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Routing Considerations, Simulation Analysis, and Dynamic Learning and Awareness Protocol for Mobile Ad Hoc Networks

Trilok Kumar Saini[1], Subhash C. Sharma[2] and Anju Saini[3]

[1]*Defence Electronics Applications Laboratory, Dehradun, India*
[2]*Indian Institute of Technology, Roorkee, India*
[3]*Graphic Era University, Dehradun, India*
[1]*trilok.saini@deal.drdo.in*, [2]*scs60fpt@iitr.ac.in*, [3]*anju.iitr@gmail.com*

Abstract

Routing is a key phenomenon in mobile ad hoc networks. The routing protocols govern the routing functionality and manage the multi-hop connectivity even in the resource constraint, and dynamic conditions. The objective of this paper is to analyze the mechanism of a reactive routing protocol and to suggest an extension of the protocol. The paper explicates the parameters which are critical for routing analysis. We do the simulation of routing protocol under varying mobility, traffic, and node density in order to resemble the protocol behavior in real circumstances. Paper extracts the simulation outcome to depict the protocol behavior. To incorporate the awareness of the local region and active route, we propose an extension to AODV based on dynamic learning and awareness (DLA-AODV) and present the concept and mechanism of the protocol.

Keywords: *Ad hoc network, routing protocol, routing metric, route awareness, MANET*

1. Introduction

Mobility of the nodes, wireless connectivity, dynamic formations, bandwidth constraints links, and the lack of infrastructure make routing protocols challenging in mobile ad hoc networks (MANETs). The routing protocols are designed to correctly route the packets and ambition to provide the loop-free path with minimum control overhead. The protocols for the mobile ad hoc networks are dynamic in nature to adapt to the varying conditions of the network [3]. There are many routing protocols that have been proposed for the multi-hop ad hoc environment. These protocols have been classified based on many criteria, the most popular classification is proactive, reactive, and hybrid categories [4] [19]. The reactive protocols discover the route only on-demand. These protocols have low routing control overhead but impose a route discovery delay before the data packets could be routed to the destination, e.g., ABR, AODV, and DSR [15]. The proactive protocols maintain the route to the destinations by periodic message exchange. Packets can be routed immediately to the destinations, but protocols have the penalty of relatively higher control flow in the network. Some of the protocols in this category are DSDV, OLSR, and WRP, etc. [13] [14]. The hybrid protocols combine the benefit of both reactive and proactive protocols and try to minimize their drawbacks, e.g., AHDR, HARP, and ZRP, etc. [16].

In each category, many protocols are available [4]. In reactive family, ad hoc on-demand distance vector routing (AODV) is one of the most popular routing protocols. Analysis and improvements are going on to improve the suitability of the protocols in real circumstances. In literature, many studies have been done on AODV to evaluate the performance and to explore the implementation possibilities. In [2], Rob van Glabbeek *et al.* performed the modeling of AODV to verify its core functionalities. In [3], Royer *et al.* provide the evolution, description, and future directions of AODV. In [6], Jianze Wu *et al.* present optimization in AODV. In

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[17], many extensions of AODV have been portrayed and analyzed. H. Xu *et al.* present the mathematical framework to evaluate the behavior of the generic routing protocol [8]. The routing performance in the mobile ad hoc network is influenced by routing decisions and the operating circumstances, i.e., mobility, traffic, etc. In this paper, we elaborate on the routing conditions and routing metrics that affect the routing process. For the analysis of the routing process in practical circumstances, we take AODV as a base protocol. To evaluate the performance of the protocol, we have chosen the simulation approach, which provides the affluence to quickly switch over various scenarios, provision to impose numerous conditions and to configure various parameters. We also propose DLA-AODV protocol, an extension to the AODV protocol for improving the situational awareness and contribute by presenting the conceptual illustration of the protocol. The rest of the paper has been organized as follows. In section 2, we discuss the routing metric, mobility, and traffic models. In section 3, simulation analysis of the base protocol in various circumstances has been done. In section 4, we present the dynamic learning and awareness extension of AODV. Finally, we conclude in section 5.

2. Routing analysis considerations

In this section, we discuss the significant aspects like routing metric, mobility, and traffic, which influence the routing process and are useful factors in the analysis of a routing protocol.

