A transport and application-layer approach to seamless service continuity across heterogeneous wireless networks

Carlos García-Rubio and Celeste Campo

Dept. Ingeniería Telemática - Universidad Carlos III de Madrid
Escuela Politécnica Superior - 28011 Leganés (Madrid) Spain
{cgr, celeste}@it.uc3m.es

Abstract. The integration of 802.11-based WLANs and GPRS/UMTS cellular networks has attracted considerable research interest during the last few years. Several topics need to be addressed, including authentication, security, QoS support, and mobility management. In the ITEA Easy Wireless project, we are focussing on ensuring transparent connectivity and seamless service continuity as users are transitioning between different wireless network technologies. In this paper we review the alternative architectures proposed so far to solve this problem, with their advantages and disadvantages. We present the solution adopted in the project, a transport layer mobility management based on SCTP (Stream Control Transmission Protocol) with some extensions. Location management is achieved using application layer protocols.

1 Introduction

During the last years there has been a great development of third generation (3G) cellular systems, and at the same time, the popularity of Wireless Local Area Networks (WLANs), especially of IEEE 802.11-based networks, has increased, offering high data rates. The integration of WLANs and 3G cellular networks, constituting what is known as beyond third generation (B3G) or fourth generation (4G) systems, is attracting considerable research interest [1].

Integrated WLAN and cellular networks can be exploited in several application areas. In the Easy Wireless ITEA project [2] we are considering three of these areas. First, for the support of mobile domestic users or workers, that move between their home/office, equipped with an Ethernet LAN or an 802.11 WLAN and connected to the Internet by an ADSL line or other medium-speed data access technology, and outdoors, with GPRS/UMTS connectivity. Secondly, for network support in public transportation systems, such as trains, to support passenger or crew member connectivity to Internet while the train is moving. Thirdly, in ad hoc networks and mesh networks, which can benefit in many areas, e.g., in emergency situations, when it is of vital importance for rescue personnel to obtain an accurate and consistent picture of the situation, and to regain control and coordination on the shortest possible term.

There are many challenges that must be addressed to make this integrated WLAN/cellular networks, and ad hoc networks, a reality [3], such as seamless service continuity, location management, quality of service (QoS) support, and authentication, authorization, and accounting (AAA).

In this paper we concentrate in two of these problems. We present the solution considered in the Easy Wireless project for seamless service continuity support and location management in the first application area described above, i.e., for mobile domestic users or workers transitioning between different wireless network technologies (WLAN and GPRS/UMTS). The other aspects and application areas are also covered in the project, but will not be described here.

The paper is organized as follows. First, in section 2 we present what we understand for seamless service continuity, and which topics need to be addressed. In section 3, we review different standardization efforts. In section 4 we describe the application scenario we are targeting to. In section 5 we present different possible solutions at different layers of the protocol stack. In section 6, we present the service continuity architecture and the mobility management solution we are considering in the Easy Wireless project. Section 7 lists the open issues, we are now broaching. Finally, we present the conclusions in section 8.

2 Seamless service continuity

We must first define what we understand for seamless service continuity.

The 3GPP [4] defines seamless service continuity as a handover between two wireless networks without user intervention and with minimal service disruptions (i.e., packet loss, etc.). Specifically, in the ITEA Easy Wireless project we concentrate on multimedia services continuity (video and audio streaming and conferencing) when transitioning between WLANs and GPRS/UMTS, in a public transportation system, and in ad hoc and mesh networks.

This transitioning between wireless networks is what is known as handover. Handover management is a process that allows the network to keep active connections while the mobile terminal (MT) is transitioning from one network to another.

According to how communication quality is preserved during the handover, there exist two basic types of handover: hard handover and soft handover. In a hard handover, the terminal only has one active connection with a network at the same time, while in a soft handover at least one active link between the terminal and the network exists during the entire handover period, and there are times when the links with both the old and the new networks are simultaneously established.

To allow a mobile node to establish simultaneous connectivity with two or more networks, the terminal must have two (or more) network interfaces. Moreover, the ranges of these networks need to partially overlap. Such an overlapping area is called the overlapping zone of the involved networks. If the overlap is sufficiently large, then it is possible for a multi-interfaced mobile node to complete a soft handover before it loses the connectivity with the previous network. Soft handovers are preferred to hard handovers, when possible.

