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An optimal path selection using lion optimization routing protocol for mobile ad-hoc network

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ABSTRACT

MANET is a set of nodes that communicate with each other directly or indirectly. The nodes in MANET can be moved freely. The dynamic nature of the network makes several challenges. One of the challenges in routing is to transfer the data from the start node (source) to the end node (destination). Routing suffers from several metrics such as power-consuming, delay, packet delivery ratio, etc. This paper proposed a new protocol called the Lion Optimization Routing protocol (LORP) based on the lion algorithm and AODV protocol. This protocol uses the Lion Optimization Algorithm to select the optimal path. Firstly, we use lion optimization to select the optimal path using the LOA maximization algorithm depending on three main metrics Power Efficiency, Throughput, and Packet Delivery Ratio. Secondly, we use the LOA minimization algorithm to select the optimal path using two metrics Delay and Short Path. In LOA Maximization algorithm metrics calculated and choose the max path value. The result of this protocol is compared with AODV, DSR, and ANTHOCNET.

Keywords: Lion Optimization Routing protocol (LORP), AODV protocol, Power Efficiency, Throughput, Packet Delivery Ratio, Delay, Short Path, LOA Maximization, and LOA minimization

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1. Introduction

The wireless communication system has reached top heights in its diversity of applications worldwide. The hasty commitment of independent mobile users has become an effective area of development in wireless communication systems. Emergency search, release mission, disaster respite efforts, mine site operations, conferences, and automated classrooms are some of the examples of diverse mobile applications. Combined networks of such users are termed as Mobile Ad hoc Network (MANET). These kinds of networks do not maintain constant infra-structure. Each node in the network changes its position correspondingly. This results in high active topology triggering cracked wireless links. The routing in ad hoc networks has been an active area of research and in earlier years, quite a lot of decisive routing protocols have been presented for MANETs. Node mobility constrained physical security, and a limited amount of resources are the major challenges tackled by MANET. Routing, multicasting, pricing structure, transport layer protocol, security, self-organization, disposition consideration, and scalability are some of the vital features which could distress the performance and design of MANET[1]. The activity of intermediary nodes should be trusted equally to initiate a new routing path and make the routing protocol of MANET to function effectively. These nodes will function as per the protocol rules. In the MANET operation system, believing any intermediate node to function as per the protocol is an important subject of issue. This is mainly due to the dynamic nature of the network. Also, these nodes incessantly join or leave any network with respect to connectivity and mobility. There are several disadvantages of MANETs. They are

- Securing broadcast wireless communication in an un-trusted environment
- Nodes initiating own routes
- Un-static network topology[2, 3].

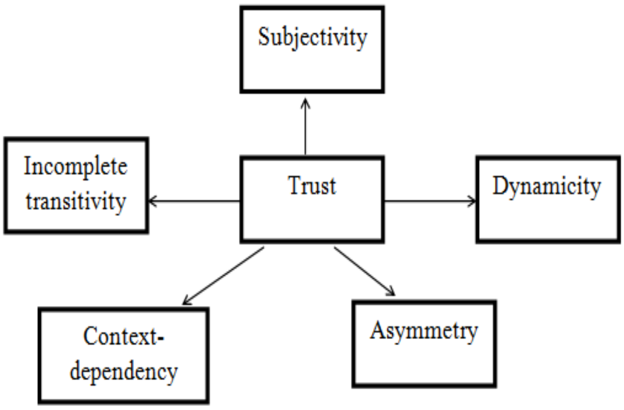

Figure 1. Trust properties of MANETs

In MANETs, numerous technical issues are also challenged by security protocol designers. Some of the reasons behind the occurrence of technical issues are crucial resource restraints in memory size, bandwidth, computational power, and unique wireless features such as openness to intrusions, absence of definite ingress and exit points, security threats, susceptibility, an unreliable form of communication, and fast changes in topologies or because of node failure[4]. Even though MANETs are adopted for their availability of technological advantages, real-world deployment of MANET is restrained due to several troubles. The huge advancements in technology are exclusively dependent on multimedia-based services. The true perspective of MANET could provide these services in case effective protocols are not suitable [5, 6]. Different services, functions, context inclined services were recommended by MANET operation. In an instance where attacks are prone to occur, the primacy is assigned to maintain the precise operation of effective services. Appropriate services necessitate capacities and guarantees in encouraging abrupt delivery even in presence of attacks, or failures. Services in MANET are divided into two main categories such as specific services and general services [7, 8].

