QoS-based Gateway Selection in MANET with Internet Connectivity

Yonghang Yan, Linlin Ci, Zhiming Wang, Wei He

School of Computer Science & Technology, Beijing Institute of Technology, China

feifanyyh@gmail.com, cilinlin@263.net, bj_wzm@sohu.com, howei6@gmail.com

Abstract— **This paper proposes a QoS-based gateway selection mechanism to select an appropriate gateway based on three QoS metrics: traffic load of gateway, path quality from MANET node to the gateway and hop count to the gateway for integrating MANET and the Internet. The Simple Additive Weighting method is used to combine these three QoS metrics to outrank the optimum gateway. Gateway with the smallest weight will be selected as a gateway. Simulation results show that the proposed scheme can improve packet delivery ratio and end to end delay.**

Keywords— **QoS; multiple metrics; gateway selection; MANET; Internet connectivity**

I. Introduction

An ad hoc network is a communication system without any pre-existing infrastructure for dynamic environments, in which users can communicate with each other, but they are free to move in the surrounding space. These users have portable devices equipped with wireless interfaces for accessing the resources of the network. The most important features of mobile ad hoc network are easy deployment and self-configurability. With the explosive increase of mobile devices as well as dramatic progress in wireless communication technology, the interest of connecting ad hoc network into Internet is becoming more and more attractive.

In order to realize the interconnection of these two heterogeneous networks, a special device which acts as a "bridge" between these two different networks is needed. The special device is called a gateway in this paper. When a mobile node in ad hoc network wants to access the Internet, it should firstly discover and select an appropriate gateway that provides Internet connectivity. Therefore, an efficient gateway discovery and selection mechanism which is aware of the quality of the Internet connectivity is needed. The existing gateway discovery approaches can be divided into three categories: proactive schemes [1][2], reactive scheme [3], and hybrid schemes [4][5]. The proactive approach can achieve good connectivity and low latency, but it suffers considerable overheads. In contrast, the reactive approach can achieve low routing overhead at the cost of increased latency. The hybrid approach combines these two approaches. That is to say, the hybrid approach uses a proactive scheme within the gateway's advertisement range, while it relies on a reactive scheme outside this coverage. Once gateway information has been received by mobile nodes in the network, gateway selection can be done. The "best" gateway is chosen among a set of candidate gateways based on some metric. Most existing gateway selection schemes use the hop count metric. Ad hoc routing protocols have long used this metric for routing in multi-hop wireless environments and its use for gateway selection was a natural extension. However, hop count is a poor choice as a metric in ad hoc networks to select a best default gateway [6]. If all the mobile nodes select the nearest gateway, as their default gateway, then this gateway would become a bottleneck, resulting in high processing latency. This weakness motivates the selection of gateway based on some other metrics.

In order to select an efficient gateway and distribute traffic load evenly among gateways, some QoS-based works were presented using different QoS metrics. In [7], physical hops, congestion level and contention level of route are combined as one single metric for gateway discovery. In [8], the author proposes a mechanism to select an appropriate gateway based on multiple node metrics: remaining energy, mobility and numbers of hops. To select an optimum gateway node, the simple additive weighting method is used to outrank the optimum gateway node. In [9], gateway load, route interference and path quality metrics are used to select the best available gateway and the route to that gateway. In [10], the author proposes a proactive load-aware gateway discovery scheme that takes into account the size of interface queue of the gateway in addition to the traditional minimum hop count metric.

In this paper, the gateway selection mechanism among others was considered as essential component to interconnect MANET and Internet. We use QoS-based metrics to select an optimum gateway. The QoS metrics we choose in this paper are gateway traffic load, path quality and the number of hops to a gateway. The traffic load metric of gateway can help to balance traffic load among gateways. The path quality metric between the mobile node and the gateway makes us to choose a gateway which has a good path quality and the number of hops metric designates the shortest distance between MANET node and the gateway. To combine these three QoS metrics as one comparable metric, one of Multi-Criteria Decision Making (MCDM) techniques called simple additive weighting (SAV) [11] method was used. We evaluate throughput performance and packet delivery ratio to show the optimization of network performance. By considering aforementioned three QoS metrics with selection method using SAV, it improves throughput performance and packet delivery ratio of integrated MANET and the Internet.

