Standardization of Femtocells in 3GPP

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ABSTRACT

Cellular system operators have identified the critical need for standardization of femtocell devices and their associated interfaces into the operators' core networks as a critical requirement for the success of femtocell products. Driven by this demand, the UMTS/UTRAN standards community has been undertaking a large-scale and comprehensive effort to specify such standards for femtocell devices and systems that are based on the UMTS/HSDPA/HSUPA family of radio access technologies. This article describes those standardization activities and provides an overview for the femtocell system architecture that has been developed within 3GPP.

INTRODUCTION

Femtocell technology began to attract widespread industry attention in late 2007 and early 2008. Cellular system operators that utilized the Universal Mobile Telecommunications System (UMTS)/UMTS terrestrial radio access network (UTRAN) third-generation (3G) radio technology were especially interested in being able to offer femtocell devices to end users and to apply femtocell technology in other environments (e.g., public hotspots, campuses, and commercial spaces) for several reasons (typically for either improved UMTS coverage or increased system capacity to satisfy the needs of large numbers of data-intensive PDAs and laptops using UMTS for packet data service). These market pressures resulted in the Third Generation Partnership Project (3GPP) undertaking an intensive effort to create a complete set of industry standards for UMTS/UTRAN femtocells. This article describes the standards that emerged from those efforts.

DRIVERS, MOTIVATION, AND IMPORTANCE OF STANDARDIZATION

Just as for any other new technology, industry standardization is a very important factor from both the market acceptance and economy of scale (i.e., ecosystem) perspectives. Femtocells are no exception. In the early days of the productization, numerous proprietary femto architectures exist (as discussed later). As is a natural process in any new technology, standardizing the key aspects of the femtocell was viewed as absolutely necessary by all key players, most notably the mobile operators. It is a required element for a new technology to obtain successful acceptance and growth in the market.

SERVICE ASPECTS

In recent years femtocells have gained momentum in the mobile industry due to their unique characteristics. Femtocells provide solutions to the problems existing macrocell-based systems have. Some of those problems include the following:

- Various studies show that the majority of mobile calls are made indoors.
- However, due to the high frequency range commonly used in the 3G system, the signal from the macrocell attenuates and deteriorates quicker once the signal reaches indoors.
- In addition, one of the fundamental characteristics of wideband CDMA (WCDMA) as a radio multiplexing access technology is that the effective cell capacity is interference-limited.
- The above implies that true 3G service, which requires high-bandwidth capacity, is available to end users only when the user is located near the cell (i.e., good signal quality), and the number of simultaneous users in the cell is small (low interference at the cell level).
- However, the above stated condition is almost contradictory to the macrocell environment.
- Therefore, in reality, this leads to a situation in which the effective data rate in the macrocell environment is only a fraction of the theoretical maximum data rate.

The solution to the above described problem requires the following characteristics:

- Good indoor signal quality
- Low number of simultaneous users per cell

It is interesting to note that the characteristics just described are both met by a femtocell. In fact, as a device that is specifically intended for small-scale indoor coverage, it is intended to solve exactly the issues described above. In addition, femtocell deployment uses existing fixed broadband technology, such as digital subscriber

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line (xDSL), as the backhaul to the mobile network. This is an attractive benefit from the mobile operator's perspective as femto deployment will lead to capital expenditure (CAPEX) and operating expenditure (OPEX) reduction.

In summary, femtocell deployment will lead to both uptake of true 3G service and reduction in CAPEX and OPEX from the operator's perspective.

Radio Technology Aspects

However, due to its unique nature, femtocells have their own unique set of problems. These problems need to be addressed by good technical solutions in order to be viable and successful in the real deployment environment.

The following are some of the problems. We discuss each of them in turn:

- Radio interference mitigation and management
- Regulatory aspects
- Location detection

Radio Interference Management

Due to its very nature, interference management of femtocells is a key issue. Femtocells will be deployed in a manner similar to WiFi access points, meaning that individual users install the devices in an ad hoc fashion in their premises without coordination with one another. Given this deployment scenario, it is practically impossible to do centralized and coordinated radio planning from the network management system as has been done in the macrocell system. Most of the radio-related configuration needs to be determined based on the unique physical environment where the femtocell is installed. For example, maximum transmit power, primary scrambling code, and UARFCN for a specific femtocell needs to be determined on a case-by-case basis in order to minimize interference with the surrounding cells (both macrocells and femtocells). It may even be required that the radio configuration be adjusted and/or changed during the course of normal operation to adapt to changes in the radio environment.

