Service Differentiation Using Mobile Femtocell Virtualization

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Abstract—**This paper proposes a service differentiation architecture using virtualization of mobile femtocell. Network-prefix division multiple access (NDMA) is proposed to enable mobile devices inside a moving space to access the Internet with different service demands. With the NDMA scheme, our architecture provides multiple virtual mobile networks for diverse services which are optimized under different network conditions. We experimented on the operation of the proposed architecture with testbed implementation. The result shows the ability of multiple degrees of QoS over each virtual mobile network with additional benefits of personalization, mobility management aggregation, and so on.**

***Keywords*— Virtualization, Future Internet, Femtocell, QoS, Personalization, NDMA(Network-prefix Division Multiple Access)**

I. INTRODUCTION

As the user demands for the Internet becomes complex and diverse, modern Internet users require new features such as ubiquity, mobility, QoS (Quality of Service), personalization, security, privacy, and so on. Wireless communication technology manages to support such various user demands, while lack of mobility support, limited capacity and coverage hinders satisfactory Internet connectivity of users.

This paper proposes an architecture of mobile femtocell which provides ubiquity and service differentiation along with diverse user-requirements of mobility management optimization and virtualization. Mobile femtocell provides optimized mobility management by deploying NEMO (Network Mobility) basic support [3], and our virtualization daemon on the femtocell and mobile network nodes can provide service differentiation by implementing virtual mobile networks on the mobile femtocell.

To begin with, section II analyzes the future internet user requirements. Then section III describes the solutions for those requirements of mobility management optimization and virtualization by proposition of Network-prefix Division Multiple Access (NDMA). Finally, section IV shows the development result and its operation, then section V concludes with future research.

II. DIVERSE SERVICE REQUIREMENT ANALYSIS

As the current Internet faces the new problems and requirements [1, 2], innovative network technologies are proposed to solve those. The future trends that we are focusing on are *ubiquity* and *diversity*.

Firstly, the concept of ubiquity has been generalized as networking and computing becomes pervasive in our life. Not only communications but also general businesses, education, medical service, transformation, and so on, are done over the Internet. With wireless LAN technology, only limited level of ubiquity can be supported because of limited range and capacity of the technology. Wireless LAN technology cannot support Internet connectivity to moving users, due to its stationary characteristic. Optimized *mobility management* schemes are needed to meet this trend.

Secondly, user demands are becoming more sophisticate and diverse. To meet diverse user demands, we need different networks with diverse QoS and/or security, privacy policies for each user. Change on overall network architecture and protocol can be a solution to meet the diverse user demands, but the user demands vary over time. Thus it is not feasible to adapt the network every time the demands change. As a feasible solution to meet the trend, we can use *virtualization* technique. Using virtualization, the network can be organized and optimized as a network of networks, which can be easily modifiable to satisfy diverse user demands that change over time.

III. MOBILE FEMTOCELL VIRTUALIZATION

To meet the future requirements of ubiquity and QoS, we optimize mobility management and divide QoS levels. This paper proposes mobile femtocell architecture for mobility management optimization and network-layer virtualization for QoS differentiation.

A. Mobile Femtocell

Femtocell is a small-sized base station that is connected to fixed broadband network, and provides wireless access inside a building or at home. Fig. 1 shows femtocell network architecture. Usually femtocell is used to extend coverage of an ordinary macrocell base station. For example, femtocell cell is provided to cover shadow area, e.g., inside of building or underground.

As the concept of space becomes converging, demands for the support of femtocell will become broad, e.g., fixed space or moving space. For example, aircrafts or ships are the spaces which are moving. Thus the support of mobility for the femtocell can provide aircrafts or ships with wireless access to the Internet.

We deploy the NEMO Basic Support protocol [3] to support mobility for the group of mobile devices inside a moving space. NEMO Basic support deploys mobile router (MR) which delegates mobility management signals of mobile devices inside a moving space, i.e., mobile network.