2.1. Routing metric

In the routing, a metric is associated with the cost of the link and is used to compute the interface cost for making the routing decision. It specifies the cost or quality of the chosen route. Some of the typical routing metrics are based on the hop count, load, financial cost, delay, bandwidth, energy, reliability, loss, link-quality, etc. The selection of the routing metric is governed by the quality requirement, the possibility to access the metric parameter, and its handling capability by the routing protocol [5]. The minimum hop-count metric may not be appropriate in every situation, especially in the wireless domain. An example scenario is shown in figure 1, in which two routes exist between the source (S) and destination (D). The first route via node A is the minimum hop route, while second route via nodes B and C contains the higher number of hops. In the illustrated scenario, routing protocols designed for the shorter path prefer to choose route-1, i.e., the minimum hop path. If route-1 has some limitations, i.e., either link S-A, or A-D is poor, unreliable, low data rate, heavily used, congested, or insecure, it may not be auspicious to select the minimum hop route. In such conditions, if route-2 possesses a better quality path, then it is good to select the longer path rather than the intermittent shorter path.

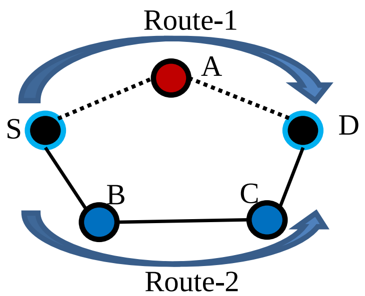

Figure 1. Illustration of route selection

Routing metric affects the choice of the route as routing protocols prefer to choose the lowest metric route for forwarding the traffic. In an ad hoc environment, routing

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algorithms and metrics may have versatile optimization objective like minimizing delay, maximize throughput, and minimize energy consumption, etc. The routing protocols are intended to utilize the metric based on the optimization objective and resource availability. The metric can be of the form of additive, multiplicative, concave, or statistical. In additive metrics, costs of the connecting links are added to calculate the cost of the path. The concave metric represents the minima of the cost along the path, while the multiplicative metric is calculated by the multiplication of the cost of an individual link. Some of the metrics have been exemplified in this section. The hop count metric represents the number of links traversed in which every hop denotes a single unit irrespective of the characteristics of the link, it is an additive metric and can be expressed as $\sum_{i=1}^{hops}(\eta) \mid \eta = 1$. The load metric represents load due to traffic flow. The length metric is used to represent the length of the connected links, and a longer path imitates a higher metric. The cost metric indicates the cost to carry traffic over the link, i.e., financial or logical cost of the uses of the link. Delay metric represents delay caused by queuing, processing, transmission, etc. The bandwidth metric represents the rate or capacity of the link between two locations. The path throughput metric can be dictated as the minima of the link throughput in the path and can be represented as $(\min T_l \mid l \in R)$, where T_l is the throughput over the link *L* in the route *R*. Energy metric is commonly used for residual energy or energy consumption, etc. The total energy consumption can be expressed as $\sum_{i=0}^{i=n-1} e_{i,i+1}$, where $e_{i,j}$ represents the energy consumed over link *i* to *j*. The cost assigned based on residual energy can be expressed as $1/E_r$, where E_r is the residual battery energy. The reliability metric reflects the level of assurance for data delivery over the link. The loss metric represents the probability of packet loss due to errors, collision, link failure, congestion, etc. The minimum loss metric is derived from the success probability of each link. It is a multiplicative matric and can be represented as $\prod_{i,j \in R} P(S)_{ij}$, where *ij* is the link with success probability $P(S)_{ij}$ over the route *R* [18]. The link quality metric indicates the link-ability governed by the parameter of transmission, such as signal strength, error rate, and interference, etc. [7]. If there are multiple possible paths with different cost factors, then the selected route based on minimal cost can be expressed as $P_s = \{r \in P \mid C_r < C_q, \forall\ q \in P\}$, where C_i indicates the cost along the path *i* and *P* represents the total possible paths.

2.2. Mobility model

In the typical ad hoc circumstances, nodes possess the moving capability. Initial deployment of nodes in the network can be random, and the nodes $i \in V = \{1, 2 \ldots N\}$ can have independent movement [15]. In the simulation analysis of the ad hoc network, the mobility pattern of nodes can be resembled with the real situations using various mobility patterns. Nodes in the network can have stationary and moving profiles distributed in the time domain. Some of the randomly selected nodes in the network can adopt different trajectories i.e. $T_r = \{T_{r1}, T_{r2}, T_{r3} \ldots\}$. In segment based trajectories, nodes follow a series of segments $(S_1 \to S_2 \to S_3 \ldots\ldots S_n)$ that define the movement of the nodes, and each segment can also have its distinguished features. The node may cover each segment in a fixed interval, or it may take a variable interval over each segment with varying wait and traversal time. The mobility of nodes in the network can also be specified with vector-based trajectories (T_v) defined by ground speed, bearing, and ascent rate $T_v = f(S_g, B, R_a)$.

