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A Comparative Performance Analysis on NEMO-QoS and MIPv6-QoS in Heterogeneous Environments

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Abstract: Mobility management in heterogeneous networks is an important area since the mobile network may be moving between multiple types of access networks which involve several service providers such as 802.11b WLAN, 802.16 WiMAX and UMTS Networks. In crowded environments, the bottleneck is often between the access link and the mobile network. Being able to prioritize the traffic and allocate a minimum bandwidth guarantee for each user is crucial in this environment. This study presents a novel dynamic QoS provisioning mechanism for network mobility in heterogeneous networks integrated with IEEE 802.21 Media Independent Handover (MIH) protocol. Network Mobility (NEMO) Basic Support protocol has three important nodes Mobile Network Nodes (MNNs), Mobile Router (MR) and Home Agent (HA). The dynamic QoS provisioning mechanism which consists of traffic marking, prioritizing and scheduling are implemented at the mobile network node domain. While the admission control module is implemented at a mobile router domain. Several experiments are conducted to evaluate the mechanism. The results have shown the importance of less packet loss and delay and higher packet forwarding rate.

Key words: Network mobility, mobile IP, prioritization, QoS provisioning, mobile network node, media independent handover

INTRODUCTION

Recently there has been large scale deployment of wireless hotspots in public areas such as cafes, airports, libraries, campus areas, schools and train stations. They offer free surfing for their customers however some offer with charges. Most of personal user devices such as laptops, PDAs and mobile phones are built-in with an IEEE 802.11b g⁻¹. Furthermore, the users are able to access the Internet at anytime and anywhere. In public areas, a user could access the Internet without losing the connection while moving. Network Mobility Basic Support (NEMO BS) protocol (Devarapalli *et al.*, 2005) allows Ipv6 enabled devices access to the Internet whilst on the move. This is because the devices have the mobility functions to stay connected to the Internet. The mobile network can be moved within its administrative domain or different administrative domains (Wang *et al.*, 2005). A mobile network has a limited bandwidth to support several mobile nodes. The behavior of a wireless channel is limited when a MNN and a MR are sending packets, typically 11 Mbps (802.11b) or 54 Mbps (802.11g)

(Tsukada *et al.*, 2005). This is assuming that the MR's interface is configured as either 802.11b or 802.11g. With this amount of bandwidth, the number of traffic flows the mobile network can support is limited. If each user requires different resource reservation for different applications, this increases the control overhead on the entire mobile network. Therefore, the mobile network should be able to offer the user the required services (Tlais and Labiod, 2005). The requirements of the performance parameters such as reliability, delay, jitter and bandwidth vary from one application to another. For example, for Electronic Mail, File Transfer and Remote Terminal, the bandwidth requirement is low, since the data is transferred as small batch files. In web browsing, the bandwidth requirement varies, because the data is transferred in a series of burst files. In streaming video and voice applications, the bandwidth requirement is high and very delays sensitive. Wu (2010) proposes QoS scheduling for real time multimedia applications in IEEE 802.16. The mechanism is evaluated using NS2 simulation where several network parameters are compared between two case studies. The network performance has

shown improvement compared to the conventional mechanism. The mobile network must provide support for real-time and non real-time applications. Each user may run an application that requires suitable QoS support and is willing to pay for reliability and guarantee to achieve the requirements (Ahlund *et al.*, 2007). Using transport protocol may improve the performance of multimedia traffic over wireless networks. Adaptation of Random Early Detection (RED) mechanism by Al-Nabhan *et al.* (2006) has improved the packet throughput by minimizing the probability of packet dropped. Hence, mechanisms for traffic prioritizing, scheduling, resource provisioning are needed to determine the traffic limits and to keep the channel non-saturated.

Eshanta *et al.* (2009) presented QoS provisioning in wireless networks, IEEE 802.11 and IEEE 802.16. The study has shown that distributing the traffic flows within IEEE 802.11 and less probability of call blocking would maximize the resources in integrated networks. Meanwhile, Shahid *et al.* (2008) compared the performance of Mobile WiMAX and Cellular networks. Both articles concerned about the issue of resource utilization by comparing the technologies. Mobile WiMAX offers high bandwidth compared to 3G cellular networks. However, the behavior of a dynamic topology in both networks may see packet dropping or loss. In contrary, defining multipath routes for the mobile node may improve data delivery in wireless sensor networks (Ruan and Sun, 2011). The proposed mechanism is suitable to be applied in mobile network due to the similarities of dynamic movement of mobile node.

The first aim of this study is to compare the performance of mobility protocols (i.e., Mobile IPv6 and Network Mobility Basic Support protocols) based on dynamic QoS provisioning. The second aim is to integrate a dynamic QoS provisioning mechanism into NEMO BS protocol and MIPv6 protocol so that the mobile users would have QoS guaranteed in heterogeneous networks. The mechanism is implemented in NS2 simulation, to evaluate the performance of NEMO BS and MIPv6 protocols. Some researches have been done QoS provisioning in wireless network or mobile networks where they focused on resource reservation signaling (Sesay *et al.*, 2004), maximum wireless link quality (Jabri *et al.*, 2008; Singh and Sohi, 2008). However, there were none of the comparison study between two mobility protocols, NEMO BS and MIPv6.

MOBILE IPv6 AND NEMO BASIC SUPPORT PROTOCOL

Bohnert *et al.* (2008) was developed Mobile IP for Internet connectivity and created to support an "always-

on" scenario for mobile devices whilst roaming from one place to another. The common scenario is when the user wants to access the Internet; the user needs to dial into a specific Internet Service Provider (ISP) to establish a connection. When the user moves, the connection is terminated and the user must dial back to establish a new connection. The goal of Mobile IP is to provide a continuous Internet connection no matter where the user goes (Perkins, 1996). Mobile IP is a standard protocol that builds on the Internet Protocol by making the mobility transparent to the upper layer protocols. Mobile Internet Protocol version 6 (MIPv6) (Johnson and Perkins, 2004) is completely transparent to the upper layer protocols, e.g. Transmission Control Protocol (TCP), this allowing for session continuity. There are three entities in MIPv6, a HA, a MN and a Correspondent Node (CN). When the MN moves from its home network to a foreign network, a CoA is created for the MN to identify its current location. The MN uses the CoA to communicate with its HA either to receive or send packets. The CoA procedure is based on ICMP Router Advertisements described in RFC 1256 (Deering, 1991). In MIPv6, the functionality of the Foreign Agent (FA) is accomplished by IPv6 enhanced features, namely neighbor discovery and address auto-configuration.