Several technical topics need to be addressed when a user is moving from one network to another. The more important ones are seamless transition, location management, it should require as little infrastructure as possible, and security. See [3] for more details.

3 Related work

Different standardization efforts have recently been made in the area of WLAN /cellular internetworking [1]. In this section we briefly review the fundamental characteristics of the solutions proposed so far.

The ETSI has classified the WLAN/Cellular internetworking architectures into two types: tight coupling and loose coupling solutions.

- With tight coupling, the WLAN appears as another access network to the cellular core network, extending current protocol standards in order to interoperate. Both data traffic and signalling is transferred through the cellular network.
- With loose coupling, both networks (WLAN and the UMTS/GPRS) are considered independent networks, using or not a common subscription. Minimal adjustments to each network are required. They may not deal with the provision of services such as WAP and MMS from the WLAN, but service continuity after inter-system handover is possible. Cellular and WLAN infrastructures may belong to different providers.

In this section we will concentrate on the tight coupling solutions.

3GPP [4] is the main contributor in the field of tight couplin WLAN/Cellular internetworking. Its standardization work in UMTS/WLAN internetworking has been considered by TSG SA WG1 (Services). Efforts toward service continuity and seamless service provision are left for Release 7, which started in the second half of 2004.

The 3GPP has also defined the Fixed Mobile Convergence (FMC) service. This service tries to use the fixed infrastructures to route the traffic of the mobiles in a seamless way, provoking an important The Unlicensed Mobile Access (UMA) [5] is the standard adopted by 3GPP for convergence solutions Fixed-mobile pre-IMS (IP Multimedia Subsystem) in the residential segment. This standard has been released by the UMA Consortium, forum of operators and vendors of handsets and infrastructure. UMA provides access to the cellular services and allows the transference between the mobile and fixed networks by means of the non license technologies such as WLAN.

In addition to 3GPP, the IEEE 802.21 Working Group (WG) [6] is also actively contributing to the integration process. IEEE 802.21 is developing standards to enable handover and interoperability between heterogeneous networks including both 802 and non 802 networks.

4 Application scenario

Seamless service continuity across heterogeneous (WLAN/cellular) wireless networks has interest for both the home and the office.

- In the home, where domestic users enjoy entertainment services, data services, do videoconferene with other users, and for home automation.
- In the office, where remote access systems to company services must be implemented to facilitate mobile employees' work. The full private network of the company must be available from anywhere.

Both scenarios have very similar requirements, and in the Easy Wireless project they will be be demonstrated in Telefonica's Digital Home & Office Lab at Boecillo (Valladolid, Spain).

A mobile domestic user or a mobile employee wants to have access to the same set of services (remote home or office control, audio/video conferencing, video streaming, file download, etc) when at his/her home or office, or while in the move. The service must not interrupt when transitioning from one network to other.

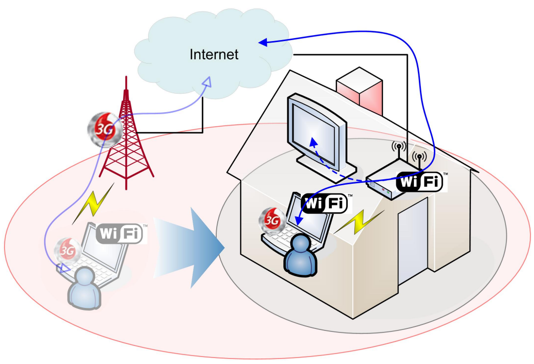

Fig. 1. Seamless service continuity in the home/office scenario

Figure 1 shows a typical seamless service continuity scenario in the home/office. The main elements involved are a mobile terminal (a PC, laptop, Tablet PC or PDA), a corresponding node (initially we will consider a fixed PC) and the edge routers.

The mobile node is using a service from the corresponding node, be it a simple file download or a complex multimedia service (e.g., video and/or audio streaming or conferencing). This service must not interrupt when the mobile terminal transitions from a cellular network to a WLAN, or vice versa, or between two WLANs or two cellular networks. Corresponding node mobility must also be supported. Third devices in the environment (such as cameras, displays, etc.) can be dynamically discovered and incorporated as input or output devices to the service (e.g., the video received from the corresponding node can be redirected to a wide TV screen in the home).

