Performance Evaluation of MANET Routing Protocols in Random Waypoint Mobility Model

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ABSTRACT
With the advancement of wireless technology, portable devices that are capable of wireless communication have become extremely popular making possible the establishment of wide ubiquitous networks. Mobile Ad Hoc networks (MANETs) are wireless networks where the exchange of messages between the nodes does not rely on any pre-deployed infrastructure. This architecture, nevertheless, suffers from a highly unstable topology as the links between the nodes break constantly due to movement of the users. Path routing and protocol selection are the key strategies behind the design of any wireless network. In this paper we study and evaluate the effect of mobility on the routing protocols viz. AODV, DSDV, DSR and OLSR in terms of packet delivery ratio, average end-to-end delay and normalized routing load.

Keywords
MANETs, Reactive Routing Protocols, Proactive Routing Protocol, Mobility Models

1. INTRODUCTION
Mobile Ad Hoc Network (MANET) is an autonomous, infrastructureless, self-healing and self-configurable network of mobile nodes with wireless links providing connections among them. Node mobility is an inherent characteristic of MANETs. The nodes move about randomly and may join or leave the network in a random manner. This degree of randomness results in an unpredictable topology. This calls for development of dynamic routing protocols that can efficiently find routes between two communicating nodes. Thus, path routing and protocol selection are the primary strategies behind design of MANETs. Due to unpredictable making/ breaking of links resulting from node mobility, the network routing protocols need to rapidly adapt to the network changes and establish new paths that avoid the failed links. But incorporating quick adaptation is a challenge in itself owing to energy and bandwidth constraints. This in addition to the overhead may significantly impact the overall performance of MANET.

Fig. 1 shows a simple MANET.

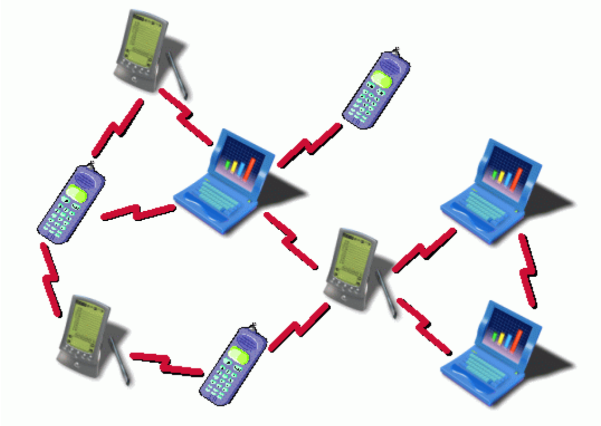

Fig. 1: **MANET**

The movement pattern or mobility of the nodes is characterized by mobility models and each routing protocol demonstrates specific characteristics for these models [1]. The above discussion leads us to infer that prior to selecting a protocol for a particular scenario, it is important to understand and evaluate the behavior of routing protocols in different mobility scenarios. Previous studies with routing protocols have selected Random Waypoint mobility models for simulations [3]. However, surveys on mobility models [1,4,5] verify that just the random mobility models may not be enough as the protocols may not exhibit optimum performance in the presence of other mobility models. Certain mobility models based on traces [6,7,8] have been developed. Graph based mobility models [9,10] have also been developed. Tools like IMPORTANT [11] and Bonnmotion [12] have been developed which can aid researchers in simulating mobility models.

In this paper, we have evaluated the performance of the protocols using Random Waypoint model for ease of simulation. The paper is organized as follows. Section 2 briefs about related work. Section 3 provides an overview of the MANET routing protocols. Section 4 describes the different mobility models. Section 5 details our experimental setup with results and critical analysis. We conclude with an outlook to future work in Section 6.