2. Related works

A gateway selection structure is suggested that deliberates multiple QoS path constraints such as existing latency and capacity, path availability period, and choosing probable gateway node. This research advances the availability of path, computation accuracy, and the feedback system for rationalized path dynamics to traffic source nodes [9]. Multipath routing is measured to be a hard task and the correspondence between the letdowns of the paths in a path set has to be as minor as possible. Sharing of nodes and links between the paths are common types of failure points. The disjoint path sets preconditions for the multiple paths to be either link-disjoint or node-disjoint. The selection of the most optimal path is an NP-complete problem. A Hopfield neural network as a path set selection algorithm is discovered. As this algorithm delivers a set of backup paths with sophisticated consistency, it is well innovative for MANETs [10]. An assortment of trustworthy paths that could last as long as possible is a serious issue for routing in MANET. This is because the incurable mobility might cause radio links to be fragmented frequently. To solve this problem, a path consistency criterion is obligatory. Prediction based link obtain ability approximation for enumerating link reliability is presented primarily. This quantity uses presently existing data and considers the dynamic nature of link status to replicate the link dependability[11]. A Topological Change Adaptive Ad hoc On-demand Multipath Distance Vector (TA-AOMDV) routing protocol is presented which could acclimate to high-speed node measure for supporting QoS. A stable form of path selection algorithm is intended which not only precedes node resources as path choice constraints but also it ruminates the link stability probability among the nodes. The link interrupts the prediction mechanism is integrated into the protocol in order to adapt to the sudden change in topological structure. This mechanism modernizes the routing approach cantered on the periodic probabilistic estimations of link strength [12, 13]. A novel bio-inspired algorithm is advocated for resolving optimal communication paths in wireless sensor networks. Adaptively is the most noteworthy feature of this algorithm. In this algorithm when the edge weight change, it could auto-regulate and renovate all possible edges impulsively. The presented method practices a high level of parallelism while getting applied to actual wireless sensor networks in forthcoming future researches with the aid of self-determining CPU of each sensor[14, 15]. A broad examination of review devoted to all engineers of recent improvements on the PEMFC cold start concerns are presented. The systems and approaches used for fuel cell shutdown are explicated and they are categorized into purge solution and material for eluding freezing. Internal and External heating procedures are classified by contingent on their heating sources concerning the structure and resolutions for PEMFC cold start-up[16]. An asynchronous two-way relay network is measured where two single-antenna transceivers customs a single carrier communication system. This system is used for substituting information and sustaining diverse delays. The relay nodes could gather the energy from the neighbouring location. Harvest-then-forward protocol is used to forward the acknowledged messages with the aid of collected energy. As the transceiver paths are well exposed to various propagation delays, the end-to-end channel is estimated as a multipath channel. This system affects inter-block-interference (IBI) in signal blocks achieved by both transceivers. A relay choice system in which only those relay nodes are designated that subsidizes to a single tap end to end channel is organized for abolishing IBI[17, 18]. The concern of power effective distributed estimation of vector parameters related to localized phenomena is considered. Here both sensor selection and routing assembly in WSN are augmented in a collective way to accomplish the best conceivable approximation concert for a total power budget. Initially, this optimization problem is projected as an NP-Hard issue. Then, Fixed-Tree Relaxation-Based Algorithm (FTRA) and Iterative Distributed Algorithm (IDA) are deployed to improve the sensor selection and routing configuration[19]. Identification of the optimal tour is an effective NP-hard problem. A heuristic, known as Weighted Rendezvous Planning (WRP) is presented in which each sensor node is allotted suitable weight analogous to its hop distance [20].

3. LORP Protocol

3.1. System model

In this section, a new modeling approach is introduced to analyze the properties of the MANET network. At the initial stage, n no of nodes deployed in the traditional ad-hoc network which is represented as an idle set [1]. Sink nodes are located anywhere around the network and it is monitored. Secondly, the Euclidean distance is represented as d(x,y) and the coverage area is less than its radio transmission radius as well as it is related to the distance between the node x and y respectively. According to the data link layer bi-directional transmission is performed with the help of an undirected graph. Finding an optimal path during the process of communication between the source and the sink is the main objective as so to improve the overall performance of the network in an effective manner.

3.2. Network model

In the network layer for routing is one of the kinds of the on-demand vector routing protocol. LOPR protocol is one among the reactive routing protocol which is based on (on-demand) function. This protocol is designed in a hop-by-hop model where the neighbor hop node decides the path of packets where it has to be forwarded next. The routing information of the node includes the routing table to secure the new path details which consist of hop count, neighbor node details, and sequence number. LORP is a type of distance vector function. Only in the essential situation, it requests a path otherwise it will not take any help of inactive nodes to fix the path to the destination. Some of the other characteristics of LORP protocol are loop release and link breakages. LORP routing includes two sections are Route discovery and Route maintenance. At the initial stage, it will send hello packets to find the hop nodes in the network. The other message types are Route Request (RREQ), Route Reply (RREP), and Error Message (RERR).

3.3. Optimal Route Selection using lion swarm optimization algorithm

The major objective of our research work is finding the optimal route in routing using lion swarm optimization in MANET. The drawback of the MANET network is mobility management and dynamic topology. According to the characteristics of MANET finding the optimal path becomes a complicated task. Due to dynamic topology, the energy consumption is so high which leads to reduce the lifetime of the network. An efficient routing model is essential to overcome this problem. This work provides a routing algorithm to find an optimal path using LOA maximization and LOA minimization concepts.

3.4. LOA maximization and LOA minimization

The LOA maximization and LOA minimization of the network generally deals with energy values, packet delivery ratio, network throughput, delay, and short path. The initial energy allocation is the basic necessity of the node. The node with nominal energy value will work better than the node with minimal energy values. For this reason, the node with minimal energy value crosses the cut-off or link breakage issue in any instant of time which leads to an increase the packet drops and traffic collision within the network. Therefore, energy is considered in the trust model. The secondary factor is the packet delivery ratio, it is also considered as one among the trust model which is used to calculate the input and output data. During the data transfer both the input and output data rate is measured, if it is more or less equal then the node is considered as a consistent node. A network with more number of consistent nodes provides an effective packet delivery ratio. Then throughput is concentrated which is the overall packets transmitted according to the time taken. LOA Maximization: The following section provides a detailed explanation of the maximization model. At the initial condition, the initial energy of the nodes ranges from (0, 1). The inactive node is represented with the energy values 0. The highest energy value for the node is 1. In intermediate, it has three more categories which are quarter, half, and three fourth energy values. Table 1 explains the energy allocation in detail.