The Network Mobility Basic Support protocol is an extension of Mobile IPv6. This protocol is defined by the IETF Working Group in RFC 3963 (Devarapalli *et al.*, 2005). The NEMO BS protocol works as similar as MIPv6, however, MIPv6 supports only host mobility while NEMO BS protocol supports network mobility. A Mobile Router (MR) is responsible for mobility and is always connected to the Internet in a manner that it is transparent to the attached nodes. Multiple Mobile Network Nodes (MNNs) are connected to the MR to communicate with the Correspondent Node (CN). This protocol provides transparency of mobility to the MNNs. The MNN may be a Local Fixed Node (LFN), a Local Mobile Node (LMN) or a Visiting Mobile Node (VMN). When the mobile network moves from its home network to a foreign network, the MR obtains a temporary address which is called a Care-of-Address (CoA) (Senan *et al.*, 2011). Then the MR sends a Binding Update (BU) message which contains its CoA to the HA. When the BU process is completed, a bi-directional tunnel is established between the MR and the HA. Any packets from the CN destined to the MNN on the mobile network are intercepted by the HA before forwarding to the MNN. In the opposite direction, the MNN sends the packets to the MR to be tunneled to the HA before sending out to the CN. In network mobility, a MNN can act as a mobile host and MR. If the MNN acts as the mobile host, the HA does not require to maintain

any prefix information related to the mobile host's home address. If the MNN acts as a mobile router, the information about its home address is maintained in a binding cache. In the NEMO BS protocol message format, this can be distinguished by the value in the MR flag (R). If the value is set to 0, the HA assumes that the MR is acting as the MNN. If the value is set to 1, the packets are from the MR. A mobility option field includes the binding update, type, length, reserved, prefix length and mobile network prefix. When the MR is attached at its home network, the MR needs to be reconfigured to prevent other nodes from configuring the mobile router as the default router. The configuration involves the sending of the RA, replying with the RS on the home network interface and setting a lifetime field to 0 (zero). In the foreign network, the MR should not send unsolicited RA and should not reply to the RS. However, the MR should reply with the NA when it receives the NS on the egress interface.

802.21 MEDIA INDEPENDENT HANDOVER PROTOCOL

IEEE 802.21 is the primary standard for Media Independent Handover (MIH) or vertical handover that is applied in heterogeneous networks (De La Oliva *et al.*, 2008). This standard supports handovers between different layer two technologies, such as GPRS, 3G, 802.11, 802.16, etc. The objective of this protocol is to provide an interaction between a link layer and upper layer. This is to avoid any communication disruption especially during a voice call. One notable point about this standard is that, it does not specify any rules or policies for the handover decisions either at a terminal or a network. However, the architecture makes the decisions itself. This reflects the basis of the MIH functions. An Event Service, Information Services and Command Services are used by the MIH functions that are located in the mobile nodes to be exchanged when a handover occurs between different networks. The MIH Event Service performs the events from the link layers which involves for example the communications between a wireless LAN interface and 3G interfaces. The binding acknowledgment is sent and received during and after the handover. If the handover is successful, then the mobile node will send the successful message. However, if the handover fails, the mobile node sends the failure message. The MIH Information Services provide information regarding the neighboring networks characteristics such as mobility support, QoS standard, etc. The third MIH function, Common Services, provide the means to the upper layers to configure, control and obtain information

from the lower layers. The process involves the connection procedure during the layer 3 handover. During the handover, the MIH message is sent to a mobility manager to get a list of available networks that the mobile node could handover to Choi *et al.* (2010). The mobility manager that is connected to the access networks supports a seamless handover for the mobile node. The MIH message is used by the mobile nodes and mobility manager to communicate. The IEEE 802.21 standard also supports the handover of mobile nodes and fixed nodes. The aim of the handover is to provide and maintain the active communications when the user changes the point of attachment. The MIH functions that reside at a layer 2 allow packets to be sent and received at layer 3 using the MIH agent. It communicates with the layer 2 (MAC layer) and the higher layer (MIH users). The MIH user uses the MIH functions to handover. To perform the handover in a heterogeneous environment, multiple interface (multiface) nodes are created to support different technologies. The Neighbor Discovery (ND) agent that resides in each of the multiface node is used to detect the layer 3 movements. The Access Points (APs) and Base Stations (BSs) periodically send the Router Advertisements (RAs) for an AP or BS's network prefix. The ND agent receives the RAs and determines if the message contains a new prefix. The RS is sent after the MN is attached to a new network after the handover (Kim *et al.*, 2009).

DYNAMIC QoS PROVISIONING MECHANISM

Figure 1 shows a dynamic QoS provisioning model that has been proposed by Noor and Edwards (2006). The model has been refined to meet the requirements. In the model, the QoS mechanism is applied in between the mobile network nodes and mobile router. Each module is discussed below:

Classification and marking: The Mobile Network Nodes (MNNs), Mobile Router (MR) and Home Agent (HA) control the QoS functionalities of IPv6 and MIPv6 packets. The IPv6 packet format consists of two fields that support QoS functionality, the traffic class and flow label. The MNNs use these two fields to perform traffic classification and marking. When the MR receives an IPv6 packet, resources are provisioned according to QoS requirements that are defined in both fields. Then, the IPv6 packet is queued based on the classification process. All packets from the same class receive the same treatment from a scheduler. The MR will re-mark the packet before forwarding to the HA through the bi-directional tunnel.

