Broadband Radio Access for IP-Based Networks (BRAIN)

Dave Wisely[1], Werner Mohr[2] and Josef Urban[2]

[1]BT Labs, Adastral Park, Martlesham Heath, Ipswich IP5 3RE, United Kingdom
Phone: ++ (44) 1473 – 643848 Fax: ++ (44) 1473 - 646885 Email: dave.wisely@bt.com

[2]Siemens AG, ICM CA CTO PE, Hofmannstrasse 51, D-81359 Munich, Germany
Phone: +49 89 722 23958 / 24138 Fax: +49 89 722 44958
Email: werner.mohr@icn.siemens.de / josef.urban@icn.siemens.de

Abstract

Wireless LAN technology is complementary to 3G systems and could be used to provide high bandwidth hot spot coverage, for example in railway stations and offices, for the high bandwidth video and broadband services that are beginning to emerge on fixed networks. The IST BRAIN Project has been formed to solve the problems of integrating an enhanced HIPERLAN 2 air interface into emerging 3G systems for use in these hot spots- this paper describes how the BRAIN Project is tackling them.

Introduction

Mobile technology is set to change the face of telecommunications. Starting with analogue systems in the 1980's we have witnessed the evolution of second generation digital systems (GSM, IS-95, IS-54, ANSI-136 and PDC) to provide voice communications and low data rate services. GSM now has more than 330 million subscribers in 120+ countries. Aided by new marketing strategies such as, Pay as You Go, to the point where it is estimated that there will be 600 Million cellular connections world-wide by 2002 [1].

At the same time we have seen, largely on fixed networks, the rise of multimedia applications based on IP technology. This has been driven by: key applications, such as Email and WWW browsing; new charging strategies (free local calls in the US); the great reduction in PC costs; the availability of licence free source code and the very rapid and pragmatic standardisation process.

Mobile data has been slow to grow in comparison with voice traffic. However, a very significant increase is forecast [2] as GSM moves from data circuits at 9.6 kbit/s to 10's of kbit/s with the introduction of more advanced data services such as High Speed Circuit Switched Data (HSCSD), and General Packet Radio Service (GPRS). These technologies will also introduce per-packet and subscription charging strategies which are more attractive for users with bursty, internet-style, data.

Third generation (3G) mobile radio systems (IMT-2000 in ITU and UMTS in Europe) are now standardized worldwide and are aimed at further supporting mobile data..3G systems will 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 [3].

New Access technologies

In addition to cellular systems, such as GSM and UMTS, other radio access technologies are also developing rapidly. Wireless LANs have characteristics that make them complementary to typical cellular systems:

- Short range (typically <100m)
- High bandwidth (HIPERLAN 2 [4] offers 10Mbit/s+)
- Low cost (Plug-in cards for PCs)
- Support for asymmetric traffic
- License-exempt spectrum

Wireless LANs have been proposed to provide pico-cellular, high bandwidth, coverage of hot spots such as railway stations, shopping malls and offices [5].

Another important technological development, which will be deployed on the same time-scale as 3G networks, is ADSL (Asymmetric Digital Subscriber Line). This will allow high speed data (typically 1Mbit/s) to be transmitted down existing copper wires to fixed customers. Domestic customers will be offered low cost, high bandwidth connectivity to the Internet and this is predicted to further fuel the development of higher bandwidth multimedia applications such as video on demand and video telephony.

