***I.J. Wireless and Microwave Technologies*, 2017, 2, 57-75**
Published Online March 2017 in MECS(http://www.mecs-press.net)
DOI: 10.5815/ijwmt.2017.02.06

***Available online at* http://www.mecs-press.net/ijwmt**

Efficient Adaptive Path Load Balanced Gateway Management Strategies for Integrating MANET and the Internet

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Abstract

Mobile nodes in a mobile ad hoc network communicate with each other. In order to facilitate communication of mobile nodes with fixed nodes in the Internet, gateways are used. The resultant integrated heterogeneous architecture is called Integrated Internet MANET in the literature. Such heterogeneous architectures are needed in order to realize the potential of, and to achieve the stated objectives of proposed 5G networks of the future. Gateways in Integrated Internet-MANET may be fixed or mobile. Several issues arise in Integrated Internet-MANET. In this paper, three critical issues encountered in Integrated Internet-MANET are addressed together. These issues are, efficient gateway selection mechanism, adjusting the gateway advertisement range and dynamically adapting the periodicity of gateway advertisements. Three strategies are proposed which use a path load balancing mechanism for efficient gateway selection. These strategies address the issues of adjusting the gateway advertisement range and dynamically adapting the periodicity of gateway advertisements in different ways. The proposed strategies have been simulated in a two-tier as well as a hybrid architecture using network simulation tool ns-2. The simulation results are presented and the scenarios, under which each of the proposed strategies is useful, are discussed.

Index Terms: Mobile Ad Hoc Network, Integrated Internet MANET, Gateway Selection, Path Load Balancing, Hybrid Architecture

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1. Introduction

Mobile ad hoc Networks (MANET) are deployed on temporary basis when networking infrastructure is not available or installing networking infrastructure is not feasible. In order to facilitate communication of mobile nodes within the MANET with fixed nodes on the Internet, gateways are used. The resulting heterogeneous architecture is referred in the literature as Integrated Internet MANET [1]. The Integrated Internet MANET architecture can be used to realize the stated objectives and use case scenarios of the proposed 5G networks [2]. For instance, one of the scenarios envisaged in 5G networks is of mobile hot spots, wherein mobile users within a fast moving train may need instantaneous and reliable Internet connectivity. Another use case is in emergency scenarios like natural disasters, where survivors are left with mobile devices which require Internet connectivity. Various issues arise in integrated Internet MANET, chief among them being efficient discovery of gateways by mobile nodes; efficient mechanisms for routing packets within the MANET and between the mobile nodes and gateways. Gateway discovery is a crucial issue in Integrated Internet-MANET (IIM). Mobile nodes in the MANET discover gateways through agent advertisement messages (GWADV). In the literature [3], three main approaches for gateway discovery have been proposed, namely proactive, reactive and hybrid. These three gateway discovery approaches are demonstrated in fig1. In the proactive approach, gateways periodically broadcast GWADV messages into the MANET. In the reactive approach, gateways do not broadcast GWADV messages. Mobile nodes which need Internet connectivity broadcast gateway solicitation messages (GWSOL). When a gateway receives a GWSOL message, it unicasts a GWADV message to the requesting mobile node.

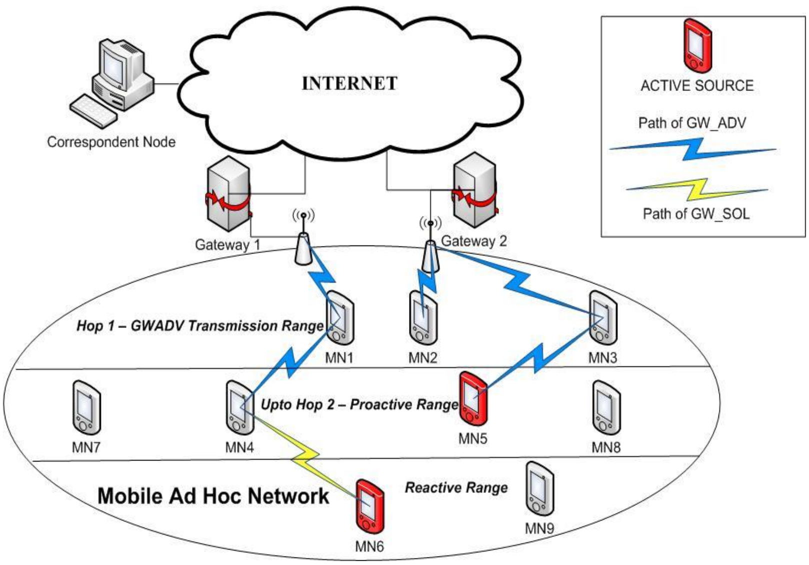

Fig 1. Gateway discovery in Integrated Internet-MANET.

The hybrid approach is a combination of the proactive and reactive approaches. Gateways broadcast GWADV messages into a limited range in the MANET determined by the TTL value of the GWADV message. Mobile nodes which are outside the TTL range use reactive approach to discover gateways. In the traditional hybrid approach, the TTL value and periodicity of GWADV message is static. Two factors which determine the efficiency of a gateway discovery method are the TTL value and periodicity of the gateway advertisement (GWADV) message. The TTL value determines the range of the MANET in which the GWADV message propagates and the periodicity determines its frequency. A modified form of hybrid approach, called Adaptive gateway discovery [4] dynamically adjusts the TTL value and periodicity of GWADV messages, depending on various network parameters.

