International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:9, No:1, 2015

Parameters Used in Gateway Selection Schemes for Internet Connected MANETs: A Review

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***Abstract*—**The wide use of the Internet-based applications bring many challenges to the researchers to guarantee the continuity of the connections needed by the mobile hosts and provide reliable Internet access for them. One of proposed solutions by Internet Engineering Task Force (IETF) is to connect the local, multi-hop, and infrastructure-less Mobile Ad hoc Network (MANET) with Internet structure. This connection is done through multi-interface devices known as Internet Gateways. Many issues are related to this connection like gateway discovery, handoff, address auto-configuration and selecting the optimum gateway when multiple gateways exist. Many studies were done proposing gateway selection schemes with a single selection criterion or weighted multiple criteria. In this research, a review of some of these schemes is done showing the differences, the features, the challenges and the drawbacks of each of them.

***Keywords*—**Internet Gateway, MANET, Mobility, Selection criteria.

I. Introduction

THE Mobile Ad Hoc Networks (MANET) can be defined as a set of mobile nodes that agreed upon forming a spontaneous, temporary network without any infrastructure or any form of centralized administration [1]. In MANET, the Mobile nodes communicating with each other can also forward packets for other nodes acting as routers and hosts at the same time. There is no size limitation for the MANET but it depends on the node distribution, the link layer technology, and on the traffic conditions, and there is a possibility of having a large-scale MANET with coverage areas of hundreds of Kilometers, and even more.

However, the integration between the MANET and the Internet became a necessity in order to connect the MANET's mobile nodes with the Infrastructure networks. Though, the network architectural of MANET and the Internet are mismatched due to the differences of their structure, topology and communication protocol. To solve this mismatches, [2] introduced the concept of the gateway, which has two interfaces. One of them is connected to the Internet and configured with IP routing mechanisms to be used to transmit packets from/to the MANET, while the other interface is connected to MANET using ad-hoc routing protocol to route packets within MANET. Fig. 1 shows a MANET connected to the Internet via gateways.

The Gateways are responsible for providing the mobile nodes of the necessary information to allow the construction of a valid global IP addresses [3]. Therefore, MANET's gateway should have routing table contains the prefix of the active nodes in the network. The gateway should also advertise itself in order to be discovered by other visited nodes, reply any gateway discovery request and enable the mobile nodes to stay connected during handoff from one gate to another. When multiple gateways exist, certain metrics should be specified in order to choose the optimum gateway which will improve the overall performance of the network. Another Gateway responsibility is to forward the packets in the MANET, from the Internet to the MANET nodes and from the MANET nodes to the Internet using all necessary strategies like: encapsulation/ decapsulation and routing protocols.

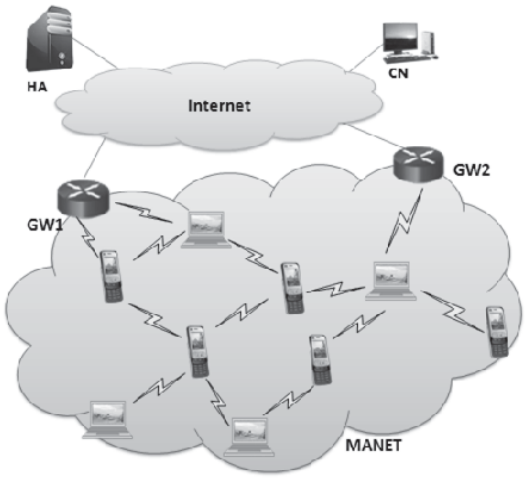

Fig. 1 MANET Connected to the Internet via Gateways

The objective of this paper is to review different Internet gateway selection schemes proposed for MANET integration with the Internet, focusing on the parameters used in each of them and examining their differences, features, challenges and drawbacks. The paper is organized as follows: Section II describes the works used a single criterion as a gateway selection parameter. Section III states some of the researches which used multiple criteria to evaluate the gateways or the path toward them in order to find the best choice for the host nodes to connect the Internet. A discussion about the different

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parameters used in the literature is presented in Section IV. Section V concludes this paper.