Table 1. Energy value allocation

Energy Values	Node Representation
0	Inactive Node
0.25	Node with Quarter Energy
0.5	Node with half Energy
0.75	Node with Three-Fourth Energy
1	Highly Active Node

The resident energy of the node is the modifier in a node lifetime, so path stability depends on the energy, cases in nil energy causing congestion, and packet losing. Hence energy is an important factor in identifying the path lifetime or stability.

$P_c = P_w + P_d$

Where P_c represented the electronic energy, and P_w represents the power-consuming in transmission energy, and P_d indicates data aggregation energy. So to calculate the current energy of node i after transmission the formula become

$P_{ower} = P_n – P_c$

Where P_{power} is the power remaining in node after transmission process, P_n is the power of node, when we calculate the p for each node in the path will become

$P = \frac{P1 ,P2,......Pn}{N}$ …….. (1)

Where N is the number of nodes in the path.
Finally, the P takes as a percentage between 0 to 1, where 1 denoted the full energy, and 0 denoted the nil energy the number resulting in the lifetime of the path from calculating the entire P_{power} for all nodes in the path.
Likewise, we calculated the input and output packet delivery ratio of the node. At the initial stage, the input and output data rate may vary. At certain conditions the node will forward all the input information then that node is considered as a trustworthy node in the network. In case, if the output ratio is below the half rate of the input ratio then the particular node is considered as a selfish or malicious node in the network. Those nodes are calculated as an inactive node and it cannot able to participate in any of the routine activities. In Table 2 the information about the packet delivery ratio allocation is given in detail.

Table 2. Packet delivery ratio allocation

Rate of Packets	Node Representation
0	$P_{out} = 0$
0.25	$P_{out} = P_{in}/4$
0.5	$P_{out} = P_{in}/2$
0.75	$P_{out} = 4P_{in}/3$
1	$P_{out} = 1$

Where, P_{out} = output packets , P_{in} = input packets

Due to this computation model, all the nodes are assigned with values. The packet delivery ratio of the node is ranged between (0, 1). The node which transmits all the packets and null packets are allocated as 1 and 0 correspondingly. Then the values which lie in between 0's and 1 are selected intentionally according to the node properties. The network reliability will be more when the network consists of more number of nodes with the highest packet delivery ratio.

The packet delivery ratio is the relationship between the incoming packet and outgoing packet the percent of dividing the outgoing in the following formula

$$PD = \frac{outgoing\ packet}{in\ comming\ packet} \quad \ldots\ldots\ldots (2)$$

The number always between 0 and 1, where 0 denote nil forwarding ability for the node, and 1 denote a high level of the ability.

Throughput:

The throughput is the message queue length, meaning calculating the number of the message (packet) in the queue in the node, the following formula show throughput.

$$TH = \frac{MC}{Total\ number\ of\ node} \quad \ldots\ldots. (3)$$

Where MC denotes the total number of messages in the queue. Also, we can calculate TH and normalization by the following equations,

$$N = \frac{(TH-Ol)*(Nh-Nl)}{Oh-Ol} \quad \ldots\ldots\ldots\ldots (4)$$

Where,

- Ol and Oh are the least and the highest values of value, in this case, is 0 to 3, and
- Nh, Nl represents the upper and lower limits of normalized value which is 0 to 1.

Now the calculation of the above equation to identify a value to select using the Lion Swarm algorithm the equation to calculate the previous equations is

$$\text{LOA Maximization(Lmax)} = \sum_{i=1}^{N} \frac{P+PD+TH}{3} \quad \ldots\ldots. (5)$$

Here, T_V is the final trust value of the model. Immediately after the calculation of the trust value, we can use the LSO algorithm to find the optimal path for the network.

Where M represents the metrics

LOA Minimization:

Delay:

Sum all the delay in each path to the destination

$D_{total} = D_1, D_2 \ldots\ldots D_{n-1}, D_n$ where n is the number of node in the path ……… (6)

Short path:

Calculating using the path weight, which counts the number of hops using by the path between the source and destination

SH = number of node in the path …… (7)

LOAMinimization(Lmin)= $\min_{D,SH} \|\ D\ \&\ SH\ \|$ ……(8)

Among the entire possible path, the best optimal path is selected based on the lion swarm optimization (LSO) algorithm. LSO algorithm is one amid of the bio-inspired algorithms because it is developed using the characteristics of the lion's kingdom. The group of lions that live together is called pride. This pride consists of two categories of lions called resident lions and nomadic lions. Pride is a collection of five to six lions, lionesses, and their cubs. Once the cubs become lions it has to prove its strength to others. In case if it fails then that particular lion will be thrown out from the pride and it is called nomadic lions. Once after getting trained the nomadic lions will again reach the pride to show its strength to occupy its pride. This strategy is used in the LSO algorithm to find the optimal path in the network.

