Automated Service Provisioning and Management for Integrated Femtocell/Wi-Fi and Cellular Networks

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***Abstract*—The explosion of the mobile broadband data traffic and the expected needs of ever increasing bandwidth demand present great challenges and opportunities for mobile operators. To mitigate the challenges, mobile operators usually offload mobile data traffic from cellular networks to alternative networks by utilizing IEEE 802.11 wireless fidelity (Wi-Fi) access points and deploying femtocells to leverage their service offering and reduce their operational expenditure (OPEX). The end-to-end services provisioning and management of the integrated femtocell/Wi-Fi and cellular networks is one of the key challenges for fixed-mobile providers. The inter-provider service provisioning involves information exchange interfaces which are basically manually set up and managed. As a result, the service provisioning takes lots of time and work and the OPEX is increased.**

In this paper, we first describe the business management model of the integrated femtocell/Wi-Fi and cellular networks from the perspective of fixed-mobile providers. We then propose a platform of service provisioning and management for the integrated networks that aims at providing an automated end-to-end quality assured services. To support the provision of better and diversified services to users, advanced management functionality needs to be introduced in the integrated systems, which will enable optimum, end-to-end operation. Finally, the results show that the proposed service provisioning and management which is automated and optimized, significantly reduces the duration of inter-provider service delivery of the integrated network, and reduces the OPEX.

Keywords- Mobile data offloading, Femtocell, Wi-Fi, Integrated Network, Automated service provisioning .

I. INTRODUCTION

The introduction of mobile broadband services offers great opportunities for mobile providers to diversify their revenue stream. In the meantime, the convenience and reliability of mobile broadband services drive an explosive growth of mobile data traffic and the subsequent expected needs of ever increasing bandwidth demand [1-4]. As a result, operators are faced with unprecedented challenges and opportunities. Since the deployment of cellular base stations is a significant capital expense, to meet these challenges, mobile operators usually offload mobile data traffic from cellular networks to alternative networks by utilizing IEEE 802.11 wireless fidelity (Wi-Fi) access points (APs) and deploying femtocells.

Both femtocell and Wi-Fi technologies are attractive since they are cost-effective way to significantly increase the user data rates and can improve the coverage as well as increase system capacity. In general, fixed-mobile operators (i.e., operators who providing both fixed and mobile services) will use their fixed and mobile infrastructure networks to deploy such a integrated femotcells/Wi-Fi and cellular networks to leverage their service offering and reduce their OPEX and capital expenditures (CAPEX). Conventionally, mobile services and fixed services were in their respective network domains, each supported by different technologies, rendering different service types, and with separate charging. Therefore, the corresponding domain-dependent business supporting systems (BSS) and operational supporting systems (OSS) approaches for providers offer isolated service provisioning and management for each specific domain. When it comes to integrated networks, multi-domain service provisioning and management becomes indispensable. The inter-provider service provisioning or modification involves information exchange interfaces which are basically manually set up and managed. As a result, the service provisioning take lots of time and work and the OPEX increases significantly.

In this paper, we begin with the overall integrated network architecture and briefly introduce the technologies of femtocell and WiFi. Furthermore, from the fixed-mobile operators' perspective, we present the business management model of the integrated femtocell/Wi-Fi and cellular network. We then present our scheme of the end-to-end automatically service provisioning and management systems in the integrated network. As noted above, inter-provider service provisioning or modification involves manual intervention interfaces, and lasts days or even weeks, while the proposed architecture reduces the service provisioning time frame to minutes. Results show that the integrated provisioning and management systems effectively speed up the deployment of FMC services, reduce the OPEX, and result in higher customer satisfaction.

The remainder of this paper is organized as follows. In Section 2, we present the emerging integrated femtocell/Wi-Fi and cellular network architecture. In Section 3, we present the business management model of the integrated network. In Section 4, we describe the design of the automated end-to-end service provisioning and management systems for integrated network in detail. We then present the results and related works. Finally, concluding remarks are given.

II. THE OVERALLNETWORK ARCHITECTURE

A typical deployment network architecture of emerging integrated femtocell/Wi-Fi and cellular networks is depicted in Figure 1. The typical integrated network is composed of a cellular network, an internet service provider (ISP) network, and a fixed broadband network.

Both femtocell access points (FAP) and Wi-Fi access points are short-range, low-power, and low costs devices [2, 14]. They are usually deployed in residential, enterprise, or hotspots and utilize subscribers' broadband connection (typically digital subscriber line (DSL) or cable). A femtocell (also called Home NodeB) is generally adopted to improve system capacity and provide indoor data coverage [1,7]. Femto gateway (FGW) aggregates femtocell traffic into the IP network instead of cellular networks. On the other hand, 3GPP specified interworking wireless local area network (I-WLAN) and generic access network (GAN) approaches for the integration of WLAN and cellular networks [16, 17]. The management of service connectivity is achieved by a set of wireless network control (WNC) servers [3].