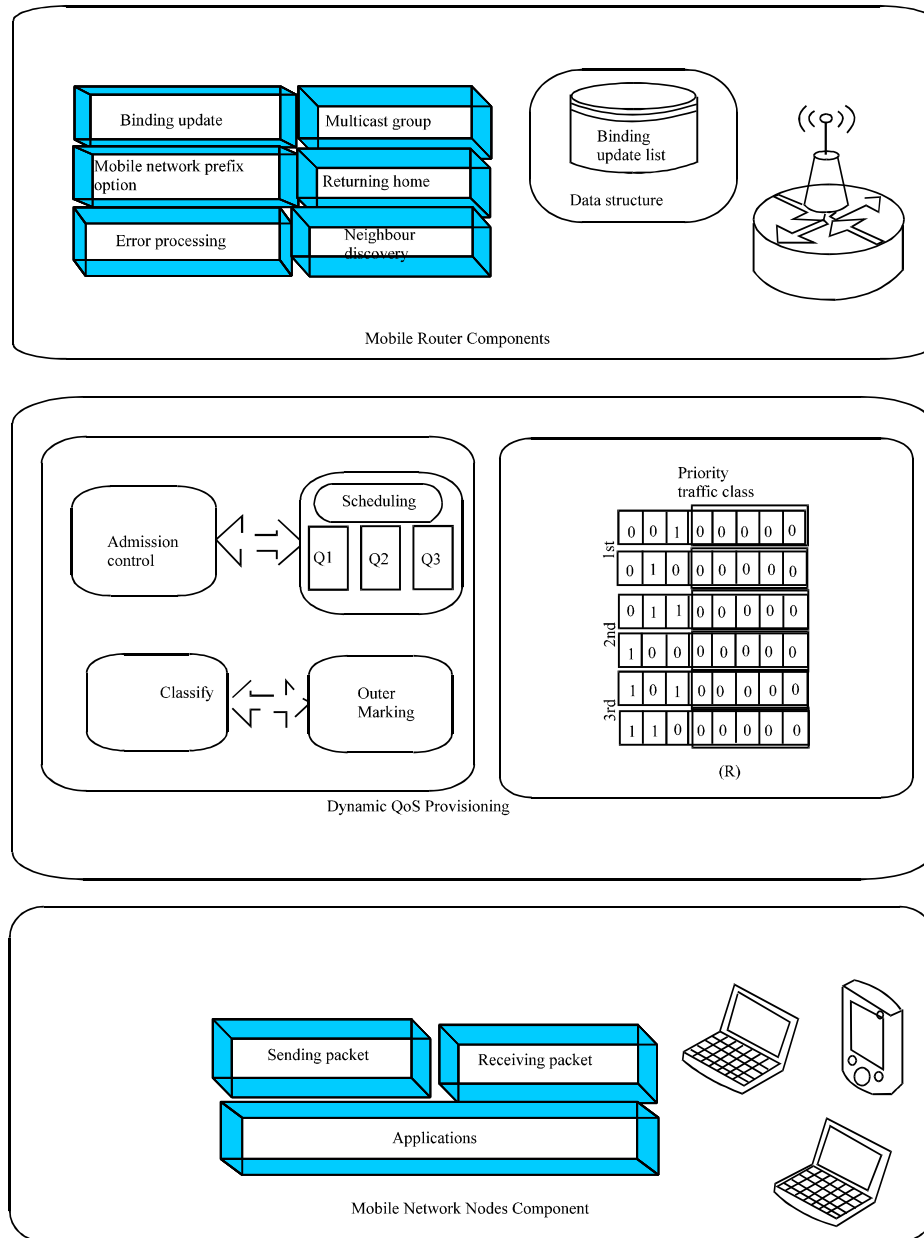


Fig. 1: QoS provisioning mechanism

Traffic priority: In our priority module, there are three priority classes for the service: Premium, Intermediate and Default. To avoid an overflow of data, each queue has a maximum size, 30. Traffic is aggregated into a specific class that it belongs to. For example, real time traffic from the Premium class is queued in the real time classifier class. Then, the traffic in the class is queued and configured using the different scheduler algorithms. A scheduler selects the highest priority queue to put into the first queue and then the medium priority, in a second

queue and so on. The mobile network node assigns the traffic flow into different priority classes; premium class with bandwidth guarantees, intermediate class for bandwidth assurance and default class for best-effort traffic. A classifier separates the arriving packets into different queues for every class. To avoid monopolization of the bandwidth by the specific class flow, the resources reserved for this class should have a limit. The premium class is dedicated to the mobile users who want to have QoS guarantees. A bandwidth link is given to the highest

priority class, i.e., CBR flows, until the CBR queues are emptied and then the scheduler will serve the VBR flows. While the best-effort flow is background traffic without QoS guarantees. Therefore, the FCFS scheduling mechanism is used for the best effort traffic.

Traffic queuing and scheduling: A packet scheduling algorithm can differentiate the service class and user class. There are many types of scheduling algorithms such as Priority Queue (PQ) (Demoor *et al.*, 2011), Dynamic Queuing (Wang *et al.*, 2008), Class Based Queue (CBQ) with Weighted Round Robin (WRR) (Mao *et al.*, 2001), Weighted Fair Queuing (WFQ) (Hwang *et al.*, 2008), First Come First Served (FCFS) (Osman and Woodward, 2008) and Two-Layer Channel-Aware Scheduling Algorithm (Ghazizadeh *et al.*, 2009). In a mobile network, the simplest scheduling, FCFS is applied for the default service and lower user class. For the other service and user classes, the scheduling algorithm used is PQ. The difference between PQ and FCFS is that PQ gives high priority to the defined traffic and controls it,

whereas FCFS processes the traffic according to their arrival time. PQ is implemented in a non-preemptive manner where the ongoing traffic (e.g., lower priority class) is not interrupted when there is incoming traffic (e.g., higher priority class or other priority classes). This is because the resources have been reserved for the higher priority traffic before transmitting.

Admission control: A mobile network requires admission control in the case of a dynamic topology that will support different QoS requirements. The NEMO Admission Control (NEMO-AC) scheme is defined in mobile network architecture to allocate resources for the Mobile Network Nodes (MNNs). The NEMO-AC includes the MAC parameter tuning algorithm where AIFS, CW and AC determine whether a new flow coming from the MNNs will be granted for the new resources or not. The NEMO-AC uses the algorithm to guarantee the QoS requirements for the three access categories (i.e. Premium, Intermediate and Default).

