Dynamic Gateway Load Balancing in Integrated Internet-MANET

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Abstract: Mobile Ad hoc Network (MANET) is a network of mobile devices capable of configuring itself. MANETs do 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 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.

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.

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. give 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 node 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 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
The proposed PLB-MSC gateway discovery mechanism can be explained with the help of Figure 2.

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 Figure 2.

**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.

**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 other 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.
Another time period according to the criterion of the gateway realizes whether the 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.

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.

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 (GWRreg) packet to “GW”, and receiving a gateway registration reply (GWRrep). The GWRrep includes GW’s IP address, which will be node S’s care-of address. GWRrep 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.

Figure 3: GWAdv message format

<table>
<thead>
<tr>
<th>128-bit Gateway IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWA dv’s lifetime</td>
</tr>
<tr>
<td>NN</td>
</tr>
<tr>
<td>32-bit sequence number</td>
</tr>
</tbody>
</table>


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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,

\[ GW_{Exp} = DS \times n + NN \times m + QL \times k \]

\[ GW = \min\{GW_{Exp1}, GW_{Exp2}, \ldots, GW_{Exp}\} \]

\[ n + m + k = 1 \]

Where \( n, m, k \) are weighted factors, \( GW_{Exp} \) 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,

\[ FA_{Exp} = DS \times n + NN \times m + QL \times k \]

\[ FA = \min\{FA_{Exp1}, FA_{Exp2}, \ldots, FA_{Exp}\} \]

\[ n + m + k = 1 \]

Where \( FA_{Exp} \) 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.
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 outperforms. Figure 5 shows the output of existing strategies and proposed algorithm.

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.

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.
- \( R_f \): Count of unique packets received from flow \( f \).
- \( T_f \): Count of packets transmitted to flow \( f \).

**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:

\[ \text{Throughput} = \frac{\text{received data}}{\text{DataTransmissionPeriod}} \times 8 \]

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.

**Routing Overhead**

Routing overhead is calculated using the formula:

\[ \text{Routing Overhead} = \frac{\text{Routing Packets Count}}{\text{Total Number of Flows}} \]

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.
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


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