird cannot differentiate its eggs from those of a parasite egg and its own eggs. For simplicity, a CSO has 3 rules:

1) One egg is laid at a time by each cuckoo.
2) The best nests with high quality eggs are carried forward.
3) The number of available host nests is fixed.

CS algorithm follows these steps:

Step 1: Random Initialized population of n Host Nest.
Step 2: Calculate Fitness Value for each solution in Each Nest.
Step 3: Generate New solution by using Levy Flight.
Step 4: Cuckoo will update its location followed by Levy Flight.
Step 5: Until Global Best Point is Found.

The calculations that take place under the CSO are as follows:

- Equation for Random Walk is:

$$x_i^{t+1} = x_i^t + \alpha \otimes L(\lambda) \quad (1)$$

Where,
  - x_i^{t+1} indicates a New Solution
  - x_i^t indicates an Existing Solution
  - α indicates Step Size which is entry wise multiplied with $L(\lambda)$ which indicates Levey exponent.
- Step Length Levy(s) can be calculated using:

$$s = \frac{U}{|V|^{\frac{1}{\lambda}}} \quad (2)$$

Where,
  - s indicates the Step length.
  - $U \approx N(0, \sigma_u^2)$ and $V \approx N(0, \sigma_v^2)$ where σ follows the levy distribution.
- Step Generation - Levy's Flights

$$step = \alpha s \otimes (x_i^t - x_{best}) \quad (3)$$

Where,
  - α indicates step-size-scaling factor.
  - x_{best} denotes the current best solution in the nest, whereas s is the step size.
- New position of Cuckoo

$$x_i^{t+1} = x_i^t + \epsilon . \alpha s \otimes (x_i^t - x_{best}) \quad (4)$$

Where,
  - ϵ denotes a uniformly distributed random number.
- Local Random Walk is calculated using:

$$x_i^{t+1} = x_i^t + H(p_a - \varepsilon) \otimes (x_i^t - x_k^t) \quad (5)$$

Where,
  - H(u) is a Heaviside function

$$H(u) = \begin{cases} 0, & u < 0 \\ 1, & u < 0 \end{cases}$$

  - p_a is the switching parameter.
  - ε denotes a uniformly distributed random number.
  - x_j , x_k were chosen at random using a permutation table.

B. Particle Swarm Optimization

Particle swarm optimisation is a metaheuristic method. It is a stochastic search strategy that employs a population to discover the optimal solution. The cooperative behaviour of birds in flocks served as inspiration for PSO, a population-based search method. In its pursuit of Optimum, PSO continually improves its generational data. PSO is the computational approach that we are using to address issues related to optimisation.

Problems were addressed using PSO's Population of Candidate Solutions (also known as Swarms), which were named Particles.

- Representation of Potential Answers
- Each particle's velocity is influenced by the particle's best-known location in its immediate environment.

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The value will be re-initialized if any optimal control value of any particle surpasses in the searching space. This will cause the value to be reset [18].

ADVANTAGES

- PSO is simple to implement
- PSO has a limited number of parameter options.
- Effectively used in the training of neural networks, also known as artificial neural networks, fuzzy control systems, and function optimisation.

PSO Initialization

- In Particle Swarm Optimisation, node is referred to as a Particle, while the whole population is referred to as a Swarm..
- We will begin by determining the population's initial positions, which correspond to the initial population, and the particles have the ability to move in any direction at random.
- To find what it's looking for, each particle traverses three tiers of the seeking area and keeps track of its location in relation to itself and its neighbours at all times.

Algorithm steps for PSO

STEP-1: Initialization

- Initialise Parameters
- Initialise the Population
- Determine the initial location (xi) of each particle in a random order.
- Determine the initial velocity (vi) of each particle in a random fashion.

STEP-2: Evaluate fitness f(x_i^t)

- Determine the optimality of each particle.
- if the event that fitness exceeds the optimal value (gBest), then.
- Change old value to the new one (gBest)
- Pick the particle with the highest fitness and label it gBest.

