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PERFORMANCE EVALUATION OF ROUTING PROTOCOLS IN VEHICULAR AD HOC NETWORKS

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ABSTRACT: Vehicular Ad Hoc Networks (VANETs) are a new communication paradigm that enables the communication between vehicles moving at high speeds on the roads. This has opened doors to develop several new applications like traffic engineering, traffic management, dissemination of emergency information to avoid hazardous situations and other user applications. VANETs are direct offshoot of Mobile Ad Hoc Networks (MANETs) but with distinguishing characteristics like movement at high speeds, constrained mobility, sufficient storage and processing power, unpredictable node density and difficult communication environment with short link lifetime. Internet Engineering Task Force (IETF) is developing Dynamic MANET On-demand (DYMO) routing protocol which is successor to the popular Dynamic Source Routing (DSR) and Ad Hoc On-demand Distance Vector (AODV) routing protocols and shares many of its benefits. Performance evaluation of DYMO has been carried out in VANET scenarios and contrasted with traditional DSR and AODV. Results demonstrate the merits of DYMO under intense network conditions and the packet delivery fraction can be improved by as much as 30% when compared with the competing schemes.

Key words: VANET, MANET, DYMO, AODV, DSR, IETF.

INTRODUCTION

In Vehicular Ad Hoc Networks (VANETS) (Ibrahim, 2009; Khan, 2009; Watfa, 2010) nodes are vehicles. VANET is a network in which vehicles communicate with each other. Communication may be among vehicles or vehicles and road side fixed equipment. The aim of a VANET is to improve road safety by giving information to the drivers about different situations.

There is a special kind of electronic device placed in each vehicle for communication that is responsible for ad hoc connectivity of passengers. Vehicles are used as nodes and this node communicate wirelessly. Routing tables are used to produce mobility awareness and then routes are created based on geographical information.

In a VANET, drivers get more secure. Drivers can get the advance information about traffic congestion and also about the emergency situations. In such a network, warnings can be given to the drivers about upcoming accident situations. In case of fog, it can guide the drivers. It can inform the drivers about the road which is under construction. Users can get the internet facility for entertainment purpose.

This paper presents a thorough evaluation of Dynamic MANET On-demand (DYMO) routing protocol (Chakeres and Perkins, 2008) and draws comparisons with well known protocols - Dynamic Source Routing (DSR) (Johnson *et al*., 2007) and Ad Hoc On-demand Distance Vector (AODV) (Perkins *et al*., 2003) protocols. All the protocols have been examined with varying mobility and offered load using the Network Simulator NS-2 (NS-2.34, 2009). The comparison focuses on the following performance metrics: goodput, average end-to-end delay, routing overhead and normalized routing load. The contribution of the paper is to demonstrate the advantages and limitations of DYMO protocol in VANET environment and make recommendations about how the performance of such protocol can be improved.

MATERIALS AND METHODS

VANETs consist of mobile nodes having dynamic topology hence the mechanism of finding, maintaining and using routes for communication is not trivial for fast moving vehicles. Short lifetime of communication link, less path redundancy, unpredictable node density and strict application requirements make routing in VANETs quite challenging. In the related and similar domain of MANETs, there has been extensive research about the routing protocols during the past decade. Because MANETs and VANETs have many similar characteristics, early prototypes and studies about VANETs made use of the routing protocols developed for MANETs; however there is a lack of a systematic comparison and performance evaluation study that presents conclusive results about the performance of both reactive and proactive routing protocols in VANETs environment.

Dynamic Source Routing (DSR) protocol: The Dynamic Source Routing (DSR) protocol (Johnson *et al*., 2007) is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. Using DSR, the network is completely self-organizing and self-configuring, requiring no existing network infrastructure or administration. Network nodes cooperate to forward packets for each other to allow communication over multiple 'hops' between nodes not directly within wireless transmission range of one another. As nodes in the network move about or join or leave the network and as wireless transmission conditions such as sources of interference change, all routing is automatically determined and maintained by the DSR routing protocol. Since the number or sequence of intermediate hops needed to reach any destination may change at any time, the resulting network topology may be quite rich and rapidly changing.

Ad Hoc On-Demand Distance Vector (AODV) protocol: The Ad Hoc On-Demand Distance Vector (AODV) algorithm (Perkins *et al*., 2003; Rahayu Abdul Aziz *et al*., 2009) enables dynamic, self-starting, multi hop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. AODV allows mobile nodes to obtain routes quickly for new destinations and does not require nodes to maintain routes to destinations that are not in active communication. AODV allows mobile nodes to respond to link breakages and changes in network topology in a timely manner.

Dynamic MANET On-demand (DYMO) routing protocol: The Dynamic MANET On-demand (DYMO) routing protocol (Chakeres and Perkins, 2008; Sommer and Dressler, 2007) enables reactive, multi hop unicast routing between participating DYMO routers. It is currently being developed in the scope of Internet Engineering Task Force (IETF) MANET working group and is expected to reach Request For Comment (RFC) status in the near future. DYMO is considered as a successor to the AODV routing protocols. DYMO has a simple design and is easy to implement (Thorup, 2007).