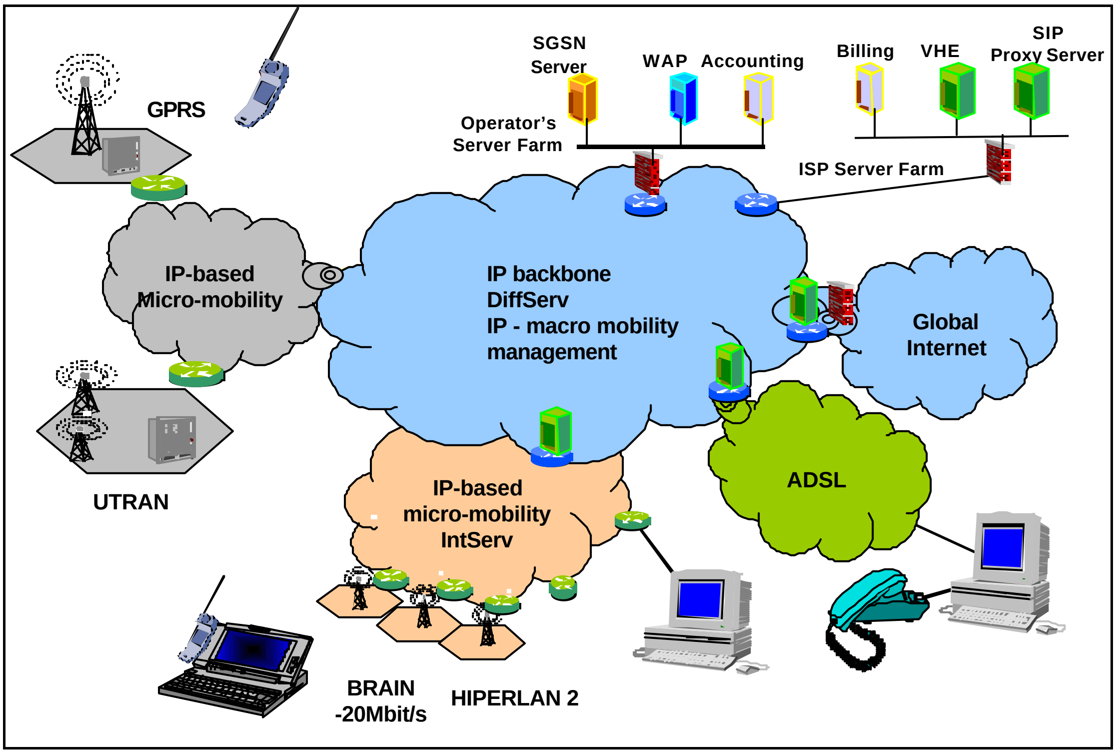

Fig. 1 BRAIN in an evolved 3G/broadband network

As UMTS develops through successive releases it looks like including more and more IP technologies. In Release2000, for example, both voice and data will be transmitted using IP packets and the call control will be managed using SIP (Session Initiation Protocol) signalling and the call servers (Call Server Control Function) will effectively be SIP servers [6]. With IP being used for both transport and signalling there is obviously the potential to integrate Wireless LANs and fixed access technologies, such as ADSL, within an evolved 3G network – this is the BRAIN vision for systems beyond 3G (Fig. 1). We envisage users having personal mobility – able to use any terminal on any access technology – but able to access the same services, suitably presented and adapted for the terminal and link bandwidth etc.

In order to move beyond 3G and allow operators to provide users with this kind of functionality we have created the BRAIN project [7]– Broadband Access for IP Networks. The BRAIN project is targeting three major technical areas:

- To support seamless service provision – providing QoS (Quality of Service) adaptation in the face of, for example, radio signal deterioration or lower bandwidth on hand-over.
- To design an IP-based access network that will support non-cellular mobile technologies (e.g. Wireless LANs) – adding functionality to allow them to complement 3G systems (Fig. 1).
- To define the requirements of a broadband (10Mbit/s+) air interface suitable for pico-cellular hot spots, and to propose modifications and enhancements to the evolving HIPERLAN 2 standard

The IST BRAIN Project

The stated objectives of BRAIN 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 – R&D (France), NTT DoCoMo, 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).

BRAIN Top-down approach

We have defined a series of scenarios - carefully chosen to be representative of the locations, terminal equipment and range of services - to derive exactly what users will expect from the BRAIN system:

- Leisure-time – A scenario which demonstrates that users may wish to be connected to Hiperlan/2 for low cost and high bandwidth in the home or shopping mall but will also want to connect to cellular technologies (e.g. UMTS or GPRS) from the same terminal and access the same services. In particular, the users in this scenario require support for vertical handover between the two technologies.
- Nomadic worker – In this scenario we have looked at a future corporate worker, demonstrating that Hiperlan/2 may be used as part of office intranets providing integration with fixed intranets. The scenario also produces the idea of profiles – when on company business a worker requires different preferences, charging strategies etc. but when on personal business he will want to use only one terminal and access the same basic services such as Email.
- Medical care – This scenario demonstrates a specialized application of the BRAIN system. The main point arising from this scenario is that users can have very different priorities for the supply of the same quality service – in this case the patient being monitored requires absolute priority.

