Interworking of Wimax and 3GPP Networks based on IMS

Fangmin Xu, Luyong Zhang, and Zheng Zhou, Beijing University of Posts and Telecommunications

ABSTRACT

The 3GPP specifies the IP multimedia subsystem (IMS) to provide several kinds of multimedia services in UMTS Release 5 and later releases. Interworking at the service layer between 3GPP and Wimax networks requires interworking between IMS functionality. By studying several interconnection scenarios and the main functionality of IMS, this article analyzes how the interworking of 3GPP and Wimax networks can be performed to support different levels of service interconnection. Special attention is paid to the interconnection at the session negotiation level, using SIP (the base protocol of the IMS), COPS/Go, and Diameter protocols/interface to provide session negotiation with QoS and AAA (authentication authorization accounting) support.

INTRODUCTION

Future mobile communication networks are evolving from traditional circuit-switched architectures to an ALL-IP based structure. It is suggested that these mobile networks will be integrated by a high-bandwidth IP-based core network and a variety of heterogeneous wireless access technologies such as universal mobile telecommunications system (UMTS) or Wimax. Mobile terminals will be able to access different multimedia applications and advanced services while roaming across zones covered by different access technologies. The wireless research community is investigating new ways to facilitate interworking between these technologies. Currently, the Third Generation Partnership Project (3GPP) is developing a feasibility study on providing seamless service continuity between UMTS and WLAN (wireless local area network) [1].

Interworking can be viewed from different aspects. Perhaps the most important aspect is the session negotiation level, which provides service continuity from the user perspective. At this level, the protocol used by the 3GPP is Session Initiation Protocol (SIP) [2], which is the foundation of the IP multimedia subsystem (IMS) architecture defined to support real-time multimedia services in future mobile networks. Interworking between SIP-based networks may present various problems caused by one of the main features of this protocol, extensibility. Most of these problems are discussed in this article.

The levels of interworking and convergence may be classified into convergence of service, network, and technique. The goal of service convergence is to share a service system based on interworking. Providing a uniform service experience for users, through a uniform service system, would enable customers to use different terminal devices to access heterogeneous networks, to access the same service, and to achieve common billing and session management. Service convergence is only the first step of the convergence. Seamless roaming and handoff between different networks is the problem that must be solved by network convergence. There are significant differences between the PHY technique of 3GPP and Wimax. These are beyond the scope of the discussion for this article.

The remainder of this article is organized as follows. First, we briefly describe the IMS architecture defined by the 3GPP. Then we introduce the main characteristics of the SIP and Wimax respectively. Finally, we offer an analysis of the problems identified in the previous sections and provide our main conclusions and solutions.

BACKGROUND KNOWLEDGE

IMS ARCHITECTURE FOR 3GPP NETWORKS

UMTS will be standardized by the 3GPP in several releases (Release 5 was finalized in June 2002, and Release 6 was frozen in 2004). Within the UMTS core network, IMS is defined by the 3GPP as the component that provides support for multimedia services (e.g., voice or video) based on packet switching with quality of service (QoS) and the provision of AAA. The left side of Fig. 1 shows a general view of the IMS architecture [3]. From this general view of the architecture, we can appreciate how the core network is organized in two networks: a signaling or control network and a data or transport network. The signaling network is composed of a set of call control session control function nodes (CSCFs). In essence, they are signaling proxies whose task is to establish, modify, and release media sessions.
with guaranteed QoS and AAA and charging (AAAC) support.

Proxy CSCF (P-CSCF) is the entry of IMS which acts as the user agent in SIP. Serving CSCF (S-CSCF) is the key functional entity in IMS that takes charge of session management and user registration. Interrogating CSCF (I-CSCF) performs functions of proxy and topology that hides between operators. These proxies are defined as functional entities so that IMS implementations are free to combine or split this functionality into different components of physical equipment.

Other entities are the media gateway control function (MGCF) and IMS media gateway (IMS-MGW), which are responsible for control signaling and media stream. The media resource function controller (MRFC), performs the processing of media streams through the corresponding media resource function processor (MRFP). A key element of the UMTS network is the home subscriber server (HSS), a centralized database that stores user authorization and profile information. An HSS is similar to the home location register (HLR) in a GSM network. In addition, application servers (AS) can be connected to the IMS to provide advanced services.

Note that user equipment (UE) gains access to the IMS via the UMTS terrestrial radio access network (UTRAN), which is responsible for providing access for mobile stations and managing terminal mobility. SIP, COPS, and Diameter [5] are the major protocols involved in this architecture.

