Improvement of Adaptive Load Balanced Gateway Discovery Protocol in Hybrid Integrated Internet-MANET

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Abstract—Integrated Internet-MANET is a heterogeneous networking architecture which is the result of interconnecting wired Internet and wireless MANET. Multiprotocol gateways are used to achieve this interconnection. There are two types of Integrated Internet-MANET architectures, two-tier and three-tier. A combination of two-tier and three tier architectures also exists, called the Hybrid Framework or Hybrid Integrated Internet-MANET. Some of the most important issues common to all Integrated Internet-MANET architectures are: efficient gateway discovery, mobile node registration and gateway load balancing. Adaptive WLB-AODV is an existing protocol which addresses the issues of Gateway load balancing and efficient Gateway discovery. In this paper, an improvement is proposed to Adaptive WLB-AODV, called Adaptive Modified-WLV-AODV by taking into account route latency. The proposed protocol has been implemented in Hybrid Integrated Internet-MANET and has been simulated using network simulation tool ns-2. Based on the simulation results, it is observed that the proposed protocol delivers better performance than the existing protocol in terms of performance metrics end-to-end delay and packet loss ratio. The performance of the proposed protocol is further optimized using a genetic algorithm.

Keywords—Mobile Ad Hoc Network, Gateway Load Balancing, Integrated Internet MANET, WLB-AODV, Adaptive Gateway Discovery, Genetic Algorithm, Hybrid Framework

1   Introduction

The study of Mobile Ad Hoc Network (MANET) has been undertaken extensively by several researchers. This study has mainly been concerned with the issue routing protocols in MANET, with very less effort being spent into realizing the practical benefits of MANET. In the recent years, a heterogeneous architecture called Integrated Internet-MANET (IIM) [1] has been proposed, which is an interconnection of wired Internet and wireless MANET. The IIM architecture enables mobile nodes in the MANET to access remote services available over the Internet and also to communicate with wired nodes. The features of IIM can be used to realize the use case scenario of future 5G networks [15], wherein, a group of survivors in a disaster can use their mobile devices to communicate with the outside world.
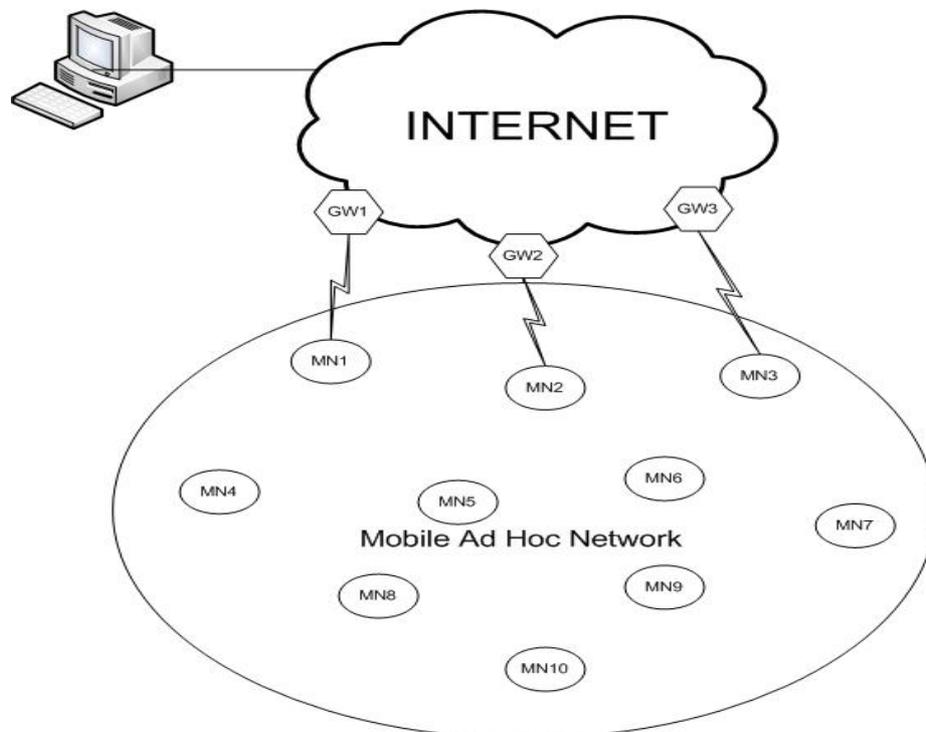