In the next section, the proposed QoS-based gateway selection scheme was presented. Section III presents various simulation results to verify the effectiveness of the proposed method. Some conclusions are given in Section IV.

II. Proposed Scheme

A QoS-based gateway selection mechanism in MANET for Internet Connectivity is proposed in this paper considering multiple QoS metrics of each gateway to improve interconnection performance between MANET and the Internet. This proposed scheme can increase the packet delivery ratio and improve throughput performance and can also distribute the traffic load evenly among gateways. In order to realize those objectives, we define three QoS metrics: number of hops to the gateway, gateway load and path quality to select the appropriate gateway in interconnected MANET with Internet.

We use the traffic load metric because traffic load of gateway is an important parameter to avoid choosing the overloaded gateways and decrease the processing latency of packets from/to the Internet. If a gateway is overloaded some time, then the packets will queue in the interface of the gateway and they will wait for a long time to be processed. When the traffic load metric is used, we can get the congestion status of the gateway through this metric and then the overloaded gateway is avoided to choose as the default gateway. Furthermore, the path quality is another important metric which can help us identify the quality of wireless links from the MANET node to the gateway. Generally, the interference metric can only measure the interference present on the link due to the activity in the neighbour nodes, but does not covey information about the quality of the link itself. For example, a link may have a poor SNR ratio or high bit error rates due to physical factors such as obstructions while having zero interference. So, to select a relatively better wireless path between MANET node and the gateway, the path quality metric is essential. The last metric is the number of hop to the gateway. It designates the distance from the MANET node to the gateway. One of the advantages of using the number of hop metric is rapid convergence and thriftiness of resources. Smaller number of hop creates shorter distance between MANET node and the gateway. The original MANET node can simply choose the weighting factor of each metric according to need or priority. In general, these three metrics are then calculated by the original MANET node and then it outranks the weighted values of gateway candidates and selects the best gateway.

A. Gateway Selection Mechanism

As mentioned in the previous section, to select an appropriate gateway, we need to calculate the QoS metrics of each candidate gateway. Simple additive weighting method is used to combine these three QoS metrics as one comparable metric. The advantage of this decision making technique is that it considers multiple criteria, such as weight of importance level and gateway outranking according to the user preference or priority. So, this technique is effective to solve the quality ranking of these candidate gateways based on these three QoS metrics.

Since the hop count metric can be achieved in the GWADV message sent by the gateway, here we define the method for estimating the current traffic load of the candidate gateway and path quality between the MANET node and the gateway.

***1) Traffic load of gateway*:** The traffic load of gateway is defined as the average queue length of the network layer interface of the gateway in the MANET. To distribute the traffic load evenly over multiple gateways instead of overloading a few gateways, we use (1) to estimate the current traffic load of gateway *i* at time *T*:

$$Q(i,T) = \alpha \times Q(i,T-2\Delta T) + \beta \times Q(i,T-\Delta T) \quad (1)$$

Where $0 \le \alpha,\ \beta \le 1,\ \alpha+\beta=1,\ \Delta T$ is an estimation window. Furthermore, we bring this metric value into non-dimensional value using (2) to calculate the combined metric conveniently.

$$LB(i) = \frac{Q(i,T)}{Q\_\max(i)} \quad (2)$$

Where $Q\_max(i)$ is the maximum queue length of the network layer interface of gateway *i* in MANET. According to (2), we can infer that the smaller the value of $LB(i)$, the less congestion of the gateway. To disseminate the information of the traffic load of the gateway to the MANET nodes, we modify the format of the GWADV message and add a new field called gateway_load to record the status of the traffic load of the gateway.

***2) Path Quality*:** To estimate the quality of wireless path between the MANET node and the gateway, we use the technique used in [9]. The original MANET nodes periodically broadcast small probe packets. Based on the average success rate of these packets in either direction on the wireless link, an approximation of link quality can be made. The expected link quality is estimated using (3):

$$ELQ(i) = 1/d_f(i) \quad (3)$$

Where d_f represents the forward packet delivery ratio of the probe packets. So the path quality can be calculated using (4):

$$Path\_Quality(p) = \sum_{i \in p} ELQ(i) \quad (4)$$

According to (3), the higher the value of the forward packet delivery ratio of the probe packets, the smaller the value of $ELQ(i)$. So, according to (4), the smaller the value of the $Path\_Quality(p)$, the better the path quality between the MANET node and the gateway.

