A Preliminary Study on Common Radio Resource Management in Heterogeneous Wireless Networks

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ABSTRACT
Users equipped with multiple wireless interfaces can get seamless services across heterogeneous wireless networks. If radio resources in heterogeneous wireless networks are managed in integrated fashion, we can handle scarce resources efficiently. In this paper, we present a preliminary study on common radio resource management in heterogeneous wireless networks. First, we propose an integrated network selection algorithm which chooses a target network for newly coming users. Second, an integrated vertical handover algorithm is proposed. When the capacity of a specific network becomes full, some users being serviced in the network are forced to move to another candidate network through our integrated vertical handover. The decision of two algorithms can be made based on the given objective functions which consider various factors such as signal strength, capacity, cost, and current load. The preliminary simulation result shows that the proposed algorithms reduce the blocking probability significantly.

Keywords
CRRM, RAT selection, Vertical handover

1. INTRODUCTION
The provision of seamless services, in the heterogeneous access networks, is considered to be one of the primary issues in the communication networks of the coming generation. A variety of wireless access network technologies [1] (e.g. 802.11a/b/g WiFi, 802.11p WAVE, 802.16 WiMAX, GPRS, and UMTS networks) have been converging their network infrastructure into the Internet Protocol (IPv4/6), and results in the necessity of Common Radio Resource Management (CRRM).

Fig. 1 shows services between networks in the heterogeneous wireless network environment. Each network has a different cell coverage and a service rate, and they exist in overlaid manner [2]. In such wireless network environment, users having multiple interfaces can be serviced from multiple networks in the same location, but yet each network deals with their user's authentication and resource management independently. This situation is, however, very inefficient in the aspect of network management. Therefore, a sound provision of common resource management becomes a critical issue under the environment of heterogeneous wireless networks.

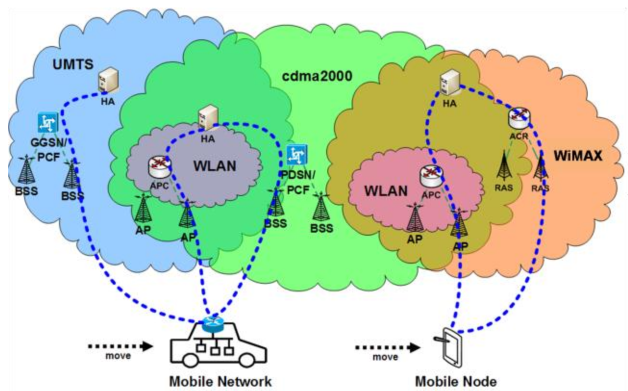

Figure 1. Services in heterogeneous wireless network

In addition, wireless technologies such as 3G, WLAN, and WiMAX will be connected to All-IP based core network [3], and this will enhance high-bite rate multimedia services, and will ensure its QoS, ultimately. More and more user equipments have been developed with wireless interfaces, and therefore mobile users can access wireless services through multiple interfaces (e.g. WLAN, WiMAX). However, as the number of wireless networks increases, the network operator, in the heterogeneous wireless network environment, should be able to provide additional services such as vertical handover and common admission control, etc.

In the overlaid heterogeneous networks, users who have multiple interfaces will use any of available interfaces continually, while moving. That is why the resources of each network should be managed commonly, and the Common Radio Resource Management [4] (CRRM) should be able to manage the resources efficiently.

The CRRM is a concept of using resources of heterogeneous networks as a single resource pool. It brings about significant benefits to the heterogeneous network by improving load balancing, interference distribution, and service blocking probability.

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The proposed scheme in this paper, in relation to the CRRM, consists of two algorithms. First, we propose an integrated network selection algorithm that enables to select an appropriate target network for newly coming users. Second, an integrated vertical handover algorithm is proposed to reserve the capacity of a network by handing over its existing users to the other overlaid network.

The rest of this paper is organized as follows: Section 2 describes the related work and in Section 3, the proposed CRRM scheme is discussed. Section 4 presents the performance evaluation for the proposed scheme and conclusions are made in section 5.

