Development of Gateway Discovery and Selection Scheme for MANEMO (MGDSS)

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Abstract

To achieve the requirement of the improvement applications and guarantee the Internet access for mobile hosts and networks, the Internet Engineering Task Force (IETF) proposed Mobile Ad Hoc NEMO (MANEMO) architecture. However, the integration of NEMO and MANET introduces many challenges such as the redundant tunnel problem and Exit Router selection when multiple Exit Routers to the Internet exist. This paper aims to propose a scheme that discovers and selects the gateway which improves the performance and the robustness of the network regardless of routing protocol used. This is done by extending the Tree Discovery Protocol (TDP) used by NEMO BSP and the Neighborhood Discovery protocol used by MANET and the gateway selection is based on multiple criteria: the hop count, the nested level, the stable time and the number of nodes registered at the intermediate nodes. The OPNET Modeler 14.5 is used to evaluate the proposed scheme and compare its performance with the standard NEMO BSP and the Multi-homed MANEMO (M-MANEMO) approach. The results show that the average data packets dropped of the proposed scheme is 28.6% less compared to the NEMO BSP and 63% compared to the M-MANEMO. And in a larger scale MANEMO with high traffic load and fast mobility, the proposed scheme outperforms the M-MANEMO with reduced end-to-end delay around 21.6%. Whereas NEMO BSP has 68.7% more end-to-end delay in compare. These delays cause that the proposed scheme has 66.6% less voice jitter compared to M-MANEMO.

Keywords: *Mobile Ad Hoc NEMO, MANEMO, Network Mobility, MANET*

1. Introduction

The Internet users and applications around the world are increasing in number as 46.4% of the world populations nowadays are using the Internet [1]. This creates challenges to the researchers in order to provide Internet connection anytime and anywhere with continuous session connectivity of the wireless networks.

Mobility is still one of the core fields of studies to keep the ongoing connections while changing the access to the Internet. The IETF NEtwork MObility Basic Support (NEMO BS) protocol was presented by [2] to improve the network access in various scenarios such as the public transport, Personal Area Networks (PANs), and Vehicle Ad hoc Networks (VANETs). With NEMO BS, the network's devices do not required any additional software or protocol supporting mobility. They are connected to a Mobile Router (MR) which deals with different access networks while the network in move.

On the other hand, the Mobile Ad Hoc Networks (MANET) [3] supports mobility of the Mobile Hosts and Mobile Routers. This is by using optimized routing protocols specially designed to operate between mobile devices mainly to support network scenarios which have no former infrastructure. The MANET protocols were designed to maintain inter-connection between the MANET devices but improved later to connect any nodes on the Internet.

The integration of Network Mobility (NEMO) technology and the Mobile Ad Hoc Networks (MANETs) known as (MANEMO) [3] can form scalable, global reachable, optimized network topologies. With MANEMO, the optimized, multihop routing offered by MANET protocols can be used to solve the inefficient routing problems experienced by Nested NEMO configurations. On the other hand, the globally reachable Home Agent-based properties of NEMO can be utilized to provide MANET networks with permanent reachability to the Internet without flooding their routing information into the infrastructure. According to [4], the mobile entity in MANEMO is considered to be a MR, like the NEMO BS models. It manages the mobility of the entire network and the connection with the Internet using its Egress interface. Whereas, the Ingress interface present for the connection of the IP devices just like the static networks.

MANEMO allows the mobile nodes at the edge of the Internet to use wireless interfaces to form a network in an ad hoc style and are able to provide Internet connectivity. This can support large scale networks including many applications like: the mesh networks, layer 3 sensor networks, crowd of personal mobile router, and disaster-ready municipal network [5]. The MANEMO's MR is required to select the best Exit Router toward the Internet. Therefore, it is important for the MRs to have all the necessary information about the neighbor nodes and the available gateways connected to the Interne. This is in order to select the optimal path to the selected router efficiently and with a degree of intelligence.

In this paper, a new gateway selection scheme for MANEMO is introduced by extending the Tree Discovery Protocol (TDP) used by NEMO BSP and the Neighborhood Discovery protocol used by MANET to collect the necessary information to evaluate the gateways using gateway selection method based on multiple criteria: the hop count, the nested level, the stable time and the number of nodes registered at the intermediate nodes. The rest of the paper is organized as follows: section 2 states some of the related works. Section 3 covers the design of the proposed scheme. In section 4, performance evaluation of the proposed scheme compared with NEMO BS, and Multi-homed MANEMO. The obtained results are discussed in section 5. Finally section 6 concludes the research findings.