1.1 RELATED WORK
Several researchers have evaluated and presented performances of MANET routing protocols in the presence of various mobility models. Several conclusions have been drawn with regard to the performance of routing protocols in presence of these mobility models. The behavior of routing

protocols needs to be analyzed at varying node speeds, number of traffic nodes, network size and node density, in order to identify the most adaptive and efficient routing protocol [2]. Fahim Maan *et al*. have compared reactive and proactive routing protocols in [20] to provide a basis for selection criterion for routing protocols to meet specific network criterion. Asma Tuteja *et al*. have compared DSDV, AODV and DSR protocols together and individually in [21]. Pratap S. Prasad *et al*. have evaluated the effects of mobility on network parameters in highly mobile hierarchical ad hoc networks in [22]. C.P. Agrawal *et al*. have evaluated the performance of AODV protocol for different mobility models in [23]. Their experimentation suggests that several parameters such as traffic patterns, node density and initial pattern of nodes also affect the routing performance and need to be investigated with various scenarios. Bhvyesh Divecha *et al*. have evaluated the performance of DSDV and DSR in presence of various Mobility models in [24]. Their emprircal results illustrate that the performance of a routing protocol varies widely across different mobility models and hence the study results from one model cannot be applied to other model, which necessitates the consideration of mobility of an application while selecting the routing protocol.

2. MANET ROUTING PROTOCOLS

Routing protocols can be broadly classified into the following categories:

A. *Reactive Routing Protocols*

Reactive (or on-demand) Routing Protocols employ a lazy approach whereby nodes only discover routes to destinations on-demand. In other words, a route is discovered only when needed. They consume much less bandwidth but the delay in determining a route can be substantially large.

1) *Ad hoc On-Demand Distance Vector (AODV)*

AODV [13,25] offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network. It uses destination sequence numbers to ensure loop freedom at all times, avoiding problems associated with classical distance vector protocols. The destination sequence number is created by the destination to be included along with any route information it sends to requesting nodes. Route Requests (RREQs), Route Replies (RREPs), and Route Errors (RERRs) are the message types defined by AODV. These message types are received via UDP, and normal IP header processing applies. AODV uses the following fields with each route table entry:

- Destination IP Address
- Destination Sequence Number
- Valid Destination Sequence Number flag
- Other state and routing flags (e.g., valid, invalid, repairable, being repaired)
- Network Interface
- Hop Count (number of hops needed to reach destination)
- Next Hop
- List of Precursors
- Lifetime (expiration or deletion time of the route)

The Route Discovery cycle from source node to destination node is as depicted in Fig. 2 below.

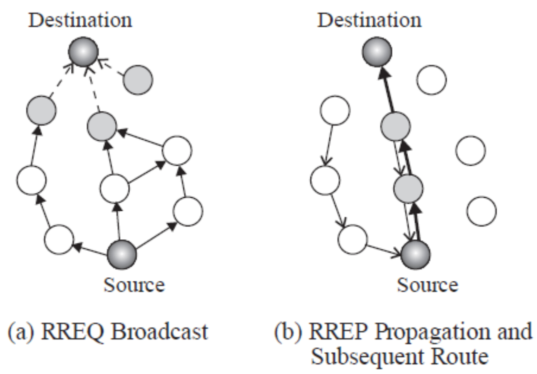

Fig. 2: Route Discovery Cycle in AODV

2) *Dynamic Source Routing (DSR)*

Like AODV, DSR [14] establishes a route to the destination when a source node requests one. DSR uses the *source routing* strategy. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which to forward the packet; the sender explicitly lists this route in the packet's header, identifying each forwarding "hop" by the address of the next node to which to transmit the packet on its way to the destination host. In DSR, nodes maintain route caches that contain the source routes which the node is aware of. Entries in the route cache are continually updated as new routes are learned. It consists of two major phases: route discovery and route maintenance. When a node has a packet to send, it first consults the cache. If it has a route, it will use this route to send the packet. If the node does not have such a route, it initiates route discovery by broadcasting a route request packet. If the discovery operation is successful, the initiator receives a response packet that lists the sequence of nodes through which the destination can be reached. Route maintenance is accomplished through the use of route error packets and acknowledgements.