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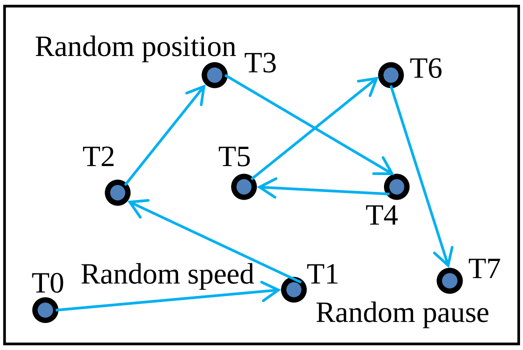

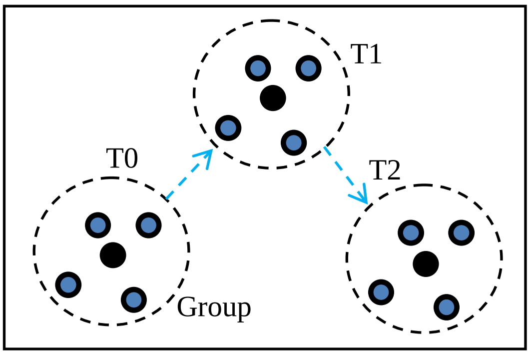

Figure 2. Mobility illustration (a) random waypoint mobility (b) group mobility

Apart from moving along the trajectories, the mobility of nodes in the ad-hoc environment is also characterized by the motion governed by the random movement of the participating nodes in the network. There can be many popular mobility models for simulating the effect of moving nodes like random waypoint, pedestrian mobility, and group mobility, etc. The random waypoint mobility (RWM) and group mobility pattern are shown in figure 2. In RWM, the node moves towards a random position at a randomly selected speed $v = (0, V_{\max}]$, upon reaching pause at that point for a period (T_p) and then repeat the process [9]. In group mobility, a group of nodes moves together [16] [10].

2.3. Traffic model

Traffic in the network may be generated by user applications executing on selected nodes. The profile of the traffic can be characterized by the specific application, e.g., constant bit rate, variable bit rate, etc. The traffic can also be generated by injecting the packets in the network using parameters like packet size and inter-arrival time, if P_s represents packet size in bits and ΔT is the packet inter-arrival time, then traffic generation can be given as $C_b = P_s / \Delta T$ [11]. For different traffic requirements, various distributions in packet generation, different data rates, and packet inter-arrival can also be applied. Apart from the explicitly generated traffic (P_e), there can also be the background traffic (P_b) in the network. Traffic in the network can follow the combination of explicit and background traffic, i.e. $(P_e + P_b)$. The source of the traffic can be modeled to yield high (L_h), moderate (L_m), or low load (L_l) in the network $(L_h > L_m > L_l)$ to verify the performance of the protocol under different load conditions.

3. Analysis of routing protocol

In the ad hoc network, each node may function as a source, destination, or as an intermediate router. Reactive routing discovers the routes as and when required and maintains for the duration of their uses [4]. In this section, we discuss the concept of the baseline protocol AODV. We simulate the behavior of the protocol under the unpredictable conditions of the mobile ad hoc network using the OPNET simulator. We attempt to resemble the simulation conditions with real circumstances. We analyze the effect of mobility, traffic, and the node density on the protocol using the hop-count routing metric.

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3.1. Base protocol

Ad hoc on-demand distance vector routing is one of the most promising protocols of the reactive family in the charter of the Internet engineering task force (IETF) MANET working group [2]. AODV protocol, as defined in RFC [1], has been exemplified here. This routing protocol acquires and maintains routes only when needed. The basic operations of the protocol include path discovery, forward & reverse-path setup, routing table management, local connectivity management, and path maintenance. Route-request, route-reply, and route-error are the messages used by the protocol. Source node desiring a route to the destination broadcasts route request across the network, which is responded with the unicast route reply either by the destination or by the intermediate nodes having a valid route to the destination [17]. Nodes receiving the route request setup backward pointers to the source. They may either send route reply or rebroadcast the route request or may discard the route request if they have already processed it. As the route reply propagate back to the source, nodes set up forward pointers to the destination. On receiving the route reply, the source node may begin to forward data packets to the destination [1] [12].