WIMAX TECHNOLOGIES

Wimax is the broadband wireless access (BWA) system designed mainly for wireless metropolitan area networks (WMAN). It is generally believed that Wimax and WLAN can be utilized as a powerful complement to 3G/UMTS.

3G/UMTS offers the benefits of a wide area coverage, full mobility, integral security, roaming, and full integration with charging systems. On the other hand, Wimax combined with 3G, offers high-speed rate data service in addition to original voice service in hotspot areas. It can supply mobile broadband for everybody, everywhere, whatever the technology and access mode.

IEEE 802.16 specifies a WMAN protocol to enable a wireless alternative for last mile broadband access, as well as providing the backhaul for 801.11 hotspots. The subsequent 802.16d standard supports low latency applications such as voice and video and provides broadband connectivity without requiring direct line of sight between terminals. BS; 802.16e adds nomadic mobility to enhance the performance. However, full commercialization of Wimax technology is not expected before 2007.

The Wimax network bearer consists of a wireless bearer and an IP transmission bearer. The former provides a wireless access service by the IEEE 802.16 mechanism, and the IP bearer deploys differentiated services (DiffServ) and MPLS and so on, to guarantee QoS.

The Wimax network model is composed of the following network entities: mobile user terminal, ASN (access service network), CSN (connectivity service network), user terminal including application agents, and MSS (mobile subscriber station).

The QoS strategy agent is located in CSN, and ASN is served as a strategy server. The QoS request is initialized by CSN. Subsequently, ASN implements the QoS negotiation according to a user’s information and the predefined QoS strategy. ASN consists of two QoS functional entities: SFM (service flow management) and SFA (service flow authorization). SFM manages 802.16 service flow and access control and SFA responses for QoS negotiation and authorization. CSN is composed of the application server, Strategy Agent, and AAA server. The network model of Wimax is shown in Fig. 2.

Wimax technologies are believed to be essential for the future of mobile communication. The compatibility of Wimax with existing cellular networks and the potential for seamless handover between different networks makes it a promising technology for deployment in the next generation of mobile networks.
There are two methods for WiMax networks to interwork with other wireless networks: loose couple and tight couple. There is little difference between loose couple and existing networks; WiMax utilizes the AAA server of 3GPP network, and data streams are not passed through the core network of 3GPP. This method guarantees the independence of WiMax network; however, it results in high handover latency between two networks (in [5], the handover between WLAN and UMTS was researched, and the average handover latency results for loose couple and tight couple are 400ms and 150ms, respectively). Therefore, it is not suitable for real-time services.

In tight couple mode, the data streams of WiMax must pass through the RNC (Radio Network Controller) and the core network of 3GPP, so each of the existing networks must modify their protocols, interfaces, and services to meet the requirements of interworking. The BS of WiMax connects with RNC of WCDMA or SGSN directly. The advantage of this mode is that it reduces the handoff latency and guarantees seamless handoff. If different operators own both 3G and WiMax networks, the integration would be troublesome for the open of network interface. The architectures of the two interworking modes are shown in the Fig. 3.

**CORE ARCHITECTURE BASED ON IMS**

As described in the previous section, WiMax is commonly used to transport IP packets. Thus, 3GPP-WiMax interworking should be built on the top of the IP protocol and not be limited to a specific WiMax technology.

Figure 1 presents the interworking reference architecture and the appropriate reference points used in this article, showing the signaling and data interfaces between both networks. The figure also shows the I-CSCF proxy as the signaling entry point in the interconnection between IMS and WiMax, according to the 3GPP CSCF role definition in [3].

Reference point Wo remains as defined in [1] and refers to tunnel establishment and tear down between MSS and the appropriate PDG (packet data gateway), as well as user data packet transmission through this tunnel. PDG functionality is described in detail in [1].

Reference point Wo is dedicated to transporting AAA messages coming from the MSS between the AAA clients located in the WiMax Access Network and the 3GPP AAA server. An AAA proxy/server must be located in the CSN to provide keys for mobile IP operation within the WiMax network.

**INTERWORKING LEVELS**

Interworking modes described in the former section provide the available interconnection architecture. In addition, different interconnection levels must be defined to represent different operational capabilities. These levels are suitable for either interworking mode.

Six interconnection levels between WLAN and 3GPP were taken into consideration, as well as the operational capabilities of each of them, based on the interconnection levels described in [1]. The interworking is not limited to 3GPP and WLAN, but also includes the internetworking between 3GPP and other wireless access technologies based on IP. To maintain consis-
interworking with Wimax networks must be based on the same model that is shown in Table 1.