B. *Proactive Routing Protocols*

Proactive (or Table-Driven) Routing Protocols employ classical routing strategies such as distance-vector or link-state routing and any changes in the link connections are updated periodically throughout the network. They mandate that nodes in a MANET should keep track of routes to all possible destinations so that when a packet needs to be forwarded, the known route can be used immediately. This allows the table driven routing protocols to transmit less overall control packets, keeping the protocol overhead minimum. However, when frequency of link breakage is high, the proactive routing protocols need a higher rate of routing table updates, which lowers the network performance.

1) *Direct Sequenced Distance Vector (DSDV)*

DSDV [16] is a proactive hop-by-hop distance vector routing protocol, requiring each node to broadcast routing updates periodically. Here, every node in the network maintains a routing table for all possible destinations within the network and the number of hops to each destination. Each entry is marked with a sequence number assigned by the destination node. Nodes manage their own sequence numbers by assigning a value two greater than the old one. Route entries are replaced when new routes of higher sequence numbers are received. Route updates are transmitted either periodically or immediately after a significant topology change is detected. Updates can either be full dump where nodes transmit their routing table entries or incremental where nodes only forward newly updated entries.

2) Optimized Link State Routing (OLSR)

OLSR [17] is a proactive protocol based on the link state algorithm. It employs three mechanisms for routing; (1) periodic HELLO messages for neighbor sensing, (2) control packet flooding using Multi-Point Relay (MPR), and (3) path selection using shortest path first algorithm. Each node, by using its two-hop neighbors, selects a set of MPRs such that all its two-hop neighbors are accessible. Nodes then rebroadcast only those messages that are received from nodes who selected it as an MPR. This mechanism efficiently reduces the broadcast control overhead and thus each node has a partial topology graph of the whole network. Each node selected as an MPR, transmits Topology Control (TC) messages to broadcast its presence to its MPR selector set. TC messages contain originating node address and its MPR selector set. Once routes are available to source node, it selects the optimal path using shortest path first algorithm.

3. MOBILITY MODELS

In the performance evaluation of a protocol for an ad hoc network, it should be tested under realistic conditions including a sensible transmission range, limited buffer space for the storage of messages, representative data traffic models and realistic movement of mobile users (i.e mobility models). There are two types of mobility models: Traces and Synthetic Models [1]. Traces are those mobility patterns that are observed in real life systems and provide accurate information about the participants. Synthetic models, whereas, realistically represent the behavior of nodes without the use of traces.

Mobility Models can also be broadly classified into: Entity Mobility Models (that represent mobile nodes whose movements are independent of each other) and Group Mobility Models (that represent mobile nodes whose movements are dependent on each other).

A. Entity Mobility Models

Random Walk – A simple mobility model based on random directions and speeds.

Random Waypoint – A model that includes pause times between changes in destination and speed.

Random Direction - A model that forces MNs to travel to the edge of the simulation area before changing direction and speed.

Gauss-Markov - A model that uses one tuning parameter to vary the degree of randomness in the mobility pattern.

City Section – A simulation area that represents streets within a city

B. Group Mobility Models

Reference Point Group Mobility (RPGM) – Represents the random motion of a group of mobile nodes as well as the random motion of each mobile node within the group. Group movements are based upon the path traveled by a logical center for the group [18]. The logical center for the group is used to calculate group motion vector.

4. PERFORMANCE EVALUATION

Simulations have been performed in Network Simulator, NS-2.34 on Ubuntu 12.04 LTS Platform, to determine the impact of mobility on performance of routing protocols. We evaluate four MANET protocols (AODV, DSDV, DSR, and OLSR) in terms of Packet Delivery Ratio, Average end-to-end delay and Routing Overload, against Random Waypoint Mobility Model. The simulation parameters are as presented in Table 1 below.

