A Framework for Multiple Wireless Services in Heterogeneous Wireless Networks

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ABSTRACT

As the variety of wireless network services, such as WLAN, WiBro, cdma2000, and HSDPA, and the range of choices of wireless services for users have expanded, MCoA (Multiple Care of Addresses) concepts that enable users to use wireless interfaces simultaneously have been presented in IETF MONAMI6 WG. In this scheme, users can access several networks simultaneously by using multiple wireless interfaces. Various wireless connection technologies continue to advance as they are connected and integrated to All-IP-based core networks and, at the same time, heterogeneous networks are being overlaid according to the coverage of the wireless connection technologies. Under such circumstances, needs for an integrated architecture have arisen and thus, a multiple wireless services framework is required that effectively manages heterogeneous networks which coexist with next generation networks for 4G. In this paper, a multiple wireless services framework is suggested considering the current wireless service environment. The modified Multiple Care of Addresses helps to select the most effective network by considering characteristics of various interfaces as well as users' preferences. In addition, the framework introduces techniques to minimize the packet loss caused by handover operations.

Categories and Subject Descriptors

C.2.3 [**COMPUTER-COMMUNICATION NETWORKS**]: Network Operations – *Network management*

General Terms

Management

Keywords

Mobile IP, MCoA (Multiple Care of Addresses), Heterogeneous network

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1. INTRODUCTION

Currently, the use of various high speed internets and wireless mobile communications is increasing along with the needs of users who want to use data services anytime and anywhere. To support these demands, technologies such as all-IP [1-3] shown in Figure 1 may offer a solution. A mobile communication system based on all-IP can offer high bit-rate data services for high quality multimedia services and the convergence of wired and wireless systems for broadcasting and legacy services. Through the service convergence of networks, many new services could be offered. Therefore, a next generation mobile communication service with convergence heterogeneous networks is possible [4-8].

New wireless technologies related to 3G, WiBro, and WLAN are increasing, and therefore, numerous wireless networks are deployed, as shown in Figure 1. Mobile nodes or mobile networks can connect to various overlaid networks, as shown in Figure 1. Although heterogeneous networks are overlaid and a node has multiple interfaces, if each network operation is working separately, the node can choose only one proper network. In an overlaid heterogeneous wireless network, nodes may choose the same network so network congestion may occur even though efficient networks are overlaid. In order to solve this problem, we propose a framework for multiple wireless services in heterogeneous wireless networks. The framework provides three schemes: an extended MCoA scheme that considers the characteristics of each network, a network selection scheme that considers user preferences, and an efficient vertical handover scheme that uses extended MCoA. The rest of this paper is organized as follows. Section 2 describes the related work and in Section 3, the proposed schemes are discussed. Section 4 presents the performance evaluation for the proposed schemes and conclusions are made in Section 5.

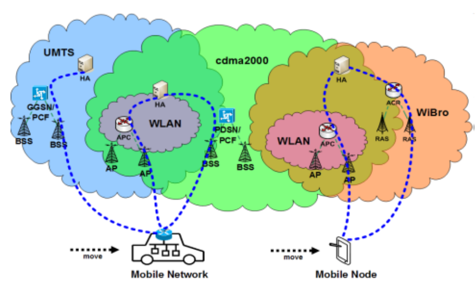


Figure 1. Overlaid heterogeneous wireless network

2. RELATED WORK

2.1 MCoA in IETF MONAMI6 WG

MCoA (Multiple Care of Addresses) techniques based on Mobile IPv6 (MIPv6) are employed for using various Care of Addresses simultaneously. The MCoA scheme was proposed in the IETF MONAMI6 working group draft [9-11]. In the scenario shown in Figure 2 for using multiple interfaces simultaneously in a single node, a binding update sub-option field is added in a binding update message when a binding update procedure is activated between the HA (Home Agent) and a CN (Correspondent Node). To identify each CoA, a BID (Binding Unique Identification) value is added in the binding update sub-option field. Each BID value is assigned differently. Using the BID value, each CoA can be identified and a node that has multiple interfaces can connect to various networks simultaneously or selectively.

