An Overview of Interworking Architectures in Heterogeneous Wireless Networks: Objectives, Features and Challenges

O.Khattab and O.Alani

School of Computing, Science & Engineering, University of Salford, UK
e-mail: o.khattab@edu.salford.ac.uk; o.y.k.alani@salford.ac.uk

Abstract

Loose coupling and tight coupling are two main interworking architectures have been proposed by European Telecommunication Standards Institute (ETSI) for integrating between the different types of technologies (3GPP, non-3GPP) such as Global System for Mobile Communication (GSM), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE). On the other hand, Media Independent Handover IEEE 802.21 (MIH) and IP Multimedia Subsystem (IMS) frameworks have been proposed by IEEE group and 3GPP, respectively to provide seamless Vertical Handover (VHO) between the aforementioned technologies by utilizing these interworking architectures to facilitate and complement their works. In this paper, we overview loose and tight coupling interworking architectures and highlight their objectives, features, and challenges. Then, we conclude that loose couple is more suitable with MIH and contributes for enhancing its vital role in heterogeneous wireless environment.

Keywords

Heterogeneous Wireless Networks, IP Multimedia Subsystem (IMS), Loose Coupling, Media Independent Handover (MIH), Tight Coupling, Vertical Handover (VHO).

1. Introduction

With the advancement of wireless communication and computer technologies, mobile communication has been providing more versatile, portable and affordable networks services than ever. Therefore, the number of users of mobile communication networks has increased rapidly as an example; it has been reported that "today, there are billions of mobile phone subscribers, close to five billion people with access to television and tens of millions of new internet users every year" (International Telecommunication Union [ITU], 2013) and there is a growing demand for services over broadband wireless networks due to diversity of services which can't be provided with a single wireless network anywhere anytime (Angoma *et al*. 2011), (Chiu *et al*. 2011), (Ma *et al*. 2011) and (Dimitriou *et al*. 2011). This fact means that heterogeneous environment of wireless systems such as Global System for Mobile Communication (GSM), Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX) and Universal Mobile

Telecommunications System (UMTS) will coexist providing Mobile User (MU) with roaming capability across different networks. One of the challenging issues in Next Generation Wireless Systems (NGWS) is achieving seamless Vertical Handover (VHO) while roaming between these technologies; therefore, telecommunication operators will be required to develop a strategy for interoperability of these different types of existing networks to get the best connection anywhere anytime. To fulfill these requirements of seamless VHO two main interworking architectures have been proposed by European Telecommunication Standards Institute (ETSI), namely; loose and tight coupling for integrating between the different types of technologies. In this paper, we are going to present loose coupling and tight coupling as well as highlight their objectives, features, and challenges. Finally, we conclude that loose couple interworking architecture is more suitable with Media Independent Handover (MIH) and contributes for enhancing its vital role in heterogeneous wireless environment.

The rest of the paper is organized as follows: section 2 describes the VHO procedure. In section 3, we present MIH and IMS frameworks. In section 4, we describe the loose coupling and tight coupling interworking architectures with their objectives, features, and challenges. In section 5, a comparison between the two interworking architectures is presented. In section 6, the relation of loose and tight coupling with MIH is highlighted and finally, we conclude the paper in section 7.

2. **Vertical Handover (VHO) Procedure**

The mechanism which allows the MUs to continue their ongoing sessions when moving within the same Radio Access Technology (RAT) coverage areas or traversing different RATs is named Horizontal Handover (HHO) and VHO, respectively. In the literature most of the research papers divide VHO procedure into three phases: Collecting Information, Decision and Execution (Abdoulaziz *et al.* 2012), (Busanelli *et al.* 2011), (Gondara and Kadam, 2011), (Louta *et al.* 2011) and (Zekri *et al.* 2010), as described below.

A. Handover collecting information

In this phase, all required information for VHO decision is gathered, some related to the user preferences (e.g. cost, security), network (e.g. latency, coverage) and terminal (e.g. battery, velocity).

B. Handover decision

In this phase, the best RAT based on aforementioned information is selected and the handover execution phase is informed about that.