II. Gateway Selection Parameters

In general, we can classify the proposed works for MANET gateway selection into three types: first, works consider the gateways criteria as the selection parameters. For the Second type, the route to the gateway was the main concern in the selection procedure. And for both types, a single parameter was used or multiple of them. However, for the third type which can only be a multiple-parameter selection scheme, both the gateways capacities and the route to them were evaluated. In the following sections, the different parameters were presented in details.

III. Gateway Selection Based On Single Parameter

A. Hop Count Parameter

The hop count is a very important metric that can be obtained easily. MANET routing protocols used this metric for routing in multi-hop wireless environments and its use for gateway selection was a natural extension [4]. However, the gateway can become a bottleneck when the traffic load is heavy as shown in Fig. 2. Also, there is a possibility of increasing route error because of the intermediate nodes mobility while the gateway selection doesn't considering. Another drawback of using the hop count as the only parameter for selecting the gateway is that because all the packets are sent to the Internet via that gateway, the gateway runs out of energy shortly.

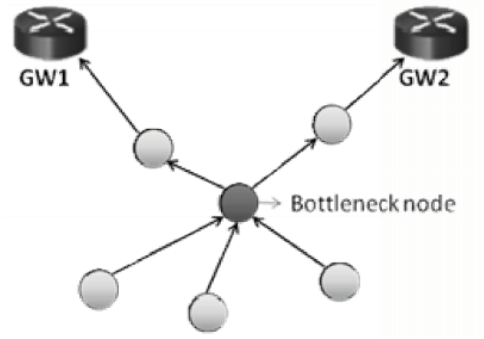

Fig. 2 A Bottleneck Node

B. Path Quality Parameters

To integrate MANET with cellular network, the gateway selection method used in [5] is based on one parameter which is High Data Rate (HDR) downlink channel rate. For the same purpose, the author of [6] only considers link cost parameter for gateway selection scheme. However, both parameters are not considering the capability of the gateway itself. Without considering the queue length, the energy and the number of nodes sending their packets to the Internet via this gateway, the packets could be dropped when the gateway is overloaded. Another attempt to use the link quality as a selection parameter was done by [7]. The variance in arrival times of the broadcasted gateway advertisement was used to evaluate the quality of the path between mobile nodes and the gateway. But to compute the variance an intelligent selection of a history window is needed to state how long is the needed history to calculate the mean value and variance. This can be done using periodical gateway advertisement with small advertisement interval which will cause huge load in the network.

C. Load-Balancing Parameter

The authors of [8] considered the number of waiting packets in the nodes' interface queue as the gateway selection parameter. For this, an additional field was added to the packets and to the routing table of each node in the MANET. On the other hand, [9] used the number of the waiting packets in the node's routing queue as a selection parameter select a gateway. This modification increases the throughput by choosing the less congested paths and reduces the routing overhead compared to [8]. However, according to [10] the load-based selection methods may use more intermediate nodes in order to connect a lightly-loaded IGW, resulting in more traffic for those nodes.

D. Mobility Parameters

According to [11] the mobility metric states the speed of each node in the path to the GW. The too fast node can cause topology change that needs reselection of the path which will increase the routing overhead.

Reference [12] proposed a gateway selection scheme which uses the Mobility Tracing-Value (MTV) as a basic metric to select the gateway. The MTV value increases if a neighboring node does not receive a Hello message before its duration expires. So, the larger value of MTV means the higher probability of link failure. Therefore, the gateway node on a path with the minimum MTV is selected. Though, this procedure consumes higher processing power than the hop count.

However, considering the speed of the nodes adds additional cost to the selection method which will affect the network's performance.

E. Gateway Capability Parameters

Some other researches considered the gateway capabilities in order select the best gateway. Reference [13] used simulation experiments to evaluate the gateway with the highest energy level (HEL) and the gateway with the least number of neighbors (LNN). The first method balances the energy consumption among the gateways, it keeps them alive as much as possible. On the other side, the gateways with HEL might have large number of neighbors, which they will be affected by its transmission. Reference [13] compared the performance of HEL and LNN schemes and combinations of them. In the HEL scheme with threshold, the threshold was set as an energy level. If the energy goes below that threshold, then the gateway will be selected with HEL regardless of the number of neighbors. In the LNN scheme with threshold, the threshold was sat as the number of neighbors. If the number of neighbors goes beyond the threshold then the gateway with

HEL will be selected. The end-to-end packet delivery results as shown in Fig. 3.