3) Hop count: it is defined as the number of hops from the MANET node to the gateway.

After the mobile node gets the hop count and the gateway load and completes the calculation of the path quality, it then uses (5) to combine these three QoS metrics.

$$GS = \alpha \times hop\_count + \beta \times LB(i) + \gamma \times Path\_Quality(P) \quad (5)$$

Where $0 \leq \alpha, \beta, \gamma \leq 1$, $\alpha+\beta+\gamma=1$, *hop_count* represents the hop count from the MANET node to the gateway.

After obtaining the GS value of each candidate gateway, we can finally outrank them. The smallest one will be selected as a gateway.

B. Gateway Discovery

When the MANET node wants to access the Internet, it will firstly discover all the gateways available. The reactive gateway discovery scheme is used in this paper to discover the best gateway.

When the mobile node wants to access the Internet, it constructs a GWSOL message and sends it to the gateway by broadcasting. When the gateway receives the GWSOL message, it constructs a GWADV message and unicasts it to the mobile node. The GWADV message is modified to take the information of traffic load of gateway, so every MANET node can achieve this information through the GWADV message sent by the candidate gateway.

After getting these three QoS metrics information of each candidate gateway, the MANET node use the gateway selection mechanism presented in the previous section to select an appropriate gateway. Once the MANET node selects the optimum gateway, it will register with this gateway and create a route in its routing table. Finally it can access the Internet through this gateway.

III. PERFORMANCE EVALUATION

In this section, we evaluate the performance of the proposed scheme through simulation using ns-2.34 network simulator [12] with CMU wireless extensions [13].

A. Performance Metrics

The performance of the proposed scheme is analysed using the following performance metrics:

- Packet Delivery Ratio: it is defined as the percentage of the number of packets received to the total number of packets sent.
- End to End Delay: this is the average overall delay for a packet to traverse from a source node to a destination node.

B. Simulation Model

In order to support wireless LAN in the simulator, the Distributed Coordination Function (DCF) of IEEE 802.11 is adopted as MAC layer protocol [14]. As a mobility model, we use the random waypoint model [15] in rectangular field where a node moves from one random place to another random place with a randomly chosen speed. The node mobility speed we chosen in the simulation varies from 0 to 10 m/s. Constant Bit Rate (CBR) traffic sources are used with different packet generation rates to model different network scenarios. In our simulation, we create different scenarios with the network load varying from 1000-4000 Kbps. We use 1000m×1000m simulation area with 50 mobile nodes and 5 gateway nodes. The maximum transmission range of each node is 150 meters. Simulations are run for 600 s. Mobile nodes use AODV+ protocol [16] to communicate with its peers and to access wired networks through a gateway. To manage the mobile nodes' mobility between ad hoc networks, both mobile nodes and gateways run mobile IP [17], where mobile IP foreign agent (FA) and home agent (HA) are hosted in the gateways. The simulation parameters are given according to Table 1.

TABLE 1. SIMULATION PARAMETER

Parameter	Value
Area	1000m×1000m
Wireless MAC Interface	IEEE 802.11
Propagation Model	Two Ray Ground
Transmission Range	150m
Number of Nodes	50
Gateway Nodes	5
CBR Packet Size	512 bytes
Mobility Model	Random Waypoint
MANET node speed	0-10 m/s
Simulation Time	600 seconds

In our simulation, we empirically set α=β=γ=0.333, because choosing an optimal weighting combination which works for all types of node mobility, node density, traffic patterns is difficult. In the simulation, there are 15 source nodes send CBR traffic flows to five gateways with different sending speed. Four different schemes were compared: the minimal hops gateway selection, gateway traffic load based gateway selection, path quality based gateway selection and the proposed QoS-based gateway selection.

C. Simulation Results

From figure 1 we can see that the proposed QoS-based scheme outperforms minimal hops based scheme, traffic based scheme and path quality based scheme and it achieves the best packet delivery ratio among these four schemes.