In this paper, three strategies are presented which dynamically adapt the GWADV TTL value and GWADV periodicity. These three strategies are called the Path Load Balanced Average Hops strategy (PLB-AVG), the Path Load Balanced Maximal Source Coverage strategy (PLB-MSC) and the Path Load Balanced Adaptive Distributed gateway Discovery strategy (PLB-ADD). The proposed strategies use a fuzzy logic based mechanism to adjust GWADV periodicity based on three parameters, namely: number of received GWSOL messages (NMRG), link changes (LC) and TTL Changes (TTLC). This fuzzy logic based mechanism was first proposed in Yuste et al [5] and used in [6]. The TTL value is adjusted as follows: In PLB-AVG, the TTL value of the next advertisement cycle is set according to the average hops metric first proposed in [7]. In PLB-MSC, TTL value is set based on the Maximal Source Coverage [8] algorithm. In PLB-ADD, the GWADV message is forwarded based on a distributed adaptive algorithm proposed by Javaid et al [9]. All the three proposed strategies use the path load balancing metric [10] for gateway selection and for efficient routing of packets.

The rest of the paper is organized as follows: Section 2 presents work related to the proposed strategies. In section 3, the proposed strategies are presented in detail. Section 4 presents the simulation results of the proposed strategies. Section 5 concludes the paper.

2. Related Work

A lot of researchers have worked in the area of Integrated Internet MANET. More recently, many authors have concentrated on developing optimized routing protocols in Integrated Internet MANET. A few of the strategies are presented below. Wherever applicable, justification is provided about how the proposed strategies improve upon the existing work. After presenting the related work, motivation is provided for the proposed work.

- The problem of distributing the packet load across multiple paths evenly was addressed by Khan et al [10]. Gateway queue occupancy, route queue length and path load are used, based on which routing decisions are made by mobile nodes while forwarding packets. This proposal is an improved version of a similar strategy proposed by Kumar et al [11].
- The path load balanced fuzzy logic based adaptive gateway discovery mechanism was presented in [6], which is referred as PLB-AVG in this paper. It was shown using simulations that the proposed strategy gives better packet delivery ratio and lesser normalized routing load than maximal source coverage.
- The path load balanced adaptive gateway discovery proposed in [12], used the maximal source coverage mechanism to adapt the TTL value. GWADV periodicity was not adjusted dynamically. This strategy delivered better results than existing approaches.
- In the hybrid approach of gateway discovery, mobile nodes within the proactive zone use the proactive gateway discovery mechanism and mobile nodes outside the proactive zone use the reactive approach of gateway discovery. Many modifications have been proposed to the hybrid approach of gateway discovery, which dynamically adjust the proactive zone, depending on various network parameters. Such approaches, called adaptive gateway discovery mechanisms are surveyed in detail in [4].
- Yuste et al [5] used fuzzy logic based mechanism to determine the periodicity of the next gateway advertisement message. This same approach is used in PLB-AVG and PLB-MSC strategies proposed in this paper to determine periodicity of the GWADV message in the next cycle. The maximal source coverage algorithm is used to dynamically adjusting the TTL value of GWADV.
- In [7], a metric based on average hop count of active sources and signal quality was proposed to determine the TTL value of the gateway advertisement messages. Periodicity of gateway advertisement is not addressed. In this paper, PLB-AVG strategy uses the average hops metric to determine the TTL value of the next gateway advertisement message.

- Javaid et al [9] proposed a novel distributed approach of adaptive gateway discovery. In the beginning, the TTL value is set to zero, that is, there is no proactive zone and mobile nodes which want Internet connectivity use the reactive approach for gateway discovery. The GWADV message which is sent by gateways in response to the GWSOL message from mobile node is propagated only towards the requesting mobile node. GWADV periodicity is not addressed in this paper. The PLB-ADD strategy proposed in this paper used the adaptive distributed gateway discovery method of [9] to propagate the GWADV message.
- Pandey et al [13] proposed a strategy which uses fuzzy logic approach on two parameters hop count and latency to determine the TTL value of GWADV message. The periodicity of GWADV message is not addressed.
- In Xu et al [14] a gateway pheromone based approach is used to delineate the proactive area dynamically. GWADV messages traverse robust paths by calculating link quality based on various parameters. In this approach as well, the problem of GWADV periodicity is not addressed.
- In [18], an analytical model for estimating the overhead of strategies for Integrated Internet-MANET is proposed, using which the different strategies can be analytically compared without the need for simulating them.
- In [21], the authors tackle the very important issue of energy efficiency in MANETs. The AODV routing protocol is modified for energy efficient routing.

From the above discussion, we conclude that many strategies exist in the literature which addresses the problem of gateway discovery in Integrated Internet-MANET. The problem of gateway discovery can be subdivided into determining the TTL value and periodicity of GWADV dynamically. Some authors [8][9][12][13][14] address the problem of dynamically adjusting the TTL value while others [15][16][17] only address GWADV periodicity. Only a few strategies [5] address the two issues in gateway discovery. In this paper, three strategies are proposed which address the gateway discovery problem in different ways. Moreover, the proposed strategies also use efficient gateway selection and routing approaches, which is not the case with existing solutions.

3. Efficient Adaptive Path Load Balanced Strategies for Integrated Internet-MANET

The salient features of the proposed strategies are: Path load balancing, dynamic adjustment of TTL value of GWADV messages, and adapting the periodicity of GWADV messages. The mechanisms for path load balancing and adapting the periodicity of GWADV messages are common to all the three strategies. The three proposed strategies use the path load balancing mechanism [10] for routing of packets and gateway selection, which is discussed below.