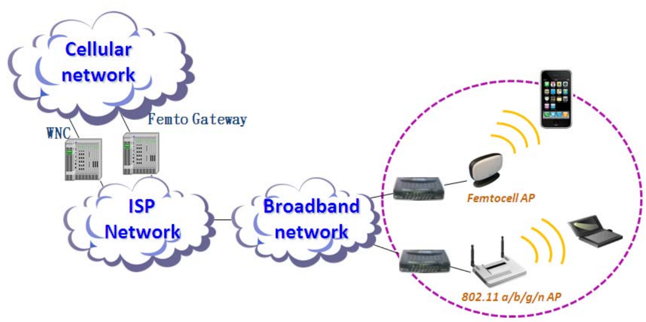

Figure 1. A typical integrated femtocell/Wi-Fi and cellular network architecture.

III. BUSINESS MANAGEMENT MODEL

From a business management perspective, the service provisioning of integrated networks requires a collaborative platform involving the mobile operator (MO), the internet service provider (ISP), and the broadband network provider (BNP) , as depicted in Figure 2. The platform should provide a unified and flexible structure for contacting all business players and should be responsible for the workflows of all administrative issues, such as service setup, management, ceasing, and revenue share. Moreover, the business management model includes a suite of agreements such as billing, service level agreement (SLA), and security.

The unified platform overcomes the inefficiency of traditional isolated service platforms. It also helps to bring in additional revenue from emerging businesses for fixed-mobile operators. Generally, the platform includes unified BSS/OSS, where BSS consists of billing system and customer relationship management (CRM) while OSS is equipped with functions of service activation, service problem management, and workforce management. During the service life cycle, development should take into account the following key workflows.

Service feasibility checking. When a subscriber wants to sign a contract with the fixed-mobile operator for his desired quad-play services, the operator starts with the service feasibility checking by checking whether all the providers can offer the service or not. This phase is used to check if the service can be fulfilled with the support of the underlying integrated networks.

Network planning and site survey. After fixed-mobile operator signs contract with the customer, the order system begins the automated service provisioning and management procedures. Then the mobile operator triggers the process of network planning and site survey. During the network planning phase where to place the access points is decided.

Service activation. The platform is responsible for the service provisioning workflows and contact with all providers' service provisioning system, as depicted in Figure 2. It is worth noting that during the service setup phase the service provisioning system of ISP assigns the public IP address of femtocell/Wi-Fi access points and exchanges the information with other operators' OSSs. Furthermore, to reduce the amount of manual operations involved in the new provisioned access point, the process of device management should also be automated for any management protocol of device supported. Due to the small size of the access points, the technician is required to take a photograph of the installation location of the access point and send it to BNP's OSSs for the purpose of future operational maintenance.

Service management. In this phase, it includes the service monitoring to guarantee its SLA. In addition, the information about modification of access points should be exchanged among providers automatically.

Service termination. When the service time expires or a customer requests to unsubscribe, the service will be "torn down". The service termination process is also managed automatically, by signaling the new status of the service to the participating OSSs. It also needs to instruct all operators' OSSs to release the reserved resources.

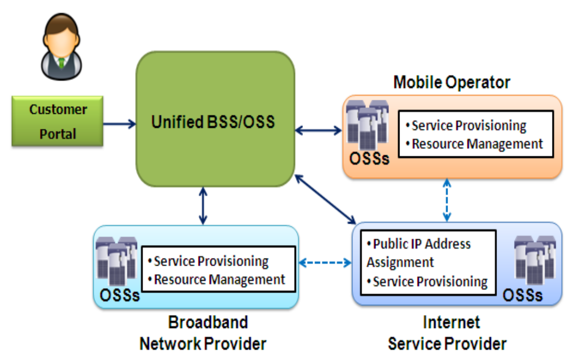

Figure 2. Business management model for integrated femtocells/Wi-Fi and cellular networks.

IV. AUTOMATED SERVICE PROVISIONING AND MANAGEMENT

A. The Management Architecture

To fulfill an automated service provisioning and management for convergence services, a unified BSS/OSS is developed, as presented in Figure 3. The unified BSS/OSS consists of order system, billing system, convergence service configuration system (CSC), service problem management system, and the service quality management system. Moreover, each provider has its inventory management, service configuration & activation (SC&A), and a variety of resource provisioning and resource management systems.

All of the enabling network devices, links, and elements need to be provisioned, monitored, and tested. Thus, all these network devices and elements are required to support standard network management protocols, such as Technical Report 069 (TR-069)[9] and simple network management protocol (SNMP) [11]. The enabling devices/services are monitored and configured by a variety of resource provisioning and resource management systems of the corresponding network domain.

