CHAPTER 3

SWITCHING AND ROUTING IN WIRELESS NETWORKING

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PREFACE

In the course of WTEC site visits to organizations in Europe and Japan, very little attention was given to the subject of switching and routing in wireless communication networks. The draft site reports of October 1999 had only two short references to the subject. This is not for want of questions, but rather that the sites the panel visited. The researchers were focused on RF circuitry, modulation and (some) coding, software issues, and the design of the user terminal. There is perhaps a feeling, with exceptions, of course, that the core network is there anyway, so let that be a given. This report therefore, incorporates ideas expressed by a limited number of individuals who had opinions on this issue. In the interest of making this report somewhat more complete than simply a recitation of a small portion of the site visits, it is supplemented by a perusal of the literature and by off-line conversations with others knowledgeable in the subject.

INTRODUCTION

Convergence

There is a consensus that wireless data and multimedia traffic will overtake voice traffic in a relatively short span of time (perhaps as early as 2002). Cellular technologies are developing at a very rapid pace. As outlined elsewhere in this summary report of the panelists, new techniques have been developed for the third generation (3G) ranging from radio frequency components, antenna technology, signal processing, source and channel coding, interference reduction, and the various methods for improving spectral efficiency. Virtually all of these novelties and inventions are directed at improving the air interface, i.e., what happens between a mobile user and a base station at radio frequency transmission, reception and subsequent signal processing. However, for the most part, the large-scale (core) network that ultimately connects a wireless user to other remote users (wireless or otherwise) is still based on the traditional circuit switched network designed to carry telephonic voice traffic. One of the major dilemmas facing network designers is how to make a convergence among four apparently different service objective as shown in Fig. 3.1.

Figure 3.1 shows on the lower left the historic basis of communication networks, i.e., (voice) telephony. Traditionally, and for the most part, using a wired network. Furthermore, and perhaps more importantly, the talking path and end to end connection is circuit switched with dedicated resources being allocated (trunk lines, switching, monitoring subroutines, etc.) exclusively for each call. While call set up has progressed to a (logically) separate packet switched data network (SS7), the concepts remain rooted in the dominance of fixed location telephony. The wired network started to be used for the transmission and reception of non-voice data traffic over 30 years ago using modems, and more recently, with ISDN, ADSL, cable systems and
even fixed point satellite access. These, and the older transmission means, are now providing multimedia and Internet traffic to homes and offices. This service development is the third bubble on the lower right of Fig. 3.1. Finally, the upper left bubble is wireless technology that allows tetherless and roaming access to users.

![Diagram of Four Way Convergence](image1)

**Fig. 3.1.** Four way convergence.

For the most part, as stated earlier, wireless services have been, until very recently, mostly telephony and short message services (paging, etc.). The core mechanism for switching and routing of wireless services remains dependent on the telephony circuit switching even for the third generation (3G) of wireless network. It is a prime objective of many organizations in Europe, North America, Asia, and elsewhere to converge all these and possibly future service on a common platform. In this report, we review some of the ideas and plans to accomplish that. A fairly conservative approach currently being deployed is shown in Fig. 3.2.

![Diagram of Seamless Wireless Network](image2)

**Fig. 3.2.** Vision of a seamless wireless network.

The objectives of such a plan is to “marry” the circuit switched cellular wireless systems shown on top, with the IP (Packet switched) Internet network via gateways. Such a solution could include first and second generation wireless or other legacy air interfaces, but it is wholly insufficient for the kind of features required for mixed media and broadband services. These features include, but are not limited to the following:
- on demand bandwidth for real time traffic
- scalable architecture
- differentiated services and, if required, differentiated pricing
- multiple aggregated radio links
- transport to/from heterogeneous mobile end-users
- flexible resource management
- full roaming capability
- World Wide Web (WWW) and other Internet services
- virtual networks

Roaming capability is provided for in 2nd generation systems by transferring the database relating to a roaming user from a *home* location register (HLR) to a *visitor* location register (VLR) over a signaling network. An illustration of this for GSM is shown in Fig. 3.3 where the standard B, C, D, and G interfaces are used to link the VLR to the HLR and the Mobile (circuit) Switching Centers (MSC) to each other.