3.2. Simulation model and parametric details

The performance of the protocol has been analyzed in the scenario, in which N smart devices are participating in the network, where N ϵ {K, 2K, 3K}, and K is an integer defining the node density in the network. Participating devices are capable of forming the on the move network. A test range of 2000M × 2000M has been taken to showcase the capabilities of the underlying routing protocol. These devices transmit 2 mW of power for wireless transmission and have receiver power threshold specification of -95 dBm. The participating devices support IP services and possess random mobility. In this scenario, it is assumed that initially, all devices are placed randomly, and 10% of the devices are the active source of traffic generation and choose distinct destinations for data transfer while other devices behave like the forwarding entities. The parameters used for simulation have been mentioned in table 1, and the configuration of the protocol is given in table 2.

Active source nodes initially generate low-intensity traffic at the rate of 100 packets per second with each packet of 1024 bits. After a few minutes of time, devices double the traffic generation rate. In the middle of the experiment, sources further double the rate of existing traffic flow. It is assumed that 80% of the devices utilize their moving capabilities and move arbitrarily at the speed of 5m/s within the defined area, while the rest 20% remain stationary. We simulate the situations with N = K, 2K, and 3K number of nodes in the network, where K = 20. We analyze the effect of node density on the protocol and its effect on the flow of the traffic towards the destination. If S is the source and D is the destination, in the first case (C1), two independent traffic flows have been configured in the network, and the traffic is flowing between two pairs of source and destination {S1 → D16}, {S9 → D12}. This is designated as the case of less traffic flow and less node density. In the second case, traffic pattern is like {S1 → D16}, {S9 → D12}, {S21 → D36}, {S29 → D32}, in which there are four traffic flows. It is designated as case-2 (C2) of moderate traffic and node density. In the third case, when the numbers of nodes in the network are 3K, traffic pattern comprises the six flows i.e. {S1 → D16}, {S9 → D12}, {S21 → D36}, {S29 → D32}, {S41 → D56}, {S49 → D52}. It is designated as case-3 (C3) of high traffic flow and high node density. In the subsequent analysis, case-4 (C4), we gradually divert the traffic of active nodes towards a specific destination (D-16) in the step of low, medium, and high load. We further analyze the impact of load on the protocol performance. The traffic generated by the source node with respect to simulation time is shown in table 3. The data flow in the network is given in table 4.

Table 1. Simulation parameters

Parameter	*Value*
Simulation time	3000 sec
Data rate	11 Mbps
Transmit power	0.002 W
Packet reception threshold	-95 dBm
Mobility	Random waypoint

Table 2. AODV parameters

Parameter	*Value*
Route request rate limit	10 packets/sec
Route request retries	5
Active route time out	3 sec
Hello Interval	Uniform (1, 1.1) sec
Allowed hello loss	2
Net diameter	35
Gratuitous route reply	No
Destination only flag	No

Table 3. Traffic generation by source node

*Time (seconds) (*T1 = 30 sec, T = 3600 sec*)*	*Packet generation rate (packets/sec)*	*Packet size (bits)*
(0, T1)	0	1024
(T1, T/4)	100	1024
(T/4 , T/2)	200	1024
(T/2, T)	400	1024

Table 4. Data flow in the network

Nodes	*Traffic*		*IP Traffic flow*	
Participating Nodes (N)	*No of flow towards the destination (D-16)*	*Total flow in the network*	*Measured Statistics (Node SX to Node DX)*	*Other Parallel Traffic Flow (Node SX to Node DX)*
20	1	2	S1 → D16	S9 → D12
40	1	4	S1 → D16	S9 → D12, S21 → D36, S29 → D32
60	1	6	S1 → D16	S9 → D12, S21 → D36, S29 → D32, S41 →D 56, S49 → D52
60	1	6	S1 → D16	*No explicit flow to D16*
	3	6	{S1, S21, S41} → D16	
	6	6	{S1, S9, S29, S21, S41, S49} → D16	

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3.3. Simulation analysis and results

In the analysis, we capture the effect of the node density, mobility, load, and dynamic formations on various performances metric of the protocol, including traffic received at the destination.

3.3.1. Analysis of protocol performance: To analyse the routing protocol, received data traffic, hop-count, routing traffic, and the size of the routing table has been considered as the performance metric.

A. Data traffic received: The received data traffic has been measured as the total number of data bits received per second by the destination node. It is always desirable to maximize the successfully received packets by the destination. The numbers of nodes in the mobile ad hoc network affect the performance of the protocol because the presence of the nodes influences the formation and availability of path while the excess of nodes in the network may affect the ongoing transmission. The statistics have been collected for three cases (C1, C2, and C3) with 20, 40 and 60 nodes and the number of traffic flow in the network 2, 4, and 6 respectively. The results shown in figure 3, display the traffic received by node-16. In the graph, Y-axis represents the traffic received in bits per second, and X-axis represents the simulation time. Figures 3(a) and 3(b) represent instantaneous and average values, respectively.