Difference between AODV & DYMO: DYMO works much like the AODV routing protocol, but there is a subtle and important difference between the two routing protocols. In addition to the route about the requested node, the originator of the RREQ message using DYMO protocol will also get information about all intermediate nodes in the newly discovered path. In AODV, only information about destination node and the next hop is maintained, while in DYMO, path to every other intermediate node is also known.

Routing information dissemination in AODV and DYMO is illustrated in Fig. 1. In AODV, when node A initiated a route discovery process for node D, it only learned about routes to node B, its next hop neighbor, and the destination node D after route discovery process is finished. While when DYMO is used in the same scenario, node A additionally learned about the route to node C and B. This important feature in DYMO is referred to as path accumulation.

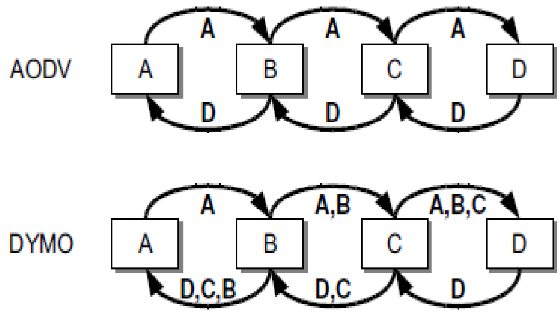

Fig. 1: Routing information dissemination in AODV and DYMO

RESULTS AND DISCUSSION

Simulation Framework: The platform used to execute the evaluation of protocols is the NS-2 (NS-2.34, 2009). The simulation environment consists of 50 wireless nodes forming an ad hoc network, moving over a 1000m x 300m flat space. The physical radio model uses the characteristics of the 914MHz Lucent WaveLAN direct sequence spread spectrum radio with minimal range of 250m and nominal bit rate of 2Mbps. The Distributed Co-ordination Function (DCF) of IEEE802.11 is used as the Medium Access Control (MAC) protocol using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) technique. An InterFace Queue (IFQ) is used to queue all routing and data packets at the routing layer (until the MAC layer can transmit them). The IFQ has a maximum size of 50 packets, maintaining a queue with two priorities each served in a First-In First-Out (FIFO) order. Routing packets are assigned a higher priority than data packets.

Traffic and Mobility Models: Random Constant Bit Rate (CBR) traffic connections and Transmission Control Protocol (TCP) are established between mobile nodes using a connection pattern generator script. Connection patterns are 25 CBR traffic sources at a rate of 10 packets per second (each packet containing 512 bytes). Simulations are run for 900 simulated seconds. Each data point represents an average of ten runs using different seeds. The mobility model used is a rectangular field, which can be setup using a scenario generator script. Mobility models were created with varying speeds (20, 30, 40, 50, 60, 70 and 80 meter/seconds) with the pause time kept at 0. A pause time of 0 seconds corresponds to complete continuous motion. Table-1 shows the overall simulation parameters.

Table-1: Simulation Parameters

Parameter	Value
NS-2 Version	2.34
DSR Implementation	NS-2 Default
AODV Implementation	NS-2 Default
DYMO Implementation	DYMOUM
Transmitter range	250m
Nominal channel bandwidth	2Mbps
Simulation time	900sec
Number of nodes	50
Pause time	0sec
Terrain size	$1000x300m^2$
Traffic type	CBR
Packet rate	4 packets/sec
Packet size	512 bytes
Number of sources	25
Maximum speed	20,30,40,50,60,70,80 m/s
No. of runs	10

Performance Metrics: Four important performance metrics (Zafar *et al.*, 2009) are evaluated:

- *Packet Delivery Fraction (Goodput):* the ratio of the data packets delivered to destinations and those generated by the CBR sources.
- *Average End-to-End Delay:* includes all possible delays caused by buffering during route discovery, queuing at the interface queue, re-transmission delays at the MAC, propagation and transfer times.
- *Routing Overhead:* the number of routing packets transmitted per data packet sent to the destination. Each hop-wise transmission of a routing packet is counted as one transmission.
- *Normalized Routing Load:* the number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission.

Analysis: In this section the simulation results of routing schemes (AODV, DSR and DYMO) are discussed for VANET scenarios. The main purpose of finding these results was to measure the ability and also to investigate that how a routing mechanism reacts to the network topology, how they act under different changes made in the network and under such circumstances how the successful delivery of data packets to their destinations are processed. To get this ability and surety, we evaluate all these three routing mechanism performance and compare them under high mobility as in VANET scenario the nodes move with at a high speed.

Comparison of Packet Delivery Fraction: Fig. 2 shows the simulation results for the performance metric of Packet Delivery Fraction (PDF) and varying speed for all the three routing schemes. From the results it is clear that DYMO work better as compared to DSR and AODV at high mobility. On the second level AODV work well because it remain stable throughout the variation of speed while the DSR values goes down at high mobility due to its source routing nature.