3GPP has included the first three levels in Release 6, and the last two will be developed in future releases. The first level is the simplest and includes common billing (the customer receives just one bill for usage of both 3GPP and Wimax services) and common customer care (the user need not be concerned about which platform required a consultation with customer service). The first level does not have any impact on either 3GPP or Wimax architecture. The subscriber is charged on the same bill for usage of both 3GPP and Wimax services. Customer care will be ensured independently of the connecting platform.

The second level (3GPP system-based access control and access charging) includes the usage of the 3GPP access procedures (including authentication and authorization) for Wimax users within the 3GPP domain. In addition, Wimax nodes use the UMTS charging systems for charging data records (CDR) generation. A subscriber may use the Wimax Access network to access the Internet, for example, but AAA operations are handled by the 3GPP platform.

The third level extends the IMS services to the Wimax, however, it is a matter of implementation as to whether all services are provided or just a subset of the services. This scenario lacks service continuity, so the user must re-establish the session in the new access network. Continuity is considered in this context as the ability to maintain an active service session when moving from one access network to another (e.g., between Wimax and 3GPP UTRAN) at the signaling level, without considering a transport level-related continuity issue like bandwidth or packet loss. Level 3 allows the operator to extend 3GPP system PS based services to the Wimax network. In this scenario, an authenticated 3GPP subscriber can access 3GPP PS services through a Wimax access network by interworking with its 3GPP PLMN (non roaming case) or with a visited 3GPP PLMN (roaming case).

The last three levels are not considered by the 3GPP in Release 6 and may be developed in future releases. The fourth level introduces service continuity, as described in the previous paragraph, although the handover process may be perceptible to the user (due to data losses or delays). The fifth scenario provides seamless continuity, with no noticeable service interruption greater than that perceived in intra-3GPP handovers. The need for seamless service provision could include transport-level-related issues in this level, which is beyond the scope of this article.

### Extensions of SIP Relate to Interworking

In this section, SIP extensions contained in the 3GPP specification are analyzed. We mainly focused on the issues of QoS guarantee and AAA provision.

#### QoS Guarantee

Due to the differences in the network bandwidth, providing users with a constant level of service is not feasible. The goal of QoS guarantee is to offer suitable quality of service in the given network, in accordance with users’ QoS profiles and application requirements. The QoS guarantee involves the task of mapping the QoS parameters from P-CSCF, GGSN, PDF, QoS negotiation, and the resource reservation mechanism.

UMTS defines four classes of QoS services based on different application requirements: conversational, streaming, interactive, and background. Wimax also defines four classes of QoS: UGS (unsolicited grant service), real-time polling service (rt-PS), non-real-time

---

**Table 1. WiMAX-3GPP interworking scenarios (based on Table 3 of TR 22.934).**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Name</th>
<th>Common billing and common customer care</th>
<th>3GPP-Based access control and access charging</th>
<th>Access to 3GPP PS services without continuity</th>
<th>Access to 3GPP PS services with continuity</th>
<th>Access to 3GPP PS seamless services</th>
<th>Access to 3GPP CS based services</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Common billing and common customer care</td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>2</td>
<td>3GPP system-based access control and access charging</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>3</td>
<td>Access to 3GPP IMS-based services</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>4</td>
<td>Service continuity</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>5</td>
<td>Seamless services</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>6</td>
<td>Access to 3GPP CS services</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>
In our interworking architecture, the policy control function (PCF) plays the role of the PDP [4]. The PCF can be a logical component of a P-CSCF or a separate entity. Since the GGSN is in the data path, it is suitable for acting as the PEP. The policy repository can be an entity external to the PCF. A lightweight directory access protocol (LDAP) capable data store is likely to be used for this purpose. Figure 4 shows the architecture of QoS-enabled interworking based on COPS.

The PCF communicates with the GGSN via the Go interface. It enables two modes of operation. In the push mode, the PCF initiates communication with the PEP and sends the decision to GGSN. In the pull mode, the GGSN initiates communication with the PCF to request a decision for a particular IP flow.

During the establishment of a SIP session, a P-CSCF is the first contact point in the IMS domain for a UE. Hence, it is the natural place to authorize usage of network resources such as the bandwidth requested by the UE. The QoS requirements of the UE are carried in the SDP description within a SIP message. Besides the QoS requirements, the PCF also examines the source and destination IP addresses and port numbers for its decision making. The PCF manages the local domain refer to the policy rules stored in LDAP. It then generates an authorization token that uniquely identifies the SIP session across multiple PDP contexts terminated by a GGSN. The UE obtains an authorization token from the P-CSCF via a SIP signaling message during session setup, so that the UE can use it to identify the associated session flows to the PEP in the GGSN in subsequent transmissions of IP packets. This token is used to provide the binding mechanism that associates the PDP context bearer to the IP flow. By examining this token received from the GGSN, the PEP can direct the GGSN to admit or drop the flow.

