

Broadband Radio Access for IP-Based Networks (BRAIN) – A key enabler for mobile internet access

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ABSTRACT

Second generation digital mobile radio systems have been very successful for voice communications and are now beginning to offer support for data services. Third generation mobile radio systems are currently being standardized worldwide to be initially deployed starting in 2001 providing support for multimedia applications with a flexible air interface and higher bandwidths. 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 emerging video and broadband services that will begin to emerge on fixed networks. The IST BRAIN Project, which is partly funded by the European Commission, has been formed to solve the problems of providing seamless service for broadband users in these hot spots. This paper describes these problems in greater detail as well as outlining how the BRAIN Project is tackling them.

1. INTRODUCTION

The introduction of mobile technology has changed the face of the telecommunications industry. Beginning with analogue systems in the 1980's we have seen 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. The dominant second generation technology is GSM, with more than 250 million subscribers in 120+ countries. Subscriber numbers have been growing at an ever increasing rate in many 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 worldwide by 2002 [1].

Another major technological revolution has been the rise, largely on fixed networks, of multimedia applications based on IP technology. This revolution 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 not, to date, grown at anything like the same rate as voice traffic (Fig. 1). GSM has long offered data circuits at 9.6 kbit/s but the introduction of more advanced data services such as High Speed Circuit Switched Data (HSCSD), General Packet Radio Service (GPRS) and the EDGE system (Enhanced Data rates for GSM Evolution), are expected to increase data traffic by both increasing capacity as well as being more efficient for bursty, internet-type, traffic.

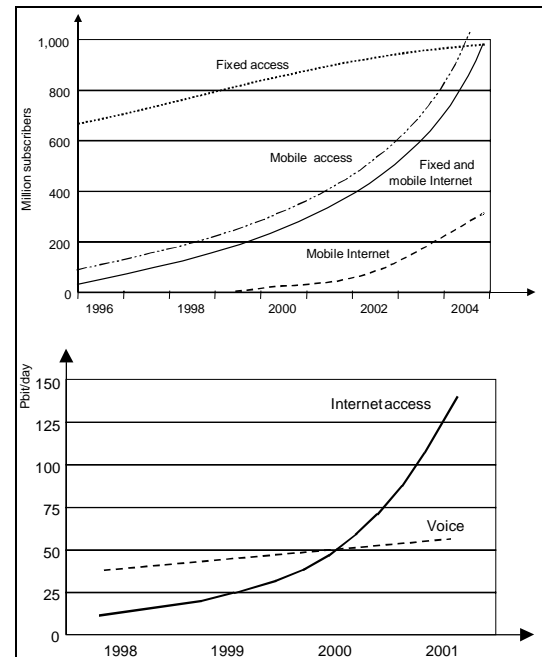


Figure 1 Growth in traffic for different access systems and voice and data services

Third generation (3G) mobile radio systems (IMT-2000 in ITU and UMTS in Europe) are now standardized worldwide and aim to provide further support of mobile data. The main goals of 3G systems 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 [2 - 5].

2. FIXED-MOBILE CONVERGENCE

In addition to traditional mobile 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 (Hiperlan2 [6] offers 10Mbit/s+)
- Low cost (Plug-in cards for PCs)
- Support for asymmetric traffic
- License-exempt spectrum

Wireless LANs have been proposed to provide picocellular, high bandwidth, coverage of hot spots such as railway stations, shopping malls and offices [7].

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. In fixed networks there is also a major trend for companies to consolidate their data and voice applications using IP technology. IP virtual private networks and high speed Internet access are major growth areas and telcos are typically responding to these changing needs by building very large IP backbone networks.

