Computer Networks 55 (2011) 1533–1548

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

Vertical handovers among different wireless technologies in a UMTS radio access-based integrated architecture

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ARTICLE INFO

Article history:
Available online 25 February 2011

Keywords:
UMTS
Integration
Radio access
Very tight coupling
Heterogeneous networks
Vertical handover
WLAN
WiMAX
DVB-H
MBMS

ABSTRACT

The demands for accessing services at high data rates while on the move, anyplace and anytime, resulted in numerous research efforts to integrate heterogeneous wireless and mobile networks. The focus was mainly put on the integration of the Universal Mobile Telecommunications System (UMTS) and the wireless local area network (WLAN) IEEE 802.11, which is beneficial in terms of capacity, coverage and cost. With the advent of IEEE 802.16(e) the attention of the research community was shifted to its interworking, on one side, with complementary WLANs, and on the other, with UMTS for extra capacity. In addition, there has been also research on UMTS interworking with different broadcasting systems, including the Digital Video Broadcasting system for handheld devices (DVB-H). All these research activities resulted in various heterogeneous architectures where the interworking was performed at different levels in the network. In this article, we address the integration at the UMTS radio access level, known also as very tight coupling. This integration approach exhibits good vertical handover performance and may allow for seamless session continuity during the handover. However, it is a technology specific solution, where not all the mechanisms applied to the integration of one wireless technology can be straightforwardly reused for embedding another. This integration approach introduces various modifications to UMTS that have to be standardized, which makes it a long-term solution. We present here the general architecture for the integration at the UMTS radio access level and discuss the extension of the architectural framework for various types of access systems with as few as possible additional modifications. The focus of the work is put on the vertical handovers. We discuss various vertical handovers among WCDMA, IEEE 802.11, IEEE 802.16e and DVB-H in the considered heterogeneous architecture. We present new handover types, describe the vertical handover procedures and provide performance evaluation of the vertical handovers in different scenarios and for different combinations of the wireless access technologies.

1. Introduction

In the marketplace, there are various types of wireless and mobile networks that cover different areas, support different levels of mobility and provide different data rates. The demands for accessing services at high data rates while on the move, anyplace and anytime, triggered research efforts to integrate the heterogeneous access networks. The fourth-generation (4G) mobile network is envisaged as the interconnection of various access networks, organized in a hierarchy of complementary layers that range from the lower layers that provide high bandwidth to slowly-moving users in hotspots to the higher layers that offer lower-rate services to fast-moving users over larger distances.

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doi:10.1016/j.comnet.2010.12.028

The Universal Mobile Telecommunications System (UMTS) [1] is characterized by a wide coverage and the use of the licensed frequencies. UMTS initially offered point-to-point voice connections and packet switched services at moderate data rates, while the following enhancements have supported higher data rates and multicast and broadcast multimedia services (MBMS). On the other side, wireless local area networks (WLANs), such as IEEE 802.11 [2], provide higher capacity at the license-exempt frequencies at hotspots. The WLAN rapid deployment and complementary characteristics to UMTS in terms of capacity, coverage and cost resulted in numerous research efforts on their integration. The research activities also included the wireless metropolitan area networks (WMAN), such as Mobile Worldwide Interoperability for Microwave Access (WiMAX) IEEE 802.16e [3]. There were proposals for WiMAX integration with complementary WLANs as well as with UMTS for the provision of extra capacity, which can be beneficial especially in rural areas. Besides, there has also been research on UMTS interworking with different broadcasting systems, including the Digital Video Broadcasting for handheld devices (DVB-H) [4]. Although the efficient provision of point-to-multipoint (PTM) connections is now also possible with UMTS, it would reduce the UMTS capacity for its essential and more profitable point-to-point (PTP) services. DVB-H integration into the UMTS network may be a feasible way to provide the mobile operator with additional cheaper capacity for MBMS services. This could result in the support of a higher number of video streams with better resolution at a lower price.

In the literature, various architectures were proposed for interworking of the heterogeneous wireless access systems [5]. Here, we address the integration at the UMTS radio access level, known also as very tight coupling. The article is organized as follows. After presenting a brief overview of the UMTS network architecture and possible interworking architectures, we describe the general architecture for the integration of a wireless technology at the UMTS radio access level. Then we present the initial UMTS modifications for the integration of a single WLAN and discuss the extension of the architectural framework for other wireless broadband and broadcasting technologies. This is followed by a discussion on various vertical handovers that may take place in such an integrated architecture. We describe new handover types and new handover procedures and provide performance evaluation of the vertical handovers in different scenarios and for different combinations of the wireless access technologies. Finally, we draw conclusions.

2. Overview of UMTS

UMTS is a third-generation (3G) mobile communication system based on the functional principles of the Global System for Mobile Communications (GSM). It was initially designed to provide data rates up to 2 Mbps, while the enhancements for high speed packet access (HSPA) allowed for 14.4 Mbps in the downlink and 5.7 Mbps in the uplink. Its standardization is conducted by the Third Generation Partnership Project (3GPP) [1].

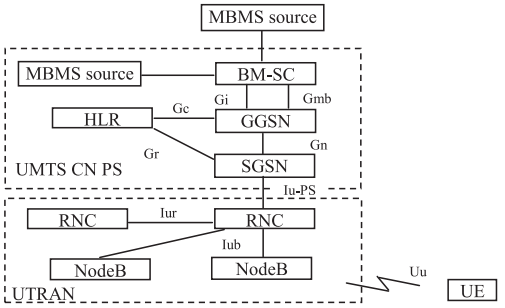

Fig. 1. The UMTS network architecture.

The UMTS infrastructure [6] consists of two domains: the Core Network (CN) and the Access Network (AN). The standard specifies a strict separation between the domains, allowing their independent evolution. We give here a brief overview of the CN packet-switched (PS) domain and the UMTS Terrestrial Radio Access Network (UTRAN), which are shown in Fig. 1. The main CN PS elements are the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). The SGSN is responsible for the PS domain mobility management, session management, and routing, while the GGSN provides connectivity to external data networks. They are interconnected over the Gn interface, while both are connected to the Home Location Register (HLR) via the Gr and Gc interfaces, respectively. Via Iu-PS, the SGSN is connected to the UTRAN, which consists of one or more radio network subsystems (RNS). Each RNS includes a number of base stations called NodeBs and a Radio Network Controller (RNC) that are interconnected via the Iub interface. The interface between the RNCs is called Iur. The radio interface Uu between the User Equipment (UE) and a NodeB is based on the wideband code division multiple access (WCDMA).

From the Rel'6 series of specifications, UMTS includes the support for MBMS services, i.e. unidirectional PTM connections in broadcast and multicast modes. The Broadcast Multicast Service Centre (BM-SC) is a new CN PS entity for data delivery from external and internal data sources. BM-SC is attached to the GGSN via the Gmb interface in the control plane and Gi in the data plane. The MBMS provision introduced modifications both to the GGSN and the SGSN as well as the UTRAN [7], which was modified for the efficient use of the WCDMA resources for the MBMS services.

3. Interworking architectures

Various interworking architectures were proposed in the literature, which can be categorized in different ways. This section briefly reviews the interworking solutions from different points of view, that is, with respect to the protocol layer at which the mobility management mechanisms are deployed and the network interface where the integration is performed.

3.1. Protocol-based categorization

The mobility management mechanisms can be deployed at any of the protocol layers from the link layer to