Since there are myriads of Wi-Fi and femtocell AP devices which support either SNMP protocol or TR-069 protocol, the proposed access point management system (APMS) is designed to have provisioning, automated management, configuration management, fault management, and performance management functions. To reduce the amount of manual operations involved in the deployment of the new provisioned AP device, the process of device management is required to be automated. The automatically management function is developed to eliminate most on-site operations of basic settings and subsequent updating of customer premise equipment (CPE).

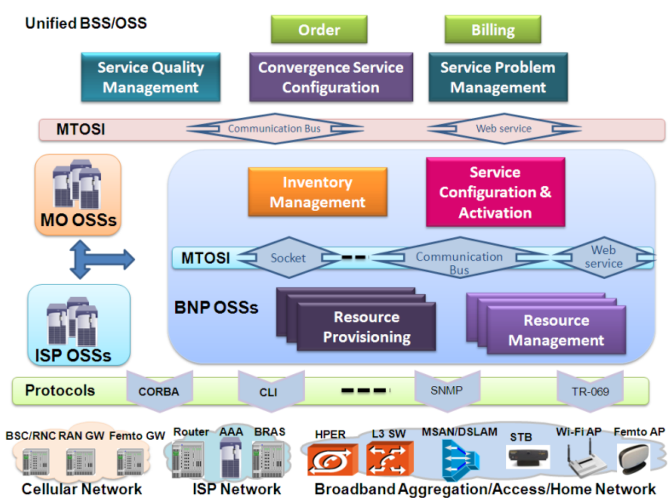

Figure 3. Management architecture of integrated networks.

B. The Automated Service Provisioning And Management

When fixed-mobile operator signs contract with the customer, the order system notifies CSC system to start the automated service provisioning and management procedures. First of all, the CSC system assigns a unique service identification (serviceID) to the service and sends corresponding service requests to all providers' SC&A system. Each provider then automatically reserves and activates the service in the corresponding network domain. As Wi-Fi and femtocell APs are deployed at home network of BNP, we illustrate the inter-provider service provisioning via the example of BNP. When BNP SC&A receives CSC request, it first sends a service query request to ISP SC&A to get the AP device's profile The BNP SC&A then starts its aggregation and access networks' service provisioning procedures. Based on the customer's location and service assurance parameters, BNP SC&A plans its service delivery path, assigns related network devices' parameters, and issues a series of provisioning requests for bundled services to resource provisioning systems [12].

To fulfill automated device management for either TR-069 based AP devices or SNMP based AP devices, the device management is a two-phase procedure. During the first phase (the service provisioning phase), the integrated systems informs BNP's APMS to pre-bind the AP information. In the second phase, integrated systems starts automatic device management operations. In the first phase, BNP SC&A will assign a unique CPE identification (CPEID) to this device and inform related systems. When the service is activated successfully by all of the providers, the order system sends a deployment order to the deployment department. According to the order information, the on-site operator assigns the CPEID to the AP device. When the installation and testing is successfully completed, a photo of the installed-location will be taken and sent to CSC system. These photos will facilitate future operational maintenance. The automated device management procedure is determined by the device's management protocol and is described as follows.

- TR-069 based device automated management

  When the newly installed access point is turned on, it informs the APMS of the authentication information including serviceID, CPEID, MAC address, and a predefined provisioningCode. Checking the predefined provisioningCode and the pre-bound CPEID, the APMS would know that it is the first time this AP requests to register. The APMS then checks whether its CPEID is legitimate or not, if true, APMS saves the device's authentication information into its database and returns the registration successful message to AP. Finally, APMS forwards the updated provisioningCode to the access point.

- SNMP-based device automated management

  For those devices without the TR-069 capability, since this kind of device can't inform APMS, integrated systems is required to provide the automatic device management function. When order system notifies CSC system that the AP device is installed successfully. The CSC system will then forwards to BNP SC&A. BNP SC&A then sends the corresponding AP template to APMS. The AP template consists of serviceID, CPEID, AP public IP address, customer information, and QoS parameters. According to the AP template, the APMS first checks if the device already exists or not. If not, it creates the AP device and its corresponding information. The APMS then checks if the AP device is reachable via the ICMP protocol. If not, the APMS issues a corresponding trouble ticket to notify its operator and SPM system. Furthermore, the APMS uses SNMP protocol to retrieve its configuration information and enables its related setting. Finally, the APMS periodically polling and monitors these AP devices.

