Mobile Network Evolution: A Revolution on the Move

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ABSTRACT

This article gives an overview of the evolution in the mobile communications world. The uptake of 2G technologies has been tremendous, even though several systems exist that are not interoperable. 3G will bring some convergence, but will not achieve the goal of a single global technology. At the network level, IP is becoming more important. In hot spot environments, WLAN is bringing a complementary technology toward cellular.

INTRODUCTION

In the first half of 2002, the number of cellular users will break the 1 billion mark. This revolution in our life has been realized through a continuous evolution of standards and products keeping an optimum level of performance. This evolution started in the early ’90s with the replacement of the analog mobile network by the digital one, and is continuing today with the deployment of the third generation (3G). From circuit-driven networks we now enter the packet world through intermediate overlay networks, followed in years to come by all-IP networks.

Global System for Mobile Communications (GSM) now accounts for about 66 percent of the world’s total market. This market share is likely to increase as major time-division multiple access (TDMA) actors have started the move to GSM. The reason behind the TDMA migration to GSM is not only technical but also, and more important, financial thanks to GSM’s huge economy of scale.

Another technological consolidation is occurring with 3G mobile technologies, where Universal Mobile Telecommunications System (UMTS) is the chosen evolution for all GSM networks, as well as for the Japanese Personal Digital Cellular (PDC) network. As a result UMTS is the 3G choice of about 85 percent of mobile operators.

Up to now, the growth of mobile phone users has been almost purely driven by voice services. It is only recently that data has started to contribute at a considerable level to the revenues of mobile operators, reaching about 10 percent in the second quarter of 2001 for advanced operators [1] like NTT DoCoMo (iMode) or Orange (Short Message Service, SMS). Voice mobility is becoming a commodity for end users, and the market is demanding new applications. Operators currently face the challenge of performing a cultural transition from a voice-only service offering toward offering new applications. This transition is required to keep their revenues growing.

The objective of this article is to give an overview of the different radio technologies and their evolution, the evolution of the network architecture toward all-IP networks, and the interworking of different wireless access technologies.

THE EVOLUTION OF THE CELLULAR TELEPHONE SYSTEM

In the following paragraphs we describe the major cellular telephone systems, in particular the evolution of radio technologies.

FIRST-GENERATION MOBILE SYSTEMS

During the early ’80s, analog cellular telephone systems were deployed. At that time each country developed its own system, limiting usage within national boundaries and avoiding economies of scale. In most countries these systems were replaced by 2G systems during the ’90s.

SECOND-GENERATION MOBILE SYSTEMS

Currently, four 2G technology systems coexist: GSM, cdmaOne, TDMA, and PDC (Fig. 1).

GSM — In order to develop a pan-European digital cellular system, the Groupe Spécial Mobile (GSM) was formed in 1982 by the Conférence Européenne des Postes et des Télécommunications (CEPT). In 1989, GSM specifications were made by the European Telecommunications Standards Institute (ETSI) and recently transferred to the 3G Partnership Project (3GPP).

GSM commercial service started in July 1991, but handsets were really available only in the course of 1992. By 1993, there were 36 GSM networks in 22 countries, including non-European countries such as Australia and South Africa. In January 2002, there were more than 470 GSM operators in 172 countries with 646 million users.

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GSM allows up to eight users to share a single 200 kHz radio channel by allocating a unique time slot to each user. GSM is used in the 900 and 1800 MHz bands all over the world except North America (1900 MHz band). Soon, new frequencies will be used in the 450 and 850 MHz bands.

Since its inception, GSM has been offering SMS, a connectionless packet service limited to messages containing less than 160 characters. Data transfer are also made possible using circuit-switched data (CSD), which offers throughput up to 14.4 kb/s. These limitations led to the standardization of the High Speed Circuit Switched Data (HSCSD) and General Packet Radio Service (GPRS).

HSCSD enables higher rates (up to 57.6 kb/s), but like CSD is circuit-based. Therefore, it is inherently inefficient for bursty traffic, continuously using several radio channels (up to four). The weaknesses of HSCSD mean that only around 30 operators have introduced it so far. Most operators use GPRS instead.

GPRS, which keeps the GSM radio modulation, frequency bands, and frame structure, is designed around a number of guiding principles:

- Always on: Allows sending or receiving data at any time
- High bit rates: An actual bandwidth roughly equivalent to a wireline modem
- Improved usage of radio resources: Same radio channels shared between several users
- Separate allocation of uplink and downlink channels
- Simultaneous voice call and data transfer
- Billing based on volume

In September 2001 around 100 operators, including several American operators, deployed GPRS.

Enhanced Data Rate for Global Evolution (EDGE) improves GPRS by introducing a new radio modulation scheme that triples the bandwidth offered by GPRS. The EDGE upgrade will start in 2002, mostly in the United States during the first phase.

The further evolution of the GSM standard is handled now by the GSM EDGE Radio Access Network (GERAN) group of 3GPP. This group covers in particular the connection of GSM/EDGE to 3G core networks and support of real-time services.

cdmaOne — Spread spectrum technology has been used in military applications for a very long time. In the mid-'80s, the U.S. military declassified this technology, and it was tested for cellular telephony applications.

