

Novel Signaling Scheme for 1x CDMA-based Femtocell Networks

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Abstract—Femtocell networks can support isolated coverage area and provide high data rates for mobile users by using wired Internet lines such as xDSL and cable TV networks for backhaul connectivity. Femtocell networks can be classified into 3GPP UMTS-based networks and 1x CDMA-based networks. Although 3GPP UMTS-based femtocells are standardized in the form of Home Node-B, 1x CDMA-based femtocells are not currently standardized. So, operators and communication system vendors are developing and launching such networks with proprietary specifications. From the viewpoint of an operator seeking to reduce its setup-costs, the adoption of the Femto Access GateWay (FAGW) is preferred. If femtocell networks based on the FAGW are adopted, an efficient signaling between the femtocells and the FAGW is required. The SIP-based signaling technique may suffer from an overload to support large number of femtocells. In this paper, we propose a novel signaling mechanism for FAGW and evaluate its performance in comparison with the SIP-based signaling method.

Keywords— 1x CDMA-based femtocell, Femto Access Gateway, Signaling mechanism.

I. INTRODUCTION

Femtocells can be deployed in small areas such as home or office with low-power and low-cost cellular base stations. Mobile Stations (MSs) can be connected to a femtocell base station which provides high speed backhaul for Internet access [1]. The 3GPP UMTS-based femtocell is standardized with Iu-h interface between a Home Node-B and Femto Access Gateway (FAGW) [2]. The 1x CDMA-based femtocells are being launched by some equipment manufacturers and communications system operators. Various integration models between 1x CDMA-based femtocells and a 1x CDMA core network have been proposed in the femto forum [3]. By default, because the Internet is used for backhaul connectivity, a security gateway for IPsec tunneling between the femtocells and a core network is configured as a separate node.

Three main configurations have been proposed: femtocells are connected 1) directly to the Mobile Switching Center (MSC), 2) indirectly to the MSC through a gateway such as a Base Station Controller (BSC)-based gateway, or

3) directly to an IP Multimedia Subsystem (IMS). Among them, the best solution in terms of the cost-effectiveness is to deploy a gateway. The gateway should have various functionalities, i.e., BSC functions, interconnections for lots of femtocells, No.7-based Interoperability Specification (IOS) signaling with MSC, and E1/T1-based Time Division Multiplexing (TDM) functions for voice traffic. The gateway configuration method requires standardizing the signaling interface between the femtocells and the FAGW, e.g., 3GPP Iu-h interface.

The interface uses a secure tunnel such as IPsec. The interoperability issue between two network elements connected by the Internet may occur. In this context, some appropriate signaling interfaces have been suggested by various manufacturers. Among the proposals, one of the representative mechanisms uses a Session Initiation Protocol (SIP) as the signaling interface and Real Time Protocol (RTP) as the data traffic interface. This approach may be appropriate in terms of the IMS network migration and the Internet signaling protocol. However, it incurs some compatibility issue with the existing core networks. Therefore, we propose a new signaling protocol that refers to the 3GPP2 IOS specifications. By comparing the performance of the proposed new signaling mechanism with that of the basic SIP-based signaling, it is shown that the proposed signaling is appropriate.

When an SIP message is delivered, the A1 messages should be transferred as the contents. So, we have to define a new type of contents to discriminate. And, there is mismatch between the air interface flow connecting femtocell and the A1 flow connecting the MSC. Therefore, the basic SIP flow must be modified and the additional flows are required. Since the modifications of the SIP signaling flow between the femtocells and FAGW may limit the performance and interoperability, a signaling flow has to be carefully designed. In this paper, we first consider a basic SIP-based signaling flow and evaluate its performance. And, we propose a novel signaling flow taking interoperability into consideration. The new signaling approach between the femtocells and FAGW is based on the existing A1 interface flow and the Signaling Connection Control Part (SCCP).

The organization of this paper is as follows. Section 2 describes the basic SIP-based and the proposed signaling-based network architectures. Section 3 describes the basic SIP-based and the proposed signaling flow for the 1x CDMA femtocells.

Section 4 presents the simulation environment and compares the performance of the SIP-based and the proposed signaling flows. Finally, Section 5 provides conclusion and presents a design guideline.

II. FEMTOCELL SYSTEM ARCHITECTURE

A femtocell is generally installed indoors and is connected to a core network through access network, e.g., an xDSL or cable TV networks [5]. Since it goes through an insecure network, the signaling and traffic information need to be forwarded through an IPSec tunnel. In this environment, an interface such as a gateway can be configured for the sake of its interoperability with the existing macrocell network.