The mobile router allocates one or more mobile network prefixes (MNPs) which are advertised to the mobile devices inside a mobile network. Thus the mobile devices configure their addresses using these mobile network prefixes so that the mobile router can manage the mobility of all those devices. By deploying NEMO Basic Support, mobility management signals of each mobile device inside a moving space can be aggregated and then optimized.

B. Virtualization with NDMA

To support diverse service demands from different users or applications, this paper proposes virtualization. Virtualization for wireless networks has been proposed in terms of time (TDMA), frequency (FDMA), code (CDMA), and so on. In this paper, we propose a virtualization scheme called Network-prefix division multiple access (NDMA) which is implemented on the network layer.

We divide a mobile network by mobile network prefixes so that each virtual mobile sub-network allocates its own mobile network prefix. To deploy multiple mobile network prefixes, we focus on the issues of prefix delegation, path selection, and preference setting as described in [4].

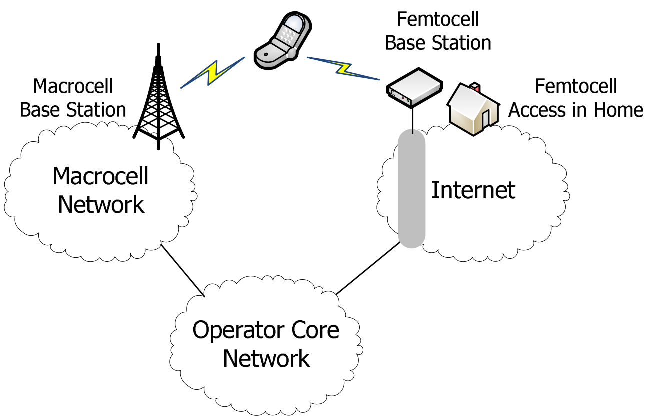

Figure 1 Femtocell Network Architecture

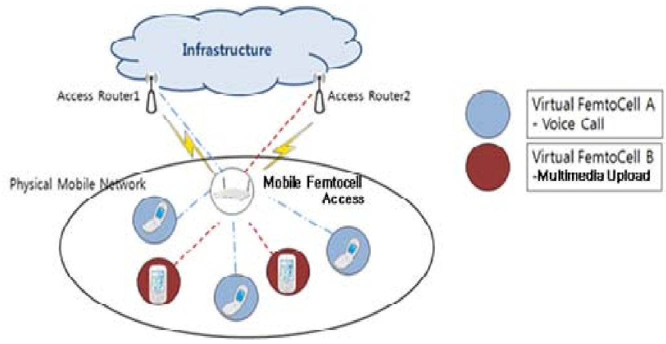

Figure 2 Example of mobile femtocell virtualization

By implementing multiple prefixes, our proposal can support multiple accesses to the Internet according to the requirements of distinguished services. Fig. 2 shows the service differentiation concept by virtualization with different QoS policies. In Fig. 2, for example, the mobile devices composing virtual femtocell A and B access the Internet for voice call and multimedia content upload respectively. By the provision of virtual mobile networks as in shown Fig. 2, we can optimize each of them in different ways. For instance, we can choose HSDPA (High-Speed Downlink Packet Access) for voice call with the benefit of wider coverage and WiMAX for multimedia content upload with broader and cheaper bandwidth. On the other hand, we can also choose different security policies for each virtual femtocell.

IV. OPERATION AND TESTBED

To test the feasibility of the proposed NDMA scheme and to solve the virtualization issues of path selection and preference setting, we implemented *mobile femtocell cache*. Fig. 3 shows the mechanism that our mobile femtocell cache provides the benefit of path selection and preference setting.

Our testbed is composed of one mobile femtocell, two mobile network nodes for two virtual mobile networks, and one correspondent node. In the mobile femtocell, we deployed virtualization daemon. In this case the mobility function of the mobile femtocell is not our main concern, thus we attached the mobile femtocell to a foreign network initially.

