White Paper

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Iuh: A Protocol Solution for Scaling Femtocells

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Overview

The initial euphoria surrounding femtocells has given way to pragmatism in order to identify and knock down real-world deployment barriers such as RF interference, business cases for consumers/operators/vendors, scaling the technology to support millions of Femtocell Access Point (FAP) units worldwide, enabling "plug-and-play" solutions, etc.

CONTENTS

In a previous paper, *Femtocell Network Architecture* and Signaling Protocol Options [1], we had listed various signaling protocol options to realize a femtocell network solution at the Fa interface, illustrated in Figure 1. 3GPP and Femto Forum worked closely to identify tunneled-Iu as the preferred signaling protocol solution for Universal Mobile Telecommunication System (UMTS) networks. To this end, Femto Forum members worked closely with 3GPP to define the Iuh (Iu home) interface between a FAP and a Femto Gateway (FGW).

This paper focuses on signaling protocol solutions identified and defined to scale femtocells to millions of units of deployment worldwide. In particular, the paper describes and analyzes the control and data plane operations of a femtocell network with respect to the Iuh interface and protocols. Note that throughout the paper, the terms FAP and Home NodeB (HNB) are used interchangeably, as are the terms FGW and Home NodeB Gateway (HNB-GW).

Iuh Interface Overview

Figure 2 illustrates the tunneled-Iu or Iu-over-IP approach for UMTS networks using existing UMTS protocols. In fact, most first generation UMTS Femtocell solutions will implement the signaling protocol illustrated in Figure 2. While this is an evolutionary and the least intrusive means of adding femtocell capability to the network, it does have certain limitations:

1. The current Iu interface is not scalable to support millions of HNBs (one for each femtocell-capable home/enterprise) that are going to attach to core network (CN) elements such as the Mobile Switching Center (MSC). The SS7 emulation provided by Signaling Connection Control Part (SCCP) running over Message Transfer Part 3 User Adaptation (M3UA) protocol using underlying Internet Protocol (IP) networking does not provide enough addressing capability (i.e., point codes) to support millions of HNBs.

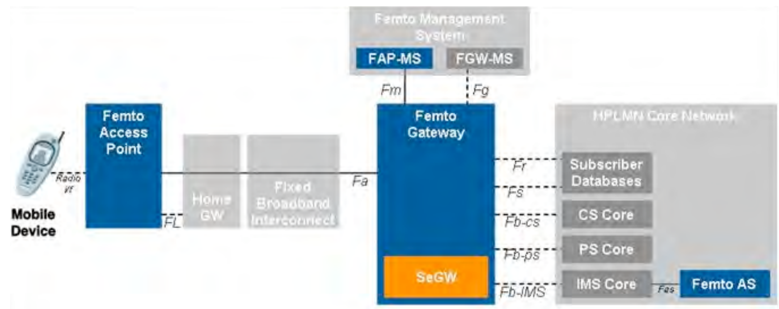

Figure 1. *Femtocell Reference Model (Source: Femto Forum)*

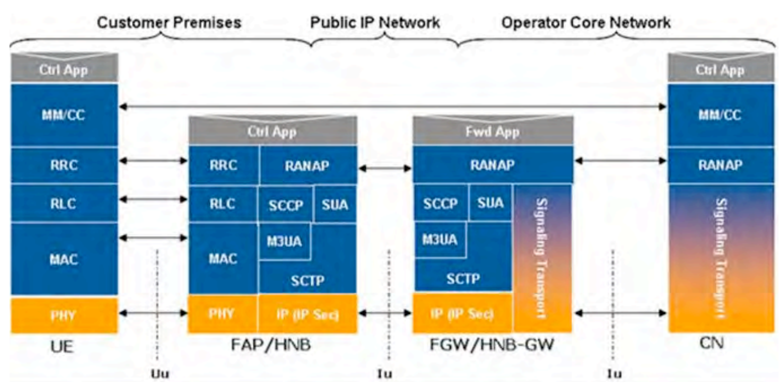

Figure 2. *Signaling Protocol Stack for Iu-Over-IP Approach*

2. In a femtocell network, because an HNB is a customer premise device it is possible that it will be powered on only when the femto subscriber wants to use femtocell services. This means that an HNB may dynamically join and depart from the network, similar to the subscriber's user equipment (UE). So, we need an HNB registration and de-registration procedure in addition to UE registration and de-registration, which is not supported by existing UMTS protocols.