Figure 2 shows a dynamic QoS provisioning process flowchart. The process describes the operation flows of

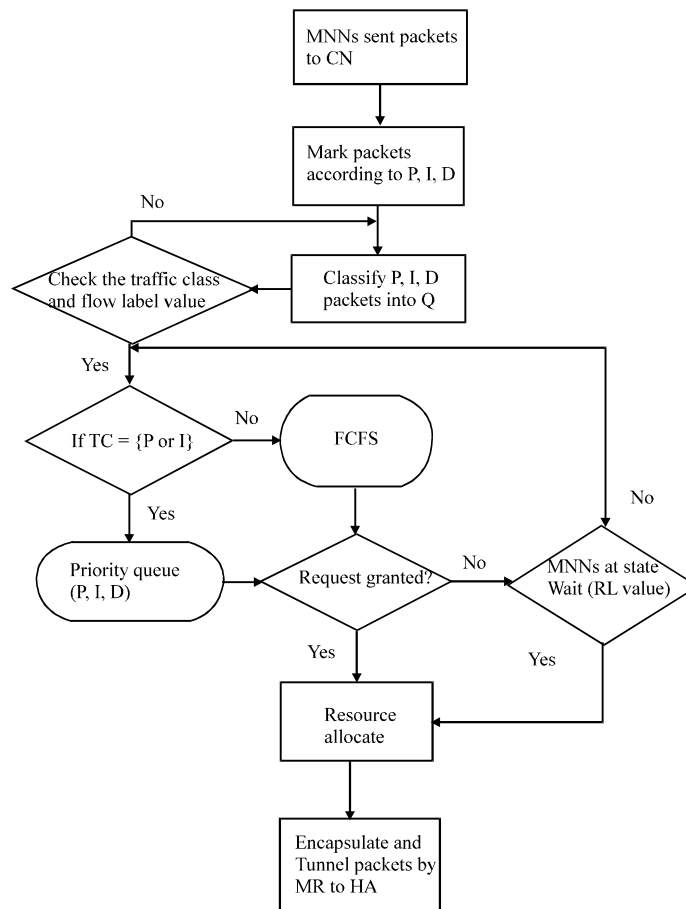


Fig. 2: Dynamic QoS provisioning flow chart

(1) Mobile Network Node (MNN) where it sends packets to a Correspondent Node (CN). The packets are marked and classified according to three classes; Premium (P), Intermediate (I) and Default (D). The packets are checked according to traffic class and flow label value before prioritizing it. There are two queuing mechanisms used in this model; priority queue and First-Come First-Served (FCFS). The next is the operation flow of (2) Mobile Router (MR) where it performs the scheduling and admission control. Upon receiving the transmission from the MNNs, the MR checks whether the resources are available to grant the request according to the queue classes or not. If yes, the queue class is admitted with amount of resources or else the queue will reschedule and retransmit after a random time. The packets are encapsulated and forwarded by the MR to a home agent (HA).

Integration of NEMO bs and MIH architecture: IEEE 802.21 (Media Independent Handover) standard is designed purposely for a seamless handover in a wide variety of heterogeneous networks. The National Institute of Standards and Technology (NIST) developed this protocol for NS-2 (http://www.arcst.whu.edu.cn/web_kongrs/nemo_sim.htm) and made it available to be used for research purposes. The package is installed under the NS-2 version 2.29 to simulate the mobile network scenarios in a heterogeneous environment. The package contains the mobility (MIPv6), Neighbor Discovery (ND) and Media Independent Handover (MIH) modules, suitable to enable experiments with mobile networks over different type of technologies (e.g., 802.16 WiMAX, 802.16e Mobile WiMAX, Bluetooth, 802.11b and UMTS). The main purpose of IEEE 802.21 is to allow the handover between different technologies without any service interruption, hence improving the user experience on the mobile network. To achieve the goal, IEEE 802.21 defines the media-independent entity that provides a generic interface to be used between the layer two technology and the upper layers. The generic interface is called a virtual node (i.e., MultiFaceNode) which functions to control the interface changes between different technologies during the handover. The ND module is designed to provide the movement detection at layer three. It is also used to send Router Advertisement (RA) and receive a Router Solicitation (RS) messages. These modules are not been implemented in NEMO BS package. Therefore, the ND module is available to be integrated with the NEMO BS protocol. The MIH configurations and descriptions are described as follows:

- `$ns node_config -multiIf ON` - is to create a multi-interface node at the beginning of the TCL code. The

declaration is defined before creating a base station or mobile node

- `Set multiFaceNode add-interface-node $mobile_router-to` add the MultiFaceNode (i.e., virtual node) into a mobile router
- `Set nd_bs ($bstation802 install-nd)-is` to install the neighbor discovery module into the base station. The neighbor discovery module is also added into all the base stations and mobile nodes that have been defined in the TCL code
- `Set handover (new Agent/MIHUser/IFMNGMT /MIPv6/MR/Handover/Handover2) $multiFaceNode install-ifmanager $handover-is` a handover configuration that is declared before installing an interface manager (IFMNGMT) into a multi-interface node. A handover module is created inside the MR package
- `Set mih ($multiFaceNode install-mih)-is` to install the MIH into the multi-interface node
- `$handover connect-mih $mih-is` to connect between the MIH and IFMNGMT using a handover function

The MIH module in IEEE 802.21 is modified to allow the NEMO BS protocol to run on this platform. Two modules in this package are modified. First, the existing mobile nodes are modified as a mobile router, a mobile network node and a home agent. The second modification is the priority module in the MAC layer to prioritize the traffic. Figure 3 shows the MIH and NEMO BS protocol modifications model.

IMPLEMENTATION

The NEMO BS protocol package an extension from a MobiWan package built by MOTOROLA Labs, Paris, in collaboration with the INRIA PLANETE team (<http://www.inrialpes.fr/planete/mobiwan>). The package is built to simulate Mobile IPv6 (MIPv6) under a large Wide Area Network (WAN). In NS-2, a hierarchical address is divided in three levels which are a domain level, site level and node level. All routers at the same site (e.g., border router, site router and base station) have the same prefix (address), i.e. this corresponds to the prefix of the site. Moreover, each router in the site has its own subnetwork prefix. This means that the end-systems on the same subnetwork share the same subnetwork prefix. In the NEMO BS protocol, each base station is responsible for a site and the mobile network has its own mobile network prefix. One part of the NEMO address is allocated for the mobile networks and the remaining address is reserved for the attached mobile router and mobile network nodes.