The Regulatory Aspect

Since a femtocell is in essence a small-scale cellular base station, it transmits the radio frequency (RF) using licensed spectrum. The licensed spectrum is granted by the appropriate government agency to the mobile operator who operates the system and provides service to end users. This requires that the mobile operator be responsible for the control of radio transmission in a strict manner under regulation. The femtocell system needs to include appropriate mechanisms to control this in order to meet the government's regulatory laws and regulations. This is likely to include detection and verification of the physical location where the femtocell is being installed as a part of the service authorization step during initialization.

Location Detection

Since the femtocell is an end-user customer premises equipment (CPE) device, physical installation is dependent on the owner/end user. To put it in an extreme case, it is possible to install it anywhere or move it anywhere. However, from both the regulatory and radio interference management perspectives, location detection is mandatory before the femtocell is allowed to provide service. It is likely that this process will be done at every initialization of the device.

Ecosystem Development

Another significant driving force behind the strong industry desire for femtocell standardization is the potential standards have to support the development of a healthier ecosystem for femtocell devices and the various components that comprise femtocells, and to provide femtocell technology to be embedded in other devices (e.g., DSL modems, fiber-to-the-home residential gateways, and cable modems). Standardized interfaces from the core network to femtocell devices can potentially allow system operators to deploy femtocell devices from multiple vendors in a mix-and-match manner. Such interfaces can also allow femtocell devices to connect to gateways made by multiple vendors in the system operator's core network (e.g., home NodeB gateway [HNB-GW] devices).

Perhaps even more profoundly, standards may ultimately lead to an ecosystem for key components (e.g., application-specific integrated circuits [ASICs]) of femtocell devices, such as radio components, baseband components, GPS or other location determination components, or system timing components that ensure the high degree of frequency accuracy required by advanced radio technologies. Such standards may extend beyond the typical interoperability-focused specifications (e.g., the radio interface signaling between the mobile device and the femtocell, and the communication protocols between femtocells and the system operator's core network) into areas such as application programming interfaces (APIs) between the elements of the femtocell logical architecture, electrical interfaces between those elements, and even physical requirements (e.g., dimensions and packaging). This type of standardization may be performed through various industry associations or femtocell-related industry fora; in fact, the Femto Forum is in the early stages of discussing such APIs and interfaces with hopes of finding a standardization forum that can eventually assume responsibility for the work.

History of Standardization

In the beginning of 2008 when the Femto Forum started discussion on the femto architecture, there were 15 different variations. It was viewed as absolutely necessary by participants that the common standardized architecture be defined for the success of the product in the market. In May 2008 a major milestone was achieved by the members by agreeing on a single architecture. It is based on a modified version of the existing Iu interface, adapted and customized to the unique needs of the femtocell. This agreement has led to the proposal to 3GPP that became the Iuh interface.

The licensed spectrum is granted from the appropriate government agency to the mobile operator who operates the system and provides service to end users. This requires that the mobile operator is responsible for the control of the radio transmission in a strict manner under the regulation.

3GPP terminology	Generic terminology	Definition
HNB (home NodeB)	Femtocell	The consumer premises equipment (CPE) device that functions as the small-scale nodeB by interfacing to the handset over the standard air interface (Uu) and connecting to the mobile network over the Iuh interface.
HNB-GW (home NodeB gateway)	FAP-GW (FAP Gateway)	The network element that directly terminates the Iuh interface with the HNB and the existing IuCS and IuPS interface with the CN. It effectively aggregates a large number of HNBs (i.e., Iuh interface) and presents it as a single IuCS/PS interface to the CN.
HMS (home NodeB management system)	ACS (Auto-Configuration Server)	The network element that terminates TR-069 with the HNB to handle the remote management of a large number of HNBs.

Table 1. *3G femtocell terminology.*

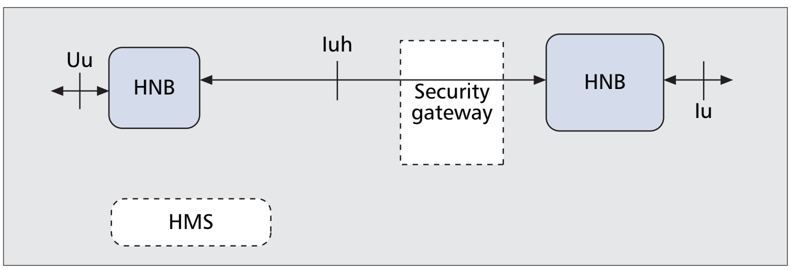


Figure 1. *Iuh reference point.*

Overview of Standards Organizations Involved in the Current Standards Work

There are two main standard development organizations (SDOs) shaping the standard for UMTS-related (UTRAN) femto technology: 3GPP and the Broadband Forum (BBF).

