International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Dynamic Gateway Load Balancing in Integrated Internet-MANET

Manjula S [1], Suresha[2]

[1]Research Scholar DoS in Computer Science, University of Mysore Manasagangotri, Mysore, India

[2] Professor, DoS in Computer Science, University of Mysore Manasagangotri, Mysore, India

Abstract: ***Mobile Ad hoc Network (MANET) is a network of mobile devices capable of configuring itself. MANETs does not have any fixed topology. MANETs are combined with internet forming a hybrid network to widen the coverage and to access the global services. The mobile Nodes in MANET can be connected to the internet through gateways. There are 2 types of gateways. Namely Static gateways, Dynamic gateways. To connect mobile nodes with internet these nodes must find and register with the gateways using gateway discovery mechanism. In this paper we are proposing the concept of Dynamic gateways. One of the issues in integrated internet-MANET is congestion. To address this issue we proposed a load balancing algorithm. Our algorithm reduces congestion in the network by balancing the load among mobile nodes and gateways as well. The parameters used for the performance analysis of our algorithm are Packet delivery ratio, throughput and routing overhead.***

Keywords: MANET, Integrated Internet-MANET, Hybrid Networks, Routing Protocols, Gateway Discovery, Congestion.

1. Introduction

A Mobile Ad-hoc Network is a collection mobile nodes which doesn't have any fixed topology. Each node in MANET can move independently in any direction. Because of this, links between mobile nodes will change frequently. Each mobile node consists of wireless interface and communicates with other nodes through radio signals. Each mobile node maintains the information required to properly route the packets. MANETs use routing protocols like AODV, DSDV, DSR and OLSR etc., to route the traffic between nodes. To widen the MANET Network coverage and application domain, we integrated MANET with Internet forming a Hybrid Network. Mobile nodes in MANET can be connected to the Internet through an interface called gateways. For a mobile node to get connected to the internet it has to first find the available gateways and register with it through gateway discovery mechanism. Once the mobile node gets connected to the gateway it can communicate with the remote node which is connected to the internet. In this work we are using dynamic gateway for the communication of mobile nodes and fixed nodes. A dynamic gateway is a MANET node with extra capability, which is one hop away from foreign agent. Thus the movement of dynamic gateways is limited to the coverage of foreign agent. When dynamic gateways move out of coverage area of foreign agent it becomes normal MANET node not a dynamic gateway. Figure 1 Shows MANET-Internet Connectivity.

This integration of MANET-Internet can be simulated using NS2 simulator. In this kind of networks, various issues arise. Two of the issues of interest in the current work are discussed here. For a mobile node to get connected to gateways, it has to first find and then register with the gateway. This can be achieved in one of three ways: proactive, reactive or hybrid. Second issue in hybrid network is congestion among mobile nodes and gateways. To circumvent this problem, some load balancing mechanism must be employed to reduce packet loss due to congestion.

In this work we are proposing load balancing algorithm which reduces the congestion in the network by balancing the load among mobile nodes and dynamic gateways.

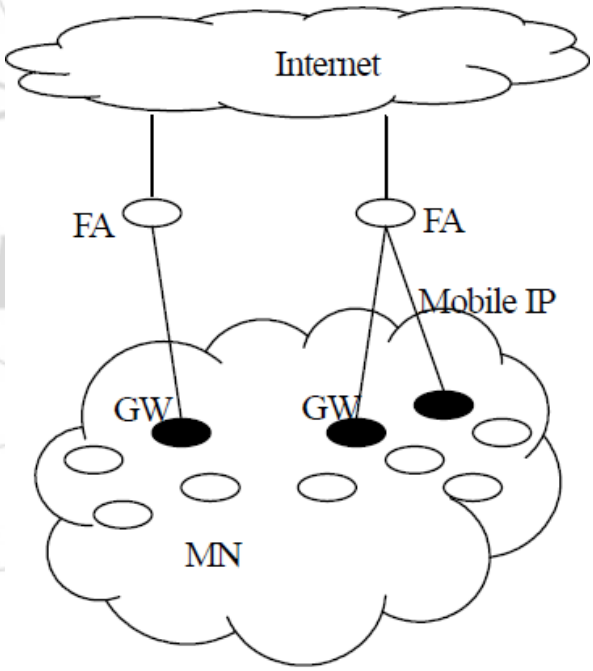

Figure 1: MANET-Internet Connectivity

2. Related Work

In this section we discuss briefly on the existing work on integrated Internet-MANET and in this for integrated Internet-MANET various architectures are present in the literature.

