Broadband Radio Access for IP-Based Networks in the IST BRAIN Project

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Abstract

Second generation mobile radio systems are deployed worldwide. These systems are evolved to higher data rates and packet transmission. Third generation mobile radio systems are currently being standardized worldwide to be initially deployed starting in 2001 in different regions of the world. Advanced multimedia services are under development and first services are already being offered in second generation systems. Broadband WLAN type systems are emerging, which will be part of systems beyond third generation. The IST BRAIN Project, which is partly funded by the European Commission, is working on a concept to integrate second and third generation cellular systems and broadband radio access systems through a common IP network platform. Horizontal and vertical handover between these systems provide seamless service. This paper focuses on this concept as a step towards systems beyond third generation mobile communications and the investigations in the BRAIN Project.

1. Introduction

Mobile radio communication systems have been successfully deployed in different regions of the world since about 1980 to extend telephone services to mobile users. First generation systems are based on analog technology. Second generation systems (GSM, IS-95, IS-54, ANSI-136 and PDC) introduced digital technology. The worldwide dominating second generation standard is the GSM system (Global System for Mobile Communication) with more than 250 million subscribers in about 120 countries. Based on the big worldwide footprint of GSM this system is being further developed to more advanced data services by techniques as High Speed Circuit Switched Data (HSCSD), General Packet Radio Service (GPRS) and the EDGE system (Enhanced Data rates for GSM Evolution).

In addition to these evolutionary steps third generation mobile radio systems (IMT-2000 in ITU and UMTS in Europe) are standardized worldwide. Their main goals are to support broadband data services and mobile multimedia up to 2 Mbps by a wideband radio interface, international roaming for circuit-switched and packet-oriented services. IMT-2000 supports time division duplex (TDD) and frequency division duplex (FDD) to enable asymmetric and symmetric data services in a spectrum efficient way [1 - 4].

With the evolution of the second and third generation systems more advanced data and multimedia services are becoming available in addition to mobile telephony. These trends and requirements are affecting the vision of future systems beyond third generation.

The number of subscribers for mobile communications increased much faster than expected. The annual growth rates in important markets increased from 1998 with about 60 % to expected 100 % per year in 2002. In 2000 the number of mobile subscribers is higher than 400 million worldwide and for 2010 more than 1700 million mobile subscribers are expected [2; 5 and 6]. With third generation systems the combination and convergence of the different worlds IT industry, media industry and telecommunications will integrate communication with information technology. It is expected by the UMTS Forum that in Europe in 2010 about 90 million mobile subscribers will use mobile multimedia services and will generate about 60 % of traffic in terms of transmitted bits. The major step from the second to the third generation was the ability to support advanced and wideband services. The user expectations are increasing on a large variety of services and applications with a high quality and grade of service (QoS and GoS). Therefore, seamless services and applications via different access systems will be the driving forces for future developments. Due to the dominating role of IP based data traffic in future the networks and systems have to be designed for economic packet data transfer. The new expected data services are highly bandwidth consuming. This results in high data rate requirements for future systems.

2. Technological Trends

The fulminate growth of Internet usage is one of the major technical trends for future communications. The growth of subscribers for fixed access will reach saturation around 2004 for voice usage (Figure 1a). The number of mobile subscribers is increasing very fast and it is expected that it will exceed the number of fixed subscribers around 2004 [7]. The fixed Internet penetration is growing in parallel to the mobile radio access penetration. About 80 % of fixed Internet users are also using mobile communications. Therefore, these users are interested to get the same services also on mobile terminals.