At the initial condition, the population of lions is generated which includes both the pride and the nomadic lions. The pride of the lion controls the overall region, the lioness mainly concentrated on hunting and teaching the cubs to hunt. In the algorithm concerning the fitness values, the nomadic lions are arranged. The lion with the highest fitness value is selected as a pride, minimal fitness values are selected as resident lions and with least fitness values are considered as nomadic lions and those are thrown out from the pride. The process is continued until to reach the best fitness values. The fitness calculation of the proposed work is mathematically given below.

$$F_{value} = \sum_{i=1}^{N} \frac{(Lmax1, Lmax2 \ldots\ldots Lmaxn)}{N} \text{ -------------------------- (9)}$$

The best fitness value can be calculated using equation 9 and here the optimal path is chosen by using the LSO algorithm. Like this, the optimal path is selected from the possible path which helps to reach the highest level of reliability which leads to improving the overall performance of the network. This algorithm selects the best possible path other than selecting the shortest path. When the shortest path is chosen as a route then the quality and strength of the path are not accessed. This may cause link failure, increase latency during transmission. So rather than selecting the shortest path, it's advisable to select the path which is naturally examined.

4. Simulation results and analysis

The performance analysis of LORP protocol is measured by calculation of the output parameters such as delay, throughput, packet delivery ratio, and network lifetime. And our method is compared with a few other earlier methods namely AODV, DSR, and Hoc Net protocol. These earlier protocols are among the reactive routing protocols. Whereas DSR is based on source routing, both AODV andHocNet utilizes hop by hop communication model during the process of data transmission. In our simulation model, we used mobility impact for all the protocols and it varies according to the number of nodes in the scenario. Our research contains three types of scenarios which are 50 nodes and 100 nodes with variable traffic connections. The simulation parameters and values are described in Table 1.

Table 3. Simulation parameters details for LORP protocol

Parameters	Values
Simulator	NS-2.34
Simulation Period	100ms
Coverage Area	1000*1000
No of Nodes	50, 100
Standard	IEEE 802.11
Propagation Model	Two Ray Propagation Model
Antenna	Omni-directional Antenna
Traffic Type	FTP
Traffic rate	0.01 sec to 0.50 sec
Agent Type	TCP
Routing Protocol	LORP
Initial power	1000 J
Idle Power	0.1 J
Queue Type	Drop-Tail

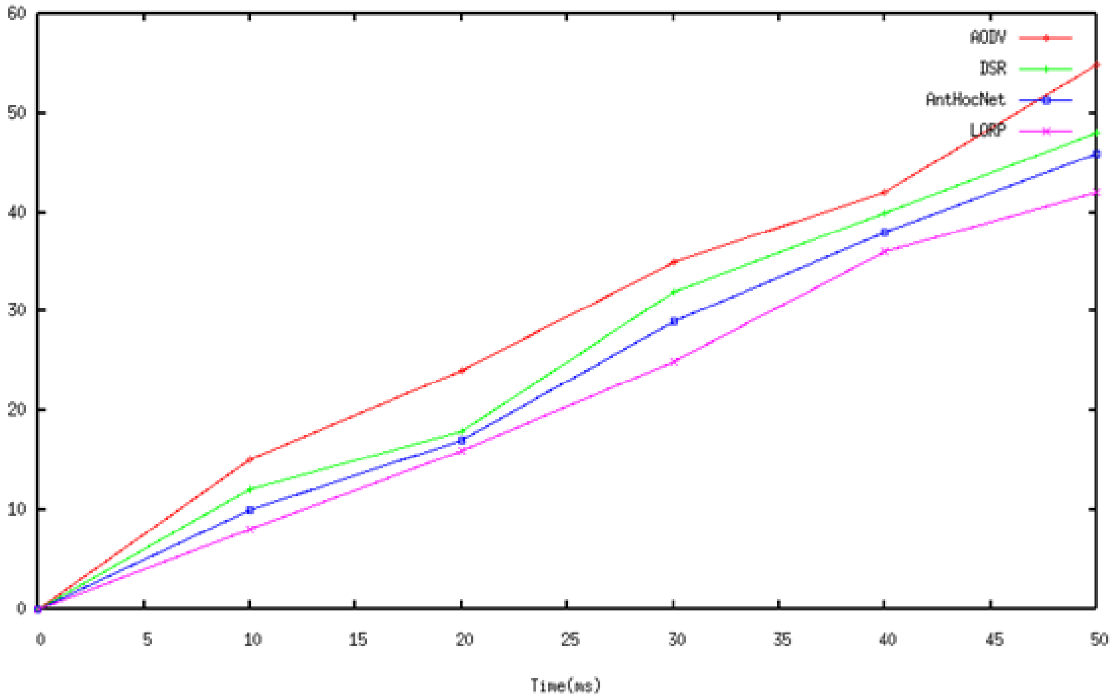

Figure 2. Packet loss calculation scenario 2

In Figure 2, the x-axis represents Time (ms) and the y-axis represents packet loss of the network. In this scenario 2 the number of nodes that are deployed for the simulation is 50 nodes and the packet loss of LORP is 42. The performance of earlier protocols is AODV is 55, DSR is 48 and Hoc Net is 46. Comparing to the earlier protocol is proved that our proposed LORP protocol performed well in terms of packet loss.