We consider connecting an FAGW with femtocells. Fig. 1 shows the general femtocell network architecture based on the SIP signaling and the overall protocol stack. From the femtocells to the Femto Security Gateway (FSG), IPSec is enabled by default. In general, the signaling for the FAGW uses SIP. The received SIP messages should be changed to the A1 Interface messages (see Fig. 1). Because the MSC recognizes the FAGW as one of the BSCs, to achieve the A1 signaling with the MSC, the functions of the FAGW need to be modified. Since the femtocell includes most of the features of the BSC or Base station Transceiver System (BTS), the SIP message body, which contains the A1 parameters, should be forwarded to the FAGW.

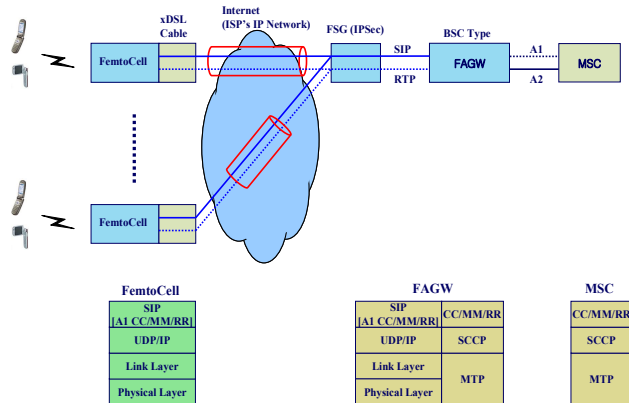


Fig. 1. Femtocell architecture based on SIP signaling.

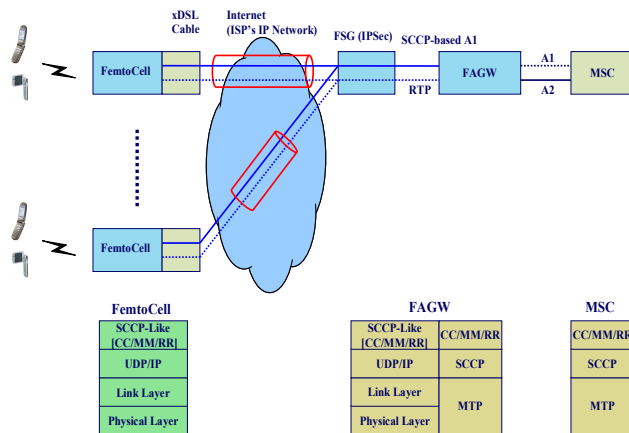


Fig. 2. Femtocell architecture based on the proposed signaling.

The FAGW receives the SIP messages and then parses the A1 parameters. So, the FAGW should provide a decision function to determine what kinds of A1 parameters exist. The SIP layer delivers the messages of the A1 interface related to Call Control (CC), Radio Resource management (RR), and Mobility Management (MM). In fact, an FAGW should support a lot of femtocells through SIP signaling. And as a transport layer protocol, User Datagram Protocol (UDP) is used.

Fig. 2 shows the proposed femtocell network architecture and its protocol stack. This network refers to the IP transport layer of 3GPP2 IOS and interoperates with the existing MSC. Its interoperability with the MSC is similar to that of the basic SIP-based architecture. Since the A2-bearer's interface delivers the network data traffic through the RTP, it is basically the same as that of the SIP-based signaling. The 1x CDMA femtocell network architecture proposed in this paper minimizes the modification of the legacy CDMA core network, and the FAGW is recognized as one of the BSCs. Therefore, the femtocell network can be installed without any modification to the existing communication network. Fig. 3 shows the proposed A1 femtocell network and the legacy CDMA network. This femtocell network configuration enables rapid deployment of femtocells.

III. PROPOSED FEMTOCELL NETWORK'S SIGNALING

Fig. 4 shows the basic SIP-based signaling flow. The SIP-based signaling protocol should translate the SIP messages and their contents into A1 messages and parameters. Then, the FAGW can transmit the A1 message to the MSC. And, the paging message needs to be transmitted only to the femtocell at which the subscriber is registered. So the FAGW should support a database containing the subscriber's and femtocell's identities. Thus the FAGW has to perform operations that convert the SIP message and contents into No.7-based A1 messages and parameters.

In order to meet the requirements, a new signaling mechanism is proposed. The proposed A1 signaling flow is similar to the 3GPP2 IOS flow. However, the parameters for the bearer setup are different (see Fig. 5). The paging message for incoming call setup is only delivered to the femtocell at which the subscriber is registered, not to all of the femtocells.