The overall data traffic will exceed voice traffic in terms of transmitted bit for both service types already around 2000 with much higher growth rates than for voice (Figure 1b). The growing data and Internet traffic results in dominant packet oriented traffic in the access systems compared to circuit switched traffic [7; 8]. These data services require a high degree of asymmetry between uplink and downlink especially for Internet type services with much higher

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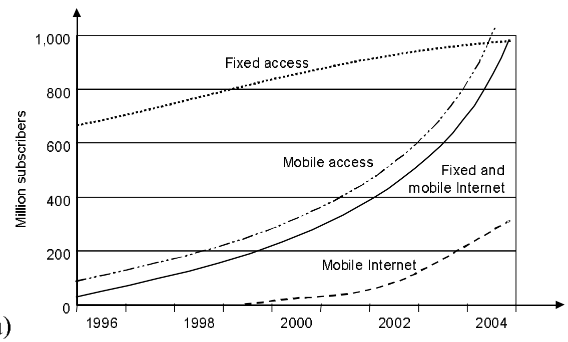
expected capacity on the downlink [2], which is already taken into account by IMT-2000 / UMTS due to the combination of FDD and TDD and especially in the WLAN type systems as HIPERLAN 2.

a)



b)

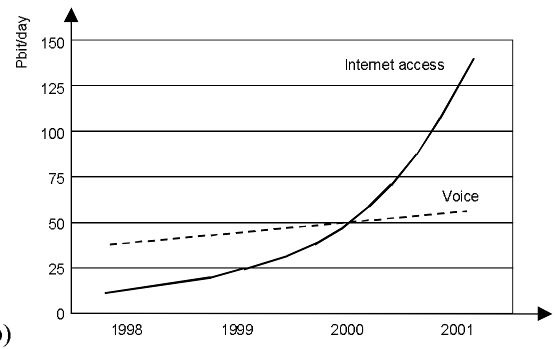


Figure 1 Growth in traffic for different access systems and voice and data services

Several access technologies are evolving and emerging. The second generation system GSM is evolving via GPRS, HSCSD and EDGE to UMTS. In addition, WLAN type systems (Wireless Local Area Network) as HIPERLAN 2 and IEEE 802.11a, DAB (Digital Audio Broadcasting) and DVB-T (Digital Video Broadcasting) are becoming available. For short range connectivity systems like Bluetooth and DECT are being developed. In the fixed access, systems as xDSL and in particular ADSL (Asymmetric Digital Subscriber Line) are increasing the user data rate significantly on the last mile. All these technologies might be part of systems beyond third generation. However, they are developed independently. The transport capacity of the core network increased within about 10 years by a factor of 10^6 with decreasing transmission costs by technology steps from PDH (Plesiochronous Digital Hierarchy), to SDH (Synchronous Digital Hierarchy) and optical communications with WDM (Wavelength Division Multiplexing) [9]. According to Moore's law the signal processing power is increasing by a factor of 100 within 10 years. The core networks are moving towards more transparent transport techniques without any distinction between circuit switched and packet oriented networks to support real-time and non real-time services in the same network [10]. From the today's perspective IP (Internet Protocol) is the most promising solution.

3. The IST BRAIN Project

These trends towards systems beyond third generation, the limitations of second and third generation systems in terms of available data rate and spectrum and the goal of seamless service provisioning via different access systems are the main drivers for the BRAIN Project, which is partly funded by the European Commission in the IST (Information Society Technologies) Framework Programme.

BRAIN is working on a broadband extension for Third Generation mobile radio systems to complement UMTS and GSM. Therefore, the BRAIN architecture will address systems beyond third generation. The access network will be based on IP. The BRAIN objectives are:

- To develop seamless access to IP-based broadband applications and services.
- To specify, optimize and validate an open architecture for wireless broadband Internet access.
- To create new business opportunities for operators, service providers and content providers to offer high-speed (up to 20 Mbps) services complementary to existing mobile services.
- To contribute to global standardization bodies.

Project partners are from the different areas:

- **Manufacturers:** Ericsson Radio Systems AB (Sweden), Nokia Corporation (Finland), Siemens AG (Germany) and Sony International (Europe) GmbH (Germany).
- **Network operators:** British Telecommunications plc (UK), France Telecom – CNET (France), NTT Mobile Communications Network, Inc. (Japan) and T-Nova Deutsche Telekom Innovationsgesellschaft mbH (Germany).
- **SME, research and academia domain:** Agora Systems S.A. (Spain), INRIA (France) and King‘s College London (UK).