3GPP has overcome these limitations by eliminating SS7 emulation between the HNB and the HNB-GW and defining a new interface called Iuh, which introduces two new protocols—HNB Application Part (HNBAP) and RANAP User Adaptation (RUA)—as shown in Figure 3. The following subsections give a brief overview of these protocols.

Home NodeB Application Part (HNBAP)

HNBAP provides the signaling service between the HNB and the HNB-GW for HNB (De)Registration (to register/deregister the HNB with the HNB-GW to enable the HNB-GW to provide service and core network connectivity for the HNB), UE (De)Registration (for HNB to convey UE identification data to the HNB-GW in order to perform access control for the UE in the HNB-GW), and error handling.

Figure 4 illustrates message flows for HNBAP. The HNB initiates its registration with the HNB-GW over an SCTP association using an HNB REGISTER REQUEST message. In this procedure, it provides its identifier, location information, and cell information. After the HNB-GW authenticates the HNB, it accepts its registration using an HNB REGISTER ACCEPT message and passes on the Radio Network Controller Identifier information. If the HNB-GW cannot authenticate the HNB, or if there is any error, HNB registration is rejected using an HNB REGISTER REJECT message.

Once the HNB is registered, the HNB initiates UE registration using a UE REGISTER REQUEST message. In this procedure, it provides the UE Identifier and in return gets a UE REGISTER ACCEPT from the HNB-GW (if the authentication/registration is successful) along with the Context ID for this UE. The UE registration request is rejected (if authentication is not successful or due to some other error condition) using a UE REGISTER REJECT message.

The HNB and UE are De-registered using HNB DE-REGISTER and UE DE-REGISTER messages respectively. At the time of de-registration of the UE, Iu connection context is also deleted. De-registrations could be initiated either by the HNB or the HNB-GW. An ERROR INDICATION message is used to flag errors in either direction.

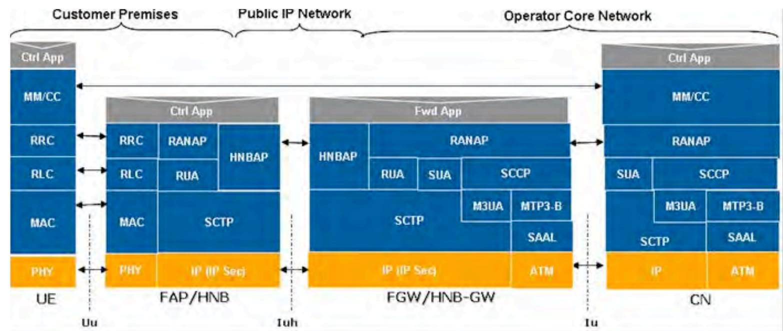

Figure 3. *Iuh Control-Plane Signaling Protocol Option 1 (Full RANAP Processing at HNB-GW)*

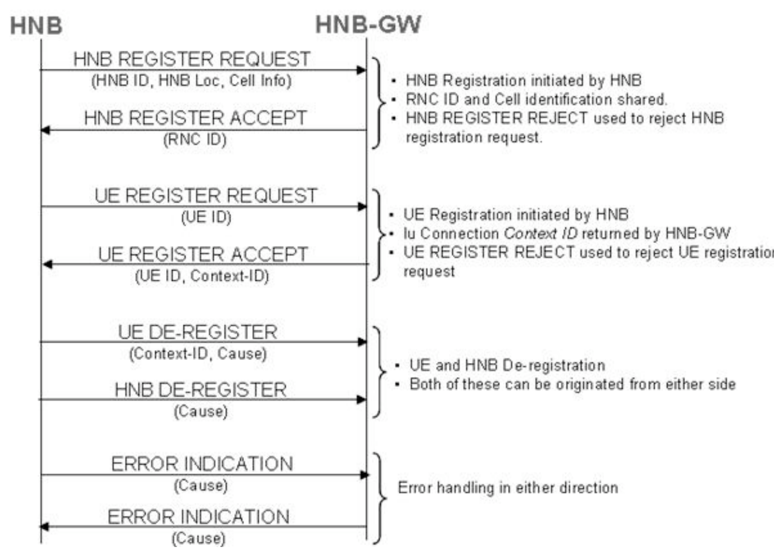

Figure 4. *HNBAP Message Flows*

RANAP User Adaptation (RUA)

RUA provides the signaling service between the HNB and the HNB-GW primarily to transport RANAP messages transparently. Key functionalities supported by RUA includes setting up and deleting RANAP Iu connections over the Iuh interface, transferring RANAP messages associated with the Iu connections, transferring connectionless RANAP messages, and error procedures.

