

# Deployment of Law Enforcement Department Using Manhattan Mobility Model over Hybrid Network

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**Abstract** — Manhattan Mobility is a model of Vehicular Ad-hoc Network (VANET) where nodes have flexibility to connect and disconnect from the network at any time and have also freedom of movement. Manhattan Mobility Model is proposed generally for urban areas that have grid streets topology, this model is organized in a specific way where there are number of vertical and horizontal streets. In Ad-hoc networks, routing protocols play a vital role in the network's performance because it defines the way of selecting a path from the source node to the destination. In this paper, we are evaluating the performance of three routing protocols namely AODV, DSDV and DSR. The performance evaluation has been done using Network Simulator (NS-2). The comparison was based on the Throughput, Goodput, End-to-End Delay and Network Coverage Area. In our simulation, AODV shows better performance in Throughput and Goodput and DSR performs better in the Network Coverage Area. The performance of the three protocols is comparable with respect to End-to-End Delay.

**Keywords** — AODV, DSDV, DSR, Throughput, Goodput, End-to-End delay, Network Coverage Area, Manhattan Mobility Model, Network Simulator.

## I. INTRODUCTION

Mobility models are classified into several classes. Some classes are based on their dependency on space and time. However, there is a mobility class which has no dependencies on space and time such as Random mobility model. There are models such as Space-dependent models in which the nodes' mobility may be restricted by some geographic restrictions such as street or highways. Some nodes' mobility can be affected by their history. These models are called Temporal models.

The Manhattan Mobility Model (MMM) has high spatial and temporal independences. Nodes' movement on roads is restricted by using a map as shown in Fig. 1. The map shows an urban environment which consists of number of vertical and horizontal streets and each of them has two lanes. The direction of the node in every street is either vertical: north and south or horizontal: east and west. Also, the movement of the nodes is confined within these vertical and horizontal streets. In the intersections (cross point locations), the node movement is represented in three cases. There is a probability for each case. For instance, the probability of a node to take the left turn or right turn is 0.25 and the probability of a node to go straight on the line is 0.5 as shown in Fig. 2 [1].

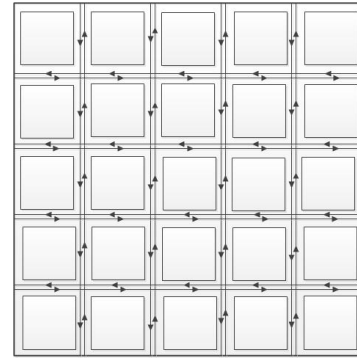


Fig.1. Map shows Manhattan Mobility Model

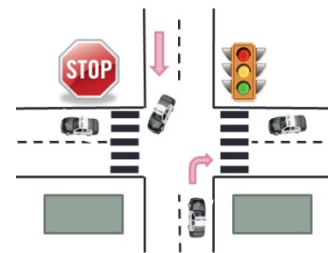


Fig.2. Mobile nodes at the intersections

In each time interval, the mobile node is independent of speed, and by the speed limits on the same street. Moreover, the nodes' speed is limited by the speed of the front nodes in the same line. In the simulation, the nodes' speed cannot be changed. However, in order to make the model more realistic, an ability to change the speed in some situations can be integrated. The speed of a mobile node in a period relies on the node's speed in previous period [2]. Also, Manhattan Mobility Model is called City Street mobility model because of its wide use in city street environment [3].

## II. RELATED WORK

Vehicular Ad-hoc Network (VANET) attracts many information and communication technologies such as the Intelligent Transportation System (ITS) which aims to provide safety, security, reliability and productivity when it is deployed with the current related technologies [4]. The research in Ad-hoc networks has been an active area especially in VANET and MANET networks.

Tuteja *et al.* studied and analyzed the performance of Destination-Sequenced Distance-Vector (DSDV), Ad-hoc On Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) protocols in MANET using NS-2 [5]. The authors found that DSDV has less throughput

performance and high routing overhead than AODV and DSR routing protocols. On average End-to-End Delay, DSR performs better than AODV. Increasing the packet size has no effect on performance of DSDV, but the performance of AODV and DSR are better for shorter packet sizes. By increasing the number of nodes, the performance decreases for all the three protocols.

