IMS-based Network Architecture for NGN–WiMAX Interworking

Mohamed M. Zahra, Adly Tageldien, Mona Kamal

Assoc. Prof., Electrical Engineering Department, Faculty of Eng., Al-Azhar University.
Assist. Dr, Electrical Engineering Department, Faculty of Eng., Benha University.
Communication Engineer, Telecom Egypt company.

Abstract: IP Multimedia Subsystem (IMS) is a set of specifications that describes the Next Generation Networking (NGN) architecture for implementing IP based telephony and multimedia services. IMS defines a complete architecture and framework that enables the convergence of voice, video, data and mobile network technology over an IP-based infrastructure. IMS is based on the specification of Session Initiation Protocol (SIP) as standardized by Internet Engineering Task Force (IETF). IMS can be considered as architecture for the convergence of data, speech, fixed and mobile. A heterogeneous network model based on the IMS is presented, this model integrates the Worldwide Interoperability for Microwave Access (WiMAX), New Generation Network (NGN) technologies and provides guaranteed QoS. This paper present the complete signaling flow concerning the authorization, registration, session set up, as well as, an analytic model for cost analysis of the proposed architecture is analyzed.

Key words: NGN, IMS, Interworking, WiMAX.

INTRODUCTION

Fixed-Mobile Convergence is one of the most eagerly anticipated changes in communication and services provision for end-users, and poses unique challenges for operators and service providers (A. Shneyderman, 2008). The vision is for people to use one phone with one number, address book and voicemail bank, taking advantage of cheap, high-speed connectivity in their fixed-line home or office setting, while enjoying mobility outside in the wide-area mobile phone network (J. Ghetie, 2008). It also includes a seamless handover of calls between fixed-line and mobile networks.

The IP-based Multimedia Subsystem (IMS) is the Next Generation Network (NGN) architecture, set of components, and interface specifications that allow convergence of wired and wireless networks (M. Poikselk, 2009). Convergence/integration of fixed and mobile wireless networks is part of the broader convergence. The IMS convergent network will emerge from an Internet Protocol (IP)-based network infrastructure and a common service platform, allowing the development of a large array of telecommunications and multimedia applications. IMS is a user/operator-centric architectural framework that shifts much of its intelligence to the network periphery.

In this paper, an interworking model that integrates a Worldwide Interoperability for Microwave Access (WiMAX) network,(NGN) network in an IMS compatible architecture is proposed.

The rest of the paper is organized as follows; Section 2 presents an overview of the IMS including key features, architecture particularities and supported signaling protocols. The proposed network architecture is presented and analyzed in Section 3. Analytical models for cost analysis of the proposed architecture, as well as, Numerical results that are used to evaluate the performance of the proposed architecture are presented in Section 4. Finally, conclusions and some future research directions is presented in section 5.

2. IMS Architecture:

The IMS framework shown in Fig. 1 is divided into three separate grand domains (M.Wuthnow, 2010): Transport Layer, Service/Applications Layer, and the IMS Layer.

2.1 Application Layer:

It provides an infrastructure for the provision and management of services, and defines standard interfaces to common functionality including Home Subscriber Server (HSS), Charging Gateway Function (CGF).

2.2 Control Layer or (IMS Layer):

It exists between the application and transport layers. It routes the call signaling, tells the transport layer what traffic to allow, and generates billing information for the use of the network. At the core of this layer is the Call Session Control Function (CSCF).
2.3 User Layer:

It provides a core QoS-enabled IPv6 network with access from User Equipment (UE) over mobile, WiFi and broadband networks. This infrastructure is designed to provide a wide range of IP multimedia server-based and P2P service (M. Poikselk, 2009; P. Bellavista, 2008).

