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AFSA DSR- ARTIFICIAL FISH SWARM ALGORITHM DYNAMIC SOURCE ROUTING PROTOCOL FOR MANET

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ABSTRACT

Aims: *Information technology is being extensively used during emergencies for efficient handling of data and communication. In emergencies due to natural disasters like earthquakes or tsunamis Wireless Ad Hoc Networks provide a reliable communication link when existing infrastructure has collapsed. Ad hoc networks do not require any fixed infrastructure and networks can be formed on demand and hence can be used in counter terrorism operations also. For efficient operation of Ad hoc network routing plays an important role and the routing technique should be capable of adapting itself to the scenario under which it is deployed. This work proposed an optimized Dynamic Source Routing (DSR) protocol for MANET. To locate optimal paths between communicating nodes, traditional DSR algorithm is modified based on multiple objectives and called as Link Quality Load Balanced Dynamic Source Routing (LQLB-DSR). Solutions obtained using LQLB-DSR is suboptimal due to dynamic variation of network parameters. To overcome this an Artificial Fish Swarm Algorithm (AFSA) to achieve deserved Quality of Service (QoS) is proposed. Extensive simulations showthe improved performance of the proposed routing protocol*

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KEY WORDS

Mobile Ad-Hoc Networks (MANETs), Dynamic Source Routing (DSR), Link quality, mobility, end to end delay, Artificial Fish Swarm Algorithm

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INTRODUCTION

MANETs use the dynamic distributed system concept with many highly mobile devices communicating through a wireless medium. Every device has limited energy and communicates without fixed infrastructure. As each device/node moves arbitrarily, topology changes frequently and unpredictably. These characteristics make location prediction and reliable routing a challenge in MANETs. Each MANET node acts as host and router dynamically based on joining of new nodes and exit of current nodes. MANET can also work with existing wired local area networks. Key features of MANETs can be listed into [1]:

- All nodes are self-configurable dynamically.
- Every node may move in different directions and differing speeds.
- They work on constrained bandwidth.
- A node provides essential network functionalities like routing and maintenance, as there is no fixed infrastructure.
- Distributed algorithms are used for organizing, routing and scheduling.
- Security is limited as wireless medium is used for communication.

With availability of low cost devices and rugged operating systems for hand held devices MANET can become the first line of communication during natural emergencies like earthquakes, tsunamis and manmade emergencies such as war and terrorism [2]. Emergency applications of MANET includeSearch and rescue operations, Replacement of fixed infrastructure in case of environmental disasters, Fire fighting. Figure-1 shows a disaster communication setup using wireless network.

MANET efficiency depends on the cooperation of wireless nodes [3] and efficient routing. Conventional routing algorithms come under three categories including table driven or proactive algorithms, on demand or reactive algorithms and hybrid routing algorithms. Table driven routing algorithms are based on recently collected information on active paths stored in each node as a routing table and updated regularly. Periodic updates identify

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when a path is invalid or establishes a new path. Updating routing table consumes node's power and wireless medium bandwidth due to additional overheads [4]. If updating interval is long, then routing table does not have most recent topology change leading to stale routes. Wireless Routing Protocol (WRP), Destination Sequence Vector Routing (DSDV) and Fisheye State Routing (FSR) are proactive routing protocols.Demand driven or On-demand routing algorithms begin route discovery to send data to destination node. When a source node wants to send a packet to a wireless node, source node starts the discovery process. A path is found and registered with agreement between source and destination nodes. In this technique, route discovery introduces delays [5]. Dynamic Source Routing (DSR) and Adhoc On demand Distance Vector Routing (AODV) are popular reactive routing protocols. Hybrid routing improves routing by combining table driven and on demand routing algorithms best features [6,7]. Zone Routing Protocol (ZRP), Zone based Hierarchical Link State Routing (ZHLS), and Hybrid Adhoc Routing Protocol (HARP) are examples of hybrid routing protocols.