Figure 5 illustrates the message flows between the HNB and the HNB-GW. CONNECT and DIRECT TRANSFER messages are used to set up Iu connection context using the Context-ID, which is obtained during the UE registration procedure executed by HNBAP. The Iu signaling connection can be disconnected by either the HNB or the HNB-GW using a DISCONNECT message. CONNECT and DISCONNECT messages are overloaded to carry initial and last Iu RANAP messages respectively. DIRECT TRANSFER messages are used in either direction to carry RANAP messages transparently on the Iuh interface using Context-ID to associate the RANAP messages with Iu signaling connections. CONNECTIONLESS TRANSFER is used to carry connectionless Iu messages transparently over the Iuh interface in either direction. An ERROR INDICATION message is used for error flagging in either direction.

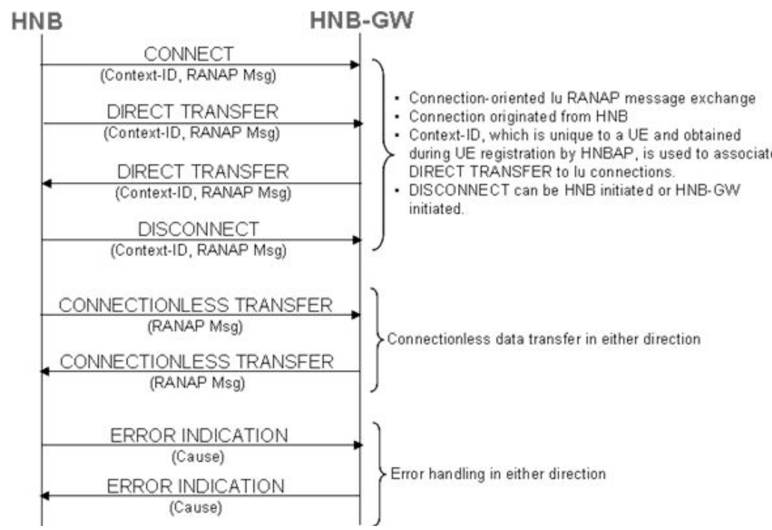

Figure 5. *RUA Message Flows*

Protocol Implementation Choices

The following subsections analyze control plane and data plane protocol implementation options specifically focused on HNB-GW protocol flows.

Control Plane

On the control plane, the critical aspect to consider is how RANAP messages are handled at the HNB-GW, i.e., whether the HNB-GW acts as a simple concentrator passing RANAP messages silently onto the CN (illustrated in Figure 6) or whether the HNB-GW does intelligent processing of RANAP messages and relays the RANAP message (illustrated in Figure 3) after decoding/encoding it. Another minor aspect to consider would be whether the HNB-GW is connected to the CN using ATM infrastructure or IP infrastructure. In the case of ATM infrastructure, Broadband SS7 is used as signaling transport, and in the case of IP infrastructure, SIGTRAN (i.e., SUA with SCTP or SCCP with M3UA ® SCTP) is used as signaling transport between the HNB-GW and the CN.

Table 1 compares both of these options. In both cases, RAB Establishment messages need to be decoded in order to map the port numbers used by the CN and the HNB at the HNB-GW. In case of traditional CN, the HNB-GW has to map the packets from the IP network to the ATM network (using AAL2).

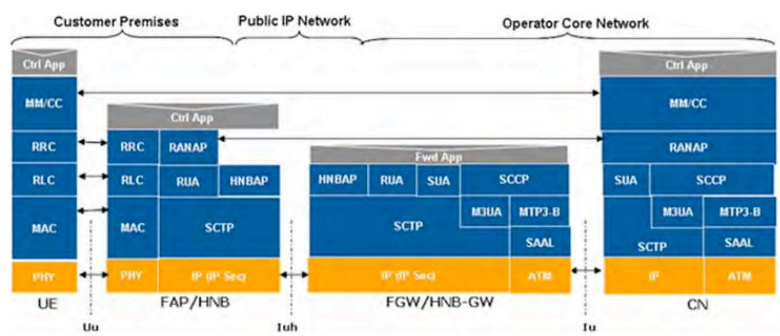

Figure 6. *Iuh Control Plane Signaling Protocol Option 2 (Limited RANAP Processing at HNB-GW)*

