Architecture for Integrating UMTS and 802.11 WLAN Networks

Toni Janevski, Zaklina Bogoeska

Abstract – **Cellular networks, e.g. UMTS, provide voice and data services to mobile users. In hotspots where users need high speed data services operators can deploy low-cost high speed WLANs, e.g. 802.11, to cover hot-spots. This paper proposes a possible architecture of integrating UMTS and 802.11 WLAN. The architecture allows a mobile node to maintain data (PS) connection through WLAN and voice (CS) connection through UMTS in parallel.**

Keywords – **Architecture, UMTS, Wireless LAN.**

I. INTRODUCTION

The 3G cellular networks, e.g. UMTS [1], support real-time and non-real-time multimedia services. The sustainable data rate per user in reality is up to several hundreds of kbps. On the other hand, clusters of high-speed usage of the mobile network can be found in certain areas, such as Internet cafés, office buildings, apartment buildings etc.

These clusters of high-speed usage areas are called *hot spots*. Fortunately, these areas are scattered within a wireless operator's domain. The operators would like to deploy lowcost high-speed solution to cover the hot spots that is either an extension of UMTS or inter-workable with UMTS so that they can maximally utilize the already deployed infrastructure. Wireless LANs, e.g. 802.11[2], which provide affordable services offers a viable and attractive choice as being high-speed (up to 54Mbps) and low-cost.

Both UMTS and WLANs are already commercially available and become increasingly popular. The number of mobile users is growing rapidly and so does the demand for wireless access to the Internet services, imposing the need for a unified QoS support framework in both UMTS and WLAN.

In particular, the users in the UMTS-WLAN interworking scenario require support for vertical handover (handover between heterogeneous technologies) between WLAN and UMTS. Existing solutions to vertical handover supporting the integration of UMTS and WLAN include network and application layer techniques based on Mobile IP (MIP) [3] and Session Initiation Protocol (SIP) [4], respectively.

In this paper we refer to the architectures for interworking of UMTS and WLAN. The paper is organized as follows. In the next section we give some background for the analysis. Possible integration architectures for UMTS-WLAN are discussed in Section 4. Finally, conclusions are given in Section 5.

[1]Toni Janevski is Associate Professor at the Faculty of Electrical Engineering, Karpos 2bb, Skopje, Macedonia. E-mail:tonij@etf.ukim.edu.mk

[2]Zaklina Bogoeska is graduate student at the Faculty of Electrical Engineering, Karpos 2 bb, Skopje, Macedonia.

II. BACKGROUND

A. UMTS

UMTS provides packet data (PS) service for data applications and circuit-switched (CS) service for telephony voice applications. In UMTS, the network of RNCs and Node Bs constitute the radio access network (RAN), called *UTRAN*.

The network of one RNC and its Node Bs is called *RNS*. Each Node B constitutes a cluster of base stations and a group of Node Bs is connected to a single RNC. The packet core network (CN) is comprised of SGSN and GGSN. In RAN, the RNC receives downlink packets from the SGSN and converts them into radio frames before sending them to Node Bs. On the reverse path the RNC receives radio frames from Node Bs and converts them into IP packets before sending them to the SGSN. The RNC manages the radio resources of Node Bs and sets up Radio Access Bearers (RABs) through them. The core network is connected to the Internet through GGSN. The SGSN manages mobility states of mobile nodes, establishes the data sessions, and controls the RAB set-up through RNCs. The IP packets are transported through GTP tunnels between GGSN and SGSN, and between SGSN and RNCs.

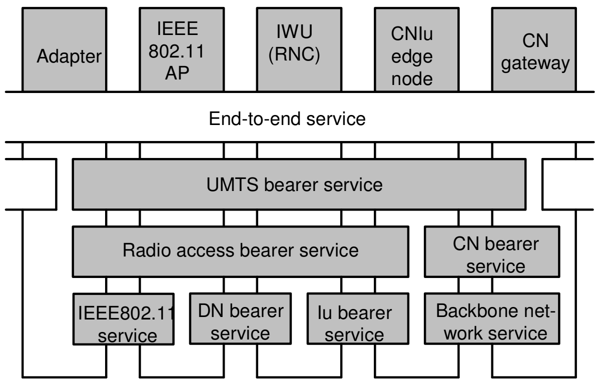

Fig.1. Adapted UMTS bearer concept using IEEE 802.11 bearer

Four different QoS classes are defined for the [5]: conversational class, streaming class, interactive class, and background class. The first two are targeted to real-time services, such as voice-over-IP and video/audio streaming, and the last two are targeted to non-real-time services, such as web-browsing (interactive) or email (background), etc.