Fig. 1. Two Tier Integrated Internet-MANET Architecture

Many types of Integrated Internet-MANET (IIM) architectures have been described by various authors. The Integrated Internet-MANET architecture shown in fig1 is called two-tier architecture. In two-tier architecture, the multi-protocol gateways (GW1, GW2 and GW3 in fig1) are used to interconnect the wired Internet to the wireless MANET. The set of Gateways forms the upper layer and the set of mobile nodes in the MANET forms the lower layer. Hence it is called two-tier architecture. Mobile nodes in the MANET use a MANET routing protocol (like AODV or DSDV)

to establish communication between them. In case a mobile node wants to communicate with a wired node which lies outside the MANET and which is connected to the Internet, the MANET routing protocol needs to be modified in order to make it work in a wired-cum-wireless scenario. AODV+ [6] is a modified version of AODV MANET routing protocol which works in a wired-cum-wireless networking scenario. It addresses issues like Gateway discovery by mobile nodes, mobile node registration with Gateways, addressing, besides implementing the regular AODV routing protocol for routing within the MANET. In this paper, the AODV+ routing protocol is used for implementing the Integrated Internet-MANET architecture.

Apart from the two-tier IIM architecture, three-tier IIM architecture also exists. In this type of IIM architecture, a set of mobile gateways (MG1, MG2 and MG3 in fig2) forms an intermediate layer between the upper layer of Gateways which are now called fixed Gateways, and the lower layer consisting of MANET mobile nodes. Mobile Gateways register with fixed Gateways, whereas MANET mobile nodes register with mobile gateways. Therefore, registration is a two-step process. An example of three-tier IIM architecture is shown in fig2. A comprehensive survey of two-tier and three-tier architectures in IIM can be found in [19].
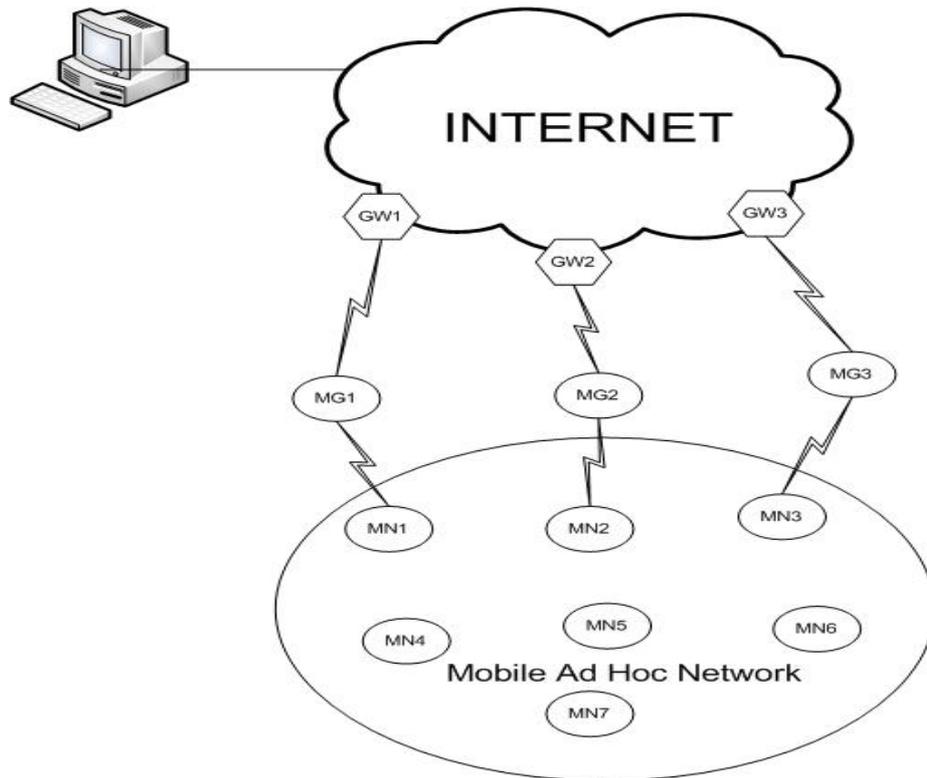

Fig. 2. Three Tier Integrated Internet-MANET Architecture

A combination of two-tier and three-tier architecture, called the Hybrid Framework for Integrated Internet-MANET is described in [20]. The Hybrid Framework consists of fixed gateways as well as mobile gateways as shown in fig3. The upper part of the figure shows mobile nodes in a MANET being serviced 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).