The BID value is made and managed by a mobile node and the BID is added to the sub-option attached to the binding-update message, as shown in Figure 3. During the binding-update operation, the BID value is registered in the HA and CN. However, the current MCoA scheme does not consider the characteristics of each network (data-rate, network cost, etc.) in the heterogeneous network environment. In other words, the current MCoA scheme does not provide information about each network and only considers the identity of each network. In the network selection process, information about the characteristics of the networks is needed for appropriate network selection. The current MCoA scheme does not consider wired and wireless network environments and service characteristics such as FTP, streaming video, VoIP, etc.

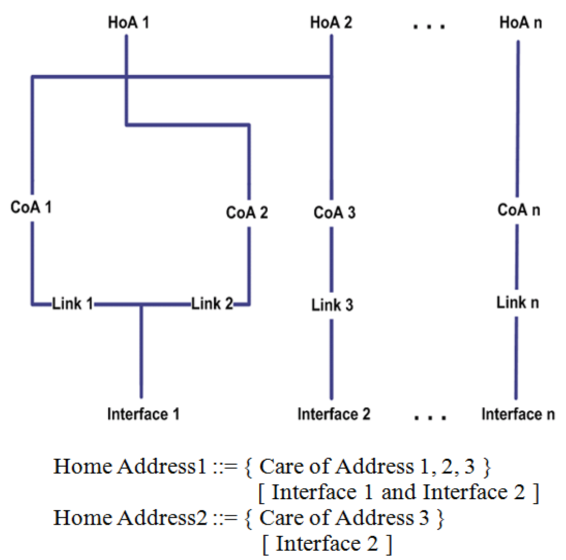


Figure 2. Multi-homing scenario

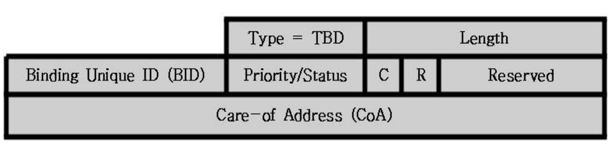


Figure 3. MCoA binding update sub-option

2.2 Multiple interfaces service

In this section, we review current related works which use multiple interfaces. First, we introduce the interface selection schemes. Sallet *et al*. [12] proposed a network selection scheme in GERAN and UTRAN network environments. The scheme considers each network's capacity for network selection. To measure the current capacity, the time slot of GERAN and cell load factor of UTRAN can be measured, but it is the weakness that this scheme considers network capacity only.

Romero *et al*. [13] considered an overlaid network environment with TDMA and CDMA networks for the network selection. Their scheme considers network interferences of the cell edge. If the node is located at the cell edge of the CDMA network, it could be more experienced about the interference, as opposed to being located in the TDMA network. Therefore, the scheme can select the appropriate network according to the location of the node. However, this scheme considers only the node's location. Other factors such as bandwidth and cost should be considered in heterogeneous networks.

Secondly, Cho *et al*. [14] proposed a load balancing scheme by using mobile routers. This scheme considers the delay time between a source and a destination node. When a mobile router is overloaded for transferring data, another mobile router could be used for load balancing by using an interface between two HAs for measuring the delay time between a current HA and a new HA, and between a new HA and a new mobile router. After measuring the delay, the use of another mobile router is advantageous because two mobile routers could be used simultaneously for load balancing. However, since this scheme uses a mobile network rather than a node in the single HA environment, the scheme utilizing two mobile routers can not be adapted.

Huang *et al.* [15] proposed a flow distribution scheme that considers the required bandwidth and available bandwidth for flow binding and flow distribution. To use multiple interfaces, a specified ID is added in the binding updated option field. In the scheme, the packet scheduler decides each interface's packet load for load balancing. The scheme uses the weighted fair queuing and jump-ahead algorithm in which many packets are assigned to the fastest interface and some of the packets are assigned to the slowest interface. Therefore, the node can receive the packets in order. That means the scheme can reduce packet re-ordering operations. But this scheme only considers each interface's bandwidth, and to apply this scheme to heterogeneous wireless network environments, more parameters such as the data flow type need to be considered.