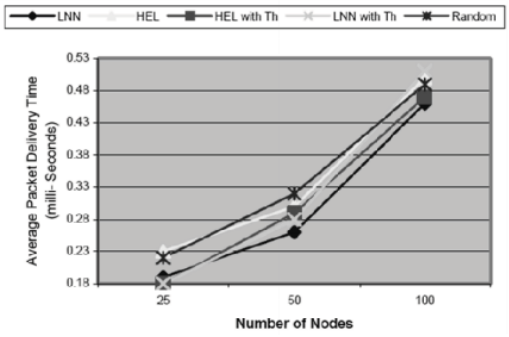

Fig. 3 Comparison of the Network End-to-end Delivery Time using LNN and HEL Parameters [13]

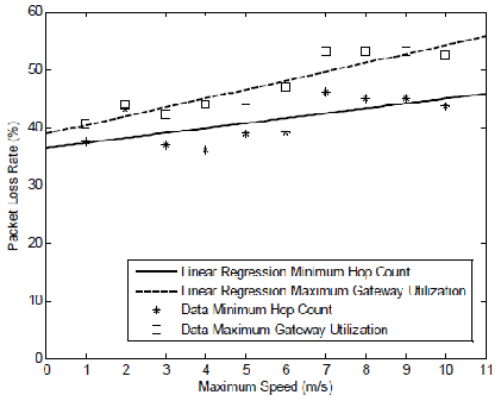

Fig. 4 Packet Loss Rate versus Maximum Speed [3]

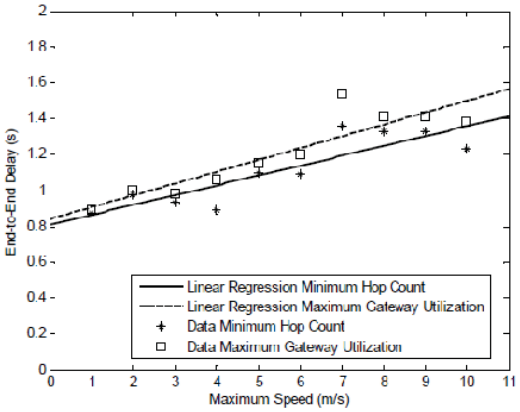

Fig. 5 End-to-End Delay versus Maximum Speed [3]

In [3] two metrics were compared: Hop count and gateway utilization which will allow the node to utilize the selected Gateway until it stops receiving the Advertisement packets because of the network mobility. The simulation results represented in Figs. 4 and 5 show that the selection based on the Minimum Number of Hops is better than the selection of the Maximum Gateway Utilization. The gateway's handoff procedure is less when the Maximum Gateway Utilization is applied. However, the long path to the gateway can be broken more often than when the Minimum Number of Hops is considered.

One of the drawbacks of the gateway capabilities approaches is that they do not consider the situation of the path from the node. Also, the gateways should have the accurate estimation of their traffic load, which may change significantly.

IV. Gateway Selection Based On Multiple Parameters

To avoid the drawbacks attached with each single parameter of selecting the gateways, researchers proposed schemes based on more than one parameter to draw together the benefits of each parameter. Following are some of these schemes divided according to the main concern.

A. Based on Gateway Capabilities

Reference [14] proposed a gateway selection scheme based on three gateway parameters: the remaining energy, signal strength and mobility speed. These parameters enable the gateway to provide service for a longer time. A simple additive weighting techniques was used to evaluate the overall capacity of the gateways in order to select the best one. This can outperform the single parameters-based selection method but the other metrics are not considered like the path quality, load balancing, and mobility of the nodes in the MANET. Another drawback is the large packets overhead.