Gateway discovery is a paramount issue in IIM, since communication between mobile nodes in MANET and wired nodes in Internet is made possible only via Gateways. Several Gateway discovery mechanism like proactive, reactive and hybrid [6] are defined in the literature. A hybrid Gateway discovery mechanism which adapts its parameters according to the changing networking conditions is called Adaptive Gateway discovery [9]. In addition to Gateway discovery, load balancing of traffic across the available Gateways [4] is also a critical issue. An integration strategy based on WLB-AODV [5] exists which performs Gateway load balancing in IIM based on three metrics namely: Hop Count (HC), Aggregate Interface Queue Length (AIQL) and Aggregate Routing Table Entries (ARTE). In [5] and in subsequent works based on WLB-AODV [13][14], weights are assigned statically to the above three parameters of WLB-AODV.
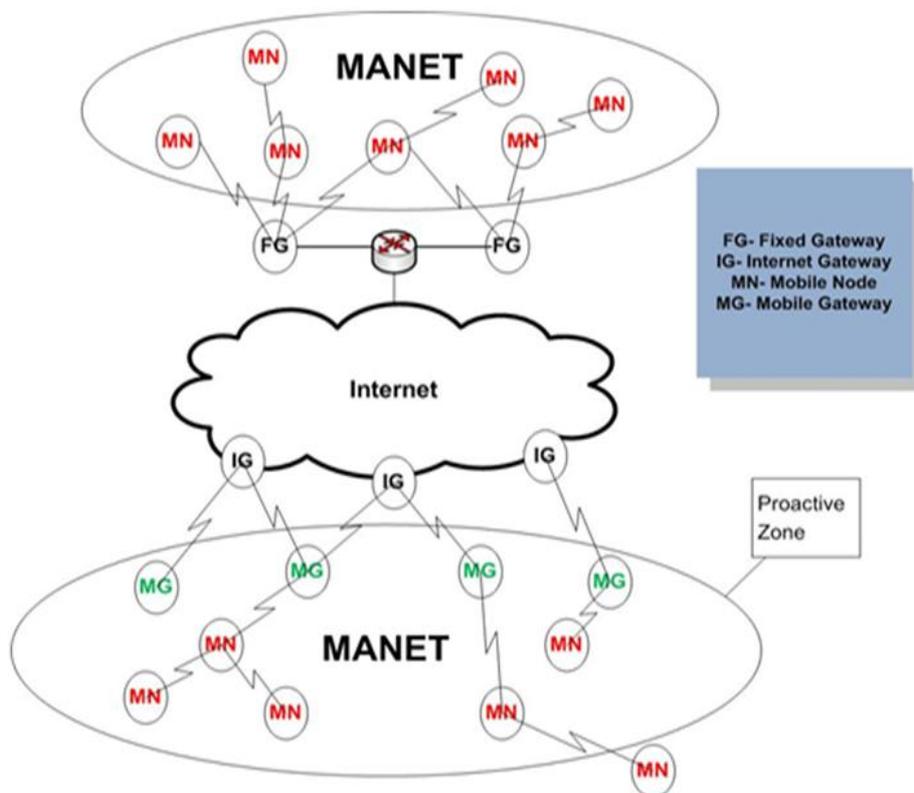

Fig. 3. Hybrid Framework using Fixed and Mobile Gateways

In addition to the above three parameters, route latency is also proposed in the recent works [16] as an important parameter in any Gateway load balancing solution. Therefore, in this paper, a modification is proposed to the existing WLB-AODV protocol by incorporating a fourth parameter called Latency, which is nothing but the time taken by a packet to traverse a route. In the proposed Adaptive Gateway load balancing strategy, the TTL value and periodicity of Gateway advertisement (GWADV) message is dynamically adjusted as in [14]. The main issue addressed in the proposed strategy is the dynamic adjustment of the weights of the four parameters of modified WLB-AODV protocol. The solution proposed is based on a genetic algorithm whose fitness function is based on fuzzy inference rule base. The methodology which is followed is, first the proposed modified version of WLB-AODV which includes the latency parameter is simulated in ns-2 in Hybrid IIM architecture. The results obtained are input the fitness function, which determines the suitability of the overall result, based on three performance parameters namely, end to end delay, normalized routing load and packet loss rate. If any of the results is found to be unsatisfactory according to the fitness function, then an off-spring is generated using the stochastic function which represents another set of weights for the four parameters of the modified WLB-AODV protocol. The proposed protocol is again simulated to check its performance against the fitness function. This process is repeated until a satisfactory result is obtained, according to the fitness function.

The rest of the paper is organized as follows: In section 2, work related to the proposed protocol is presented. In section 3, the various features of the proposed protocol are presented. In section 4, the performance comparison of the proposed protocol with respect to the existing protocol is presented. In section 5, the optimization process of the proposed protocol is presented. Section 6 concludes the paper.