Finally, we review the handover by using multiple interfaces. Taha *et al.* [16] proposed a vertical handover scheme for provisioning the network capacity. This scheme assumes that the network is overlaid with another network in the same cell coverage. When a network has no more capacity, nodes in the network can then be handed over to the overlaid network. However, this scheme needs more information regarding the network and nodes to select appropriate nodes that will be handed over to another network.

Abdul *et al.* [17] proposed a network selection scheme in WWAN and WLAN network environment. With a node moving from a WWAN to a WLAN location, the network selection scheme decides whether to perform the handover or not, depending on the service type and dwelling time. However, when adapting to heterogeneous wireless network environments, this scheme should consider other factors such as cost or other network information, not only the service type or dwelling time.

In this section, we have reviewed the current research of using multiple interfaces. When selecting a wireless network with multiple interfaces, the schemes in the current research are specified based on each network and service and consider only one or two factors. In addition, the schemes do not use IETF MONAMI6 WG MCoA but use their own idea for using multiple interfaces. Therefore, the schemes cannot be adapted to an overlaid heterogeneous wireless network environment that consists of WLAN, WiBro, cdma2000, UMTS, etc. Therefore, a framework which is based on MCoA is needed and should consider the heterogeneous wireless network environment characteristics. In this paper, we present such a framework as follows: First, we propose new message format based on IEEE MONAMI6WG MCoA to consider various wireless heterogeneous networks. Next, we propose a multiple interfaces selection scheme that considers user's preferences for appropriate network selection. Finally, we propose a multiple interfaces handover that can reduce the packet-loss during handover operation by using multiple interfaces registration.

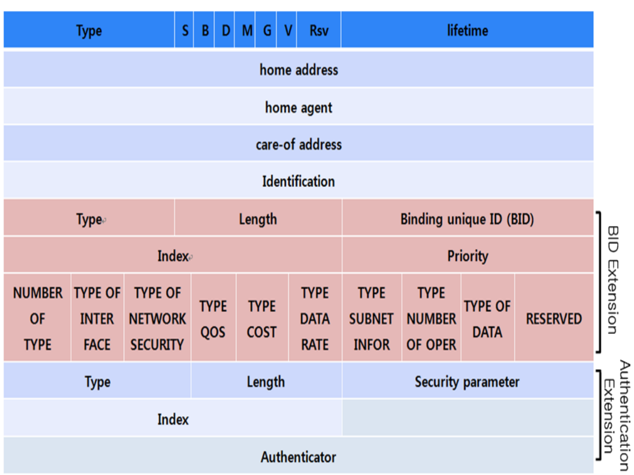


Figure 4. BID extension MIPv4 Registration Request message

3. MCoA BASED FRAMEWORK FOR MULTIPLE WIRELESS SERVICES

In this section, we propose a common service framework based on the characteristics of the heterogeneous interfaces for MCoA. The MCoA scheme employs several interfaces simultaneously. However, the scheme ignores not only the overlaid situation among different networks but also the characteristics of the radio network. Because commercial networks employ the MIPv4 protocol, which supplies efficient multi-interface services in the overlaid heterogeneous radio environment, we propose a MIPv4 framework based on the MIPv6 MCoA scheme. The proposed framework consists of three parts: registration and the initial operation procedure employing the MCoA scheme, message format which considers the environment of the heterogeneous networks, and an efficient handover scheme using multiple interfaces.

Table 1. BID extension field definitions

BID sub-option field	**Description**
NUMBER OF TYPES	The number of interfaces
TYPE OF INTERFACE	The type of interface
NETWORK SECURITY	0. IPsec not used
	1. IPsec used
QOS	Interface QoS requirement
COST	Interface cost
DATA RATE	Interface data rate
SUBNET INFO.	The number of sub networks of the interface
NUMBER OF OPER. ID	Service operator ID
SERVICE	0. default (not used)
	1. streaming
	2. transferring
	3. VoIP

3.1 Multiple interfaces service scenario

The IETF MONAMI6 WG proposed the scheme of MIPv6 MCoA. In that scheme, each terminal can keep several CoAs and employ several interfaces independently and simultaneously. While values of BID exist for distinguishing each CoA, the scheme does not consider the values with respect to network parameters such as interface type, service type, QoS, cost, and etc. Furthermore, the IETF MCoA scheme does not consider the characteristics of each interface. In this paper, we define the message format for the registration request BID extension based on the MIPv4 protocol illustrated in Figure 4.

