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A Study of Network Infrastructure based Wireless Network Management Service across the Integrated Heterogeneous Networks

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Abstract

Networks nowadays are comprised of the integration of heterogeneous wired and wireless networks. The cooperation of a variety of telecommunication standards is essentially important for the interoperability and seamless flow mobility of multimedia contents for wireless networks. This paper deals with the study and analysis of the network infrastructure based wireless network management service using flow mobility of multimedia contents over the integrated heterogeneous wireless networks. The interoperability among heterogeneous wireless networks is maintained as mobile devices moves across the coverage areas of multiple radio access networks. The system optimizes the best features of the network infrastructure based wireless network management service in order to ensure the seamless flow distribution of multimedia contents.

Keywords: *flow distribution, PMIPv6, network-based mobility management*

1. Introduction

Nowadays, the Internetworking has evolved from the use of traditional wired networks into the integration of wired, wireless, and mobile network systems. The continuous growth in the evolution of telecommunication technologies such as powerful handheld devices (*e.g.*, smartphones, PDAs, notebooks, *etc*…) and the rapid increase in the deployment of heterogeneous radio access technologies (RATs) such as 3G, 4G or Long Term Evolution (LTE) and Wi-Fi or IEEE 802.11n has begun the era of ubiquitous computing. That is, multimedia contents can be accessed anytime, anywhere and in any device. Based on the complete Visual Networking Index (VNI) Forecast [1], the global IP traffic in 2016 stands at 96 EB (Exabytes) per month and will nearly triple by 2021, to reach 278 EB (Exabytes) per month. The consumer IP traffic will reach 232.7 EB (Exabytes) per month and business IP traffic will be 45.5 EB (Exabytes) per month by 2021. That means that the mobile traffic growth continuously increases at a very fast rate.

In this regard, there is a continuously increasing demand for the increased bandwidth of mobile internet traffic in order to provide the Internet users with seamless and balanced flow mobility in the distribution of multimedia contents. A seamless real-time communication session and an efficient flow mobility distribution are essentially required by the increasing number of mobile internet users and the amassed volume of multimedia contents in the Internet. With the integrated heterogeneous wireless networks, mobile devices are continually moving

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from one point of attachment (PoA) to the next, and the need for continuous network connectivity is a must. The use of host-based mobility management protocols (*e.g.*, standard MIPv6, HMIPv6, or FMIPv6) involves the mobile user devices (MNs) on all mobility-related signaling in order to warrant its mobility support. The MN's IP address changes and its protocol stack is in need of modification as it moves around across heterogeneous wireless networks. In addition, the MNs being involved with the mobility-related signaling increases the MN's complexity, power consumption, and radio resources. The host-based mobility management protocols also have higher handover latency, higher packet loss rate, and signaling overhead.

This paper aims to provide a study of the analysis of a multipath flow mobility distribution of multimedia contents across the integrated heterogeneous wireless networks based on a network-based mobility management provided by the Proxy Mobile Internet Protocol version 6 (PMIPv6) protocol. It provides the mobile devices of the Internet users to roam around the available wireless networks without being required of any signaling to register its movements. Thus, the user mobile devices moves between radio access networks freely as it is not required to register or update its current location in every movement. The optimized path for the traffic flow in the distribution of multimedia contents is determined through identifying the traffic conditions among the integrated heterogeneous wireless networks. The path with the best bandwidth will be determined in order to optimize the traffic flow distribution of multimedia contents. Thus, a robust handoff scheme between wireless network technologies needs to be warranted through the analysis of the PMIPv6 based multipath flow distribution.

The rest of this paper is organized as follows: Section 2 provides an overview of PMIPv6; the analysis of the integrated heterogeneous wireless networks is discussed in Section 3; the multipath flow distribution of multimedia contents across the integrated heterogeneous wireless networks is outlined in Section 4; and the concluding remarks in Section 5.

2. PMIPv6 Overview

The Mobile Internet Protocol version 6 is standardized by the Internet Engineering Task Force (IETF) in order to address the depleting available addresses of the MIPv4 as well as other issues such as high signaling loads, and packet delays due to triangular routing [2, 3, 4]. The MIPv6 allows a mobile node (MN) to maintain connectivity with its correspondent nodes (CNs) as it moves across different radio access networks within the Internet domain. The multimedia contents IP packets to be sent by the CN to the MN are delivered through the MN's home agent (HA). The HA provides a fixed home address (HoA) to the MN and a care-of address (CoA) is given whenever it moves into another network. The MN can reachable through its CoA when it is away with its home network. The multimedia contents IP packets sent by the CN to the MN's HoA will be intercepted by the HA and will be tunneled to its current CoA.