B. IEEE 802.11 W LAN

The IEEE standard 802.11 operates in ad-hoc and infrastructure modes. In infrastructure mode, an Access Point (AP) coordinates the transmission among nodes within its radio coverage area, called service set. Only the infrastructure mode is relevant to WLAN integration with cellular network.

A Mobile Node (MN) can only associate with one AP at a time. Roaming across APs is supported in layer-2 through Inter-AP Protocol (IAPP). The APs generate beacons periodically that contain the network id (or Extended Service Set Identifier, ESSID) and cell-id (which is the AP's MAC address) in addition to other information. When the MN moves to a new cell where it receives a beacon with the same network-id but a new cell-id, it associates with the new AP by sending re-associate request frame that includes the MAC address of the old AP. The new AP can communicate with the old AP through IAPP [6] to obtain the context information.

QoS control is required to handle QoS guaranteed services over the WLAN component of the integrated network. In this section, a policy-based QoS architecture is proposed for WLAN as a prelude to the QoS architecture for an integrated UMTS–WLAN system. Typically, a WLAN network comprises a number of WLAN access points (APs) connected to a WLAN router (WR) that provides access to external networks. QoS mechanisms at the network layer in the form of IP packet header marking, policing and conditioning in the differentiated services (DiffServ) architecture, and at the data link layer in the form of WLAN QoS mechanisms (802.11e), media access control (MAC) frame priority indication (802.1p), and virtual LAN (VLAN) tagging (802.1q) are controllable by the QoS architecture. The MAC QoS mechanisms are provided by the WLAN APs, and the IP DiffServ mechanisms are available at the WR. In the following WLAN policy-based QoS architecture, only the DiffServ mechanisms in the WR are available to the policy control process.

There are two approaches [7] proposed for coupling WLAN networks with UMTS: tightly coupled architecture and loosely coupled architecture (Fig. 2).

In a tightly coupled architecture, the WLAN network is connected to the UMTS network as an alternative radio access network. In other words, the WR is connected directly to the serving General Packet Radio Service (GPRS) support node (SGSN) and is treated by the SGSN as a radio network controller (RNC). The data sent by WLAN devices must go through the UMTS PS domain served by the connecting SGSN to reach its destination. To ensure seamless IP QoS services in tightly coupled WLAN–UMTS networks, the UMTS session control entities such as call state control functions (CSCFs) in UMTS IMS are extended into the WLAN network. The session control entities like the CSCFs interact directly with the WLAN devices as if they are normal UMTS user equipment (UE). Thus, a PDF can enforce the network-level policies at the WR directly as if the WLAN network is a part of the UMTS PS domain. In a tightly coupled architecture, the WLAN is an alternative radio access network, so the 3GPP PDF is reused.

In a loosely coupled architecture, the WLAN is connected to a gateway GPRS support node (GGSN) of the UMTS network as a separate network. The WR is treated like a GGSN, and the WLAN network is considered a peer UMTS network. This article proposes that the WLAN constitutes a distinct policy domain with its own PDF, called a WLAN PDF (WPDF). The WPDF acts as the PDP in the WLAN domain, and the WR is the PEP that enforces the policy decisions made by the WPDF. In a loosely coupled architect-ture, the WLAN domain can use session control entities (CSCFs) in the UMTS network.

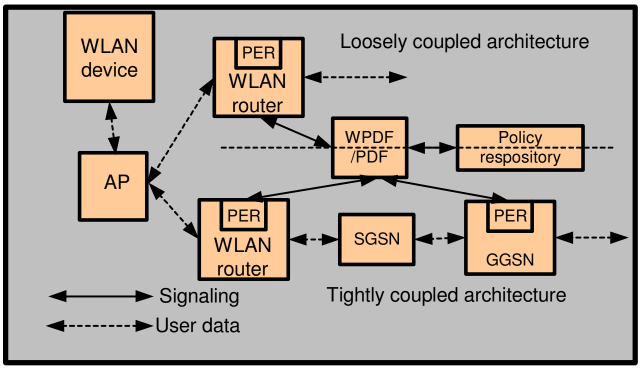

Fig. 2. Policy-based QoS architecture in WLAN

Alternatively, a session control entity can be sited in the WLAN domain to interact with the CSCFs in the UMTS network. This WLAN session control entity is related to the WPDF in the same way as the relationship between the proxy (P)-CSCF and the PDF in UMTS IMS. By adopting an additional session control entity and PDF in the WLAN domain, the distinct interface between the WLAN domain and its interconnected UMTS network is preserved. How the policies implemented in the WLAN domain are related to the policies in the UMTS network is dependent on the interworking scenarios. Consequently, the interaction method between the WPDF and the PDF of the UMTS network is determined by this policy relationship.