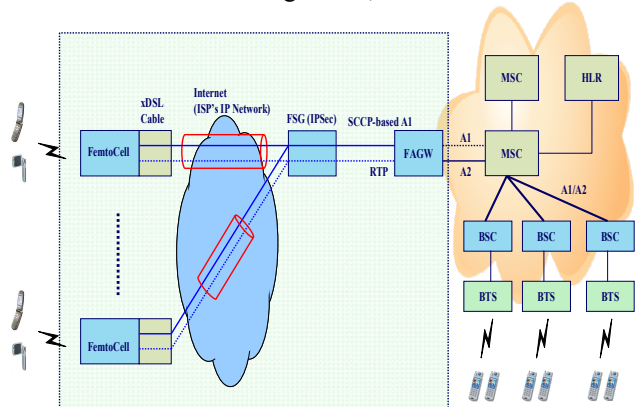


Fig. 3. The proposed A1 femtocell network and the 1xCDMA network.

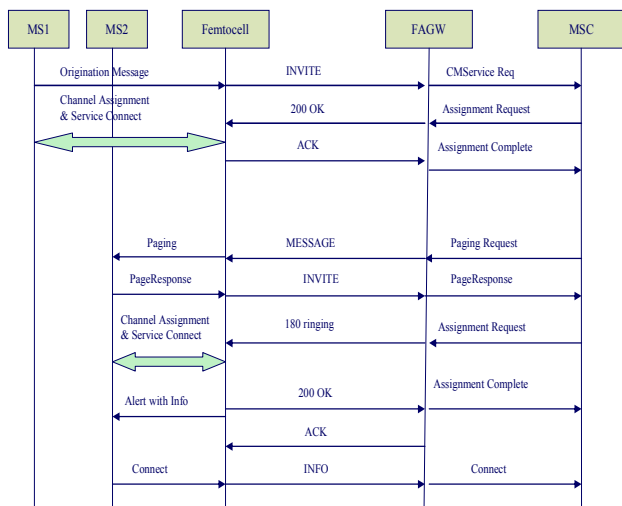


Fig. 4. The basic SIP-based A1 signaling flow.

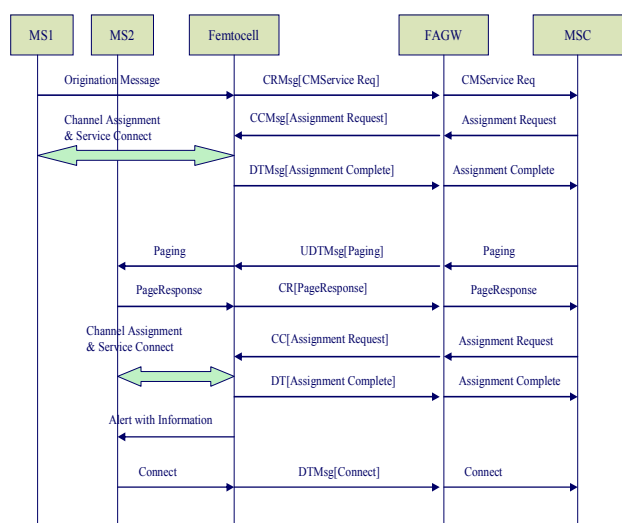


Fig. 5. The proposed SCCP-based signaling flow.

To perform these functions, a database that can store the subscriber information and the femtocell's identity is maintained. The information should be updated when the Location Update (LU) is performed. Also, a function that converts the proposed signaling to No.7-based A1 signaling is provided in the FAGW. The functionality that converts the IP-based traffic into the Pulse Code Modulation (PCM)-based data traffic is performed in the FAGW through a trans-coding function. Fig. 5 shows the proposed signaling flow.

IV. SIMULATIONS

To evaluate the performance of the basic SIP-based mechanism and that of the proposed, we build a simulation environment and simulators to simulate the MSC and femtocell functions. The femtocell simulator should be able to encapsulate the A1 signaling information into the SIP message, to load the message into the UDP layer and to run a lot of femtocell applications simultaneously. In addition,

after certain duration, each session should be released. The MSC simulator interoperates with the FAGW and issues paging messages for the purpose of terminating call-setups. Typically, it supports No.7-based protocols and issues request messages. The simulators do not support issuing voice payloads, but does support delivering information for a radio traffic channel and circuit channel. The FAGW is composed of various applications, including the SIP stack, No.7 stack and the UNIX server. To implement most of the functions of the FAGW, we consider three parts, interoperability with multiple femtocells, interoperability with the MSC using No.7 protocols, and session management and information handling for the femtocell identity and the mobile station information.

