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Reactive Gateway Discovery Routing in Hybrid MANETs

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ABSTRACT: Hybrid MANETs enables mobile nodes to access internet services, and is achieved through gateways which act as bridges between a MANET and the Internet. A gateway discovery mechanism enables a mobile node to communicate with an Internet. The reactive gateway discovery routing is based on modified AODV routing protocol, so that in this paper a modification to NS2 has been adjusted to support a modified Ad-hoc On Demand Distance Vector (AODV) routing protocol called AODV+ to integrate MANET with Internet using a stationary gateway. Due to the dynamic nature of MANET, the changes in topology are very frequent and the task of routing the data turns out to be a challenging. Hence, in this paper the performance of modified AODV has been evaluated according to three performance metrics: Discovery time, End-to-end delay and Number of dropped packets under different mobility models and varying maximum speed for different number of nodes.

KEYWORDS: MANET; reactive gateway discovery; AODV+; NS2; discovery time; mobility models

I. INTRODUCTION

In recent years, mobile wireless networks have become increasingly popular in the computing industry. There are currently two variations of mobile wireless networks. The first is known as the infrastructure network which is a network with fixed and wired gateways. The bridges for these networks are known as base stations [1]. A mobile node within these networks connects to, and communicates with, the nearest base station that is within its communication range. As the mobile travels out of coverage of one base station and into the coverage of another, a “handoff” or in GSM “handover” occurs from the old base station to the new, and the mobile is able to remains connected seamlessly throughout the network.

The second type of mobile wireless network is the infrastructure-less mobile network, commonly known as an ad hoc network or mobile ad hoc network (MANET). Infrastructure-less networks have no fixed routers; all nodes are capable of movement and can be connected dynamically in an arbitrary manner [2]. The ease of distribution and absence of the need for any infrastructure make MANET an attractive choice for a diversity of applications. The term “ad hoc” implies that the network is meant for special purpose, it should be able to set up with lowest manual effort and short time. The interconnection of Mobile Ad hoc Network (MANET) and the internet into a hybrid network increases the network capacity, widen the coverage of wireless network and enlarge the communication base as well as the application range of ad hoc networks [3]. There has been much research done on combination of MANET with Internet during last years [4]. Solution that was used to provide the connectivity of MANET with Internet but with time it was declined is Mobile IP [5] concept. So an attention was on internet gateway beside ad hoc routing protocols.

The Internet and mobile ad hoc network present a set of communication features. The Internet is based on a worldwide infrastructure, whereas the infrastructure-less mobile ad hoc network offers the benefit of communication during mobility. To be able to communicate with any other device anywhere in the world using mobile node, the mobile ad hoc network is connected to the Internet, resulting in a hybrid MANET architecture [6].

As shown in the figure 1, internet gateway acts as a bridge between MANET and Internet. The principal purpose involved in this architecture is discovery of gateway by MANET for the transfer of data to wired network. To accomplish this purpose, gateways that understand not only the IP suite but also the MANET protocols stack are

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required [4]. Gateway used will operate as a bridge between wired and ad hoc network. The data transferred between two networks must go by through internet Gateway. With this the restriction of MANET of limited coverage area can be overwhelmed and the total coverage area and the application domain can be extended. Hence, the routing in such domain becomes a challenging task. The Internet Engineering Task Force (IETF) introduced many routing protocols for MANETs, such as Ad hoc On-Demand Distance Vector (AODV) [7], Dynamic Source Routing (DSR) [8], Optimized Link State Routing Protocol (OLSR) [9], Topology Dissemination Based on Reverse-Path Forwarding (TBRPF) [10] and Destination-Sequenced Distance Vector (DSDV) [11].

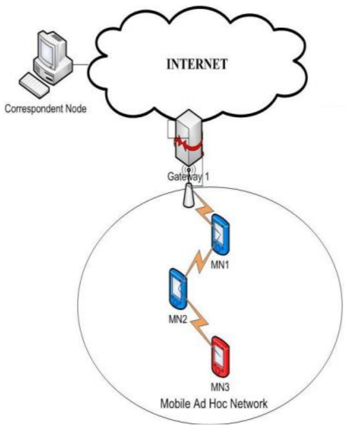

Fig. 1. Architecture of a Hybrid MANET [6]

However, these protocols were proposed for routing in an autonomous MANET, so that it needs to be modified in order to make routing between a mobile node in a MANET and a host device in a wired network. The AODV routing protocol is one of the most widely used and implemented routing protocols investigated by the IETF MANET working group [12]. Hence, in this paper, the source code of AODV in NS2 [13] has been modified in accordance with the Internet draft "Global connectivity for IPv6 Mobile Ad Hoc Networks" which presents a solution where AODV is used to provide Internet access to mobile nodes and according to modifications done in [12], that is to achieve routing of packets towards a wired network. Also, this paper studies the impact of nodes mobility on the discovery time of internet gateway. Also, it evaluates the performance of modified AODV (AODV+) [16] with different mobility models and varying number of mobile nodes according to the following performance metrics: End-to-end delay and Number of dropped packets.