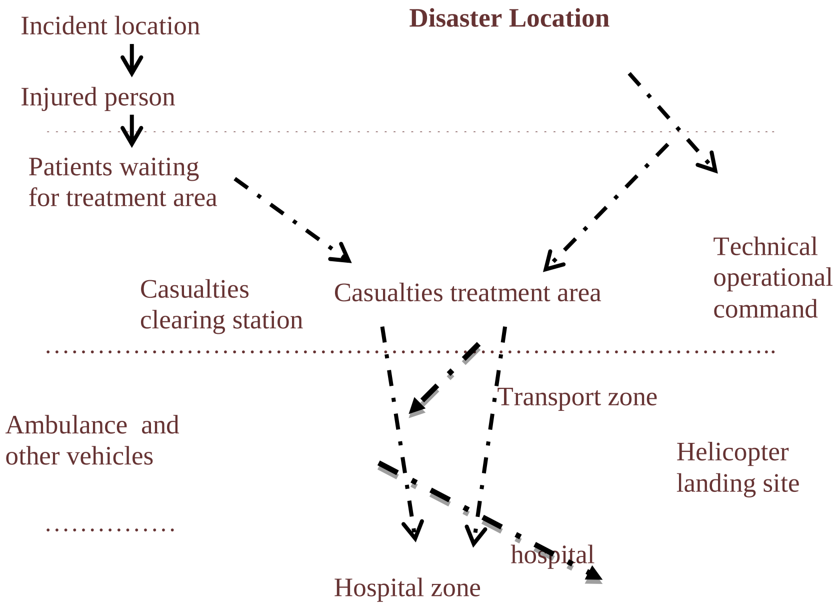

Fig. 1: A MANET based command setup during disaster

Conventional routing algorithms are not very efficient for MANETs distributed environment as network topology changes dynamically and Quality of Service (QoS) parameters differ for different applications. Traditional routing algorithms try to locate shortest path between source and the destination nodes. However, factors like latency, propagation path loss, and variable wireless link quality, protection against intentional jamming, interference, fading, power consumed, reliability, security and recovery from failure can be used for optimization the routes for specific applications. Failing to consider these parameters can degrade network performance and dependability [8].

Current MANET routing protocols do not consider parameters like network load along the path, processing capability of the intermediate node or the available bandwidth during the route selection process. To overcome the disadvantages this work proposed a Link Quality &Network Load Balanced Dynamic Source Routing is proposed (LQLB-DSR). Since multiple parameters have to be optimized, the routes discovered by LQLB-DSR are suboptimal and NP-Complete. To overcome this aSwarm Intelligence technique based on the behaviour of Fish Swarm is proposed. The rest of the work is divided into the following subsections. Section 2 discusses existing work, section 3 describes the proposed algorithmwith section 4 discussing the experimental set up and results obtained. Section 5 concludes the paper.

RELATED WORKS

The performance of various routing protocols like DSDV, AODV, and DSR for MANETs was investigated and compared by Manickam et al., [9],Shrestha and Tekiner [10]& Fan et al., [11]. After investigation, authors conclude that DSDV was suitable when number of nodes are limited and mobility is low due to storing routing details in nodes. DSR suited moderate size networks with moderate traffic, as DSR used source routing and route cache at nodes. AODV provided best packet delivery ratio but had high end to end delay.

An Enhanced Multi-Path DSR algorithm (EMP-DSR) was proposed by Asl et al., [12]. The proposed algorithm used Ant Colony Optimization (ACO) to get global information about nodes and individual paths reliability. Simulation showed that EMP-DSR's overall reliability and end to end delay was higher than simple Multipath DSR but had additional overheads. Rajesh et al., [13] proposed an Artificial Neural Network (ANN) to secure MANET resources thereby enhancing DSRs performance. When routing, if a legitimate node is erroneously mistaken for a rogue node then QoS deteriorates. A new method to optimize route discovery in DSR routing algorithms was proposed by Hussein [14] using fuzzy logic. The objective of optimization was to minimize number of broadcast of RREQ packet, as this influenced overhead significantly in DSR routing. The author suggested a decision algorithm through a fuzzy logic system where each link was assigned a weight when destination path was constructed. Weights were based on the individual link's load and quality. When a node receives a RREQ, only good quality nodes reply. Simulations showed decrease in RREQ overhead by 30% compared to traditional DSR.An optimized routing algorithm was proposed by Arafat et al [15] using ACO. The multi objective optimization problem considered estimated link quality, delay and energy parameter. An algorithm to detect many disjoint routes from a specific source to a destination node was proposed by PrabhakaraRao et al., [16]. Route life was expressed by factors like Link Expiration Time (LET), Drain Rate (DR) and link stability. Link stability is proportional to LET and indirectly proportional to DR. An optimal path was selected to use bandwidth efficiently based on these factors. DSR routing found multiple disjoint paths by modifying RREQ and RREP packets at source node. An efficient algorithm to select multiple paths for source destination pairs based on location and bandwidth information and energy parameters was proposed by Shuchita et al., [17] toensures constant, stable, healthy node disjoint paths satisfying many QOS parameters.A Multi-population Firefly Algorithm (MFA) for correlated data routing in Underwater Wireless Sensor Networks (UWSNs) was presented by Xu and Lin [18]. Three kinds of fireflies were used with coordination rules to improve adaptability of building, selecting, and optimizing routing path considering data correlation and sampling rate in sensor nodes. Different groups of fireflies conducted optimization independently to improve convergence speed and the proposed algorithm's solution precision.