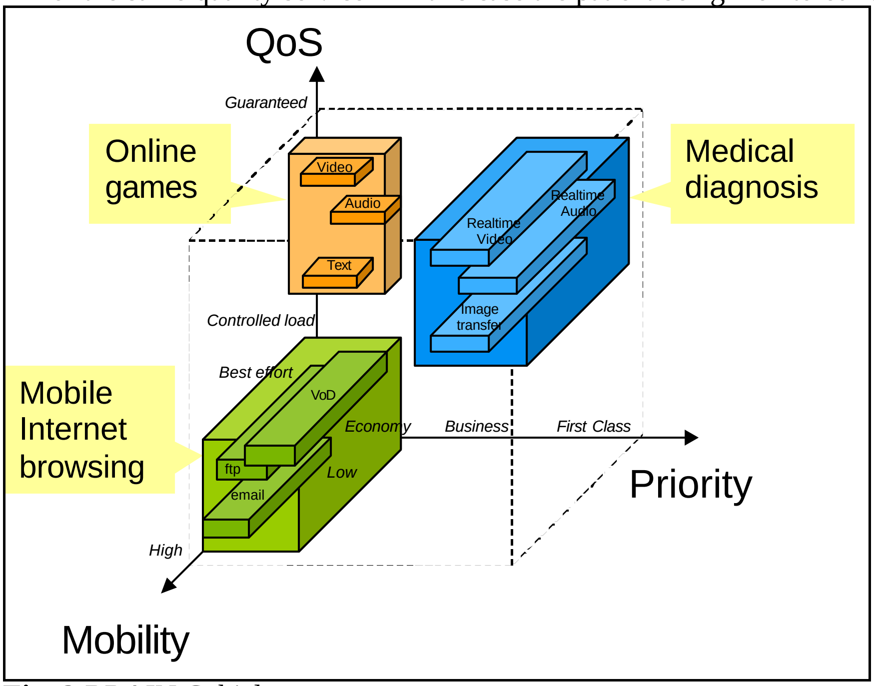

Fig. 2 BRAIN Cubicle

We have developed the concept of the cubicle (Fig. 2) to summarize some of our conclusions from the usage scenarios: the cubicle characterizes services in a cube whose axes are: mobility, quality of service and user priority. A single service, such as two-way video, can occupy different parts of the cubicle parameter space – e.g. (low mobility, low priority, high quality) for children's games and a different part of the space (medium mobility, high priority, high quality) for business video

conferencing. From this model and the scenarios we have identified user requirements such as: multiple fixed and mobile access technologies; user profiles; hand-over support and user priority support.
We will go on to derive the requirements that this business model and that the usage scenarios imply for the abstract functions (e.g. mobility management) of the BRAIN system – covering the whole concept from access technologies, network protocols to application support in the end terminals. These are then used to evaluate current protocols and architectures – before the project goes on to make enhancements to, for example, IP mobility protocols or HIPERLAN 2.

BRAIN Terminal stack

We have identified two approaches to the way applications will interface with the network. Firstly what we have termed the IETF protocol solution. In this approach the emphasis is on lightweight component protocols – i.e. there is no network API. Applications in the terminal interface directly with these protocols to set up sessions, negotiate QoS with the network and deal with QoS violations. An example application would be Microsoft NetMeeting with plug-ins in supporting SIP [8] (Session Initiation Protocol) and RSVP [9] (Resource ReSerVation Protocol).
The other approach we have termed Adaptive QoS Middleware. This consists of both an enhanced end terminal stack as well QoS brokers, mobility gateways and media filters located within the network – forming a complete distributed architecture for QoS management. Applications are presented with a standard API, rather than having to deal with session and QoS negotiation and violations themselves.
In the BRAIN project we have recognised the merits of both approaches and developed a modular, component-based architecture that encompasses both. We have firstly designed enhancements to the terminal stack (Fig. 3) that provide interfaces to a number of different application types: legacy (type A); those that utilise session protocols (type B); those that can make use of a component API (providing frame grabbers, packetizers ..) (type C) and those that can make use of a full blown QoS broker to deal with all connection issues (type D).