A. Sharmila, R. Selvakumar, *et al.* describes a study on integrating MANET with Internet in [1].Ali Hamidian, Ulf Korner *et al.* gives solutions to Internet Access for Mobile Ad-hoc Network and the traditional gateway discovery mechanisms are also described and simulated in [2].In [3]

Harjeet Kaur, Varsha Sahni *et al.* gives a survey of various types of routing protocol such as Proactive, Reactive and Hybrid..Various types of mobility models are present in the literature. Tracy Camp, Jeff Boleng *et al.* describes about survey of mobility models simulated in the paper [4].The issue of gateway load balancing is addressed by various authors in the literature. Rafi U Zaman, Khaleel Ur Rahman Khan *et al.* in [7], proposed review of existing gateway load balancing strategies.

Pedro M. Ruiz *et al.*, in [8] proposes maximal source coverage algorithm which is used to dynamically adjust the proactive zone of the Integrated Internet-MANET. This was the first attempt to address the issue of adaptive gateway discovery.

Khan K. U. R., Reddy A *et al.* presented the issue of path load balanced routing in [9]. Kumar, R., Misra, *et al.* in [10], an optimized version of the approach presented in [9] was discussed.

Javaid, U., Rasheed *et al.* proposed a novel method of adaptive gateway discovery was discussed which worked in a distributed mode in [11].

In [8] and [11], adaptive gateway discovery mechanisms were presented which used the fuzzy logic concepts to adapt the gateway discovery according to various parameters. Zaman, R.U., Khan, *et al.* in [13]. Proposed the concept of dynamic gateways.

3. Routing Protocols

A routing protocol indicates how routers in a network communicate with each other and report changes. It uses algorithms to determine optimal path and perform data transfer between network nodes. MANET routing protocols are classified into 3 types:

Proactive
Proactive routing protocols are also called as Table Driven routing protocols because, they have to maintain routing information of the nodes in the table. Each node in proactive routing protocol maintains such table containing routing information so that data can be transferred to the destination. Each entry in the table contains information such as cost of the route to be followed and next hop to reach a node. Proactive routing protocols are not recommended for large networks, since it is difficult to maintain table entries for large network. DSDV (Destination Sequenced Distance Vector) is proactive protocol.

Reactive
Reactive routing protocols are also called as On Demand routing protocols because in reactive routing protocol routes are established only on demand. In this protocol when a source wants to communicate with the destination, it starts a route discovery mechanism to find an optimal path to the required destination. Here the routes are created on demand by broadcasting Route Request packets. AODV (Ad hoc on demand Distance Vector), AOMDV (Ad hoc on demand Multipath Distance Vector), DSR (Dynamic Source Routing) etc. are Reactive protocols.

Hybrid
Hybrid routing protocol is a combination of both Proactive and Reactive routing protocol. Hybrid protocol was proposed to reduce the routing overhead caused by proactive protocol and also to reduce the latency caused by route discovery in reactive protocol. ZRP (Zone Routing Protocol) and TORA (Temporarily Ordered Routing Algorithm) are hybrid protocols.

4. Gateway Discovery

A Mobile node which wants to communicate with a wired node which is connected to an internet, first needs to find available gateways through gateway discovery mechanism and then gets connected to it. There are three major types of gateway discoveries which are briefly explained below.

a) Proactive Gateway Discovery
In this approach, the gateway discovery mechanism is initiated by the gateway itself by periodically broadcasting gateway advertisement messages (GW_ADV). The advertisement intervals should be set in such a way that network is not flooded with unnecessary GW_ADV message. Only those nodes within the transmission range of gateway receive the GW_ADV message. And the nodes outside the transmission range of gateway do not receive GW_ADV message. A mobile node which wants to communicate with the wired node which is connected to the internet sends a reply to the GW_ADV message and gets connected to the gateway. All the traffic from the source node is routed to the destination through gateway to which it is connected.

b) Reactive Gateway Discovery
This approach is the opposite of Proactive gateway discovery. GW_ADV messages are not periodically broadcasted in Reactive gateway discovery. Here the mobile node which wants to communicate with the internet initiates gateway discovery mechanism by broadcasting a gateway solicitation (GW_SOL) message. When a gateway receives this GW_SOL message it replies with GW_ADV message to the requesting mobile node.

c) Hybrid Gateway Discovery
This gateways discovery process combines both Proactive and Reactive gateway discovery forming a Hybrid gateway discovery Mechanism. To reduce the disadvantage of Proactive/Reactive Gateway Discovery both are combined. For mobile nodes within the range of gateway, proactive gateway discovery is used and for nodes outside the range of gateway, reactive gateway discovery is used.