The Equipment Identification Register (EIR) is used to verify and identify the individual mobile user equipment. CDMA also uses a similar kind of architecture with the main differences being the air interface modulation and the interface between the Base Station (BS) and the Base Station Controller (BSC), Abis. As shown in Fig. 3.3 there are also provisions for the MSC to connect directly to the Public Switched Telephone Network (PSTN) via digital lines or to use ISDN.

**BROADBAND AND INTERNET ACCESS**

At most locations the panel visited in Europe and Japan, it saw a need to design an architecture for wireless networks that was capable of providing much higher data rates than exist in second generation cellular systems, regardless of the details of the air interface standards. Furthermore, the need exists for multimedia delivery to a small (handheld or laptop) terminal. At the present time, the focus is in supplying World Wide Web (WWW) and general Internet services. While there is limited potential for doing this using the PSTN, which the second generation relies on, such an approach is likely to prove inadequate and both the air interface and the core network switching and routing will need to change to accomplish the task. There are a number of competing approaches. The two most prominent are (1) wireless ATM and (2) some form of packet radio. Both of these ultimately envision packet or cell transmission end to end. That is, including the
air interface, but also fundamentally changing the routing and switching in the core network away from traditional voice oriented circuit switching. Among the many variations of these proposals, the one that stands out because it is currently implemented and shows promise for smooth evolution to the full convergence is General Packet Radio Service (GPRS).

**GPRS**

GPRS is an outgrowth of GSM/TDMA in Europe. Its basic architecture is the transmission of packets and is designed to support IP while minimizing hardware modifications of existing network elements. The packet format and its derivation from the GSM eight time slot air interface are shown in Fig. 3.4 using slot number 4.

![GPRS packet format](image)

This can provide about 18 kbps of true throughput (overhead excluded) per slot. Several slots can be used to increase this rate. The layered architecture for GPS is shown on figures 3.5a, 3.5b, and 3.5c. Here is illustrated the interface, $U_m$, between the mobile transceiver and the Base Station Controller (BSC).
SNDCP: Subnetwork dependence Convergence Protocol
LLC: Logical Link Control
RLC: Radio Link Layer
MAC: Medium Access Control
Ref: GSM 03.60 series

Fig. 3.5a. GPRS architecture.

Fig. 3.5b. GPRS network.

Fig. 3.5c. GPRS routing.
Once the packets get to this point, they can be switched and routed by any kind of packet switching network such as the Internet. The next step in the evolution of GPRS is Enhanced GPRS (EGPRS). This provides for a higher radio interface rate and more flexible user rates. Enhanced Data Rates for Global Evolution (EDGE) will be introduced to boost network capacity and increase the data rates of both circuit switching using High Speed Circuit Switched Data (HSCSD) and packet switching (GPRS) up to three fold. Possible rates may then exceed 400 kbps. The evolution of GPRS is believed by many to be the migration path towards a Universal Mobile Telecommunication System (UMTS) and the UMTS Radio Access Network (UTRAN)

**Wireless ATM**

An alternative contender for providing integrated wireless access and core network switching and routing is Asynchronous Transfer Mode (ATM) or perhaps more properly called “cell switching.” Originally developed for wireline multimedia services, ATM has connection oriented features and the ability for differentiated services and negotiated bandwidth plus Quality of Service (QoS) guarantees, that has much to recommend it. One can build an entire end to end network based on ATM. Wireless ATM has become a candidate architecture that assumes that multimedia service will be ATM based. Figure 3.6 illustrates the basic architecture. In this structure, developed by NEC Research, the air interface is ATM cells and a special ATM access point is provided to serve each geographical microcell. A new Mobile Network to Network Interface (M-UNI/UNI) is added. The User to Network (UNI) is standard. If IP networking is required then the proposal suggests carrying IP packets over ATM (IP/ATM).

![Wireless ATM system](image)

**Fig. 3.6. Network architecture: Wireless ATM system.**

**Shortcomings**

Wireless ATM appears to have some serious shortcomings. For example, since Adaptation Layer 2 (AAL2) appears to be the ideal mode to support both the radio interface and the core switching network, the use of minicell packets (up to 42 octets) within AAL2 requires specific overhead for signaling and switching, the result is a significant loss in efficiency. In addition, for high mobility users the Wireless ATM scheme may not be easily scalable.