C. Handover execution

In this phase, the active session for the MU will be maintained and continued on the new RAT; after that, resources of old the RAT are eventually released.

3. Media Independent Handover (MIH) and IP Multimedia Subsystem (IMS) Frameworks

In a previous work (Khattab and Alani, 2013), we have classified the VHO approaches proposed in the literature into four categories based on MIH and IMS frameworks (MIH based VHO category, IMS based VHO category, MIP under IMS based VHO category and, MIH and IMS combination based VHO category) in order to present their objectives in providing seamless VHO. It has been concluded in (Khattab and Alani, 2013) that MIH is more flexible and has better performance providing seamless VHO compared with IMS framework; hence, the majority of approaches in the literature were based on MIH framework. The IEEE group has proposed MIH to provide a seamless VHO between different RATs (Neves *et al.* 2009) and (Lampropoulos *et al.* 2008). The MIH defines two entities: first, Point of Service (PoS) which is responsible for establishing communication between the network and the MU under MIH and second, Point of Attachment (PoA) which is the RAT access point. Also, MIH provides three main services: Media Independent Event Service (MIES), Media Independent Command Service (MICS) and Media Independent Information Service (MIIS) (Marquez *et al.* 2011) such that MIH relies on the presence of mobility management protocols, e.g., MIPv4 and MIPv6. In a previous work (Khattab and Alani, 2013), we have classified the VHO approaches proposed in the literature into two categories based on the mobility management protocols (MIPv4 and MIPv6) for which we have presented their performances and characteristics. It has been concluded in (Khattab and Alani, 2013) that providing service continuity through MIPv4 category under MIH will allow the operators to diversify their access networks take into account advantages of this category, while MIPv6 category under MIH requires future work improvements in terms of VHO decision criteria, additional entities, complexity, diversity of RATs and evaluation using empirical work real environment.

A. Media Independent Event Service (MIES)

It is responsible to report the events after detecting, e.g. link up on the connection (established), link down (broken), link going down (breakdown imminent), etc. (IEEE Group, 2013).

B. Media Independent Information Service (MIIS)

Figure 1 shows that MIIS is responsible for collecting all information required to identify the need for handover and provide them to MUs, e.g. available networks, locations, capabilities, cost, etc. (IEEE Group, 2013).

C. Media Independent Command Service (MICS)

It is responsible to issue the commands based on the information which is gathered by MIIS and MIES, e.g. MIH handover initiate, MIH handover prepare, MIH handover commit and MIH handover complete (IEEE Group, 2013).