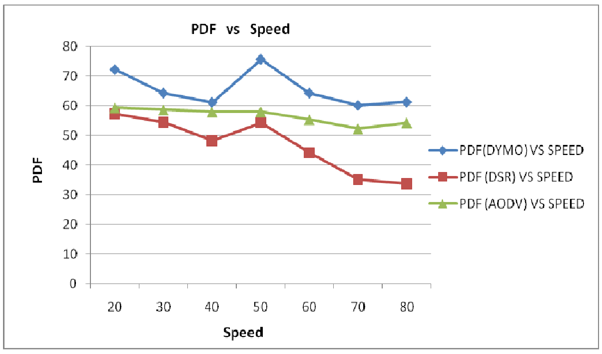

Fig. 2: Simulation result of Packet Delivery Fraction versus Speed

Comparison of Average End-to-End Delay: Fig. 3 shows simulation results for the performance metric of average end-to-end delay and varying speed for all the three routing schemes. From the results it is clear that DSR work poor as compared to DYMO and AODV. Because of high varying speed the DSR failed to transmit and receive data in an early time while the AODV and DYMO perform better and the DYMO delay is less and it works better but the AODV has a stable and constant delay throughout all speeds.

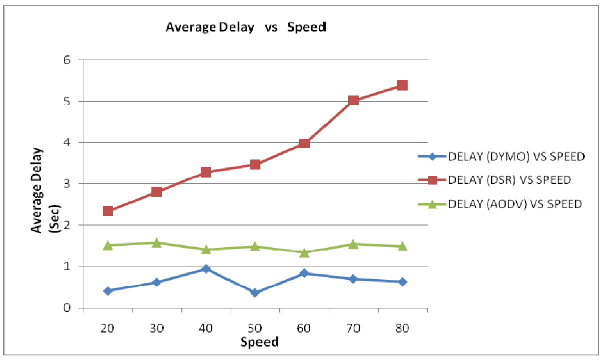

Fig. 3: Simulation result of Average End-to-End Delay versus Speed

Comparison of Routing Overhead: Fig. 4 shows the simulation results for the performance metric of routing overhead and varying speed for all the three routing schemes. From the results shown below it is clear that DYMO and AODV have high routing overhead as compared to DSR because they have details about every node and these details are path details and their values increases as the simulation time increases. But the values of DSR vary as mobility increases and the other two routing schemes remains almost constant which is consistent. As compared to DSR, DYMO and AODV show stability throughout the varying mobility.

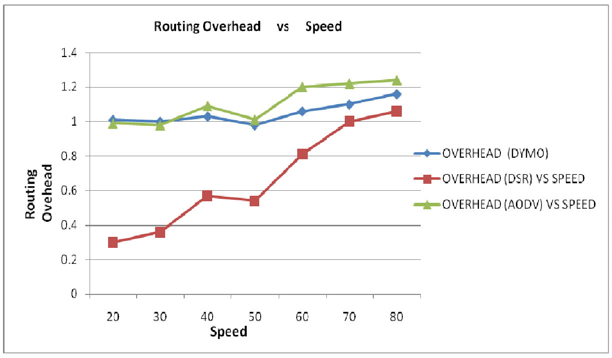

Fig. 4: Simulation result of Routing Overhead versus Speed

Comparison of Normalized Routing Load: Fig. 5 shows the simulation results of this performance metric of Normalized Routing Load (NRL) with varying speed for all the three routing schemes. From the results shown below it is clear that DYMO and AODV perform better at high speeds. The degradation in DSR's performance is the result of the resurrection of data packets at source nodes, when the MAC-managed transmissions fail.

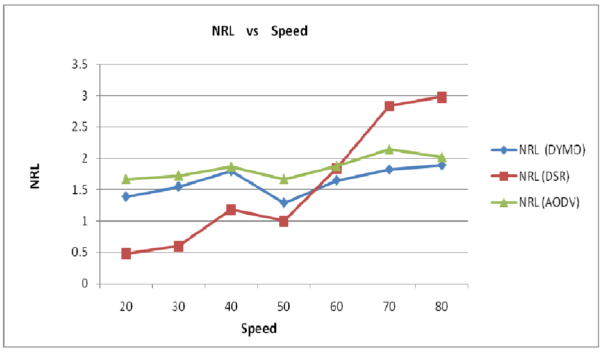

Fig. 5: Simulation result of Normalized Routing Load versus Speed

Conclusion: A performance comparison of DYMO in VANETs has been presented and contrasted with traditional DSR and AODV. Performance evaluation shows that DYMO perform better at certain mobility and offered load. However, at higher mobility, performance of all protocols degrades due to higher routing overheads.

To improve performance in terms of delay bounds or guarantees and lower routing overheads, it will be necessary to develop mechanisms to:

- Update routing tables of the nodes between which communication was broken in order to reduce the route request overhead.
- Remove expired routes and/or determine freshness of routes in the routing tables as these stale routes do contribute unnecessarily to the load in the routing layer.
- Compute multiple paths that can improve routing performance. Due to traffic dispersion it can perform load-balancing, minimize the energy consumed by nodes or prevent traffic congestion.
- Support Quality of Service (QoS) in terms of multiple metrics. For instance, when searching for multiple paths that have the required bandwidth, it is desirable to identify the most reliable paths.

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