The spread-spectrum-based code-division multiple access (CDMA) standard, was approved in July 1993 by the Telecommunications Industry Association (TIA). CDMA commercial networks opened in 1995, but by mid-1998 had attracted only 9 million users. Things have improved since that time, with today around 100 million users, mostly in the Americas (55 million) and Asia (40 million). CDMA is now called cdmaOne to differentiate it from 3G CDMA systems.

With CDMA, many users (up to 64) share the same 1.25 MHz channel. Attaching a pseudo-random code to each user allows decoders to separate traffic at each end. All base stations transmit the same pseudo-random code with a time offset; therefore they must remain synchronized. CDMA is used in the 850 MHz and the 1900 MHz bands.

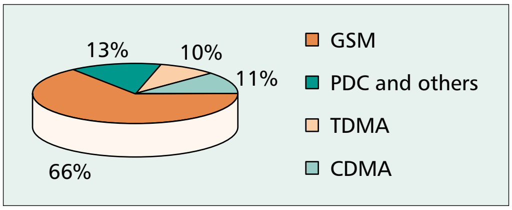

Figure 1. *Mobile standard global distribution (EMC: August 2001).*

Like GSM, IS-95A, the first version of CDMA, offers throughput limited to 14.4 kb/s. In June 1997 IS-95B CDMA specifications were completed. By assigning up to seven supplementary codes in addition to the fundamental code, data rates up to 64 kb/s are possible. Some Asian operators have started to implement IS-95B CDMA offerings.

TDMA — With analog cellular systems, such as Advanced Mobile Phone Service (AMPS), a single subscriber at a time is assigned to a 30 kHz channel. D-AMPS, the TDMA system designed to coexist with AMPS systems, divides this 30 kHz channel into three channels, allowing three users to share a single radio channel by allocating unique time slots to each user.

Recent developments show that the TDMA community is moving toward GSM. AT&T Wireless was the first to announce its decision in November 2000. Since then, Cingular Wireless in the United States and other major Latin American TDMA operators have announced their preference for GSM.

These new GSM networks will integrate GPRS and EDGE. Deployment of UMTS will require additional spectrum and be limited to 3G operators gaining new frequencies.

PDC — PDC is the Japanese TDMA-based standard operating in the 800 and 1500 MHz bands.

PDC hosts the most convincing example of mobile Internet, iMode. iMode has already conquered over 30 million subscribers (January 2002) thanks to a large service offering and an excellent business model (billing on volume, revenue sharing arrangement with content owners, etc.).

The congestion of the PDC system urged NTT DoCoMo to replace it rapidly with a 3G system.

Third-Generation Mobile Systems

The idea of 3G became evident with the need for more capacity, new frequencies, and higher bit rates. A unique truly international standard was targeted, but unfortunately not successfully. Two main proposed systems for 3G (Fig. 2) have been recognized by the International Telecommunication Union (ITU):

- UMTS is composed of two different but related modes:
  –*CDMA-direct spread*: Wideband CDMA, also called frequency division duplex (FDD)
  –*CDMA-TDD* (time-division duplex)
- cdma2000: CDMA multicarrier, which is the evolution of cdmaOne

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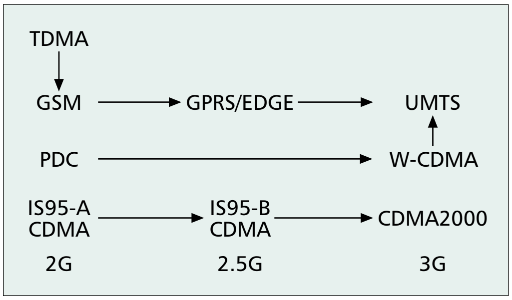
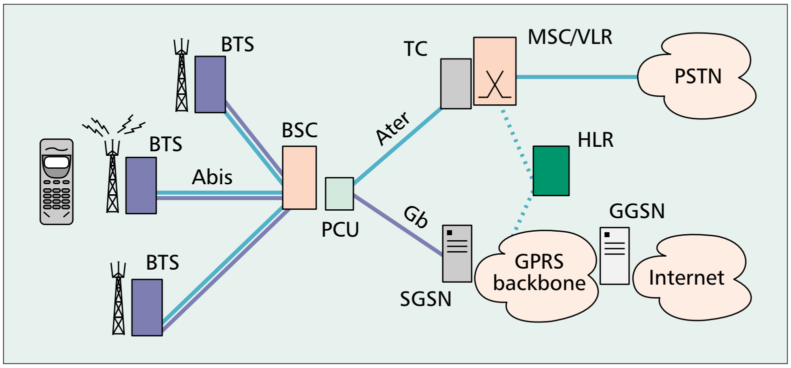


■ **Figure 2.** *Standard evolution from 2G to 3G.*



■ **Figure 3.** *A GSM/GPRS network.*

EDGE, despite being part of the approved 3G systems, should be considered a simple evolution of the GSM system described earlier.