The virtualization daemon is composed of two components, server and client. The server daemon runs on the mobile femtocell, and the client daemon runs on each mobile network node. The daemons work as follows. Firstly the server daemon reads the virtual mobile network setting information from the configuration file, and generates network prefixes according to the configuration. Also it detects the incoming network prefix, and generates routing rules that connect each virtual mobile network and foreign network prefix. If an appropriate configuration is saved in the configuration file, then different access network will be connected to different virtual mobile network. The network prefixes are sent to all mobile network nodes. The same information is also forwarded to the mobile network nodes that are newly connected.

The client side of the virtualization daemon receives the information of virtual mobile network. According to the pre-defined preference setting information on the client, the client daemon can decide preferred virtual mobile network to which the mobile network node attaches. Then the client daemon sends the selected virtual mobile network information to the server daemon, and the server daemon stores the attachment information. After the selection, the server daemon stores the list of virtual mobile networks and nodes that are connected to each virtual mobile network.

On our testbed, we experimented on service differentiation mechanism using virtual mobile networks. We have two virtual mobile networks in our testbed, one for the administrator of the network and the other for plain users. In Fig. 3, the devices (i.e., mobile network nodes, MNNs) in virtual mobile femtocell (i.e., virtual mobile network, VMN) 1 can execute the functions for network administrators while femtocell 2 for plain users.

Fig. 4 through Fig. 6 show the experimental result of our testbed with above configuration. Fig. 4 shows the example of mobile femtocell administrator's user interface which shows the selection of virtual mobile femtocell according to the preferences. In this case, the mobile network node is attached to the virtual mobile network with prefix 2001:a:f:1::/64, which is administrator's virtual mobile network. After the selection, the mobile femtocell separates the administrator's traffic from the plain user's traffic. Finally, administrator's service is only permitted to the nodes in the virtual mobile network for administrator.