2. RELATED WORK

Until now, operators of 2G & 3G have only considered handover or QOS for the resource management of its own network. However, as many different network technologies have appeared, it has created an environment where one operator manages several networks and how to manage various resources simultaneously has been paid attention to. Fig. 2 shows the relationship of CRRM and local RRM [5]. Each network has functions of local resource management and under the strategy of CRRM, each network is managed globally. In the aspect of implementation, CRRM initially takes charge of resource management at the minimum level, and the actual functions of resource management are carried out by each network. However, in the next phase, the resource management functions of each network can be moved to CRRM, and thus the least functions may remain in the local RRM after all.

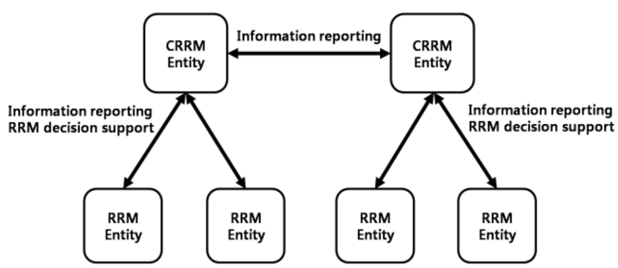

Figure 2. CRRM functional model

Concerning CRRM, the RAT selection, including studies of network selection and vertical handover has been dealt with in the literature. The RAT selection is a key research issue in CRRM [6]. The following subsection will introduce various RAT selection schemes.

2.1 Load balancing based RAT selection

In [7, 8] the authors introduce load balancing algorithm by using a load threshold. A predetermined threshold is set for each of the cell. If the load of a cell exceeds the threshold, a load reason handover is triggered. The load threshold of a cell is adjusted periodically according to the loads of its inter-RAT cells [8]. In [9, 10] there exist the schemes of procuring resources of current network by vertical handover for newly entering users, when the capacity of the network is full, by establishing supporting network, which is overlaid with existing network and has the same cell-coverage as existing network's. In this way existing users can be handed over to another network, and thus the resources of the existing network can be reserved.

As supporting network and current network are overlaid with the same cell-coverage, users can be serviced through the supporting network just by vertical handover without actually moving them to the network. At present, various wireless services such as WLAN and WiMAX coexist in overlaid manner and all-IP based services will be provided. In order for the users to be serviced effectively in heterogeneous wireless environment, common radio resource management should be devised according to the characteristics of each network.

2.2 Network characteristics based RAT selection

In [11, 12] network characteristics are considered. If the cell radius is larger than 1km, the UTRAN voice users at the cell edge will experience more transmission errors due to the power limitations and the interference limited nature of WCDMA technology, so users had better use the service through GERAN. Three CRRM solutions are introduced for WWAN/WLAN networks in [13]. First, WWAN is selected as the default RAT to reduce the number of vertical handovers. Second, if the session is overlaid with a hotspot area then the user moves to WLAN area due to its higher bandwidth. Third, an adaptive algorithm that considers service type, RAT load, mobility, location prediction, and service cost is presented. When a user is predicted to stay in a hotspot area, the algorithm determines to move to hotspot area. If the current state is not satisfied by the parameters in hotspot area, then the service will be moved to the WLAN.

Recent researches on the resource management in relation to network selection and vertical handover have been undertaken in the viewpoint of users. However, the resource management studies, in the viewpoint of operators, which consider heterogonous wireless network environment, are still in early stage. Therefore, in this paper, a common radio resource management scheme will be proposed which considers characteristics and status of each network in the heterogonous wireless network environment.

3. COMMON RADIO RESOURCE MANAGEMENT

As described earlier, our CRRM contains two algorithms. The one is an integrated network selection which concerns a scheme to select the optimum network for newly entering users. The other is an integrated vertical handover that allows new users by handing over existing users to the supporting network. For example of the supporting network in Korea, cdma2000 network covers the entire area of the country, so cdma2000 network can be overlaid with any wireless network in the country. Hence, the supporting network can provide sufficient capacity in the current network, when the network can allow new users no longer. The two different algorithms are explained below in details.

