International Journal of Advances in Computer Networks and Its Security– IJCNS
Volume 4: Issue 2 [ISSN: 2250-3757]
Publication Date : 25 June 2014

Performance Analysis of On-Demand Routing Protocols in Mobile Ad-Hoc Networks

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***Abstract*— Security of On-demand routing protocols are of utmost significance in Mobile Ad-hoc Networks (MANETs), which form a transient network and are not using the existing infrastructure or centralized administration. Performance evaluation of Dynamic Source Routing (DSR) protocols is performed as a precursor for improving secure routing schemes in ad-hoc networks. Simulation results for determining efficiency in terms of throughput, delay and routing overhead are given.**

***Keywords* — Mobile Ad-hoc Network (MANET), Dynamic Source Routing (DSR), On-Demand Distance Vector (AODV), Ad-Hoc Network Performance**

I. Introduction

Wireless networks can be classified as either a wireless fixed network or wireless ad-hoc network. Wireless fixed networks operate mostly using most dedicated network equipment such as base stations, routers and switches. Wireless ad-hoc networks, on the other hand, utilize radio waves for transmission. They can be deployed any place at any time. Each mobile node operates not only as a host but also as a router, forwarding packets for other nodes. To establish routes between nodes farther than a single hop, specially configured dynamic routing algorithms are used. The routing protocol used should have the ability to acquire, maintain and recover routes in spite of a mobile and dynamic topology.

II. On-Demand Routing Protocols

In MANETs a dynamic routing protocol is used, which is enable to correct and efficiently establish routes between pairs of nodes to deliver packets in a timely manner. MANET routing protocols can be divided into the following categories, as shown in Fig.1 [1]:

i. *Flat Routing Protocols*
   a) Proactive Routing (Table-Driven)
   b) Reactive Routing (On-Demand)

ii. *Hierarchical (Zone/Cluster-Based) Routing Protocols*

iii. *Geographic Position Assisted Routing Protocols*

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Flat routing protocols regard the Ad hoc network as a number of nodes without subnet partitioning, thus not requiring a hierarchical addressing structure [2].

In Flat Routing Protocols, as the name infers, all MANET nodes and routing are on the same level or tier [3]. The reactive on-demand MANET protocols are a significant departure from more traditional proactive routing protocols, in that they find routes between all source-destination pairs, regardless of the use or need of such routes. Table I lists the differences in properties of proactive and reactive routings in this category.

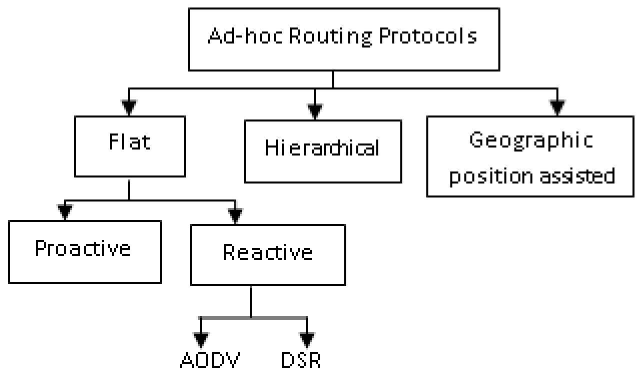

Figure 1 – Classification of MANET routing protocols

The route in Ad hoc On-Demand Distance Vector (AODV) protocol is achieved by a route discovery cycle involving a broadcast network search and a unicast reply containing discovered paths. In this scheme no multiple paths are stored or available. Each routing table entry has an associated lifetime value. If a route is not utilized within the lifetime period, the route will expire and then be deleted from the routing table.

Table I - Properties of proactive and reactive routing

Proactive Protocols	Reactive Protocols
Complete knowledge of the topology	Incomplete knowledge of network topology
Routing table with a route to all destinations	Routes maintained only between nodes that need to communicate
Exchange of full routing table for convergence	Stores routes already traversed
Not on-demand	On-Demand basis

The AODA initiates a route discovery procedure to find a route. If an intermediate node has a valid route in its routing table, it will generate a *Route Reply Packet (RREP)* containing the route to the destination and send it back to the source node only if the route entry fulfills the condition of a corresponding sequence number that is at least equal or greater than the one contained in the route request RREQ [5]; i.e., $dseq_{\text{rt}} \geq dseq_{RREQ}$. If more than one RREP is received, the source node selects the route with the highest sequence number and smallest hop count [6].