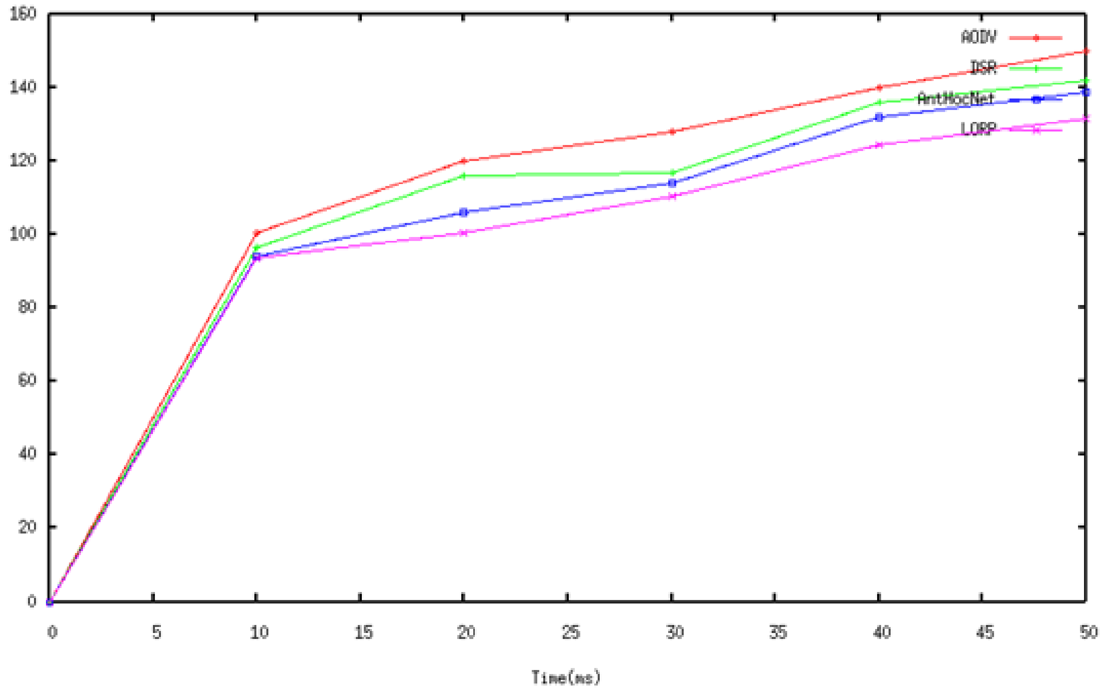

Figure 3. End to end delay calculation scenario 2

Figure 3 shows the end to end delay performance of AODV, DSR, Hoc Net, and LORP protocols. The x-axis in the graph shows the Time is taken in (ms) and the y-axis shows the end-to-end delay of the network. While comparing the earlier protocols and our proposed protocol, LORP rises from 10.245ms and reaches the utmost level up to 131.51 ms which are comparatively lesser than the earlier routing protocols. Here the end to end delay of scenario 2 is lesser then scenario 1 which proves that when the number of nodes increases it reduces the end to end delay of the network

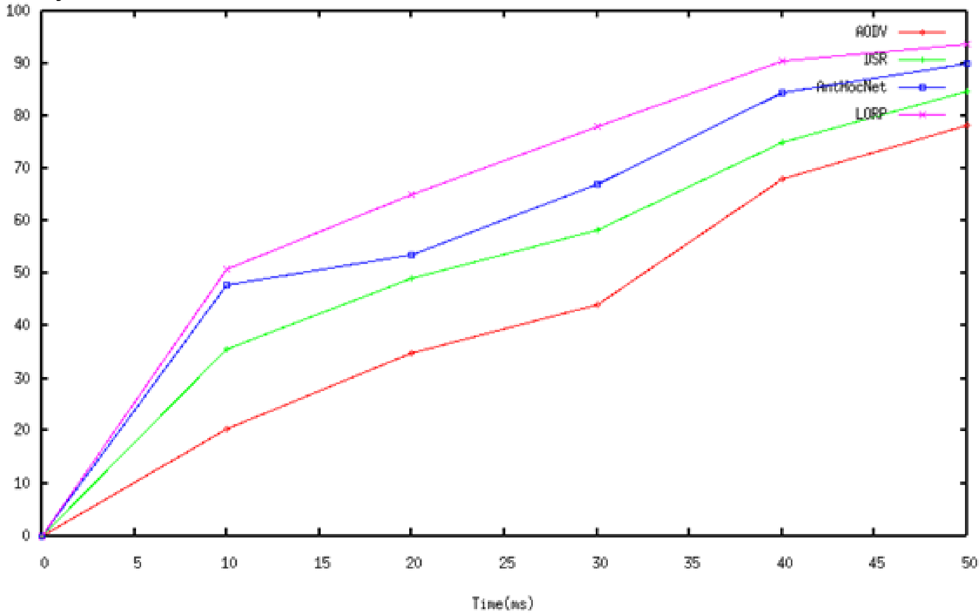

Figure 4. Packet delivery ratio calculation scenario 2

Figure 4 shows the Gnuplot of AODV, DSR, AnHocNet, and LORP protocols. The x-axis in the graph shows the Time (ms) and the y-axis shows the packet delivery ratio of the network. In scenario 2, the number of nodes that are deployed for the simulation is 50 nodes and the packet delivery ratio of LORP is 93.7 percent. The performance of earlier protocols is AODV is 78.3 percent, DSR is 84.9 percent and AntHocNet is 90.0 percent. Comparing to the earlier protocol is proved that our proposed LORP protocol performed well in terms of packet delivery ratio.