However, every time the MN moves between access networks, it is required to inform the HA with its current location through the binding update (BU) messages. Thus, it raises several issues such as higher handover latency, higher packet loss, and signaling overheads. In addition, it required protocol stack modification that includes from the physical layer, data link, and network layers up to the transport and application layers. It also requires a number of mobility management signaling such as movement detection (MD) messages, Router Solicitation (RtSol) requests, Duplicate Address Detection (DAD), Binding Update (BU) messages, etc. Thus, the quality of service (QoS) requirements for a seamless real-time and multimedia service cannot be addressed fully.

The Proxy Mobile Internet Protocol version 6 (PMIPv6) is standardized by the Network-based Localized Mobility Management (NETLMM) working group of the Internet Engineering Task Force (IETF). [5, 6] It is based on the signaling concepts and functions of the standard MIPv6 protocol wherein processing of the mobility related signaling of mobile devices (MNs) are relegated the network entities. The MNs are not required to partake in the mobility management but are provided with mobility support allowing them to move around the heterogeneous wireless networks. Thus, the handover performance is improved for the number of mobility signaling for MNs are reduced [6].

The basic operations of PMIPv6 are depicted in Figure 1.

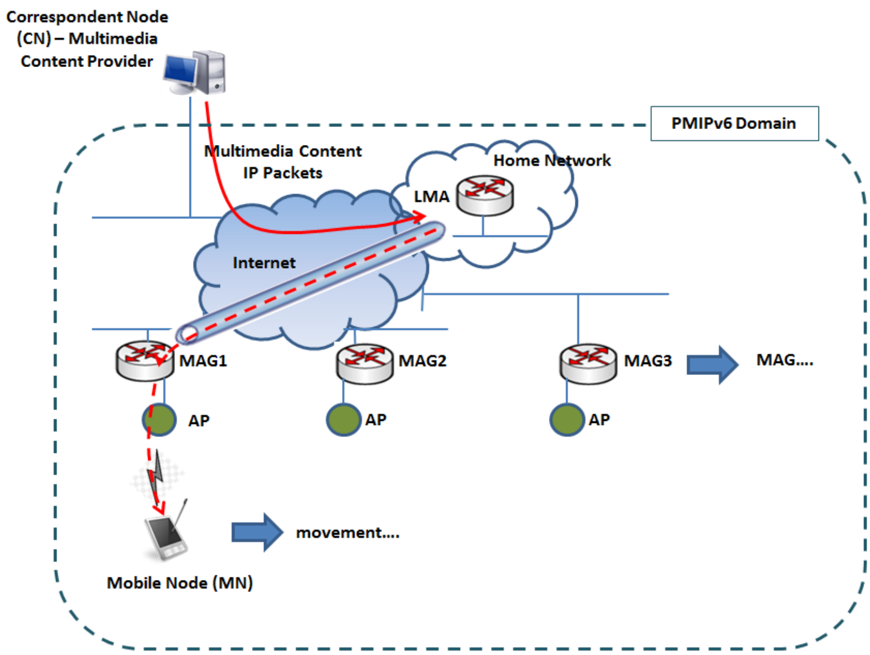


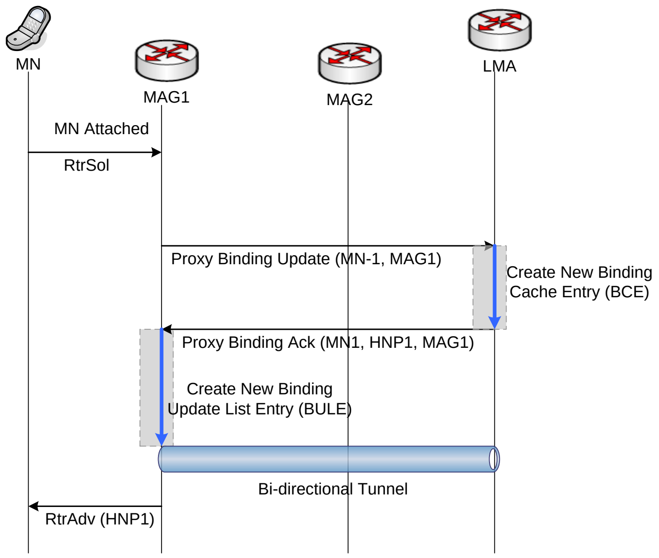
Figure 1. PMIPv6 Basic Operations

As a mobile node (MN) transfers its point of attachment (PoA) from one network to the other, a proxy mobility agent performs the mobility signaling initializations instead of the MN itself. Two network entities to handle the mobility management were defined in PMIPv6.