The route maintenance for a link break in AODV is performed by two different ways: (i) by the use of periodic local broadcasts (*'hello'*) messages, and (ii) through a link signaling mechanism when the link is used.

Dynamic Source Routing (DSR) uses source routing rather than hop-by-hop routing, with each packet carrying in its header the complete ordered list of nodes through which the packet must pass. The routes are stored in a route cache [7]. In DSR protocol, a source node A for route discovery to a destination node D will broadcast a *Route Request Packet (RREQ)*, which is received by nodes within wireless transmission range of D. If an intermediate node receiving an *RREQ* does not have an entry in its local route cache, it adds its own IP address to the *route record* of the *RREQ* packet and then it rebroadcasts the *RREQ* by forwarding the packets along its outgoing links. This *RREQ route record* comprises a list of intermediate nodes that have forwarded this *RREQ* up to this point including the source node. A *RREP* is generated when the route request reaches the destination D or an intermediate node has in its cache an unexpired route to the destination.

In DSR routing scheme, if confirmation is not received after a number of retransmission attempts for a packet, the link from the node to the next hop will be considered broken and a *Route Error Packet* (*RERR)* identifying and notifying about this broken hop is returned to the source node A.

III. AODV and DSR Comparison

We compare the properties AODV and DSR and contrast their characteristics and mechanisms, as given in Table II and Table III.

Table II – Property comparison of AODV and DSR

Property	AODV	DSR
Multi-Path capability	*No*	*Yes*
Uni-directional Link	*No*	*Yes*
Scalability	*Yes*	*No*
Multicast	*Yes*	*No*
Quality of Service	*No*	*Yes*
Route Record	*Route tables*	*Route cache*
Route Update	*Hello*	*Beaconless*
Frequency of Updates	*Periodic and event*	*Event triggered*
Multicast capability	*Yes*	*No*

It is seen that DSR is simple and designed for routing purposes in multi-hop wireless ad-hoc network. On the other hand, because of its reactive nature and its efficient route maintenance mechanisms, AODV can handle highly dynamic behavior.

Table III – AODV and DSR Differences

DSR	AODV
Source Routing	*Table-Driven*
Soft State approach	*Hard State* routing
Features based on *Link State Routing* algorithm	Mainly features from *Distance Vector*
Multiple route cache entries for a destination	One entry in the routing table per destination
Does not support timer-based states	Entry has an associated lifetime value
Replies to all RREQ from a single request cycle	The destination replies only once to the first RREQ

IV. Performance Evaluation

We evaluated AODV and DSR routing protocols based on performance metrics:

i) ***Throughput*** – this is the ratio between transmitted packets and delivered packets. Essentially, it is the number of bits transmitted between source and destination per unit time:

$$Throughput\ \% = \frac{\sum_t^n CBR\_received}{\sum_t^m CBR\_sent} \times 100$$

ii) ***Latency*** – This includes all possible delays caused by buffering during route discovery latency:

$$Average\ Delay\ \% = \frac{\sum_t^n (CBR_{sent_{time}} - CBR_{receive\_time})}{\sum_t^n CBR\_received} \times 100$$

iii) ***Routing Overhead*** – This is the ratio between the total numbers of routing or control packets transmitted to data packets:

$$Routing\ Overhead = \frac{\sum_t^k Routing\_packets}{\sum_t^n CBR\_received} \times 100$$

where *n* denotes the number of packets received, *k* denotes the number of routing packets, and *CBR* is the *constant bit rate*.

V. Simulation Results

The simulation tool we used for analysis is NS-2, which is a discrete event simulator targeted at networking research. We used traffic and mobility model based on CBR traffic sources. Only 512 byte data packets are used. The source-destination

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pairs and hence the mobility was simulated using varying pause times for the nodes. The simulation test –bed values are given in Table IV. The mobility model used is the random way point model in a rectangular field. We chose a rectangular area to force the use of longer routes between nodes than would occur in a square field with equal node density.