3GPP (http://www.3gpp.org) was created in 1999 as a partnership among SDOs around the world, chartered to harmonize the worldwide 3G WCDMA standardization efforts. The 3G specification it created, UMTS (also known as UTRAN), evolved from the Global System for Mobile Communications (GSM) system. For 3G and beyond, it has defined high-speed packet access (HSPA) to enhance both downlink and uplink capacity. For a fourth-generation (4G) system, it has completed the Release 8 specification work for Long-Term Evolution (LTE) and System Architecture Evolution (SAE).

The Broadband Forum (http://www.broadband-forum.org) was called the DSL Forum until last year. As an SDO to meet the needs of fixed broadband technologies, it has created specifications mainly for DSL-related technologies. It consists of multiple Working Groups. The Broadband Home WG in particular is responsible for the specification of CPE device remote management. The specification is called CPE wide area network (WAN) Management Protocol (CWMP), which is commonly known by its document number, TR-069.

Aside from the SDOs, there are several non-SDOs that play an important role in the standardization of femto technology. The two notable ones are the Femto Forum and Next Generation Mobile Network (NGNM).

The Femto Forum (www.femtoforum.org) is a non-standard organization established in July 2007. The membership represents mobile operators, equipment, and component vendors. Its main goal is to promote the femto technology by removing barriers for the introduction and adaptation of the product and services. As such, the Forum addresses issues common to the industry. It has proven to be an effective place to discuss and build consensus on key issues. Many of the discussions' outcomes led to joint contributions to SDOs such as 3GPP.

One of the primary examples is the consensus on the common femto architecture that eventually became the Iuh interface in 3GPP. When the Femto Forum tackled this issue in May 2008, over a dozen different proprietary architectures existed, and 3GPP had not yet started defining the standard architecture for the HNB. The discussion and subsequent consensus in the Femto Forum led to the rapid acceptance of a harmonized approach to femtocell architecture (based on the Iuh interface and the BBF TR-069 family of standards for femtocell device management). This allowed the corresponding standards to be developed on rapid schedules that were almost without precedent in 3GPP and BBF.

Another important activity is the data model definition work leading to collaboration with the BBF.

UMTS 3G Femto Standardization in 3GPP

Architecture and Terminology

In 3GPP specific terminologies are used for the femtocell. Table 1 shows the mapping and terminology definitions.

Figure 1 shows the high-level view of the HNB access network architecture and reference point. The HNB connects to the mobile network through the HNB-GW. The HNB-GW acts as a concentrator to aggregate a large number of HNBs. This interface is called Iuh. In addition, this connection goes through a security gateway (SeGW) to provide an appropriate security mechanism. Specifically, an IPsec tunnel is established and maintained between the HNB and SeGW. This means that all Iuh interface traffic is tunneled through this connection.

Connection from the HNB-GW to the core

network (CN) is done with the existing IuCS/IuPS interfaces. This implies that the HNB-GW acts as a concentrator to aggregate a large number of HNBs which are logically represented as a single IuCS/IuPS interface to the CN. In other words, from the CN's perspective, it appears as if it is connected to a single large radio network controller (RNC). This satisfies a key requirement from 3GPP system operators and many vendors that the femtocell system architecture not require any changes to existing CN systems.

The radio interface between the HNB and UE is the existing Uu interface. Essentially, the existing standard is reused unchanged, except for some minor modifications in order to accommodate HNB specific needs, such as inclusion of closed subscriber group (CSG) related information in the RRC in the Uu interface.

Iuh

Figure 2 shows the protocol stack for the Iuh interface between the HNB, SeGW, and HNB-GW.

Note: For the CN connection, both legacy asynchronous transfer mode (ATM)-based architecture or "all-IP"-based architecture exist. Only the latter is shown to keep the diagram simple.

Two new protocols were defined to address HNB-specific differences from the existing Iu interface protocol to 3GPP UMTS base stations (chiefly, RANAP at the application layer). They are shown in boxes with bold borders in Fig. 2.

- **HNB Application Protocol (HNBAP)**: An application layer protocol that provides HNB-specific control features unique to HNB/femtocell deployment (e.g., registration of the HNB device with the HNB-GW).
- **RANAP User Adaptation (RUA)**: Provides a lightweight adaptation function to allow RANAP messages and signaling information to be transported directly over Stream Control Transport Protocol (SCTP) rather than Iu, which uses a heavier and more complex protocol stack that is less well suited to femtocells operating over untrusted networks from home users (e.g., transported over DSL or cable modem connections).