The loosely coupled WLAN architecture offers a major advantage over the tightly coupled architecture: integration flexibility offered by the distinct WLAN policy domain. It permits easy integration of the WLAN domain into a multi-operator multidomain environment. This flexibility permits simple extension of the QoS policy control architecture in [8] into the WLAN domain regardless of the UMTS–WLAN integration scenarios.

III. Integration Architecture

Defining an architecture that integrates the UMTS and 802.11 networks would face the following challenges.

1. What is the impact of differences in QoS models of the two radio access networks on the types of applications users can run and consequently on the traffic handled in each network? The UMTS RNS supports QoS for four well defined service classes – interactive, voice, stream, and best effort. In contrast, the QoS support for 802.11 is still under discussion.

2. How to deal with different connection paradigms used in each network? The GPRS is connection oriented, whereas 802.11 is a connection-less wireless LAN network.

3. How to ensure packet routing across the two networks when different mobility management schemes are employed in each network? In GPRS packets are routed through tunnels established between GGSN-SGSN and SGSN-RNC. In contrast, a number of mobility solutions are proposed for the IP network, which can be used for802.11 WLAN (e.g. HMIPv6 [9], CIP [10]).

4. How to select the best integration point when multiple integration points exist each with different cost-performance benefit for different scenarios? For example, the WLAN can be connected to either RNC, or SGSN, or GGSN.

Three scenarios are considered in the following subsections to illustrate the feasibility of the proposed architecture:

- One operator controls the UMTS network and WLANs.
- Different UMTS operators share a WLAN.
- An independent WLAN is interconnected to UMTS.

A. Scenario 1: UMTS and WLAN under one operator

Scenario 1 is a PLMN model where the operator installs and operates an integrated UMTS–WLAN network. The operator fully controls its WLAN sites. For the integrated UMTS–WLAN environment in a single operator's network, the hierarchical policy architecture is used (Fig. 3).

The master policy controller (MPDF) connects to the policy controller of the WLAN network (WPDF) and the UMTS policy controller (PDF). The MPDF of the UMTS network serves as the master policy node of the WPDF so that the policies implemented in the WLAN domain are integrated into the operator's policy hierarchy. The MPDF translates the network-wide policies into domain-specific net- work-level policies on behalf of the WPDF and PDF, and stores them in the policy repository.

The PDFs just retrieve these network-level policies from the repository, translate them into device-level policies, and install these policies in the network devices under their control. Note that these policies are enforced on all new IP multimedia sessions uniformly unless there are policy conflicts regarding the authorization of a new session's QoS requirements. In this case, the policy conflicts must be resolved through the MPDF. The communications protocol between the MPDF and the PDFs is based on the Common Open Policy Services (COPS) [11] protocol.

Note that a two-level hierarchy is shown in Fig. 3 for illustrative purposes only. The network operator may decide to provide intermediate levels of policy conflict resolution for more granular control over its network.

B. Scenario 2: A WLAN network shared by multiple operators

The normal range of a WLAN AP is less than 150 m in open space and just 50 m in closed environments. To provide full WLAN coverage over a built-up area like a city requires deployment of a large number of WLAN APs.

As a result, the cost of providing extensive WLAN services is high for a single operator, and it is desirable for operators to share their WLAN infrastructure to reduce upfront costs. Scenario 2 is such a risk-sharing PLMN model to provide different services in an integrated UMTS–WLAN environment. Multiple operators install and operate shared WLAN sites at different locations that are connected to their own UMTS networks. In this scenario, operator A may usually target business subscribers while operator B targets youth subscribers. The shared WLAN sites are configured to provide different amounts of resources at different times of the day. For example, operator A may be allocated more resources to provide business services during daytime, while operator B may get more resources to provide entertainment services after work hours. To provide end-to-end QoS in this environment, a WPDF is deployed in the shared WLAN domain. Scenario 2, shown in Fig. 4, illustrates how the WPDF interacts with the MPDFs of the cooperating operators' networks.