2.4 IMS Entities and Functionalities:

2.4.1 Call Session Control Function (CSCFs):

They are used to process SIP signaling packets in the IMS. A P-CSCF (Proxy-CSCF) is a SIP proxy that is the first point of contact for the IMS terminal (X. Zheng, 2008). All SIP signaling traffic from the UE will be sent to the P-CSCF. There are four unique tasks assigned for the P-CSCF; SIP compression, IPSec security association, interaction with Policy and Charging Rules Function (PCRF). An I-CSCF (Interrogating-CSCF) is a SIP proxy located at the edge of an administrative domain. The I-CSCF queries the HSS using the DIAMETER Cx and Dx interfaces shown in Fig. 1 to retrieve the user location, and then route the SIP request to its assigned S-CSCF. A S-CSCF (Serving-CSCF) is the central node of the signaling plane. The S-CSCF uses DIAMETER Cx and Dx interfaces to the HSS to download and upload user profiles - it has no local storage of the user.

2.4.2 Databases (HSS-SLF):

There are two main databases in the IMS architecture; Home Subscriber Server (HSS) and Subscription Locator Function (SLF). The HSS (Home Subscriber Server) is the master user database that supports the IMS network entities that are actually handling the calls/sessions. It contains the subscription-related information (user profiles), performs authentication and authorization of the user, and can provide information about the physical location of user. An SLF (Subscriber Location Function) is needed when multiple HSSs are used (P. Bellavista, 2009).

2.4.3 Service Functions:

They are Multimedia Resource Function Controller (MRFC), Multimedia Resource Function Processor (MRFP) and Application Server (AS) (J. Fabini, 2008).

2.4.4 IMS-CS Interworking Functions:

A Breakout Gateway Control Function (BGCF) is a SIP [S. Munasinghe2007] server that includes routing functionality based on telephone numbers. BGCF selects a Media Gateway Control Function (MGCF) to handle the session further. If the breakout takes place in another network, then the BGCF forwards the session to another BGCF in a selected network. The latter option allows routing of signaling and media over IP near to the called user. A Signaling Gateway (SEG) interfaces with the signaling plane of the circuit switched network. It transforms lower layer protocols as stream control transmission protocol (SCTP which is an IP protocol) into message transmission part (MTP which is a SS7 protocol), A Media Gateway (MGW) interface can transcode when the codec's don't match (Wei-Kuo Chiang, 2008).
3. A NGN-WiMAX Interworking Architecture:

A NGN-WiMAX interworking proposed model as presented in Fig. 2, integrates a NGN (C. Sarrocco, 2008) network and WiMAX (L. Nuaymi, 2007) network in an IMS compatible architecture. Users can engaged in call through NGN or WiMAX after authenticated and registered in IMS core network.

![Fig. 2: A NGN-WiMAX interworking architecture.](image)

3.1 Network Entry Process:

The user who wants to communicate to this architecture through NGN network or WIMAX network will follow specified procedure as will be presented below.

3.1.1 NGN Entry Process:

A complete network entry process, as shown in Fig. 3, for a user will be register through NGN (A. Caric, 2000; Q. Wei, 2003) network follow these steps:

1- NGN user starts negotiation with its originating Exchange using SS7 signaling protocol.
2- The Exchange forwards Initial address message (IAM) to the signal gateway (SG).
3- Signal gateway replies with address complete message and start alerting.
4- Signal gateway starts connecting to softswitch (F. Baroncelli, 2010) in SIGTRAIN protocol with SCTP message.

![Fig. 3: NGN entry process signaling.](image)

3.1.2 WIMAX entry process:

User passes through many stages, depicted in Fig. 4, to enter to IMS core network through WiMAX access network (N. Psimogiannos, 2010):

1- Negotiation of basic capabilities of MS stage:

MS sends to BS (SBC-req) and MS reply with (SBC-response) in the same time the BS send to ASN gateway (MS-preattachment- req) and ASN reply with (MS- preattachment- res) and MS reply with (MS- preattachment- Ack) (P. Calhoun, 2003).
2- Authentication & authorization of MS stage :
Ms starts Extensible Authentication Protocol (EAP) authentication and key agreement(AKA) include EAP procedure between MS and AAA proxy and Traffic Encryption Key (SA-TEK) procedure bet MS and BS.