Figure 3 is another representation of the protocol stack diagram being used in TS 25.467.

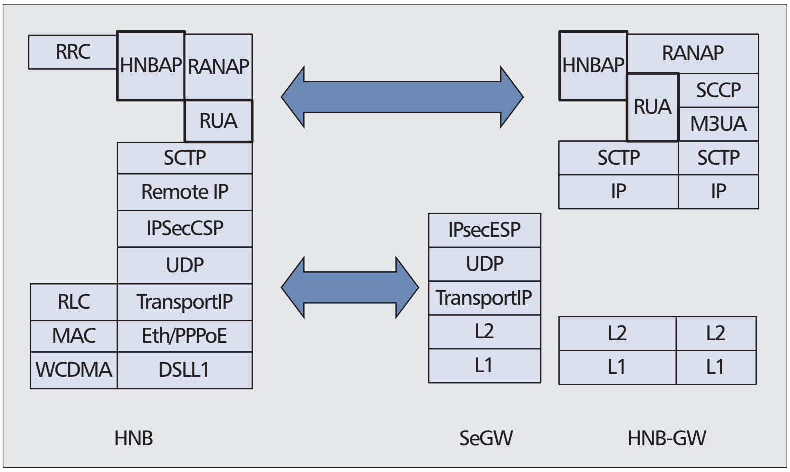


Figure 2. *Iuh interface protocol stack.*

Radio and Minimum Performance Aspects

Femtocells raise certain concerns about the potential for radio interference that are highly unique to the operating characteristics, deployment environment, management methods, and security aspects of femtocells. Considerable effort has gone into the investigation and characterization of these concerns to ensure that effective and robust solutions exist to prevent femtocells creating potentially catastrophic problems due to interactions between femtocell devices, and between femtocells and the existing (or future) macrocellular radio access networks. These activities have occurred in the Femto Forum and 3GPP RAN4 TSG, among other fora. Following these investigations, there is broad industry consensus in both fora that practical solutions exist to solve the potentially serious radio interference challenges femtocells introduce. Because femtocells must coexist with unmodified UMTS radio access networks and provide service to existing deployed mobile devices, no standards changes are possible, and none have been made.

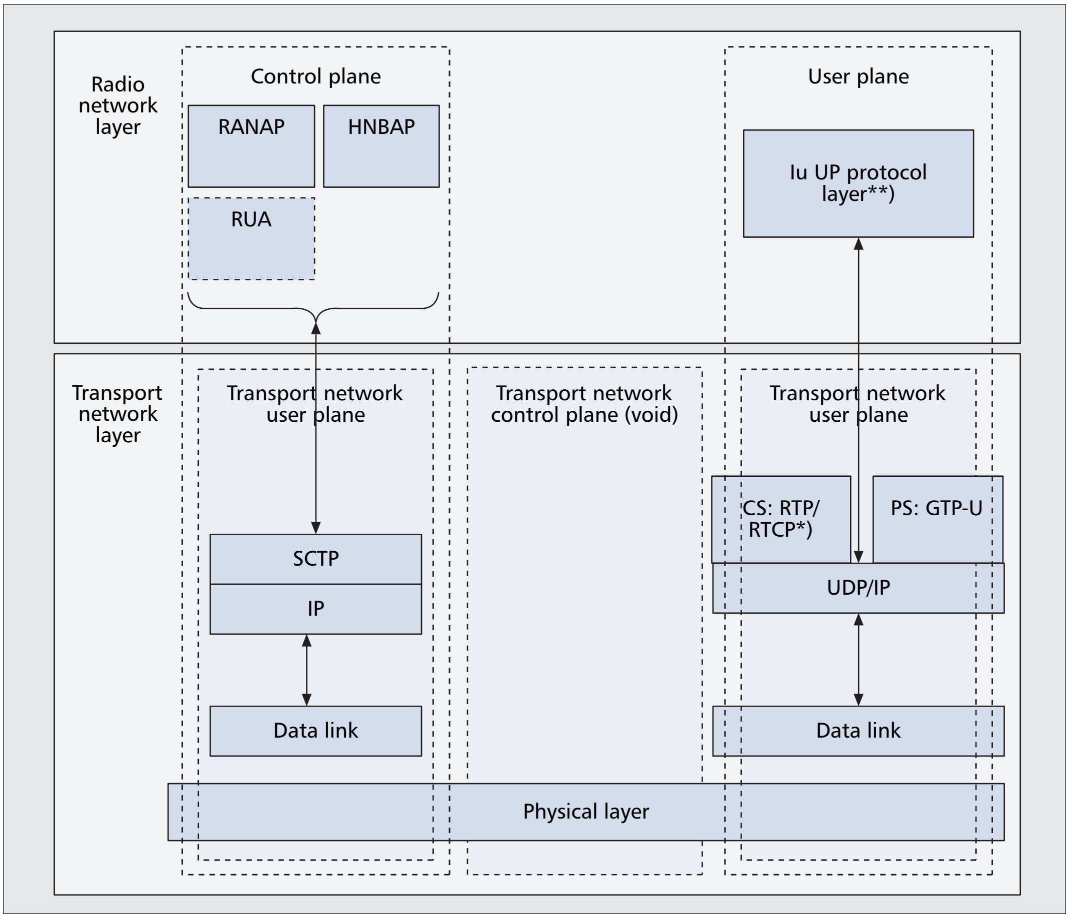
A second radio-technology-related issue is the rigorous rules that control the radio signal quality and interference aspects of devices that conform to the UMTS radio standards when they operate in licensed spectrum. These rules (sometimes referred to as *minimum performance specifications*) have generally been created from the perspective of existing macrocellular systems and deployments, and are thus inappropriate in some ways for small, generally low-power, standalone femtocell (HNB) devices that are deployed by end users in uncontrolled environments and subject to very aggressive cost targets. 3GPP RAN4 has addressed these issues and modified the minimum performance specifications to address femtocell-specific issues such as timing accuracy requirements, transmission power classes, and out-of-band emission requirements (e.g., transmission waveform masks).