TABLE I
SIMULATION PARAMETERS

Parameter	**Value**
NS2 Version	2.34
OS	Ubuntu 12.04 LTS
Topology	700 m X 700 m
No. of nodes	20, 30, 40, 50, 75
Speed in m/s	10, 20, 30, 40
Routing Protocols	AODV, DSDV, DSR, OLSR
Simulation time	500 s
Traffic type	CBR
Packet size	200 bytes
No. of sources	1
Transmission range	250 m

awk [25] scripts were run on the trace files to determine the performance parameters. The comparison is drawn by measuring the following performance parameters:

Pr = Total packets received

Ps = Total packets sent

tr = Packet send time

ts = Packet receive time for the same packet

Pc = Control packets sent

t = Simulation time

- *Packet Delivery Ratio (PDR)*

Packet Delivery Ratio is a measure of the total data packets delivered to the destination successfully. Higher the PDR better is the performance of the routing protocol.

$$PDR = (Pr/Ps) \times 100 \qquad (1)$$

- *Average end-to-end delay (Davg)*

Davg indicates the time taken for a packet to travel from the source node to application layer of the destination node.

$$Davg = \Sigma(tr - ts) / Pr \qquad (2)$$

- *Routing load (RL)*

RL is the ratio of control packets to the total simulation time. It is a measure of the protocol routing overhead.

RL = Pc/t(3)

The performance parameters have been measured under two scenarios:

- Varying node density at a constant speed of 10 m/s
- Varying speed at a constant node density of 50

A. *Varying node density, constant speed*

1) *Packet Delivery Ratio*

The simulation results for PDR measured for the four routing protocols have been shown in Fig. 3.

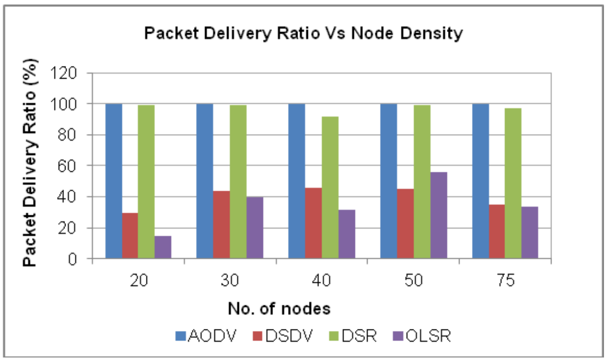

Fig. 3: PDR Vs Node Density

Proactive routing protocols deliver less packets as compared to their reactive counterparts. DSDV and OLSR have lower performance because of frequent node breakages owing to the random movement of nodes. The performance deteriorates with increase in node density. Thus, the best routing protocol for scenarios where RWP model is suitable is AODV, closely followed by DSR.

2) *Average end-to-end delay*

Fig. 4 below shows the simulation results for average end-to-end delay.

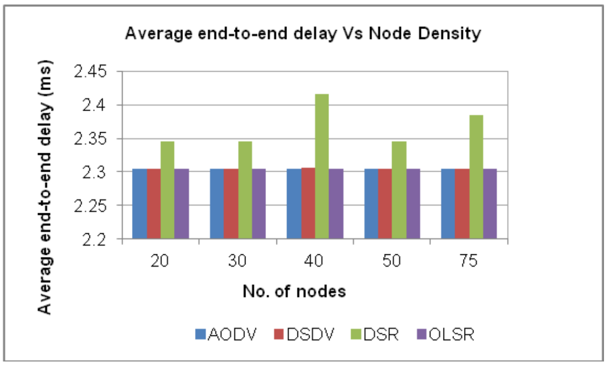

Fig. 4: Average end-to-end delay Vs Node Density

Reactive routing protocols have comparatively lower average delays than proactive routing protocols, with the exception of DSR. Other than DSR, the routing performance of the compared protocols is same.

3) *Routing load*

Fig. 5 below shows the simulation results for routing load.

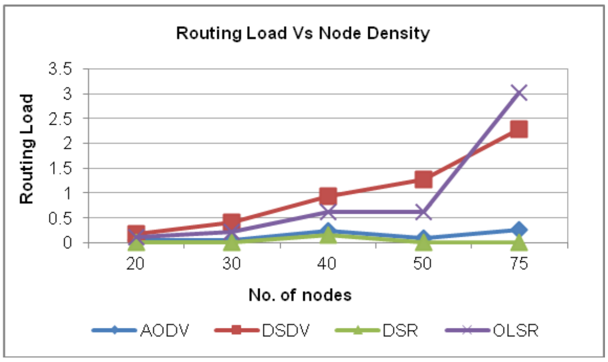

Fig. 5: RL Vs Node Density

Routing load increases with node density for all protocols. The impact of link breakages is more prominent due to random movements, resulting in a significant increase in routing load with an increase in number of nodes from 20 to 75.