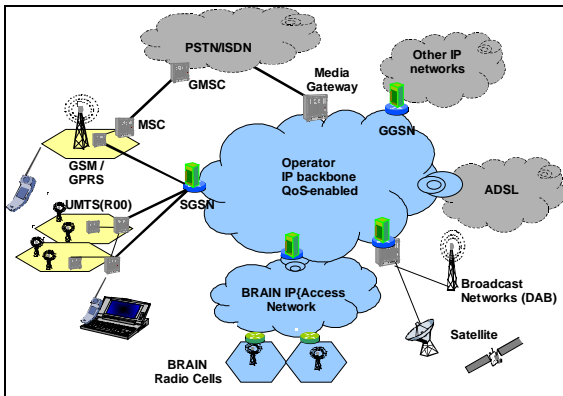


Figure 2 BRAIN in an evolved 3G/broadband network

The big question facing operators and manufacturers is how to make sense of a multi-media, multi-access future? Of course future communication users do not care about the technology. What they require is access to services – access to the same services wherever they are, whatever connection or terminal they are using. They also require mobile access to the high bandwidth services that will become common on the fixed network. They want

seamless access so that a change of access technology, including change of bandwidth, domain etc. is all taken care of without intervention.

In order to move beyond 3G and allow operators to provide users with this kind of functionality we have created the BRAIN project [8]– 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. 2).
- To define the requirements of a broadband (10Mbit/s+) air interface suitable for picocellular hot spots, and to propose modifications and enhancements to the evolving Hiperlan type 2 standard to realize this.

3. 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).

4. BRAIN USAGE SCENARIOS

The BRAIN project is using a top-down, user-centric view to derive a number of application and usage scenarios – ensuring that user functionality is the key project driver.

To date the project has identified 3 basic usage scenarios:

- Desktop applications – temporarily fixed but movable machines in a small office. Users would expect excellent QoS but only limited mobility support.

- The nomadic worker – In this scenario the user has a portable PC, is quite mobile at low speed around an office environment and is willing to accept a lower QoS.
- Hand portable applications – in this scenario a small machine, such as a PDA (personal digital assistant), is used in a warehouse-type environment, running a dedicated application. The QoS requirements are modest but a large number of users must be supported.

In order to illustrate the functionality that the BRAIN will bring to users we now give a detailed example of a nomadic user.

Carole is visiting the University of Southampton and has taken her laptop PC with her. On arrival at the meeting room she boots up her machine starting the BRAIN software – this automatically detects the presence of an enhanced Hiperlan type 2 network and, based on Carole’s pre-defined policy, selects this for communications. Carole’s terminal is automatically configured to sit on the University network and then registration and authentication take place with her remote service provider. Carole is not actively using her terminal but can receive incoming calls/multimedia according to the preferences she has set at her Virtual Home Environment.

When Carole wants to make a video call to Peter she starts a video application by clicking on a small image of Peter’s face. The application makes use of the BRAIN API (application programming interface) to deal with the complicated task of setting up the QoS-enabled session and dealing with QoS changes that occur. The BRAIN software knows that Carole wants a high-quality connection because during working hours it uses her business preferences or policy when setting up sessions and then proceeds to negotiate with a peer application on Peter’s terminal over the parameters of the call (codec, bandwidth etc.) – or possibly a video message storage service if he is busy or unavailable. Once the parameters for the call are known the BRAIN software then signals and negotiates with the network(s) to obtain an appropriate QoS service.

Carole then moves from the meeting room to a café but still wishes to continue her session with Peter. Fortunately there is continuous coverage from the enhanced Hiperlan 2 network and a hand-over between the 2 base-stations takes place. Behind the scenes there is a small loss of packets due to a momentary break in connection but this is masked from the user by a media filter in the BRAIN software. The BRAIN access network is responsible for the hand-over – essentially re-negotiating the QoS with the new Hiperlan access point, using new BRAIN Hiperlan 2 functions that support this, and dealing with the mobility of the terminal during active sessions.