5. Existing Approaches

In Hamidian gateway discovery method [2], the interconnection of the Internet with a mobile ad hoc network as an Integrated Internet-MANET is defined. The Internet is based on a worldwide infrastructure, whereas the infrastructure less mobile ad hoc network offers the benefit of communication on the move. To let mobile devices within an

ad hoc network to communicate with any other device connected to the Internet, anywhere in the world, the mobile ad hoc network is connected to the Internet.

In the existing gateway discovery mechanisms, the proactive zone is set once and never adjusted. The periodicity of the gateway advertisement interval is also set when the gateway starts up and never changed. This results in a static proactive zone with a static gateway advertisement periodicity. At the same time, in the traditional Integrated Internet MANET strategies, the routing of packets is done based on the hop count metric. Path load balancing is not followed.

In [15] a path load balancing algorithm to overcome the above issue is discussed. This algorithm helps in balancing the load on different paths by directing traffic towards less congested paths and at the same time dynamically adjusting the range in which gateway advertisement messages are broadcast so as not to congest the ad hoc network with unnecessary control messages. The mechanism presented incorporates path load balancing and adaptive gateway discovery in the form of maximal source coverage algorithm.

We call this approach the Path Load Balanced – Maximal Source Coverage (PLB-MSC) gateway discovery mechanism. The proposed PLB-MSC gateway discovery mechanism can be explained with the help of Figure2.

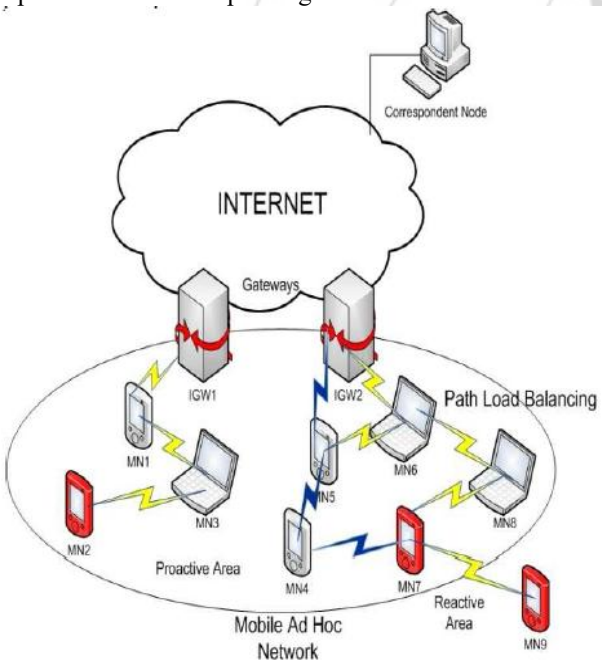

Figure 2: Working of PLB-MSC Gateway Discovery mechanism

In this Figure, the red nodes denote the active sources, that is, the sources which are communicating with correspondent nodes through the gateways. The communication lines indicate the path taken by data packets. In our example, the advertisement zone is currently 3. Since one of the active sources is outside the proactive zone, in the next cycle of gateway advertisements, the proactive area will be reset to 4 and the active source MN9 will come inside the proactive area. This is the working of the maximal source coverage area adaptive gateway discovery mechanism. For actual gateway selection, the path load balancing mechanism is used. Consider the active source MN7 which uses the route MN4-MN5 to communicate with Internet gateway IGW2. During the course of time, this path becomes overloaded, which is shown with blue communication lines, whereas yellow communication lines denote normal load. When this occurs, the path load balancing mechanism will redirect the communication between MN9 and IGW2 through the less loaded path MN8-MN6. This is the working of the path load balancing mechanism.

a) Algorithm for Path Load Balanced – Maximal Source Coverage mechanism.

Step 1: Use the Path Load Balancing mechanism for routing packets between mobile nodes and between mobile nodes and gateways.
Step 2: Initialize the proactive zone by setting the initial TTL value.
Step 3: Calculate the TTL value to be used in the next cycle using the maximal source coverage algorithm.
Step 4: Goto step 2.

6. Dynamic Gateway Strategy

a) The Dynamic Gateway

The existing approaches for integrating MANET and Internet are summarized in this section. In [16], Lei and Perkins have proposed a method to construct ad-hoc networks and provide Internet access for MANET nodes. A routing protocol is used within MANET, a modified Routing Information Protocol (RIP) to interconnect the ad-hoc network with the Internet. Sun *et al.* [17] have proposed an approach, which enables the cooperation of AODV and Mobile IP to guarantee ad-hoc Internet connectivity. While AODV is used to discover and maintain the routes within MANET, Mobile IP provides the mobile nodes with the *care-of addresses*. However, handoff occurs only if either a mobile node has not heard from its foreign agent for more than one beacon interval, i.e., the time between two successive agent advertisements, or when its route to a foreign agent has become invalid.