Figure 5 shows the registration procedure of Registration Request message including the BID extension. Through the procedure, the MCoA Registration Request message delivers the characteristics of the network environment can be transmitted and can send the HA registration messages making use of several interfaces. Moreover, in the binding cache, several interfaces can be distinguished which employ different values of the BID from each allocated CoA.

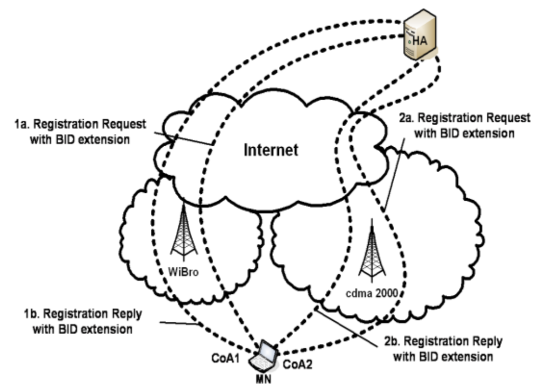


Figure 5. MCoA scenario in heterogeneous networks

Various terminals equipped with multiple interfaces may make use of the MCoA that can simultaneously register the various interfaces to the single HA and unsuspectingly receive various services with high bandwidth. Figure 6 shows the registration procedure through the interfaces of the WLAN and WiBro to a single HA.

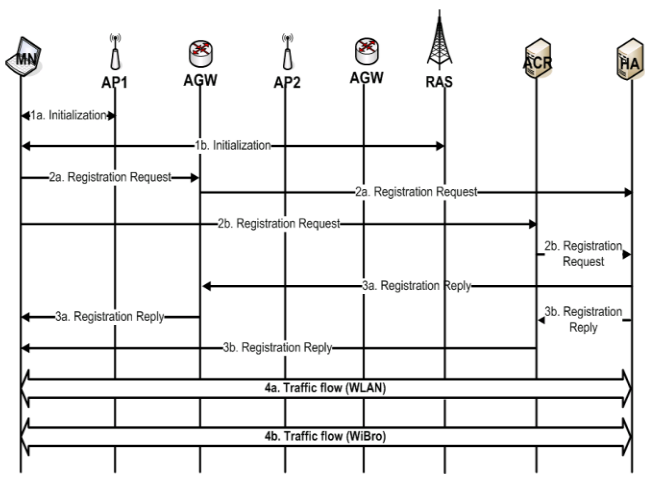


Figure 6. Multiple interface registration call-flow

3.2 Multiple interfaces selection

The interfaces may be used alternatively with consideration of the characteristics through different interfaces according to the proposed BID extension which employs the multiple interfaces. However, from the user's point of view in the heterogeneous overlaid networks, even if the network interface is selected according to the characteristics of service, because the user may receive the services from a discontented network, a scheme which considers user's preferences when selecting the appropriate network is needed. Therefore, we propose a network selection scheme that not only satisfies the required bandwidth but also the defined user preference.

Figure 7 shows the multiple interfaces selection algorithm according to the user preference. In the real environment, when the user moves around and changes his/her position, the available bandwidth will change and the request service will be dropped. Therefore, when selecting the network, the mutative request bandwidth for the user preference can be considered. The user preference can be defined as the value of the corresponding satisfaction among the several available interfaces. The cost and bandwidth between the different interfaces is also considered. In this algorithm, the symbols R, B_k, P_i, A, M, and k represent the request bandwidth, the available bandwidth, the interface preference, the aggregation of the unselected interfaces among the available interfaces, the number of the available interfaces, and the available bandwidth of the selected interfaces, respectively. If the request bandwidth is defined after a new incoming user call for service from a candidate network, the user may choose the interface which is in the high level preference among the available interfaces. On the other hand, if there is not enough bandwidth for the new incoming user, it will select the interface orderly which is barely in the down level preference.