STEP-3: Find velocities and position of each particle

- find position of particles by:

$$x_i^{t+1} = x_i^t + v_i^t * t \tag{6}$$

- Calculate velocity by:

$$\dot{v}_{k+1}^i = wv_k^i + C_1r_1((xBest_i^t) - x_i^t) + C_1r_1((gBest_i^t) - x_i^t) \tag{7}$$

STEP-4: Calculate fitness $f(x_i^t)$
Calculate current best [gBest]

STEP-5: increment t=t+1

STEP-6: Output gBest & x_i^t

C. OLSR (Optimized Link State Routing)

An OLSR network uses an improved protocol to route data across links. It's a protocol based on a proactive system of tables. In this scenario, the connection statuses of all nodes are continuously broadcast. When a node receives data on the status of a link from another node, it stores that data locally. Each node determines the subsequent hop to each destination using the preceding data. Every node relays the connection status data it has learned from its neighbours. A spanning tree grows from each node. The whole topology of the network is available to every node. MultiPoint Relaying (MPR) is a crucial idea in this method [20].

Advantages

- Applications that need the least amount of delay possible benefit from using OLSR because of its lower average end-to-end latency.
- Compared to other protocols, OLSR implementation is easier to use and operates with less problems.
- It's a simple routing protocol as well.
- The routing procedure does not need a centralised administration system.
- It improves the protocol's fitness for use in an ad hoc network, where the source and destination pairings are constantly shifting.
- The connection reliability in managing messages is not required since messages are delivered on a periodic basis and delivery is not required to be consecutive.

Disadvantages

- It keeps track of all the potential routes in a routing table.
- The control messages add more and more overhead as the number of mobile hosts grows.
- Locating a lost connection may be a time-consuming process.

IV. SIMULATION ENVIRONMENT

Ad-hoc networks utilise Network Simulator-2. This open-source programme analyses network protocols. NS2 simulates Internet protocols. OTCL and C++ form NS2. NS-2 has rich network simulation and animation features. Event-driven NS2 simplifies future wireless network simulation. Travel, traffic, and malice may impair your network. Named network nodes. All network components use the same wireless channel, hence its name is irrelevant. Examine networks by moving and removing NAM nodes. Active NAM provides packet and node data. Network animation has trace annotation. Table 1 displays simulation environment.

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TABLE I. SIMULATION SETUP

Parameter Type	Parameter Value
Simulation time	30s
No of nodes	50,100,150.200
Area of simulation	1216m x 768m
Transportation protocol	UDP
Packet type	CBR
Packet size	512 bytes
Rate of packets	4 Packets / sec
Maximum packets	Constant Bit Rate
Propagation model	TwoRayGround
Initial energy	1000J
TxPower	1.3 w
RxPower	1.4 w

A. *Performance Metrics*

Performance metrics in Mobile Ad hoc Networks (MANETs) are used to evaluate and measure the efficiency, effectiveness, and quality of different aspects of the network's operation. These performance metrics provide insights into different aspects of a MANET's operation and help researchers and network designers evaluate and compare different protocols, algorithms, and optimization techniques for improved network performance. Here are some commonly used performance metrics in MANETs:

1) Throughput(t)

$$t = \frac{\sum Received\ packet\ size}{Stop\ time - Start\ time} \text{ bytes / sec or bit / sec} \quad (8)$$

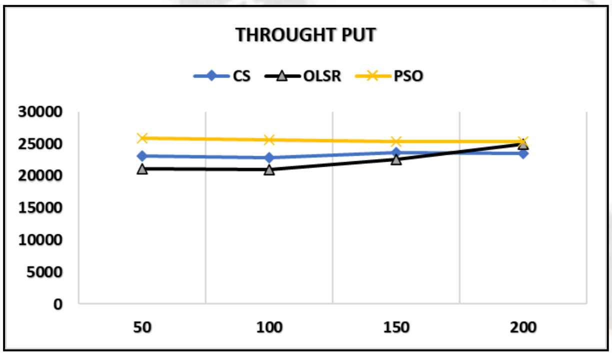

Figure 1. Analysis of Performance Regarding Throughput

Figure 1 shows that PSO has higher throughput than OLSR and CS.