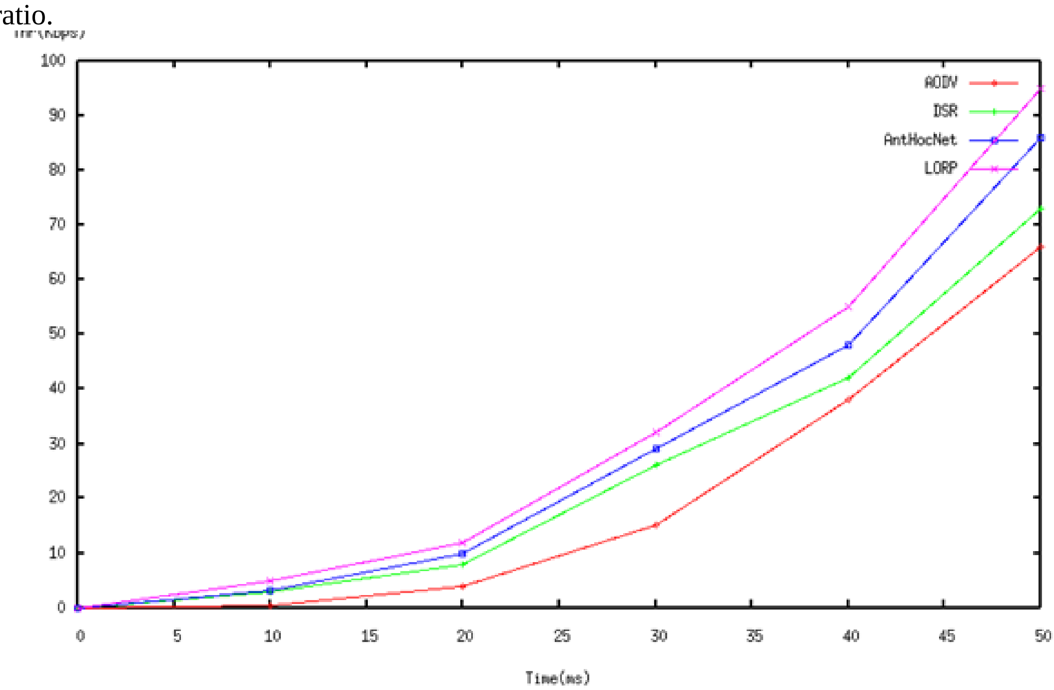

Figure 5. Throughput calculation scenario 2

Figure 5 examines the throughput comparison for AODV, DSR, AntHocNet, and LORP protocols. The performance of earlier protocols is AODV is 66 kbps, DSR is 73 kbps and AntHocNet is 86 Kbps. Comparing to the earlier protocols, it is proved that our proposed LORP protocol performed well in terms of network throughput. Here the throughput of scenario 2 is lesser then scenario 1 which proves that when the number of nodes increases it reduces the throughput of the network

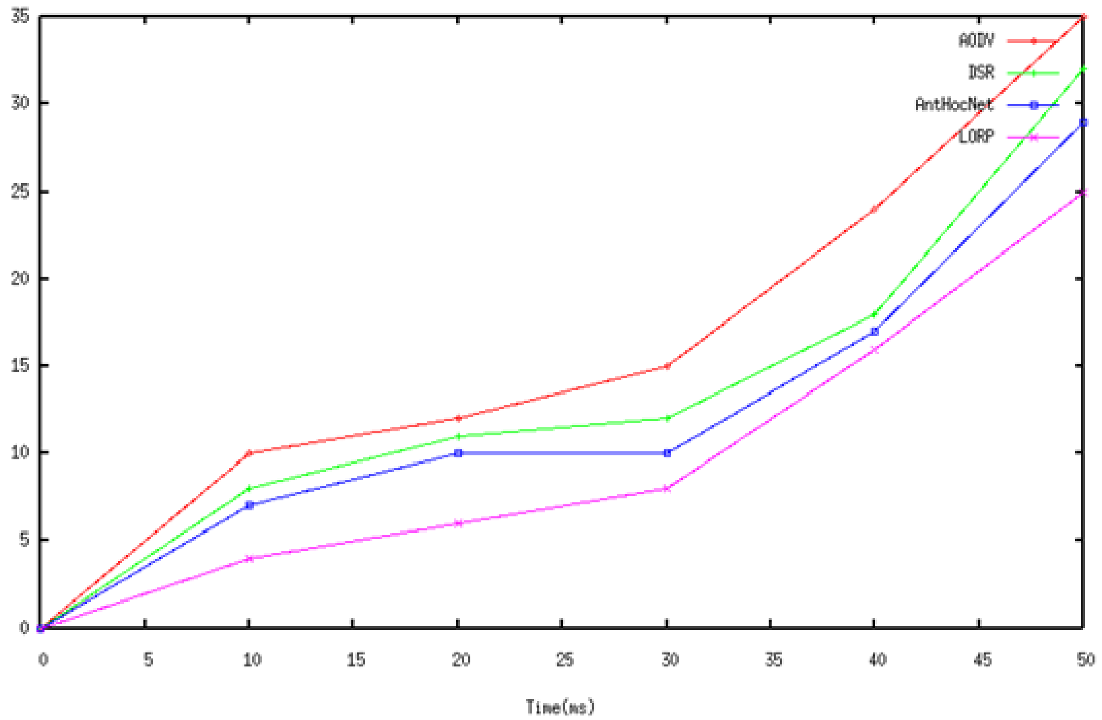

Figure 6. Packet loss calculation scenario 3

In Figure 6, the x-axis represents Time (ms) and the y-axis represents packet loss of the network. In this scenario 3 the number of nodes that are deployed for the simulation is 100 nodes and the packet loss of LORP is 25. The performance of earlier protocols is AODV is 35, DSR is 32 and AntHocNet is 29. Comparing to the earlier protocol is proved that our proposed LORP protocol performed well in terms of packet loss.