Circuit and Packet Services

In the 3GPP UMTS HNB architecture, all circuit and packet services are provided via the existing CN elements using the existing interfaces and protocol stacks from the HNB-GW to the existing CN entities. Specifically, circuit services (e.g., circuit voice calling) are implemented using the existing IuCS protocol stack and packet services (e.g., IP services to support packet data applications in mobile devices) are implemented using the existing IuPS protocol stack. Collectively, IuCS and IuPS are referred to as Iu.

Security Aspects

Security for femtocell networks consists of two major parts: femtocell (HNB) device authentication, and encryption/ciphering of bearer and control information across the untrusted Internet connection between the HNB and the HNB-



■ **Figure 3.** *Iuh interface protocol stack.*

3GPP specifications have defined four types of traffic types. Given that the femtocell is being deployed using the non-dedicated fixed broadband technology such as xDSL, QoS is one of the aspects that require special attention to preserve and maintain the service quality.

GW (e.g., non-secure commercial Internet service). The 3GPP UMTS femtocell architecture provides solutions to both of these problems. 3GPP was not able to complete the standardization of security aspects in UMTS Release 8; however, the basic aspects of the architecture were agreed on, and were partially driven by broad industry support for a consensus security architecture facilitated in discussions within the Femto Forum. All security specifications will be completed in UMTS Release 9 (targeted for the end of 2009).

HNB Device Authentication

HNB devices always have a globally unique identifier (HNB-ID) and security credentials that allow mutual authentication between the HNB and the SeGW that serves as a point of access into the HNB system operator's CN. Mutual authentication is performed using X.509 certificates that are configured in the HNB and HNB-GW. Furthermore, HNB devices may also have an optional UICC (similar to a SIM card in GSM and UMTS mobile devices) that defines a secondary hosting party ID and provides its own secure authentication. The HNB and HNB-GW use the Internet Engineering Task Force (IETF) IKEv2 protocols to perform mutual authentication of the HNB and HNB-GW, and to (optionally) perform secondary authentication of the hosting party ID between the HNB-GW and the UICC in the HNB.

Encryption/Ciphering

Encryption over the IP transport network between the HNB and HNB-GW is performed using IETF IPsec protocols following the IKEv2 HNB device and (optional) hosting party authentication procedures.

3GPP is presently investigating methods to secure the HNB device itself as well as the computing environment, but the final architecture and specific protocols have not yet been agreed on by the standards community.

QoS

3GPP specifications have defined four traffic types (conversational, streaming, interactive, and background). Given that the femtocell is being deployed using non-dedicated fixed broadband technology such as xDSL, QoS is one of the aspects that require special attention to preserve and maintain service quality.

Specifically, the uplink direction from the femto to the mobile network is the primary focus in this area given the fact that the fixed broadband technologies are typically asymmetrical in link capacity, and the uplink is usually the one with less capacity. In addition, the broadband link will likely share both femto and non-femto traffic. In this respect, the QoS scheme in the uplink direction needs to be carefully designed to preserve the QoS of mobile traffic (through the femtocell) as well as that of fixed traffic.