3.1 Integrated Network Selection algorithm

In case a user joins new network with multiple interfaces, the user usually chooses its target network according to user's policy or user's preference. Regarding the network selection, although various issues can be considered in the environment of heterogonous networks, in this paper, the integrated network selection algorithm (INS), which enables to select the optimum network among all of available networks through the consideration of current capacity and required bandwidth, will be mainly dealt with.

In the environment of overlaid wireless heterogeneous networks, when new user enters a network, INS selects the most appropriate network for the user among all of available networks. At this time, the objective function of Eq. (1) chooses the network based on its signal strength and cost. Through this objective function, values of each network are calculated. The network with the highest value is the candidate network which satisfies both signal strength and cost in Eq. (1). The algorithm is given in Fig. 3. We will extend our work by changing the objective function and parameters in the function.

Table 1. Notation used in Integrated Network Selection

Symbol	Definition
b_{req}	Bandwidth requested
δ_k	Signal strength at network *k*
$B_{rem,k}$	Remaining bandwidth of network k
K	Number of networks
A	Allocation vector

$$f_1(k) = \left(\frac{B_{rem,k} \times \delta_k}{B_{\max}} \times \alpha\right) + \left(1 - \frac{C_k}{C_{\max}}\right)(1-\alpha) \tag{1}$$

Algorithm IntegratedNetworkSelection

$Input: b_{req}, \delta_k, B_{rem,j} (1 \le k \le K)$

$Ouput: \mathrm{A} = (a_1, a_2, \cdots, a_K)$

$\Theta = \{k \mid 1 \le k \le K\}, a_k = 0 (1 \le k \le K)$

$while\ \Theta \ne 0\ and\ b_{req} > 0\ \ do$

$\quad j = k_{\max} \leftarrow \max\{ f_1(k) \mid \forall k \in \Theta\}$

$\quad if\ b_{req} \le B_{rem,j}\ then\ a_j = b_{req}$

$\quad else\ a_j = B_{rem,j}\ endif$

$\quad B_{rem,j} = B_{rem,j} - a_j$

$\quad b_{req} = b_{req} - a_j$

$\quad \Theta = \Theta - \{j\}$

$end\ while$

Figure 3. Integrated network selection algorithm

3.2 Integrated Vertical Handover Algorithm

The integrated vertical handover algorithm (IVH) is a solution for the case where no more users can be allowed in a specific network on its request, because the capacity of the network reaches its limit.

The integrated vertical handover enables to reserve the capacity of a specific network, by dispersing its users from handing over to another network.

Table 2. Notation used in Integrated Vertical Handover

Symbol	Definition
N	Number of users
$\delta_{i,k}$	Signal strength of user i at network k
A	Allocation matrix
H	Handover execution matrix

$$f_2(\mathrm{H}) = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{K}\sum_{k=1}^{K}\left\{\left(\frac{b_{rem,k} \times \delta_{i,k}}{B_{\max}} \times \beta\right) + c\left(1 - \frac{C_k \times c}{C_{\max}}\right)(1-\beta)\right\}$$

$$b_{rem,k} = \begin{cases} B_{rem,k} & if\ h_{i,k} \ne 0 \\ 0 & if\ h_{i,k} = 0 \end{cases}$$

$$c = \begin{cases} 1 & if\ h_{i,k} \ne 0 \\ 0 & if\ h_{i,k} = 0 \end{cases} \tag{2}$$

Algorithm IntegratedVertica Handover

$Input: b_{req}, \mathrm{A} = \|a_{i,k}\| (1 \le i \le N, 1 \le k \le K)$

$Ouput: \mathrm{H}_{\min}$

$b_{req} = b_{req} * \gamma$

$Search\ \ \Omega = \{\mathrm{H} \mid \mathrm{H} = \|h_{i,k}\|, 1 \le i \le N, 1 \le k \le K\}$