3.1. Path Load Balancing:

The problem of efficient routing of packets between mobile nodes in MANET, and between mobile nodes and gateways in Integrated Internet-MANET has been addressed in [10] and [11]. In the path load balancing mechanism of [11], path selection is based on the load along a path. The path with lesser load is selected. The proactive approach is used for broadcasting gateway advertisement messages and is statically set to 3. Mobile nodes which fall outside the proactive range cannot access Internet connectivity. The path load metric is used to calculate the path load along a route, based on which the gateway selection decision is made. Path load metric is defined as follows:

$$q\_occupancy = \frac{q\_len + \sum_{i=1}^{n} nb\_q\_occupancy}{(n+1)} \quad (1)$$

$$pathload = \sum_{j=1}^{m} q\_occupancy \qquad (2)$$

Where nb_q_occupancy is the queue length of neighbor nodes, n is the number of neighbors of a node, and q_len is the queue length of the node. Pathload is the queue occupancy of all the nodes on the path, where m nodes lie on the path. The pathload metric of equation (2) is used to make routing and gateway selection decisions.

3.2. Adjusting the GWADV periodicity value:

In the proposal of Yuste et al [5] a fuzzy logic based approach was proposed to dynamically adjust the GWADV periodicity. A similar approach [6] is used in the proposed strategies which uses three metrics: Number of received GWSOL messages (NMRG), Link Changes (LC) and TTL Changes (TTLC) as input to the fuzzy logic system in order to determine the convenience or necessity of transmitting a GWADV message in the proactive zone. These three metrics are defined below:

- Number of received GWSOL messages (NMRG): It measures the ratio of total number of GWSOL messages generated by active sources to the number of active sources. It is given as:

$$\text{NMRG} = \frac{\text{number of GWSOL messages}}{\text{number of active sources}} \qquad (3)$$

- Link Changes (LC): It measures the mobility of nodes near the gateway. It represents the ratio of number of link changes a gateway detects to the number of active sources. It is given as:

$$\text{LC} = \frac{\text{number of link changes}}{\text{number of active sources}} \qquad (4)$$

- TTL changes (TTLC): It measures the ratio of changes in the distances of active sources to the gateways to the number of active sources. It is given as:

$$\text{TTLC} = \frac{\text{number of TTL changes}}{\text{number of active sources}} \qquad (5)$$

The values produced by the above three metrics are given as input to the fuzzy system. The fuzzy system generates a convenience value, which can be one of Very Low (VL), Low (L), Moderate (M), High (H) and Very High (VH), according to table 1, adapted from [5]. These convenience values are mapped to GWADV periodicity using table 2:

Table 1. Input parameters to the fuzzy system.

Number of MRS (NMRG)	Link Changes (LC)	TTL Changes (TTLC)	Convenience
Low	Low	Low	Very Low
Low	Low	Moderate	Very Low
Low	Low	High	Low
Low	Moderate	Low	Very Low
Low	Moderate	Moderate	Low
Low	Moderate	High	Moderate
Low	High	Low	Low
Low	High	Moderate	Moderate
Low	High	High	High
Moderate	Low	Low	Very Low
Moderate	Low	Moderate	Low
Moderate	Low	High	Moderate
Moderate	Moderate	Low	Low
Moderate	Moderate	Moderate	Moderate
Moderate	Moderate	High	High
Moderate	High	Low	Moderate
Moderate	High	Moderate	High
Moderate	High	High	Very High
High	Low	Low	Low
High	Low	Moderate	Moderate
High	Low	High	High
High	Moderate	Low	Moderate
High	Moderate	Moderate	High
High	Moderate	High	Very High
High	High	Low	High
High	High	Moderate	Very High
High	High	High	Very High

Table 2. Gateway Advertisement Interval values

Convenience	GW_ADV Periodicity
Very Low	2
Low	3
Moderate	4
High	5
Very High	6

3.3. Adjusting the GWADV TTL value:

The three proposed strategies differ in the way they adjust the GWADV TTL value. The procedures followed by each of the three strategies are outlined in the following sub-sections:

3.3.1. Path Load Balanced Average Hops Strategy (PLB-AVG):

Adjustment of the TTL value of GWADV results in adjusting the proactive zone of a gateway. In PLB-AVG, every gateway periodically adjusts its TTL value according to the following metric, given in [6]:

$$TTL_{n+1} = \lceil TTL_n + \Delta TTL_{Source} \rceil \quad (6)$$

Where, TTL_{n+1} is the TTL value of the next cycle, TTL_n is the TTL value of the last gateway advertisement cycle and ΔTTL_{Source} is given as:

$$\Delta TTL_{Source} = \frac{\sum_{i=1}^{N_{n+1}} Hops_i}{N_{n+1}} - \frac{\sum_{i=1}^{N_n} Hops_i}{N_n} \quad (7)$$

Where N_{n+1} and N_n are the number of active sources registered with a gateway in (n+1)th and nth cycles respectively. $Hops_i$ is the distance in number of hops from the gateway to mobile node i.

In fig2, the initial TTL value is set to 2 for all gateways. MN6 is outside the proactive range of gateway1. For gateway2, MN2 is one hop away and within the proactive zone whereas MN5 is 3 hops away and outside the proactive zone. For the next GWADV cycle, the gateways adjust their respective proactive zones using the metric in equation (6).