4. Evolving and Emerging Access Technologies

The evolving and emerging access technologies can be grouped in the categories cellular mobile radio systems (second (GSM etc.) and third generation (IMT-2000 / UMTS)), cordless systems (e.g. DECT), systems for short range connectivity as Bluetooth and DECT data system, WLAN type systems as HIPERLAN 2, HIPERACCESS, IEEE 802.11a etc., fixed wireless access or wireless local loop systems, broadcasting systems as DAB and DVB-T and cable systems as twisted pair with xDSL, in particular ADSL, and coaxial cables (e.g. CATV systems). Figure 2 shows the basic application areas for wireless systems versus supported data rate, range and grade of mobility.

The WLAN type systems are designed in particular for high and asymmetric data rate access, low range and in general for low mobility. They are applicable for corporate networks and public access as complement to cellular mobile radio systems for hot spot applications as company campus, conference centers, airports, railway stations etc. Table 1 summarizes the main parameters of important exemplary access technologies [11 - 15].

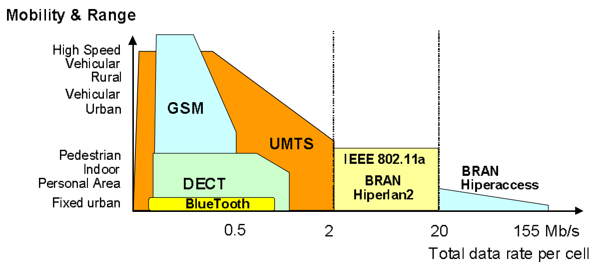


Figure 2 Wireless systems versus supported data rate, range and mobility

The BRAIN architecture is considering the cellular systems GSM and UMTS and is especially focussing on HIPERLAN 2 for the broadband extension. The physical layer of the ETSI BRAN system HIPERLAN 2 is harmonized with IEEE 802.11a and MMAC in Japan, which would basically allow global roaming. The HIPERLAN 2 air interface is based on TDD and dynamic TDMA. Time slots can be allocated dynamically in an asymmetrical way for uplink and downlink with respect to the transmission needs [14; 15]. OFDM is used as modulation scheme with 52 subcarriers (48 for actual data and 4 for phase tracking and coherent detection) to support high data rates according to Table 2 in a flexible way. In addition, forward Error Correction (FEC) by convolutional coding is used.

Figure 3 summarizes the available frequency ranges of the cellular second and third generation mobile radio systems and the WLAN type systems, which correspond to the BRAIN platform for seamless service provision. These systems correspond to a very powerful and flexible platform.

System	Data rates	Technology	Range	Mobility	Application area
GSM (voice, GPRS, HSCSD and EDGE)	9.6 Kbps up to 384 Kbps	TDMA, FDD	up to 35 Km in GSM, lower for data	high	public and private environment
IMT-2000, UMTS (UTRA)	max. 2 Mbps	IMT-2000 family, WCDMA (FDD) + TD-CDMA (TDD)	30 m – 20 Km	high	public and private environment
Bluetooth	max. 721 Kbps	Direct sequence or frequency hopping	0.1 – 10 m	very low	cable replacement, SoHo environment
HIPERLAN 2	25 Mbps up to 54 Mbps	OFDM, TDD	50 – 300 m	low	corporate environment, public hot spots
IEEE 802.11a	about 20 Mbps up to 54 Mbps	OFDM, TDD	50 – 300 m	low	corporate environment, public hot spots
HIPERACCESS	about 25 Mbps	not yet specified	2 – 10 km	no	business access, feeder