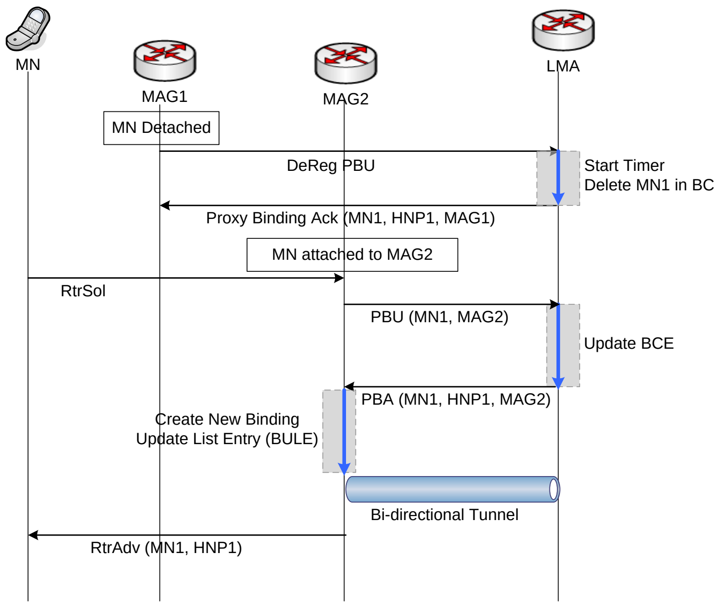
(1) The mobility access gateway (MAG) is a new functional entity that performs the mobility related signaling operations for the MNs that are currently attached into its access links. MAGs are also responsible for the movement detection of such MNs. The MAG usually resides in the access router (AR) wherein it detects the MN's movement, coordinates routing state updates, and provides IP connectivity with the MN.

(2) The local mobility anchor (LMA) is a PMIPv6 entity maintains the collection of IP address of all MNs attached within the localized mobility domain (LMD). It resides within the MN's home network and acts as its local home agent within the LMD.

LMA and MAG creates a bidirectional tunnel and the MN maintains its assigned address as long as it is located within the LMD. The multimedia contents that are intended to the MN are intercepted by the LMA and tunneled to the corresponding MAG wherein the MN is currently attached. The MAG then forwards the received multimedia contents IP packets to the MN locally. Thus, the LMA acts as the central controller for the flow distribution of multimedia contents traffic.



(a) Attachment of a Mobile Host to Local Mobility Anchor in PMIPv6 Domain



(b) A Mobile Host Changes its Attachment in PMIPv6 Domain

Figure 2. PMIPv6 Handover Operations

The handover procedure for the movement of an MN within the PMIPv6 domain is outlined in Figure 2. In Figure 2(a), the establishment of the point of attachment for the MN is depicted. As soon as the MN attaches to one of the available links of the MAG, it sends a router solicitation (RtrSol) message and triggers the MAG to send a proxy binding update (PBU) message to the LMA. The LMA in return send a proxy binding acknowledgement (PBA) message to the MAG with an address assigned to the MN. The LMA creates a new binding cache entry (BCE) if the MN enters the LMD for the first time, otherwise, it will only update its previous entry. Similarly, a binding update list entry (BULE) is maintained by the MAG in order to oversee the attachments of all MNs on its links. A bidirectional tunnel is then created by the LMA to the MAG in order that traffic flows can be directed to the MN. Finally, the MAG sends a router advertisement (RtrAdv) message with the home network prefix(es) for the address auto-configuration of the MN.