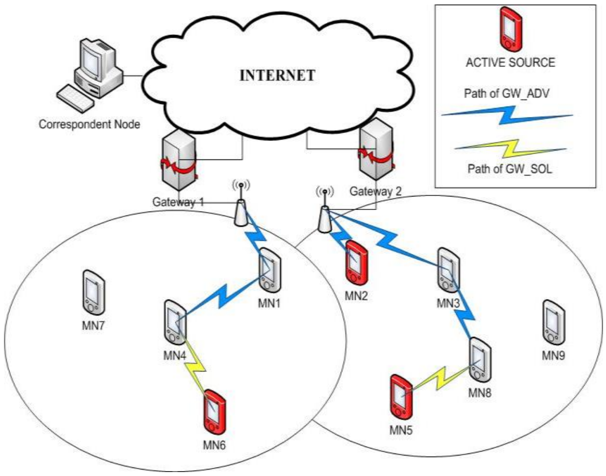

Fig.2. Adjustment of TTL value.

The PLB-AVG algorithm can be summarized as follows:

Algortihm1. Path Load Balanced Average Hops Strategy (PLB-AVG)
Step 0: Use the path load balancing mechanism for routing packets within the MANET. Step 1: Initialize the first TTL value. Let it be TTL_0. Step 2: Calculate the TTL value to be used in the next cycle, TTL_{n+1}, using equation (6). Step 3: Calculate the metrics NMRG, LC and TTLC. Step 4: From the metrics gathered in step 3, estimate the convenience of transmitting a GWADV message, using table1. Step 5: Calculate the gateway advertisement interval for the next cycle, using table 2. Step 6: goto step 2.

3.3.2. Path Load Balanced Maximal Source Coverage strategy (PLB-MSC):

The PLB-MSC strategy uses the maximal source coverage algorithm [8] to dynamically adjust the proactive zone. In maximal source coverage algorithm of adaptive gateway discovery, every gateway maintains the distance to each of its active sources, in terms of hops. The TTL value of the next GWADV is the maximum of the distances of all the active sources of a gateway. For example, in fig2, the TTL value of both the gateways will be set to 3 in the next cycle. The PLB-MSC algorithm can be summarized as follows:

Algortihm2. Path Load Balanced Maximal Source Coverage strategy (PLB-MSC)
Step 0: Use the path load balancing mechanism for routing packets within the MANET. Step 1: Initialize the first TTL value. Let it be TTL_0. Step 2: Calculate the maximum distance to an active source. This will be the TTL value in the next GWADV message. Step 3: Calculate the metrics NMRG, LC and TTLC. Step 4: From the metrics gathered in step 3, estimate the convenience of transmitting a GWADV message, using table1. Step 5: Calculate the gateway advertisement interval for the next cycle, using table 2. Step 6: goto step 2.

3.3.3. Path Load Balanced Adaptive Distributed gateway Discovery strategy (PLB-ADD):

In the third and final proposed strategy called PLB-ADD, the adaptive distributed gateway discovery method [9] is used for adjusting the TTL value. In this method, initially, the TTL value is set to 0. That is, reactive method is used and the gateways refrain from broadcasting any GWADV message. When mobile node broadcasts a GWSOL message, each node through which the GWSOL message passes through marks itself as an intermediate node. Finally, when the GWSOL reaches a gateway, the gateway responds with a GWADV message by setting its TTL value to 1. All the neighboring nodes of the gateway receive this GWADV. Only those neighbors which have marked themselves as intermediate nodes reset the TTL value to 1 and rebroadcast the GWADV and all the other non-intermediate nodes throw away the GWADV message, since the TTL value has become 0. In this way, this strategy ensures that GWADV messages traverse only that area of the MANET which leads to the requesting active source. The PLB-ADD algorithm can be summarized as follows:

Algortihm3. Path Load Balanced Adaptive Distributed gateway Discovery strategy (PLB-ADD)

Step 0: Use the path load balancing mechanism for routing packets within the MANET.
Step 1: Initialize the first TTL value to 0. That is, TTL_0=0.
Step 2: A mobile node initiates gateway discovery by sending a GWSOL message.
Step 3: If a mobile node receives the GWSOL message Then
Set itself as an intermediate node.
End If
Step 4: On receipt of GWSOL message, gateway sends GWADV with TTL=1.
Step 5: If a mobile receives a GWADV message Then
If the mobile node is an intermediate node Then
Set TTL=1 in GWADV message and forward it.
Else
Throw away the GWADV message since TTL=0.
End If
End If
Step 6: Calculate the metrics NMRG, LC and TTLC.
Step 7: From the metrics gathered in step 6, estimate the convenience of transmitting a GWADV message, using table1.
Step 8: Calculate the gateway advertisement interval for the next cycle, using table 2.
Step 9: goto step 2.

4. Performance Evaluation

In order to ascertain the performance of the proposed strategies, they have been simulated using network simulation tool ns-2 [19]. The AODV+ framework proposed by Hamidian et al [3] is used as the underlying Integrated Internet-MANET framework. Simulation of the proposed strategies was performed in two different networking architectures: The first one is two-tier architecture and the second is hybrid architecture [20]. Three performance metrics, namely Packet Delivery Ratio, End to End delay and Normalized Routing Load are used to as parameters based on which the proposed strategies are compared with each other.

4.1. Performance Metrics

- Packet Delivery Ratio: Packet delivery ratio measures the percentage of packets delivered to the intended destinations.
- End to End Delay: End to End delay is the sum of delays experienced by all the transmitted packets.
- Normalized Routing Load: Normalized routing load measures the number of control packets generated for each data packet delivered.

4.2. Simulation in Two-Tier Architecture

In the two-tier architecture in the fixed nodes on the Internet form one tier and the mobile nodes in the MANET form the second tier. This architecture is the same as shown in fig1. Simulation parameters for the first set of simulations in the two-tier architecture are shown in table 3.