2 Related Work

In Cabrera et al [2] the concept of Dynamic Gateways is defined, which are selected when current Dynamic Gateways are overloaded. The Gateway discovery process handles the load balancing mechanism. In Hsu et al [3], the proactive range of a Gateway expands and contracts dynamically based on current traffic load and Gateway load balancing is integrated into the Gateway discovery and selection process itself.

Traditional Gateway discovery mechanisms like proactive, reactive and hybrid [6] exist which help a mobile node to discovery and register with gateways which offer Internet connectivity. An efficient gateway discovery mechanism is proposed in [8] which implements path load balanced routing of packets within the MANET but does not perform gateway load balancing. In [10], dynamic adjustment of TTL and periodicity of GWADV messages is proposed, based on fuzzy logic. Adaptive gateway discovery mechanisms have been proposed which perform the task of gateway discovery efficiently [9]. As stated in section 1, in [13] GWADV periodicity was adjusted using the metrics Number of Nodes (NN), Average Hops (AH) and Aggregate Interface Queue Length (AIQL) as parameters to the Mamdani Fuzzy Control Architecture [11]. In this work, gateway advertisement TTL value was not adjusted, where-

as, [14] uses the same method to adjust gateway advertisement periodicity, while enhancing the work in [13] by adjusting the TTL value using the maximal source coverage algorithm as well.

In [16], fuzzy logic mechanism based on route latency is used to make decisions about route selection. In [17], robustness of a path is considered for making routing selection decisions. In [18], Yuste et al propose a method of generating fuzzy intervals using a genetic algorithm based on a fuzzy fitness function. The solution proposed in this paper for determining optimal weights for the parameters of WLB-AODV protocol is based partly on the work of Yuste et al [18]. In [21], the protocol proposed in this paper was implemented in Two-Tier Integrated Internet-MANET architecture.

3 Adaptive Load Balancing in Hybrid Integrated Internet-MANET using Modified WLB-AODV

Hamidian et al [6] have proposed a modification to the AODV routing protocol in order to implement the IIM architecture. The modified protocol is called AODV+. In this paper, the AODV+ framework is used to implement the Hybrid IIM architecture.

3.1 Modified WLB-AODV Routing Protocol (M-WLB-AODV)

As stated earlier, three parameters are used to implement Gateway load balancing in the WLB-AODV routing protocol [5]. In this paper, a modified form of WLB-AODV is proposed. The WLB-AODV routing protocol is extended to reflect route latency by adding one more parameter to the metric. The modified metric M_i is calculated according to the following equation:

$$M_i = a * HC + b * AIQL + c * ARTE + d * Latency \qquad (1)$$

Where a, b, c and d are the weights given to the respective parameters HC, AIQL, ARTE and Latency, and,

$$a + b + c + d = 1 \qquad (2)$$

The working of Modified WLB-AODV works in Integrated Internet-MANET is follows: a Gateway inserts the following information into every Gateway advertisement message (GWADV). The number of mobile nodes registered with the Gateway for accessing the Internet, the interface queue length of the Gateway and the route latency to the gateway, which is initialized to 0. The modified GWADV message which includes the AIQL (ad_qlen), ARTE (ad_no_of_reg) and Latency (ad_laency) metrics is shown in fig2. Hop Count, which is the fourth parameter of the metric shown in eq. (1), is already a apart of the GWADV message. Along with the modified GWADV message, the routing table of a mobile node is also modified to include entries for AIQL (rt_qlen), ARTE (rt_no_of_reg) and Latency (rt_latency).

Type	Reserved	Prefix Size	HopCount
Broadcast ID			
Destination IP Address			
Destination Sequence Number			
Source IP Address			
TTL			
Timestamp			
ad_qlen			
ad_no_of_reg			
ad_latency			

Fig. 4. Modified GWADV format to include gateway queue length, number of registrations of a gateway and latency

A mobile node updates the GWADV message as follows: it updates the queue length information field of the GWADV message by adding its own interface queue length and updates the route latency by recalculating it. Thus, the aggregate interface queue length is maintained at all times in the GWADV messages along the route that it traverses. A mobile node which desires Internet connectivity calculates the new metric value M_i, and compares it with the metric value based on the values stored in its routing table, which is called the old metric value. If the new metric is better than the old metric value, the new path is set as the default path to the gateway, and the routing table is updated to reflect the new gateway's AIQL, ARTE and Latency parameters. The modified routing table of WLB-AODV is shown in fig5.

rt_dst	rt_seqno	rt_hops	rt_qlen	rt_no_of_reg	rt_latency	…

Fig. 5. Routing table of modified WLB-AODV

3.2 Adjustment of GWADV TTL value:

The time-to-live (TTL) field in the GWADV message denotes the number of hops a GWADV message can traverse in the MANET. It is initialized to a certain value, and is decremented on each hop. The GWADV message is not forwarded any more when the TTL value reaches 0. In proactive and hybrid gateway discovery mechanisms, the TTL is set to a static value. In a modification to the hybrid approach, called the Adaptive Gateway discovery mechanism, the TTL value is adapted to changing networking conditions. In this paper, the TTL value is adjusted by every Internet gateway using the Maximal Source Coverage algorithm [7].