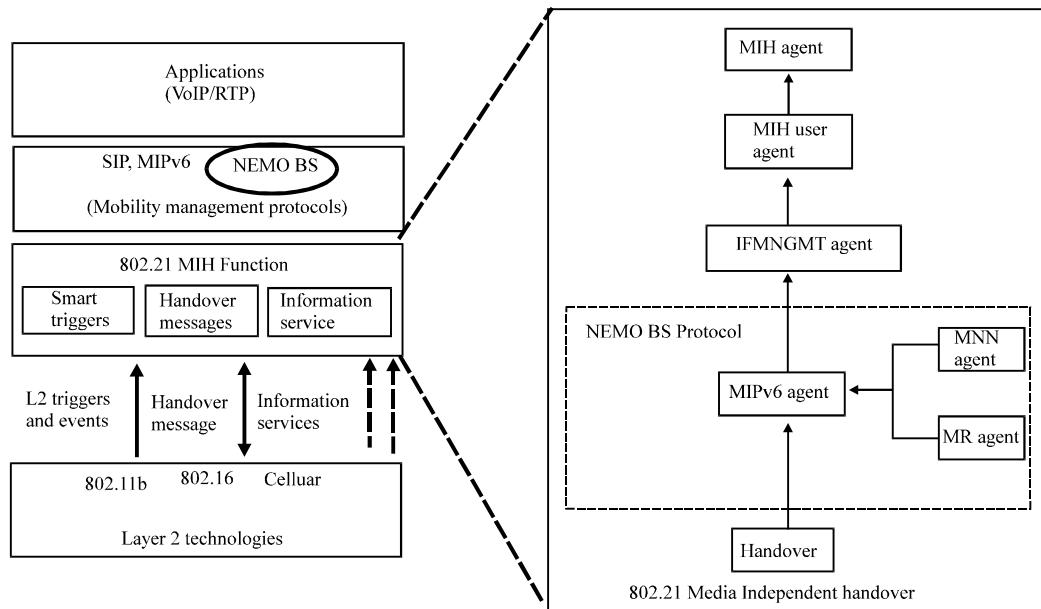


Fig. 3: NEMO-MIH stack

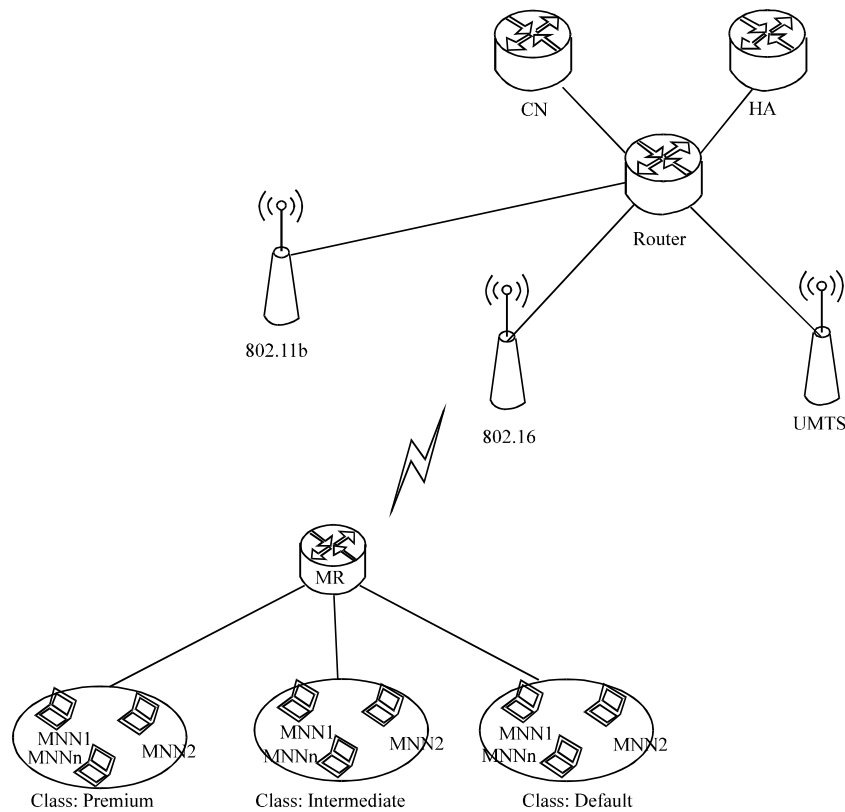


Fig. 4: NS-2 simulation topology for NEMO

Simulation topology: Figure 4 and 5 show the network topology in NS-2. The basic topology consists of a core router which connected to a Home Agent (HA) and a

Correspondent Node (CN). A wired-link configuration is 1Gbps. The wireless topology consists of three base stations from different layer two technologies which are

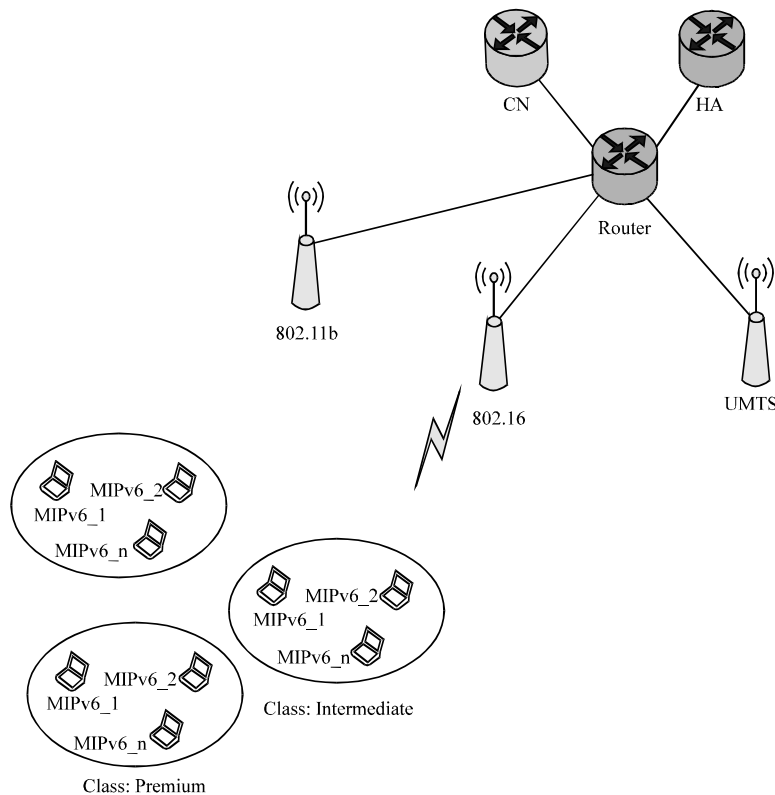


Fig. 5: NS-2 simulation topology for MIPv6

802.11b access point, 802.16 base station (Bohnert *et al.*, 2008) and UMTS base station. Each technology has different data rates and characteristics.

Figure 4 represents a mobile network which consists of a Mobile Router (MR) connected to three groups of Mobile Network Nodes (MNNs) where each group has five MNNs. The first group is a Premium user subscription where the traffic has the highest priority; the second group is an Intermediate user subscription where the traffic has the second highest priority; the Default user subscription is the last priority traffic where the traffic is treated as best effort mechanism. The MR is roaming between three different layer technologies to create a heterogeneous network. Meanwhile, Fig. 5 represents mobile IPv6 nodes where the mobile nodes are grouped into Premium class, Intermediate class and Default class. The experiment is conducted to compare the efficiency of mobile protocol when transmitting different types of traffic.