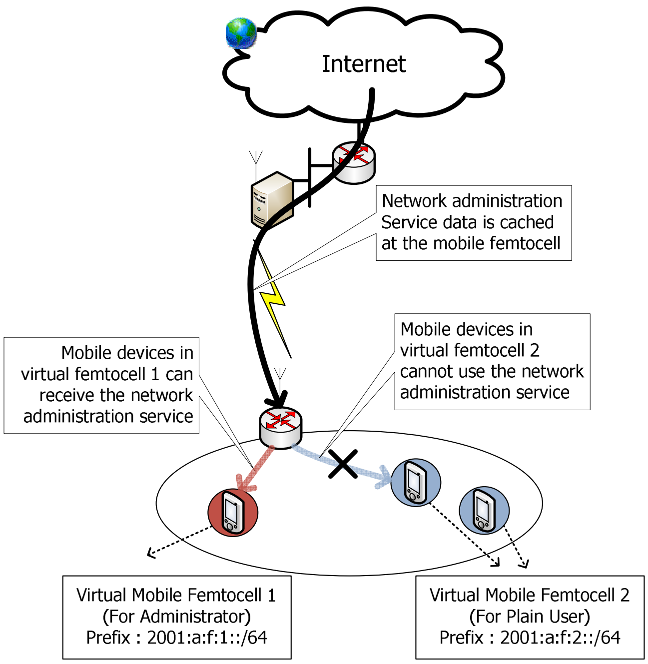

Figure 3 Testbed architecture and mobile femtocell cache operation

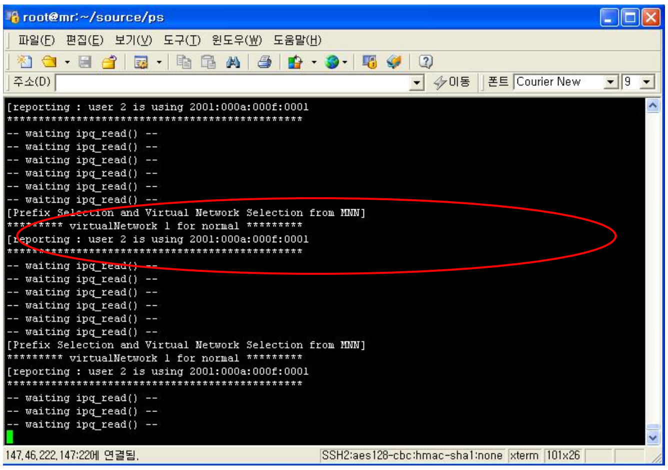

Figure 4 Example of mobile femtocell administrator's user interface

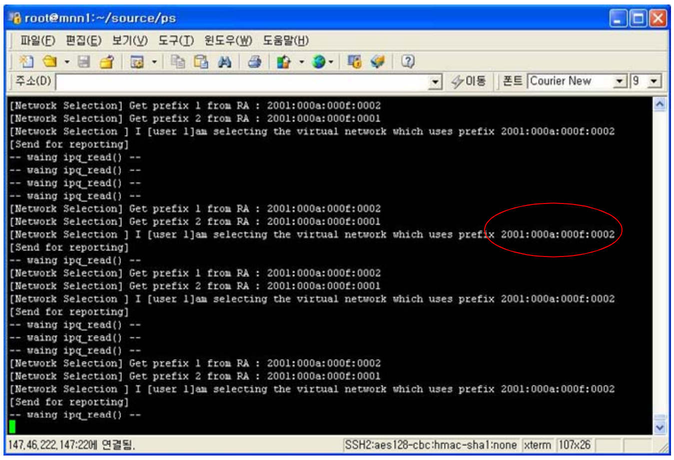

Figure 5 Example of mobile network node interface

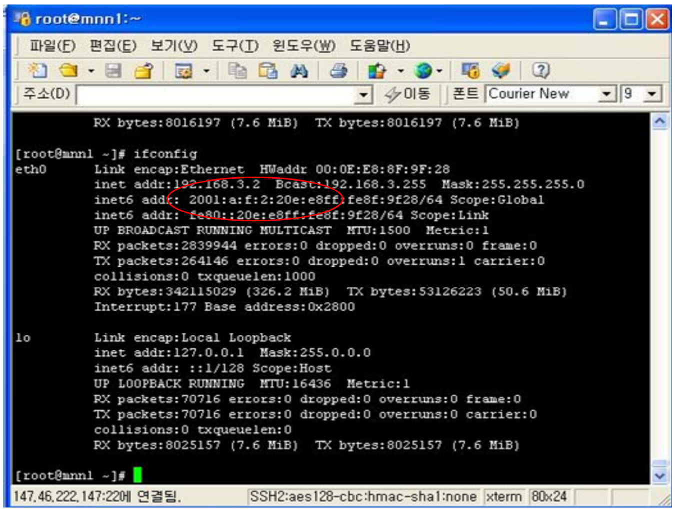

Figure 6 Address configuration according to selected virtual mobile network

Fig. 5 shows the selection of virtual mobile network at the client daemon with a prefix for administrator (2001:a:f:2::/64 in this Fig). After the selection, the address of the mobile network is auto-configured with the prefix in Fig. 6.

V. CONCLUSION AND FUTURE WORKS

In this paper, we proposed the mechanism of service differentiation using mobile femtocell and network-layer virtualization, and then we made experiment on the operation by implementing testbed. The experimental result shows that the proposed mobile femtocell provides diverse QoS and administration in a moving space by mobile network virtualization and the policy cache deployment.

The developed mobile femtocell provides service differentiation with the following benefits.

- *Preference setting*: Users can set their personal preference with the femtocell cache.
- *QoS and security*: QoS and/or security can be provided with different levels of user requirements by NDMA and virtualization.
- *Mobility optimization*: Mobility management can be optimized by signal aggregation.

To support real-world deployment, we will implement our architecture over emerging wireless access technologies such as WiBro (Wireless Broadband Network) or HSDPA as a future work.

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