3.3 Adjustment of GWADV periodicity value:

Periodicity or Advertisement Interval of a GWADV message is the number of times a GWADV message is transmitted in a given time interval. In traditional gateway discovery approaches like proactive, reactive and hybrid, the periodicity is set

statically, whereas in adaptive gateway discovery mechanism, the periodicity is adjusted based on changing networking conditions. In the proposed strategy, a Gateway uses three metrics, namely number of nodes registered with it (NN), average hops of active sources (AH) and AIQL to adjust its GWADV periodicity. The three metrics are fuzzified to produce a final periodicity value. The complete method of obtaining the periodicity value is detailed in [13], and the same is used in the proposed protocol.

4 Performance Evaluation

The proposed protocol has been simulated using the network simulation tool ns-2 [12], and its performance compared with the existing protocol called Adaptive-WLB-AODV protocol [14], based on the performance metrics packet loss rate, end-to-end delay and normalized routing load.

The Adaptive-WLB-AODV [14] protocol as described in section-2 uses WLB-AODV with three parameters namely, Hop Count (HC), Aggregate Interface Queue Length (AIQL) and Aggregate Routing Table Entries (ARTE). The a,b,c values of these three parameters have been set to {0.5,0.25,0.25} respectively, since these were the values used in the simulations in [14]. It uses the maximal source coverage [7] algorithm for dynamic TTL adjustment and Mamdani fuzzy control for dynamic periodicity adjustment of GWADV messages [13]. In [14], the Adaptive-WLB-AODV protocol was implemented in two-tier IIM, whereas in this paper, both the Adaptive-WLB-ADOV and Modified Adaptive-WLB-AODV are implemented in a Hybrid IIM architecture.

In the following figures, the proposed protocol is referred to as Adaptive-Mod-WLB-AODV to reflect the fact that the original Adaptive-WLB-AODV protocol has been modified to include a fourth parameter, latency. The weights of these four parameters have been initially set to the values {0.25,0.25,0.25, 0.25}. Moreover the proposed protocol is implemented twice, once with the weights {0.25,0.25,0.25, 0.25} in which case it is referred to as Adaptive-Mod-WLB-AODV-1, as in figures 6, 7 and 8. Later the proposed protocol is implemented with optimized weights obtained from the genetic algorithm in section 5, in which case it is referred to as Adaptive-Mod-WLB-AODV-2.

4.1 Simulation Setup

The simulation setup consists of fifty mobile nodes, five Fixed Gateways and four Mobile Gateways. Out of the five Fixed Gateways, three are in the three-tier architecture and two are in the two-tier architecture. The three mobile gateways are part of the three-tier architecture. The speed of mobile nodes varies from 1 to 6 metres /second (mts/sec), with a pause time of 60 seconds. The random waypoint mobility model is used. The traffic type is constant bit rate with packets being sent at 5 per second. The topology size is 1200 x 1200. Each scenario was simulated for 900 seconds with the traffic starting after 100 seconds of simulation. This is done so that the mobile nodes stabilize. For each node speed, ten different mobility scenarios were used. The final

value is the average of these ten scenarios. In this way, for 6 speed values, 60 simulation runs were conducted for each protocol. The simulation parameters are summarized in the table 1.

Table 1. Simulation Parameters of The Proposed Protocol

Simulation Parameter	Value
IIM Architecture	Hybrid
Number of Mobile Nodes	50
Number of Fixed Gateways	5
Number of Mobile Gateways	4
Toplogy	1200m x 1200m
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
Packet Sending Rate	5 packets/ sec
Number of destination nodes	2
Pause Time	60 seconds
MANET Routing Protocol	AODV+

4.2 Performance Metrics

The performance metrics in order to do comparative analysis are defined as follows. The efficiency of a protocols performance is in minimizing the values of these performance metrics.

Packet Loss Ratio: This parameter measures the ratio of number data packets lost in transit to the actual number of packets sent by all the traffic sources combined.