Routing with TCP protocol was extensively studied by Swain et al., [19]. Kim et al., [20] proposed a disaster communication network and simulated the performance and showed the usefulness of MANET for telemedicine services. Kulla et al., [21] proposed data replication to support critical applications in disaster management. The proposed technique used fuzzy logic and optimization technique to improve the QOS. Lee & Yang [22] proposed an emergency escape system from disaster area using their own mobile devices. The proposed system utilized users' information such as weighted distances, weighted directions and revisit counts. The solution was implemented on a double-layered MANET to reduce traffic and to collaborate with each otherproving that the proposed system could be an effective life-saving rescue system.Bai et al., [23] proposed an integrated communication system by composing heterogeneous wireless networks to facilitate the rescue teams and victim people to communicate inside and outside the disaster site.

MATERIALS AND METHODS

Based on literature survey it can be concluded that QOS requirement changes based on the scenario where the MANET solution is deployed. To achieve this multiple objectives need to be optimized as solution outcome under different scenario will be sub optimal. This work proposedtwo new techniques Link Quality & Load Balanced –DSR (LQLB-DSR) and Artificial Fish Swarm Algorithm-DSR (AFSA-DSR) which is optimization of the LQLB-DSR.

In DSR routesare located when a source node needs to transmit data to a specific destination. This is a unicast routing protocol where a node uses cache memory to store route information of a node's recently taken routes. The two DSR routing steps are Route discovery and Route maintenance. When a source node attempts to send a packet to destination node, it checks its route cache [24, 25]. If route is available to destination node, then it transmits packet in the available path. Or else a route discovery process is initiated by broadcasting Route Request packets (RREQ).Nodes on receipt of RREQ check its route cache. If routing entry is not in it, the node appends its own address in RREQ packet and broadcasts it to neighbouring nodes. If RREQ packet reaches destination or a node with routing information to destination, it generates a Route Reply (RREP). Reply packet has nodes addresses traversed by the request packet. To maintain routing information, when data link layer finds a link failure or disconnection, a ROUTE ERROR packet is generated and transmitted from failed point to source node backward of sent data. So, all intermediate nodes delete route information via failed link. Then source node initiates another route location process. DSR benefits include route discovery control overheads reduction as it uses route cache. DSR's limitation is large size of packet header as per length of route due to source routing.

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PROPOSED LQLB MECHANISM

In the proposed technique Link Quality (LQ) and Network Load (NL) is measured and the path with high LQ and low NL is selected. Link quality (LQ) varies in a wireless medium compared to wired medium due to noise generated by outside source, distance between nodes being higher leading to higher packet loss. LQ can be evaluated based on the type of antenna in the node, the power capability of the antenna and can be computed by

$$P_r = Tx_p \times R_g \times T_g \times \frac{\lambda^2}{(4 \times \pi \times d)^2}$$

$$\begin{aligned}
&where\\
&\text{Pr} = \ received\ power,\\
&Tx_p = \ Power\ used\ for\ transmission,\\
&R_g = \ Gain\ of\ \ antenna\ at\ receiver,\\
&T_g = \ Gain\ of\ \ antenna\ at\ transmitter\\
&\lambda = \ wavelength,\\
&d = \ dis\tan ce\ between\ two\ nodes.
\end{aligned}$$

The equation evaluates link quality based on received signal strength descriptive which is based ondistance and mobility for a given time period[26].Two more wireless link quality metrics, Hop Count metric for the entire route andPer-hop Round Trip Time (RTT) is also measured.