Table IV – Simulation Test-bed

Parameter	**Value**
Simulation Software	**Network Sim (NS-2)**
Node density	50
Maximum velocity	20m/s
Environment Size	1200m x 300m
Traffic Type	Constant Bit Rate
Packet Rate	4 (kb/s)
Pause Times (mobility)	0 to 840secs
Mobility model	Random waypoint
Size of packets	512 bytes
Error Margin	±0.003

We performed experiments utilizing 20 nodes CBR and 40 nodes and we measured the throughput, latency, and routing overheads. The results are summarized in Table V.

Table V – Summary of Simulation results

Pause Time (seconds)	**Throughput (%)**		**Latency (seconds)**		**Routing Overhead**	
	AODV	**DSR**	**AODV**	**DSR**	**AODV**	**DSR**
0	84.8	84.5	0.32	0.42	26	10
40	85.1	85.0	0.30	0.35	25	9
80	85.8	86.2	0.29	0.33	24	8.5
120	86.2	89.0	0.28	0.30	22	8.25
240	86.9	92.0	0.17	0.17	10	4
480	89.0	95.0	0.16	0.15	9	3
720	90.5	96.1	0.15	0.13	8	2
840	92.3	96.6	0.15	0.12	7.2	1.75

The throughput measurements are shown in Fig. 2. As depicted in this figure, DSR consistently produces the best result in lower mobility with higher pause times.

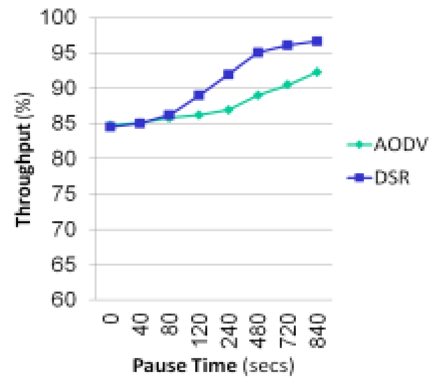

Figure 2 - Throughput

The latency measurements are depicted in Fig. 3. It is seen that at high mobility, AODV has the best delay while the DSR performance is improving at lower mobility.

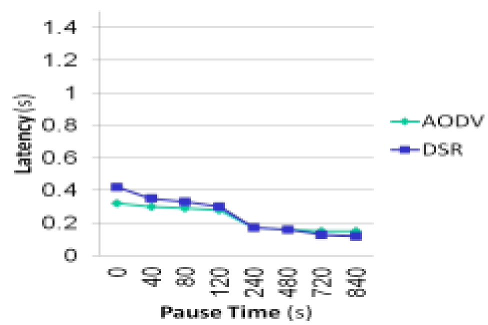

Figure 3 - Latency

The routing overhead measurements are shown in Fig. 4. The DSR routing consistently generates the lowest routing overhead at low and higher mobility for both higher and lower nodes concentration.

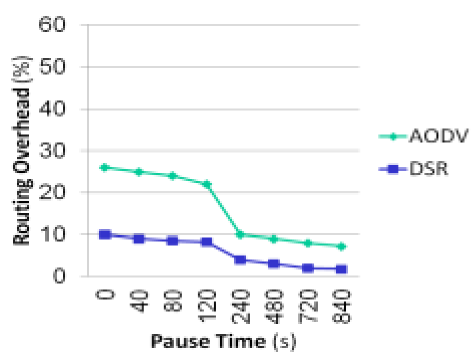

Figure 4 – Routing overhead

VI. Conclusion

We conducted a performance analysis of the AODV and DSR routing protocols, highlighting their features, differences and characteristics. The simulation results of their performance metrics such as throughput, latency, and routing overhead are obtained.

It is seen that the DSR protocol consistently has the best percentage of throughput and routing overhead while the AODV tends to have a better latency at higher mobility. From our simulation results we conclude that the DSR is the most efficient on-demand routing protocol, which affords a low routing overhead for our ongoing work of adding security enhancements in mobile ad-hoc networks.

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