3- Secure connection stage:
Three-way-handshake process starts for the establishment of a secure connection bet MS and BS. MS request from BS the keys that will be used in encryption and BS responds with the key response message.
4- Registration stage:
   MS send to BS (Reg - Req) and BS response with Reg- Req which is registration application message of
   the 802-16 it incorporates MS’s capability concerning mobility and handoff support. BS exchange with
   ASN gateway (MS attachment req) and (MS attachment resp) and BS informs ASN gateway that the
   successful completion of user registration by (MS- attachment- ACK).after completion of these steps, MS is
   registered to WIMAX domain.

5- Assigning IP address to MS stage:
   This is done by CSN following DHCP procedure by exchange these messages bet MS and DHCP server
   (CSN); DHCP discover message, DHCP offer message, DHCP request message and DHCP response
   message.
   The addressing can be done based on either IPV4 or IPV6 protocol.

6- Service flow creation stage:
   This stage to insure the quality of service, three messages exchanged between MS and BS (DSA
   REQ/RES/ACT).

7- Registration in IMS stage:
   MS to be registered in IMS, it need to know the IP address of PDG and P-CSCF this done by:
   I-DHCP procedure toward retriever of IP address.
   II-Use the OPTIONS field of DHCP message.
   During this SIP registration, the MS’s registered state is stored in HSS and a S-CSCF is assigned to MS (J.
   Fabini, 2008).

3.2 Session Set Up:
   Users that access services from WIMAX are capable of communicating with users residing in the NGN and
   vice versa.
   During the session setup procedure, each MS has to reserve resources of his access network in order to
   support the session. The P-CSCF that serves each MS must authorize the QoS parameters that have been
   negotiated by the MS.

3.2.1 WIMAX-NGN Session Setup:
   The session setup happens between the two networks through the IMS core network, the signaling flow of
   the session is presented in Fig.5.
   Each user in network assigned to it a specific P-CSCF and S-CSCF but there is only one I-CSCF in IMS
   core network.

Fig. 5: NGN-WiMAX session setup signaling process.
Session setup procedure is following these steps:
1- The MS send INVITE [RADVISION2008] message to P-CSCF1 which doing SIP integrity check if it is valid it pass it to S-CSCF1 which become known during registration procedure.
2- The S-CSCF1 is tries to allocate the I-CSCF and forward the INVITE message to it.
3- The I-CSCF wants to forward the INVITE message to the S-CSCF2 which allocated to user 2. So I-CSCF send Diameter LIR (Location information request) to HSS which search in its data base about the address of S-CSCF2 and answers with (Diameter LIA). So I-CSCF forwards the INVITE request to the S-CSCF2.
4- User 1 starts signal/data flow to user 2, User 2 IMS terminal responds with Bye and user 1 respond with 481 call transaction message.

4. Performance Evaluation:
An analytic model for cost analysis is analyzed in order to evaluate the performance of the proposed architecture is presented.

The total cost ($C_{total}$) for the intersystem communication of two users belonging to two different networks is computed as the aggregated cost for the transmission of the IMS signaling and data traffic, for the encapsulation, decapsulation and routing of packets, and for the queuing of packets of each entity [A.Munir2007]. This cost can be given by:

$$C_{total} = C_{trans} + C_{proc} + C_{queue}$$ (1)

Where $C_{trans}$, $C_{proc}$, $C_{queue}$ denote the transmission cost, processing cost, and queuing cost, respectively.

The transmission cost $C_{trans}$: is the cost incurred due to the transmission of signaling and/or data. It depends on the packet arrival rate, the transmission rate of the link, and the distance between the neighboring network entities.

The processing cost $C_{proc}$: is the cost associated with the encapsulation, decapsulation and routing of packets.

The queuing cost $C_{queue}$: is the cost incurred due to the queuing of packets in each network entity.

4.1 NGN-WIMAX Scenario:
In this analysis we consider the case of a user belonging to a NGN network tries to communicate with a user belonging to a WIMAX wireless network.