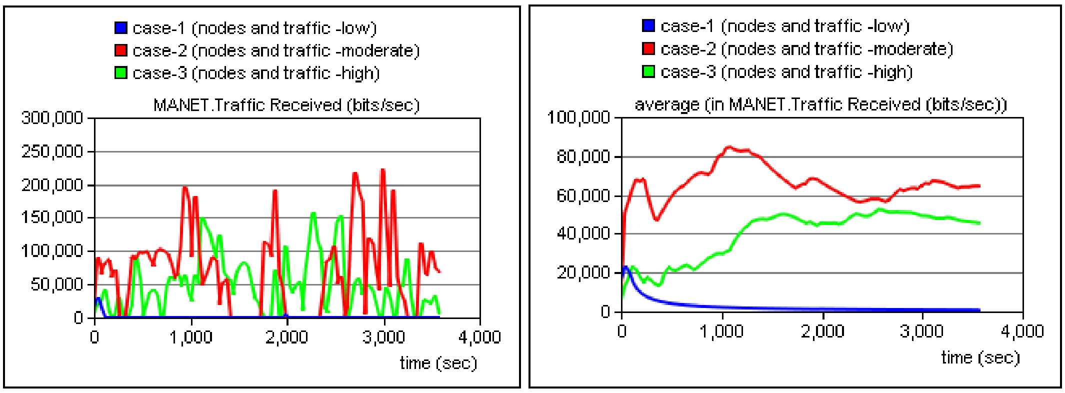

Figure 3. (a) Instantaneous traffic received (b) Average traffic received

B. Number of hops: This parameter represents the number of hops in the route to the destination. Statistics collected in the experiment is shown in figure 4(a), which represents the number of hops per route recorded at the source node. The numbers of hops between source and destination are dynamic in nature and depend on the instantaneous connectivity.

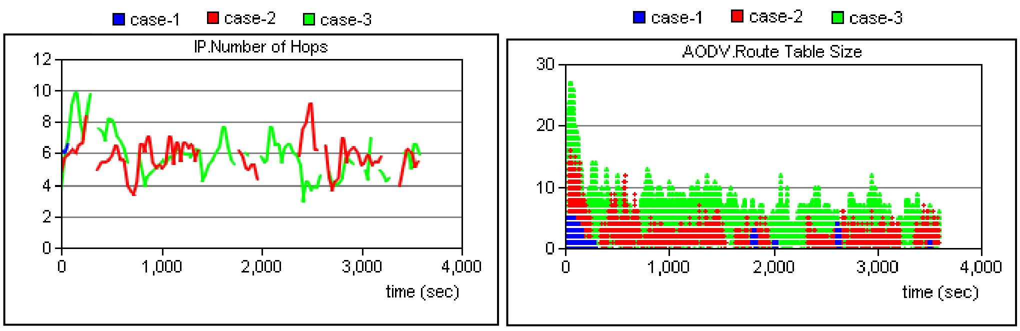

Figure 4. (a) Instantaneous number of hops (b) Routing table size

C. Routing table size: It represents the size of the AODV route table on the node. Results shown in figure 4(b) represent the size of the routing table at the source node. As the number of nodes in the network grows, the size of the routing table also increases.

D. Routing Traffic: Routing traffic sent and received by the node. Figures 5(a) and 5(b) represent the sent and received routing traffic recorded by the source node. Results indicate that routing traffic is increasing with the number of nodes in the network.