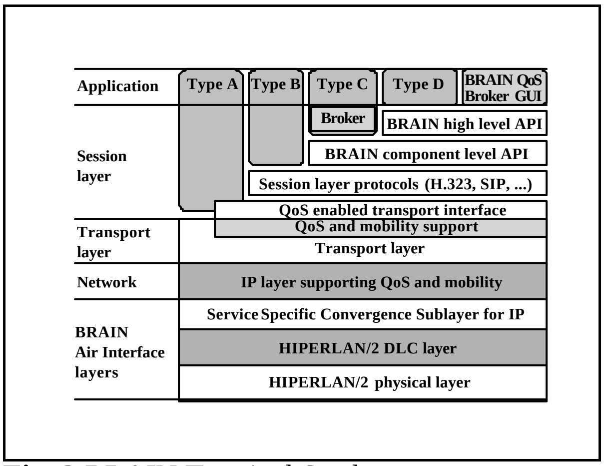

Fig. 3 BRAIN Terminal Stack

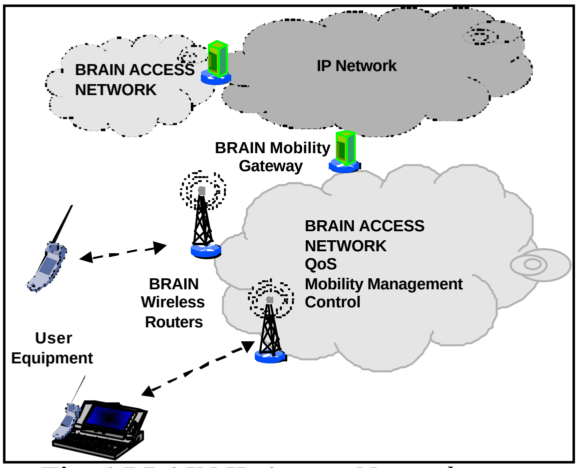

Fig. 4 BRAIN IP Access Network

BRAIN Access Network

The BRAIN Access Network (BAN) (Fig. 4) is intended to be deployed over a campus sized area – a city centre, Science Park or airport. Within this domain it will offer terminals Quality of Service (QoS), Terminal Mobility and Vertical Hand-over support. Personal mobility and service creation will largely reside outside of the BAN.
Terminal mobility will be provided by a modified micro-mobility protocol such as MER TORA[10] or HAWAII [11]. A mobile host terminal will acquire an IP address for at least the duration of a session and the routers of the BAN will create per-host entries to allow packets to reach the mobile, however it moves within the domain. At present the BRAIN project is evaluating the currently proposed protocols for micro-mobility against the perceived requirements from the usage scenarios outlined above. These requirements include attributes such as: Scalability, minimal loss of packets on

hand-over, fast hand-over suitable for real-time services and minimum signalling traffic. The result of this process will be both a new architecture and new protocols to support this– this will include an interface definition for the layer2/3 boundary. This interface will attempt to standardize the way layer 2 access technologies interface to the IP layer – to support hand-over and QoS at both layers in a generic way. This will be in line with the recent IETF OBAST/CRAPS [12] proposals that are also looking at this problem. In the case of HIPERLAN 2 a convergence layer will be written (see below) to implement the interface but, equally, Bluetooth or 802.11 link layers could be supported.

If the mobile host moves to another domain – either supporting another access technology or belonging to another authority – mobile IP will be used to provide a tunnel to the new domain, after suitable authentication, so that the same IP address may be used to continue the session. One of the main research areas of the BRAIN is to look at service adaptation when, for example, a hand-over between HIPERLAN 2 and GPRS takes place. The adaptation will be achieved by co-operation between the terminal software and elements in the network.

In a similar way the BAN will support network QoS and, because the BAN is limited in extent by the non-scalability of the micro-mobility protocols, it is possible to use either IntServe solutions, RSVP being used to signal the required QoS, or DiffServ solutions. IntServe is useful at the edge of the network where the traffic becomes "lumpy" and a single large multimedia stream can dominate the local flows. The BAN is also responsible for the radio resource management and admission control parts of QoS.

Overlying this terminal mobility, i.e. the support of a single session on a moving terminal, is the concept of personal mobility. This is largely beyond the scope of the BRAIN project but is essential to the concept of a Virtual Home Environment. Personal mobility allows me to contact a person using a friendly name (dave.wisely@bt.com) and, depending on: who I am; the time of day; the media requested etc., route the session request to one or more of the terminal that the user is currently logged on to. See [13] for description of how SIP can be used to provide personal mobility in IP networks.

Enhanced Hiperlan 2

BRAIN has chosen a Wireless LAN standard – HIPERLAN 2 – as the basis for its broadband radio interface. The BRAIN project will define enhancements to the Physical and Data Link Control layers as well as define a BRAIN-specific convergence layer in order to make HIPERLAN 2 suitable for IP transport in the usage scenarios we have outlined. Since HIPERLAN 2 will operate in unlicensed spectrum there is a need to optimize for maximum efficiency with respect to transmitted power rather than simply to optimize for spectral efficiency which would be the case for licensed spectrum. As an example the use of variable coding schemes for different classes of traffic, to protect real-time applications from delays due to re-transmissions, is not always spectrally efficient but gives overall better system performance.

Specifically the BRAIN-enhanced HIPERLAN 2 system will support:

- Efficient transport of IP packets for all multimedia applications.
- A QoS service to the IP network layer.
- Network layer mobility management protocols – e.g. by providing paging
- Hand-over of users to other BRAIN Wireless routers (horizontal hand-over) as well as non-BRAIN networks (vertical hand-over) – with minimum delay/loss of packets.
- Unicast, Multicast and Broadcast services
- A transparent service to the IP layer.