2) Delay (End-To-End Delay)

$$Delay = \frac{\sum Packet\ Received\ \ Time - Packet\ Sent\ Time}{Packet\ Received\ Successfully} \quad (9)$$

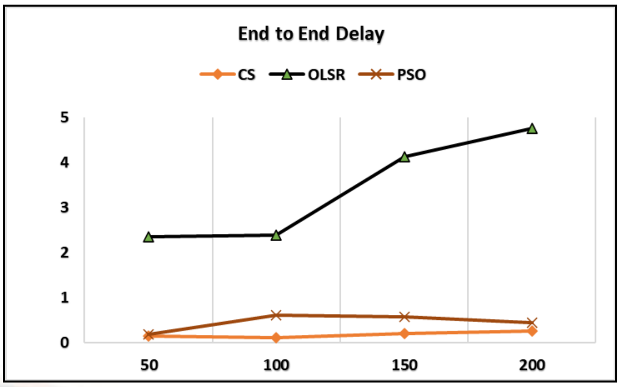

Figure 2. Analysis of Performance Regarding Delay

In Figure 2, the Delay of CS is better than the OLSR and PSO.

3) PDR (Packet Delivery Ratio)

$$PDR = \frac{Total\ number\ of\ packets\ receievd}{Total\ number\ of\ packets\ sent}\ X\ 100 \quad (10)$$

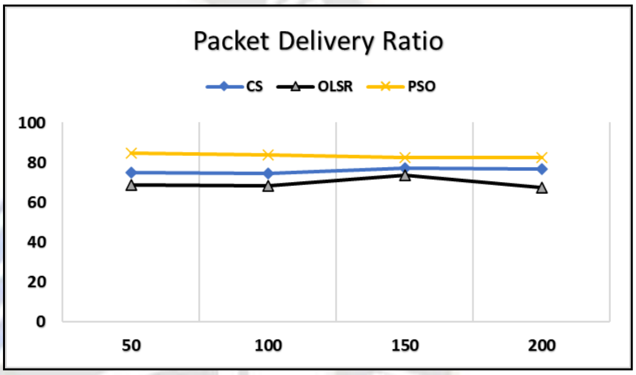

Figure 3. Analysis of Performance Regarding PDR

In Figure 3, the PDR of PSO is better than the CS and OLSR.

4) Average Energy Consumption (AEC)

$$\text{Average Energy consumption} = \frac{i-r}{N} \quad (11)$$

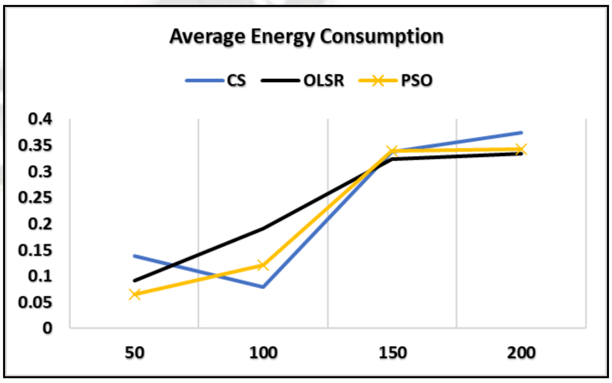

Figure 4. Analysis of Performance Regarding AEC

In Figure 4, Almost all are same in average energy consumption.

5) PLR (Packet Loss Ratio)

$$PLR = \frac{Total\ number\ of\ packets\ lost}{Total\ number\ of\ packets\ sent}\ X\ 100 \quad (12)$$

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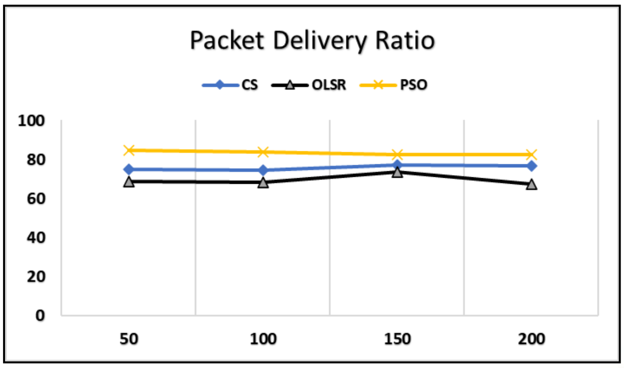

Figure 5. Analysis of Performance Regarding packets Drop

In Figure 5, the packet dropping in PSO is better than the OLSR and CS.

