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IGP: Inter-operable Gateway Protocol for Routing in Heterogeneous Mobile Ad-hoc Networks

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ABSTRACT: Heterogeneous mobile ad-hoc network (MANET) has received less attention in the research community although its communication potentials are highly enduring in fifth generation networking system. The serious challenges in this case is to ensure an effective inter-domain routing and a robust gateway system that can perform the conversion of the control message from one to another domain of heterogeneous mobile ad-hoc network, which is the problem of interoperability. This paper presents a framework called as Interoperable Gateway Protocol (IGP) that performs conversion and processing of the control data among different forms of routing protocols in different domains. With support of algorithm and elaborated analytical methodology, the proposed work presents a routing mechanism along with message conversion technique. The outcome of this study is found to have better interoperable features in comparison to existing techniques.

KEYWORDS: Inter-Domain Routing, Heterogeneous Mobile Ad-hoc Network, Gateway Protocol, Control Message.

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) consists of a collection of mobile nodes which are not bounded in any infrastructure. Nodes in MANET can communicate with each other and can move anywhere without restriction. This non-restricted mobility and easy deployment characteristics of MANETs make them very popular and highly suitable for emergencies, natural disaster and military operations. Nodes in Homogeneous Ad-hoc networks possess same characteristics of hardware configuration where as in heterogeneous Ad-hoc networks, nodes differ according to the hardware configuration [1].

II. INTEROPERABILITY PROBLEM

Heterogeneous mobile ad-hoc network consists of various forms of ad-hoc-based networks. Such forms of networks are accomplished by integrating mobile ad-hoc networks with various applications or with various networking standards to accomplish a specific task (Fig.1).

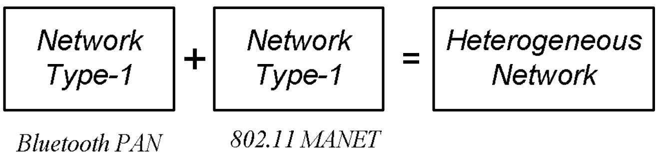

Fig.1. Formation of Heterogeneous Mobile Ad-hoc Network

Figure.1 shows the formation of the heterogeneous MANET, where wireless ad-hoc network is being integrated with different forms of wireless standards (Bluetooth PAN). One challenge in such network is processing the control messages such as route request, route reply, route error, and route acknowledgement. Exchange of the control messages between two communicating nodes is carried out by a large range of routing protocols that are used in mobile ad-hoc

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networks [2], [11]. Each of the routing protocols has specific way of exchanging and processing the control messages. Although, routing can be established easily for homogeneous mobile ad-hoc networks, it poses a significant challenge in heterogeneous MANETs. Inter-domain routing protocol can assist in establishing communication in heterogeneous MANET [12]. However, processing multiple control messages based on the cardinality of the domains is still a challenging task. This phenomenon can be termed as interoperability problem. It can also be defined as co-operativeness of heterogeneous MANETs to provide communication services to its customer base [13]. This paper presents a technique that incorporates interoperability in inter-domain routing for heterogeneous MANETs. It has good supportability of both reactive and table-driven routing protocol.

III. RELATED WORK

The most recent work carried out in [14] presents a scheme of routing protocol using clustering approach for addressing the traffic congestion problem over MANET. The authors have used on-demand routing approach in the presented technique. The study has discussion of cluster head which is responsible for surveilling the traffic condition. Another most recent study was presented in [15] with a technique to select multiple gateways for enhancing the quality of service. The dominant term used in the paper was *migration* where it performs selection of gateway based on stable path. The outcome was found to posses better throughout and packet delivery ratio. The work in [16] has better novelty in which authors have presented a discussion of resource allocation problems for heterogeneous ad-hoc network using Lagrangian approach. The authors have assessed the outcomes of the study using rate of flow, utility, and throughput.
Nordstorm et al. [17] have presented a scheme of forwarding the potential gateway in ad-hoc network. The authors have correlated their study impact with respect to aggregation of routes, transparency of protocols, stability, minimization of overheads, and supportability of multiple gateways. The outcome of the study was evaluated with respect to percentage of controlled traffic per data, delivery ratio, throughput, etc. It proved tunneling approach as the best forwarding scheme of gateways. Natarajan and Rajendran [18] have presented a study of routing protocol using reactive approach and enhanced shortest path technique. They have formulated a cost factor for node and route disjoint path. The presented technique also controls the dynamic topology effect by using route recovery and identifying loop structures. The technique was finally compared with most frequently using Dynamic Source Routing and Optimized Link State Routing with respect to propagation delay, packet delivery ratio, and throughput mainly. Joshi et al. [19] have presented a technique for selection of the robust gateway in the mobile ad-hoc network. The work was more inclined towards clustering technique in ad-hoc network using reactive technique and the outcome was evaluated with respect to delay, overhead, throughput.