Finally Carole decides to walk outside the building – as soon as the signal strength of the Hiperlan begins to fade the BRAIN software in her terminal uses the GPRS card, also installed in her laptop, to set up a QoS context capable of continuing the session. If this is successful then session can be handed over but there will probably be a gap of service and a lower bandwidth after the hand-over. The BRAIN software is able to buffer some data before hand-over, inform the user the connection is still live and

perform filtering – either in the terminals or the network – to adapt the video to the new bandwidth.

5. SEAMLESS SERVICE

The above example gives a good idea of a seamless service provisioning in the multi-access, multi-media world beyond 3G. In this section we describe the technical approach BRAIN is developing to solve this problem.

Three main QoS processing steps have been identified:

- The user specifies his subjective wishes – the user perceived QoS
- These are mapped down through the different system components/layers (application, middleware, network ..)
- Finally there is negotiation between components at the various layers to establish QoS and subsequently handle renegotiation required by any of the layers (user/network etc.)

This leads to the concept of QoS layers (Fig.3). Two major approaches to implementing QoS, encompassing the BRAIN capable terminal and the BRAIN access network, have been identified. 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 [9] (Session Initiation Protocol) and RSVP [10] (Resource ReSerVation Protocol). NetMeeing would negotiate directly with a peer application regarding the session parameters using SIP (bandwidth, codec etc.) and then with the network using RSVP to attempt to secure the required QoS from the network. This approach is seen to be: flexible, (new protocols are easily added/adapted and largely independent), lightweight, simple and providing maximum choice for application developers.

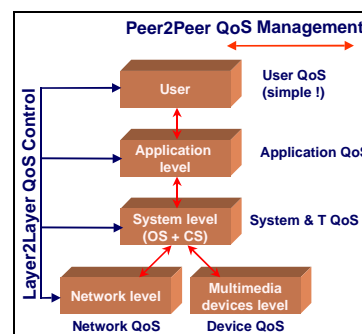


Figure 3 QoS layers

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. The advantages of this approach are that it makes application programming much simpler – QoS violations and negotiations are automatically handled – and it offers a much better user interface.

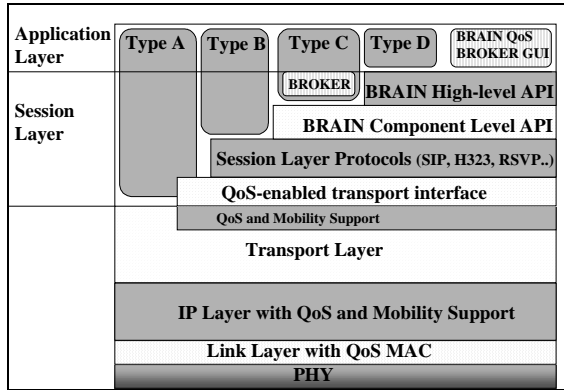


Figure 4 BRAIN end terminal stack

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. 4) 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).

In addition we are proposing a very clear interface – called the Service Interface – between the transport layer and the rest of the enhanced mobile stack (shown as the QoS-enabled transport interface on the diagram).

There are numerous advantages to this approach:

- It will support any implementation of QoS in the network (including over-provision, Intserve etc.)
- All types of applications are supported – NetMeeting and Explorer will run without modification.
- Extra QoS support elements (gateways, QoS brokers) can be used as a service- but are not in any way built into the network architecture.
- Users can select and download the required components of the terminal stack – allowing simple/lightweight stacks on, for example, baby alarms.

6. BRAIN ACCESS NETWORK

The BRAIN access network will be based on IP and will provide two major functions for mobile terminals – QoS and mobility support. As terminals move around the radio cells connected to the access network they will be able to maintain real-time sessions. The main elements of the

architecture are shown in Fig. 5. BRAIN wireless routers (BWRs) are essentially normal routers but are connected – by the enhanced Hiperlan 2 link layer – to the mobile terminals. The BWRs are responsible for interfacing QoS and mobility management with the Hiperlan radio links – allocating radio resources, assisting with handover and reporting QoS violations.