	Advantages	Disadvantages
Option 1: Full RANAP Processing	• Simple HNB-GW application, can utilize the existing RANAP implementations • HNB-GW application just relays RANAP message coming on the RUA/Iuh interface to a SIGTRAN or Broadband SS7 interface.	• All RANAP messages need to be decoded and encoded at the HNB-GW, thereby consuming processing headroom.
Option 2: Limited RANAP Processing	• Full RANAP protocol implementation not required at HNB-GW, thereby relaxing processing headroom at the HNB-GW.	• HNB-GW application becomes a bit more complicated due to the need for: o Partially decoding RANAP messages for routing; all connectionless messages will have to be decoded. o Some Iu connection states to be maintained in the HNB-GW application.

Table 1. *Iuh Control Plane Signaling Protocol Option Comparison*

Data Plane

On the data plane, the critical aspect to consider is whether the HNB-GW maintains RTP (for Circuit Switched (CS) or voice calls) or GTP-U (for Packet Switched (PS) or data calls) sessions (illustrated in Figure 7), or whether it acts as a transparent tunnel (illustrated in Figure 8) for these packets encapsulated within IP packets. Table 2 compares both of these options.

In case of RTP/GTP-U tunneling (illustrated in Figure 8) at the HNB-GW, tunneling is achieved using (1) IP routing with Network Address Translation (NAT) to convert the source IP address of RTP packets at the Iuh interface to the IP address at the Iu interface or vice-versa and stripping/adding IPsec header information, or (2) IP-in-IP encapsulation/de-capsulation by removing the outer IP header and forwarding in the downlink (HNB-GW to HNB) direction or adding the outer IP header and forwarding in the uplink (HNB to HNB-GW) direction. This option requires the HNB-GW to maintain a mapping of Iuh user plane sessions (IP address + Port) to Iu user plane sessions (IP address + Port).

In case of RTP/GTP-U processing (illustrated in Figure 7) at the HNB-GW, the HNB-GW application (1) creates and maintains an RTP/GTP-U session toward the HNB, and (2) creates and maintains an RTP/GTP-U session toward the CN (in the case of ATM transport, it creates and maintains AAL-2 sessions toward the CN). It also maintains a mapping between these two sessions to switch the packets. In this scenario, the HNB-GW is RTP/GTP-U session-aware on both the Iuh and Iu interface. Note that this scenario could add delay due to bearer traffic processing.