Algorithm MultipleInterfacesSelection

begin

input: R, P_i, B_k, A, M

output: P_k, r_k, A

$A=\{i|1\leq i\leq M\}$

$r_i = 0$

while $A\neq 0$ *and* $R > 0$ *do*

$P_k \leftarrow \max\{P_i|i\in A\}$

$r_k \leftarrow \min(B_k, R)$

$R \leftarrow R - r_k$

$A \leftarrow A - \{k\}$

end while

end

Figure 7. Multiple interfaces selection algorithm

The proper values of user preferences are adjusted by considering several network parameters such as QoS, bandwidth, cost, and service type, so that the user can select the appropriate network according to the network status. In the overlaid heterogeneous network, each user can be supplied the proper services based upon the user preference. It is supposed that as the available interfaces are added, which are supported by new discovered networks, the interfaces adopt new preference values according to the network status that can support the user demand efficiently.

3.3 Multiple interfaces handover

In this section, we describe the handover scheme for the user equipped with multiple interfaces. First, the pre-handover operation for multiple interfaces is presented when a user terminal can detect handover events a priori. Second, we discuss the post-handover operation when a user terminal does not detect handover events because of the fast movement between networks.

3.3.1 Pre-handover operation

When a user terminal which simultaneously makes use of multiple interfaces moves to another candidate network and changes the corresponding interface before breaking from the already served network, packets from the CN/HA are transmitted to the new interface in the Make-Before-Break operation to achieve no loss in delivery. Figure 8 illustrates that the user terminal equipped with WLAN and WiBro interfaces connect from WLAN to the WiBro network after finishing the operation shown in Figure 6.

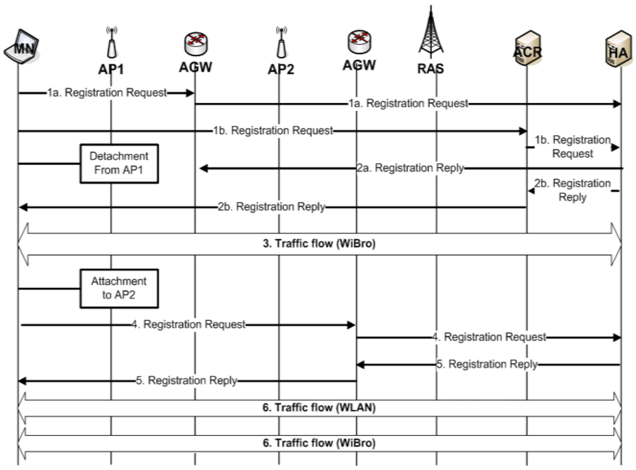


Figure 8. Multiple interface pre-handover scheme

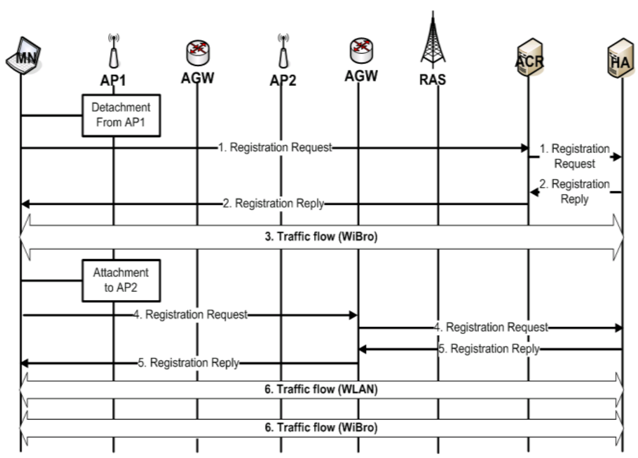


Figure 9. Multiple interface post-handover scheme

As shown in Figure 8, the user terminal moves out of WLAN along with a signal decrease from the WLAN network. The terminal will send a Registration Request message to the HA through both WLAN and WiBro networks to notify the HA that it will not get service from WLAN. When the HA receives the Registration Request message from the terminal, it will update the WLAN lifetime stored in the binding cache to a value of 0 so as to prevent transmitting packets to WLAN. The user will receive the Registration Reply message from the WiBro network although the Registration Request message is sent to the two networks simultaneously, as the connection is broken from AP1 after the user moves out of the WLAN area. The HA will send packets to the WiBro interface and the user will receive packets through the WiBro network after the operation process. This operation can avoid the packet loss.