In many scenarios the traffic in the MANET is high in certain regions of the network leading to load balancing problems [27] leading to congestion, buffer overflow and packet drop. Effectively the channel is affected due to the low bandwidth typically available in MANETs[28]. In such scenarios the routing algorithms may not stabilize. Figure 2 shows how nodes can be affected by excessive traffic flow. It can be noted that node 4 faces congestion as it handles traffic from node 2,3,7,6 and 1.

The overall data carried by each node for duration are computed. Route is selected based on the three parameters stated.

During route discovery process, the source node broadcasts Route Request (RREQ) packet with a LQLB query in packet header. Each node updates the LQLB once it receive the RREQ based on the sequence number concept of DSR. The LBLQ collects the total packet generated by each node and the number of packets it has received for a given duration and this represents the load balancing parameter identifying the weakest node. LQ identifies the weakest link in the route. LQLB field is added in each routing table entry and this gets updated when [29]:

- The received sequence number is higher than sequence number stored in the routing table.
- The sequence numbers are equal, but the hop count in the new RREQ is lower than the hop count stored in the routing table.
- The sequence numbers are equal, the LQLB in the routing table is smaller than the pre-defined
- LQLB value in the routing table is higher than current value.

The various routes are ranked and the best route selected. The ranking is based on the QOS parameter selected.

$$R_c = (w/H) + (1-w)\sum_{i=1}^{n}(P_{r,i} + (D_{g,i} + D_{f,i}))$$

$$\begin{aligned}
&where\\
&R_c\ \text{ is the route quality}\\
&P_{ri}\ \text{ is the normalized Link quality of node } i\\
&H \text{ is the hop count}\\
&D_g\ \text{ is the normalized packet generated by node } i\\
&D_f\ \text{ is the normalized packet forwarded by node } i\\
&w \text{ is a constant between 0 and 1. Here } w=0.5
\end{aligned}$$

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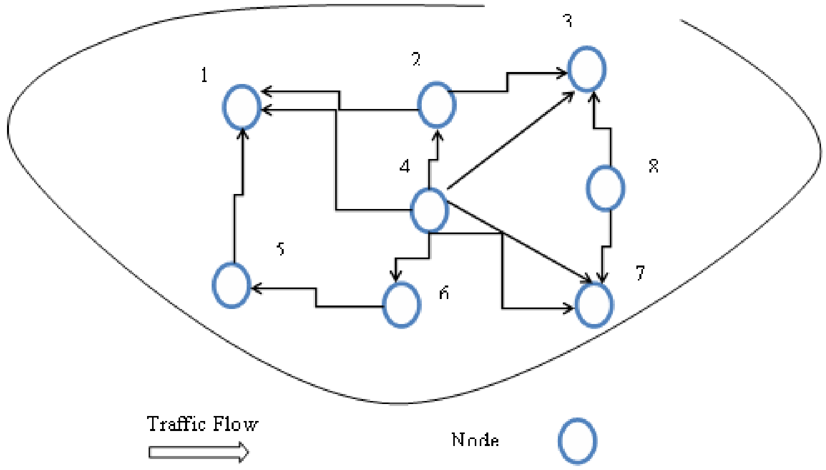

Fig. 2: Network Load

Route Selection Mechanism

The protocol decides whether particular route should be eliminated at the routing layer instead of making the decision at the link layer and filtering out all routing traffic over the bad links and reducing the chance of selecting a bad route.

In DSR link failure is detected by regularly using hello packets. If the neighbour does not respond to the hello packet sent by a node then the Route Error (RERR) is initiated so that source reinitiates the route discovery process. This leads to high routing overhead and to overcome this disadvantage, the proposed system monitors the link quality and the source node starts the new route detection process before the current link is broke.