2. Related Works

Many researches have been done to overcome MANEMO's challenges. As for [6], switching routes in the Mobile Gateway from NEMO to MANET reduces latency when a direct link between the nodes exist. However, the network topology of MANEMO changes as the nodes move. Therefore, MANET could provide shorter routes to the CN without passing by the Internet GW but it is not always providing better quality than NEMO paths. Selecting the path in MANEMO should be using efficient switching decisions.

The NEMO-Centric MANEMO (NCM) was proposed by the IETF NEMO Working group [7]. The Nested NEMO structure can be considered as a mobile ad hoc network of NEMO mobile networks. Therefore, local communication can be performed between the NEMOs in the Nested NEMO structure using extended MANET routing protocols. In another scenario,

Another approach proposed by [5] when MANEMO provide an efficient Internet connection to the MR's forming a MANET and it is called MANET-centric MANEMO (MCM). In this situation the Nested NEMOs are part of the ad hoc structure by default and the MANET protocol is the one performing the routing. So the NEMO protocol is engaged only when a NEMO is disconnected from its ad hoc structure so it uses NEMO BS tunneling to tunnel packets to the MANET.

The Unified MANEMO Architecture (UMA) proposed by [8] implements as a protocol architecture designed to support the different MANEMO models mentioned previously using one unified solution. Based on the study, the Unified MANEMO Architecture (UMA) was presented as a solution using two protocols for Nested NEMO scenarios: Tree Discovery (TD) protocol and the Network In Node Advertisement (NINA) protocol. The TDP broadcasts information among the interconnecting MRs and allows them to form optimal, loop-less tree topologies. While NINA propagates route information up the tree topologies that have been formed by the TD process. The two protocols TDP and NINA were developed as extensions of Neighbor Discovery (ND) process. Fig. 1 shows the unified MANEMO Architecture.

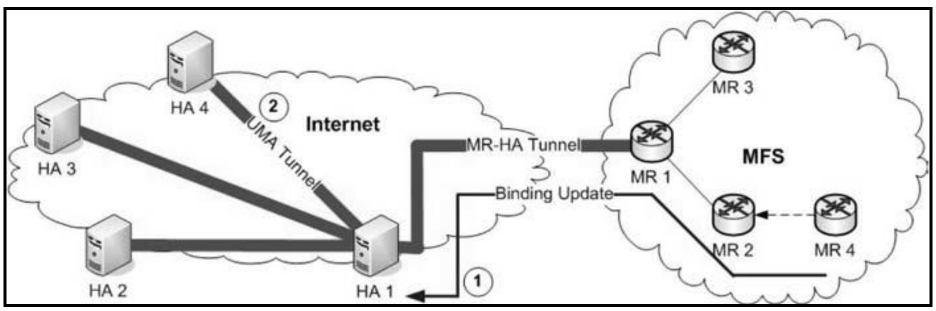

Fig. 1. Unified MANEMO Architecture (UMA) [8]

The efficient multi-path selection method for MANEMO (eMANEMO) is another approach proposed by [6] to be applied to Vehicle-to-Vehicle (V2V) communication network. It proposes a system that uses path cost to enable Mobile Gateway to select the best route between MANET and NEMO. The switching execution based on path quality eMANEMO is preventing the inefficient path switching in order to achieve the highest performance for V2V communication network.

NAT-MANEMO is a NEMO route optimization method used Network Address Translation (NAT) as a key element to avoid redundant paths proposed by [9]. It supports ad hoc communication among MRs and eliminate automatic address configuration to ease the address configuration of MANET interfaces. The address translator NAT is used to guarantee the global reachability of each MR in the MANET. The IGW advertises its own CoA using the routing protocols so the MR uses this address as its own CoA. The IGW has an address list of MRs used to recognize each of them and to translate the packets from HA to MR. Although NAT has many drawbacks, address translation is limited to the address of the MR, leaving packets from the end node (MNN, Mobile Network Node) untouched. Therefore, it does not break the application transparency for MNN communication.