B. Route Quality Parameters

To ensure the load balancing in the MANET and reduce the delay and packet loss, [4] suggested a QoS-based gateway selection method for integrating MANET and the Internet. It consists of three QoS metrics: path quality from MANET node to the gateway, the hop count, and the traffic load of gateway. The traffic load is defined as the average interface queue length of the gateway in the MANET. Selecting the less interference queue size can distribute the traffic load evenly over multiple gateways with less packet drop rate and less delay because no gateway will be overloaded.

Another gateway selection scheme with multi-metrics was proposed by [15] that considered multiple Quality of Service path parameters like path availability period, available capacity latency and link quality to select a potential gateway node.

C. Route and Gateway Parameters

Reference [1] suggested using two metrics to select the MANET Gateway considering both the route length and the gateway capacity. The method used is based on the weighted sum of the load of the gateways, defined as the number of registered MANET nodes, and the Euclidean distance between MANET nodes and mobile gateways.

Another research, done by [16], proposed a three components selection method to provide load-balancing in the MANET. These metrics are the hop count between the MANET node and the selected gateway, the number of

registered MANET nodes at the gateway, and the optimal node density to delivery traffic successfully. However, the proposed load-balancing selection scheme introduces extra routing load and overhead compared to the hop count scheme as shown in Figs. 6 and 7.

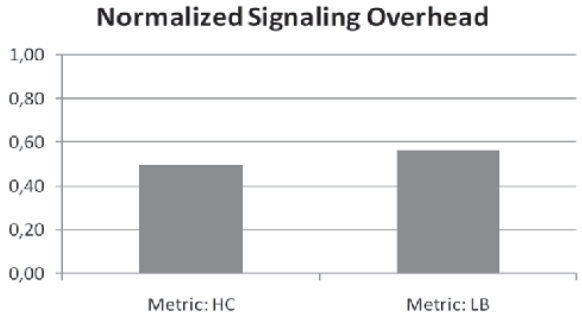

Fig. 6 Signal Overhead [16]

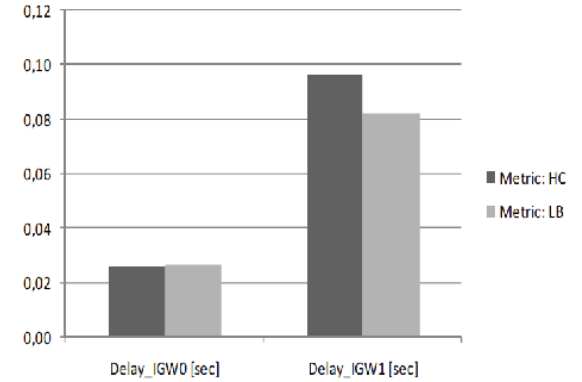

Fig. 7 Average Packet Transmission Delay [16]

Whereas [17] proposed a path and gateway selection method considering the hop count parameter, the total number of neighbors down the route as well as the node interface queue length. The total number of neighbors of each node prevents the usage of the crowded route to the gateway.

On the other hand, to reduce the time needed for path recovery when the topology changes [11] proposed a new approach to discover all paths to the gateway and select the best among them. The metrics used for selection are: node mobility, number of hops, and node congestion. The node congestion was calculated as the ratio of the data to the available buffer size. The three metrics are calculated between every node and its neighbors. Figs. 8 and 9 show the comparisons between using the multi-path to Internet GW scheme MIGWDS and the normal AODV routing protocol.

V. Discussion

Many researches were done to find the best selection parameters for Internet-connected MANETs in different scenarios. This paper presented different researches done in this area and categorized them according to the number of parameters used in their presented gateway selection schemes. Mainly, the single-parameter methods can depend on the gateway capability, the path quality, or load balancing in the network. Each of them has its own features and drawbacks, as Tables I and II conclude.