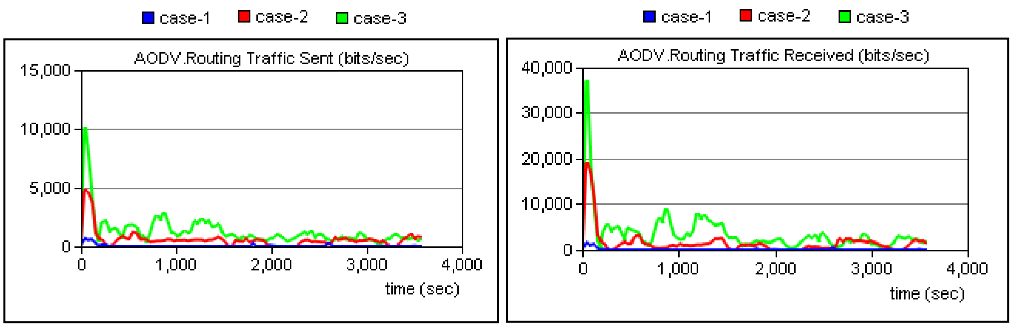

Figure 5. (a) Routing traffic sent (b) Routing traffic received

3.3.2. Analysis of Increasing Load: We further look into the impact of diverting traffic from multiple traffic sources to a single destination. We analyze the effect of traffic flow from different sources with diversified random locations towards a single destination. We increase traffic linearly based on the incremental load pattern. Three patterns of low load {S1 → D16}, medium load {S1, S21, S41 → D16}, and high load {S1, S9, S21, S29, S41, S49 → D16} have been simulated. The results are shown in figures 6(a) and 6(b). The results indicate that the network is able to sustain the load, and the received traffic at destination increases with the increase in the sent traffic.

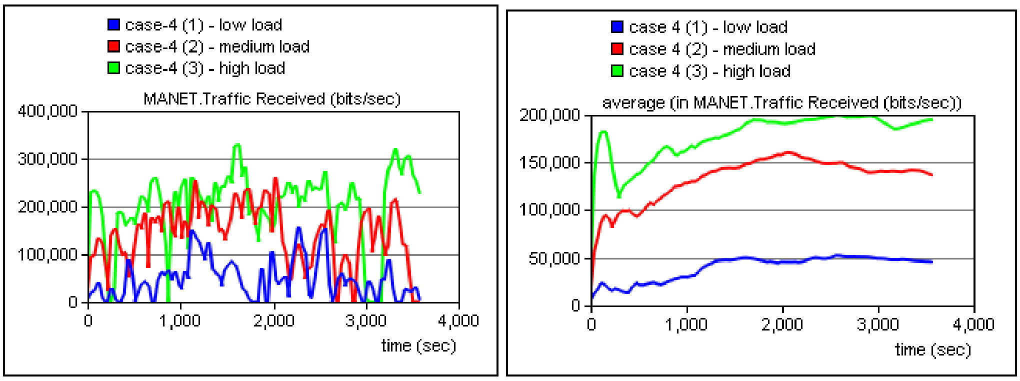

Figure 6. (a) Instantaneous traffic received (b) Average traffic received

4. Dynamic learning and awareness (DLA) protocol

In this section, we propose the dynamic learning and awareness extension of the AODV and present the logical illustration and algorithm of the protocol. In the mobile ad hoc networks, the positions of nodes are not always known; nodes may be in the neighbourhood, or separated by multiple hops. In many real-life situations, e.g., tactical applications, sometimes it is desirable to have an awareness of the neighbours and the information of the serving nodes in the active path to the destination. Considering such a scenario, the objective of the proposed dynamic learning and awareness extension (*DLA-AODV*) is to provide the active network awareness, quality provisioning in route formation, and to minimize the route discovery initiation.In the proposed extension, an active network is considered in

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the context of the source node, which is willing to initiate the data transfer or is in active communication. The awareness zone covers the two-hop neighbourhood and the path of the intended destination. The protocol persists the on-demand route discovery property of the AODV and gathers the awareness information of the active network only on the trigger by the services. The network awareness is maintained for the active transfer period and thereafter for the idle wait period. If no new data transfer is observed in the idle period, the protocol exponentially decreases the update period for the control packets required to maintain the active network awareness. The protocol discovery mechanism supports the source nodes to learn the desired path and the information of at least two hops neighbours. The additional information assists in suppressing the route discovery by the source node for the known nodes. The protocol also tunnels the routing information to the application for representing the topological view of the active network for user awareness.

4.1. Dynamic learning message

The protocol incorporates the concept of dynamic learning message (*DLM*), which helps to collect the routing information for all the nodes within two hops by piggybacking the information of one-hop neighbours. To reduce the control flow in the network, the learning process of neighbours is dynamic. Only active source initiates the neighbour learning, and the update of the neighbour information is also dynamic. The periodicity of *DLM* messages and the variation in periodicity is derived from the mobility and pattern of the received response packets. The *DLM* messages also have the provision to exchange the link quality information (*LQI*). If no explicit feedback on link quality or lower-layer information is available, the received *DLM* counts assist in deriving the quality factor.

4.2. Local topology awareness

In the local topology awareness procedure, the protocol makes use of the *DLM* message, which contains source flag (*S*), relay flag (*R*), and the capability to piggyback the neighbour information. On receiving the service request, the protocol needs to maintain the local topology at the source node.