In Figure 2(b), the MN's movement from the initial MAG to the new MAG is depicted. As the initial MAG detects the MN's movement away from its link, it sends a deregistration PBU (DeReg PBU) message to the LMA (i.e., DeReg PBU lifetime is zero). The LMA identifies the corresponding mobility sessions for the sending MAG, deletes the MN in the binding cache, and sends back a PBA indicating that the request for deregistration is accepted. Whenever the MN attaches to the link of the new MAG, the process for the establishment of the point of attachment shown in Figure 2(a) is followed. However, instead that the LMA creates a new BCE for the MN, it is just updated that the MN's location is with the new MAG and not on the previous MAG. The new MAG also updates its BULE as soon as it receives the PBA from the LMA which indicates that the new attachment is accepted. The bidirectional is again established by the LMA, but at this time, with the new MAG. To complete the MN's movement, a router advertisement (RtrAdv) message that contains the MN's home network prefix(es) is sent by the new MAG to the MN.

The multimedia contents to be delivered by the correspondent nodes (CNs) of the MN will be intercepted by the LMA and tunneled to the corresponding MAG wherein the MN has established its connection. The MAG will then be responsible to de-capsulate the received IP packets and forward it locally to the MN.

In comparison, the traffic flow as well as the handover for PMIPv6 is considered to be relatively of better performance as compared with the standard MIPv6. This is the result of the reduced interruptions during the handover between MAGs and due to the reduced number of signaling wherein the MN is directly involved. The network entities (i.e., MAG and LMA) are held responsible for mobility support of the MN, hence, MNs are free to roam the PMIPv6 domain without worrying about their registrations. In this regard, PMIPv6 has been considered to become the basis for the interworking and cooperation of various radio access networks.

3. Analysis of the Integrated Heterogeneous Wireless Networks

The integrated heterogeneous wireless networks are comprised of multiple radio access technologies with different base stations that are overlapping with each other [7, 8, 9]. The integration of these wireless networks is too complex and faces major challenges such as the establishment of backhaul deployment and technologies, the coordination and management of inter-cell interferences, and handover of mobility support between radio access networks. An improved handover performance between radio access networks is essentially important in achieving the optimized coverage and capacity for the integration of the different wireless network systems. A seamless mobility support for every radio access network must be expected in order to meet the increasing demand of multimedia contents traffic over the Internet.

Figure 3 outlines the overlapping heterogeneous wireless networks (*e.g.*, 3GPP-LTE, Wi-Fi (802.11n), and WiMax (802.16)). With the availability of numerous access points (AP), mobile nodes (MNs) can be provided with mobility support whichever network system it links its point of attachment. However, the seamless and uninterrupted service provision can only by attained with a robust handover scheme between network systems whenever a mobile device is in motion. In the case of MN1 in Figure 3, it only depends its connectivity with the base station of 3GPP-LTE. For MN4, it has the option to connect to either of the serving access points (APs) of Wi-Fi (802.11n). The handover could be in between the two overlapping APs, and can redirect the traffic flow whichever has an optimized path.