5 Mobility support at what layer?

Networking is a complex problem that traditionally has been broached by splitting its functionality between different layers in a protocol stack. The OSI model and the TCP/IP protocol stack are the most popular examples of protocol stacks. These architectures were defined several decades ago, before the deployment of today mobile devices and wireless networks. Mobility functions were not included in any layer [7] [8]. We have to take this into account when proposing an architecture for service continuity in heterogeneous WLAN/cellular networks.

Sub-network layer protocols mobility support is required for detecting and joining new networks. The IP layer needs to be configured for each network, which can be accomplished through Dynamic Host Configuration Protocol (DHCP). However, these mechanisms alone cannot provide service continuity.

The IETF has proposed the support of mobility at the network layer either by Mobile IP [9] or the more recent Mobile IPv6 protocols. The main disadvantages of this solutions are increased delays (triangle or quadrangle routes). Various solutions for overcoming these problems have been proposed.

To implement mobility at the transport layer, the host must be able to detect networks to which it moves, and obtain new IP address in the, through DHCP or a similar mechanism. Higher layer protocols, such as DNS and Dynamic DNS, help maintain reachability for new connections. The transport layer must implement is providing a mechanism for dynamic rebinding of open connections. This is the case of the mobility improvements of SCTP [10].

In recent years, there have been several proposals for application layer mobility support based on Session Initiation Protocol (SIP) [11]. However, the handover procedure using SIP may introduce latency for the signalling messages procedure and overhead for IP encapsulation.

Finally, there are proposals to include a new layer in the protocol stack specifically to deal with mobility. For example, the Host Identity Protocol (HIP) [12] is being designed by the IETF to establish secure communication and to provide continuity of communication at a 3.5 layer (between layers 3 and 4).

6 Solution adopted

We have divided the functionality of our service continuity solution into the following modules:

- Network discovery and monitoring: It tries to be aware of the available networks, and of the available resources (e.g. SNR, packet loss, power consumption, etc) in each network. It also gets the network parameters of the new networks discovered.

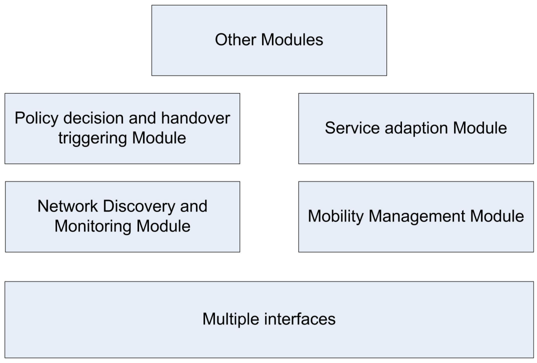

Fig. 2. Service continuity architecture

– Policy decision / handover triggering: It decides when to make the handover, following a set of rules. QoS parameters (e.g. BW available) affect the decision of when to do the handover. It also manages the handover in order to achieve a fast and seamless handover (user initiative, channel condition degradation, loss coverage, and new networks).
– Mobility management: It's in charge of the mobility management.
– Service adaptation: It is in charge of notifying the application about the changes in the underlying network, so it can adapt to the new characteristics (bandwidth, delay, SNR ratio, etc.).
– Other modules: Other optional modules may be present, depending on the necessities, such as service discovery, for dynamically discovering the services in the environment.

The mobility management module is the core of the service continuity architecture, the ultimate responsible for the support of the service continuity when transitioning between wireless networks. Due to the heterogeneous nature of our application scenario, solutions which are independent of the networks used are more appropriate, so we decided to use a loose coupling approach. We assume the mobile node has several network interfaces (e.g., WLAN, and UMTS), what allows using both interfaces at the same time, so soft handovers are possible.

Regarding at what layer of the protocol stack we should support mobility, we adopted a transport layer approach, in conjunction with support from the application layer (DHCP, Dynamic DNS). A transport layer solution uses optimal routes, does not depend on infrastructure beyond DHCP and DNS, and soft handovers are possible if the node has several network interfaces.