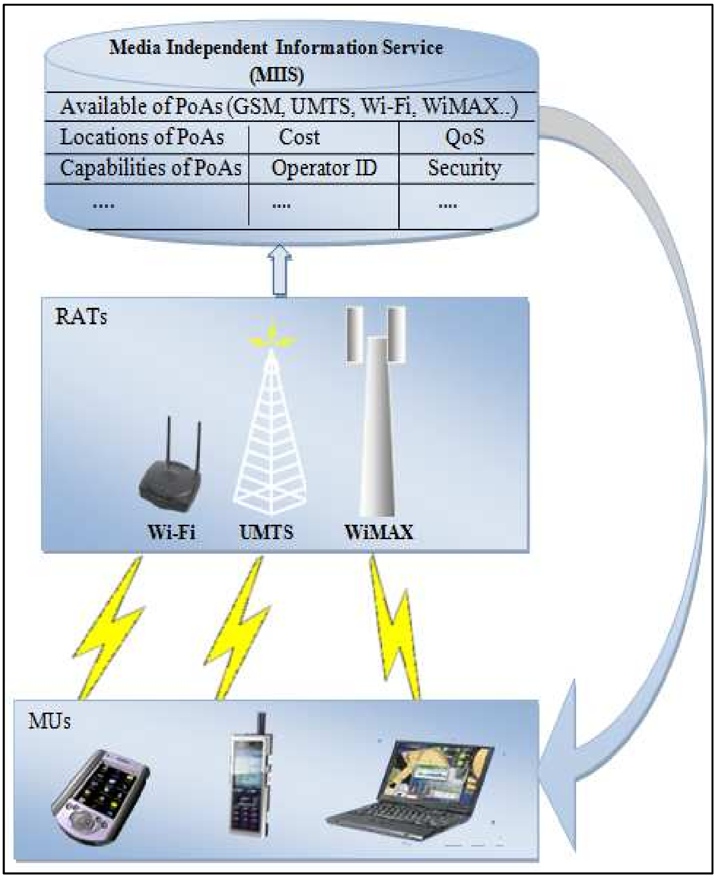

Figure 1: Media Independent Information Service (MIIS) Passing Information about Radio Access Technologies (RATs) to Mobile Users (MUs)

4. Interworking Architectures

The NGWS will consist of heterogeneous wireless access networks, such as UMTS, Wi-Fi, WiMAX and LTE, these different RATs have significant different capabilities in terms of supported data rate, coverage area, cost, etc. For example, The UMTS provides high coverage area, high cost and low data rate from 144 Kbps to 2 Mbps at 10 Km/h to maximum 500 Km/h depending on propagation channel, while the Wi-Fi provides low coverage area, low cost and high data rate from 1 Mbps to 54 Mbps at 30 m to maximum 450 m (Haji *et al*. 2009). Therefore, complementarity of these technologies through interworking architectures is essential to provide ubiquitous Wireless access abilities with high coverage area, high data rate and low cost to MUs. Consequently, the challenge would be the ability to move MUs seamlessly between these different types of wireless technologies. The two main interworking architectures found in the literature are loose coupling and tight coupling (Nguyen-Vuong *et al*. 2007), (Lampropoulos *et al*. 2007) and (Kassab *et al*. 2010); these are discussed next.

A. Loose coupling

In loose coupling architecture, each of the existing access wireless networks, such as UMTS, Wi-Fi and WiMAX is independently deployed. Both of WiMAX and Wi-Fi data do not pass through 3rd Generation Partnership Project (3GPP) core network this in turn means, there is no need to modify any architectural change, no additional cost and the interworking point occurs after 3GPP core network in particular, follow Gateway GPRS Support Node (GGSN) with internet. Also, the networks interconnection in this architecture based on MIP while for roaming service the Authentication, Authorization and Accounting (AAA) server connects between different RATs which allows the Wi-Fi and WiMAX data go directly to the internet without requiring for direct link between their components and 3GPP core network (Ronald, 2009).

B. Tight coupling

In tight coupling architecture, the Wi-Fi and WiMAX data pass through 3GPP core network before going to the internet and significant modifications of existing access wireless networks are necessary for providing seamless service to the MU to move from one network to another (Fangmin *et al*. 2007), this in turn impacts the 3GPP core network performance in terms of complexity, congestion and packet loss due to the overload. The networks interconnection in this architecture is based on the existing 3GPP core network functionalities (e.g. core network resources, subscriber databases and billing systems) that ensure MUs to continue their ongoing sessions when moving within different RATs. There are two types of tight coupling (Benoubira *et al*. 2011):

- Tight coupling integration at the GGSN level.
- Tight coupling integration at the RNC level.

    - Tight coupling integration at the GGSN level

In this architecture, all of the RATs are connected together by Virtual GPRS Support Node (VGSN) which is responsible to exchange subscriber information and route packets between the wireless access networks, the handover duration (latency) is equivalent with loose coupling where MIP is used (no need of MIP functionalities) and it requires less complexity modification in 3GPP core network (Ronald, 2009).

    - Tight coupling integration at the RNC level

In this architecture, Access Point (AP) and Base Station (BS) in Wi-Fi and WiMAX, respectively are connected with Radio Network Controller (RNC) by Interworking Unit (IWU). The IWU main functionality is to translate protocol and signalling exchange between RNC and another RATs interface, such as AP and BS (Benoubira *et al*. 2011).

5. Loose Versus Tight Coupling Comparison

In section 4, we have presented two main interworking architectures: loose coupling and tight coupling and their purposes, features and challenges have been discussed. To provide comparison of the two interworking architectures, we summarize their specifications on: efficiency of handover duration, probability of packet loss, mobility management, congestion, complexity, overload, additional modification, and additional cost, this is shown in Table 1.