Table 3. Simulation Parameters for Two-Tier Architecture

Simulation Parameter		Value	
Architecture	*Two-Tier*		
Number of Mobile Nodes	50	25	15
Number of gateways	5	3	2
Toplogy Size	1200X1200	1000X1000	800X500
Mobile node radio range	250m		
Simulation time	900 sec		
Number of traffic sources	5		
Traffic Type	CBR		
Mobility Model	Random Waypoint		
Node Speed	1-6 Mts/Sec		
Number of destination nodes	2		
Pause Time	60 seconds		
Ad Hoc Routing Protocol	AODV+		

4.2.1. Results Discussion

The simulation of the two-tier architecture was carried out in three different topologies containing 15 nodes, 25 nodes and 50 nodes, as shown in the above table. The nodes speed was used as the variant based on which simulations were conducted. Node speed was varied from 1 mt/sec to 6 mts/sec in order to reflect real world human movement. Figures 4 to 12 show the simulation results for the two tier architecture. Figures 4, 5 and 6 show the comparison of the three strategies based on the packet delivery ratio metric. From figures 4,5 and 6, it is observed that PLB-AVG generally provides better packet delivery ratio, followed by PLB-MSC and then PLB-ADD. PLB-AVG and PLB-MSC have predefined criteria for setting the proactive zone whereas, PLB-ADD does not have any predefined proactive zone. It can be concluded that having a predefined proactive zone is a good idea to achieve a better packet delivery ratio. Figures 7,8, and 9 show the performance comparison of the three strategies based on the End to End delay metric.

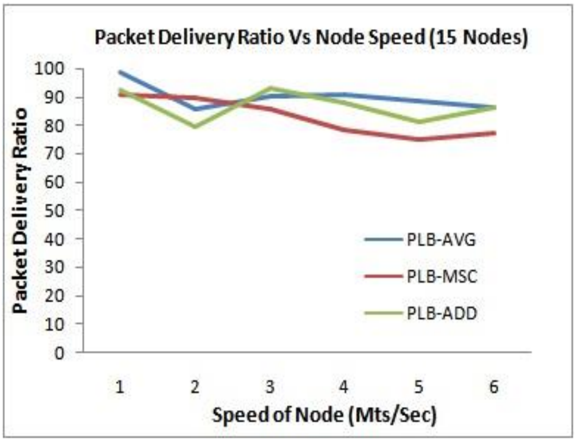

Fig.4. Packet Delivery Ratio Vs Node Speed (15 Nodes)

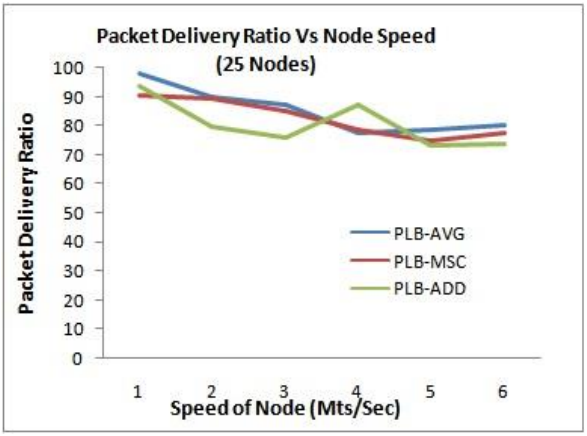

Fig.5. Packet Delivery Ratio Vs Node Speed (25 Nodes)

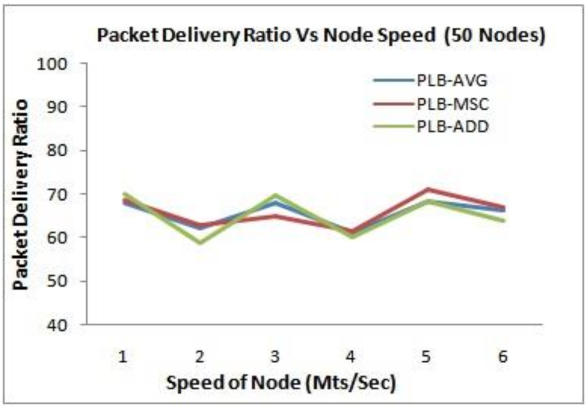

Fig.6. Packet Delivery Ratio Vs Node Speed (50 Nodes)

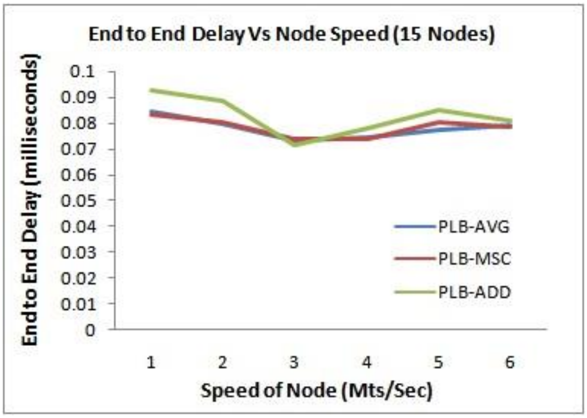

Fig.7. End to End Delay Vs Node Speed (15 Nodes)