The rest of this paper is organized as follows: section 2 presents related work in the area of gateway discovery in heterogeneous networks. Section 3 contains problems with AODV and its solutions to make it suitable for hybrid MANETs. Section 4 provides a brief overview of the three types of traditional gateway discovery methods. Section 5 introduces simulation model and performance evaluation followed by section 6 which provides simulation results. Finally, section 7 concludes this paper.

II. RELATED WORK

The work in [12] proposed three methods of gateway discovery methods namely: proactive, reactive and hybrid by modifying the AODV routing protocol. The performance of all the gateway discovery methods was studied according to end-to-end delay, packet delivery ratio and overhead using random waypoint only and nodes' speed is distributed uniformly in the interval [1, 19] m/s. In [15], authors reveal that the reactive Internet gateway discovery approach scale poorly with increase in number of traffic sources and node mobility to access Internet as compared to the proactive and hybrid gateway discovery approaches. However, reactive gateway discovery results higher throughput and lower end-to-end delay for the same situation than proactive and hybrid approaches. Hybrid Internet gateway discovery approach performance was always observed in between reactive and proactive approaches.In [4], the performance of the key protocols modified AODV and Destination-Sequenced Distance Vector (DSDV) has been evaluated by simulating

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them in the wired cum wireless scenario and their performance has been compared on the basis of three performance metrics: packet delivery ratio, average end-to-end delay and average throughput. The work presented in [14] considers the mobile nodes to be mobile but at a constant speed range and constant pause time, using random way point mobility model to compare the gateway discovery methods.

All the previous related work doesn't refer to impact of nodes mobility on gateway discovery time under different mobility models. In [2], author observed that the gateway discovery time increases with increasing the maximum speed of the nodes. Also concluded that, when the pause time is varied keeping the maximum speed of all the nodes at 50 m/s, the effect on discovery time is observed to be almost negligible after the pause time exceeds the value 30 second. But this work doesn't refer to other performance metrics like: end-to-end delay, dropped packets and overhead. Also this work uses only random waypoint mobility model and doesn't refer to the impact of any other mobility model on discovery time.

III. Modified AODV (AODV+)

Suppose that a mobile node (S) needs to communicate with another node (D) and that node S does not have any route to D in its routing table. Hence, S does not know whether D is a mobile node (located within the MANET) or a fixed node (located on the wired network). If AODV is used as the ad hoc routing protocol, node S broadcasts a RREQ, demanding for a route to D. If D is a mobile node, the node itself or another mobile node with a fresh route to it will unicast back a RREP to node S. However, if node D is a fixed node, no mobile node will send a reply to node S. So the solution for this problem on the reactive gateway discovery method applied, it is considered that, if node S broadcasts a RREQ but no corresponding RREP is received, node S assumes that node D is a fixed node. Hence, the packets are sent to the Internet by using the default route.The question here is: how many RREQs does node S have to send, without receiving any corresponding RREP, before it can assume that node D is located on the Internet? In the reactive discovery method implemented uses expanding ring search to find a route to node D. To be completely sure that node D is not a mobile node located within the MANET, node S must do, at least, one network-wide search. Since a network-wide search consumes a lot of time and link bandwidth, it is done only once [2].

A. *The Operation of Gateway upon Reception of RREQs*:

In the reactive gateway discovery method applied in this paper: If a gateway receives a RREQ and finds the host route in its routing table, the gateway unicasts a RREP (and optionally also a RREP_I) back to the originator of the RREQ. This way, a mobile node may obtain a default route although it has not demanded this route. If the mobile node is to communicate with the Internet later, this default route can be used and hence, the mobile node does not have to send another request packet in order to find a route to a gateway.