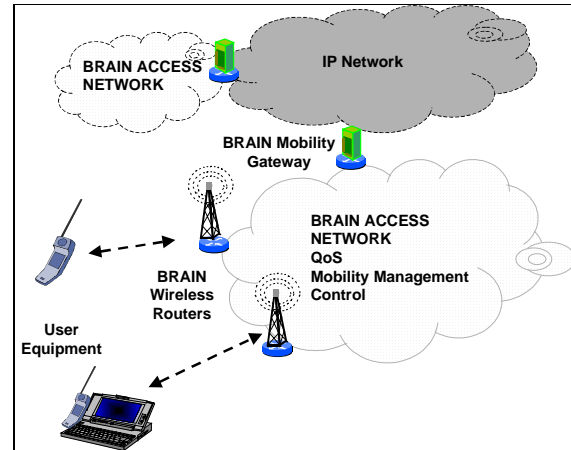


Figure 5 BRAIN Access Network (BAN)

The BRAIN Mobility Gateways are used to interface the BRAIN Access Networks. The gateway is a special purpose router with interfaces to the BRAIN access networks (BAN) and an external IP network. It basically presents the BAN as a standard IP network by, if required, interworking QoS and mobility protocols – for example by converting Intserv flows to Diffserv packet markings.

Mobility management is required in the BAN because current IP routing protocols require users to acquire a new IP address whenever they cross into a new subnet. Current terminal platforms – such as Windows and Unix – as well as network protocols such as ftp do not permit a change of network layer address during a session.

Mobile IP [11] has been widely proposed as the solution to IP mobility by providing users with a fixed home address and tunnelling packets from the home agent to the mobile user. However, Mobile IP has some serious shortcomings for users roaming across many access technologies. Firstly it utilises tunnels, often in the forward and reverse directions, and so the headers become invisible and QoS is difficult to implement. Secondly packets from the mobile to the correspondent host do not travel the same path as those from the correspondent to the mobile, which have to travel via the home agent. This again makes QoS implementations difficult and can lead to very different delays in both directions. Finally Mobile IP does not support real-time handovers because the mobile host must signal back to the home agent before packets can be re-directed to a new location. This is often the neighbouring cell but the message may have to travel to a different

continent to reach the home agent, a significant delay resulting in several seconds loss of packets.

Now there are many suggestions for additions to Mobile IP, for example binding updates [12], to overcome these difficulties – however most of these involve new changes to existing IP stacks. We are investigating a different solution, based on the concept macro and micro-mobility. A macro-mobility protocol is used to provide mobility between domains or, in this case, between the BAN and another network. Crossing domain boundaries might well involve: re-authentication; a new IP address; new QoS protocols etc. and is such a big step that it may be impossible to provide real-time session handover, thus protocols like Mobile IP can be considered for this. Within the BAN, however, new routing protocols, such as TORA [13] or HAWAII [14], can be used to provide micro-mobility. This essentially involves giving the mobile host an IP address and delivering packets addressed to that address wherever the host moves within the domain. These micro-mobility protocols support real-time session handover because the control messages travel only a few hops and the IP address is unchanged throughout the session. The cost of this is the use of per-host entries in the routing tables which has only limited scalability. Additions are also needed to these protocols to support handover – i.e. defining the interactions with the layer 2 protocols on, for example, signal to noise ratios, and for hand-over between domains.

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 Carole using a friendly name (carole.jones@xtel.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 Carole is currently logged on to. See [15] for description of how SIP can be used to provide personal mobility in IP networks.

The other major function of the BAN is to provide QoS support and, because the BAN is limited in extent by the non-scalability of the micro-mobility protocols, it is possible to use Intserve solutions, RSVP being used to signal the required QoS. 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. Finally the BAN is also responsible for the radio resource management and admission control parts of QoS.