V. RESULTS AND IMPLEMENTATION ISSUES

The proposed systems in this paper have been applied in a commercial integrated network of the largest fixed-mobile provider, Chunghwa Telecom (CHT), in Taiwan. Currently, the CHT integrated network is composed of 17,000 public hotspots. CHT has set up partnerships with site owners such as airports, cafes, hospitals, McDonalds, and retail stores. CHT has also installed Wi-Fi access points on the top of CHT's public payphones. Furthermore, CHT plans to launch femtocell services in the near future.

The traditional inter-provider service provisioning takes at least one day since the manual intervention information exchange interfaces. The proposed automated service provisioning takes about 2 minutes. The integrated and automated service provisioning significantly reduces the duration of inter-provider service delivery of the integrated networks. Furthermore, the successful rate of services provisioning is required to meet 95%. In practice the successful rate is proven to be higher than 97%.

The automated device management can be best explained via our actual deployment in 2010 Taipei International Flora Exposition (Flora Expo). The Taipei Flora Expo is composed of four beautiful parks and consists of 14 pavilions and buildings in these parks. CHT has deployed 58 Wi-Fi access points in the parks of Taipei Flora Expo. These 58 Wi-Fi APs are automatically managed via the proposed mechanism. When the service time expires (which is scheduled to be on the 26th of April, 2011), the corresponding service paths and resources will be released and APs will also be automatically removed from the APMS.

Customer Fault Summary Report						
#	Customer Name(Customer No.)	Managed # of AP	Hostspot No Response		SNMP Agent Timeout	
			Total Count	Percentage(%)	Total Count	Percentage(%)
1	7-ELEVEN(P000272)	[illegible]	[illegible]	[illegible]%	0	0.00%
6	McDonalds(P000323)	[illegible]	[illegible]	[illegible]%	0	0.00%
11	Taoyuan International Airport (P000241)	[illegible]	[illegible]	[illegible]%	[illegible]	[illegible]%
13	Taipei International Flora Expo (P000317)	58	0	0.00%	1	1.72%
16	Dante Coffee(P000117)	[illegible]	[illegible]	[illegible]%	0	0.00%

Figure 4. The fault summary report from the perspective of customer.

The proposed systems provide several types of AP summary reports, addressing the issues from the perspective of customer, management domain, and device type, respectively. As shown in Figure 4, it is a selected fault summary report from the customers' point of view. Due to the confidential issues, we blurred some information in Figure 4.

When the on-site operator needs to fix the problem, he would query the location where the AP device is installed for operational maintenance. As shown in Figure 5, the bolded circle in the ceiling depicts the location of the access point.

Figure 5. The location of the access point.

VI. RELATED WORKS

A number of papers have been published on integrated femtocell/Wi-Fi and cellular networks, most papers deal with deployment strategies, technical performance, and the capacity-coverage performance. Analysis of deployment architectures and testbeds for integrated networks is presented in [1-4]. The focus in these studies is on business deployment models from the perspective of mobile operator, operation and maintenance aspects are not covered. A detailed analysis of interworking mechanisms for WLAN and cellular integration is presented in [3]. A comparison between open and closed access is presented in [13], capacity and coverage statistics are compared in [5], and a comparison of licensed femtocell and unlicensed WiFi technologies is presented in presented in [15].

Moreover, numerous femtocell OAM schemes have been proposed and exhibit different strengths and limitations. Basically, these femtocell schemes [6,8,10] are commercial products and can achieve automated service provisioning and management for mobile operator (MO). However, the service provision and management of integrated networks are no long under the direct control of the mobile operator. Multi-domain service provisioning and management becomes indispensable. A framework, that can facilitate the integration of femtocell/Wi-Fi and cellular networks so as to satisfy multi-domain service provisioning and management for fixed-mobile providers, is missing. The contribution of this paper is in this direction. The proposed platform has been designed for contacting all business players (MO , ISP, and BNP) and being responsible for the workflows of all administrative issues. Furthermore, the proposed efficient multi-domain service provisioning and management has been followed with the goal of realizing a flexible and scalable platform that will allow the addition, removal or enhancement of devices.

VII. CONCLUDING REMARKS

Driven by the explosive growth of mobile data traffic, fixed-mobile operators usually offload mobile data traffic from cellular networks to alternative networks by utilizing Wi-Fi access points and deploying femtocells. Efficiently automated end-to-end inter-provider service provisioning is essential for the success of the integrated networks. In this paper, we have presented the business management model for the integrated networks. The proposed platform provides an unified and flexible structure for contacting all providers and is responsible for the workflows of all administrative issues such as service setup, management, and ceasing. The developed platform enables OSSs of each network domain and exchanges network capabilities. Furthermore, to reduce the involved manual operations of a myriad of access points, we have presented the automated device management for different device management protocols. The results show that the automated device management significantly shortens the duration of inter-provider service delivery from several days to 2 minutes. Finally, the proposed platform clearly overcomes the inefficiency of traditional isolated service platforms and reduces the OPEX.

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