Another solution is the Multihomed MANEMO (M-MANEMO) proposed by [10] based on merging two protocols, MANEMO and MCoA. These protocols provide the necessary functions to support different mobility and multihoming operations. They enable the establishment of a multihomed mobile tree with multiple gateways spanning across the tree to provide heterogeneous Internet access. Adopting MANEMO enables the establishment of an optimized tree-based routing model using the TD and NINA protocols and performs an enhanced home binding process. The MCoA protocol provides the multihoming functions supporting the emergence of additional Gateways within the tree. M-MANEMO also enables a potential gateway to have a NEMO home registration and tunnel to join the tree over additional egress interface. Fig. 2 shows an overview of the Multihomed MANEMO

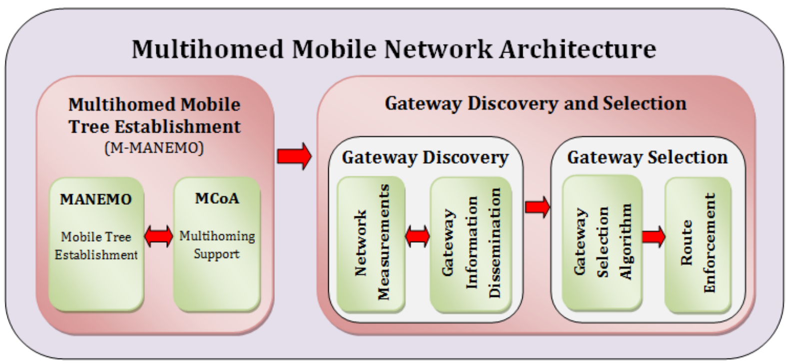

Fig. 2. An overview of Multihomed MANEMO [10]

3. The Design of the Proposed Discovery and Selection Scheme

In order to enable gateway discovery and selection in MANEMO, this research develops a novel scheme that aims to use an extension of NDP used by MIPv6-based protocols. This extension advertises the gateway existence and its criteria to enable the MRs to select the most suitable GW.

The proposed MANEMO Gateway Discovery and Selection Scheme (MGDSS) consists of 2-phases: First, is to deliver the GW selection information to the nodes using MANEMO-Tree Discovery Protocol (M-TDP) and MANEMO-Neighborhood Discovery Protocol (M-NHDP). And secondly, is to select the optimum gateway by the node. The scheme is enabled in every MR in the MANEMO in order to broadcast the gateway advertisement messages in both MANET and NEMO architecture. And also selects the optimized path to the optimum gateway avoiding unnecessary handovers.

The proposed scheme modified the structure of the NDP to enable broadcasting the selection information of each gateway to the mobile nodes and MRs. Each node stores those information at the node's gateway cache to be used later. The proposed discovery protocol is a hybrid type meaning that the gateway information will be periodically propagated to a specified number of hops. Any node beyond this area should send gateway request message.

And for those mobile nodes at the edges between the MANET and the NEMO will have all the necessary information of both networks, specifically those of the MANET gateways and the MRs. The CN and the HAs will not be modified as well as the MANET's routing protocols used by the MANET which makes this scheme easy to deploy.

The proposed MGDSS makes three possibilities for Internet connectivity: connecting MANET using the NEMO's TDP, connecting the NEMO's MR to the Internet using the NHDP, and connecting the visiting node to one of them depending on the gateway selection scheme.

- **M-TDP & M- M-NHDP**

Using the tree information option of the IPv6 Neighbor Discovery Router Advertisement messages, the gateway information can be broadcasted down to the NEMO tree structure. This TIO consists of some information and metrics for the MR to discover and select the optimum access router AR without packets loops. Beside the basic option, Sub-options can also be included into this TIO to fulfill different requirements. To define the sub-options, the type-8-bit identifier should be assigned to a number to acknowledge the receiver. The Sub-option length field represents the length of the sub-option in octets. The format of the TIO with the needed sub-options for M-TDP is shown in fig. 3

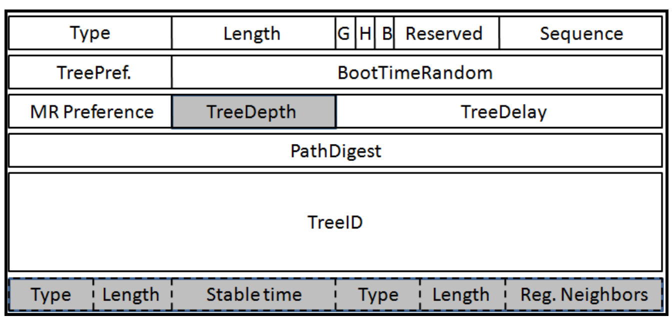

Fig. 3. TIO sub-options generic format for M-TDP

As for the MANET NHDP, the MR needs the same information regarding the MANET gateways and the path from the gateway to the MR. The M-NHDP is an extension of the IPv6-based NHDP. Therefore, the main functions of the NHDP are not changed and all the nodes can interact properly. However, additional options were added to broadcast gateways information. The Internet gateway advertisement (GW_ADV) of NHDP which is sent by MANET's gateway is having the same functions of the TDP's Router Advertisement message. Fig. 5. shows the modification made to the gateway advertisement message to hold the necessary information about the gateway.