RESULTS AND ANALYSIS

Here, we present the simulation results for three experiments that we have conducted. The first experiment compares the forwarding packet rate between NEMO-QoS

and MIPv6 QoS when they roamed between different layer two technologies.

First Experiment: Packet Forwarding Rate for NEMO vs. MIPv6:

In first experiment, packet forwarding rate vs. number of mobile nodes results are presented in Fig. 6-8 for three different QoS classes, premium, intermediate and default. To achieve a satisfied transmission quality, each traffic class has less than 500 msec in delay. Traffic flow for each class in NEMO-QoS experiment is aggregated and forwarded to the mobile router to be transmitted to the home agent before reaching the correspondent node.

In Fig. 6, the results have shown that the packet forwarding rate for NEMO-Premium and MIPv6-Premium is equally same until the number of nodes have increased to eight. The forwarding packet rates for NEMO-Premium and MIPv6-Premium have reduced to 92.76 and 96.32%, respectively. Nevertheless, NEMO-Premium packet forwarding rate is higher than MIPv6-Premium packet forwarding rate.

Packet forwarding rates decreased in NEMO-Intermediate and MIPv6-Intermediate when four intermediate traffic classes transmitted simultaneously (Fig. 7). At 20 nodes, the packet forwarding rates for

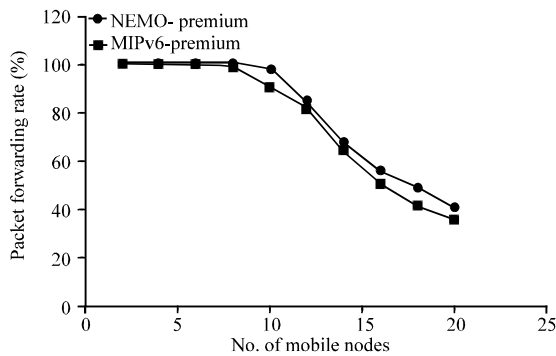


Fig. 6: Packet forwarding rate: NEMO vs. MIPv6 (premium class)

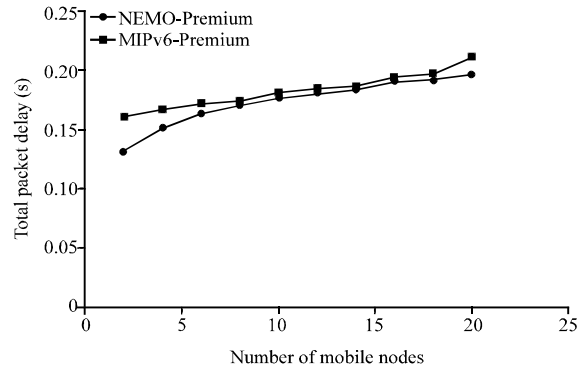


Fig. 9: Total packet delay: NEMO vs. MIPv6 (premium class)

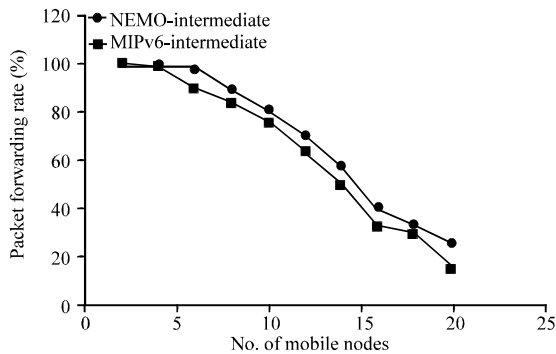


Fig. 7: Packet forwarding rate: NEMO vs. MIPv6 (intermediate class)

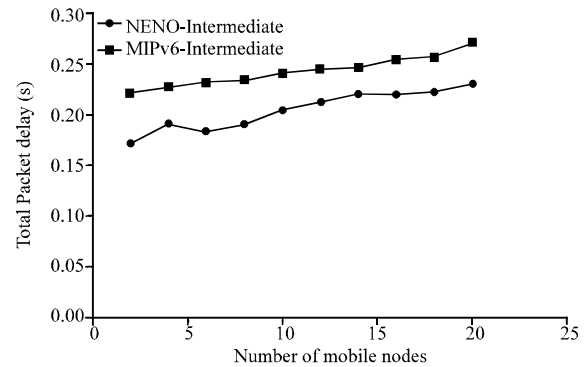


Fig. 10: Packet delay rate: NEMO vs. MIPv6 (intermediate class)

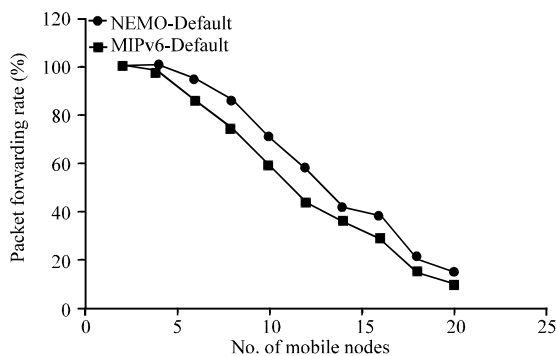


Fig. 8: Packet forwarding rate: NEMO vs. MIPv6 (default class)

NEMO-Intermediate is 27.65% and MIPv6-Intermediate is 18.03%. The results obviously reflect the bandwidth degradation when more mobile nodes transmitted packets at the same time.

In Fig. 8, we could see the packet forwarding rates for NEMO-Default and MIPv6-Default are decreased to 14.42 and 10.87%, respectively. It is observed that default class guaranteed low bandwidth compared to premium and intermediate classes.

Summarizing the above experiment results, the results have shown that the forwarding packet rate is higher in NEMO compared than the MIPv6. On the other hand, traffic in MIPv6 nodes is forwarded individually to the base station and they are struggled for a limited bandwidth. The premium class traffic has shown better results in forwarding rate compared to the Intermediate and Default classes.

Second experiment: total packet delay for NEMO vs. MIPv6:

In the following, we present the simulation results for a total packet delay vs. number of mobile nodes between NEMO and MIPv6. Handoff delay is the time that elapses between the last packet received and the arrival of the first packet. The higher the handoff delay, the performance of a network is getting poorer. The performances of packet delay due to handoff are measured for different traffic QoS class. The packet size for each class is set differently to meet the QoS class requirements, ranging from 100 Bytes to 1400 Bytes. Fig. 9-11 show the results of handoff delay until it reached 20 nodes.