Table 1 Main parameters of different access systems

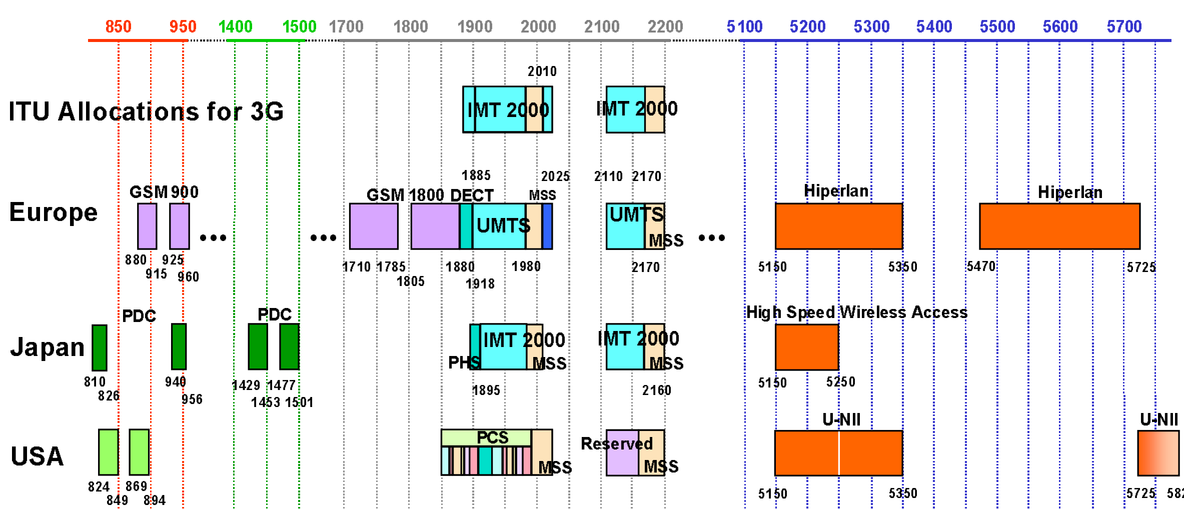


Figure 3 Available frequency ranges for second and third generation mobile radio systems and WLAN type systems

Figure 4 shows the protocol reference model of HIPERLAN 2 [14]. The Convergence Layers allows to connect HIPERLAN 2 to different core network types. The standardization of the IP Convergence Layer has started, which will allow the connection to an IP based network. The BRAIN Project is contributing to the international standardization on this convergence layer that IP QoS and mobility management (including real time handover) will be fully supported. The optimization of the HIPERLAN 2 radio interface is also in the scope of BRAIN. The evolving GSM (via GPRS) and UMTS (in Release 2000 of the ongoing standardization in 3GPP) radio interfaces will also be based on IP.

Mode	Modulation	Code rate	Phy. bit rate	Bytes/OFDM symbol
1	BPSK	1/2	6 Mbps	3.0
2	BPSK	3/4	9 Mbps	4.5
3	QPSK	1/2	12 Mbps	6.0
4	QPSK	3/4	18 Mbps	9.0
5	16-QAM	9/16	27 Mbps	13.5
6	16-QAM	3/4	36 Mbps	18.0
7	64-QAM	3/4	54 Mbps	27.0

Table 2 HIPERLAN 2 modulation scheme modes

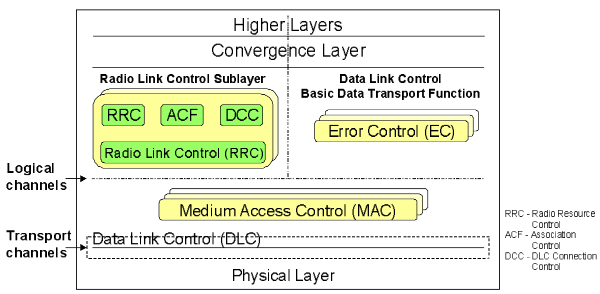


Figure 4 HIPERLAN 2 protocol reference model

These technologies represent a very flexible and powerful platform to support future requirements on services and applications. However, most of these systems have been designed in isolation without taking into account a possible interworking with other access technologies. Their system design is mainly based on the traditional vertical approach to support a certain set of services with a particular technology.

5. Technical Approach in the BRAIN Project

The BRAIN architecture integrates the cellular systems GSM and UMTS with the broadband WLAN type system HIPERLAN 2 on an IP backbone (Figure 5). Horizontal handover within the same system and vertical handover between different systems provides seamless service. Roaming is facilitated on the common platform. In this platform IP is used in the core network as well as in the radio access network for the involved radio access systems down to the mobile stations. Therefore, IP routers are deployed up to the base stations to be connected directly to the convergence layer of HIPERLAN 2 as shown in Figure 6.