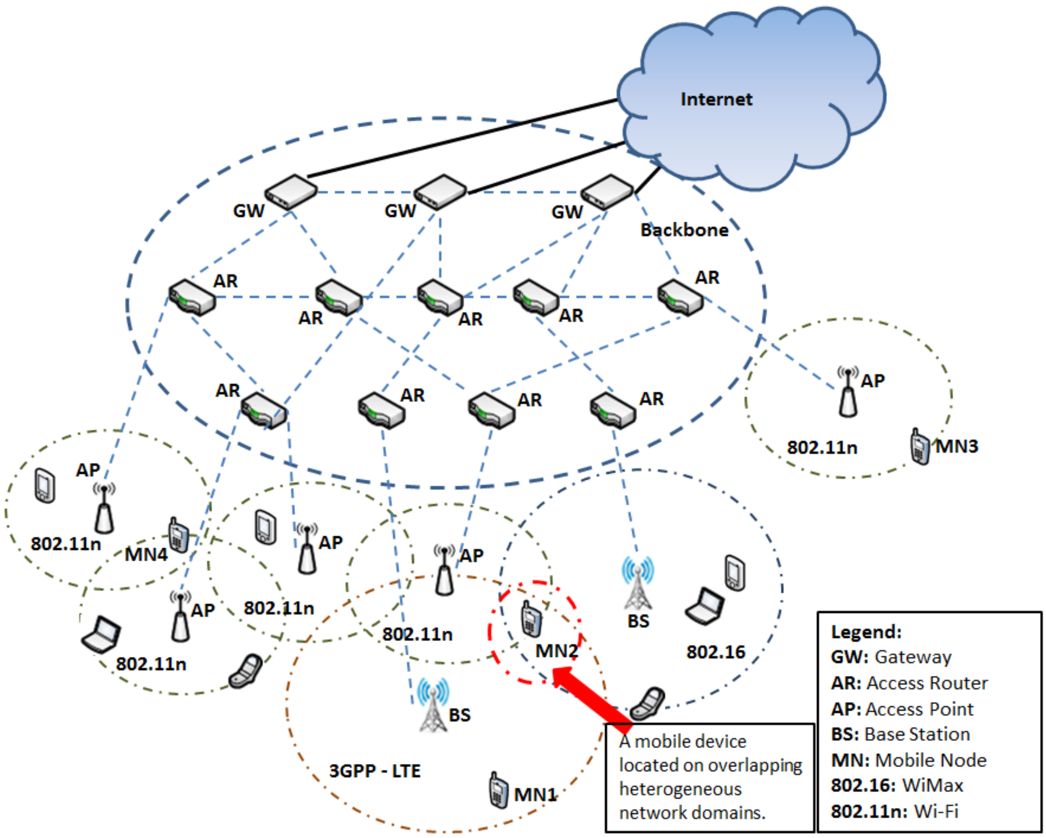


Figure 3. Overlapping Integrated Heterogeneous Wireless Networks

The biggest concern is with MN3 wherein it is located on the overlapping domains of 3GPP-LTE, 802.11n, and WiMax (802.16) as indicated in Figure 3. That is, MN3 requires a mobility support that could efficiently manage the handover of connectivity and traffic flow distribution of multimedia contents across these overlapping integrated access networks. The signals coming from the overlapping APs and base stations (BSs) could intermittently affect the performance of MN3. Each network system uses different resources in sending reference signals, such that interference from bases stations can alter the signal coming from other APs.

The other major concern is on addressing the handover of connectivity between the network systems whenever the MN3 transfers its point of attachment from one network system to the other. The handover is required to be robust in order to warrant the seamless and uninterrupted multimedia service provision. In this regard, cooperation between these wireless network systems can effectively address the performance limitations caused by the mobility of the multimedia users as well as with the scarcity of network resources. This is essentially important in improving the wireless communications performance addressing the power consumption and packet loss rate [8, 9]. The benefits of the cooperation between the heterogeneous wireless networks are outlined in Table 1.

Table 1. Benefits of the Integration of Heterogeneous Wireless Networks

Benefits of Wireless Networks Integration	Description
Channel Reliability is improved.	Multimedia contents IP packets can be redirected from one network system to the other whenever the channel between the original source and destination becomes unreliable.
Interference between radio access networks is reduced.	The use of relays reduces the power transmission, thus, improves the channel condition.
System throughput is improved.	The aggregation of resources among integrated wireless networks increases the system throughput.
Seamless and uninterrupted provision of multimedia services.	Mobile nodes (MNs) have the luxury to move between optimized paths among the integrated wireless network systems.
Reduction of operational cost.	Cooperating techniques reduces energy consumption.

4. Multipath Provision of Multimedia Contents

A seamless multimedia service provision is difficult to achieve with a single wireless network system especially if the user is always on the move. The mobile user may move outside the domain of his current network system, thus, the real-time connectivity can be interrupted. In addition, the Internet of today is comprised of the cooperation among heterogeneous wireless networks. Multimedia service provision can be distributed in any network system that the mobile device of the user can connect to. All that is needed is a robust handover scheme between the available wireless network systems. The heterogeneous wireless network systems overlap with each other's domain in such a way that the mobile node is provided with the multipath option on receiving multimedia services.

Figure 4 outlines the scenario wherein a mobile node enters an overlapped domain of 802.11n and 3GPP-LTE wireless network systems. Initially, the MN receives the multimedia service directly through its home agent whenever it is located on its home network (i.e., in this case, the 3GPP-LTE). The flow of multimedia traffic goes through the access router (i.e., AR_1) to where the access point (AP) the MN is currently attached. However, as the MN moves into an overlapped domain of the different access networks, it requires a mobility support that could efficiently manage the handover of connectivity among the overlapping integrated access networks in order to continuously enjoy a seamless multimedia service.