Souto et al. [20] have developed a model that establishes communication among the wireless components. The idea presented by the authors highly supports the heterogeneity and also posses enough supportability of the establishing communication with different interfaces of the network. An interesting work was presented by Zhu et al. [21] who have completely focused on developing an inter-domain routing technique in mobile ad-hoc network. The concept uses the clustering technique as well as performs selection of the cluster head in MANET in order to accomplish scalability problems. The outcome was assessed using delivery ratio, receiving rate, and control overhead. Durresi et al. [22] have presented a domain-specific hierarchical architecture for different network with multiple domains. The authors have used the gateway node to perform processing and transform-based operation among the multiple communication schemes. The outcome was evaluated with respect to gateway utilization and cost.

IV. RESEARCH ISSUE

From the standard definition of MANET, it can be seen that ad-hoc network is often studied in connection with inter-based gateways [23] [24] [25]. At present, if there is presence of different number of gateways then they are not dependent on each other (in terms of proxy gateways) as they maintain a unique address of a node. The generic gateway architecture can be seen in Figure.2

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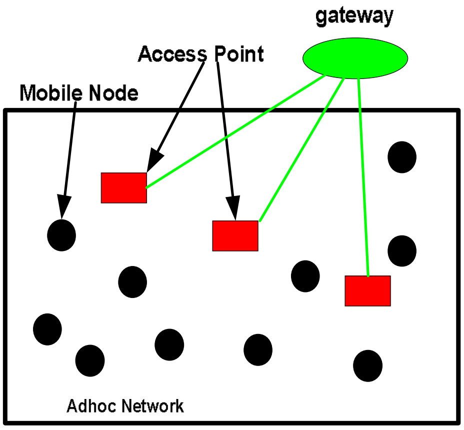

Fig.2. Gateway architecture for mobile ad-hoc network [13]

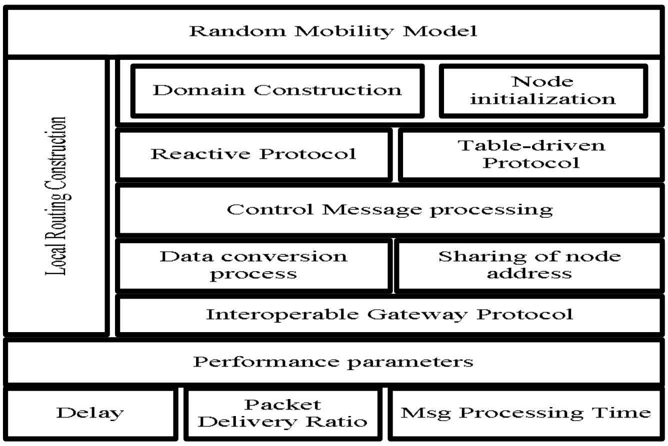

Fig.3. Schematic Architecture of IGP

It was seen the usage of Border Gateway Protocol or BGP is quite common in the gateway standards. BGP uses transport-based communication for dissemination control message [26]. Although, BGP is frequently researched and adopted commercially, in reality it is quite challenging to perform its configuration for MANETs.

V. INTEROPERABLE GATEWAY PROTOCOL DESIGN

Figure.3 represents the schematic diagram of IGP that supports an routing process among the different domains to provide interoperability. A technique of performing inter-domain routing with an aid of gateway node is presented in this work. The prime responsibility of gateway node is to convert the control message suitably that can be processed by another routing protocol. Therefore, gateway node establishes network connection by performing a data conversion process. This process is again classified into two types based on the forms of the routing protocols being used. In case of reactive routing protocol, the gateway node performs data conversion process for the control message originated from the source node. However, in case of table-driven routing, the gateway node performs exchanging of the node information in order to update the node address with both sender and recipient. Therefore, we can also state that communication made by gateway node for reactive routing is one directional while that of table-driven routing in bi-directional. The evaluation of this work is carried out considering on-demand and table-driven routing in heterogeneous MANET. The outcome is evaluated with respect to end-to-end delay, packet delivery ratio, message processing time.