In [18], Broch *et al.* proposed a mechanism for the integration of MANET and Internet with Mobile IP. They introduce the concept of border router (or gateway), which has two interfaces. The one connected to the Internet uses normal IP routing to send packets in and/or out MANET, while the another interface connected to MANET uses the dynamic source routing (DSR) protocol to route packets within MANET.

Ratanchandani and Kravets [19] proposed a hybrid approach, which makes use of Mobile IP to provide global Internet connectivity. Certain techniques such as TTL scoping of agent advertisements, eavesdropping and caching agent advertisements were used. The Time-To- Live (TTL) field is used to reduce the flooding of agent advertisements in MANET. However, all the above existing approaches consider only fixed gateways, but not dynamic multi-gateway. The dynamic gateway is one type of the multi-gateway, which uses MANET node as gateway and optimizes the gateway

according to distance, number of nodes registered, and quantity of communication. The concept of the dynamic gateway is proposed, that is the gateways are mobile and the number of gateways is variable. The gateway nodes act as gateways in one time period, but they need not be gateways in another time period according to the criterion of the gateway selection. As shown in Figure .1, ad–hoc mobile nodes (MN) access Internet source through dynamic gateway, foreign agent (FA) supply Internet connectivity to dynamic gateway. Any interaction between MANET nodes and Internet has to be provided by only dynamic gateways (GW).

A dynamic gateway is a MANET node with an extended capability, which is one hop away from foreign agent. Thus, dynamic gateway motion is limited to the coverage area of foreign agents. When a dynamic gateway moves out of one hop away from foreign agent, it becomes a normal MANET node, but not a dynamic gateway. These dynamic gateways can use Mobile IP when they communicate with the Internet, and use APDV when they interact with MANET.

The dynamic gateway provides transparent service for MANET nodes. Although many foreign agents helping dynamic gateway supply Internet connectivity for MANET nodes, no MANET nodes are aware of the details, which is so-called transparency. We consider two types of transparency namely, connection transparency and handoff transparency. With connection transparency, the MANET nodes do not realize which foreign agent is indirectly supplying the Internet connectivity. Selecting an optimal foreign agent and supplying transparent service for MANET nodes are the main tasks of dynamic gateway. With, handoff transparency, a dynamic gateway should switch foreign agent from one to another not affect the interaction of MANET nodes.

MANET nodes do not consider that which dynamic gateway is connected to. Hence we define this architecture as dynamic gateway. The dynamic gateway has several advantages:

- It eliminates the need for additional fixed gateways, reduces the system complexity, improves reliability, and lowers the cost.
- Because dynamic gateway movement causes the routes to be updated frequently, it is beneficial for the network to exchange data and improve performance.
- Dynamic change of gateway magnitude, which is determined by network environment such as MANET nodes locations and magnitude, and gateway load etc., eliminates the network congestion.
- Dynamic handoff is available. That is, with change of network environment, MANET nodes automatically switch to the optimal gateway, and the dynamic gateway can also switch to the optimal foreign agent.
- The problem of load-balancing for multi-gateway can be overcome.
- Being peer-to-peer architecture, it has neither a centralized gateway nor centralized algorithm. Therefore, dynamic gateways are able to adapt to variety of MANET nodes.

b) Operation of the Dynamic Gateway

Assume that every MANET node, including dynamic gateways, holds a routable IP home address, and a MANET node, called S, wants to access a global Internet node, known as correspondent node, say D. This access is processed as follow:

A dynamic gateway registers with a foreign agent in the following sequence. As foreign agents broadcast *agent advertisements* (FAAdv) (TTL=1 hop [19]) periodically, a dynamic gateway can make a choice among many agent advertisements according to an optimize policy. Then, the dynamic gateway unicasts the registration request. A foreign agent accepts the registration of a dynamic gateway if it does not register with this foreign agent or previous registration has expired.

A MANET node “S” selects an optimized dynamic gateway. Node S initiates a *gateway solicitation* (GWSol) and broadcasts GWSol through MANET. After dynamic gateways, which are currently present in MANET, received the GWSol, they should unicast a *gateway advertisement* (GWAdv) to node S. Only dynamic gateways registered with a foreign agent could send back a GWAdv packet. Thus, dynamic gateways not yet registered with foreign agents ignore this request packet.