UMTS — Technical specification work on FDD and TDD standardization is being done within the 3GPP. The edition of specifications is phased in different releases:

- **3GPP release 3 specifications**, formerly called release '99, define FDD and TDD modes, and are based on asynchronous transfer mode (ATM) in the radio access network. Release 3 was actually issued in March 2000 and became stable in June 2001.
- **3GPP release 4 specifications** define a new version of TDD and FDD mode improvements. Release 4 was frozen in March 2001.
- **3GPP release 5 specifications** shall include IP-based transport within the radio access network. Release 5 is scheduled for March 2002.

FDD mode is considered the main technology for UMTS. FDD mode is derived from CDMA and also uses pseudo-random codes. Separate 5 MHz carrier frequencies are used for the uplink and downlink, respectively, allowing an end user data rate up to 384 kb/s (2 Mb/s per carrier). Later on, high-speed downlink packet access (HSDPA) will allow downlink data rate transmission to increase. FDD allows the operation of asynchronous base stations.

The TDD mode likely to be deployed is time-division-synchronous code-division multiple access (TD-SCDMA). TD-SCDMA operates on low-chip-rate carriers, with 1.6 MHz carrier spacing instead of 5 MHz for the other wideband standards. It allows end-user data rates up to 2 Mb/s in optimal conditions.

NTT DoCoMo commercialized a 3G service, called FOMA, in October 2001. Elsewhere, the installation of the first UMTS system (FDD mode only) will start in 2002, and marketing of services during 2003.

Cdma2000 — Technical specification work for cdma2000 standardization is being done within 3GPP2 in the following steps:

- **cdma2000 1x**, which is an evolution of cdmaOne, supports packet data service up to 144 kb/s.
- **cdma2000 1xEV-DO** introduces a new air interface and supports high-data-rate service on downlink. It is also known as high rate packet data (HRPD). The specifications were completed in 2001. It requires a separate 1.25 MHz carrier for data only. 1xEV-DO provides up to 2.4 Mb/s on the downlink (from base station to terminal), but only 153 kb/s on the uplink. Simultaneous voice over 1x and data over 1xEV-DO is difficult due to separate carriers.
- **cdma2000 1xEV-DV**, which will introduce new radio techniques and an all-IP architecture for radio access and core network. The completion of specifications is expected in 2003. It promises data rates up to 3 Mb/s.

SK Telecom from Korea was the first operator to launch cdma2000 1x in October 2000. Since that time, only a few operators have announced cdma2000 1x service launches. Some operators recently announced setting up cdma2000 1xEV-DO trials.

The Evolution of the Network Architecture

The GSM/GPRS Network Architecture

The GSM/GPRS network configuration [3] is presented in Fig. 3.

Current services (voice and circuit-switched data) are supported via the base station subsystem (BSS) and network subsystem (NSS). The BSS consists of the base transceiver station (BTS) that handles the radio physical layer and the base station controller (BSC) that deals with radio resource management and handover. The NSS for circuit-switched (CS) services consists of the mobile switching center (MSC), the visitor location register (VLR) integrated in the MSC, and the home location register (HLR).

GPRS provides packet-switched services over the GSM radio. A new functional network entity, the packet control unit (PCU), is required in the BSS to manage packet segmentation, radio channel access, automatic retransmission, and power control. The major new element introduced by GPRS is an NSS that processes all the data traffic. It comprises two network elements:

- **Serving GPRS support node (SGSN)**: keeps track of the location of individual mobile stations and performs security functions and access control
- **Gateway GPRS support node (GGSN)**: encapsulates packets received from external packet networks (IP) and routes them toward the SGSN

The Gb interface between the BSS and the SGSN is based on the frame relay transport protocol. The SGSN and GGSN are interconnected via an IP network. No layer 2 technology has been specified.

UMTS Release 3 Network Architecture

The UMTS release 3 network, shown in Fig. 4, consists of two independent subsystems connected over a standard interface:

- **UMTS terrestrial radio access network (UTRAN)**: composed of node B and a radio network controller (RNC). Node B is functionally similar to the GSM BTS, and RNC is similar to the GSM BSC.
- **UMTS core network**: equivalent to the GSM/GPRS NSS.

The UMTS core network reuses as far as possible the GSM/GPRS NSS:

- **Packet switch (PS)**: an evolution of the GPRS SGSN/GGSN with a more optimized functional split between the UTRAN and core network
- **Circuit switch (CS)**: an evolution of the NSS with the transcoder function moved from the BSS to the core network

As described earlier, UMTS is based on a new radio technology having a big impact on the UTRAN. The UTRAN (Fig. 5) consists of several possibly interconnected radio network subsystems (RNSs). An RNS contains one RNC and at least one node B. The RNC is in charge of the overall control of logical resources provided by the node Bs. RNCs can be interconnected in the UTRAN (i.e., an RNC can use resources controlled by another RNC) via the Iur interface. Node B provides logical resources, corresponding to the resources of one or more cells, to the RNC. It is responsible for radio transmission and reception in the cells maintained by this node B. A node B controls several cells.