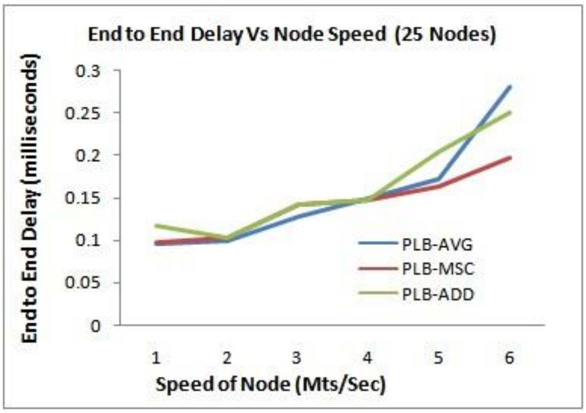

Fig.8. End to End Delay Vs Node Speed (25 Nodes)

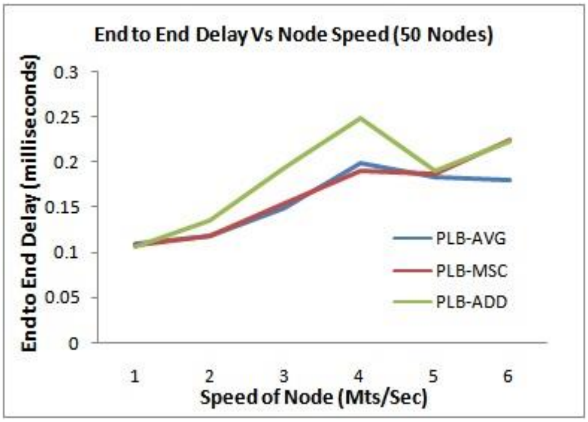

Fig.9. End to End Delay Vs Node Speed (50 Nodes)

In terms of End to End Delay, PLB-MSC gives the best results, followed by PLB-AVG and then PLB-ADD. The proactive zone of PLB-MSC is the greater than that of PLB-AVG, since PLB-MSC uses a maximum hop count metric and PLB-AVG uses an average hop count metric. In PLB-AVG, some active mobile nodes which are outside the proactive zone may experience more delay due to their following the reactive approach, and hence may experience more delay. In PLB-MSC, all active sources follow the proactive approach, and therefore, they experience less end to end delay. Active sources in PLB-ADD experience more delay when compared to PLB-AVG and PLB-MSC due to following the reactive approach. Figures 10, 11 and 12 show the performance comparison of the three proposed strategies based on the normalized routing load metric.

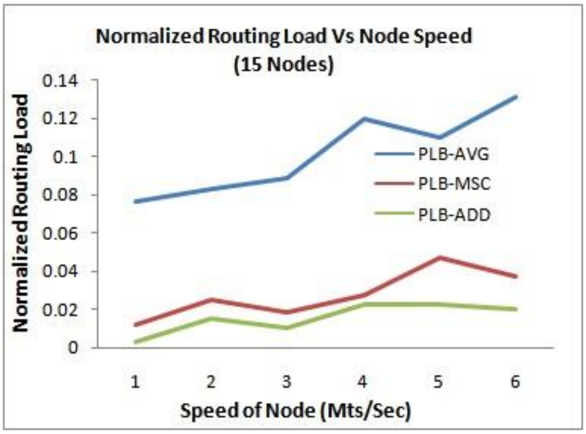

Fig.10. Normalized Routing Load Vs Node Speed (15 Nodes)

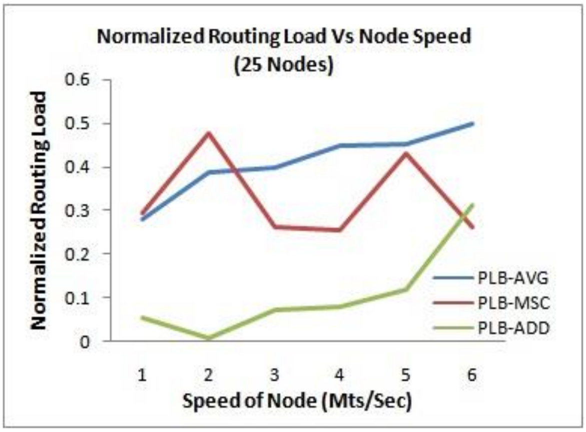

Fig.11. Normalized Routing Load Vs Node Speed (25 Nodes)

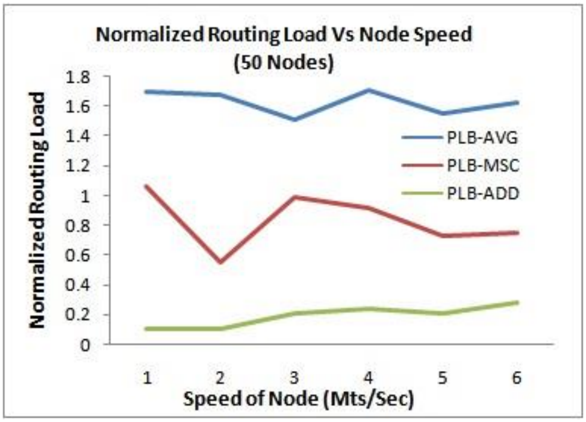

Fig.12. Normalized Routing Load Vs Node Speed (50 Nodes)

From figures 10, 11 and 12, it can be clearly observed that the PLB-ADD strategy incurs the least routing load, followed by PLB-MSC and then PLB-AVG. This is due to the fact that in PLB-ADD, GWADV messages are not flooded into the MANET unnecessarily. GWADV messages will be unicast in the MANET on receiving a GWSOL message.