B. *TheOperation of Intermediate Node upon Reception of RREQs*

When an intermediate mobile node receives a RREQ packet, it searches its routing table for a route to the destination. If the destination is a fixed node, the intermediate node must not send a RREP back to the originator of the request packet even if the route is found. Because if the intermediate node sends a RREP back to the originator of the RREQ packet, the originator considers that the destination is a mobile node that can be reached via the intermediate node. It is important for the originator of the RREQ to know that the destination is a fixed node and not a mobile node, as they are processed differently.If a mobile node can't reach any gateway and although the destination is a fixed node, mobile node broadcasts a RREQ_I packet to the IP address for the group of all gateways in the mobile ad hoc network. However, since the gateway is unreachable for the mobile node, the RREQ_I packet is not received by gateway (or any other gateway). Mobile node uses the expanding ring search technique when it broadcasts RREQ_I packets, but not even a RREQ_I packet with the TTL value set to NET_DIAMETER is received by any gateway, assuming MN cannot reach any intermediate mobile node that can forward the RREQ_I packet on its behalf.

After doing a network-wide search without receiving any corresponding RREP_I packet from any gateway, mobile node pauses for a while. When the pause is finished, mobile node does another network-wide search and pauses again if no RREP_I is received. This procedure continues until mobile node moves close to a gateway or an intermediate

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mobile node so it can receive a RREP_I from a gateway. When a gateway is found, mobile node sends its data packets to the fixed node through the found gateway.

IV. Gateway Discovery Methods in Hybrid MANETs

There are three types of Gateway Discovery algorithms depending on the gateway configuration phase initiation and also on the method of route update. If the configuration phase is initiated with the gateway, proactive method is applied. But if it is by the mobile node, reactive method is used. The combination of these two methods is called hybrid proactive/reactive method. In the following sections these methods are discussed briefly.

A. *Proactive Gateway Discovery*

In the proactive gateway discovery method, gateway discovery process is initiated by the gateway itself. The gateway periodically broadcasts a gateway advertisement (GWADV) packet which is transmitted after expiration of the gateway's advertisement interval timer that is the time between two successive advertisements must be chosen with care so that the network is not flooded unnecessarily. All mobile nodes residing in the gateway's transmission range receive the advertisement.

B. *Reactive Gateway Discovery*

In this method, discovery method is initiated by a mobile node that is to initialize or update information about the gateway. The mobile node broadcasts a RREQ_I to IP address for the group of all gateways in a mobile ad hoc network. Thus, only the gateways are addressed by this packet and only they process it. Intermediate mobile nodes that receive the packet just forward it by broadcasting it again. Since the packet format is RREQ, which has a unique request id field, duplicated RREQ_Is are discarded. Upon receipt of a RREQ_I, a gateway unicasts back a RREP_I which, among other things, contains the IP address of the gateway. The advantage of this method is that RREQ_Is are sent only when a mobile node needs the information about reachable gateways. Hence, periodic flooding of the complete mobile ad hoc network, which has obvious disadvantage, is prevented. Hence, this method is chosen for simulation in this paper.

C. *Hybrid Gateway Discovery*

For mobile nodes in a certain range around a gateway, proactive gateway discovery is used. Mobile nodes residing outside this range use reactive gateway discovery to obtain information about the gateway.

V. Simulation Model and Performance Evaluation

This section studies the impact of nodes mobility on the discovery time of internet gateway using AODV+ as a reactive gateway discovery method. Also it evaluates the performance of AODV+ with different mobility models and varying number of mobile nodes according to different performance metrics. Simulation is carried out in wired-cum-wireless scenarios using NS2.34 under Linux platform. Mobility models used in this paper are generated by using Bonn Motion scenario generation tool [17].

A. *Simulation Model*

Simulation area is 500m x 1000m, which is a rectangular topology so as to make longer rout for packet exchange and make it more suitable to evaluate the performance. The studied scenarios consists of one source node plus variable number of mobile nodes, one gateway and two wired hosts. The gateway node is placed at the bottom of the simulation area above the two hosts. The (x, y) coordinate in meters for the gateway is (250, 10). Simulations are run for 300 seconds for all scenarios. All fixed links have a bandwidth of 5Mbps, which is sufficient to accommodate all traffic coming from the mobile nodes.

IEEE 802.11 is used as MAC layer protocol and mobile nodes use modified AODV protocol to communicate with its peers and to access wired networks through an Internet gateway.The first scenario is considered when there are 20 mobile nodes, the second scenario considers 30 mobile nodes and the third scenario considers 40 mobile nodes. All

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mobile nodes in these scenarios are moving at different maximum speeds. The speeds are varied from 20 m/s maximum up to 100 m/s. The screen shot of simulation environment is shown in figure 2.