The role of the PEP is to ensure that only authorized IP flows are allowed to use network resources that are reserved and allocated to them. Thus, it authorizes the establishment of a session at the policy level.

In the IMS, the session setup signaling is separated from the data path of the session. The PCF resides on the signaling path while the GGSN resides on the data path. To actually establish the data path of the session, the GGSN must reserve the proper level of QoS resources. To tie policy-level authorization to the corresponding QoS resource reservation, the PEP, the component of the GGSN, must validate the reservation request with the PCF. The Go interface facilitates the required communication between the PCF and the PEP to realize this validation.

In the SIP architecture, the QoS requests are handled at the border of the core network by the edge routers (ERs) that implement all mechanisms required to perform admission and control decisions (possibly with the aid of a bandwidth broker(BB)) and policing function. The COPS protocol is used to make QoS reservation requests to the QoS access points (i.e., to the network ERs). In this scenario, the SIP clients are assumed to use a default SIP proxy server in polling service (nrt-PS) and BE (best effort). According to the application scenario, QoS class mapping can be implemented according to the mapping relation mentioned in [6]. The conversational and streaming services of UMTS correspond to the UGS and nrt-PS services in Wimax. The interactive service can be mapped to nrt-PS and BE services in Wimax in different application scenarios. However, the background service in UMTS has the same requirement and application scenario as the BE service in Wimax.

Note that SIP session signaling and effective QoS resource allocation (e.g., GPRS Packet Data Protocol (PDP) or DiffServ) is independent. Filtering mechanisms based on SDP descriptions are possible, either local-policy-based (through the use of COPS) or user-profile-based. The Common Open Policy Service (COPS) protocol is defined in the context of the IETF RAP working group to support policy control in an IP QoS environment. The COPS protocol provides the opportunity to combine policy control, QoS signaling, and resource control in a unified framework. The 3GPP provisionally agreed on the use of the COPS-PR protocol as the communication protocol on the Go interface. The COPS-PR protocol is an extended version of the base COPS protocol to support policy provision.

The underlying architecture model consists of policy servers that administer the network communicating decision and policy clients (e.g., network elements) where the policy decisions are enforced, which is called policy enforcement points (PEP). When a logically centralized element acts as a policy server, it is called the policy decision point (PDP). The PEP makes requests to the PDP for policy-related admission control, and the PDP provides the policy decisions.
their domain for both outgoing and incoming calls. The SIP servers are therefore involved in the message exchange between the clients and can add (and read) QoS related information in the SIP messages. The SIP servers negotiate QoS parameters among them and interact with the network QoS mechanisms. For the setup of a bi-directional QoS communication, two different reservations must be requested for the QoS network. The enhanced SIP server is called a Q-SIP server (QoS-enabled SIP server).

Resource reservation that provides QoS for IMS applications should be handled with care. As there is no policy control between IMS and Wimax, these two solutions are recommended for QoS handling.

Preconfigured resources: QoS resources that are required for the IMS application provided to a Wimax subscriber should be preconfigured at the network. This should provide the ability to prioritize, for example, VoIP traffic over other traffic.

Client triggered reservation: The UE (MS) is responsible for the QoS resource reservation and cancellation. The reservation could be triggered by a convergence sub-layer of Wimax or by an IP layer on-path QoS signaling (e.g., RSVP).

### AAA Provision

In the case of heterogeneous network roaming, a home network must be able to validate the existence of roaming agreements when a user accesses from a visited network, so that the visiting network identity is known during the registration in the home network.

From a 3GPP network perspective, currently, Wimax is considered an untrusted network. It is therefore more necessary to ensure the same level of security to a user for Wimax access through this interworking network than for a user accessing the 3GPP services.

Proper security and trust relationship must exist between the 3GPP AAA server and the Wimax access network to support proper transfer of security, authorization, and accounting information.

The technical solution selected by 3GPP for Wimax access security is to establish a tunnel between the user equipment and the 3GPP gateway located on the border of 3GPP PS.

Only the 3GPP non-roaming case (access to the home 3GPP PLMN through the Wimax access network) was considered, because the changes implied by the roaming case (when the Wimax access network is connected with a visiting 3GPP PLMN) do not affect the Wimax access network.

In addition, SIP event notification [2] is used to enable the network to deregister users or force re-registration of mobile terminals. Regarding the authorization, the P-Media-Authorization SIP header is used on session establishment, in conjunction with COPS between P-CSCF and GGSN (as shown in Fig. 1), to ensure the resource control and avoid unauthorized users using resources for which they are not paying.