4.1.1 The Transmission Cost:
The transmission cost is for the signaling and data traffic and is given by:

$$C_{trans} = C_{sigtrans} + C_{datatrans}$$ (2)

$$C_{sigtrans} = \lambda (U_{wireless} + U_{wired} (10d_{NGN-PSCCF1} + 8d_{psc cf1-scs cf1} + 10d_{scs cf1-lscs cf} + 2d_{lscf-HSS} + 5d_{lscf-scscf2} + 5d_{scscf2-pscscf} + 4d_{pscscf2-WiMAX}))$$ (3)

Where $\lambda$ denotes the IMS session arrival rate (requests per second) and $L$ denotes the number of packets per request for both signaling and data from a source node. $U_{wireless}$ and $U_{wired}$ are the unit packet transmission costs in wireless and wired link respectively. $d_i$ denotes the number of hops between the two communicated entities. The coefficient of each $d_i$ denotes the number of messages that had to be passed through the two entities.

Similarly, the transmission cost for the delivery of the IMS data traffic can be given by N. Psimogiannos, 2010):

$$C_{datatrans} = \lambda (U_{wireless} + U_{wired} (d_{NGN-pscscf1} + d_{pscscf1-lscs cf} + d_{scscf1-lscsf1} + d_{lscsf1-lcs cf} + d_{lscsf2-HSS} + d_{lscsf2-lscs cf} + d_{lscsf2-pscscf} + d_{pscscf2-wimax}))$$ (4)

4.1.2 Processing Cost:
The processing cost $C_{proc}$ which is the aggregated cost for the processing of the signaling and data traffic can given by:

$$C_{proc} = C_{sigproc} + C_{dataproc}$$ (5)
Assuming that there are N users in the network that are distributed in coverage area of each network. Therefore, the total number of users N is equal to:

\[ N = N_{\text{WiMAX}} + N_{\text{NGN}} \] (6)

the processing cost of each WiMAX & NGN entity (i.e. BS and ASN-GW) in order to encapsulate and decapsulate packets can be given by:

\[ C_{i, \text{proc}} = \lambda_i \gamma_i \] (7)

Where \( \gamma_i \) is the unit packet processing cost, \( i \) can be a BS or a ASN-GW.

and the IMS entities (S-CSCF1, S-CSCF2, I-CSCF) only forward the packets by adding their information to the packets, their processing cost can be given with similar expressions as equation 7 by replacing the value of \( c_i \) with the corresponding unit packet processing cost value. For the processing cost for the (HSS) can be given by:

\[ C_j = \lambda_j \gamma_j + \lambda_j \omega \left( \log_{10} \frac{N_j}{2} + \frac{L}{S} \right) \] (8)

where \( c_j \) is the unit packet processing cost value of each entity, \( k \) is a system dependent constant, \( \omega \) is a weighting factor, \( L \) is the IP address length in bits and \( S \) the machine word size in bits.

Therefore, the processing cost for IMS signaling traffic between the WiMAX and the NGN network is given by:

\[ C_{\text{sigproc}} = 10C_{\text{NGN}} + 10C_{\text{pcescf1}} + 8C_{\text{scscf1}} + 8C_{\text{icscf}} + C_{\text{HSS}} + 8C_{\text{scscf2}} + 8C_{\text{Wimax}} \] (9)

where the coefficients of each \( C_i \) denote the number of messages that had to be processed at each entity.