Kong *et. al.* studied the performance of different routing protocols for maritime wireless mesh network based on a topology divided into five non-overlapping regions [6]. Three routing protocols AODV, Ad-hoc On Demand Multi-Path Distance Vector (AOMDV), and Optimized Link State Routing (OLSR) are presented and compared. OLSR shows the lowest initial packet delay compared to AODV and AOMDV. On the other hand, AODV has less performance than AOMDV regarding routing control overhead and packet delay. Overall, AOMDV has the best performance for maritime communication network.

Ab Rahman *et. al.* studied and evaluated the performance of routing protocols: AODV, DSR, and DSDV in terms of End-to End Delay, throughput, and packet loss in WiMAX networks [7]. The simulation results were compatible with the results of the theoretical analysis. The performance of AODV shows the best whereas it maintains the network according to periodic exchange of information. Based on the results, AODV performs as expected. Overall, DSR shows better performance in all mobility rates and the movement speed where DSDV shows the worst.

Feng *et. al.* studied and compared the performance of four different Ad-hoc routing protocols AODV, DSDV, DSR, and OLSR in NS-2 [8]. In this paper, OLSR and DSDV show the lower average throughput compared with AODV and DSR. Each of DSDV and OLSR shows more stable and smaller average jitters. Growing the size of the network increases the number of the packets, which are generated in the network, for each OLSR and DSDV. Thus, it decreases the throughput and the stability of OLSR and DSDV routing protocols. Overall, DSDV and OLSR routing protocols are more appropriate. On the other hand, AODV and DSR routing protocols are more efficient.

Kulkarni *et. al.* studied and evaluated the performance of AODV, DSDV, and DSR for Quasi Random Deployment (QRD) in Wireless Sensor Networks (WSNs) [9]. NS-2 was used as the simulation tool. In this paper, three major techniques; Measurement, Analytical modeling, and Simulation modeling were considered for evaluating the performance of any system. As a result, DSR performs better in comparison with AODV and DSDV. Moreover, mobility was not integrated in this simulation.

Taksande *et. al.* studied a simulation comparison of AODV, DSDV, and DSR routing protocols with IEEE 802.11 MAC for grid topology in mobile Ad-hoc networks [10]. NS-2 simulations were used as a simulator tool and the comparison was based on received packets, packet delivery ratio, total dropped packets, average End-to-End Delay, considering the number of nodes for each. In this

paper, DSR has better performance than AODV and DSDV with IEEE 802.11 protocol.

Although there are many simulation studies reported in literature that investigate the performance of several MANET routing protocols, these studies are generic and do not address an actual existing network. This paper intends to investigate the performance of DSDV, AODV, and DSR protocols in a specific network that simulates the Manhattan Mobility Model (MMM)

### III. DSDV, AODV, AND DSR ROUTING PROTOCOLS

#### A. Destination-Sequenced Distance-Vector (DSDV)

The Destination-Sequenced Distance-Vector (DSDV) is a proactive routing protocol, and it's a modification of classical bellman-ford routing protocol. In DSDV, each node maintains a table that has all possible destinations in the network with the number of required hops to the destination. A sequence number is assigned for each route to the destination thus it will prevent routing loops. The highest sequence number, which is associated with a route, will always be used. There are two methods to send the updates of the routing table. First, full dump which sends the entire table and that could extend across many packets. Second, an incremental update that contains only the updated routing information since the last full dump, these updates will be sent to the network and it must go in a packet. That will happen when the network is stable. Sending the incremental updates will also avoid the extra traffic. Hence, the full dump is relatively infrequent, but in fast changing networks, the opposite will be true. The incremental updates can increase in size, therefore, full dump will be more frequent.

#### B. Ad-hoc On Demand Distance Vector (AODV)

Ad-hoc On Demand Distance Vector (AODV) is a reactive routing protocol, it establishes the route from source to destination on request only. It discovers all the possible routes from which the messages can be passed. AODV is used for mobile Ad-hoc networks (MANET) and other Ad-hoc wireless networks. The AODV is developed by a common agreement in Nokia Research Center, University of California, Santa Barbara and University of Cincinnati by C. Perkins, E. Belding-Royer and S. Das [4]. It uses a destination sequence number to determine which path is the most recent. When a source node needs to send data to a destination node, it sends a Route Request (RREQ) message to the entire nodes in the network. The message is broadcasted from the originating node to its neighbors, then to their neighbors and so on. Each node remembers the forwarded RREQ and stores it in a buffer table to prevent loops. While the RREQ messages spread in the network, intermediate nodes store the reverse path to the originating node. An intermediate node could have many reverse paths, but it always chooses the shortest path- least hop count. When a node receiving a message request, the message either reaches the destination or another possible fresh enough route to the destination is found. Then, the node sends a Route Reply

(RREP) message to the originating node through the reverse paths. While the RREP message passes the intermediate nodes, the routing table of these nodes will be updated. Thus in the future uses, the messages can be sent again through these nodes to the destination.