$such\ that\ b_{req} \le \sum_{i=1}^{N}\sum_{k=1}^{K} h_{i,k} \times a_{i,k}$

$where\ h_{i,k} = 1\ if\ \ handover$

$\quad\quad h_{i,k} = 0\ \ otherwise$

$\mathrm{H}_{\min} \leftarrow \min\{ f_2(\mathrm{H}) \mid \forall \mathrm{H} \in \Omega\}$

Figure 4. Integrated vertical handover algorithm

In this paper, as we assume that cdma2000 network has the largest cell-coverage, it is designed to hand over the users staying in the existing network to cdma2000 network, in case where the current network's capacity becomes full. So, when new user tries to join a network, our scheme enables to choose which existing users should be handed over to cdma2000 network that is overlaid with fully occupied existing network. However, in the consideration of user's satisfaction, it is proper to select and hand over the users receiving the most unfavorable services to cdma2000 network, so that the user can have a satisfactory quality of service through the newly allocated network.

In this paper, the bad service condition means the high cost and the low signal strength at the same time. The users which have the low value through the objective function of Eq. (2) means that they have the high cost and the low signal strength among all of the existing users. Therefore, the objective function of Eq. (2) enables us to pick out users in the bad condition. Fig. 4 shows the algorithm to selects users that should be handed over to cdma2000.

Based on the value obtained through the objective function of Eq. (2), users which have the low value will be selected and then will be handed over to the overlaid cdma2000 network. As a result of this vertical handover, the enlarged capacity can accommodate new users to join.

4. PERFORMANCE EVALUATION

In this section, the performance of our proposed scheme and non-CRRM is compared and evaluated. In our simulation environment, it is assumed that four networks of WLAN, WiMAX, UMTS, and cdma2000 exist in overlaid manner and that they have the service cost and bandwidth different from one another which is shown in **Table 3**.

First, Fig. 5 shows the blocking probability. Usually when new user joins a network, the network is selected just by considering the signal strength of each network. In our study, however, the proposed CRRM which considers not only signal strength but also several attributes of networks, as a preliminary study of our study.

In the non-CRRM scheme, which only considers the signal strength, if the capacity of chosen network is full, the service will be blocked. However, our proposed scheme can prioritize currently available networks, based on the values calculated with objective functions of bandwidth, signal strength, and cost. In addition, the current network's capacity becomes full, when new user tries to join a network, our scheme enables to choose which user should be handed over to the other overlaid network through our integrated vertical handover algorithm. Therefore, it enables to select a network which can provide the most optimal service to the user. Furthermore, it helps to relieve the congestion of users in a certain network by allocating them across all available networks evenly.

Table 3. Simulation Parameters

Network	Cost (1Mbyte)	Bandwidth
WLAN	$ 0.02	10 Mbps
WiMAX	$ 0.2	5 Mbps
UMTS	$ 0.5	3 Mbps
cdma2000	$ 0.5	2 Mbps

Figs. 6, 7 and 8 show the result of our simulation to find out the optimal value of α and β which are weight factors of the signal strength and the cost in Eq. (1) and Eq. (2).

Fig. 6 shows the network utilization as a result of Eq. (1) which is the objective function of integrated network selection algorithm.

If α is 1, a network is chosen in the consideration of signal strength only, and if it is zero, only cost is considered. As shown in Fig. 6 as much as signal strength is considered, we can see that the usage of the cheapest WLAN has been declined.