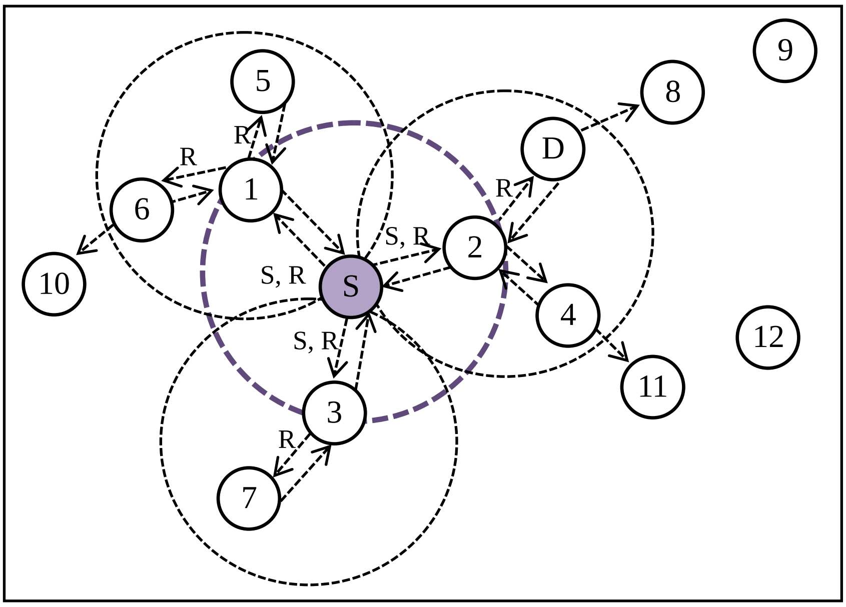

Figure 7. Local topology discovery by DLA-AODV

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The source node initiates the broadcast of the *DLM* message with both S and R flags set, and the TTL value of the message equal to 2. The nodes receiving these messages reset the S flag and keep the R flag set and piggyback their one-hop neighbours' list and further broadcast the message with a TTL value of 1. The nodes which receive these messages create the fresh *DLM* message indicating their presence and keep both S and R flags reset with a TTL value of 1. The local topology discovery of the protocol has been depicted by algorithm 1. The topology discovery scenario has been depicted in figure 7 in which the source acquires the topology and routing information for nodes {1, 2, 3, D, 4, 5, 6, 7}. This controlled propagation of the information in the local region allows creating the two-hop topology at the source node. The flow of these messages in the local region is controlled by their generation rate at the source, because generation and forwarding at all other nodes are triggered by the source *DLM*. The rate of DLM generation is decided by the change in topological information. In no change in topology is observed, then the rate of generation is kept low to avoid the unwanted flow of the messages in the network.

Algorithm1: DLA topology discovery

$Find\ Local\ Topo\log y(S)$
$\boldsymbol{in}: Control\ packets\ R_{req}; R_{rep}; R_{err}$
$\boldsymbol{out}: unicast\ route\ to\ destination$
$\boldsymbol{if}\ (node\ =\ S)\ \boldsymbol{then}$
$\quad flag\ F_S \leftarrow 1; F_R \leftarrow 1; TTL \leftarrow 2$
$\quad create\ DLM\ and\ broadcast$
$\boldsymbol{else\ if}\ ((F_S = 1)\ and\ (F_R = 1))\ \boldsymbol{then}$
$\quad flag\ F_S \leftarrow 0; F_R \leftarrow 1; TTL \leftarrow 1$
$\quad piggyback\ neighbor\ list$
$\quad broadcast\ DLM$
$\boldsymbol{else\ if}\ ((F_S = 0)\ and\ (F_R = 1))\ \boldsymbol{then}$
$\quad flag\ F_S \leftarrow 0; F_R \leftarrow 0; TTL \leftarrow 1$
$\quad create\ DLM\ and\ broadcast$
$\boldsymbol{end\ if}$

4.3. Active route awareness and route quality

For active route awareness, the protocol makes use of the path accumulation during route reply. The path accumulation of the protocol has been depicted in figure 8, in which the address of the visiting node is appended to the extended route reply message (ERREP), and the information is propagated to the source node. The route quality measurement has been depicted in figure 9, in which the minima of the measured link quality is used for the route quality.