At a later stage, an evolution of EDGE called GERAN will allow upgrading 2G infrastructure to offer UMTS capabilities such as real-time packet services. The UMTS functional split between BSS and core network will be applied to GERAN with the current assumption of a transcoder located in the core network.

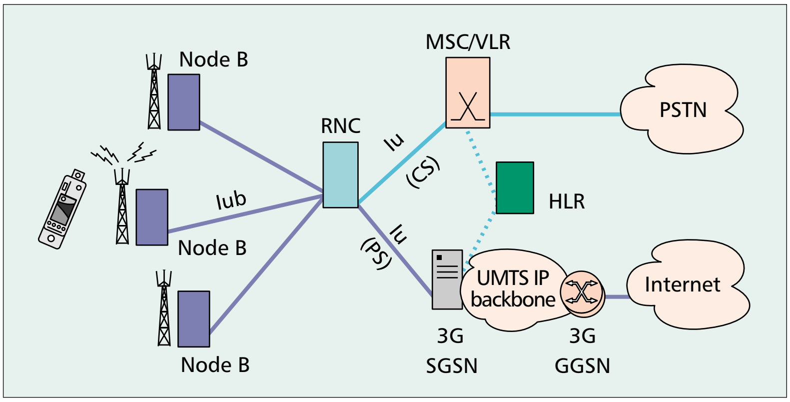


Figure 4. *A UMTS network.*

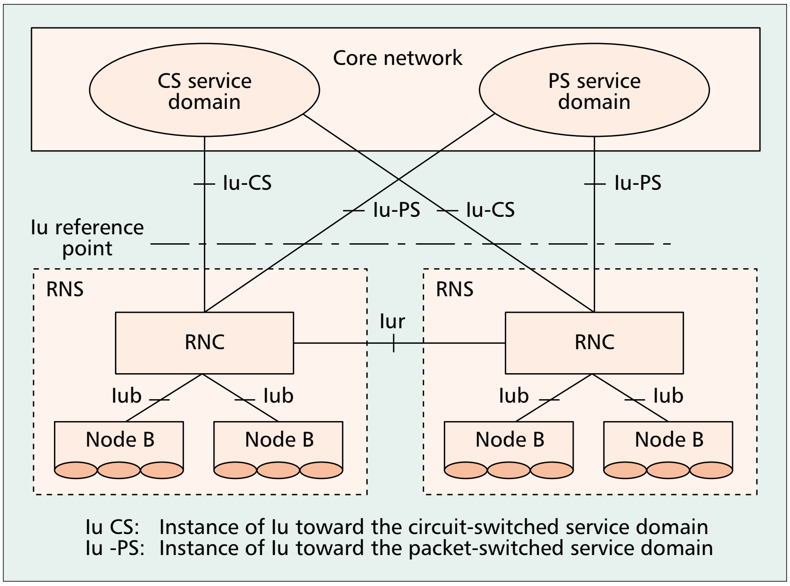


Figure 5. *UTRAN architecture.*

Evolution toward a UMTS All-IP Architecture

At the end of 1999, work started in 3GPP toward an all-IP architecture. This evolution was driven by two objectives:

- Independence of the transport and control layer to ease the implementation of new applications up to the mobile terminal
- Operation and maintenance optimization for the access network

This evolution has an impact on different parts of the network. Basically, three main (and independent) evolutions are part of this evolution toward an all-IP architecture:

• Evolution toward a next-generation network (NGN) type of architecture in the CS domain, where the MSC function is split into a control plane part (MSC server) and a user plane part (media gateway). The introduction of packet transport (IP or ATM since the network architecture is independent of the underlying transport layer) on the NSS backbone also allows moving the transcoder toward the border of the public land mobile network (PLMN). As such transcoder-free operation (TrFO) is possible, which results in much better voice quality. This feature is part of release 4.

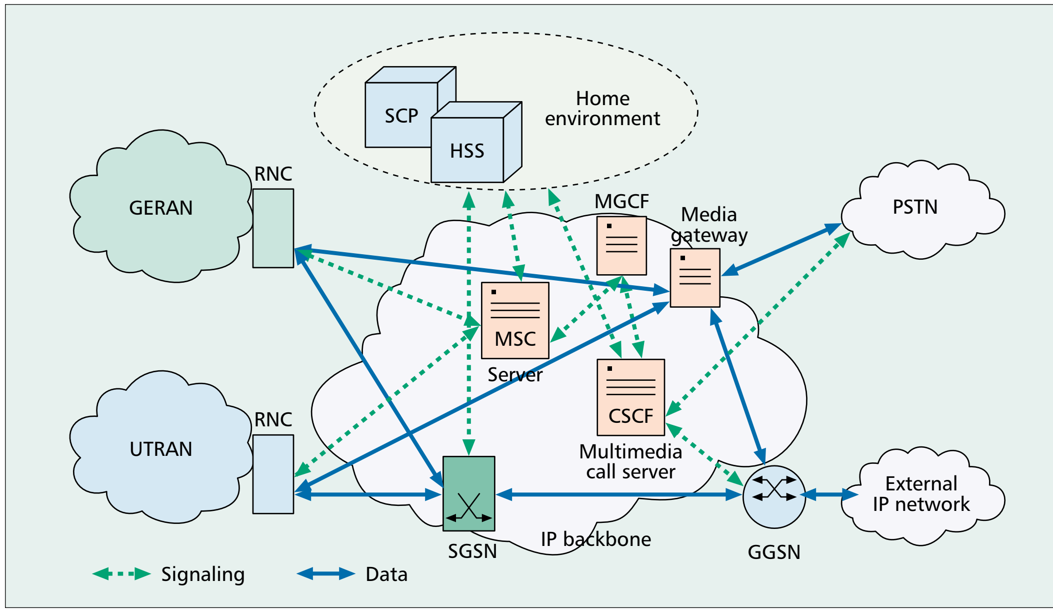
• Addition of an IP-based multimedia subsystem (IMS) that introduces the capabilities to support IP-based multimedia services, such as voice over IP (VoIP) and multimedia over IP (MMoIP), and makes use of the packet-switched network for the transport of control and user plane data. The PS domain also deals with all the mobility (handover) aspects. This feature is part of release 5.