### C. Dynamic Source Routing (DSR)

This protocol works on demand, and it eliminates the periodic updates. When a transmitting node sends a request, DSR forms a route on-demand similar to AODV. At each device in between, this protocol uses source routing instead of routing table. This protocol is formed from Route Discovery and Route Maintenance. Determining source routes needs collecting the address of each intermediate node between the source and destination during route discovery. At a route discovery, when a source needs to send a packet to a destination, it broadcasts a ROUTE REQUEST packet. The intermediate nodes that are receiving the ROUTE REQUEST check their route cache for a route to the destination. In case a route to the destination is not found, the ROUTE REQUEST goes further and the node adds its address to the listed hop sequence. This process continues until a node with a route to the destination or the destination itself is found. Acknowledgements are part of the MAC protocol in use (Link-layer Acknowledgement frame – IEEE 802.11) or they are passive acknowledgement. In passive acknowledgement, the nodes aid in forwarding packets to each other. Moreover, a node knows that its packet is received by a node in between, and it can also hear that the packet is further forwarded. If the acknowledgement is not available, a node requests an acknowledgement and sends it directly to the source node through another route. The request of acknowledgement may happen several times. Since this protocol is based on source routing, all the routing information is continually updated. When the message has reached the destination node, a Route Reply would be created, and this is the only case of generating the ROUTE REPLY in DSR. ROUTE REPLY contains the route record which is initially included in the ROUTE REQUEST. The destination node searches its route cache to find the route to the source node. If the route is found, the destination node returns the ROUTE REPLY through that route. Otherwise, the route will be reversed using the route record in the ROUTE REPLY message header. In the event of errors in transmission, the Route maintenance will start according to which the ROUTE ERROR packets are generated at a node and the erroneous hop will be removed from the route cache. Also, all routes including that hop are truncated. At this point, the Route Discovery will start again to find the possible route [4, 10].

## IV. DEPLOYMENT OF MANHATTAN MOBILITY

Our scenario aims to simulate police cars in a crowded area such as Manhattan, New York. Assume that the police cars in Manhattan are divided into 8 groups (A, B, C, D, E, F, G, and H) within a specific area. Each group is responsible for a part of Manhattan. These cars are equipped with the advanced wireless technology, meaning

that if any crime happens in each of these 8 zones, they will be informed quickly—by sending and receiving messages. Each police car can communicate with other police cars within its range. The communication range is limited, but a police car can still communicate with other police cars that are not in its range by the aid of other cars in between. This can be accomplished by relaying information to the desired destination as shown in Fig. 3.

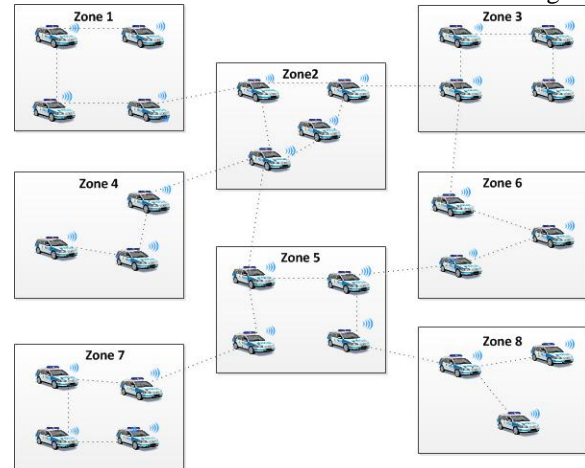


Fig.3. Group of mobile nodes

## V. SIMULATION ENVIRONMENT

### A. Simulation Model

We have used NS-2.35 for simulation of performance comparison of the three routing protocols AODV, DSDV, and DSR over Manhattan Mobility Model. To run NS-2, we chose a Linux platform which is called Ubuntu (version 10.11). Network simulator NS-2 is a discrete event simulator which is used for network investigations and studies [10, 11]. In NS-2, many events such as sending, receiving, forwarding and dropping packets can be simulated. NS-2 is written in two programming languages: C++ and Object Tool Common Language (OTCL). The simulation scripts are written in OTCL language and the simulation outputs appear in a trace file. Moreover, XGRAPH can be used to display graphically the performance metrics. By using NS-2, we can visualize the nodes' transition and other related events.