4.3. Simulation in Hybrid Framework

The second architecture, called hybrid framework, is the one proposed in [20]. The hybrid framework consists of fixed gateways as well as mobile gateways. It is shown in fig13. The upper part of the figure shows mobile nodes in a MANET being services by fixed gateways (FG). In the lower part of the network, mobile nodes register with mobile gateways (MG), which in turn are registered with Internet gateways (IG). Simulation parameters for the second set of simulations in hybrid framework are shown in table 4.

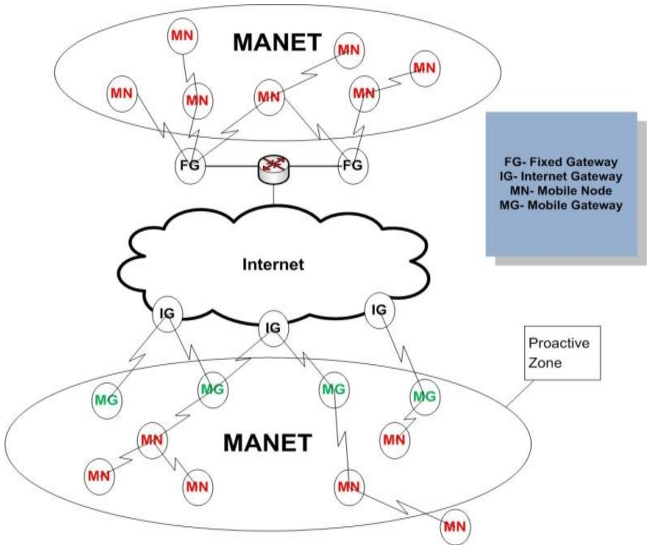

Fig.13. Hybrid Architecture

Table 4. Simulation Parameters for Hybrid Framework

Simulation Parameter	Value	
Architecture	*Hybrid Framework*	
Number of Mobile Nodes	25	15
Number of Fixed gateways	3	2
Number of Mobile Gateways	4	2
Toplogy Size	1000X1000	800X500
Mobile node radio range	250m	
Simulation time	900 sec	
Number of traffic sources	5	
Traffic Type	CBR	
Mobility Model	Random Waypoint	
Node Speed	1-6 Mts/Sec	
Number of destination nodes	2	
Pause Time	60 seconds	
Ad Hoc Routing Protocol	AODV+	

4.3.1. Results Discussion

The simulation in the hybrid framework was carried out in two different topologies containing 15 nodes, 25 nodes, as shown in the above table. The nodes speed was used as the variant based on which simulations were conducted. Node speed was varied from 1 mt/sec to 6 mts/sec. Figures 14 to 19 show the simulation results for the hybrid framework. Figures 14 and 15 show the comparison of the three strategies based on the packet delivery ratio metric for 15 and 25 nodes respectively.

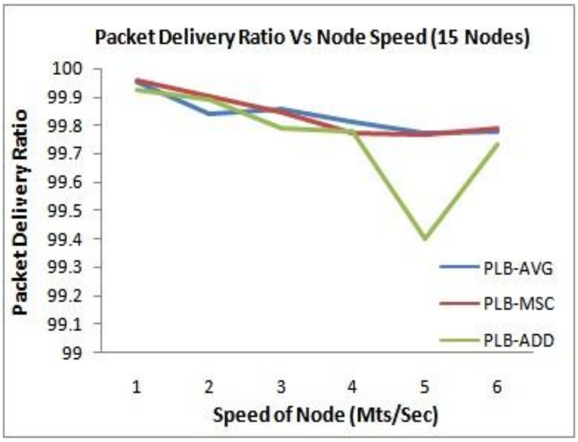

Fig.14. Packet Delivery Ratio Vs Node Speed (15 Nodes)

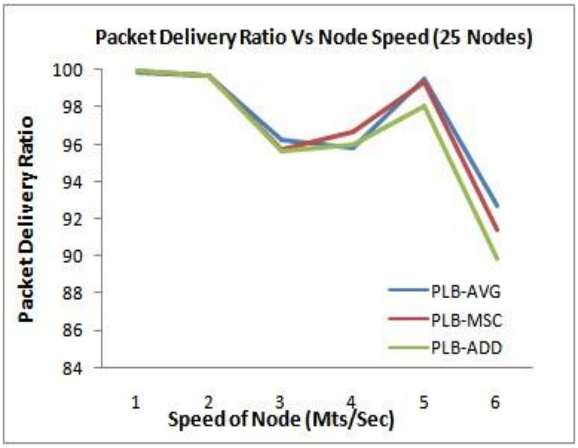

Fig.15. Packet Delivery Ratio Vs Node Speed (25 Nodes)

From figures 14 and 15, it is observed that PLB-AVG generally provides better packet delivery ratio, followed by PLB-MSC and then PLB-ADD. This result is a reflection of the observations made from figure 4,5 and 6 for the packet delivery ratio in the two-tier architecture. Therefore, we confirm our conclusion that having a predefined proactive zone is a good idea to achieve a better packet delivery ratio, even in a hybrid framework. Figures 16 and 17 show the performance comparison of the three strategies based on the End to End delay metric.