End-to-End Delay: The average time taken by all the data packets to reach their respective destination nodes.

Normalized Routing Load: The ratio of the number of control packets generated to the total number of data packets sent.

4.3 Results Discussion

In the figures 6, 7 and 9, the performance of the proposed and existing protocols with respect to the performance metrics is presented. In fig6, it is observed that, the proposed protocol Adaptive-Mod-WLB-AODV-1 is more efficient and delivers lesser end to end delay than the existing protocol.
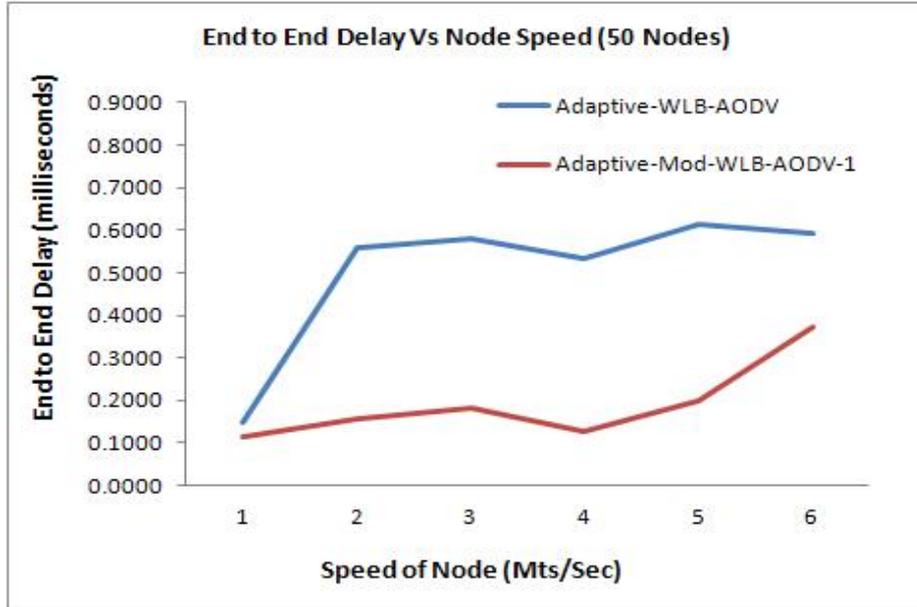
Fig. 6. End-to-End Delay vs. Node Speed of Adaptive-WLB-AODV and Proposed protocol
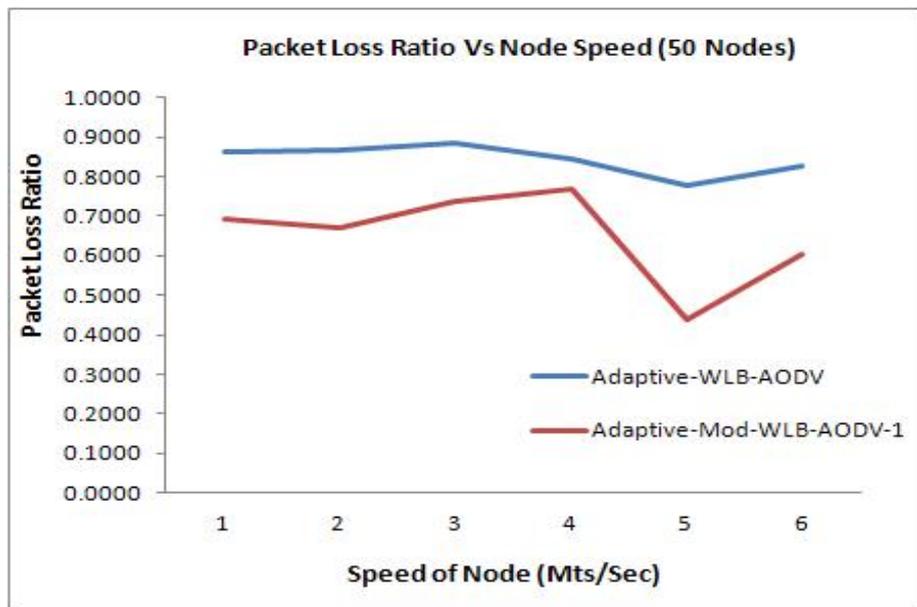

Fig. 7. Packet Loss Ratio vs. Node Speed of Adaptive-WLB-AODV and Proposed protocol