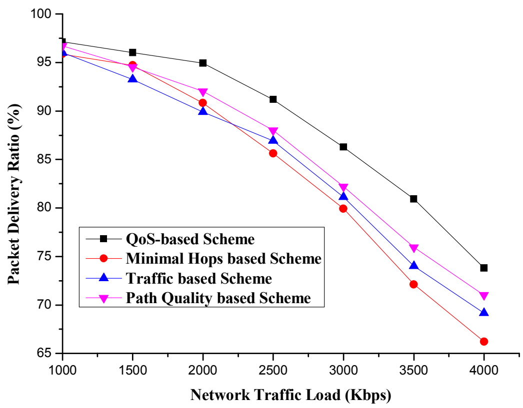

Figure 1. Packet Delivery Ratio

The path quality based scheme gets the second best packet delivery ratio. Although the traffic load based gateway selection scheme may achieve some load balancing between the gateways, it only achieves better packet delivery ratio than the minimal hops based scheme. Using a single metric such as gateway traffic load independently does not perform well because the gateway selection does not consider other factors such as path quality on the selected route. So, considering multiple QoS metrics for gateway selection can achieve good performance.

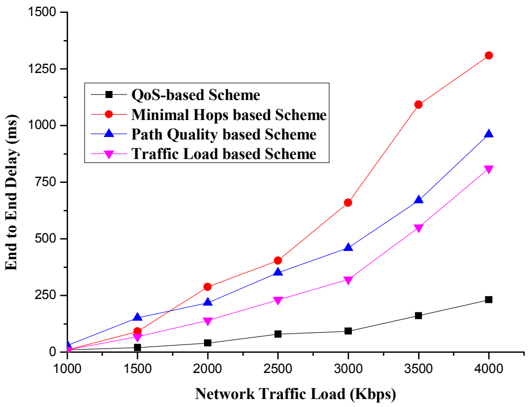

Figure 2. End to End delay

From figure 2 we can see that the proposed QoS-based gateway selection scheme achieves the best end to end delay among these four schemes. This scheme combines three QoS metrics, so it can discover and select a gateway avoiding the overloaded route and choosing a relative good path between MANET node and the gateway. The path quality based scheme gets the second best end to end delay, and the Traffic load based scheme gets the third best end to end delay. The minimal hops based scheme gets the poorest end to end delay, because many MANET nodes select the nearest gateway as their default gateway and this will result in network congestion especially in the case of increasing network traffic.

IV. Conclusions

In this paper, a QoS-based gateway selection scheme in the interconnecting MANET and the Internet is proposed. The proposed QoS-based gateway selection scheme for MANET takes into account three QoS metrics such as the hop count to the gateway, the traffic load of the gateway and the path quality to the gateway to select the optimal gateway. The simple additive weighting calculation is used to optimize the gateway mechanism according to needs and priority. Simulation results show that our proposed scheme can improve packet delivery ratio and end to end delay. In the future, we will further plan to test and improve our scheme.

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Yonghang Yan (Beijing, 1981) is a Ph.D. candidate in the School of Computer Science & Technology, Beijing, China. He is working with Prof. Linlin Ci in the Mobile Computing and Network Technology Laboratory. His research interests include computer network, Mobile ad hoc network, wireless communication, mobile computing network and QoS.

Linlin Ci (Beijing, 1950) is a professor in the School of Computer Science & Technology, Beijing, China. He got Bachelor's degree in 1976 at Beijing Institute of Technology and the major is computer science and technology. He got Master's degree in 1986 at Northwestern Polytechnical University. His research focuses on mobile computing, Artificial Intelligence, wireless sensor network and DTN.

Zhiming Wang (Beijing, 1973) is a vice professor in the School of Computer Science & Technology, Beijing Institute of Technology, China. His research interests focuses on mobile computing network and Artificial Intelligence and wireless communication.

Wei He (Beijing, 1986) is a master student in the School of Computer Science & Technology, Beijing Institute of Technology, China. He is working in the Mobile Computing and Networking Laboratory and has special interests in Mobility Content Networking. Now he is dedicated to the research of routing in opportunity networking and Delay/Disrupt Tolerant Networking under the guidance of Associate Prof. Huimei Lu.