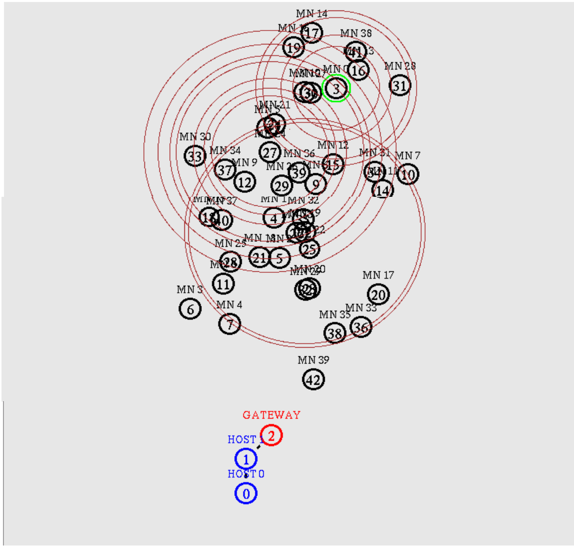

Fig. 2. Screenshot of simulation environment

B. *Mobility Models*

There are three mobility models used in this paper. The first one is Random Waypoint [19], where each mobile node starts the simulation by remaining static for pause time seconds. It then selects a random destination in the defined topology area and transfers to that destination at a random speed. The random speed is distributed uniformly between zero (zero not included) and the maximum speed given for each simulation run. Upon reaching the destination, the mobile node pauses again for pause time seconds, selects another destination, and proceeds there as previously described. This movement pattern is repeated for the duration of the simulation. The second mobility model is Manhattan mobility model. It was introduced in [20] and models the behavior of vehicles in a city area. Movements of vehicles are restricted to a map containing roads in horizontal and vertical direction. When a sensor node reaches an intersection, it randomly selects the street it will follow. The probability of moving straight is 0.5 and the sensor node turns left or right with probability of 0.25 each.

The third mobility model is Reference Point Group Mobility (RPGM). This model is proposed in [21] where each group has a center, which is either a logical center or a group leader node. For the sake of simplicity, we assume that the center is the group leader. Thus, each group is composed of one leader and a number of members. The movement of the group leader determines the mobility behavior of the entire group. One example of such mobility is that a number of soldiers may move together in a group. Another example is during disaster relief where various rescue teams (e.g., firemen, policemen and medical supporters) form different groups and work cooperatively.

C. *Communication Model*

The traffic type used here is Constant Bit Rate (CBR) which uses User Datagram Protocol (UDP) as its transport layer protocol. The data packet size is 512 Byte sent every 0.2 seconds. The reason of using UDP instead of TCP is that TCP performs poorly in ad hoc network because packets are lost due to link failure and route changes trigger TCP's congestion avoidance mechanism [18].

D. *Performance Metrics*

To evaluate the performance of reactive gateway discovery method in a hybrid MANETs, the following performance metrics are used:

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- **Discovery time.** How the gateway is affected by nodes mobility. To achieve this, the discovery time needs to be measured. It is defined as the time spent from the start time of sending request from source node until the gateway sends a reply packet. This measurement is taken for each speed change.
- **End-to-End delay.** It is defined as the time a data packet is received by the destination minus the time the data packet is generated by the source.
- **Number of dropped packets.** It is defined as the number of dropped packets at source node.

To get correct results, each data point is obtained from the average of five simulation runs with different randomly generated movement patterns.

E. *Simulation Parameters*

The parameters that are common for all simulations are given in table 1.

Table 1. Simulation parameters

Parameters	**Values**
Topology Size	500m x 1000m
Number of Mobile Nodes	20, 30 and 40 nodes
Number of wired hosts	2
Number of gateways	1
Transmission range	250 m
Simulation time	300 sec
Mobility Models	Random waypoint, Manhattan and RPGM
Mobile node speed	Vary from 20 m/s up to 100 m/s
Traffic type	Constant bit rate (CBR)
Data rate	5 packet/sec
Packet size	512 bytes

VI. SIMULATION RESULTS AND DISCUSSIONS

Simulation presented in the following sections is based on three different performance metrics as follows: gateway discovery time, end-to-end delay and number of dropped packets when varying number of mobile nodes using different mobility models.