The Diameter protocol [7, 8] is used to record CDRs in the UMTS charging subsystem. Additionally, the SIP P-Charging-Vector and P-Charging-Function-Address headers are used to distribute the IP addresses of the charging elements between IMS nodes.

HSS contains subscriber, service, and security profiles that are related to SIP proxies. When the SCPC (SIP central point of contact; here I-CSCF acts as SCPC) receives a SIP REGISTER message, it issues an AAA message to the home AAA server (AAAH). The AAA message may include information from the SIP message. The relevant signaling flow is depicted in Fig. 5.

Furthermore, the AAA infrastructure must be able to distribute (push or pull) subscriber, service, and security profiles to the relevant SIP servers based on policies.

The AAAH must be able to update the location of the assigned SIP server for the user performing SIP registration to the location database, initiate user de-registration, and distribute relevant information to the SCPC for the selection of the appropriate anchor SIP proxy for the user.

### Security

The goal of IMS security is to provide integrity and confidentiality to signaling messages on a hop-by-hop basis between nodes [9]. The key mechanism to achieve this purpose is the IPSec Encapsulated Security Payload (ESP) protocol. There should be no impact on SIP signaling due to its nature as an application-layer protocol.

An additional security requirement is the provision of a topology hiding mechanism (THIG) for network operators that want to implement it. Hiding must include network structure and node IP addresses. This is performed with the I-CSCF acting as a SIP hiding proxy, which obfuscates sensitive information.

Access security of IMS mainly includes: authorization and protection of a SIP message. The authorization of IMS adopts the authoriza-
SIP is the key signaling protocol of IMS. Interworking between SIP elements of the Wimax and CSCFs of the IMS is a key issue in reaching a high level of interworking between Wimax and 3GPP networks.

CONCLUSION

In summary, SIP is the key signaling protocol of IMS. Interworking between SIP elements of the Wimax and CSCFs of the IMS is a key issue in reaching a high level of interworking between Wimax and 3GPP networks. In this article, the overall architecture of the interworking based on IMS is represented, as well as special issues such as QoS guarantees and AAA problems are discussed. Some additional considerations are required in further study, such as:

- Network detection and selection: after the MS detects the available ASNs and corresponding CSNs in a given area, the selection of the PLMN is done according to TS 23.234.
- Wimax provides powerful and flexible QoS handling which cannot be fully utilized within the current 3GPP-WLAN interworking specification.
- Handoff capability from 3GPP network to Wimax network is usually referred to as level 4 (intersystem mobility) and 5 (seamless intersystem mobility). These levels are beyond the scope of the recent releases, but they will be addressed in future releases. The last three levels represent network convergence.

ACKNOWLEDGMENT

The authors would like to thank Dr. Paula Fonseca and Dr. Liang Jing for their warmhearted help in the writing.

REFERENCES


ADDITIONAL READING


BIographies

FANGMIN XU (xufmbupt@gmail.com) received his B.S. degree in communication engineering from the Beijing University of Posts and Telecommunications (BUPT), China, in 2003 and is working toward his Ph.D. in the field of circuit and system at the same university. He is with the School of Telecommunications Engineering, Beijing University of Posts and Telecommunications (BUP). His research interests include Cognitive Radio, Wimax, and UWB technology.

LUYONG ZHANG (zh_luyong@126.com) received his B.S. degree from Tianjin University in 1985, his M.S. degree from the University of Electronic Science and Technology of China in 1988, and his Ph.D. degree from Beijing University of Posts and Telecommunications (BUP) in 2004, all in electronic engineering. Since 1985, he is engaged in research on large wireless system engineering. In 2001, he joined the Circuit and System Center of BUP, where he is currently an Associate Professor. His research interests include UWB communications, Wimax, and WiFi.

ZHENG ZHOU (zzhou@bupt.edu.cn) [member] is with the School of Telecommunications Engineering, Beijing University of Posts and Telecommunications (BUP). He received a master’s degree in 1982 and a doctor’s degree in 1988, both in electrical engineering from BUP. From 1993-1995, he was a Visiting Research Fellow in The Chinese University of Hong Kong, supported by the Hong Kong Telecom International Postdoctoral Fellowship. In 2000, he visited the Japan Kyocera DDI Research Institute as the Invited Overseas Researcher supported by The Japan Key Technology Center. He is a professor at BUP, a member of the China Institution of Communications, Radio Application and Management Committee of CIC and the Sensor Network Technical Committee of CCF. His research interest includes short-range wireless technology, UWB wireless communications, and intelligent signal processing in telecommunications.