According to our comparison between interworking architectures in Table 1, loose coupling seems to supersede tight coupling for the majority of the compared characteristics in terms of probability of packet loss, congestion, complexity, overload, additional modification and additional cost. It provides the same efficiency for handover duration when MIP is used and lower probability of packet loss than tight coupling which is incurred due to overload in 3GPP core network.

Characteristics	Tight Coupling	Loose Coupling
Efficiency of Handover Duration	Low	Similar with MIP
Probability of Packet Loss	High	Low
Mobility Management	3GPP Core Network Functionalities	MIP
Congestion	High	Low
Complexity	High	Low
Overload	High	Low
Additional Modification	High	No
Additional Cost	High	No

Table 1: Comparing Loose VS. Tight Coupling

6. MIH with Loose and Tight Coupling

The IEEE group presented MIH to provide seamless VHO between different RATs such as UMTS, Wi-Fi and WiMAX. To facilitate its work the interworking architectures contribute for enhancing MIH vital role in heterogeneous wireless environment.

After fair comparison in section 5 (Table 1), a better performance is provided by loose coupling compared with tight coupling which makes loose coupling the interworking architecture of choice to complement MIH vital role in heterogeneous wireless environment to achieve a seamless VHO in conjunction with applying MIPv4.

7. Conclusion

In this paper, we have described two main interworking architectures: loose coupling and tight coupling and their objectives, features and challenges have been discussed.

Fair comparison based on their performance in terms of latency, probability of packet loss, mobility management, congestion, complexity, overload, additional modification requirement and additional cost requirement has been made. We have described MIH framework which provides seamless VHO between different RATs by utilizing aforementioned interworking architectures to facilitate and complement their works. Also, we have concluded that loose couple interworking architecture is more suitable to work with MIH and enhance its vital role in heterogeneous wireless environment. Therefore, we can say that in the near future, providing service continuity through MIPv4 category under MIH will allow the operators to diversify their access networks take into account advantages of loose coupling interworking architecture.

8. Reference

Abdoulaziz, I.H., Renfa, L. and Fanzi, Z. (2012), "Handover Necessity Estimation for 4G Heterogeneous Networks", *International Journal of Information Sciences and Techniques*, vol. 2, no. 1, pp. 1-13.

Angoma, B., Erradi, M., Benkaouz, Y., Berqia, A. and Akalay, M.C. (2011), "HaVe-2W3G: A Vertical Handoff Solution between WLAN, WiMAX and 3G Networks", *7th International Wireless Communications and Mobile Computing Conference 2011 (IWCMC 2011)*, pp. 101-106.

Benoubira, S., Frikha, M. and Tabbane, S. (2011), "Hierarchical Mobile IPv6 Based Architecture for Heterogeneous Wireless Networks Interworking", *3rd International Conference on Communication Software and Networks 2011 (ICCSN 2011)*, pp. 422-426.

Busanelli, S., Martalo, M., Ferrari, G. and Spigoni, G. (2011), "Vertical Handover between Wi-Fi and UMTS Networks:Experimental Performance Analysis", *International Journal of Energy, Information and Communications*, vol. 2, no. 1, pp. 75-96.

Chiu, K.L., Chen, Y.S. and Hwang, R.H. (2011), "Seamless session mobility scheme in heterogeneous wireless networks", *International Journal of Communication Systems*, vol. 24, no. 6, pp. 789-809.

Dimitriou, N., Sarakis, L., Loukatos, D., Kormentzas, G. and Skianis, C. (2011), "Vertical Handover (VHO) Framework for Future Collaborative Wireless Networks", *International Journal of Network Management*, no. 6, vol. 21, pp. 548–564.

Fangmin, X., Luyong, Z. and Zheng, Z. (2007), "Interworking of Wimax and 3GPP Networks Based on IMS [IP Multimedia Systems (IMS) Infrastructure and Services]", *IEEE Communications Magazine*, vol. 45, no. 3, pp. 144-150.