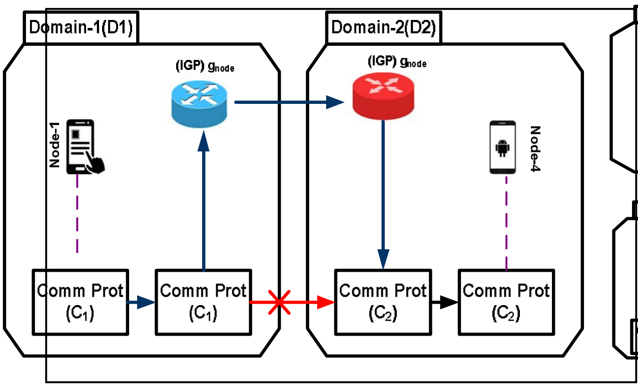

Fig.4. Adopted Scenario of Communication in IGP

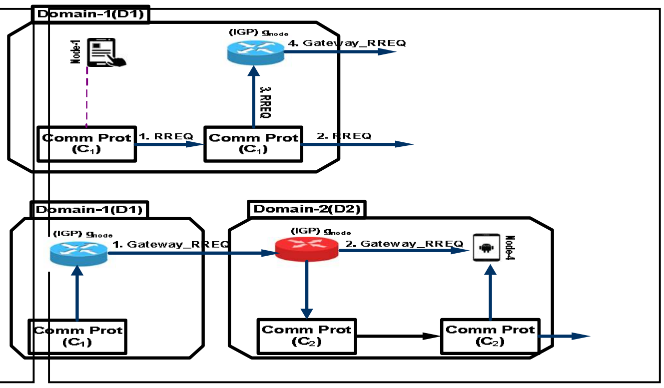

Fig.5. Processing On-demand Routing by IGP

Figure 4 shows example of two different domains D_1 and D_2 comprising of heterogeneous mobile ad-hoc network. Domain D_1 and D_2 use two different forms of communication protocol e.g. C_1 and C_2 respectively. For inter-domain routing, if we assume that $C_1 \neq C_2$ then it will mean that there is a need of a gateway that can perform appropriate

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conversion of C_1 to C_2 or vice-versa. We choose to design IGP as an algorithm that could be used as managing control message of each mobile node. This is done by storing and processing IGP from the reserved field of the control message in mobile nodes. Although the normal size of control message is around 11 bits but it could be made more flexible by reducing the 7 bits occupation of flag field.

It will allow the communication among nodes in multiple heterogeneous domains, which is elaborated in next sections. According to this principle, IGP establishes communication with the local routing protocols deployed in the nodes. The system should process any forms of routing ; on-demand or table-driven. Based on possibility of deployment of local routing, IGP uses data conversion process in case it interacts with on-demand protocols; it adopts the process of sharing the address of nodes in case of its interaction with table-driven routing. There is also a possibility that the mobile nodes could still adopt position routing. In such cases, IGP processes the positional information to map with the field of hop in the control message.

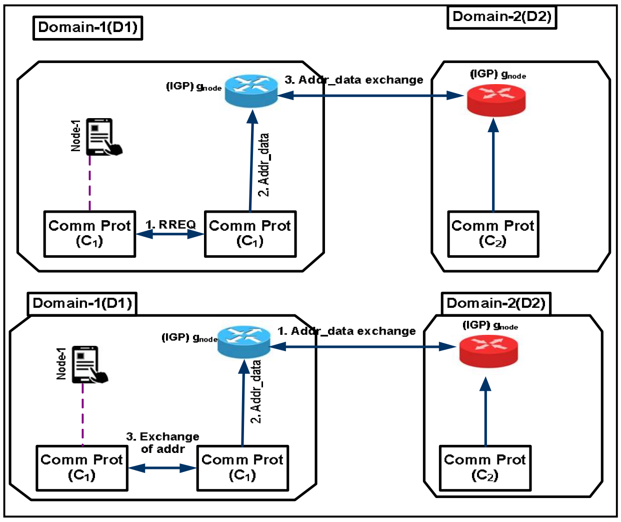

Fig.6. Processing Table-driven Routing by IGP

A. For Processing On-demand Protocols

A scenario is created where node N_1 in domain D_1 wants to establish connectivity with node N_4 residing in domain D_2. There are two different communication protocol for D_1 and D_2 by name C_1 and C_2 respectively. The node N_1 starts sending a control message for route request to the gateway node (i.e.N_2). A gateway node consists of two storage for execution part i.e. IGP execution and C_1 execution. C_1 after receiving the routing request forward the same in two directions i.e. one towards D_2 and another towards IGP of N_2. Now the IGP starts processing the route request of N_1 to node N_3 residing in D_2 (considering N_3 is gateway node in D_2). The process could be repeated on to pass from one to next IGP nodes residing in each domain in order to establish routing (Fig.5). Using the process of data conversion, each IGP node, not only establishes connectivity among the inter-domains but also instantly forwards the message for the intended recipient.