MANAGEMENT

Management of the femtocell is one of the main characteristics that represent a radical departure from the existing mobile network. From an architectural perspective, the femtocell is a logical extension of the mobile network and thus can be considered within the existing mobile network infrastructure management paradigm. However, the femtocell itself shares many characteristics of residential consumer CPE devices. Therefore, adjustments will be needed for femto management.

Specifically, a mobile operator no longer has a dedicated backhaul from the femtocell itself to the mobile access network; it is physically installed and operated on the end user's premises; the physical device is no longer under the direct control of the mobile operator. In addition, if the broadband service is provided by a third operator (i.e., another Internet service provider [ISP]), the operation and management of the broadband link may well be outside the control of the mobile operator. This represents a situation the mobile operators have not previously dealt with in order to operate and manage the network.

For residential CPE device management, the fixed broadband industry has already defined a standardized remote management mechanism. The BBF has created CWMP, also referred to as TR-069 [1]. TR-069 defines a generic framework to establish connection between the CPE and the automatic configuration server (ACS) to provide configuration of the CPE. The messages are defined in Simple Object Access Protocol (SOAP) methods based on XML encoding, transported over HTTP/TCP. It is flexible and extensive enough to incorporate various types of CPE devices using various technologies. In fact, although TR-069 was originally created to manage the DSL gateway device, it has been adopted by many other types of devices and technologies.

The fundamental functionalities TR-069 provides are as follows:
- Auto-configuration of the CPE and dynamic service provisioning
- Software/firmware management and upgrade
- Status and performance monitoring
- Diagnostics

The auto-configuration parameters are defined in a data model. Multiple data model specifications exist in the BBF in order to meet the needs of various CPE device types. In fact, the TR-069 data model is a family of documents that has grown over the years in order to meet the needs of supporting new types of CPE devices that emerge in the market. In this respect, femtocell is no exception. However, the two most common and generic data models are:
- TR-098: "Internet Gateway Device Data Model for TR-069" [2]
- TR-106: "Data Model Template for TR-069-Enabled Devices" [3]

TR-098 is the data model for the DSL gateway device, and TR-106 is for the other generic CPE devices that are connected to the TR-098 device. In other words, TR-106 is a template that defines the common minimum set of parameters that is to be used for any type of CPE device connected to the DSL gateway that terminates the xDSL connection.

The femtocell access point (FAP) data model is called TR-196 [4]. It is based on TR-098 in order to take advantage of some of the advanced features not available in TR-106. The parameters in TR-196 cover configuration management, status management, fault management, and performance management.

SPECIFICATION OVERVIEW

Table 2 shows the 3GPP documents (both Technical Specifications [TS] and Technical Reports [TR]) relevant to the 3G HNB. The version numbers below are the latest as of this writing and reflect the latest state in the respective WGs. All WGs in the table have either completed the 3G HNB work for Release 8 or are in progress for Release 9.

LOCAL IP ACCESS

3GPP is currently working on the system requirements for this capability, and it is anticipated that these features will be included in 3GPP Release 10 specifications (2010 time frame).

HAND-IN AND FEMTO-TO-FEMTO HANDOVER

The 3GPP specifications focused on handovers in only one direction initially — from femtocell devices to the macrocellular system (sometimes called *handout*). A conscious decision was made to exclude handover from the macrocellular system to the femtocell devices (sometimes called *macro to femtocell hand-in*). This decision was driven by two factors:
- There are a number of technical challenges in supporting hand-in with unmodified mobile devices and core network components.
- The system operator requirements clearly indicate that supporting handout is much more important to end users. Nonetheless, there is still a strong desire to develop open, interoperable ways to support hand-in in an efficient and reliable manner, and the second phase of standards in 3GPP is anticipated to support such a capability.

PUBLIC SPACES AND ENTERPRISE

System operators of many different radio technologies have indicated a strong interest in supporting the operation of femtocell devices in public spaces, in business in-building applications (enterprise), and in other environments where traditional macro systems have coverage limitations or are inappropriate, among various reasons. This may require specifications to define higher femtocell power classes, enhancements to the services femtocells can support, improved support for handover between macro systems and femtocells and between two femtocells, enhancements to auto-configuration procedures, enhancements to system selection and access control procedures, and so on. 3GPP is expected to address a work item in these areas for its second-phase femtocell specification development efforts (Release 9).

For the residential CPE device management, the fixed broadband industry has already defined a standardized remote management mechanism. Broadband Forum has created CWMP, which is often referred to by its document number: TR-069.