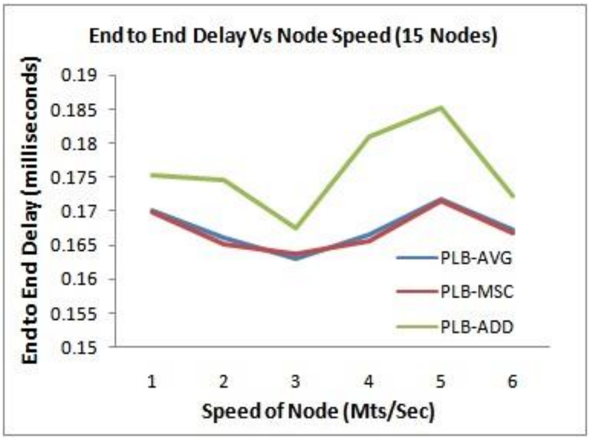

Fig.16. End to End Delay Vs Node Speed (15 Nodes)

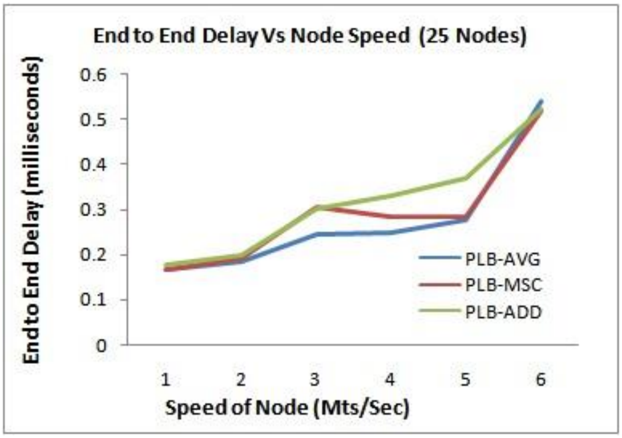

Fig.17. End to End Delay Vs Node Speed (25 Nodes)

In terms of End to End Delay, in the hybrid framework, PLB-MSC gives the best results, followed by PLB-AVG and then PLB-ADD. This result is again a reconfirmation of the result observed from the end to end delay in the two tier architecture. Figures 18 and 19 show the performance comparison of the three proposed strategies based on the normalized routing load metric.

From figures 18 and 20, it can be clearly observed that the PLB-ADD strategy incurs the least routing load, followed by PLB-MSC and then PLB-AVG. Therefore, we can conclude that the PLB-ADD strategy gives the best result when it comes to normalized routing load in the two-tier as well as hybrid architectures.

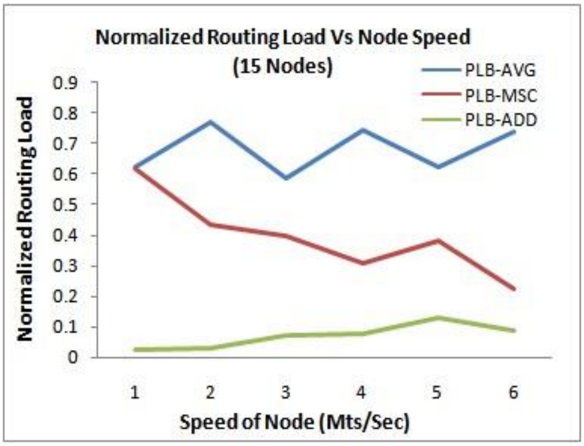

Fig.18. Normalized Routing Load Vs Node Speed (15 Nodes)

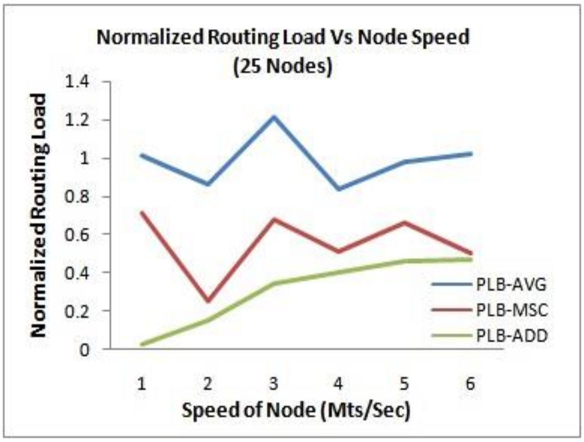

Fig.19. Normalized Routing Load Vs Node Speed (25 Nodes)

5. Conclusions

The Integrated Internet MANET (IIM) architecture is a promising development for the realization of the stated use case scenarios of ubiquitous Internet access in the 5G networking architecture. Adaptive Gateway discovery is a key issue in Integrated Internet MANET. In this paper, three gateway discovery strategies were proposed, namely PLB-AVG, PLB-MSC and PLB-ADD. These strategies address the issues of efficient gateway selection, dynamically adjusting the proactive zone and adapting the periodicity of GWADV messages. The proposed strategies were simulated in two different IIM architectures – two-tier architecture and hybrid architecture, using network simulation tool ns-2. From the simulation results it is observed that PLB-AVG delivers the best packet delivery ratio while at the same time incurring the highest routing load. PLB-MSC gives the best performance in terms of End to End delay. Finally, PLB-ADD incurs the least normalized routing load.

Therefore, it is concluded that to achieve efficiency under different performance parameters, different strategies are useful. For achieving better packet delivery ratio for mission critical applications like emergency scenarios, PLB-AVG is recommended. When the goal is to provide least end to end delay for real time applications like video streaming, PLB-MSC is recommended. When networking resources are at a premium, PLB-ADD is recommended to reduce routing load.

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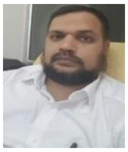

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How to cite this paper: Rafi U Zaman, S. Shehnaz Begum, Khaleel Ur Rahman Khan, A. Venugopal Reddy,"Efficient Adaptive Path Load Balanced Gateway Management Strategies for Integrating MANET and the Internet", International Journal of Wireless and Microwave Technologies(IJWMT), Vol.7, No.2, pp.57-75, 2017.DOI: 10.5815/ijwmt.2017.02.06