Fig. 6 shows the virtual simulation environment used to evaluate the performance of the basic SIP-based signaling flow. The SIP function exists between the femtocell simulator and the FAGW. The simulation environment for the proposed SCCP-based signaling flow is shown in Fig. 7. The simulation starts at the femtocell simulator and the MSC simulator sends response messages and paging messages. In order to measure the performance of the modules supporting the major functions within the FAGW, the top utility is used, which measures the CPU load. The mean holding time of the call sessions is set to 50 seconds and the registration for all MSs completes before call-setup.

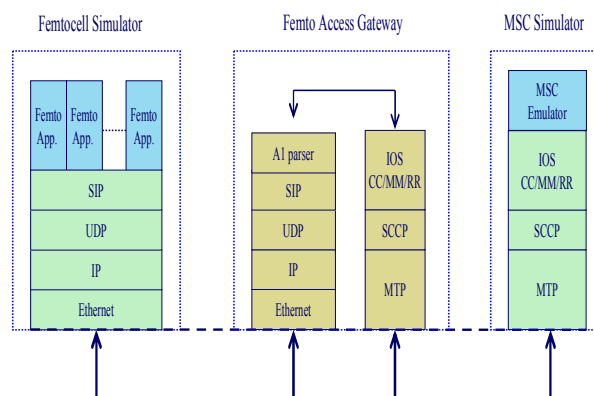


Fig. 6. The simulation environment for the basic SIP-based A1 signaling flow.

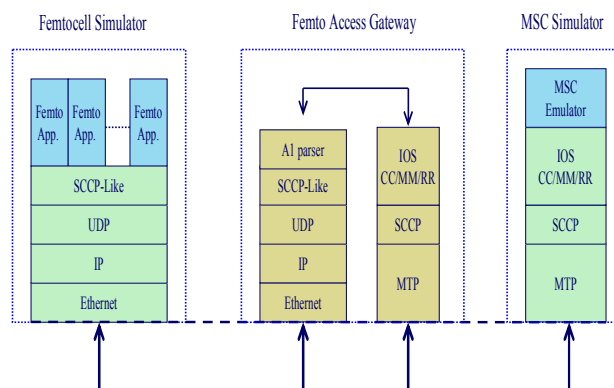


Fig. 7. The simulation environment for the proposed SCCP-based A1 signaling flow.

Table 1. Simulation Parameters.

Parameter	Value
Total number of femtocells	100,000
Total number of MSs	500,000
Average call duration	50 second
Number of femtocells	10,000 ~ 100,000
Server	SUN N440 Ultra SPARC IIIi 1.6GHz
Calls /second	20

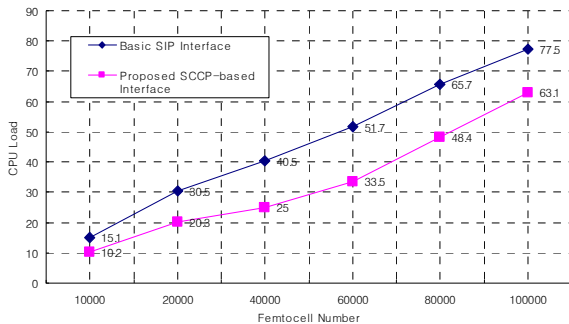
**Fig. 8. CPU load for various numbers of femtocells.**

Table 1 shows the parameters for simulation. Fig. 8 shows the simulation result. The proposed SCCP-based A1 signaling flow occupies less CPU time for various numbers of femtocells. The CPU occupation time pertaining to the function modules of interoperating with the MSC is similar for both kinds of signaling mechanisms. In the case that the number of femtocells is small, the difference between the two signaling methods is small. As the number of femtocells increases, the performance gap becomes larger. To install more femtocells at one FAGW in the basic system, we may

need to configure other kinds of expensive hardware platforms. However, by adopting the proposed signaling mechanism, we can flexibly add new femtocells with improved performance.

V. CONCLUSION

One of the easiest ways to install 1x CDMA-based femtocell networks is to employ an FAGW. For this network configuration, the signaling interface between the FAGW and the femtocells may be SIP-based. In this paper we have proposed a new SCCP-based A1 signaling interface. Through the performance evaluation of the two signaling methods, it has been shown that the proposed SCCP-based A1 signaling is more efficient and provides improved performance. When a core network is migrated to an IMS core network, our proposed SCCP-based A1 signaling is expected to improve the performance of the FAGW and to provide fast and easy deployment of femtocells.

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