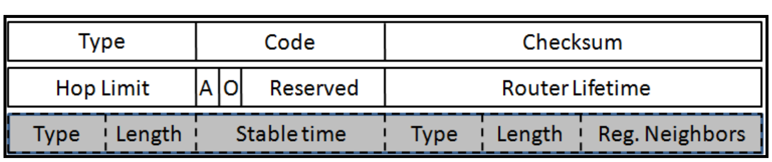

Fig. 5. IGW-ADV message format with extra gateway information sub-option

The gateways' information is broadcasted around the network using M-TDP and M-NHDP. As in TDP and NHDP, each massage contains the gateway address, location, and the time-to-live (TTL) before the packets get discarded. The gateway advertisement messages propagate from the gateway to number of hops (equals to TTL) without unnecessary flooding. Each MN updates its tables with the new information and the gateways keep the following information about the mobile nodes it serves. Then, the selection of the gateway is done at the mobile node according to the gateways and MRs lists collected using M-NHDP and M-TDP. These lists include all the needed criteria to evaluate the capabilities of the gateways. Fig. 6 shows how the information needed for gateway selection is collected at the mobile node.

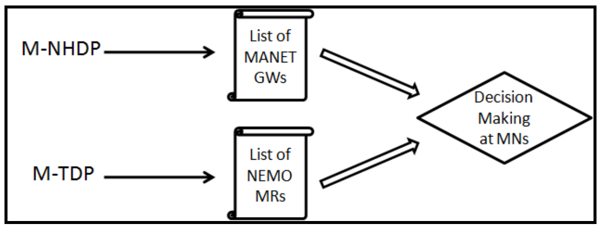

Fig. 6 Information collected using M-NHDP and M-TDP

Different criteria were chosen in the MGDSS. Each one has its features and drawbacks as describes by [11]. However, selecting the criteria carefully reduces the drawbacks. The chosen criteria for MGDSS are: hope count, NEMO nested-level, number of registered nodes, and Route Stable Time. When the MANET nodes lose the connection with their gateways, the NEMO MRs can be the solution by considering each MR as a gateway for the MANET. Then the connectivity is deployed using the NEMO tree structure. The signal flow of this procedure is shown in fig. 7 which explains how the MR behaves when it receives a gateway request message. The messages are exchanged between the MANET and the MR to register the address. Later the binding update is established.

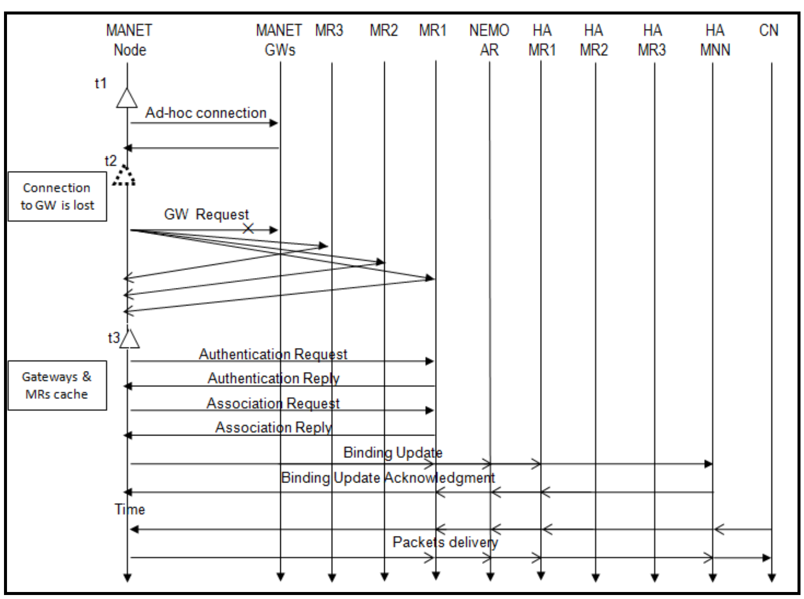

Fig. 7. Signaling flow when MANET connect to Internet through NEMO's MR

The gateway selection procedure starts only after checking the prefix of the message source. If it locates at the same topology, the MANET routing protocol will be in charge of forwarding the packets between the two nodes without passing by the gateway. This is mainly useful when the corresponding node (CN) is in the same MANEMO. The HAs are not involved in this case. The different cases of gateway selection are explained in fig. 8 which summarizes the whole selection mechanism.