### B. Simulation Parameters

According to our simulation, the network of nodes is placed within an 800 X 800 square meter area. The transmission range is 250 m. We used Mac layer IEEE 802.11 and Application layer protocol (FTP) with the transport layer protocol (TCP Reno). We have taken 120 nodes as shown in Fig. 4.

These nodes are divided into 8 groups (zones). The nodes within each group can either communicate between each other or with the nodes in other groups. The simulation time in our scenario is 100 sec and the packet size is 512 bits. Table I lists the parameters used in the simulation.

Our goal is to enhance the communication's speed between nodes inside the same zone and among different zones by using the best Routing Protocol. Thus, we try to

investigate the routing protocol that provides a robust communication in a crowded area such as Manhattan.

Table I. Parameters used in the simulation

Parameter	Value
Operating system	Ubuntu 11
NS-2 Version	2.35
Channel type	Wireless Channel
Zone	8 Zones
Simulation Time	100 seconds
Data packet size	512 bits
Area of simulation	800*800 m
Radio Propagation Model	TwoRayGround
Routing Protocol	DSDV/AODV/DSR

### C. Performance Metrics

While comparing the performance of AODV, DSDV, and DSR protocol over Manhattan Mobility Model, we selected the following performance metric: Throughput in Mb/sec versus Time in minutes, Goodput in percentage versus Time in minutes, End-to-End Delay versus Time in minutes, and Network coverage area versus Number of Mobile nodes. The throughput is the percentage of successfully received data per second to individual destinations during the network simulation. Goodput is the ratio of the expected received data payload to the expected transmission time. The following equation is used to calculate the maximum Goodput:

$$\text{Maximum Goodput} = \text{Useful Data Size} / (\text{total packet size} + \text{Packet Overhead}) * \text{Channel capacity} \quad (1)$$

End-to-End Delay is the transmission time of data packets that are delivered successfully to the intended destination. Finally, we investigated the best routing protocol in our simulation.

## VI. EXPERIMENTAL RESULTS

In this section, we discuss the results of the four simulation scenarios in terms of Throughput, Goodput, End-to-End Delay, and Network coverage area. Fig. 4 shows the creation of mobile nodes with Manhattan Mobility Model. Fig. 5 shows data transfer from a source to a destination.

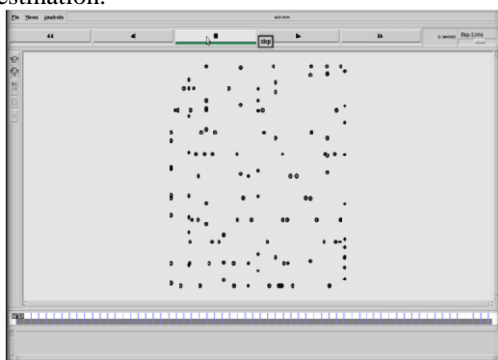


Fig.4. Manhattan Mobility Model

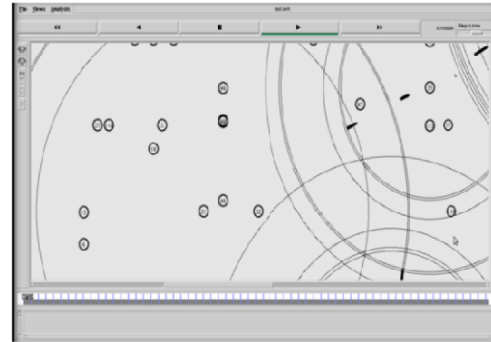


Fig.5. Simulation showing packet transfer between mobile nodes

Fig.6. shows the relative performance of AODV, DSDV, DSR protocols for Throughput with respect to time at minutes 0, 1, 2, 3, 4, 5, 6, and 7. From the figure, if we take the average we can observe that AODV protocol has better performance than DSDV and DSR protocols.