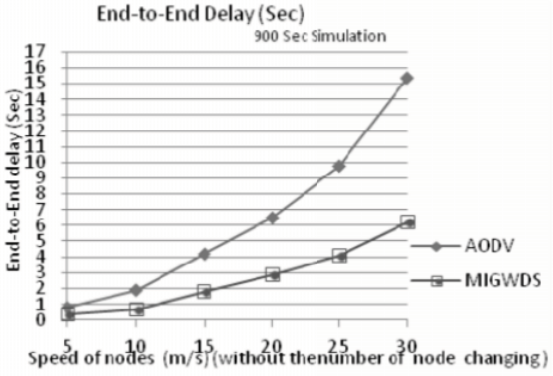

Fig. 8 End-to-End Delay of MIGWDS and AODV [11]

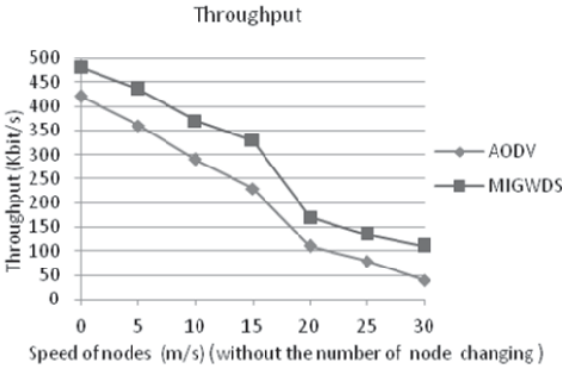

Fig. 9 Throughput of MIGWDS and AODV [11]

VI. Conclusion

Choosing the best selection parameters for Internet gateway of MANET depends on the scenario and the performance metrics focused on. But it can be concluded that the multi-parameters schemes are considering many factors regarding the Ad Hoc networks environments and specifications not like the single-parameter schemes. Also, the diversity of the parameters can cover many issues in the network like the gateway capacities, the load-balancing, the path quality and the mobility.

TABLE I
THE SINGLE PARAMETERS USED IN THE PRESENTED SELECTION METHODS

The Parameter	Used by	Features	Drawbacks
Hop count	Widely used by MANET routing protocols	Easy to obtain with no extra delay or overhead	The shortest path could be the worse in quality, also a bottleneck problem can occur, under heavy mobility rerouting is increased
High Data Rate (HDR)	Luo et al., 2007 [5]	Considers path quality to the gateway	Without considering the gateway capability, packets can be dropped when it's overloaded, and the increase overhead
The Variance in Packet Arriving Time	Ma and Liu, 2009 [7]	Path quality to the gateway is considered	Need to calculate the mean value and variance of periodical gateway advertisements. Resulting huge load
Mobility Tracing Value	Hemalatha et al., 2013 [12]	No extra overhead, reduce the rerouting process due to the mobility of the nodes,	Higher processing power, adds additional cost
Highest Energy Level of the Gateway	Sheltami, 2006 [13]	Balance the energy consumption between the gateways	Can be overloaded if the gateway has many neighbors, multi-layering complicates the procedure
Gateway Utilization	Triviño-Cabrera et al., 2007 [3]	Less handoff	Not considering the path quality and length which can affect its availability

TABLE II
PROPOSED SELECTION SCHEMES WITH MULTIPLE PARAMETERS

Researches	Selection parameters	Features	Drawbacks
Manoharan et al., 2009 [14]	Gateway's remaining energy, signal strength, and mobility speed	Chosen gateway can provide services for long time. Outperform single parameter's schemes	Large packets overhead. All are gateway parameters, with no load balancing, path quality, or mobility concerning
Yan et al., 2013 [4]	Average interference queue length, hop count and gateway traffic load	Load-balancing, less packets delay	Mobility is not considered
Iqbal and Kabir, 2011 [17]	The hop count, the total number of neighbours down the route, and node interference queue length	Prevent the usage of the long and the loaded paths	Large packets overhead, mobility is not considered
Kumar et al., 2013 [15]	Path availability period, available capacity latency and link quality	Taking on consideration the route quality and mobility, balancing the load	Complexity and the large overhead
Ammariet al., 2004 [1]	Number of registered nodes at the gateway and the distance to the gateway	Easy to count with no extra overhead	Mobility is not considered, nor path quality
Le-Trung et al., 2008 [16]	Hop count, the number of registered nodes at the gateway, and node density to deliver traffic	Balance the load on the gateways and considering the path quality	Extra routing load and overhead, mobility is not a concern
Zhanyang et al., 2009 [11]	Node mobility, hop count, and node congestion	Reduce the path recovery time by discovering all possible paths	Large packet overhead, and huge routing load in the network

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