At the physical layer the BRAIN will look at adaptive antennas, receiver diversity and smart antennas techniques. In addition turbo codes, adaptive modulation and channel tracking will also be added to the HIPERLAN 2 specification if real improvements for IP traffic are found.

At the DLC layer dynamic channel allocation will be implemented and there will be link adaptation – the modulation scheme being matched to the prevailing radio environment and the IP traffic requirements (e.g. low latency or low loss). The DLC will also feature a packet scheduler (Fig. 5) to implement QoS over the radio link, this will take inputs from the interface between the convergence layer and the IP layer to interpret the IntServe and DiffServ messages and implement the appropriate QoS at the DLC layer.

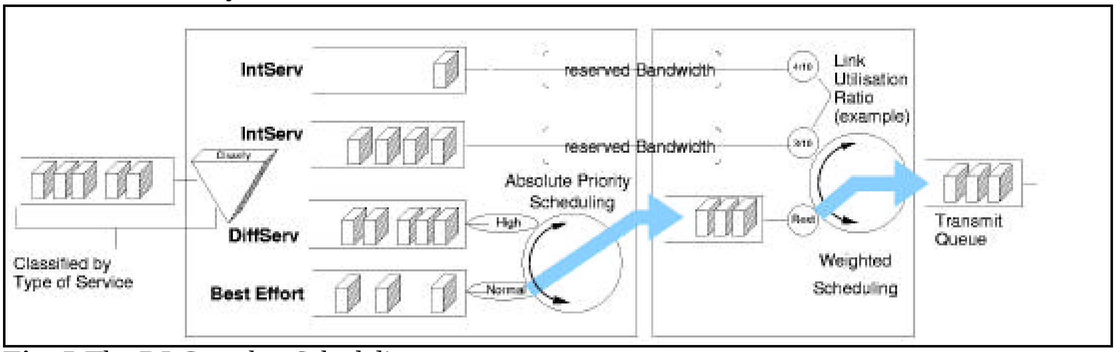

Fig. 5 The DLC packet Scheduling

Conclusions

The BRAIN project aims to deliver Broadband Radio Access over IP Networks by enhancing the HIPERLAN 2 air interface – making it suitable for supporting high performance multimedia services and connection to an IP access network. The BRAIN project will also design this IP access network, so that it will support quality of service, mobility management and authentication functions. An interface will be defined between the BRAIN IP access network and the layer 2 access technology – allowing other access technologies (e.g. Bluetooth) to connect in a standardized way. Finally BRAIN will research how applications can be supported when users may be connected from a range of different access technologies, over connections of different and changing bandwidths and quality. All of these parts constitute the BRAIN system design.

Acknowledgement

This work has been performed in the framework of the IST project IST-1999-10050 BRAIN, which is partly funded by the European Union. The authors would like to acknowledge the contributions of their colleagues from Siemens AG, British Telecommunications PLC, Agora Systems S.A., Ericsson Radio Systems AB, France Télécom – R&D, INRIA, King's College London, Nokia Corporation, NTT DoCoMo, Sony International (Europe) GmbH, and T-Nova Deutsche Telekom Innovationsgesellschaft mbH.

References

[1] http://www.gsmworld.com/membership/ass_sub_stats.html
[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] 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.
[4] ETSI BRAN: http://www.etsi.fr/bran/
[5] 'Modelling Hiperlan using Opnet', D.R. Wisely and P.L. Eardley, Proc. Opnetwork 98 Washington, May 98.
[6] 'IP Multimedia (IM) Subsystem stage 2', 3GPP, 3G TS 23.228 v0.02 (2000-8), August 00.
[7] BRAIN IST PROJECT: http://www.ist-brain.org/
[8] M. Handley, "Session Initiation Protocol", IETF RFC 2543, March 1999 http://www.normos.org/rfc/rfc2543.txt
[9] R. Braden, ed., "Resource ReSerVation Protocol (RSVP) - Version 1 Functional Specification.", IETF RFC 2205, September 1997
[10] A. O'Neill, G. Tsirtsis, and S. Corson, "Edge Mobility Architecture", Internet Draft (work in progress), draft-oneill-ema-01.txt,March '00.
[11] R. Ramjee, T. La Porta, S. Thuel and K. Varadhan, "IP micro-mobility support using HAWAII", Work in Progress (draft-ietf-mobileip-hawaii-01), June 1999.
[12] "The challenges of an all-IP UMTS network", D.R Wisely. Accepted for publication in PIMRC 2000, London, Sept. 2000.
[13] http://www.ietf.org/internet-drafts/draft-neumiller-obast-reqs-01.txt