3.3.2 Post-handover operation

The pre-handover operation can minimize the packet loss using more interfaces at the same time. On the other hand, the terminal which moves at a high speed should adopt the Break-Before-Make process to make the subsequent handover operation. Figure 9 shows the post-handover process in which the terminal equipped with WLAN and WiBro interfaces moves quickly out of WLAN after finishing the operation illustrated in Figure 6.

As shown in Figure 9, on the condition that the user terminal moves quickly as to break the connection AP1 after moving out of the WLAN network area, the terminal will send the Registration Request message to the HA to inform it to send the packets which are presently transmitted to WLAN to the available WiBro interface. The HA updates the WLAN lifetime to a value of 0 after receiving the Registration Request message from the user terminal and gives notice to the terminal with the Registration Reply message that the WLAN interface is not valid. In the user terminal, it will be realized that the HA stops transmitting the packet through the WLAN network and changes to use the WiBro network after receiving the Registration Reply message. The proposed post-handover operation intends to send packets to the available network when a connection is broken without prediction. This makes use of the other connected interface to recognize the HA and the proposed scheme can minimize the packet loss during the handover.

The proposed two operations, pre-handover and post-handover, allow the user equipped with multiple interfaces to perform the process of vertical handover among overlaid heterogeneous networks that may minimize packet loss. Furthermore, the fast handover scheme [19] can be adopted together with the proposed scheme to perform the handover more efficiently.

In this section, we proposed the framework for considering overlaid heterogeneous network environments by adopting several schemes such as multiple interfaces service scenario, the multiple interfaces network selection scheme, and the multiple interfaces handover scheme. In particular, the framework can be used to provide services efficiently in the heterogeneous wireless environment considering network parameters such as wireless network characteristics, service type, and user preferences.

4. PERFORMANCE ANALYSIS

4.1 Multiple interfaces selection

In this subsection, we compare the performance of the multiple interfaces selection scheme proposed in Subsection 3.2 with that of a scheme which considers only the interface bandwidth. We assume that each node has multiple interfaces and requests network bandwidth dependent on its services. To satisfy the required bandwidth, the proposed scheme chooses networks that satisfy both the required bandwidth and the user’s preferences while the compared scheme chooses networks that have the largest available bandwidth. The satisfaction scores for user preference change based on the user's willingness.

The simulation is performed in an environment containing 3 or 4 network interfaces, as seen in Figure 10. The user preference expresses user satisfaction in the simulation. In this assumption, a higher user preference results in a higher value of satisfaction. As shown in Figure 10, the proposed scheme satisfies the request bandwidth of the request service and considers the higher user satisfaction.

As shown in Figure 10, the proposed scheme results in a higher number of available interfaces and higher user satisfaction. In addition to the user preference, the scheme can be extended with ease to adopt more parameters including QoS, bandwidth, cost, and service type so that the scheme may efficiently satisfy the user request according to several services.