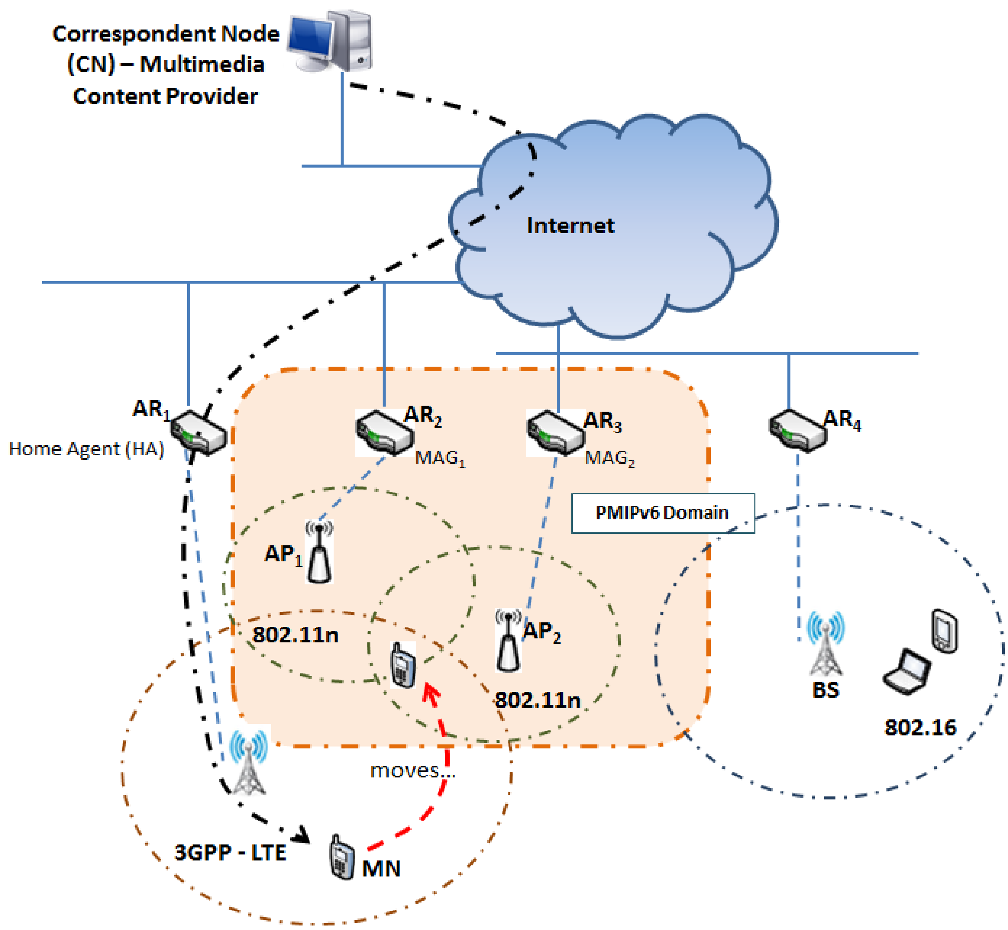


Figure 4. PMIPv6 based Multipath Provision of Multimedia Contents across Integrated Heterogeneous Wireless Networks

The handover scheme utilizes the best features of PMIPv6 in order to optimize the mobility support that will be given to the MN. The optimized path among the overlapped access networks will be determined by the MN for sending or receiving multimedia services from its CNs. In this regard, the MN sends router solicitation (RtrSol) messages to the available access routers (ARs) within the PMIPv6 domain. That is in order to determine the round trip delay time (RTT), which will be crucial in the determination of the most optimized path for the flow distribution. This is done by the MN regularly in a timely manner. Aside from the RTT, other network conditions, such as bandwidth, number of connected MNs, volume of data traffic processed, distance of MN to its strongest signal area, and the like will be determined to support and ensure the best available network path. The MN then can switch between these wireless network systems whichever the path is optimized.

The main advantage of the proposed multipath provision of multimedia services is that the mobile user devices can switch between the overlapping access networks without changing its IP address. This feature is driven by the network based mobility support of PMIPv6 wherein the MN is independent of any network registration processing. The home network prefix (HNP) of the MN remains the same even if it moves from one access point to another within the PMIPv6 domain.

5. Conclusion

This paper has presented an analysis of a multipath provision of multimedia contents across the integrated heterogeneous wireless networks. The mobile user device (MN) is allowed to switch between cooperating wireless access networks provided with a network-based mobility support of PMIPv6. The factors such as bandwidth, handoff latency, number of connected users, and volume of data traffic being processed are considered as the basis for the movement of the MN from one access network to the other. The cooperating wireless network systems provides for a seamless handover such that the provision of multimedia services can be efficiently delivered.

Acknowledgments

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