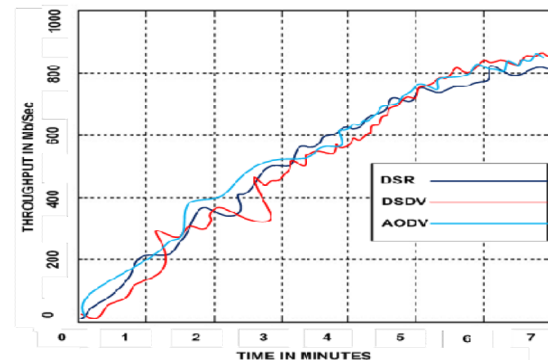


Fig.6. Throughput measurement

Fig.7. shows the relative performance of AODV, DSDV, DSR protocols for Goodput with respect to the time at minutes 0, 1, 2, 3, 4, 5, 6, and 7. In terms of Goodput, AODV shows a better performance than DSDV and DSR.

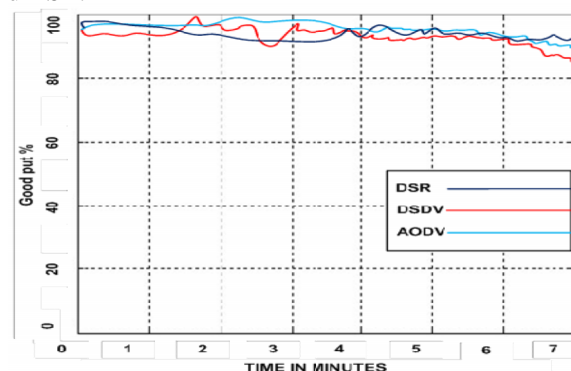


Fig.7. Goodput measurement

Fig.8. shows the relative performance of AODV, DSDV, DSR protocols for End-to-End Delay with respect to the time at minutes 0, 1, 2, 3, 4, 5, 6, and 7. In Fig. 8, we can observe that all the three protocols show comparable results. Thus, any of these protocols can be applied with no significant difference in terms of End-to-End Delay.

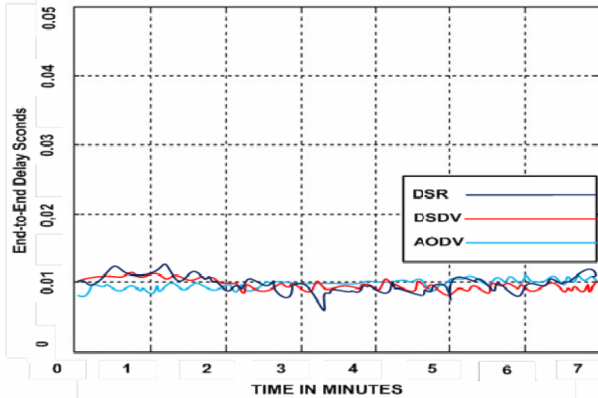


Fig.8. End-to-End Delay measurement

Fig.9. shows the relative performance of AODV, DSDV, DSR protocols for Network coverage area for a range of 0-120 mobile nodes. It is obvious from the figure that DSR outperforms both DSDV and AODV protocols. While using DSR protocol, the percentage of the coverage area increases whereas the number of mobile nodes increases.

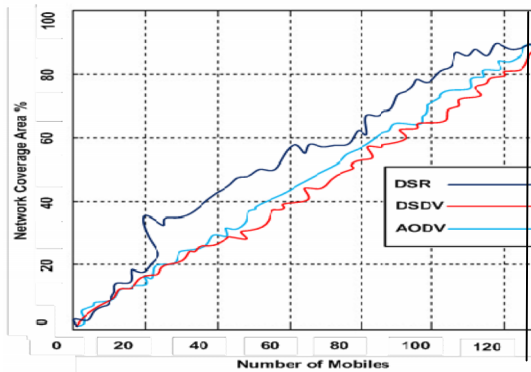


Fig.9. Network Coverage Area measurement

## VII. CHOOSING THE BEST ROUTING PROTOCOL

Table II summarizes the simulation results presented earlier. It shows the best performing protocol for each parameter according to our simulation.

Table II. Selecting the best routing protocol

Parameters	Best Protocol
Throughput	AODV
Goodput	AODV
End-to-End Delay	All are comparable
Network Coverage Area	DSR

## VIII. CONCLUSION

In this paper, we analyzed the performance of three different routing protocols; AODV, DSDV, and DSR over a complicated mobility model such as Manhattan. Through the simulation, we observed that AODV performs better than DSDV and DSR for Throughput and Goodput. End-to-End Delay for all three protocols is comparable. DSR performs the best in Coverage Area.

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