Gondara, M. and Kadam, S. (2011), "Requirements of Vertical Handoff Mechanism in Wireless Networks", *International Journal of Wireless and Mobile Networks*, vol. 3, no. 2, pp. 18-27.

Haji, A., Ben Letaifa, A. and Tabbane, S. (2009), “Integration of WLAN, UMTS and WiMAX in 4G”, *16th International Conference Electronics, Circuits, and Systems 2009 (ICECS 2009)*, pp. 307-310.

IEEE Group (2006), “IEEE 802.21 Tutorial”, http://www.ieee802.org/21/, (Accessed 15 Nov 2013).

International Telecommunication Union (ITU) (2013), “Our vision: Committed to connecting the world”, http://www.itu.int/en/about/Pages/vision.aspx, **(**Accessed 15 Nov 2013).

Kassab, M., Bonnin, J.M. and Belghith, A. (2010), “Technology Integration Framework for Fast and Low Cost Handovers-Case Study:WiFi–WiMAX Network”, *Journal of Computer Systems, Networks, and Communications, Hindawi Publishing Corporation*, vol. 2010, no. 9, pp. 1-21.

Khattab, O. and Alani, O. (2013), “A Survey on Media Independent Handover (MIH) and IP Multimedia Subsystem (IMS) in Heterogeneous Wireless Networks”, *International Journal of Wireless Information Networks (IJWIN)*, vol. 20, no. 2, pp. 215-228.

Khattab, O. and Alani, O. (2013), “Survey on Media Independent Handover (MIH) Approaches in Heterogeneous Wireless Networks”, *IEEE 19th European Wireless 2013 (EW 2013)*, pp. 1-5.

Lampropoulos, G., Salkintzis, A.K. and Passas, N. (2008), “MediaIndependent Handover for Seamless Service Provision in Heterogeneous Networks”, *IEEE Communication Magazine*, vol. 46, no. 1, pp. 64-71.

Lampropoulos, G., Passas, N., Kaloxylos, A. and Merakos, L. (2007), “A Flexible UMTS/WLAN Architecture for Improved Network Performance”, *Wireless Personal Communications Journal*, vol. 43, no. 3, pp. 889- 906.

Louta, M., Zournatzis, P., Kraounakis, S., Sarigiannidis, P. and Demetropoulos, I. (2011), “Towards Realization of the ABC Vision: A Comparative Survey of Access Network Selection”, *IEEE Symposium on Computers and Communications(ISCC)*, pp. 472-477.

Ma, X., Liu, J. and Jiang, H. (2011), “On the design of algorithms for mobile multimedia systems: A survey”, *International Journal of Communication Systems*, vol. 24, no. 10, pp. 1330-1339.

Marquez-Barja, J., Calafate, C.T., Cano, J.C. and Manzoni, P. (2011), “Evaluation of a Technology-Aware Vertical Handover Algorithm Based on the IEEE 802.21 Standard”, *IEEE Wireless Communications and Networking Conference 2011 (WCNC 2011),* pp. 617-622.

Neves, P., Soares, J. and Sargento, S. (2009), “Media Independent Handovers:LAN, MAN and WAN Scenarios”, *IEEE GLOBECOM Workshops*, pp. 1-6.

Nguyen-Vuong, Q.T., Agoulmine, N. and Ghamri-Doudane, Y. (2007), “Terminal-Controlled Mobility Management in Heterogeneous Wireless Networks”, *IEEE Communication Magazine*, vol. 45, no. 4, pp. 122- 129.

Ronald, B. (2009), “Integration of Heterogeneous Wireless Access Networks”, in Ekram, H. (Ed.) *Heterogeneous Wireless Access Networks Architectures and Protocols*, US: Springer, 978-0-387-09777-0.

Zekri, M., Jouaber, B. and Zeghlache, D. (2010), “Context Aware Vertical Handover Decision Making in Heterogeneous Wireless Networks”, *35th Conference on Local Computer Networks 2010 (LCN 2010)*, pp. 764-768.