A. *Gateway Discovery Time*

In this section, the impact of nodes' mobility on gateway discovery time is studied under three different scenarios. First Scenarioshows the impact of varying mobility speed on discovery time when number of mobile nodes is 20 nodes using three different mobility models as shown in the following.

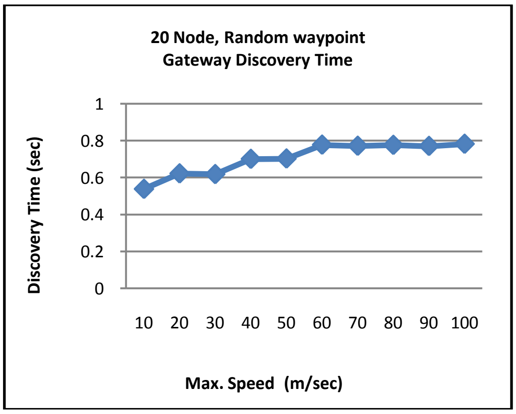

Fig. 3. Discovery time using random waypoint

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As shown in figure 3, as the maximum speed of mobile nodes increase, gateway discovery time increases. For example when max speed = 10 m/sec, discovery time equals 0.537627647 second and when max speed = 20 m/sec, discovery time equals 0.62159827 second and so on until discovery time reaches stability state.

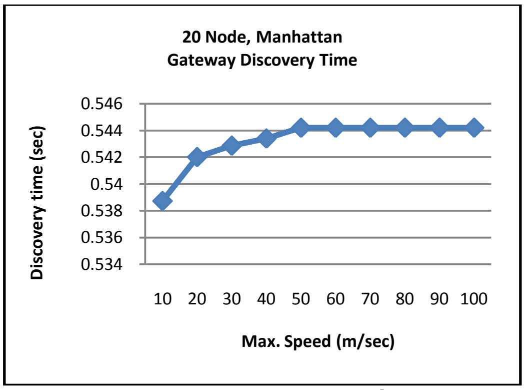

Fig. 4. Discovery time using Manhattan

Figure 4 illustrates the impact of mobility speed on discovery time using Manhattan mobility model. In this figure it can be stated that, when max speed increase, discovery time also increase. For example, when max speed equals 10 m/second, gateway discovery time equals 0.538720363 second. At max speed equals 20 m/second, discovery time = 0.542009076 second until max speed reaches 50 m/sec, at this value discovery time settled at 0.5442068 second.

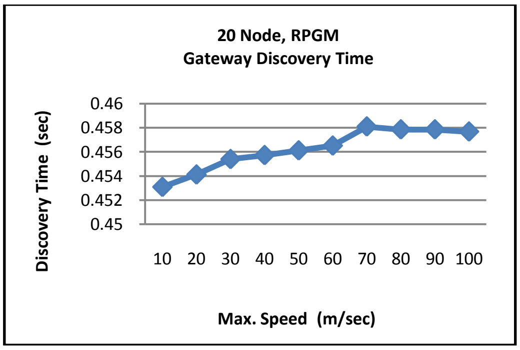

Fig. 5. Discovery time using RPGM

In figure 5, the impact of mobility speed on gateway discovery time is studied using RPGM mobility model. This mobility model is used to describe the applications such as military and battlefield operations. In this figure gateway discovery time increases when max speed of mobile nodes increase. Second Scenario, study the impact of varying mobility speed on discovery time when number of mobile nodes is 30 nodes using three different mobility models.

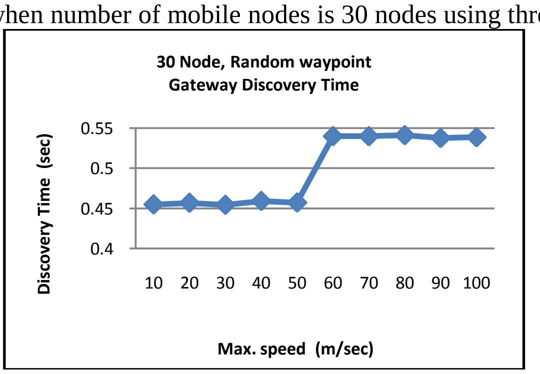

Fig. 6. Discovery time using random waypoint

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As shown in the above figure, gateway discovery time increases, as the maximum speed of mobile nodes increase. When max speed = 10 m/sec, discovery time = 0.45488618 second and when max speed = 20 m/sec, discovery time = 0.456927963 second and so on till max speed reaches 60 m/sec at this point discovery time = 0.539904485 second. After that discover time will fluctuates around small values.