In this concept the mobility management is based on IP protocols. In the initial stage BRAIN is reviewing the existing protocols Macro-mobility (e.g. Mobile IP) for roaming support [16] and Micro-mobility (e.g. Cellular IP) for handover support [17]. BRAIN is concentrating on micro-mobility and is developing new schemes where necessary.

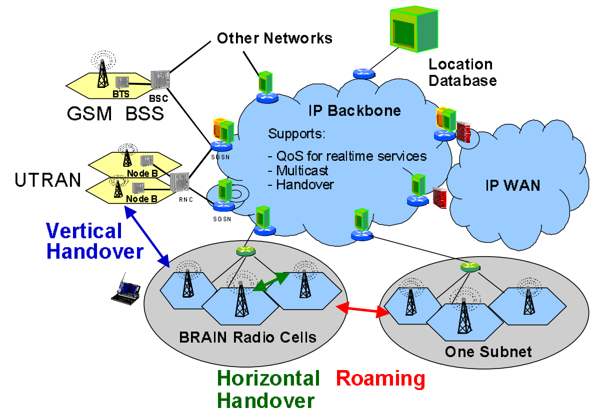


Figure 5 BRAIN network architecture

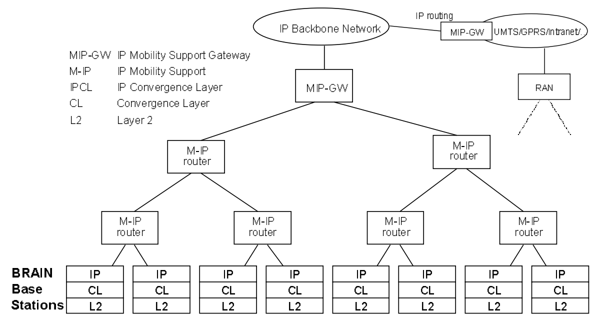


Figure 6 BRAIN visionary route

Quality of Service (QoS) is an essential issue especially for real time services with delay constraints as voice. The following protocols have been proposed for QoS support in IP networks and are taken into account in the BRAIN Project [18 – 21]:

- Diffserv (Differentiated Services) corresponds to the differentiation of services into priority classes to support QoS. The complexity is shifted to the edge routers, where the traffic classification, policing and shaping is performed.
- Intserv (Integrated Services) uses a resource reservation (RSVP) for the traffic flow to guarantee the required QoS. The receiver initiates the reservation. However, each router has to reserve resources. Extensions towards mobility are necessary.
- RSVP (Resource Reservation Protocol) reserves bandwidth for their data flows. It is receiver-oriented and is also used by the routers to forward the reservation request. Therefore, RSVP has to be implemented in the receivers, transmitters and routers.
- Combinations of RSVP with Diffserv.

With respect to the BRAIN architecture the Project is working on extensions and improvements of these protocols to support QoS with mobility based on available protocols. This is taking place in interaction with other IETF protocols,

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e.g., on security and DHCP (Dynamic Host Configuration Protocol).

For IP over wireless the impact on the spectral efficiency is an important issue. The headers of standard IP packets exhibit a significant overhead. Therefore, techniques for header compression are considered in IETF. IPv4 is currently deployed on a global basis. In IPv6 some improvements as an increased address space and better security support have been implemented. In addition, RSVP to support QoS is an integral part. Both versions and further improvements are currently under discussion.

6. Conclusions

Mobile multimedia applications are already starting today with evolved second generation mobile radio systems. Third generation mobile radio systems provide more opportunities for mobile multimedia by improved wideband and more flexible radio interfaces. Systems beyond the third generation will follow the general concept of many combined optimized access systems including broadband radio access systems based on WLAN technology on a common flexible IP network platform, which complement each other in an efficient and optimized way. Key issues of the new concept are the horizontal handover within the same system and vertical handover between different systems, service negotiation for seamless service provision and global roaming.