B. *Varying speed, constant node density*

1) *Packet Delivery Ratio*

The simulation results for PDR measured for the four routing protocols have been shown in Fig. 6.

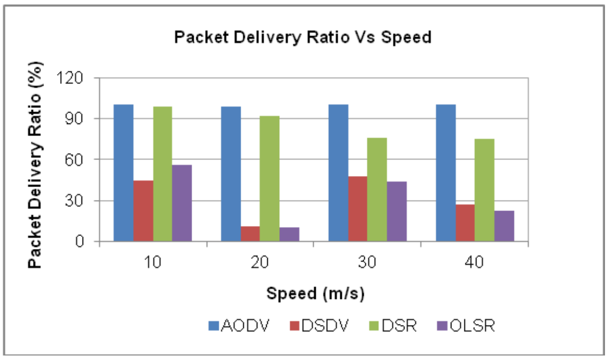

Fig . 6: PDR Vs Speed

As is observed in the previous scenario, PDR of proactive routing protocols is less as compared to reactive routing protocols. AODV outperforms all other protocols. In general, the PDR deteriorates with increase in speed and hence mobility of the nodes.

2) *Average end-to-end delay*

Fig. 7 below shows the simulation results for average end-to-end delay.

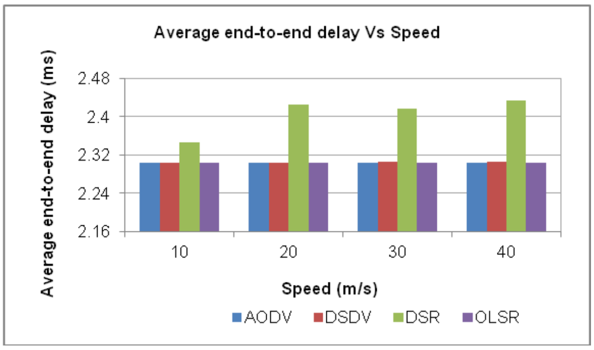

Fig. 7: Average end-to-end delay Vs Speed

Again, similar to the previous scenario, reactive protocols have comparatively lesser delays than proactive routing protocols, with DSR as an exception.

3) *Routing load*

Fig. 8 below shows the simulation results for routing load.

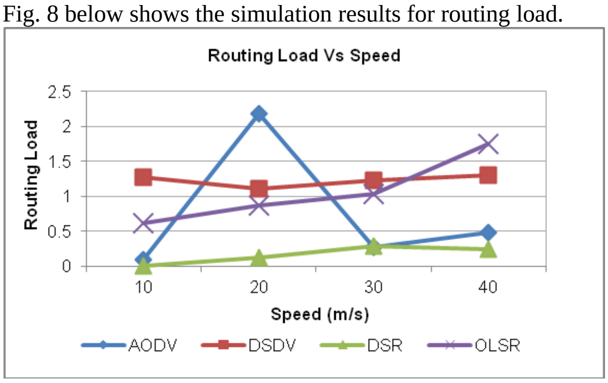

Fig. 8: Routing load Vs Speed

The graph above is indicative of the fact that the routing load, in general, increases with an increase in speed of the nodes.

5. CONCLUSION AND FUTURE WORK

In this paper, we present a brief overview of the various routing protocols and mobility models. We have also evaluated the performance of AODV, DSDV, DSR and OLSR in the presence of Random Waypoint Mobility Model. We observe that an increase in the node density has a similar impact on all network routing protocols i.e degradation in performance. A similar trend is observed with an increase in speed of the nodes. AODV outperforms all other routing protocols.

In future, we intend to study other routing protocols in the presence of other mobility models to determine the optimum protocol selection to meet specific network scenarios.

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