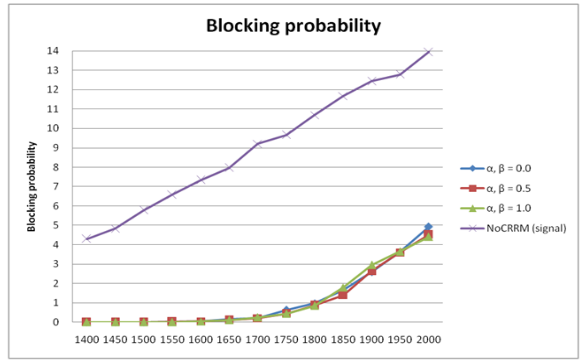

Figure 5. Blocking probability

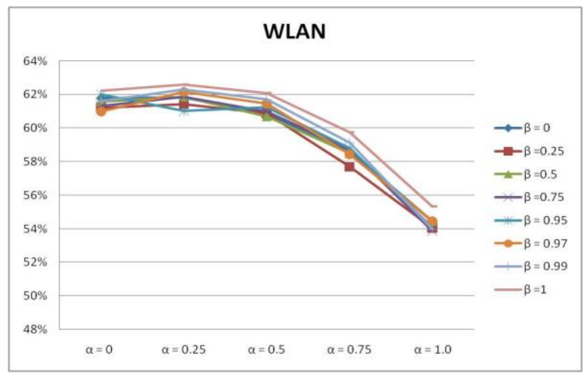

Figure 6. Network utilization (INS)

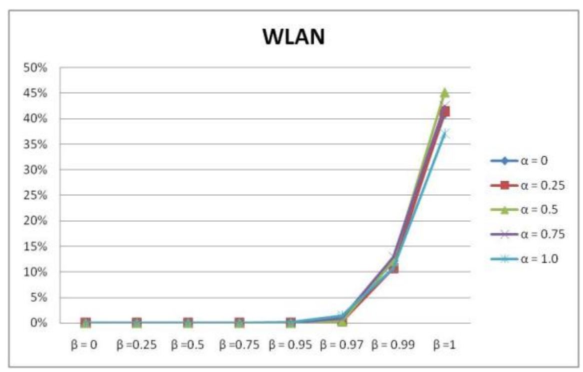

Figure 7. Vertical handover ratio (IVH)

Figs. 7 and 8 are the results of Eq. (2), that is, the objective function of integrated vertical handover algorithm. In Eq. (2), if β is 1, the user to be handed over is selected mainly in the consideration of signal strength, and if it is zero, cost is mainly considered. As much as signal strength is considered, handover ratio to the cheapest WLAN increases, while that to UMTS decreases.

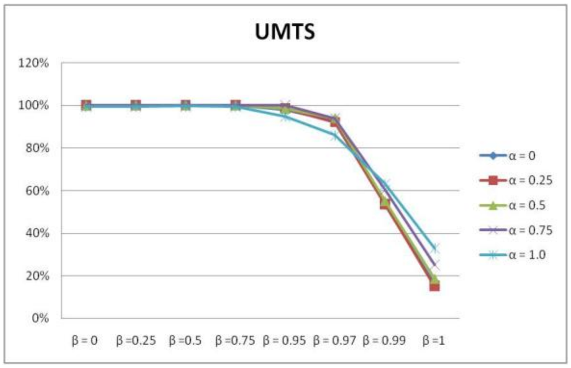

Figure 8. Vertical handover ratio (IVH)

The aim of this simulation is to find out the most optimum values of α and β by granting weight factors to the signal strength and the cost that are considered in Eq. (1) and Eq. (2), and then by adjusting the factors appropriately. However, additional work of current objective functions should be made in future studies.

5. CONCLUSION

In this paper, we have presented a preliminary result on the common radio resource management for heterogeneous wireless networks. Our proposed scheme consists of two algorithms. First, we proposed the integrated network selection algorithm that enables to select an appropriate target network for newly coming users. Second, the integrated vertical handover algorithm was proposed to reserve the capacity of existing network by handing over its existing users to the other overlaid network. Decisions of these two algorithms are made based on the given objective functions which consider various factors such as signal strength, capacity, cost, and current load of each network. The results of our preliminary simulation have shown that the proposed algorithms can significantly reduce the blocking probability.

In our future work, various factors will be considered in addition to current factors and then be added to current objective functions, in order to devise more realistic CRRM scheme. In addition, we will try to find out the weight value that optimizes the objective functions.

6. ACKNOWLEDGMENTS

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