In fig7 the performance of Adpative-Mod-WLB-AODV-1 protocol is observed to be superior to the existing Adaptive-WLB-AODV protocol in terms of packet loss ratio, for all the node speeds.
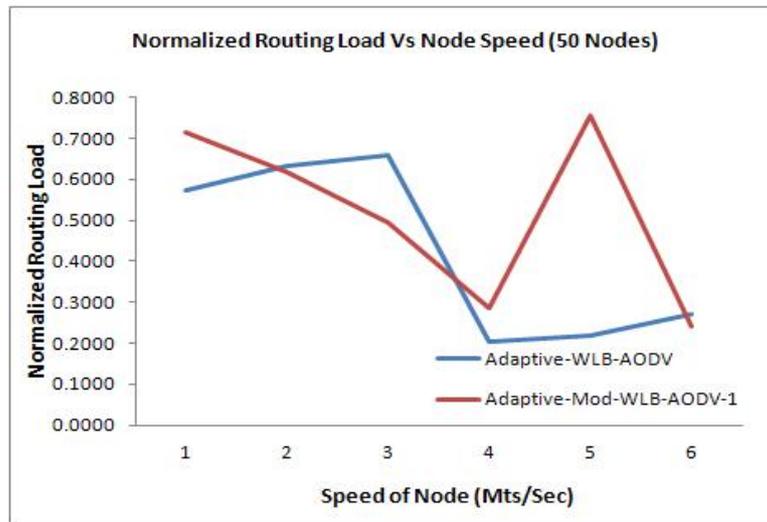

Fig. 8. Normalized Routing Load vs. Node Speed of Adaptive-WLB-AODV and Proposed protocol

In fig8, the performance of Adaptive-WLB-AODV and the proposed protocol is shown with respect to Normalized Routing Load. It is observed that the proposed protocol incurs lesser routing load for speeds 2, 3 and 6, whereas the existing protocol gives better performance for the rest of the speed. Therefore, in terms of normalized routing load the proposed and existing protocols are evenly matched.

Overall, it can be concluded that the proposed protocol outperforms the existing protocol in terms of end to end delay and packet loss rate while incurring comparable routing load.

5 Optimization of Weights of the Proposed Protocol

From, the simulations performed in section 4, it was concluded that the proposed strategy called Adaptive Modified WLB AODV outperforms the existing Adaptive WLB-AODV protocol in terms of packet loss rate and end to end delay, while incurring similar normalized load. The weight distribution was uniform across the four parameters i.e. {0.25,0.25,0.25, 0.25}. In order to determine whether this weight distribution is optimal, a mechanism based on fuzzy logic and genetic algorithm is proposed. The optimization process works as follows:

Step 1: Normalize the values obtained for the three performance parameters using the triangular function [11].

Step 2: A fitness function is generated for the genetic algorithm, based on the normalized values generated in step1. The fitness function is based on a fuzzy system which distributes the simulation values into three types: Low (L), Medium (M) and High (H) as shown in table 2. This distribution is arrived at by observing the range of averages of the values of the respective performance parameters of the proposed protocol over several simulations. The values of performance parameters are fuzzified based on the Fitness Function of table 2.

Table 2. Fuzzy Distribution for Fitness Function

Performance Parameter	L	M	H
E2E	x<=0.4	x>0.4 and x<0.6	x>=0.6
PLR	x<=0.7	x>0.7 and x<0.8	x>=0.8
NRL	x<=0.4	x>0.4 and x<0.6	x>=0.6

Step 3: The rules for generating the fitness function values are enumerated in table 3, above. These 27 rules are adapted from the rule base of fitness function of Yuste et al in [18]. The fitness function returns one of four values: Very Low (VL), Low (L), Medium (M) and High (H), reflecting the suitability of the result. In our proposal, A set of values is considered to be of acceptable if the fitness function returns any value other than High (H). If the fitness function returns a High (H) value for a particular speed, then the simulation needs to be repeated with a different set of weights for Modified WLB-AODV.

Step 4: After evaluating the results based on the rule base of the fitness function of table 3, the final fitness function values for the different speeds are obtained. The resulting fitness function values are presented in table4. We observe that, for speed 3 mts/sec, the fitness function returns value 'H', since Fuzzy-E2E, Fuzzy-PLR and Fuzzy-NRL has values H, H and H respectively. This is according to rule number 27 of table 3. The values VL, L and M returned by the fitness function are considered to be tolerable whereas, the value H is considered intolerable, that is the performance in terms of E2E, PLR and NRL taken together is not satisfactory. Therefore, another child has to be generated.