In Fig. 9, the overall performances of total packet delay for NEMO-Premium is lower than MIPv6-Premium.

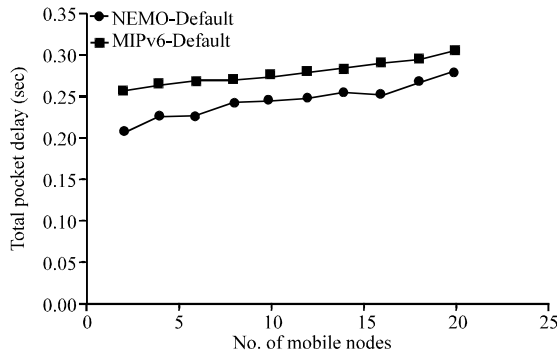


Fig. 11: Packet delay rate: NEMO vs. MIPv6 (default class)

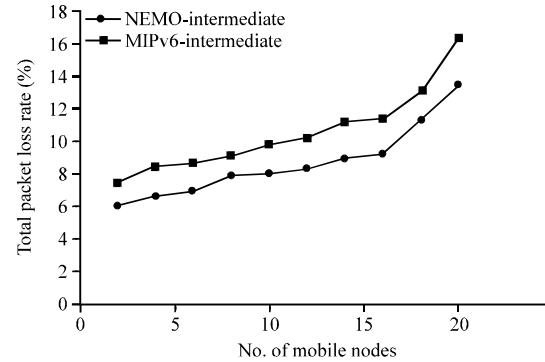


Fig. 13: packet delay rate: NEMO vs. MIPv6 (intermediate class)

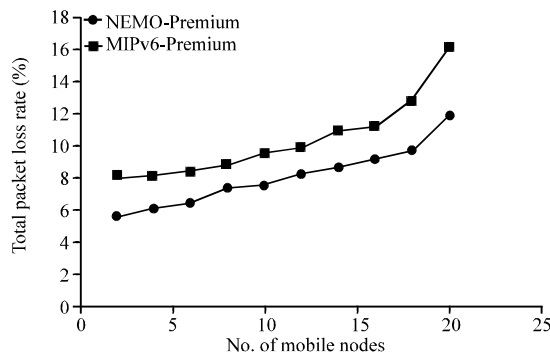


Fig. 12: Packet delay rate: NEMO vs. MIPv6 (premium class)

At 20 mobile nodes, a total packet delay for NEMO-Premium is 0.175 seconds compared to MIPv6-Premium, 0.216 sec.

When a lower priority packet transmitted over the mobile network, the total packet delay is getting bigger. In this experiment (Fig. 10), we could see a huge packet delay when it is transmitted by NEMO-Intermediate mechanism and MIPv6-Intermediate mechanism. At a single node, the total packet delay for NEMO-Intermediate and MIPv6-Intermediate is 0.169 seconds and 0.232 seconds respectively. Later at node 20, the total delay has increased to 0.217 seconds (NEMO-Intermediate) and 0.257 sec (MIPv6-Intermediate).

At a maximum number of node, 20, the total packet delay for NEMO-Default and MIPv6-Default is 0.243 and 0.285 sec, respectively (Fig. 11). The total packet delay is higher compared to the others mechanism, NEMO-Premium, NEMO-Intermediate, MIPv6-Premium and MIPv6-Intermediate. The packets must be queued and waited for transmission when traffic is overloaded the network link.

Summarizing the above experiment results, both protocols, NEMO-QoS and MIPv6-QoS draw a conclusive result where the handoff delay results are similar since the process to update the CoA with the HA and CN when the MR and MNNs change its point of attachment.

Third experiment: total packet loss rate for NEMO vs. MIPv6: When a mobile router (NEMO) and mobile node (MIPv6) perform handoff, the network link will cause packet loss. In traffic QoS class, the Premium class packet size is smaller (100 Bytes) compared to the Intermediate (1000 Bytes) and Default (1400 Bytes) classes.

The total packet loss rates vs. number of mobile nodes results for this experiment are shown in three separated diagrams.

In Fig. 12, the results have shown that a total packet loss rate for MIPv6-Premium is 15.54% compared to NEMO-Premium, 11.67%. The numbers of traffic are aggregated in NEMO-Premium before transmitting to the access network. With the proposed scheduling, it provides more bandwidth to the mobile network and better QoS then MIPv6 where the traffic is transmitted individually.

As shown in Fig. 13, the total packet loss rates for NEMO-Intermediate have been increased from 5.93 to 12.87% at its maximum number of mobile nodes. In contrary, the total packet loss rates for MIPv6-Intermediate have been increased from 7.65 to 15.79% which is higher than NEMO-Intermediate protocol. In comparison with NEMO-Default and MIPv6-Default, the results for total packet loss rates are 16.93 and 19.18%, respectively (Fig. 14).

Summarizing the above experiment results, when the traffic is heavy in the mobile network, it will exceed the capacity of available resources. The proposed mechanism, a dynamic QoS provisioning has shown that the

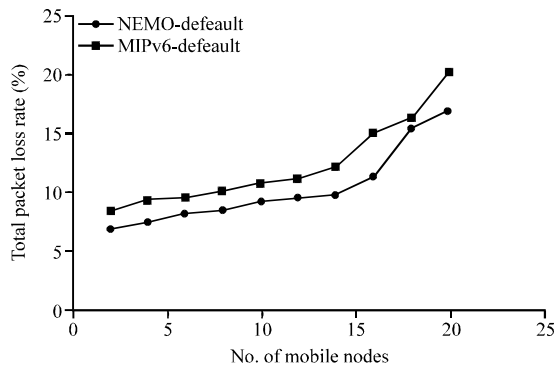


Fig. 14: Packet delay rate: NEMO vs. MIPv6 (default class)

resources are distributed accordingly to the level of QoS classes. The scheduling mechanism has provides lower packet loss rates and delays for higher QoS class, i.e., Premium.