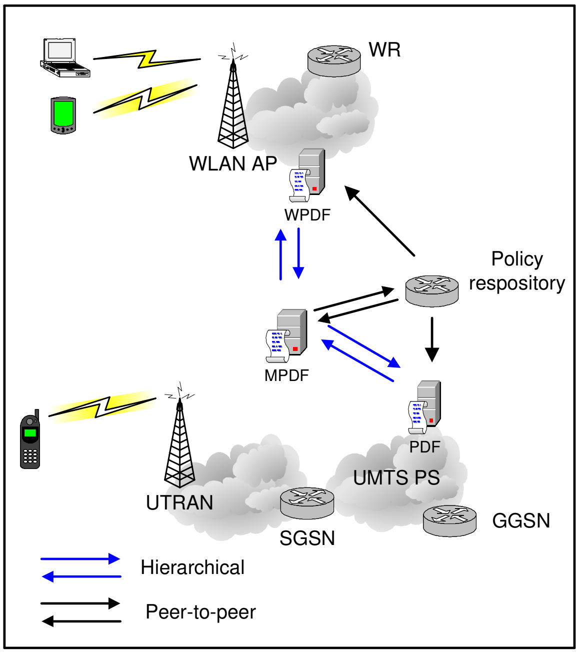

Fig. 3. WLAN and UMTS networks controlled by one operator

In scenario 2, the QoS policies to be applied in the WLAN domain are subjected to the control of operators A and B. For WLAN traffic going into operator A's network, the WPDF applies the policies supplied by operator A's MPDF. Likewise, WLAN traffic going into operator B's network is subjected to the policies supplied by operator B's MPDF. These policies specify how much resources in the WLAN access router (WR) should be provided to the traffic to be carried by the different operators' networks in order to satisfy the QoS requirements contracted by the operators. In terms of policy relationship, the WPDF is a child node in the policy hierarchies of operators A's and B's networks, and it is serving two MPDFs that are peers.

C. Scenario 3: Customer's WLAN network interconnected to operator's UMTS network

This scenario is shown in Fig. 5. Here, the WLAN may belong to an independent Internet service provider (ISP) or an enterprise that is a customer of the UMTS operator. This model allows the UMTS operator to provide wide-area mobile services to customers that have their own WLAN infrastructure.

In contrast to scenario 2, the WPDF in the WLAN domain is a peer of the MPDF in the UMTS network. The WPDF has the sole right to update its policy repository. The network-level policies to be employed by interconnecting the UMTS network and the WLAN network are determined by the service level specifications (SLSs) agreed between the peering WLAN and UMTS operators.

In these SLSs, there are static and dynamic service requirements. The static service requirements can be directly translated into enforceable network-level policies to be retrieved by the WLAN's PDF and the UMTS' PDFs in the respective networks. The purpose of SLS negotiation is to enable the interconnected networks' interdomain policy agents (IPAs) to agree on the specific service requirements that must be supported under the prevailing network states. Once the SLS negotiation is successfully completed, the participating IPAs can translate the agreed on service requirements into enforceable policies in their respective networks. Note that this runtime negotiation may not be initiated on a per-session basis. Instead, SLS negotiation is usually initiated when the IPA detects that the state of its network has changed and the existing policies are no longer enforceable.

IV. CONCLUSIONS

In this paper we have justified the use of the loose coupling approach to UMTS-WLAN integration in most scenarios. Tight coupled architectures is more suitable to situations where the cellular operator owns the WLAN and can reap the benefits of using the already in place infrastructure for billing and authentication. Despite originally being seen as competitors in the telecommunications market it has now become an industry goal on integrating the two different technologies. This integration can lead to significant benefits to service providers and end users. It will allow 3G operators to economically offload data traffic from wide area wireless spectrum to WLANs in indoor locations, hotspots, and other areas with high user density. If the 3G operators can provide a wide range of WLAN hotspots they will stand to increase their customer base and will also increase the services provided to their customers. For WLAN service providers, integration will bring them a larger user base from partner 3G networks, without having to win them through per customer service contracts. Finally the customers will also benefit greatly from such integration will the advent of greater coverage, higher data rates and lower overall cost of such a combined service.

V. REFERENCES

[1] 3GPP General Packet Radio Service (GPRS) Service description; Stage 2 (Release 4), 3GPP TS 23.060-410, www.3gpp.org, June 2001.

[2] IEEE Std. 802.11b, Supplement to ANSI/IEEE Std. 802.11, 1999 Edition, IEEE Standard for Wireless LAN MAC and PHY Specifications, PDF: ISBN 0-7381-1812-5, January 2000.

[3] C.Perkins, "IP mobility support," RFC2002, Oct. 1996.