6) Goodput

Goodput in Mobile Ad hoc Networks (MANETs) is the quantity of usable data transmitted from source to destination in a certain time period.

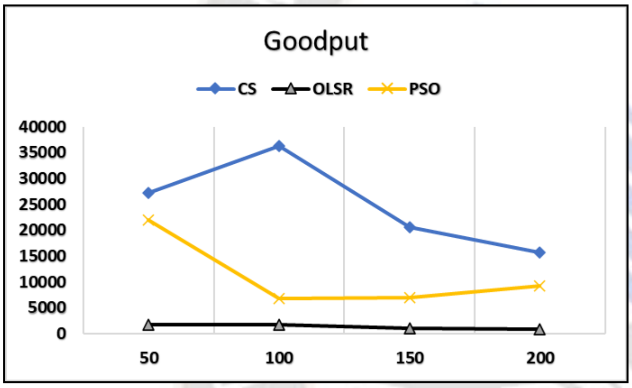

Figure 6. Analysis of Performance Regarding goodput

In Figure 6, the Goodput of CS is better than the OLSR and PSO.

7) Jitter

In Mobile Ad hoc Networks (MANETs), jitter is the difference between when packets are sent and when they arrive.

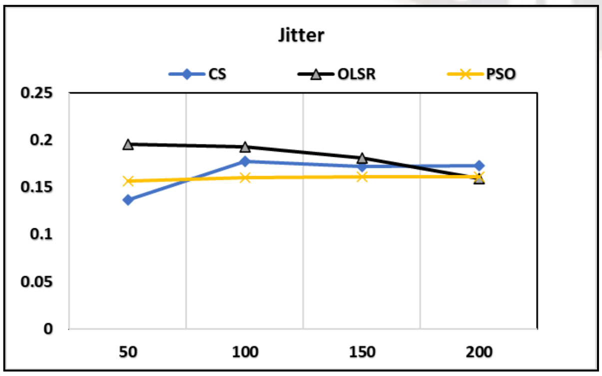

Figure 7. Analysis of Performance Regarding Jitter

In Fig 7, the Jitter for PSO is constant as compared to CS and OLSR.

8) Network Lifetime

The Lifetime Ratio is a metric used to ensure that vital data packets may always be sent over the network without interruption.

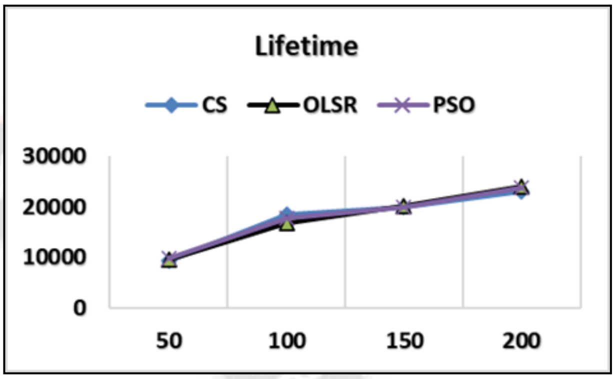

Figure 8. Analysis of Performance Regarding Network Lifetime

In Figure 8, the Lifetime is almost all same.