GPRS has its own problems in that it is a gradual approach to achieving the convergence objectives and in the initial stages it is still tied to 2nd generation wireless techniques for roaming and mobility. Furthermore, once the packet gets into the TCP/IP network, it is not distinguished from non-wireless traffic. Radio transmission is notorious for its many impairments such as fading, multipath, shadowing, and blocking which causes packets to be dropped or corrupted. The existing TCP protocols interpret this as congestion and take action that can severely reduce performance. In addition, TCP/IP is a connectionless service with no QoS guarantees and until new differentiated service features are introduced, a completely satisfactory
solution is not possible. Other problems exist in the interaction of the higher layers of the protocol stack because of the anomalies of the physical layer that exists in wireless, and especially in high mobility and handoffs.

Possibilities for Research

A possibly fruitful area of research for switching and routing in wireless networks is packet radio taken to its limits. Packet radio per se has been investigated for many years as an application in military tactical communications.

The ultimate solution may be to design the wireless network with an advanced version of packet radio more suitable for the global commercial market. The large geographic coverage requires some form of cellular structure where the mobiles act as relays to a cell site (or satellite) for long haul. In addition, the structure of the network is very “fluid” so that “ad-hoc” networks may be established without prior configuration. There is considerable research already underway for small scale ad-hoc wireless networks but that needs to be extended.

There is also a need for understanding the interaction of the higher layers of the protocol stack when they are being serviced by an unreliable and quirky wireless physical layer and the need for handoffs, mobility, and roaming. A further positive note for direct wireless packet networks is that there are new protocol suites such asIpv6, which have a very large address space, built in security features and characteristics that increase efficiency and performance. Another new direction in Internet development is Multiprotocol Label Switching (MPLS), which bears directly on the issues of the ability to independently route and switch many connections destined for the same address and allows a unique ability to optimize traffic flows and to emulate connection-oriented virtual circuit switching. MPLS has been advanced by the Internet Engineering Task Force (IETF). It is a label switching technique that integrates layer 2 switching with level 3 routing. Label switched routers can improve performance and provide for differentiated services and multiple protocols, including Ipv4 and Ipv6, among others. Although these ideas are being developed primarily with the wired network, they have many potential benefits for the new multimedia broadband wireless systems.

CONCLUDING REMARKS

In the area of networking, switching and routing there will continue to be a disconnect between European, Japanese, North American, and worldwide standards.

Even through the 3rd generation, the interfaces, signaling, and roaming will remain incompatible. Furthermore, although there is every intention of providing higher data rates as well as voice telephony, many systems are unable to integrate voice, data, and multimedia so that there is a smooth convergence of wireline and wireless networks. The third generation migration of GSM includes GPRS, which is a packetized transfer to the user level, but it is still based on connection oriented sessions by stealing slots from the GSM TDM air interface. GPRS II extends the way that databases are accessed (for roaming, etc.) but the basic architecture is the same. In the United States, there are similar methods for AMPS Cellular Digital Packet Data (CDPD), the North American TDMA IS 136 standard, as well as Packet communications in CDMA 2000. While there are many proposals to integrate ISDN, or ATM into the wireless network, there remain fundamental problems with them.

Incorporating the ability to use IP for mobile traffic is fraught with problematic issues ranging from effects during handoffs to roaming. Mobile IP as taken up by the IETF may be more suitable for relocation of computer resources than to true mobility as in rapidly moving vehicles.

It appears that one way to achieve a true four-way convergence of wireline, wireless, telephony, and multimedia traffic is to rethink the entire concept of leaving the core network as well as the air interface as a connection oriented circuit switched network.
Among the topics of needed research are the following:

- a scalable architecture that takes into account the wireless access model
- seamless operation across radio access fixed and core network
- simplified mobility procedures
- distributed databases for user services
- new ideas of the use of intelligent network (IN) concepts applied to new services including mobile wireless
- a multi-tier structure that will allow expansion of scale and new services not yet defined

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