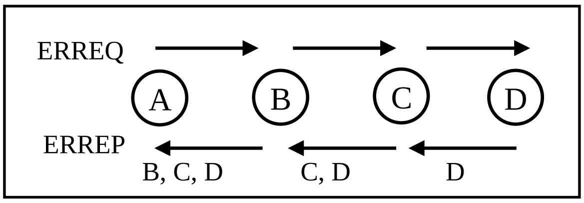

Figure 8. Path accumulation during route reply

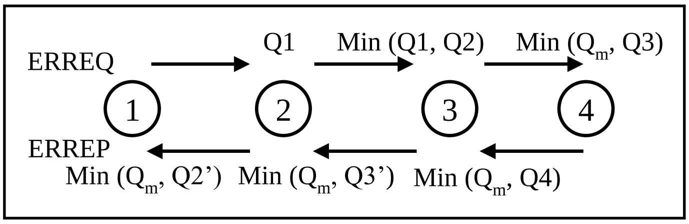

Figure 9. Route quality measurement

4.4. Route discovery

During route discovery, if an intermediate node has the topological information of the destination, it unicasts the route request to the destination that helps to reduce the *RREQ* broadcast. The protocol also extends the *RREQ* to carry the route quality information (*RQI*) and is represented as an extended route request (*ERREQ*). The protocol has the notion of path accumulation during *RREP*, and it also carries the cumulative route quality. The extension in route reply is referred to as *ERREP*. The path accumulation during route reply helps to collect the desired route information without much burden on the network, as the flow of *RREP* is confined due to the unicast nature of the message. The gathered information provides the awareness about the route availability for the intermediate nodes and assists in suppressing the route discovery for such nodes. The information is also useful to create the topological view of the active zone up to 2-hop and the route to the destination. The concept of multiple route reply creates awareness about the network and gives the possibility to choose the better route. The route discovery and route maintenance procedure of DLA-AODV have been depicted in algorithm2.

Algorithm2: DLM procedure

```
in : Node(S)
out : route to destination
Service request
  check local topology
  check available route
  initiate topology discovery(DLM)
  if (destination found)
    send data
    update topology for active period
    update RQI
  else
    initiate route request(ERREQ)
    setup reverse path
    upadte RQI
    update reply count at destination
    unicast route reply(ERREP)
    append node id
    setup forward path
    update best path
    send data
  end if
Route maintenance
  passive receive
  update LQI
  if (link break)
    unicast route error(RERR)
    reinitiate discovery
  end if
```

For quality provisioning, the protocol uses *LQI* and measures the link quality and calculates the route quality index, which is used to select the better route. Routing table keeps the information of next hop, the number of hops as well as route quality index. The comparison of the features of the AODV-DLA with AODV has been summarized in table 5.

Table 5. AODV [1] and AODV-DLA comparison

Features	*AODV*	*AODV-DLA*
DLM message	No	Yes
Active topology info	No	Yes
Path accumulation	No	Yes
Multiple route reply	No	Yes
Hello message	Yes	No
Precursor list	Yes	No
Local repair	Yes	No
The intermediate node route reply	Yes	No
Route request broadcast optimization	No	Yes
Route request cumulative quality	No	Yes
QoS Consideration	No	Yes

5. Conclusion

The paper presents the imperative factors like routing metric, mobility model, and traffic model that are useful to analyse the protocol performance in the mobile ad hoc network. The simulation study of the paper portrays the behavior and performance of the ad hoc on-demand distance vector routing protocol under varying node density and traffic conditions in the network. The analysis assists in grasping the protocol mechanism and provides the baseline for improving the protocol for the real-world requirements. The proposal of dynamic learning and awareness extension provides the mechanism to depict the local topology and the awareness of the active route that assists in reducing the route discovery initiation. We plan to simulate and implement the proposed DLA extension as a future activity.

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Authors

Trilok Kumar Saini received M.Tech. degree in computer & engineering from Indian Institute of Technology (IIT) Roorkee in 2003. He is scientist in Defence Electronics Applications Laboratory Dehradun, a laboratory of Defence Research and Development Organization (DRDO). He is a member of CSI, CET (I), IEI, and IETE. His work areas are mobile ad hoc network, routing protocols, and satellite communication.

Dr. Subhash C**. Sharma** received M.Sc., M.Tech. and Ph.D. from IIT Roorkee (erstwhile UOR) in 1981, 1983, and 1991 respectively. He is a professor at Indian Institute of Technology Roorkee. His research interest includes wireless and cloud computing, ad hoc, and sensor networks.

Dr. Anju Saini received M.Sc. and Ph.D. degree from IIT Roorkee in 2004 and 2013, respectively. She is an assistant professor in the department of mathematics at Graphic Era University, Dehradun. Her research interest includes mathematical modeling, biomechanics, and numerical analysis.