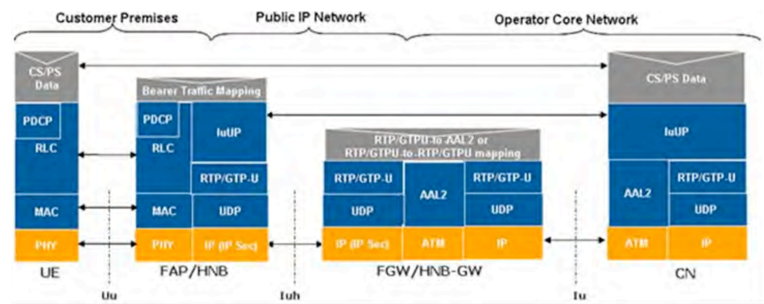

Figure 7. *Iuh Data Plane Protocol Option 1–RTP/GTP-U Processing at HNB-GW*

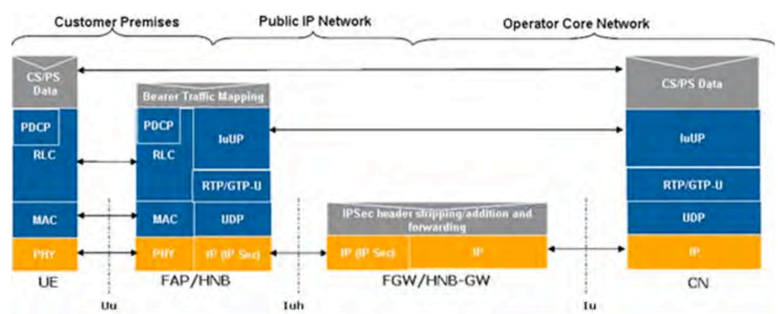

Figure 8. *Iuh Data Plane Protocol Option 2–RTP/GTP-U Tunneling at HNB-GW*

	Advantages	Disadvantages
Option 1: RTP/GTP-U Processing	• RTP multiplexing (or alternatively UDP multiplexing, IP multiplexing) can be used in the Iu and Iuh interfaces, thereby increasing efficient use of IP bandwidth.	• HNB-GW application needs to maintain RTP/GTP-U session context. For this, RAB assignment messages need to be decoded at the HNB-GW which means the RANAP messages need to be decoded and handled at the HNB-GW. • Processing of all RTP/GTP-U PDUs eats into processing headroom, thereby limiting data throughput and potentially adding delay.
Option 2: RTP/GTP-U Tunneling	• No RTP/GTP-U packet processing required at the HNB-GW, thereby helping increase throughput and reduce delay.	• Cannot use RTP/GTP-U multiplexing (or alternatively UDP multiplexing, IP multiplexing) in the Iu or Iuh interface.

Table 2. *Iuh Data Plane Protocol Option Comparison*

End-to-End Control Plane Information Flow

This section briefly explains the end-to-end signaling information flow to successfully establish a mobile-originated voice (CS) call, as illustrated in Figure 9.

Once the UE is powered on, it will establish an RRC connection with the HNB. After RRC connection establishment, the UE will send the CM SERVICE REQUEST message embedded in the RRC DIRECT TRANSFER message to the HNB. The HNB buffers this UE message and tries to register this UE with the HNB-GW using HNBAP's UE REGISTER REQUEST message, in order to contact the CN (here MSC node) via the HNB-GW.

After successful UE registration with the HNB-GW, the HNB will send the buffered UE message (CM SERVICE REQUEST) to the HNB-GW using the CONNECT message of the RUA protocol. After receiving this CONNECT message, the HNB-GW will establish an SCCP connection (using the SCCP or SUA protocol) with the CN; this is the normal Iu Connection establishment from the RNC to the CN. Once the SCCP connection is established, the HNB-GW passes on the RANAP message on the established Iu Connection. The HNB-GW maintains the mapping between the context Id (sent to the HNB in the UE REGISTER ACCEPT message) and the Iu signaling connection identifier.

At this point the HNB-GW passes on the UL/DL DIRECT TRANSFER messages from the CN to the HNB using the DIRECT TRANSFER message of the RUA and RRC protocols. The CN will respond to the UE with CM SERVICE ACCEPT to continue with signaling. After the authentication and ciphering of the UE, the CN will try to establish the bearers required for this call using the RAB Assignment procedure of RANAP by giving the necessary QoS parameters to the HNB. The HNB will establish the Radio bearers using the QoS parameters obtained from the RAB ASSIGNMENT REQUEST.

Figure 9. *End-to-End Signaling for Mobile-Originated Voice Call*

Note: HNB-GW will process the RAB ASSIGNMENT REQUEST message from the CN and obtain the bearer transport parameters, i.e., IP Addresses and port numbers in the current call scenario. Depending on the implementation choice of the bearer processing as explained in the "Data Plane" section, these transport parameters are utilized by the HNB-GW either for RTP tunneling or for RTP processing.

Once Radio Bearer establishment with the UE is successful, it will send the RAB ASSIGNMENT RESPONSE all the way to the CN, at which point the CN will alert the UE and the UE will send a CONNECT message to the CN. The CN will acknowledge it with a CONNECT ACKNOWLEDGE message, and with this the voice call is established with the required bearers.

Summary

The 3GPP-defined Iuh protocols, HNBAP and RUA, simplify the protocol operations required to setup and tear down CS/PS bearer traffic context at the Iuh interface. This approach also enables the scaling of existing core network infrastructure to support the millions of HNB/FAPs projected to be deployed in the next couple of years. The definition of these protocols comes at an opportune time in the rapid evolution of femtocells and should help be a catalyst to drive femtocell technology into mainstream adoption.

References

[1] Femtocell Network Architecture and Signaling Protocol Options, V. Srinivasa Rao & Ravi Raj Bhat, Apr 2008.

[2] UTRAN Architecture for 3G Home NodeB, 3GPP TS 25.467, Dec 2008.

[3] UTRAN Iuh Interface RANAP User Adaptation (RUA) Signaling (Release 8), 3GPP TS 25.468 v8.0.0, Dec 2008.

[4] UTRAN Iuh Interface Home NodeB Application Part (HNBAP) Signaling (Release 8), 3GPP TS 25.469 v8.0.0, Dec 2008.

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