• Introduction of IP transport technology within the UTRAN, as an alternative to the ATM-based UTRAN. This feature is also part of release 5.

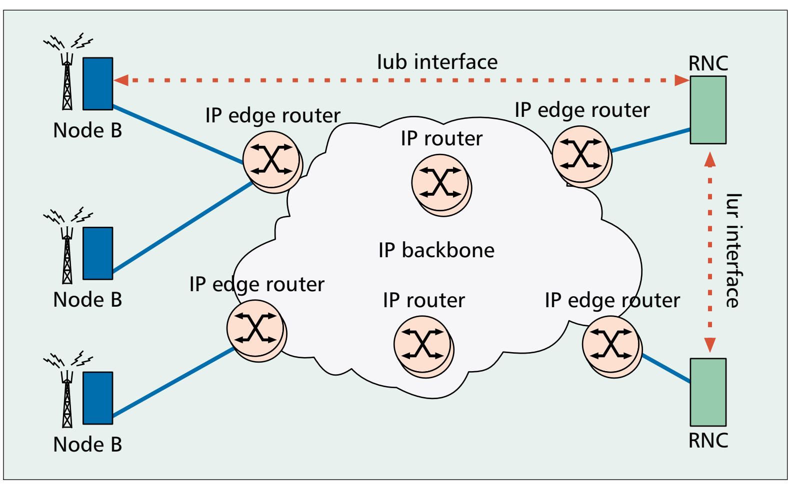
It is important to stress that these evolutions are independent of each other and can also be deployed in a fully independent way. This means that for each of these evolutions the operator can make an independent yes/no decision.

In the following sections we discuss the later evolution steps in more detail.

IMS — The introduction of the IMS system is driven by the demand to offer more and enhanced services to end users. It is clear that IP



■ **Figure 6.** *A simplified all-IP architecture.*



■ **Figure 7.** *IP-based UTRAN.*

plays a major role in the quick introduction of new services.

Operators are faced with the challenge of finding their role in these new business opportunities. Based on their specific strengths such as expertise in communication and powerful billing systems, network operators are now moving into communication-oriented services. To do this, network infrastructures must be transformed into secure, open, and flexible platforms on which third-party developers and service providers can add rapidly and cost effectively generic as well as customized applications.

The main drivers leading this transformation of the value model of the public telecom market can be analyzed along three directions:

- **Provision of user-centric solutions**: Market demand for services are evolving from a standardized "one-size-fit-all" service offer to a fully customized service offer that adapts to the user's choice and preference, as well as terminal and location.
- **Usage of the new capabilities of networks and terminals**: Available bandwidth is increasing, which enables the deployment of media-rich services making use of all capabilities for interactivity. Control capability for network resources is enabling provision of the adapted media to the user with the expected levels of quality of service (QoS) and security.
- **Evolution of marketplace and business**: With the shift in value chain, new roles are defined and new stakeholders taking their place in the market (service provider, service retailer, etc.). In parallel, deregulation and the need for timely coping with fierce competition fuel openness toward third parties and support for open service creation and provision.

3GPP has selected the SIP protocol as the only call control protocol between terminals and the mobile network. Interworking with other H.323 terminals (e.g., fixed H.323 hosts) will be performed by a dedicated server outside the PLMN. 3GPP also decided to use IPv6 as the only IP version for the IMS components.

Figure 6 shows the proposed 3GPP all-IP UMTS core network architecture [2]. New elements in this architecture are:

- **Call state control function (CSCF)**: The CSCF is a SIP server that provides/controls multimedia services for packet-switched (IP) terminals, both mobile and fixed.
- **Media gateway (MG)**: All calls coming from the PSTN are translated to VoIP calls for transport in the UMTS core network. This media gateway is controlled by the MGCF using the H.248 protocol.
- **Media gateway control function (MGCF)**: The first task of the MGCF is to control the media gateways via the Media Gateway Control Protocol H.248. Also, the MGCF performs translation at the call control signaling level between ISUP signaling, used in the PSTN, and SIP signaling, used in the UMTS multimedia domain.
- **Home subscriber server (HSS)**: The HSS is the extension of the HLR database with subscribers' multimedia profile data.