Proposed AFSA - DSR

The proposed LQLB algorithm measures multiple parameters leading to suboptimal solutions. Also the ideal value of the weight cannot be found. To find an optimal solution various swarm intelligence techniques have been proposed in literature. Artificial Fish Swarm Algorithm (AFSA) mimics the behaviour of fish swarms preying and has been found to converge very fast [30]. The search starts with random solutions mapped to each fish. Fitness is evaluated and the fish follow process is initiated and fish follows another fish with better solution. If the solution is suboptimal, the swarming process is initiated using steps. If the desired solution is not met, preying process is initiated. This process is continued till the desired threshold or termination criteria is met. The pseudocode of AFSA is given in figure 3.

```
Start AFSA
:: Initialize();
while termination criteria not met do
  switch (:: evaluate_AF ())
        case 1:
            :: AF_follow ();
        case 2:
            :: AF_swarm ();
        default:
            :: AF_prey ();
     end switch
   :: move_AF();
  Obtain_best_solution ();
end while
```

Fig.3: Pseudo code of Artificial Fish Swarm Algorithm

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Artificial Fish (AF) model is represented by preying nature of fish, free move of individual fish, swarming of fishes to find better food and follow behaviour. AF searches the problem space by those behaviours. AFSA uses random search algorithm using variable current AF position, step, visual (visibility domain), try-number (maximum attempts for finding better positions in visual), and crowd factor δ (0<δ<1) [31]. For our solution space

AF=Artificial fish = (n,s_i), $i=1,2,3....n$ the number of objectives

(x_i, y_i) is the node i position at time t

The distance between two fishes is computed using Euclidean distance

$Visual_i$: Maximum transmission distance between of node

Step : The maximum step taken is twice the transmission distance

`

During preying mode the behaviour of fish is given by

$$prey(X_i) = \begin{cases} x_i + step\dfrac{x_j - x_i}{\| x_j - x_i \|} & if \ y_j - y_i \\ x_i + (2rand - 1).step & else \end{cases}$$

Here $rand$ is random function with range [0,1].

In the swarming phase the behavior of the swarm is given by

$$swarm(X_i) = \begin{cases} X_i + step\dfrac{x_j - x_i}{\| x_j - x_i \|} & if \ \dfrac{y_c}{nf} > \delta y_i \\ prey(X_i) & else \end{cases}$$

In the follow phase the behavior is given by

$$follow(X_i) = \begin{cases} X_i + step\dfrac{x_{\max} - x_i}{\| x_{\max} - x_i \|} & if \ \dfrac{y_{\max}}{nf} > \delta y_i \\ prey(X_i) & else \end{cases}$$

The three steps mentioned ensures both global and local search and the search direction following the best food source.

RESULTS

Fifteen runs were carried out for DSR, proposed LQLB-DSR and AFSA-DSR. The communication and network parameters used in the experiment is shown in Table 1.

Table 1 Summary of Results

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Parameters	Value
Data Rate	Fixed at 2 Mbps
Transmit Power	50 mW
Packet Reception-Power Threshold	-95 dBm
RTS Threshold	None
Path Loss Exponent	3.8
Route time out	4 second
Allowed hello loss	2
Hello interval	Uniform (1,1.15) second

Discrete Event Simulations were carried out for 1200 seconds and the average values computed. Table 2 shows the mean fitness and the best fitness obtained by AFSA-DSR.

Table 2 Fitness across 15 runs with standard deviation

	Mean fitness AFSA-DSR	Best fitness AFSA-DSR
1000 sq m	0.1349± 0.0231	0.1269
2000 sqm	0.1378± 0.0208	0.1157
3000 sqm	0.2073± 0.0316	0.1766

It can be observed from table 1 that the proposed algorithm performs consistently under multiple simulation scenarios proving the stability of the proposed technique. Figure 4 shows the Packet Delivery Ratio (PDR).