Of the transport layer solutions, we have selected SCTP with mobility support [13]. The multi-homing ability enables SCTP to support mobility. A host is called multihomed if it has multiple network layer addresses (e.g. IP addresses). A transport protocol supports multi-homing if the endpoint can have more than one transport layer addresses, as is the case with SCTP. The mobility comes here from the ability to change the endpoints (e.g. IP addresses) while keeping the end-to-end connection intact. The problem in SCTP is to perform these address reconfigurations dynamically. The solution is to use the Dynamic Address Reconfiguration (ADDIP) extension for SCTP, which enables the SCTP to add, delete, and change the IP addresses during an active connection. The SCTP with the ADDIP extension is called mobile SCTP (mSCTP), and it provides a seamless handover for mobile hosts that are roaming between IP networks.

7 Future work

This solution has some open issues, we are now broaching:

- The SCTP protocol is mainly targeted for client-server services, in which the client initiates the session with a fixed server. For supporting peer-to-peer services, the mSCTP must be used along with an additional location management scheme. We are using for this Dynamic DNS, but SIP or Mobile IP are also possible.
- The ADDIP extension used in mSCTP to achieve seamless handover is only a draft, and therefore work needs to be done in the test and implementation of this option.
- How we determine which one is the primary address (interface) is an open problem. We are now using a trivial policy (we always prefer WLAN over UMTS), but much more complex policies are possible, even in a per service basis.
- Performance in wireless environments can also cause problems for SCTP. This has to be studied (analysis, simulation, experimental measurements).
- The protocol assumes that all losses are caused by congestion. This will cause SCTP to back-off unnecessarily, and result in poor throughput. This has to be improved.
- Power efficiency aspects have not been covered yet.
- For service adaptation, it is necessary to propose an enhanced SCTP sockets API that allows the applications to adapt to the changes of network characteristics when roaming between different wireless networks. This API would inform the application about the QoS parameters of the new network. According to this, the application could decide some changes, for example, sending the video using a different codec.

This solution must also be integrated with the mobility solution for the other application areas. This integration is guaranteed because we are adopting a subnetwork layer solution for the public transportation application, and a network layer for the ad hoc emergency network scenario, they both compatible with a transport layer solution such as SCTP.

8 Conclusions

The next generation of wireless communication systems will be based on heterogeneous technologies that are still evolving. A key component of these evolving systems is the multiplicity of access technologies as well as a diversity of terminals that allow users on the move to enjoy seamless high-quality wireless services. These wireless access networks will consist of different types and generations of cellular networks and include both public and private Wireless Local Area Networks.

In this paper we have reviewed the proposals presented so far to deal with this WLAN/cellular networks integration. We have presented the service continuity architecture adopted in the Easy Wireless project, with a mobility management solution based on SCTP with mobility support enhancements.

Many issues are still open. They have been presented, and will be broached during the following months of the project. The result will be presented in Telefonica's Digital Home & Office Lab at Boecillo next year.

References

1. Lampropoulos, G., Passas, N., Merakos, L., Kaloxylos, A.: Handover management architectures in integrated wlan/cellular networks. IEEE Communications Surveys & Tutorials **7**(4) (2005) 30–44
2. : Easy wireless itea project. (http://ew.thales.no/)
3. Le, D., Fu, X., Hogrefe, D.: A review of mobility support paradigms for the internet. IEEE Communications Surveys & Tutorials **8**(1) (2006) 38–51
4. : 3gpp tsg sa wg1. (http://www.3gpp.org/tb/SA/SA1/SA1.htm)
5. : Uma technology. (http://www.umatechnology.org/)
6. : Ieee 802.21 media independence. (http://www.ieee802.org/21/)
7. Eddy, W.: At what layer does mobility belong? IEEE Communications Magazine **42**(10) (2004) 155–159
8. Ratola, M.: Which layer for mobility? - comparing mobile ipv6, hip and sctp (2004)
9. Perkins, C.: (RFC 3220: Ip mobility support for ipv4)
10. Stewart, R., et.al.: (RFC 2960: Stream control transmission protocol)
11. Schulzrinne, H., Wedlund, E.: Application-layer mobility using sip. ACM Mobile Computing and Communications Review **4**(3) (2000) 47–57
12. Moskowitz, R., et. al.: Host identity protocol. Internet-Draft (work in progress) (2006)
13. Riegel, M., Tuexen, M.: Mobile sctp. Internet-Draft (work in progress) (2006)