IP-Based UTRAN — The transport mechanism in the release 3 UTRAN is based on ATM/ATM adaptation layer 2 (AAL2). At the end of 1999, Alcatel introduced a Work Item in 3GPP to specify an IP-based solution for the UTRAN transport mechanisms as an alternative to the ATM-based solution (i.e., the operator would have the choice between IP or ATM).

The reference architecture for such an IP-based UTRAN is shown in Fig. 7. The IP network that interconnects node B and RNC can be owned by the mobile operator, but can also make use of another carrier's IP network. The concentration function of the RNC is now performed by the IP transport network itself. Some technical challenges that had to be dealt with are related to QoS (due to short delay requirements in the RAN), efficiency in the last mile, and so on [4, 5].

IP-based UTRAN offers several advantages. It is more flexible in the mapping between node B and RNC servers and makes more efficient usage of transport resources. Furthermore, IP technology is cheaper due to its success, and a homogenous transport technology can save operation expenses. It reuses the existing transmission (layer 2 independence); IP can be supported by transmission equipment used today for GSM and UMTS.

Apart from the pure replacement of transport technology toward IP, it also enables other evolutions in a smooth way. The first additional evolution is to evolve from a pure hierarchical architecture as we have today in UMTS release 3 toward a distributed architecture, which allows, for example, a direct connection from serving RNC to node B, avoiding passing through the drift RNC. IP also enables easier evolution toward an NGN architecture within the RAN, where control plane functions are physically separated from user plane functions, which allows for improved scalability and flexibility features.

CDMA2000 Network Architecture

The network architecture for a cdma2000 network (defined in 3GPP2) is shown in Fig. 8.

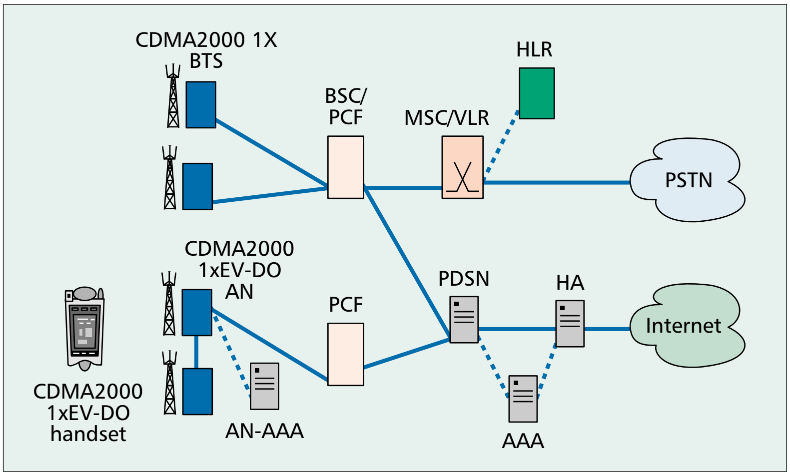


Figure 8. *cdma2000 1x and cdma2000 1xEV-DO network.*

The basic architecture is quite similar to the GSM/UMTS architecture. The main differences with the GSM/UMTS architecture are in the packet domain where a packet data switching node (PDSN) is used. It has a similar role to the SGSN and GGSN in UMTS. Mobility management within 3GPP2, however, is based on Mobile IP (RFC2002) instead of GPRS mobility management in GSM/UMTS PS networks. Furthermore, ANSI-41 MAP signaling is used instead of GSM MAP signaling. Activities have started in 3GPP2 for evolution toward an all-IP network, similar to the IMS activities in 3GPP.

Intertechnology Aspects

Interworking with Other Wireless Technologies

In parallel to the wide-area cellular mobile services, we see in the public environment operators offering wireless services in selected hot spots, airports, hotels, or coffee shops. These services are data only and oriented to nomadic use [6].

For both approaches, there is a constant objective to go for higher throughput in a mobile environment, similar to the performance users experience in the enterprise and home environments. To reach such performance, new radio interfaces have to be envisaged, similar to current wireless LAN (WLAN) technologies.

WLAN does not belong to the evolution path of mobile networks presented before, but started as a wireless extension to enterprise LAN networks. Confined to a second tier role for a long time, it has recently affected a breakthrough from its original application toward home and public space, appearing as a disruptive technology due to its undisputed cost to performance ratio. Some are seeing WLAN as a replacement for mobile networks whereas it should be seen from its strong points more as a complement to the wide-area 3G network, offering close inter-working to ensure proper delivery of services according to the most appropriate available access network.

WLAN Technologies Overview: A World of Standards

2.4 GHz Unlicensed Band — **IEEE 802.11b** leads current deployment. It reaches an actual throughput around 5.5 Mb/s per bearer (theoretical 11 Mb/s). Since last year, the Wireless Ethernet Compatibility Alliance has launched an interoperability program between 802.11b products from different vendors, which has been the cornerstone of the WLAN commercial breakthrough.