Figure 3 shows GWAdv message formats. GWAdv has some fields, such as gateway’s IP address, GWAdv’s lifetime, which node S would be able to register with dynamic gateway deadline, the number of MANET nodes (NN) registered with this dynamic gateway, the length of the queue for waiting to deliver data packets (QL), the distance (DS) between this dynamic gateway and the MANET node, i.e. hops, and a sequence number to uniquely identify GWAdv.

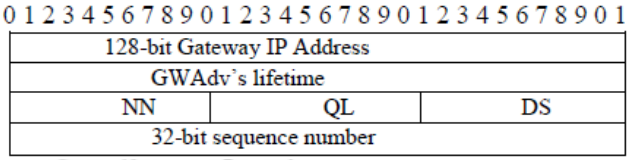

Figure 3: GWAdv message format

When node S receives all GWAdv packets, which are sent back by all dynamic gateways, it selects an optimized gateway according to the formula in Section C, denotes as GW. Then it registers with “GW” by sending back a *gateway registration request* (GWReq) packet to “GW”, and receiving a *gateway registration reply* (GWRep). The GWRep includes GW’s IP address, which will be node S’s *care-of address*. GWRep has a registration lifetime, the period of time where node S may access the Internet through the “GW”. When a registration lifetime has expired, the corresponding MANET node needs to update its registration. Many MANET nodes may register with the same gateway if only its registration is valid. After node S registers with the “GW”, any interaction with the Internet goes through this “GW”. When node S sends data packets to node D, the data packets will have to reach “GW” using AODV routing protocol. Then the foreign agent, “GW” has registered with, delivers these data packets to final correspondent node D using Mobile IP protocol.

c) Selection Formula Of the Dynamic Gateway

Dynamic gateway, providing Internet connection with MANET nodes, must register with a foreign agent and in the same manner, the MANET nodes accessing Internet must register with dynamic gateways. Several definitions are given in selecting the best dynamic gateway.

Definition 1 Node Number (NN): An effective number of MANET nodes registered with a dynamic gateway or an effective number of dynamic gateways registered with a foreign agent is defined as their load NN.

Definition 2 Queue Length (QL): The waiting queue length of data packets on dynamic gateway and foreign agent is defined as Queue Length QL.

Definition 3 Distance (DS): The Euclidean distance between two nodes is also defined as Distance DS.

A dynamic gateway would select a least loaded foreign agent. Similarly, a MANET node would select a least load dynamic gateway. To accommodate the different weights of each factor on network communication, three factors are considered, i.e., the Distance (DS), the registered number of nodes (NN) and the Queue Length (QL) of data packet delivered. Depending on the actual conditions of the network environment, the weight values can be adjusted.

The formula of the MANET nodes and dynamic gateway is given as,

$$GWExp = DS \times n + NN \times m + QL \times k \quad (1)$$

$$GW = Min\{GWExp_1, GWExp_2, \ldots\ldots, GWExp_j\} = Min\{GWExp_i\}_{i=1}^{j} \quad (2)$$

$$n + m + k = 1 \quad (3)$$

Where *n, m, k* are weighted factors, *GWExp* represents the weighted value of gateway, and *i* refers to the number of gateway advertisement (GWAdv) that a MANET node receives. Likewise, the formula for the dynamic gateways and foreign agent is given as,

$$FAExp = DS \times n + NN \times m + QL \times k \quad (4)$$

$$FA = Min\{FAExp_1, FAExp_2, \ldots\ldots, FAExp_j\} = Min\{FAExp_i\}_{i=1}^{j} \quad (5)$$

$$n + m + k = 1 \quad (6)$$

Where *FAExp* represents the weighted value of foreign agent and *i* indicates the number of foreign agent advertisement (FAAdv) that a dynamic gateway receives. In both cases, the weights *n*, *m*, *k* can be adjusted depending on the network conditions, i.e. MANET network scale, geographic environment, foreign agent quantity and channel conditions, etc. Here, *n*, *m*, *k* are set as 0.74, 0.2, and 0.06, respectively [21].

7. Dynamic Gateway Load Balancing (DGWLB)

In this work we proposed a load balancing algorithm which balances the packet load among mobile nodes as well as dynamic gateways. Thus the congestion in the network is reduced.

When a source node wants to communicate with the fixed node it starts searching for gateways using adaptive gateway discovery mechanism. Once the gateways are found the source node calculates the distance to all the available gateways. The source node starts communicating with the destination through the nearest gateway. When the traffic between source and destination node increases the congestion occurs in the network.

Our algorithm is capable of detecting congestion in the network. Whenever the congestion occurs our algorithm splits the traffic and forwards them in multiple paths through multiple dynamic gateways to the given destination. Thus the load among mobile nodes and gateways are balanced, which reduces the packet loss due to congestion in the network.