The BRAIN Project follows a top-down approach from service and application requirements to access network and radio interface requirements. Local and global mobility support for IP networks (roaming and handover) will be supported by BRAIN in an open architecture to support end-to-end IP. This ensures seamless access to broadband IP networks. QoS for IP networks is an important issue in this context. The investigations start with the IETF's approach and protocols. Improvements are developed and proposed where necessary. IP will be pushed to the edge so that the base stations are routers. In addition, techniques for enhanced system capacity – especially for the broadband radio access system based on HIPERLAN 2 - will be investigated.

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References

[1] Berruto, E., M. Gudmundson, R. Menolascino, W. Mohr and M. Pizarroso: Research Activities on UMTS Radio Interface, Network Architectures, and Planning. IEEE Communications Magazine, Vol. 36, No. 2, February 1998, pp. 82 – 95.

[2] Chaudhury, P., W. Mohr and S. Onoe: The 3GPP Proposal for IMT-2000. IEEE Communications Magazine, Vol. 37. No. 12, December 1999, pp. 72 – 81.

[3] Prasad, R., W. Mohr and W. Konhäuser: Third Generation Mobile Communication Systems. Artech House Publisher, London, Boston, 2000.

[4] ITU-R TG 8/1: Detailed specifications of the radio interfaces of IMT-2000. Document 8-1/TEMP/275-E, 18th meeting of Task Group 8/1, October 25 to November 5, 1999, Helsinki, Finland.

[5] UMTS Forum: The Future Mobile Market – Global Trends and developments with a Focus on Western Europe. Report No. 8, UMTS Forum, March 1999.

[6] IEEE Communications Magazine (several articles on telecommunication markets), Vol. 36, No. 11, November 1998, several articles, pp. 36 - 96.

[7] OVUM: Global Telecom & IP Markets, 1999.

[8] Oliphant, M.W.: The Mobile Phone Meets the Internet. IEEE Spectrum, Vol. 36, No. 8, August 1999, pp. 20 – 28.

[9] Kazovsky L.G., G.-D. Khoe and M. O. van Deventer: Future Telecommunication Networks: Major Trend Projections. IEEE Communications Magazine, Vol. 36, No. 11, November 1998, pp. 122 – 127.

[10] Jajszczyk, A.: What Is The Future of Telecommunications Networking? IEEE Communications Magazine, Vol. 37, No. 6, June 1999, pp. 12 – 20.

[11] Gibson, J.D.: The Mobile Communications Handbook. IEEE Press, New York, 1996.

[12] Jung, V. and H.-J. Warnecke: Handbuch für die Telekommunikation. Springer Verlag, Berlin, 1998.

[13] Dutta-Roy, A: A Second Wind for Wiring. IEEE Spectrum, Vol. 36, No. 9, September 1999, pp. 52 – 60.

[14] ETSI BRAN: http://www.etsi.fr/bran/

[15] Communication Networks, Aachen University of Technology: IEEE 802.11 or ETSI BRAN HIPERLAN/2: Who will win the race for a high speed wireless LAN standard? Microwave Engineering Europe, February 2000, pp. 57 – 65.

[16] Perkins, C.: Mobile IP. IEEE Communications Magazine, Vol. 35, No. 5, May 1997, pp. 84 - 99.

[17] Valko, Campbell and Gomez: Cellular IP. Internet-Draft, draft-valko-cellularip-01.txt, October 1999.

[18] Braden, R., et al.: Resource Reservation Protocol (RSVP) – Version 1 Functional Specification. IETF RFC 2205, September 1997.

[19] Blake, S., et al.: An Architecture for Differentiated Services. IETF RFC 2475, December 1998.

[20] Eichler, G., H. Hussmann, G. Mamais, I. Venieris, C. Prehofer and S. Salsano: Implementing Integrated and Differentiated Services for the Internet with ATM Networks: A Practical Approach. IEEE Communications Magazine, Vol. 38, No. 1, January 2000, pp. 132 – 141.

[21] Bernet, Y.: The Complementary Roles of RSVP and Differentiated Services in the Full-Service QoS Network. IEEE Communications Magazine, Vol. 38, No. 2, February 2000, pp. 154 – 162.

[22] Loshin, P.: IPv6 clearly explained. Morgan Kaufmann Publishers Inc., 1999.