WG	TS/TR #	Version	New	Document title
	TS25.331	8.5.0	N	RRC
RAN2	TS25.367	8.0.0	Y	Mobility Procedures for Home NodeB (HNB); Overall Description; Sage 2
	TS36.300	8.7.0	N	E-UTRA and E-UTRAN; Overall Description; Stage 2
RAN3	TS25.467	8.0.0	Y	UTRAN Architecture for 3G Home NodeB; Stage 2
	TS25.469	8.0.0	Y	UTRAN Iuh Interface Home NodeB (HNB) Application Part (HNBAP) Signaling
	TS25.468	8.0.1	Y	UTRAN Iuh Interface RANAP User Adaption (RUA) Signaling
	TR3.020	0.9.0	Y	Home (e)NodeB; Network Aspects
RAN4	TS25.104	8.5.0	N	Base Station (BS) Radio Transmission and Reception (FDD)
	TS25.141	8.5.0	N	Base Station (BS) Conformance Testing (FDD)
	TR25.967	1.0.0	Y	FDD Home NodeB RF Requirements
SA1	TS22.011	8.7.0	N	Service Accessibility
	TS22.220	1.0.1	Y	Service Requirements for Home NodeB (HNB) and Home eNodeB (HeNB)
SA2	TR23.830	0.3.1	Y	Architecture Aspects of Home NodeB and Home eNodeB
	TR23.832	0.2.0	Y	IMS Aspects of Architecture for Home NodeB; Stage 2
SA3	TR33.820	1.3.0	Y	Security of H(e)NB
SA5	TR32.821	1.0.1	Y	Telecommunication Management; Study of Self-Organizing Networks (SON) Related OAM Interfaces for Home NodeB
	TS32.581	8.0.0	Y	Telecommunications Management; Home Node B (HNB) Operations, Administration, Maintenance and Provisioning (OAM&P); Concepts and Requirements for Type 1 Interface HNB to HNB Management System (HMS)
	TS32.582	8.0.0	Y	Telecommunications Management; Home NodeB (HNB) Operations, Administration, Maintenance and Provisioning (OAM&P); Information Model for Type 1 Interface HNB to HNB Management System (HMS)
	TS32.583	8.0.0	Y	Telecommunications Management; Home NodeB (HNB) Operations, Administration, Maintenance and Provisioning (OAM&P); Procedure Flows for Type 1 Interface HNB to HNB Management System (HMS)
	TS32.584	n.y.a.	Y	Telecommunications Management; Home NodeB (HNB) Operations, Administration, Maintenance and Provisioning (OAM&P); XML Definitions for Type 1 Interface HNB to HNB Management System (HMS)

Table 2. *3GPP 3G HNB specification overview.*

Security Aspects

Due to schedule constraints, 3GPP was not able to complete this work; it is expectedto be completed in 3GPP Release 9 (by the end of 2009).

Services

IMS-Based Femto Architectures

3GPP2, driven by carrier requirements, has determined that legacy voice/circuit services for femtocells can best be provided using a Session Initiation Protocol (SIP)/IP multimedia subsystem (IMS)-based CN architecture with the SIP user agent in the FAP device itself. In contrast, the 3GPP femtocell (HNB) architecture implements optimized versions of the existing RAN to CN interfaces (i.e., Iuh, which is based on IuPS and IuCS, or the packet and circuit domains, respectively).

Some interest has arisen in defining how the 3GPP femtocell architecture for legacy (3G UTRAN) devices can evolve to integrate better with IMS CNs. This activity is being initiated as part of 3GPP's Release 9. The definition of this architecture is in a fairly early stage.

One major difference between the 3GPP2 and 3GPP IMS-based femtocell architectures is likely to be the location of the SIP user agent. In the case of 3GPP, the advanced progress or the Iu-based Iuh interface from the FAP (HNB) to the FGW (HNB-GW) may make it less attractive to modify the Iuh protocol or incorporate a SIP user agent in the HNB itself. Alternatively, it seems likely that the SIP User Agent function may be more appropriately implemented in a gateway function in the HNB-GW or possibly elsewhere in the core network to serve as a bridge between the legacy Iuh-based femtocell access network and the IMS core network. These architectural issues require further study and will be completed as part of 3GPP's Release 10 work efforts.

4G Efforts

Given the enormous installed bases of 3G cdma2000 and UMTS/UTRAN mobile devices and networks, it is obvious that the initial priority for standardization efforts for femtocells was to focus on 3G radio technologies. Given the major advances in the 3G femtocell standardization activities in 3GPP and 3GPP2, much of the effort for the next phase of standards can now be applied to enhancements for 4G femtocells, particularly for LTE, which is the designated evolution path for many 3GPP and 3GPP2-based system operators.