Algorithm (Dynamic Gateway Load Balancing)

Step 1: Initiate the gateway Discovery process.
Step 2: Once the source node finds and register with gateways it is ready for communication with the fixed node.
Step 3: Calculate the distance from source node to all the gateways.
Step 4: Calculate the current queue length of the mobile nodes and gateways.
Step 5: If the queue length exceeds the maximum queue length then split the data packet.
Step 6: Forward the split data packets through multiple paths through multiple nearest gateways.

Simulation Setup

This Simulation has been implemented using Network Simulator 2 (ns-2.33). The Simulation consists of 50 mobile nodes, 4 fixed nodes, 4 routers, 4 Base stations and 4 gateways. The simulation area is of 1000m length 1000m width. The bandwidth of all the fixed links are set to 5Mbps. The radio range of each wireless transmitter is set to 250m. All the simulations were run for a total of 500 seconds. The traffic sources used in this simulation is CBR sending data packet with size 512 bytes at an interval of 0.25 seconds. Figure 4 shows the parameters used in simulation.

Parameter	Value
Transmission Range	200m, 250m and 500m
Mobility Model	Random Waypoint
Topology size	1000 m x 1000 m
Number of Mobile Nodes	50
Number of Base stations	4
Number of dynamic gateways	4
Number of routers	4
Number of fixed nodes	4
Traffic type	Constant bit rate
Packet size	512 bytes
Pause time	10 seconds
Maximum speed	10 m/s

Figure 4: General parameters used in Simulation

8. Results and Discussion

The performance of our algorithm is compared with existing strategies like Hamidian gateway discovery [2] and Path load balanced and adaptive gateway discovery in integrated Internet-MANET[15]. The output shows that our proposed algorithm out performs. Figure 5 shows the output of existing strategies and proposed algorithm.

Parameters	Hamidian	PLB	DGWLB
Packets Sent	622	2402	2402
Packets Received	145	1879	1928
Packets Lost	477	523	474
Packet Delivery Ratio	23.3119%	78.2265%	80.2664%
Average delay	0.450105s	0.016891s	0.0148523s

Figure 5: Output Comparison

9. Performance Analysis

The Performance of different mobility models are compared with Hamidian Hybrid gateway discovery mechanism.

Packet Delivery Ratio

Packet delivery ratio is the ratio of packet that has been successfully received by the destination node to the number of packets that have been transmitted by the source. Higher the packet delivery ratio better is the performance. Figure 6 shows that the performance of our proposed algorithm is better than the existing strategies. Hence the performance of Random Direction model is better in terms of Packet delivery Ratio. The Packet Delivery Ratio is calculated using the formula:

$$F = \frac{1}{C}\sum_{f=1}^{C}\frac{R_f}{T_f}$$

F: Fraction of successfully delivered packets. *C* : Total number of flows, connection. *f* : Unique flow id. *Rf* : Count of unique packets received from flow *f* . *Tf* : Count of packets transmitted to flow *f.*

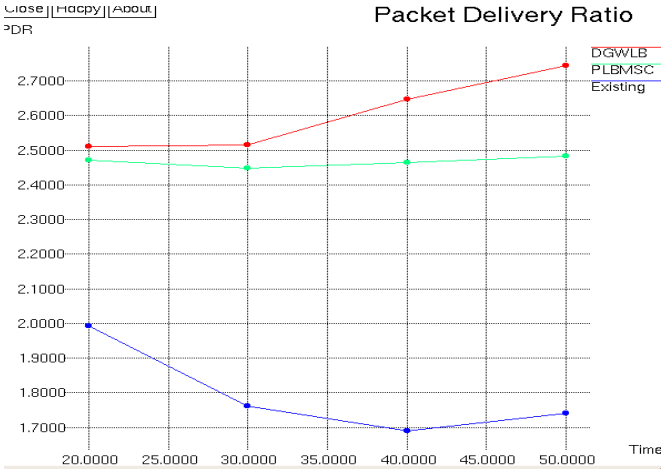

Figure 6: Packet Delivery Ratio

Throughput

Throughput is the amount of packets that are successfully delivered to the destination in a given time period. It is represented in bps. Higher throughput indicates better performance. Throughput is calculated using the formula:

*Throughput = received_data*8/DataTransmissionPeriod.*

Figure 7 shows that the performance of our proposed algorithm is better than the existing strategies. Hence the Random Direction Model Outperforms Random Walk and Random Waypoint Model.