9) Remaining Energy

$$RE = \frac{\text{Initial\_Energy} - \text{Total\_Consumed\_Energy}}{Total\ number\ of\ Nodes} \quad \text{---(13)}$$

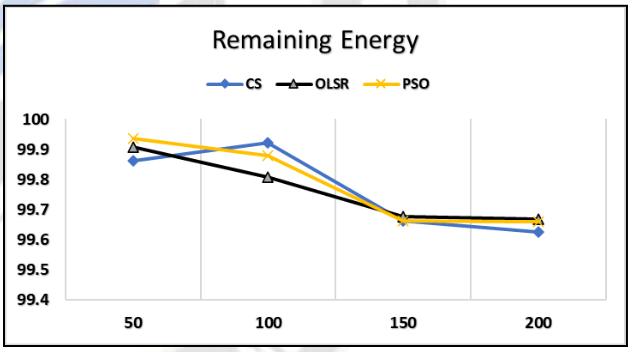

Figure 9. Analysis of Performance Regarding Remaining Energy

In Figure 9, the remaining Energy of PSO and CS are decreasing with increase in nodes while the remaining Energy of OLSR remains constant.

In the all above graphs, x-axis contains number of nodes considered in the scenario.

V. CONCLUSION

In this study, the OLSR routing protocol for Mobile Ad hoc Networks (MANETs) was compared to the Particle Swarm Optimisation (PSO) and Cuckoo Search Optimisation (CSO) metaheuristic optimisation methods. The goal was to figure out how well OLSR with PSO and CSO worked in terms of performance metrics. The results of the tests done with the NS-2 network simulator gave important information about how well the different route options work. The PSO and CSO refining algorithms were found to have made a big difference in how well OLSR worked. Both PSO-based and CSO-based OLSR did better than the traditional OLSR protocol in terms of how many packets were delivered and how fast the network moved. This shows that putting metaheuristic planning methods into MANETs could make their routes work better. But different measures were affected in different ways by the choice of refining method. The fact that PSO-based OLSR has better performance in terms of throughput, Packet Delivery Ratio, energy consumption, packet loss ratio, jitter, network latency. On the other hand, OLSR-CSO was better at adapting to node breakdowns and cases of movement, which shows that it is resilient in dynamic network conditions. These results show the differences between PSO and CSO in terms of different performance measures. This shows how important it is to take into account specific requirements and limits when picking an optimisation method for OLSR protocol improvement in MANETs. This comparison adds to what is already known by shedding light on how metaheuristic planning methods are used in MANET routing protocols. Researchers and people who make networks can use the data to choose an optimisation method that fits their needs. In order to make MANET routing methods even better, future study may look at more metaheuristic algorithms or the mix of multiple optimisation techniques.

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AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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COMPLIANCE WITH ETHICAL STANDARDS

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

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Dr. B. Hemantha Kumar holds a B.Tech degree from Chaitanya Bharathi Institute of Technology, an M.Tech degree in Computer Science and Engineering from JNTU-Kakinada, and a Ph.D. degree in Computer Science and Software Engineering from Andhra University. He currently serves as a Professor at RVR & JC College of Engineering (Autonomous), Guntur. With over 20 years of experience in the fields of education, administration, research, and innovation, He has made significant contributions. Additionally, he has more than 8 years of experience in the IT industry. He has authored multiple publications in renowned journals indexed in Scopus. His research interests revolve around Semantic Web, Information Security, and Steganography. He is an esteemed member of professional organizations such as the Computer Society of India (CSI), the Indian Society for Technical Education (ISTE), and the International Association of Engineers (IAENG). Moreover, he actively contributes to the scholarly community as a peer reviewer for several highly-regarded journals.

Udaya Kumar Addanki (Sr. Member, IEEE) holds a B. Tech. degree in Information Technology from KLCE and an M.Tech. degree in Computer Science and Engineering from Vignan's Institute of Information Technology. Currently, he is pursuing a Ph.D. degree in Computer Science and Engineering from Acharya Nagarjuna University. Presently, he serves as an Assistant Professor at GVP College of Engineering for Women. With nearly a decade of experience in the fields of education, administration, research, and innovation, he has made significant contributions. He has authored multiple publications in reputable journals and focuses his research on various areas, including mobile ad hoc networks, wireless sensor networks, cloud security, information security, and network security. He is a member of prominent professional organizations such as the Institute of Electrical and Electronics Engineers (IEEE), the Association for Computing Machinery (ACM), the International Association of Engineers (IAENG), and the International Association of Computer Science and Information Technology (IACSIT). Additionally, he actively contributes to the scholarly community as a peer reviewer for several well-regarded journals.