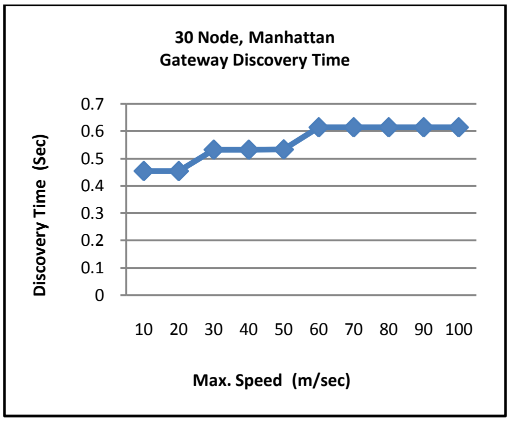

Fig. 7. Discovery time using Manhattan

Figure 7shows the impact of mobility speed on discovery time using Manhattan mobility model under 30 mobile nodes. At max speed = 10 m/sec, discovery time = 0.454580457 second and when max speed = 30 m/sec, discovery time increases to 0.532399053 second and reaches stability state when max speed equals 60 m/sec.

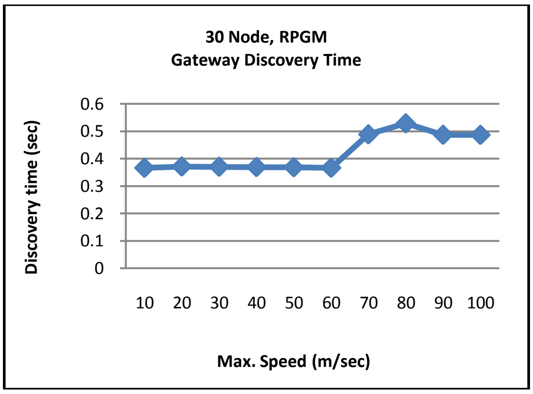

Fig. 8. Discovery time using RPGM

As shown in figure 8, the impact of mobility speed on gateway discovery time is studied. At max speed = 10 m/sec, discovery time equals 0.366891838 second and when max speed = 70 m/sec, discovery time jumps to 0.48894564 second. Third Scenario, studies the impact of varying mobility speed on discovery time when number of mobile nodes is 40 nodes using three mobility models as shown in the following figures.

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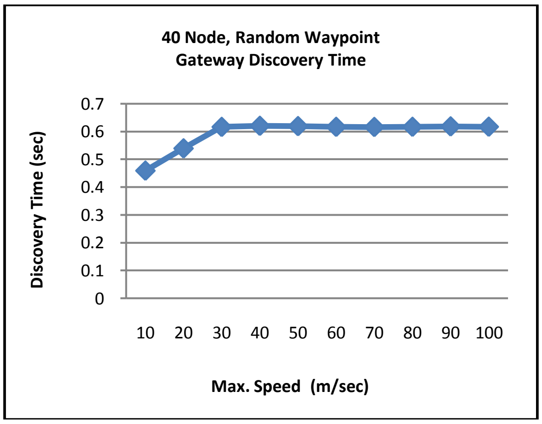

Fig. 9. Discovery time using random waypoint

In this scenario the impact of mobility speed on gateway discovery time is presented using 40 mobile nodes. As shown in figure 9, at max speed = 10 m/sec, discovery time equals 0.459113946 second and when max speed = 30 m/sec, discovery time increases to 0.616988258 second.

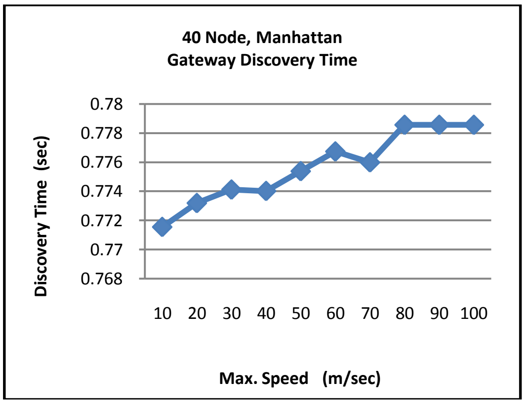

Fig. 10. Discovery time using Manhattan

As shown in figure 10, gateway discovery time increases as mobility speed of mobile nodes increase using Manhattan mobility model. At max speed = 10 m/sec, discovery time equals 0.771546846 second and when max speed equals 30 m/sec, discovery time increases to 0.774113502 second.