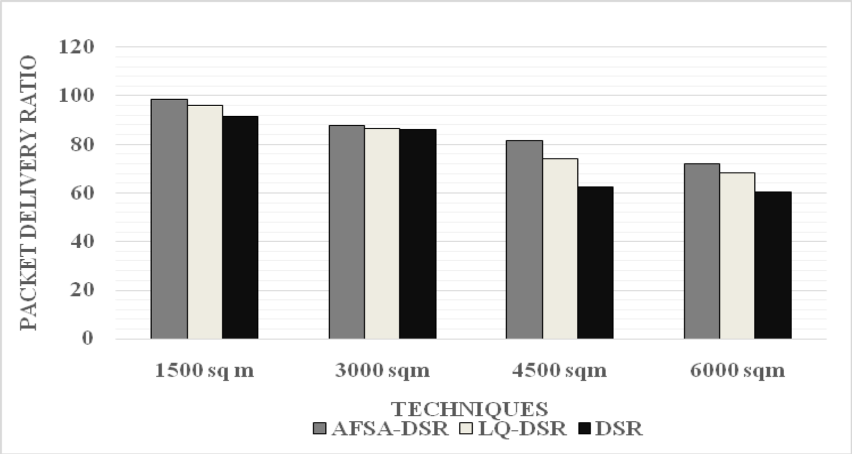

Fig. 4: Packet delivery ratio

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From figure 4 it is observed that the average PDR of the proposed AFSA-DSR improves by 4.4946 % and 12.453 %, when compared to the LQLB-DSRand traditional DSR routing. Figure 5 shows the end to end delay.

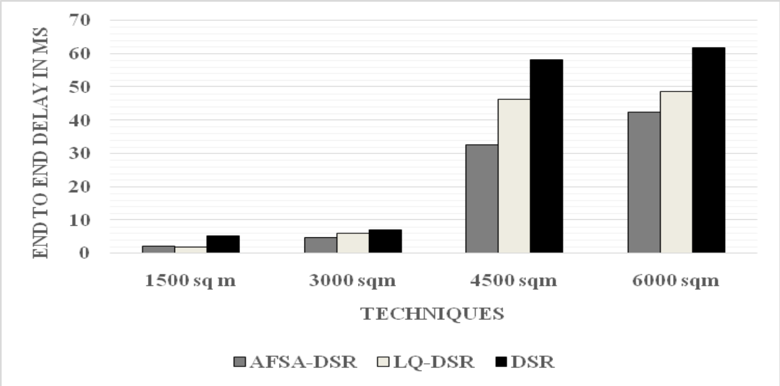

Fig. 5: End to end delay

From figure 5 it is observed that the average end to end delay of the AFSA-DSR reduces by 47.24 % and 23.04 % respectively, when compared to the Traditional DSR and LQLB- DSR routing for the simulated MANET respectively. It can also be seen that LQLB-DSR performance improves substantially over traditional DSR. From figure 6 it is observed that the average number of hops to the destination in the LQLB-DSR increases by 16 % when compared to DSR.

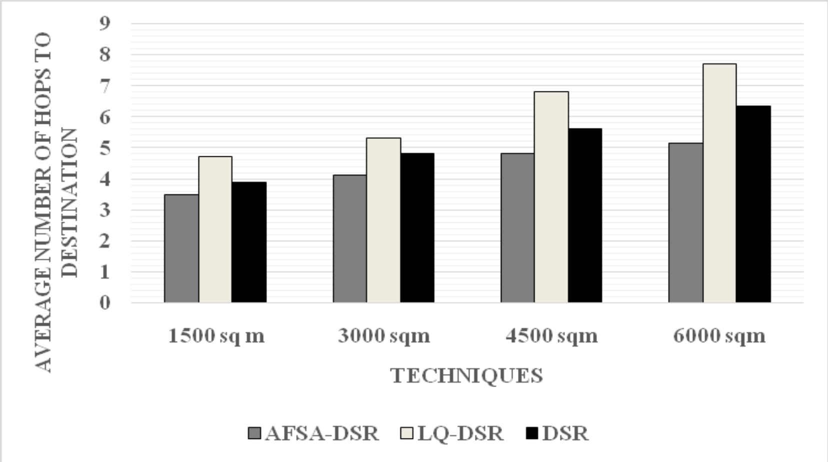

Fig. 6: Number of hops to destination

This is due to the suboptimal solutions generated based on pure computation. This is overcome by AFSA-DSR as it balances not only the network load but also avoids the sub optimal solution. However the number of hops is higher than DSR without affecting the network QOS.

CONCLUSION

This work investigated performance of DSR and proposed two algorithm LQLB- DSR and AFSA-DSR to improve the Quality of Service adaptively for different application scenarios. Fish Swarm was chosen due to its faster convergence and easier computation. Simulations were conducted by varying the network size and 15 runs were conducted for each scenario. Numerical results show that throughput of AFSA DSR increases PDRby an average of 31% than traditional DSR. End to end delay and retransmission attempts decreased considerably which is statistically significant. The number of hops to destinations increased in both versions of modified DSR compared to traditional DSR which may require further investigation

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CONFLICT OF INTEREST

The authors declare no conflict of interests.

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None.

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