CONCLUSION

In this study, we proposed the QoS classes in NEMO Basic Support protocol and the implementation in heterogeneous networks. The 802.21 MIH protocol does not support NEMO BS protocol. Several MIH modules are enhanced to meet the NEMO requirements. The comparison experiments conducted between NEMO and MIPv6 are presented. Based on the performance, we conclude that the packet forwarding, packet delay and packet loss rates are affected during MR and MN handoff. The successful total percentage of the overall performances in NEMO is higher than MIPv6 because the characteristic of MR in NEMO Basic Support protocol which provide the transparency to the mobile network nodes behind it. The handoff is performed by the MR and this contributes to the efficiency of the handoff performance. On the other hand, with appropriate QoS implementation in NEMO has improved the network performance well in terms of packet forwarding, loss and delay rates.

REFERENCES

Ahlund C., R. Brannstrom, K. Andersson and O. Tjernstrom, 2007. Multimedia flow mobility in heterogeneous networks using multihomed mobile. *J. Mobile Multimedia*, 3: 29-38.

Al-Nabhan, M., S. Yousef and J. Al-Saraireh, 2006. TCP protocol and red gateway supporting the QoS of multimedia transmission over wireless networks. *Inform. Technol. J.*, 5: 689-697.

Bohnert, T.M., M. Castrucci, N. Ciulli, G. Landi and I. Marchetti *et al.*, 2008. QoS management and control for an all-IP WiMAX network architecture: Design, implementation and evaluation. *Mobile Inform. Syst.*, 4: 253-271.

Choi, G., B. Kim and S. Min, 2010. A novel MIH handover procedure for efficient PMIPv6 network. *Proceedings of the International Conference on Information and Communication Technology Convergence*, Nov. 17-19, Jeju Island, Korea, pp: 492-496.

De La Oliva, A., A. Banchs, I. Soto, T. Melia and A. Vidal, 2008. An overview of IEEE 802.21: Media-independent handover services. *IEEE Wireless Commun.*, 15: 96-103.

Deering, S., 1991. ICMP router discovery messages. RFC1256, Network Working Group. <http://tools.ietf.org/html/rfc1256>

Demoor, T., J. Walraevens, D. Fiems and H. Bruneel, 2011. Performance analysis of a priority queue: Expedited forwarding PHB in DiffServ. *Int. J. Electron. Commun.*, 65: 190-197.

Devarapalli, V., R. Wakikawa, A. Petrescu and P. Thubert, 2005. Network mobility (NEMO) basic support protocol. RFC 3963, January 2005.

Eshanta, O.M., M. Ismail, K. Jumari and P. Yahaya, 2009. VHO strategy for QoS-provisioning in the WiMAX/WLAN interworking system. *Asian J. Applied Sci.*, 2: 511-520.

Ghazizadeh, R., P. Fan and Y. Pan, 2009. A two-layer channel-aware scheduling algorithm for IEEE 802.16 broadband wireless access systems. *J. Applied Sci.*, 9: 449-458.

Hwang, I.S., B.J. Hwang and C.S. Ding, 2008. Adaptive weighted fair queuing with priority (AWFQP) scheduler for DiffServ networks. *J. Inform. Electron.*, 2: 15-19.

Jabri, I., A. Soudani, N. Krommenacker, T. Divoux and S. Nasri, 2008. QoS protocol specification for IEEE 802.11 WLAN. *Inform. Technol. J.*, 7: 549-559.

Johnson, D.B. and C. Perkins, 2004. Mobility support in IPv6. IETF RFC 3775. Network Working Group. <http://www.ietf.org/rfc/rfc3775.txt>

Kim, M., T.W. Moon and S.J. Cho, 2009. A study on IEEE 802.21 MIH frameworks in heterogeneous wireless networks. *Proceedings of the 11th International Conference on Advanced Communication Technology*, Feb. 15-18, Phoenix Park Korea, pp: 242-246.

Mao, J., W.M. Moh and B. Wei, 2001. PQWRR scheduling algorithm in supporting of DiffServ. *Int. Conf. Commun.*, 3: 679-684.

- Noor, R.M. and C. Edwards, 2006. A dynamic QoS provisioning model for network mobility. Proceedings of the 7th Annual postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting, June 26-27, United Kingdom, pp: 1-6.
- Osman, N.I. and M.E. Woodward, 2008. A comparison of queuing models for handover strategies in cellular mobile telecommunication systems. Proceedings of the 2nd Asia International Conference on Modelling and Simulation, May 13-15, IEEE Computer Society, pp: 315-321.
- Perkins, C., 1996. IP mobility support. IETF RFC 2002. <ftp://ftp.monarch.cs.cmu.edu/pub/internet-drafts/draft-ietf-mobileip-protocol-17.txt>.
- Ruan, Z. and X. Sun, 2011. An efficient data delivery mechanism by exploring multipath routes for wireless sensor networks. *Inform. Technol. J.*, 10: 1359-1366.
- Senan, S., A.H.A. Hashim, A.S. Rashid and J.I. Daoud, 2011. Evaluation of nested network mobility approaches. *J. Applied Sci.*, 11: 2244-2249.
- Sesay, S., Z. Yang and J. He, 2004. A survey on mobile Ad hoc wireless network. *Inform. Technol. J.*, 3: 168-175.
- Shahid, M.K., T. Shoulhan and A. Shan, 2008. Mobile broadband: Comparison of mobile WiMAX and cellular 3G/3G+ technologies. *Inform. Technol. J.*, 7: 570-579.
- Singh, G. and B.S. Sohi, 2008. Experimental evaluation of medium access schemes in 802.11 wireless networks. *J. Comput. Sci.*, 4: 888-896.
- Tlais, M. and H. Labiod, 2005. Resource reservation for NEMO networks. *Int. Conf. Wireless Networks Commun. Mobile Comput.*, 1: 232-237.
- Tsukada, M., T. Ernst, R. Wakikawa and K. Mitsuya, 2005. Dynamic management of multiple mobile routers. Proceedings of the IEEE 7th Malaysia International Conference on Communications, Nov. 16-18, Kuala Lumpur, pp: 1108-1113.
- Wang, W., Y. Zhang, J. Zhao and S. Wang, 2008. Dynamic priority queue handover scheme for multi-service. Proceedings of the IEEE Vehicular Technology Conference, May 11-14, Singapore, pp: 2287-2290.
- Wang, Y., L. Fan, N. Akthar, K.A. Chew and R. Tafazolli, 2005. An aggregation-based QoS architecture for network mobility. Proceedings of the 14th IST Mobile Summit Conference, June 19-23, Germany, pp: 1-5.
- Wu, C.F., 2010. Real-time scheduling for multimedia services in IEEE 802.16 wireless metropolitan area network. *Inform. Technol. J.*, 92: 1053-1067.