[4] M. Moh, G. Berquin, and Y. Chen, "Mobile IP telephony: mobility support of SIP," in Proc. IEEE Computer Commun. And Network, Oct.1999.

[5] 3GPP TS 23.107 V5.5.0, "Universal Mobile Telecommunication System (UMTS); QoS Concept and Architecture", available at http://www.3gpp.org.

[6] Matthew Gast, 802.11 Wireless Networks – The Definitive Guide, O'Reilly, 2002.

[7] ETSI, "Requirements and Architectures for Inter-working between HIPERLAN/2 and 3rd Generation Cellular Systems, "Tech. rep. TR101 957, Aug.2001.

[8] W. Zhuang et al., "Multi-Domain Policy Architecture for IP Multimedia Subsystem in UMTS, "Proc. IFIP/IEEE Net-Con 2002-Network Control and Eng. for QoS, Security and Mobility with Focus on Policy-Based Net., Oct.2002, pp.27-38.

[9] H. Soliman, C. Castelluccia, K. Elmalki, L. Bellier, Hierarchical Mobile IPv6, Internet Draft, draft-ietf-mobileip, hmipv6-04.txt, July 2001.

[10] A. Campbell, J. Gomez, S. Kim, A. Valko, C. Wan, Z. Turanyi, "Design, Implementation, and Evaluation of Cellular IP", IEEE Personal Communications, Vol.7, No.4, pp.42-49, August 2000.

[11] T.M.T. Nguyen et al., "COPS Usage for SLS Negotiation (COPS-SLS), "work in progress, IETF, Feb.2002.

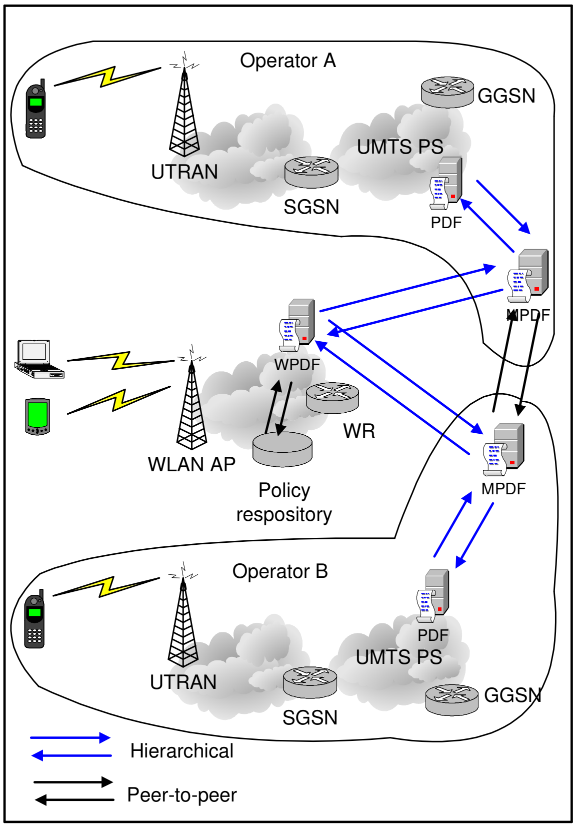

Fig. 4. WLAN shared by different operators

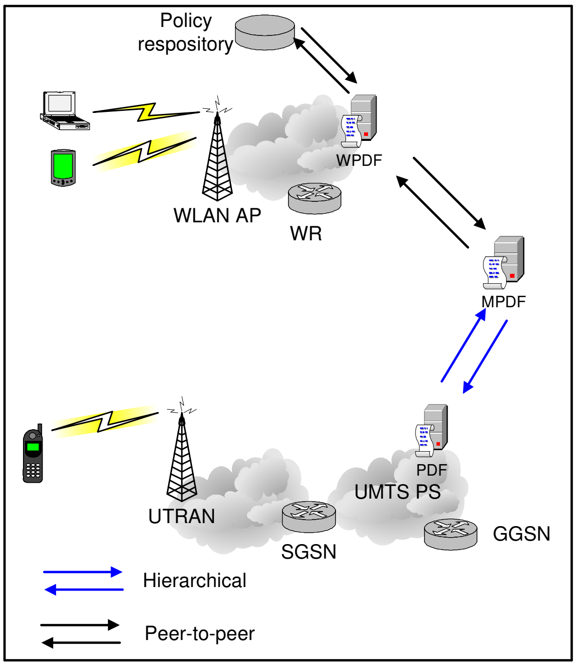

Fig. 5. Interworking of a customer's WLAN network and an operator's UMTS network