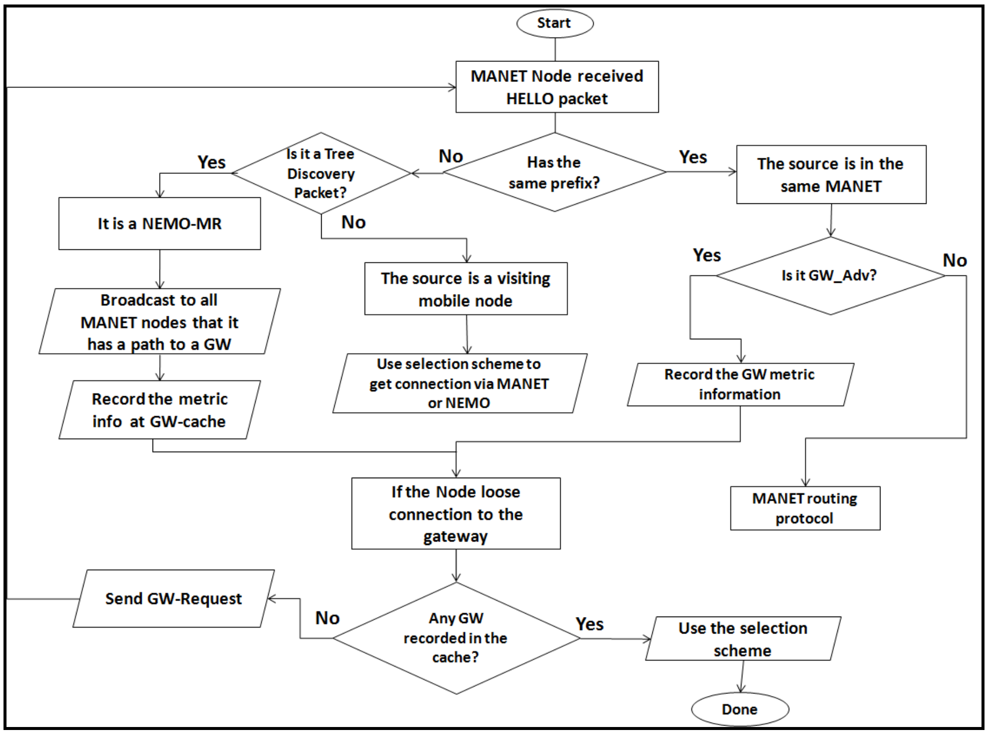

Fig. 8. Flowchart of the gateway selection mechanism

4. Performance evaluations

The first scenario in the simulation approach of MGDSS, M-MANEMO and NEMO BSP is deployed using 15 MANET nodes, 4 nested NEMO, slow mobility and low traffic load in the network. Fig. 9 shows the difference between the average WLAN delay and average throughput of MANEMO using NEMO BSP, MGDSS and M-MANEMO. The WLAN delay when using M-MANEMO is 14.3% more than the other two solutions. This is due to the re-routing process in the MANET when the intermediate nodes move out of the transmission range of their neighbors. The light weight given to the mobility selection parameter in the M-MANEMO causes higher delay. On the other hand, the throughput of the proposed scheme performs 44.5% better compared to the NEMO BSP and M-MANEMO is 56.4% better compared to NEMO BSP. This high delay of the NEMO BSP is because of the number of the HA's the packet has to go through. On the other hand, the M-MANEMO does not consider the mobility in the gateway selection method.