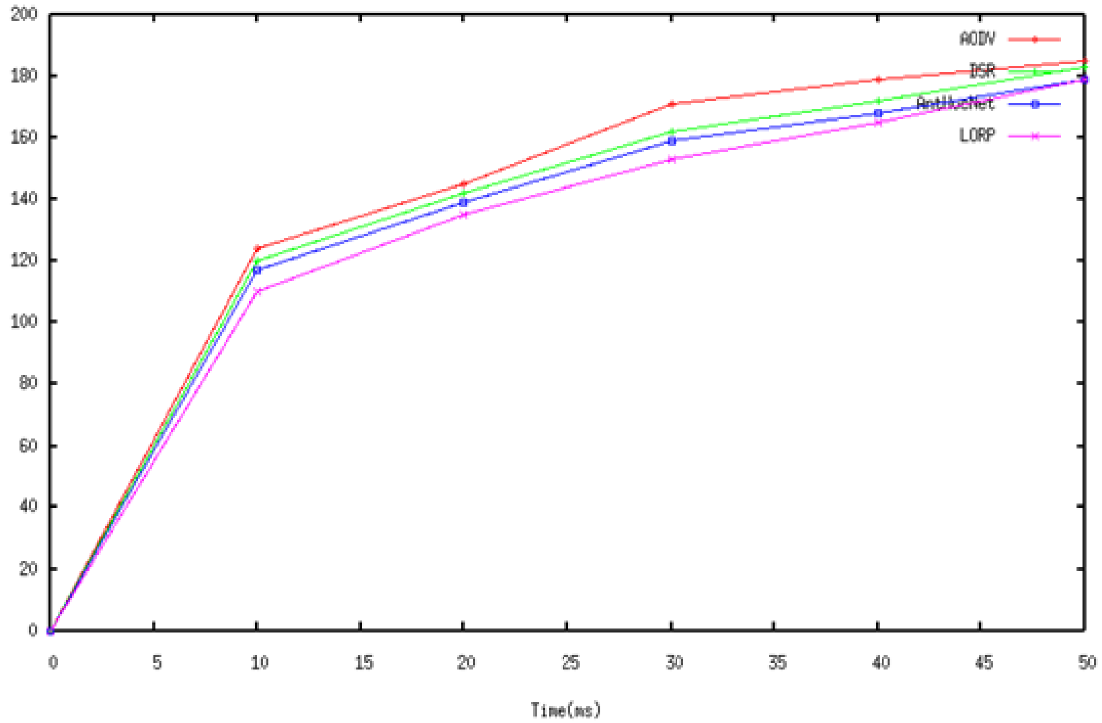

Figure 7. End to end calculation scenario 3

Figure 7 shows the end-to-end delay performance of AODV, DSR, AnHocNet, and LORP protocols. The x-axis in the graph shows the Time is taken in (ms) and the y-axis shows the end-to-end delay of the network. While comparing the earlier protocols and our proposed protocol, LORP reaches the utmost level up to 178.9 ms which are comparatively lesser than the earlier routing protocols.