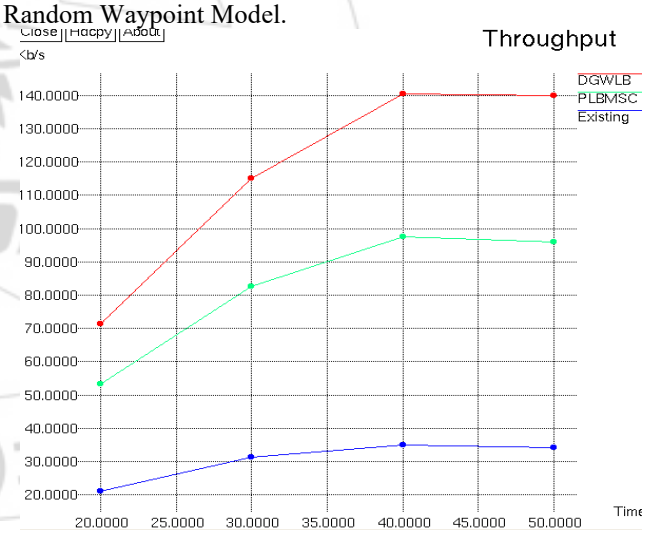

Figure 7: Throughput

Routing Overhead

Routing overhead is calculated using the formula:
Routing Overhead = Routing Packets Count

In terms of Routing overhead the performance of our algorithm is poor compared to existing strategies. The reason for this is nodes often change their location within network. So, some stale routes are generated in the routing table which leads to unnecessary routing overhead. Figure 8 shows this comparison.

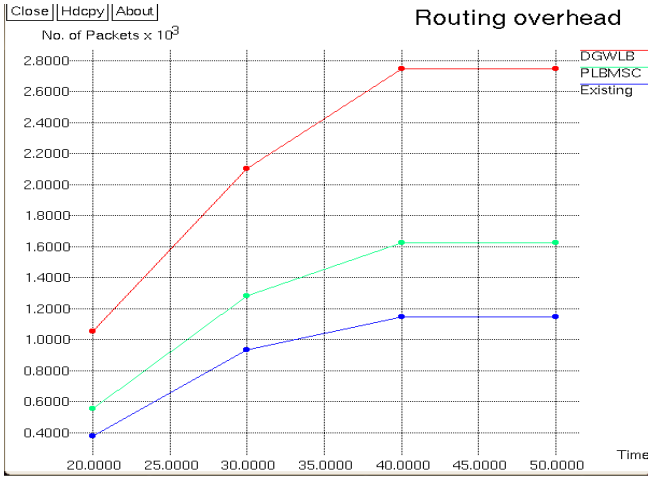

Figure 8: Routing overhead

10. Conclusion

In this paper we have created a simulation of integrated Internet-MANET and employed a Dynamic Gateway Load Balancing algorithm (DGWLB). We have compared the performance of DGWLB with existing strategies. Our simulation result shows that our proposed algorithm performs better than existing approaches in terms of packet delivery ratio, throughput and average delay. In the future, we intend to modify our algorithm to perform energy efficient load balancing and also to form clustering of mobile nodes in MANET and we try to reduce the routing overhead.