3GPP Work on LTE for R9 and Beyond

3GPP Release 8 defines the over-the-air radio signaling that is necessary to support LTE femtocells. However, there are a number of RAN transport and core network architecture, interface, and security aspects that will be addressed as part off 3GPP's Release 9 work efforts. While it is preliminary as of the publication of this article, it seems highly likely that all necessary RAN transport and core network work efforts for LTE femtocells will be completed in 3GPP Release 9 (targeted for completion by the end of 2009).

Conclusion

3GPP has undertaken a large effort on an aggressive schedule to define industry standards for all of the essential aspects of UMTS/UTRAN-based femtocells. The commitment by system operators and vendors to complete this critical work as part of UMTS Release 8 has provided the basis for the robust commercialization of open interoperable femtocell products and femtocell core network components. Looking forward, these efforts will expand to address new capabilities (such as "local breakout" of IP traffic at the femtocell device) and new radio technologies such as LTE.

References

[1] BBF TR-069, "CPE WAN Management Protocol, Issue 1, Amendment 2," 2007.
[2] BBF TR-098, "Internet Gateway Device Data Model for TR-069, Issue 1 Amendment 2," 2008.
[3] BBF TR-106, "Data Model Template for TR-069-Enabled Devices, Issue 1 Amendment 2," 2008.
[4] BBF TR-196, Femto Access Point Device Data Model," 2009.

Biographies

Douglas Knisely (dknisely@airvana.com), vice president of technology for Airvana, Inc., is an industry leader in all aspects of femtocell standardization, and is active in a broad range of fora including 3GPP, 3GPP2, and the Femto Forum (for which he is currently a board member). He has been heavily involved in all aspects of 3GPP2 femtocell requirements, architecture, and detailed specifications. He has also been a key contributor to early Femto Forum activities and 3GPP standardization activities to define Iuh and HNB management architecture in 3GPP RAN and SA working groups. Prior to femtocell work, Doug was a leading contributor to the 3GPP2 cdma2000 family of standards from its inception. For a number of years, he served as the chair for the development of all EV-DO standards above the physical layer. He has also served as chair of the MAC group for the 3G1X air interface from IS-95-A through Release D of 1xRTT. He was one of the key authors of the initial 3GPP2 ITU RTT proposal for cdma2000 and chaired the initial decision criteria team for selecting among IS-2000 Revision 0 component technology proposals. In the past he was a lead wireless data standards representative for Lucent Technologies, and he led system architecture efforts for AT&T Computer Systems' StarServer family of symmetric multiprocessor systems, specializing in I/O and data communications system architecture.

Takahito Yoshizawa (Taka.Yoshizawa@thomson.net) is a system architect for Thomson Telecom, Belgium, where he is currently focusing on the standardization of femtocells. He is the author/editor of the Femto Access Point Data Model document known as TR-196 published by the BBF, and has contributed to both 3GPP RAN3 and SA5 in the HNB standardization in Release 8. He continues to contribute on the Release 9 HeNB. Recently, he received the inaugural Femto Forum Industry Award in recognition of his contributions and the pivotal role he has played in the femtocell management specifications by working through the Femto Forum, 3GPP, and BBF. From 1992 to 2006 he worked in the Cellular Infrastructure organization of Motorola in the United States. During that period he developed his expertise in the engineering work on the complete product life cycles of 2G and 3G infrastructure products, including next-generation architecture and design, requirement specifications, software development, testing and integration, and commercial system deployment and support functions. He received his M.S. degree in telecommunications from Southern Methodist University in 2002 and his B.S. degree in information and computer science from Georgia Institute of Technology in 1992. He has several patents pending in both the United States and Europe.

Frank Favichia (f2@alcatel-lucent.com) is a DMTS in the Alcatel-Lucent Wireless CTO Office. He has over 29 years of engineering and business experience in forward looking technology development, systems development, systems integration, and network operations for public network wireline and wireless systems. He has experience in the direct management of cross-organizational engineering and product management teams responsible for technology development, systems architecture, systems engineering, software development, and product management functions. His expertise is in signaling systems, data network protocols, call processing, and operation and management systems for commercial grade public network elements. He was lead architect for the Alcatel-Lucent EVDO commercial system, wireless data, and VoIP technology. His current responsibilities are focused on fixed-mobile network convergence for 3GPP-TiSPAN-cable systems with integrated femto technology. He has a Master's degree in computer science from the State University of New York at Brockport and holds several patents (and several applications).

The commitment by system operators and vendors to complete this critical work as part of UMTS Release 8 has provided the basis for the robust commercialization of open, interoperable femtocell products and femtocell core network components.