HomeRF and Bluetooth. If there are serious concerns over long-term prospects for HomeRF technology (a combination of simplified 802.11 and DECT targeting the residential segment), Bluetooth will certainly be a success in years to come for short-range interconnection. When the amount of Bluetooth equipment becomes significant, WLAN products will certainly migrate to the 5 GHz band to avoid interference created by Bluetooth.

5 GHz Unlicensed Band — **IEEE 802.11a**, an evolution of 802.11b, will operate in the unlicensed 5 GHz band offering an actual throughput around 30 Mb/s per bearer (theoretical 54 Mb/s).

ETSI HiperLAN2 will also operate in the unlicensed 5 GHz band offering an actual throughput around 40 Mb/s, superior to IEEE 802.11a. HiperLAN2 solves many issues associated with 802.11a, in particular interference, security, and QoS.

A convergence of 802.11a and HiperLAN2 technologies would be beneficial by giving a clear market focus in the 5GHz band similar to what has been accomplished in the 2.4 GHz band. This initiative has been launched recently between IEEE and ETSI.

	Bluetooth	IEEE 802.11b	IEEE 802.11a	ETSI HiperLAN2
Frequency band	2.4 GHz	2.4 GHz	5 GHz	5GHz
Typical carrier rate	< 1 Mb/s	5.5 Mb/s	30 Mb/s	40 Mb/s
Typical range (m)	~5–10	50–100	50–100	50 (indoor)/300 (outdoor)
Fixed network support	RS-232, TCP/IP	Ethernet	Ethernet	Ethernet, ATM, IEEE.1394
Availability	Now	Now	Now	2002
Medium access control	TDD (polling)	CSMA/CA (DCF)	CSMA/CA (DCF)	TDD (polling)
QoS support	SCO	PCF	PCF (best effort)	FCA, FSA
Modulation	GFSK	CCK	OFDM	OFDM
Handover support	No	No	No	Yes
Radio link quality control	No	Link adaptation	Link adaptation	Link adaptation

Table 1. *WLAN standard characteristics.*

A convergence of 802.11a and HiperLAN2 technologies would be beneficial by providing a clear market focus in the 5 GHz band similar to what has been accomplished in the 2.4 GHz band. This initiative was launched recently between IEEE and ETSI, and thanks to the harmonization effort already made, this can be envisaged in reasonable time.

Both standards rely on the OFDM modulation to reach a good performance in highly dispersive channels. The transmitted symbols are mapped onto multiple (48) subcarriers, and in parallel pilot tones are sent to facilitate tracking. HiperLAN2's main differences are the dynamic frequency selection (DFS) process, which automatically assigns the carrier frequency according to interference measurements, and the scheduling algorithm that grants resources to connections with respect to the connection type (Table 1).

Seamless Network Architecture

Three different network layers can be defined:

- **Cellular layer** for full coverage, multimedia, medium-bit-rate applications. This is the area of GSM, CDMA, or UMTS mobile networks.
- **Hot spot layer** for high bit rates in a short-range local mobility environment. This is the area of WLAN networks.
- **Personal network layer** to provide a short range of interconnectivity between different equipment (printers, PDAs, home appliances, etc.). Interconnection of this equipment to the other layers of communications via multimode terminals is the area of Bluetooth.

The transparent delivery of services across these network layers in an optimum way will require a dynamic bandwidth management function operating on diverse wireless technologies while maintaining a continuous session. This new media access layer will connect the access networks to the core network while ensuring mobility management, security, and QoS.

The ETSI Broadband Radio Access Network (BRAN) standardization body investigates, for HiperLAN2, two approaches for interconnection of WLAN and UMTS networks:

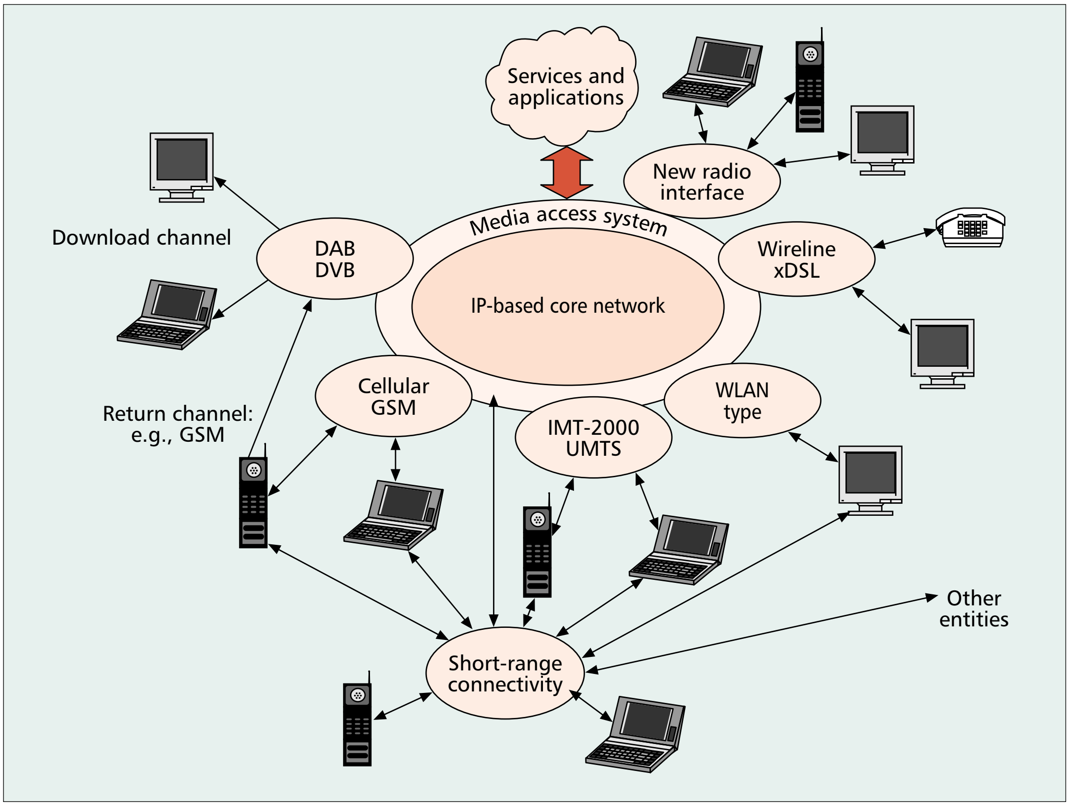
- **A tight coupling** scheme, to offer a seamless handover and the same level of security in WLAN and UMTS networks. This approach would require a simplified Iu interface for interconnection of WLAN network to UMTS core network.
- **A loose coupling** scheme, which would rely on IP protocols to organize mobility and roaming between access networks. Interworking between WLAN and the core network is performed between the authentication, authorization, and accounting server (AAA) and the home location register (HLR). Mobile IP and the home agent/foreign agent concept will extend mobility to any network while preserving seamless operation.

In the longer term, another approach is considered with the application making its own choices based on application and user requirements together with the capability of the different networks. This would require higher intelligence in the terminals to make best use of the different applications available locally. At the price of this complexity, the vision [7] brought out by the Wireless Strategic Initiative (WSI) may become real, bridging all access technologies from fixed to satellite and from person to person to customized broadcast (Fig. 9).

Conclusions

2G mobile communications has brought about a revolution in ways of living. In Western Europe the penetration rate has reached more than 70 percent in less than 10 years since the commercial launch of GSM. And the revolution is not over, with mobile Internet and 3G services being offered in coming years.

Through an evolution of technology, new services have been or will be offered to subscribers. Data services have really taken off in the last couple of years with SMS and iMode. GPRS packet data services are being launched, providing higher data rates and the always-on capability. UMTS and its evolutions will provide even higher data rates, and a more comfortable offering of more demanding services. The evolution from 2G toward 3G will also lead to more convergence



■ **Figure 9.** *The multitechnology access network [7].*

At the price of this complexity, the vision brought out by the Wireless Strategic Initiative may become real, bridging all access technologies from fixed to satellite and from person to person to customized broadcast.

through a reduction of the number of main 3G cellular technologies. In the short to mid-term, interworking with WLAN is envisioned, as well as the offering of multimedia (including real-time) services via the IMS system.

Even all this will not be the end of the evolution of mobile communications as activities are ongoing within the research community on topics beyond 3G (e.g., satellite component of UMTS, Mobile Broadband System at 60 GHz).

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Biographies

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PHILIPPE LAINÉ received his M.ST. degree in electrical engineering from UTV University in France in 1983. After undergoing a period of training in the United States, he started his career in 1985 as a software engineer, working on various projects in telecommunications and satellite image processing. In 1989 he joined Alcatel, at first working on a cable TV project, then appointed project manager in charge of the development of network management systems. From 1995 to 2001, as a marketing manager for the Mobile Networks Division, he handled the promotion of the GSM, GPRS, and 3G mobile systems. Based on this experience, he joined the Network Strategy Group to define and promote the corporate vision for the evolution of the mobile networks.

CHRISTOPHE LEROUGE is graduated from Ecole Nationale Superieure des Telecommunications in Paris (ENST) and received his M.S. in system engineering from UCLA. Major part of his career was devoted to radio system design from long distance high-capacity multilevel modulation radio link to radio access and cellular systems. He is owner of multiple patents on digital radio processing. In 1990 he joined Alcatel where he held different positions in research and development in the transmission and mobile radio divisions. He is currently mobile and data strategy director in the Network Strategy Group within the Alcatel CTO organization. His main areas of responsibilities deal with the 3G of mobile networks and the beyond 3G environment.

XIAOFENG XU is a research scientist for the Mobile Networking Technologies project in the Network Strategy Group within Alcatel in Plano, Texas. He received his B.S. in electrical engineering from the University of Science and Technology of China in 1993. He joined Alcatel in July 1993. Since then he has been involved in research and development of networking systems in GSM, GPRS, and CDMA standards, and responsible for 2G/3G wireless standardization on behalf of Alcatel in China Wireless Telecommunication Standards Group (CWTS). He is currently working on Mobile IP and CDMA2000 network research.