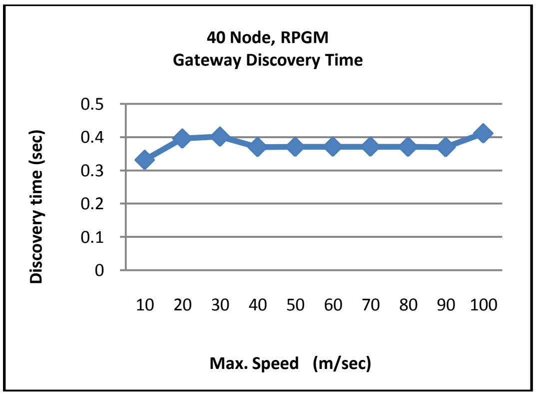

Fig. 11. Discovery time using RPGM

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In figure 11, the impact of mobility speed on gateway discovery time under RPGM mobility model is studied. As shown when max speed = 10 m/sec, discovery time equals 0.331209756 second and when max speed equals 30 m/sec, discovery time jumps to 0.401202936 second.

***Discussion and Comments*:** The dynamic topology of MANETs affects the internet gateway discovery process. The reactive gateway discovery is initiated by a mobile node as discussed in previous sections, either to initialize or update information about the gateway. The mobile node broadcasts a RREQ_I packet to all IP address for the group of all gateways in a mobile ad hoc network. Thus, only the gateways are addressed by this packet can process it.

Intermediate mobile nodes that receive the message just forward it by broadcasting it again. As nodes are free to move when a node which is on the potential gateway discovery path moves, it may go out of the radio range of communication range of the immediate neighbour node. If the two nodes are out of the communication coverage of each other, the communication between them can't be established. When similar scenario occurs on all the nodes which can be used to communicate the gateway, depending on the speed of the nodes and the direction of movement, the RREQ_I packet will be delayed. After waiting for time out period the node needs to send another RREQ_I packet. All this time is accounted for the delay for the discovery of the gateway. This implies that, the discovery time of the reactive gateway discovery process is affected when varying the speed under different types of movement patterns.

B. *End-To-End Delay*

In this section the delay time spent for sending packets from source node to the fixed host is measured when varying movement speed under different mobility models. This metric includes all possible delays caused by buffering during the Internet gateway discovery latency, route discovery latency, queuing at the interface queue, retransmission delays at the MAC layer, and propagation and transfer times.

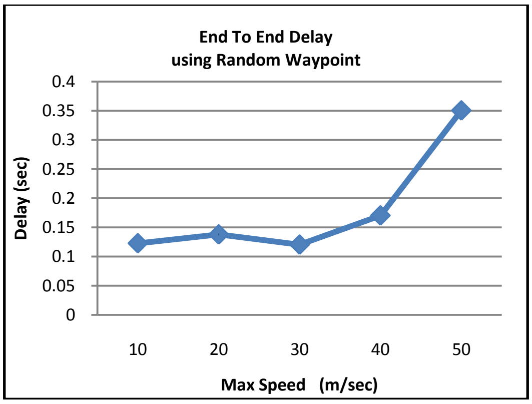

Fig. 12. End-To-End delay using randomwaypoint

Figure 12 illustrates the impact of mobility speed on the end-to-end delay using random waypoint mobility model. As shown at max speed = 10 m/sec, delay equals 0.122686897 second and when max speed = 40 m/sec, delay increases to 0.170338975 second and so on. From this figure, as mobility speed increases the end-to-end delay increases also.

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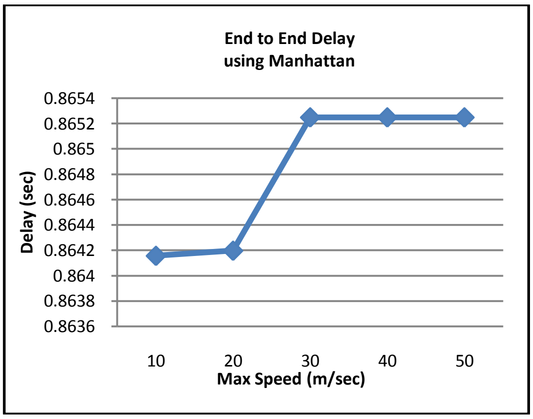

Fig. 13. End-To-End delay using Manhattan

In figure 13, the end-to-end delay is presented when varying movement speed using Manhattan mobility model. When max speed = 10 m/sec, delay equals 0.864156158 second and when max speed = 30 m/sec, delay jumps to 0.865249494.