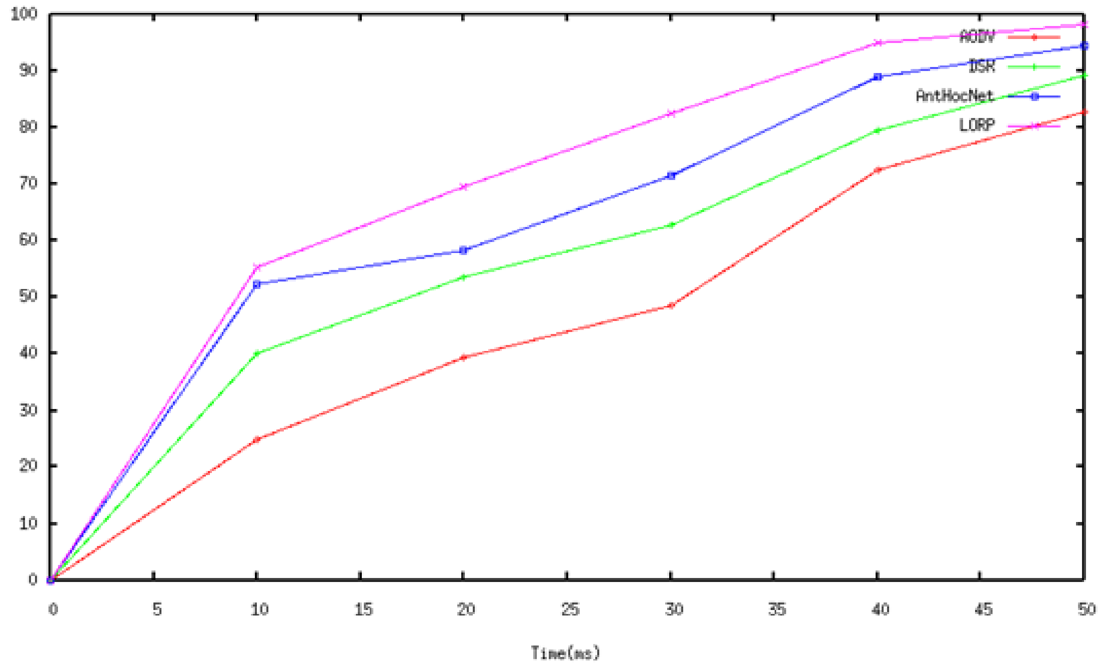

Figure 8. Packet delivery ratio calculation scenario 3

Figure 8 shows the Gnuplot of AODV, DSR, HocNet, and LORP protocols. In scenario 3, the number of nodes that are deployed for the simulation is 100 nodes and the packet delivery ratio of LORP is 98.2 percent. The performance of earlier protocols is AODV is 82.8 percent, DSR is 89.4 percent and AntHocNet is 94.5 percent.

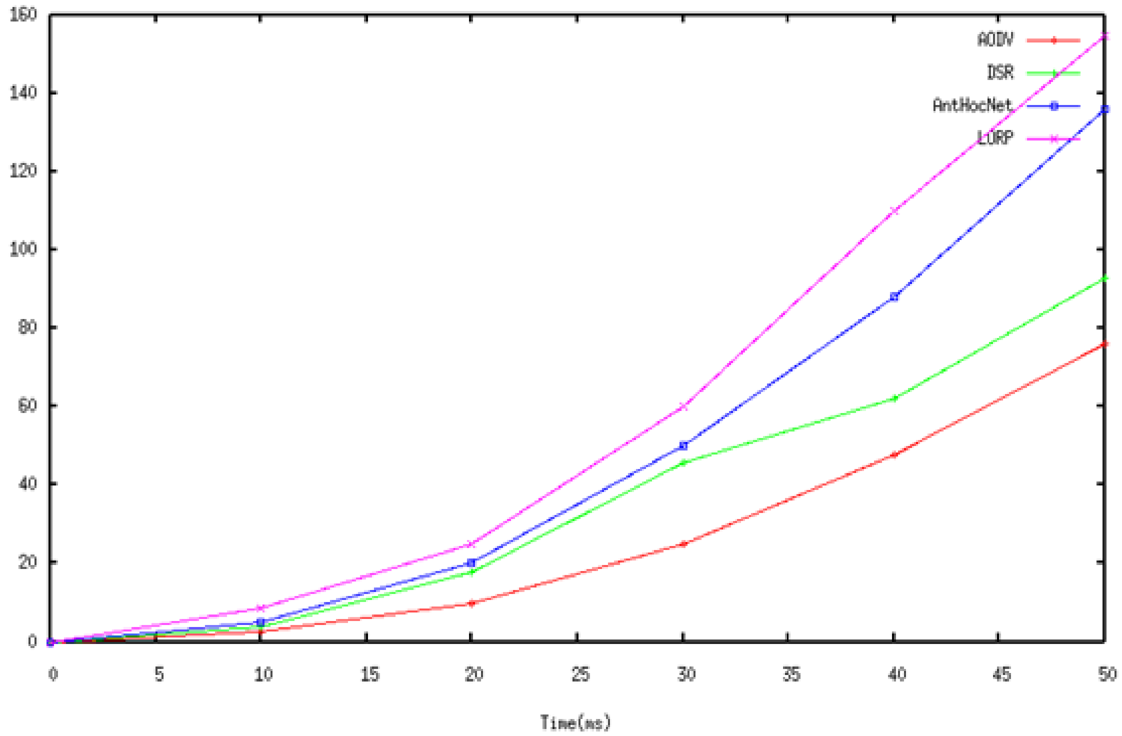

Figure 9. Throughput calculation scenario 3

Figure 9 examines the throughput comparison for AODV, DSR, Hoc Net, and LORP protocols. In scenario 3, the number of nodes that are deployed for the simulation is 100 nodes and the throughput of LORP is 155 Kbps. The performance of earlier protocols is AODV is 76 kbps, DSR is 93 kbps and Hoc Net is 136 Kbps. Comparing to the earlier protocols, it is proved that our proposed LORP protocol performed well in terms of network throughput.

5. Conclusions

MANET routing algorithms and the lion swarm optimization algorithm are elaborately discussed with all the key points. Here to find the optimal path in the network the new protocol is developed namely LORP protocol. The major sections of the protocol which are explained are ratio and system model, networking model, LSO algorithm, and finally optimal pathfinding using a lion swarm optimization algorithm. The major parameters of optimal pathfinding are packet delivery ratio, energy, throughput, delay, and short path. To achieve higher reliability, the LOA maximization and minimization concept are introduced. These parameters play an important role in finding the optimal path. Among the entire possible path, the optimal path is chosen using the LSO algorithm which is a bio-inspired algorithm. The simulation evaluation is carried out in the NS-2 testbed and it is discussed elaborately in the next chapter. The considered output parameters are network delay, packet delivery ratio, throughput, and packet drop. Then the values are compared with the earlier methods which are AODV, DSR, and ANT-HOC-NET.

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