B. For Processing Table-Driven Protocols

The process as well as role of gateway protocol is quite different in case of table-driven routing. With similar scenario of nodes, routing, and domains, the sender node N_1 forwards the request to exchange routing information (Fig.6). Once the request for route data is forwarded to the gateway node N_2, the IGP does the same operation for forwarding the request for routing data exchange. However, the uniqueness is IGP request for exchange of specific address data to the IGP node of inter-domain IGP node N_3. It is to be noted that entire communication is bidirectional that is quite conventional in route discovery process in mobile ad-hoc network. One interesting fact about the proposed mechanism is node N_1 in D_1 as well as node N_4 in D_2 can perform exchanging of the routing table that makes the updation of the routing table quite faster. Uniqueness is seamless connectivity of inter-domain IGP nodes that makes the communication quite faster.

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VI. IMPLEMENTATION

A. Algorithm for Processing On-Demand Protocols

It is considered that the sender and recipient nodes are located in two different domains of the network. In such case, the control message bearing the request to establish the route is transmitted by the sender node but chances of reaching the recipient node is quite less. No communication channel possibly gets constructed.

Algorithm for Processing On-Demand Protocols

Input: *n* (total number of nodes), g_{node} (gateway node), D (domain), R_o (Routing), α (data conversion process)
Output: Processing of On-demand protocols
Start
1. Init $rand_{mob}(n)$, g_{node}, D, and R_o
2. Define D = {D_1, D_2, ….., D_m}, where m<<n
3. Alloc $D_i \leftarrow n_p$ & $D_j \leftarrow n_q$ // $n_p+n_q \leq n$, $n_p \neq n_q$, & $i+j \leq m$
4. Insert single $g_{node} \rightarrow$ unique {D}
5. For D=1: *m*
6. $n_{1i} \rightarrow RREQ(R_{o1})$
7. $R_{o1} \rightarrow RREQ\ (g_{node(Di)})$
8. $g_{node(Di)} \rightarrow IGP\_RREQ(g_{node(Dj)})$
9. $g_{node(Dj)} \rightarrow \alpha(R_{o2})$
10. $\alpha(R_{o2}) \rightarrow n_{2j}$
11. Increase count
End

The proposed algorithm for processing on-demand request considers the presence of *m* number of domain (D_1, D_2, …., D_m) where each domain has one gateway node g_{node} bearing the discrete routing protocol of on-demand type. There could be many forms of on-demand routing techniques on each domain. The algorithm initially performs implementation of random mobility model for *n* number of mobile nodes dispersed in simulation area. It also allocates domain D and variable forms of on-demand routing R_o (R_o = (R_1, R_2, ….)). Line-3 discusses the allocations of particular number of nodes n_p or n_q over different domains D_i and D_j. A single gateway node g_{node} on each domain is assumed. (Line-4). The proposed system works with an assumption that there are definite numbers of routing protocols in use and gateway node is endowed with the capability of data conversion process from one routing protocol to another. Hence the g_{node} identifies the forwarded request from its own domain and interacts with g_{node} of another domain to process the route request further. The route request is initiated by a specific sender node n_{1i} in one domain D_i that is initially processed by the local routing R_i. However, due to usage of different routing R_j in domain D_j, it is not possible for R_i to directly communicate with R_j. This communication is made possible by forwarding the route request message of n_{1j} by R_i to gateway node gnode in D_i. The g_{node} after receiving the route request message is however unknown of particulars of routing protocol used in another domain D_j. In order to establish communication, both the g_{node} inter-exchange their private information about the routing charecteristics. This enables the gnode in D_i to perform data conversion process that alters the message suitably to be processed by routing protocol R_j exercised in domain D_j. The process gets repeated till the communication is established from sender node in one domain to recipient node in another domain.