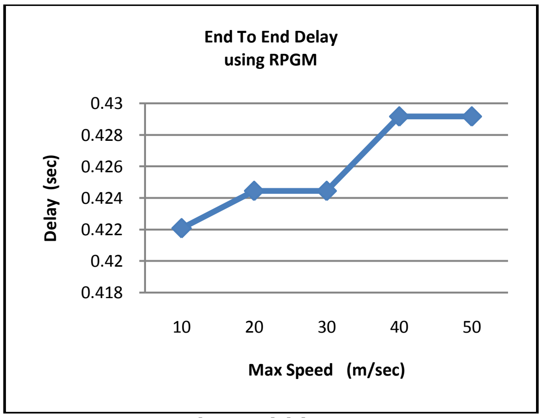

Fig. 14. End-To-End delay using RPGM

As shown in figure 14, the impact of mobility speed on the end-to-end delay is studied using RPGM mobility model. For example when max speed = 10 m/sec, delay equals 0.422070662 second and when max speed = 40 m/sec, delay increases to 0.429160597 second.

Discussion and Comments: When a mobile node which is part of a route moves, it may go out of the radio range of communication coverage of the immediate neighbour node, which is part of the same route. If the two nodes are out of the communication range of each other, the link between them will fail. In order to continue the communication a new route has to be discovered, which does mean additional time to replace the filed route. Since the next packet will be transmitted after the failed route is replaced, the time spent to find a new route may increases the end to end delay of packet transmission. Hence from the previous figures, as the speed of mobile nodes increase, the end-to-end delay increase under different movement patterns.

C. *Number of Dropped Packets*

In this section number of dropped packets is measured when varying movement speed which ranges from 10 m/sec. up to 50 m/sec using random waypoint mobility model and number of mobile nodes equals 30 nodes.

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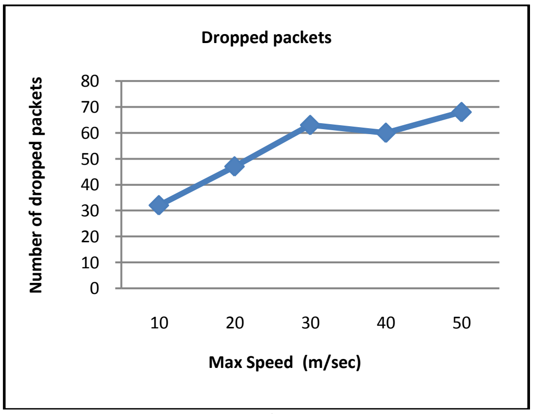

Fig. 15. Number of Dropped Packets

***Discussion and Comments*:** In MANTE, if the two communicating parties are found out of the communication range of each other, the path between them will use intermediate nodes. Since in MANET nodes are free to move, the established route will be affected by the movement of the nodes on the path. As stated before, when a node which is part of a route moves, the two nodes are out of the communication range of each other hence the link between them will fail. This in turn causes the route, which uses the given link, to fail. As a consequence of the route failure, packets to the destination on the route will be dropped. From the previous figure, number of dropped packets increases when the speed of mobile nodes increases.

VII. CONCLUSION

In this paper the impact of node mobility on the performance of reactive gateway discovery routing is studied for a heterogeneous wired cum wireless networks (hybrid MANETs). Hence, NS2 has been adjusted to support a modified Ad-hoc On Demand Distance Vector (AODV+) routing protocol so as to integrate MANET with Internet using a stationary gateway. The evaluation process has been implemented according to three performance metrics as follows: Gateway discovery time, end-to-end delay and number of dropped packets. These metrics has been applied with varying mobility speed, mobility model and number of mobile nodes so as to assess the simulation and gets accurate results. According to the first metric, the gateway discovery time is affected by the mobility of the mobile ad hoc network nodes. The higher the mobility, the longer the discovery time will be. This also implies that, the mobility of the mobile nodes in MANTEs needs to be given a special attention while evaluating gateway discovery time as a metric. According to the second metric, end-to-end delay increase as the speed of mobile nodes increase under different movement patterns due to longer time spent to find a new route as a link fails. According to the third metric, due to frequent link failures as a speed of mobile nodes increase, number of dropped packets increase under different mobility models.

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