References

[1] A. Sharmila, R. Selvakumar, M. Preetha "A Study Of MANET Integration Through Internet", IJCSMC, Vol. 2, Issue. 7, July 2013.
[2] Ali Hamidian, Ulf Korner and Anders Nilsson "Performance Of Internet Access Solutions In Mobile Ad hoc Networks", Springer's Lecture Notes in Computer Science *(LNCS)*, pp 189-201, 2004.
[3] Harjeet Kaur, Varsha Sahni and Dr. Manju Bala "A Survey of Reactive, Proactive and Hybrid Routing Protocols in MANET: A Review", IJCSIT, Vol. 4 (3), 2013.
[4] Tracy Camp, Jeff Boleng and Vanessa Davies "A Survey of Mobility Models for Ad Hoc Network Research", WCMC, vol. 2, no. 5, pp. 483-502, 2002.
[5] *"The Network Simulator: Contributed Code"*: http://nsnam.isi.edu/nsnam/index.php/Contributed_Code.
[6] A. Hamidian. *"A Study of Internet Connectivity for Mobile Ad Hoc Networks in NS 2"*.Master's thesis. Department of Communication Systems, Lund Institute of Technology, Lund University. January 2003.
[7] Rafi U Zaman, Khaleel Ur Rahman Khan and A. Venugopal Reddy, "A Review of Gateway Load Balancing Strategies in Integrated Internet-MANET", International Workshop on Advances in Peer-Peer Technology IWAP2PT'09 co-located with IMSAA-09, IIIT Bangalore, 9-11 December 2009. Proceedings in IEEE Digital Library, pages: 141 – 146.
[8] Pedro M. Ruiz, Antonio F. Gomez-Skarmeta: "Maximal Source Coverage Adaptive Gateway Discovery for Hybrid Ad Hoc Networks, Lecture Notes in Computer Science, vol.3158, 28-41, (2004).
[9] Khan K. U. R., Reddy A. V., Zaman R. U., Kumar M. "An Effective Gateway Discovery Mechanism in an Integrated Internet-MANET (IIM)," Proc. of the International Conference on Advances in Computer Engineering, India, pp. 24-28, June 2010.
[10] Kumar, R., Misra, M. and Sarje, A.K., "An Efficient Gateway Discovery in Ad Hoc Networks for Internet Connectivity", Proc. Of the International Conference on Computational Intelligence and Multimedia Applications, pp 275-281, 2007.
[11] Javaid, U., Rasheed, T.M., Meddour, D., Ahmed, T.: Adaptive Distributed Gateway Discovery in Hybrid Wireless Networks. WCNC – 2008, 2735-2740. (2008).
[12] A.J. Yuste, Alicia Trivino, F.D. Trujillo, E. Casilari: Using Fuzzy Logic in Hybrid Multihop Wireless Networks. International Journal of Wireless & Mobile Networks Volume 2, Issue 3, 96-108, (2010).
[13] Zaman, R.U., Khan, K.U.R., Reddy, A.V.," A Survey of Adaptive Gateway Discovery Mechanisms in Heterogeneous Networks", I. J. Computer Network and Information Security, 2013, 7, 34-42 Published Online, in MECS (http://www.mecs-press.org/) DOI: 10.5815/ijcnis.2013.07.04, June 2013.
[14] Jinhua Zhao, Ling Wang, Yoohwan Kim, Yingtao Jiang, Xiaozong Yang, " Secure Dynamic Gateway to Internet Connectivity for Ad-hoc Network", International Journal of Information Technology Vol. 11 No. 2.
[15] Rafi U Zaman , Khaleel Ur Rahman Khan, A. Venugopal Reddy, "Path Load Balanced Adaptive Gateway Discovery in Integrated Internet-MANET", IEEE, 2014.
[16] P. Johansson, T. Larsson, N. Hedman, B. Mielczarek, and M. Degermark, Scenario-based Performance Analysis of Routing Protocols for Mobile Ad-hoc Networks, Proceedings of the 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom'99), Seattle, Washington, USA, August 15-19, 1999, pp.195-206.
[17] Y. Sun, E. Belding-Royer, and C. Perkins, Internet Connectivity for Ad hoc Mobile Networks, International Journal of Wireless Information Networks, Special Issue on Mobile Ad Hoc Networks (MANETs): Standards, Research, Applications, April 2002.
[18] J. Broch, D. A. Maltz, and D. B. Johnson, Supporting Hierarchy and Heterogeneous Interfaces in Multi-Hop Wireless Ad Hoc Networks, Proceedings of the Workshop on Mobile Computing, Perth, Australia, June 1999.
[19] P. Ratanchandani and R. Kravets, A Hybrid Approach to Internet Connectivity for Mobile Ad Hoc Networks, Proceedings of IEEE Wireless Communications and Networking Conference (WCNC), New Orleans, Louisiana, USA, 16-20 March, 2003, pp.1522-1527.
[20] Ns 2 Home page: http://www.isi.edu/nsnam/ns/index.html
[21] Jinhua Zhao, Ling Wang, Yoohwan Kim, Yingtao Jiang, Xiaozong Yang "Secure Dynamic Gateway to Internet Connectivity for Ad-hoc Network", International Journal of Information Technology Vol. 11 No. 2 ,2006.
[22] Marc Greis' Tutorial for the Network Simulator "ns": http://www.isi.edu/nsnam/ns/tutorial/

[23] Sukumar Panda, Rahul Mohapatra "Implementation and Comparison Of Mobility Models in NS2".
[24] M. Geetha, Dr. R. Umarani, R. Kiruthika "A Comparative Study of Gateway Discovery Protocol in MANET", IJCA Volume 11– No.2, December 2010.
[25] Koojana Kuladinithi, Asanga Udugama, Nikolaus A. Fikouras, and Carmelita Gorg, "Experimental performance evaluation of AODV implementations in static environments", http://www.comnets.unibremen/de/~koo/AODV-Perf-ComNets.pdf.
[26] C. Perkins, E. Belding-Royer, and S. Das, (2003) "RFC 3561: Ad hoc on-demand distance vector (AODV) routing", category: experimental. [Online]. Available: ftp://ftp.isi.edu/in-notes/rfc3561.txt.