7. ENHANCED HIPERLAN 2

BRAIN has chosen a Wireless LAN standard – Hiperlan 2 – as the basis for its broadband radio interface component in addition to GSM and UTRA because:

- It has large amount of license- exempt spectrum at 5 GHz
- It can support broadband multimedia sessions (10 Mbit/s+)
- It supports asymmetric traffic

- It can support a number of network protocols using a convergence layer.
- It is being standardised and equipment/test-beds will soon be available.

The HIPERLAN 2 air interface is based on TDD and dynamic TDMA. Time slots can be allocated dynamically in an asymmetrical way for up-link and down-link with respect to the transmission needs [16]. OFDM is used as modulation scheme with 52 sub-carriers (48 for actual data and 4 for phase tracking and coherent detection) to support high data rates in a flexible way. In addition, forward Error Correction (FEC) by convolutional coding is used. Fig. 6 shows the Hiperlan 2 reference model.

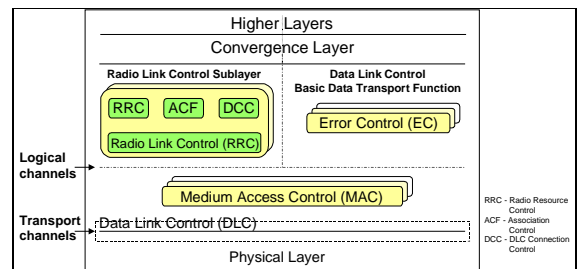


Figure 6 Hiperlan 2 reference model.

The BRAIN will define new DLC and Convergence layers in order to efficiently support mobile users connected to the BRAIN access network. These will

- Ensure efficient transport of IP packets for all multimedia applications.
- Provide a QoS service to the IP network layer.
- Support the network layer mobility management protocols – e.g. by providing paging
- Assist the 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.
- Support Unicast, Multicast and Broadcast services
- Provide a transparent service to the IP layer.

One very important requirement is for header compression – small IP packets (e.g. voice) have relatively large headers, compared to the payload, and require header compression for efficient use of the radio interface. Solutions for header compression are a compromise between transparency (not breaking the layer model and preventing the layer 2 knowing anything about the payload/headers) and radio efficiency [17].

Another important enhancement concerns error correction: IP protocols (e.g. TCP) can interpret packet loss as congestion and erroneously reduce throughput. There are many well known solutions to this problem, however, the BRAIN architecture requires that Hiperlan handles this problem if standard TCP is to be used. One possible solution is

enhanced Forward Error Correction (FEC) (see [18] a survey of TCP performance).

The BRAIN will define a standard interface between the IP layer and the Hiperlan Convergence layer. This will allow the access network to utilise any layer 2 technology, for example Bluetooth, once a suitable convergence layer is written.

8. CONCLUSIONS

Mobile multimedia applications are beginning to appear on second generation mobile systems such as GSM. Third generation cellular systems have been designed to support multimedia services and will offer a more flexible air interface and higher data rates than second generation systems. We believe that systems beyond 3G will have to incorporate a wider range of access technologies – including new Wireless LAN standards (WLANs). Wireless LANs potentially complement 3G systems by providing hot spot coverage, in airports, shopping centres and offices. With large amount of license-exempt spectrum allocated to Wireless LANs around the world they can support broadband services up to 10 Mbit/s and beyond. The key issues for integrating WLANs into the emerging IP networks being built by operators to support future fixed and mobile traffic are:

- Providing seamless service – dealing with variations in bandwidth and QoS especially during hand-over to other WLANs (horizontal hand-over) and to other access technologies (vertical hand-over)
- Designing an IP access network to which the WLANs can be attached. This access network must support QoS, mobility and real-time hand-over between LANs.
- Enhancing an existing WLAN standard to support seamless QoS, efficient transport of IP packets and mobility.

We have created the BRAIN project to solve these key issues in moving beyond 3G. By enhancing the Hiperlan 2 standard and modifying existing protocols, as well as adopting a modular approach to the terminal stack, we will rapidly produce designs to truly enable broadband mobile multimedia services.

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.

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