B. Algorithm for Processing Table-Driven Protocols

Proposed system incorporates the address sharing features among the gateway nodes. This algorithm ensures that gateway node must disseminate the respective address with gateway node of another domain. Hence the data conversion process differs from on-demand protocol by enabling the gateway node to inter-exchange the location information. The algorithm for implementing the interoperable processing of table-driven protocols is discussed as follows.

The initial operation performed is almost same as that of on-demand protocol processing. The initial processing of the proposed algorithm starts when node n_i wants to communicate with n_j, where both nodes reside in different domains. The node n_{1i} forwards its route request message to its local routing R_t. The local routing forwards a response to node n_{1i} and immediately forwards the address information of n_{1i} to the gateway node g_{node} in D_i.

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Algorithm for Processing Table-driven Protocols

Input: n (total number of nodes), g_{node} (gateway node), D (Domain), R_t (Routing), β (address sharing process), *addr* (Address Information)

Output: Processing of table-driven protocols

Start

1. Init $rand_{mob}(n)$, g_{node}, D, and R_t
2. Define D = {D_1, D_2, ….., D_m}, where m<<n
3. Alloc $D_i \leftarrow n_p$ & $D_j \leftarrow n_q$ // $n_p+n_q \leq n$, $n_p \neq n_q$, & $i+j \leq m$
4. Insert single $g_{node} \rightarrow$ unique {D}
5. For D=1: *m*
6. $n_{1i} \rightarrow RREQ(R_{t1})$
7. $Res(R_{t1}) \rightarrow n_{1i}$
8. $R_{t1} \rightarrow$ *addr* ($g_{node(Di)}$)
9. $g_{node(Di)} \rightarrow$ *req_ addr* (*addr*($g_{node(Dj)}$))
10. $g_{node(Dj)} \rightarrow$ *addr* ($g_{node(Di)}$)
11. $g_{node(Di)} \rightarrow \beta (R_{t2})$
12. $R_{t2} \rightarrow addr(n_{1i})$
13. Increase count

End

The gateway node inspite of forwarding the route request to D_j shares the address information of n_{1i}. Upon receiving the address information of the node n_{1i}, the gateway node of D_j shares its own and connected neighbor node information back as response to g_{node} of D_i. Upon receiving the address information, the g_{node} of D_i shares the same with the local routing R_t, which uses address sharing process that is disseminated back to source node n_{1i}. The benefit of this technique is one request leads to generation of address information to maximum possible nodes connected with their respective gateway. Hence, allocation of resources and their dependencies are quite less in processing table-driven protocols as compared to on-demand routing protocol. The second beneficial factor of this algorithm is enabling the inter-domain routing with only the established entries of the nodes in routing table makes the communication more secured. It is also essential to understand the message exchanging mechanism. The control message required for this operation usually consists of address of node and sequence number. The address of the node usually pertains to the IP address and sequence number is used to understand the freshness of the message.

VII. RESULT DISCUSSION

A gateway undertakes the load of the data conversion from multiple domains in heterogeneous networking system. Hence, its effectiveness can be evaluated by assessing the communication performance. Performance parameters such as end-to-end delay, packet delivery ratio, and processing time are considered to assess the effectiveness of interoperability. Outcome of the proposed system is compared with the most standard literature of Chau et al. [27] and Kaddoura et al. [28]. Chau et al. [27] have introduced Inter-domain Routing Protocol for mobile ad-hoc network called as IDRM. The authors have presented a novel design of gateway using a specific beaconing process among the gateway. The focus was towards overhead minimization. Similarly, Kaddoura et al. [28] have introduced a gateway protocol that performs communication for mobile domain called as BGP-MX. The authors have also introduced an optimization for the routes. Both IDRM and BGP-MX are not intended for addressing the complexity raised by heterogeneous mobile ad-hoc network. Both the protocols perform effective routing among the mobile domains using border gateway protocol, which is not applicable for heterogeneous mobile ad-hoc network. Hence, comparative analysis is done to understand the implications of proposed IGP with existing standards i.e. IDRM and BGP-MX. The transmission range of the nodes varies for each domain in the range of 200-300 meters considered for 1000 seconds of simulation time. Consider 0.5 seconds of pause time as gap between transmitting the control message. The total number of the nodes is simulated for 50-500.

A. Analysis of End-to-End Delay

As shown in fig.7, End-to-end delay is one of the effective performance parameters to investigate the success rate of gateway. It is computed by time taken by the test data packet (2000 bytes). The outcome in Fig.7 shows that proposed

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IGP has much reduced delay as compared to existing IDRM and BGP-MX. The reason lies in the method of processing the control message in IGP. In proposed IGP, a node will be required to extract the address information of other node residing on different domain.