The processing cost for IMS data traffic between the WiMAX and the NGN network is given by:

\[ C_{\text{dataproc}} = C_{\text{NGN}} + C_{\text{pcescf1}} + C_{\text{scscf1}} + C_{\text{icscf}} + C_{\text{HSS}} + C_{\text{scscf2}} + C_{\text{Wimax}} \] (10)

4.1.3 Queueing Cost:

The IMS network is modeled as a tandem M/M/1 queuing network. The queuing cost is proportional to the total number of packet in the tandem queuing network [A. Caric 2000]. The queuing cost \( C_{\text{queue}} \) which is the aggregated cost for the queuing of the signaling and data traffic can be given by:

\[ C_{\text{queue}} = C_{\text{sigqueue}} + C_{\text{dataqueue}} \] (11)

The queuing cost for IMS signaling traffic between the WiMAX and the NGN network is given by:

\[ C_{\text{sigqueue}} = 10E_{\text{NGN}} + 10E_{\text{pcescf1}} + 8E_{\text{scscf1}} + 8E_{\text{icscf}} + E_{\text{HSS}} + 8E_{\text{scscf2}} + 8E_{\text{Wimax}} \] (12)

where \( E_{(ai)} \) denotes the expected number of packets in each queue and it can be expressed as:

\[ E_{ni} = \frac{\lambda_i}{\mu_i - \lambda_i} \] (13)

where \( \lambda_i \) and \( \mu_i \) denote the arrival rate and the service rate respectively at each entity of the network. In addition, the queuing cost for IMS data traffic between the WiMAX and the NGN network is given by:

\[ C_{\text{dataqueue}} = E_{\text{NGN}} + E_{\text{pcescf1}} + E_{\text{scscf1}} + E_{\text{icscf}} + E_{\text{HSS}} + E_{\text{scscf2}} + E_{\text{Wimax}} \] (14)

4.2 Numerical Results:

These are the numerical results for the proposed architecture in several use cases:

The unit packet transmission cost for the wireless links \( U_{\text{wireless}} \) and the wired links \( U_{\text{wired}} \) are set to 0.1 and \( 3.84 \times 10^{-6} \) respectively.

The hop distances for the \( d_{\text{scscf2}} \) and the are set to 4, while the rest hop distances are set to 2 in accordance with (A. Caric, 2000). The IP address length \( L \), as well as, the machine word size \( S \) are set to 32 bits. Also, the system value \( k \) is selected to be 5. The Weighting factor \( \omega \) is set to \( 1 \times 10^{-6} \) as the lookup delay is increased by
100 ns for each memory access. The service rate \( \lambda \) at all network entities is set to 250 packets/s. Furthermore, the unit processing cost for all the network entities are set to \( 8 \times 10^{-6} \).

The numerical results for the architecture in the case of a user belonging to a NGN and tries to communicate with a user belonging to a WiMAX wireless network (N. Psimogiannos, 2010).

Fig. 6 depicts the transmission cost for signaling and data traffic for different values of IMS arrival rate \( \lambda \).

As it was expected the transmission cost for signaling IMS traffic is the same as the transmission cost for IMS data traffic. As it is shown from the Fig. 7 the processing cost for signaling IMS traffics is higher than the processing cost for IMS data traffic. This difference is decrease as the value of the arrival rate \( \lambda \) increases.

![Fig. 6: The transmission cost versus different IMS arrival rate.](image1)

![Fig. 7: The processing cost versus different IMS arrival rate.](image2)

As it is shown from the Fig. 8 the queuing cost for signaling IMS traffics more than 10 times higher than the queuing cost for IMS data Traffic. This difference is kept constant independently of the value of the arrival rate \( \lambda \).
Fig. 8: The queuing cost versus different IMS arrival rate.

5. Conclusion:

The IP Multimedia Subsystem (IMS) seems to be the technology that will prevail in Next Generation Networks (NGNs) and its main goal to make convergence between any IP networks and a vertical handoff may happening depend on the user requirements (services, Qos, etc.).

In this thesis it was presented an IMS based interworking architecture for NGN-WiMAX networking through which it prevail that how any two user from any two different IP based network can be involved in a session under the umbrella of IMS management. by presenting a complete signaling flow for concerning the authorization, registration, session set up and vertical handoff processes between two networks.

Evaluating the performance of this architecture using cost analysis model and validated its concept by Numerical results which denote the transmission, processing, queuing cost for signaling IMS traffic is higher than the transmission, processing, queuing cost for IMS data traffic.

REFERENCES