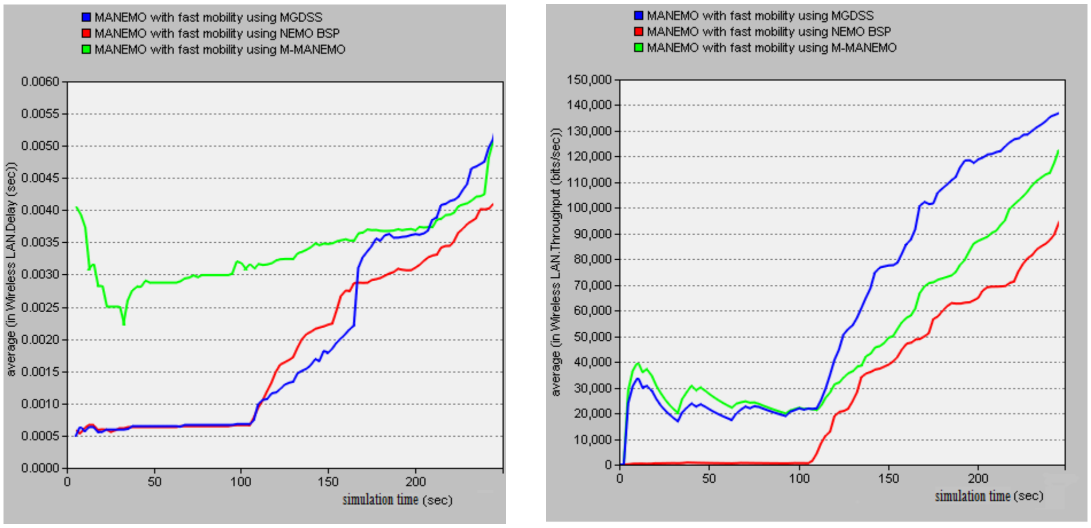

Fig. 9. Average WLAN delay and throughput in MANEMO with fast mobility

The performance of the proposed scheme and the benchmarks were also evaluated using different scenario with high traffic load, fast mobility, and large scale MANEMO. Fig. 10 shows the average end-to-end delay of voice packet and the average jitter in the MANEMO. The MGDSS outperforms the M-MANEMO in respect of the end-to-end delay around 21.6%. Whereas NEMO BSP has 68.7% more end-to-end delay compared to MGDSS. This is because of the number of MR-HA tunnels the packets will go through. Because of the different delays, the MGDSS has 66.6% less voice jitter compared to M-MANEM. It is also the effect of multi-homing where multi paths are used to send packets. Whereas NEMO BSP has average jitter much higher because of the number of MR-HA tunnels the packets will go through causing delay and packets retransmissions.

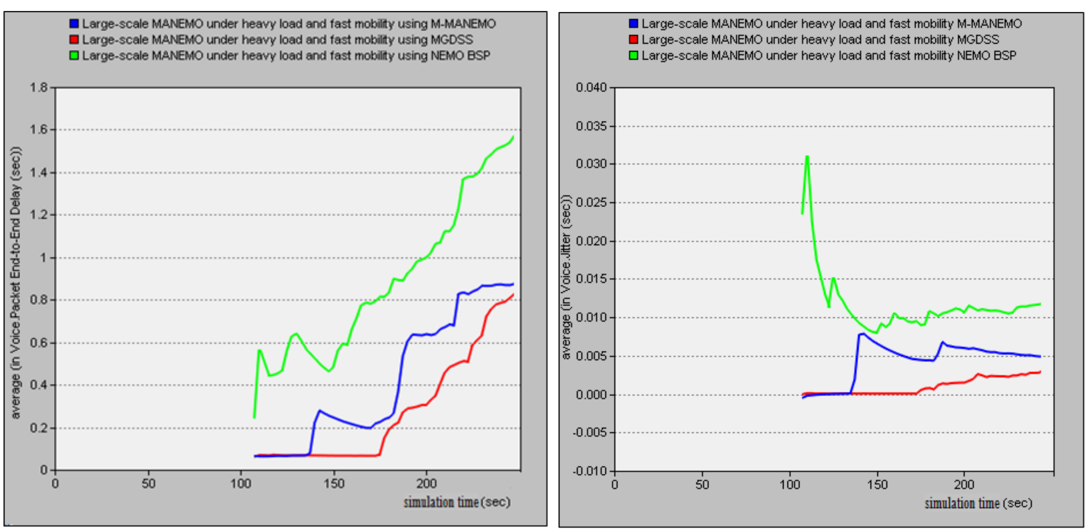

Fig.10. Average end-to-end delay of voice packet and average jitter in MANEMO with a worse-case scenario

5. Conclusion

In this research, a new gateway discovery and selection scheme for MANEMO is proposed based on enhanced TDP (M-TDP) which propagates the necessary gateway information down NEMO tree structure. And another enhancement made to NHDP (M-NHDP) to suite the MANEMO environment. For the selection mechanism, four criteria were used: Hop count, Nesting level, number of registered neighbors, and the stable time. The evaluation of the proposed scheme is done using OPNET simulator. The performance parameters selected to evaluate the proposed MGDSS and compare it with the chosen benchmark are: WLAN delay, Ethernet delay, Voice Jitter, WLAN dropped data packets, HTTP response time, WLAN throughput, packet delivery overhead, and handover delay.

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