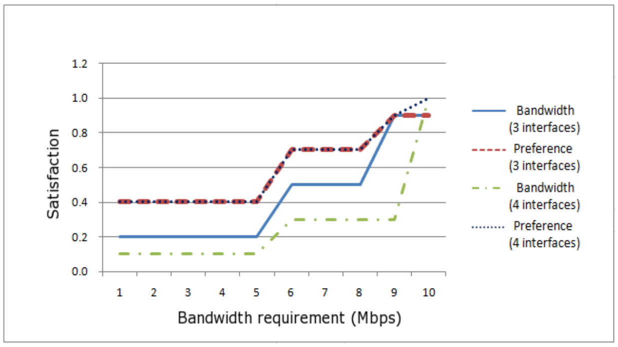
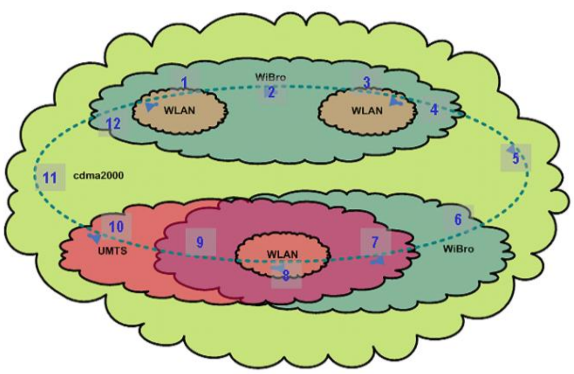


Figure 10. Satisfaction score of required bandwidth



Distance	1. 200m	2. 1000m	3. 100m	4. 400m	5. 7500m	6. 500m
	7. 500m	8. 200m	9. 800m	10. 500	11. 4000m	12. 300m

Figure 11. Simulation scenario

4.2 Multiple interfaces handover

In this section, we discuss the results of the simulation analysis for the multiple interfaces handover. The simulation environment considered is when the terminal equipped with multiple interfaces keeps moving through heterogeneous networks and assumes the handover takes place while the user enters the available network. A comparison has been made with the handover scheme equipped with multiple interfaces using one interface at a time because there is no scheme based on MCoA for using multiple interfaces at one time. Figure 11 shows the handover simulation scenario describing the tracking of user movement across overlaid networks including WLAN, WiBro, CDMA2000, and UMTS.

As shown in Figure 11, the mobile terminals move across and receive packets from the WLAN, WiBro, CDMA2000, and UMTS networks. Meanwhile, the handover may occur when the terminal arrives at an intersection between several networks. As shown in the scenario, the mobile terminal may receive a packet when moving along the circle from number 1 to 12. Terminal speeds of 5 km/h, 10 km/h, 30 km/h, and 60 km/h are used and due to high speeds we assume the post-handover operation which may lead to packet loss. The service model is assumed: the streaming service and the WWW service.

The results about packet loss are shown in Figure 12. Using the multiple interfaces handover resulted in less packet loss than using the single interface handover. Because the multiple interfaces handover scheme connects both interfaces during the handover time, the node can notify the handover procedure to the network more rapidly. In this simulation, we assumed only the post-handover procedure case which means that the mobile node moves fast so that the Registration Request message is sent after disconnection. Even the post-handover operation reduces the packet loss compared to the single interface handover.

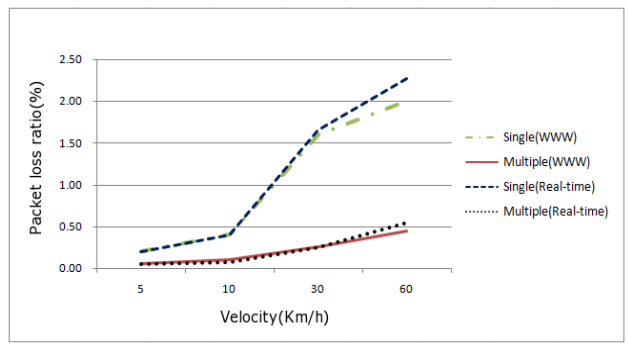


Figure 12. Packet loss ratio (%)

5. CONCLUSION

In this paper, we have proposed a framework that enables multiple wireless interfaces services over heterogeneous wireless networks. The contribution of this paper consists of three parts: First, we proposed new message format based on IEEE MONAMI6WG MCoA to consider various wireless heterogeneous networks. Second, we proposed the multiple interfaces selection scheme that considers user's preferences for appropriate network selection. Third, we proposed the multiple interfaces handover that can reduce the packet-loss during handover operation by using multiple interfaces registration. We believe the framework proposed in this paper may be employed to provide multiple interfaces services in future heterogeneous wireless networks.

6. ACKNOWLEDGMENTS

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