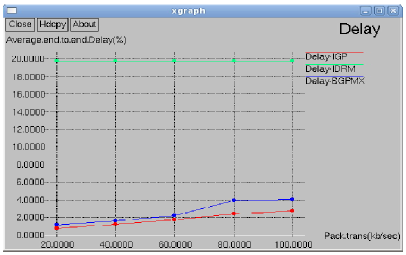

Fig.7. Comparative Analysis of Delay

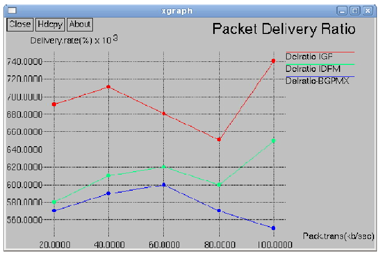

Fig.8. Analysis of Packet Delivery Ratio

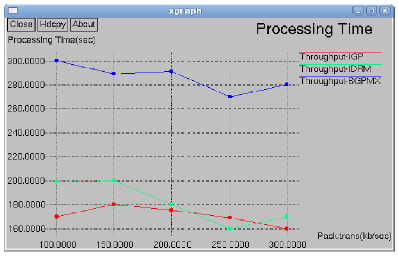

Fig.9. Analysis of Processing Time

Hence, the prime task of the gateway node will be to aggregate the respective address of the mobile node and keep on exchanging it with other gateway node. In this way, it is feasible for the entire network to accomplish the maximum routing data in shorter simulation time. This phenomenon also saves much of the time for extracting route information from other nodes. Because gateway node only exchanges the information of node address that has been recently updated in order to minimize the overhead of the sharing process of node address. Although, IDRM does focus on overhead reduction, it doesn't emphasis on updating the routing table and hence doesn't share it with its neighbor. This results in massive difference in delay factor in proposed IGP and IDRM. On the other hand BGP-MX performs routing advertisement mechanism and it performs selection of the most stable routes based on mobility index. However, the prime responsibility of mobility index is to track if the gateway nodes are still part of network. Unfortunately, this occupies an iterative search mechanism that results in stabilized link. Hence, BGP-MX ensures stabilized links but it has slight degradation of end-to-end delay.

B. Analysis for Packet Delivery Ratio

Packet delivery ratio is another performance factor that is evaluated with the amount of data being already transmitted to the recipient node divided by total number of the data. The outcome in Figure.8 shows that proposed IGP has better data delivery performance compared to IDRM and BGP-MX. The proposed system offers an extensive processing of data generated by discrete routing protocol on multiple domains. The conversion process leads to generation of multiple structures of routing table as alternative routes from one source to destination. This leads to faster disseminating of the data from multiple routes with lesser probability of message replications.

C. Analysis of Processing Time

Processing time refers to total amount of time being required by the gateway node to process the route request. In Fig 9. with increasing amount of the rate of traffic load, time consumption factor is monitored. The prime reason for reduced processing time is that gateway node is highly capable of meeting the requirements of dynamic topology of mobile ad-hoc network apart from data processing. The adverse effect of dynamic topology leads to intermittent link, which can break at any moment during the transmission that can increase the processing time to large extent. IGP resolves this problem by ensuring the repairing of unstabilized links. Thereby this process reduces the load on normal mobile nodes to repair the links. IDRM and BGP-MX does the repairmen of the links with a shared responsibility for both nodes and gateway nodes. However, IGP frees the node from this responsibility by strengthening the association of nodes and gateway nodes. Hence, processing time is quite faster as gateway nodes do not have much constraint of resources.

VIII. CONCLUSION

The existing technique of routing strategies for mobile ad-hoc network is more inclined on establishing communication among the mobile nodes with similar administrative rights. However, this is not applicable when multiple and different administrative schemes are used giving a shape of heterogeneous mobile ad-hoc network. The paper has presented a technique called as Interoperable Gateway Protocol (IGP) supported by simulation study using network simulator. The study mainly focuses on presenting a gateway node that is capable of converting the control message and generates

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interoperable feature between two different domains. The interoperable problems for both reactive and table driven protocol are addressed. The outcome of the study is compared with the most standard inter-domain routing protocol to find IGP better in providing interoperable features with respect to delay, packet delivery ratio, and processing time.

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