Step 5: Since one of the values for the fitness function was found to be unsatisfactory, an off-spring needs to be generated. The parent is the initial weight tion{0.25,0.25,0.25, 0.25}. Various functions like mutation, crossover and Gaussian or Stochastic can be used for off-spring generation in genetic algorithm. Using the Stochastic function we got the offspring value and distributed the weights accordingly as{0.2,0.1,0.1, 0.6}. Apart from this off-spring, any other off-spring could have been used.

Step 6: The proposed protocol is simulated again using the new set of weights obtained in step5. The simulation of the proposed protocol the second time is referred to as Adaptive-Mod-WLB-AODV-2. Its fitness function values are shown in table 5. We observe that all the values returned by the fitness function are within tolerable limits, and none of them is H. Therefore, we can conclude that the off-spring {0.2,0.1,0.1, 0.6} gives optimized performance when compared to the

ent{0.25,0.25,0.25, 0.25}. In this way, the adaptive gateway load balancing protocol can be optimized. It has to be noted that the off-spring {0.2,0.1,0.1, 0.6} is optimal only for the current scenario of 50 nodes. For other scenarios, other off-spring might be optimal.

Table 3. Rule Base for Fitness Function

Rule	Delay	PLR	NRL	FF
1	L	L	L	VL
2	M	L	L	VL
3	H	L	L	L
4	L	M	L	VL
5	M	M	L	L
6	H	M	L	L
7	L	H	L	L
8	M	H	L	L
9	H	H	L	M
10	L	L	M	VL
11	M	L	M	L
12	H	L	M	L
13	L	M	M	L
14	M	M	M	L
15	H	M	M	M
16	L	H	M	L
17	M	H	M	M
18	H	H	M	H
19	L	L	H	L
20	M	L	H	L
21	H	L	H	M
22	L	M	H	L
23	M	M	H	M
24	H	M	H	H
25	L	H	H	M
26	M	H	H	H
27	H	H	H	H

Table 4. Generating the Fuzzy Values of Fitness Function for Adaptive-Mod-WLB-AODV-1

Speed	E2E	Fuzzy-E2E	PLR	Fuzzy-PLR	NRL	Fuzzy-NRL	FF
1	0.111854	L	0.776220	M	0.355271	L	VL
2	0.740573	H	0.655459	L	0.762216	H	M
3	0.842357	H	0.829427	H	0.749268	H	H
4	0.383106	L	0.778483	M	0.557679	M	L
5	0.398948	L	0.665502	L	0.709882	H	L
6	0.555112	M	0.651284	L	0.926167	H	L

Table 5. Generating the Fuzzy Values of Fitness Function for Adaptive-Mod-WLB-AODV-2

Speed	E2E	Fuzzy-E2E	PLR	Fuzzy-PLR	NRL	Fuzzy-NRL	FF
1	0.116368	L	0.693747	L	0.716023	H	L
2	0.156502	L	0.671860	L	0.616469	H	L
3	0.180259	L	0.736290	M	0.494671	M	L
4	0.127650	L	0.769262	M	0.284494	L	VL
5	0.197231	L	0.439539	L	0.754933	H	L
6	0.371780	L	0.602783	L	0.242103	L	VL

6   Conclusion

Integrated Internet-MANET architecture can be a candidate for realizing the potential of future technologies like 5G networks, where interoperability of different networks is a major issue. Moreover, different types of Integrated Internet-MANET architectures like two-tier, three-tier and Hybrid Framework have been proposed in the literature. Within Integrated Internet-MANET, several open issues exist, chief among them efficient gateway discovery and gateway load balancing. A strategy called Adaptive WLB-AODV exists which addresses the above two issues. In this paper, a modification is proposed to Adaptive WLB-AODV by including the Route Latency metric into the protocol. The modified protocol is called Adaptive Modified WLB-AODV protocol. Adaptive WLB-AODV and Adaptive Modified WLB-AODV have been simulated in Hybrid Integrated Internet-MANET architecture, which is a combination of two-tier and three-tier architectures.

Based upon the simulation results, it is inferred that the proposed solution gives better performance than the existing solution in terms of Packet Loss Ratio and End to End Delay, while incurring comparable Normalized Routing Load. Moreover, in order to optimize the weights of the proposed protocol, a genetic algorithm based on fuzzy logic fitness function was used. The proposed protocol was simulated again using the off-spring values generated by the genetic algorithm. It is observed that the values of weights generated by the off-spring function give better performance vis-à-vis the fitness function of the genetic algorithm, thus improving the performance of the proposed protocol further.

In the future, the proposed protocol can be tested by implementing different off-spring generation techniques like mutation, crossover and Gaussian operators. Studying the performance of the different operators with respect to each other and under different networking conditions is another interesting problem.

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