# Requirements for an Integrated System and Service 4G Architecture


I.Ganchev, M.O'Droma
ECE Department
University of Limerick
Ireland
ivan.ganchev@ul.ie
mairtin.odroma@ul.ie

H. Chaouchi
LIP6
University of Paris VI
Paris, France
hakima.chaouchi@lip6.fr

I. Armuelles
DIT
Technical University of Madrid, Spain
ivan@dit.upm.es

M. Siebert
ComNets
Aachen University of Technology, Germany
mst@comnets.rwth-aachen.de

N. Houssos
CNL
University of Athens, Greece
nhoussos@di.uoa.gr



***Abstract*—The emerging 4G networks intend to provide a variety of adaptable services to mobile and nomadic users by using integrated heterogeneous network infrastructure. In this paper the commonalities and differences among the various approaches in the integration of 4G systems and services are identified on the basis of an analysis of the research done by well-known international projects. Building on this and other ideas, the requirements for an integrated system and service 4G architecture are defined. Considerations and ideas discussed include AAA functions, network system management, end-to-end QoS negotiation and support, mobility management, adaptability and reconfigurability, support for multiple communication modes, ABC&S, service and access network advertisement, discovery and association, wireless billboard channel, and security and privacy challenges.**



***Keywords-4G system and service integration; 4G archictecture; Always Best Connected (ABC); Always Best Service (ABS)***


## I. Introduction

The emerging of different wireless technologies and the development of variety of mobile terminals are evolving to support better user mobility and the deployment of new narrowband to wideband services. 4G networks are envisioned as the integration of different existing wireless network technologies (WPAN, WLAN, WMAN, MANET, 2G, 2.5G, 3G, satellite, DAB, DVB-T) and future wireless network technologies, in order to ensure seamless handovers from one technology to another, thus providing a continuous and always best service to always best connected user anywhere, anytime, anyhow. To lay the foundations to attain an integrated system various issues and problems need to be addressed, and solutions found to network, terminal, user, and services questions which arise. Here an analysis is presented of ongoing ANWIRE[1] efforts of system and service integration for the design of a 4G framework architecture [1].

Within the following Section II, a brief description of ongoing efforts mainly of the EU IST research projects related to 4G system and service integration is given. Section III highlights commonalities and differences between the different approaches. In section IV, the integration requirements and issues are presented. Section V concludes this work.

## II. Brief Description of Ongoing Research Efforts Related to 4G System and Service Integration

Within this section, an overview of ongoing or already completed research work related to system and service integration issues will be given reflecting major trends as seen by dedicated consortia.

### A. ETSI BRAN/3GPP

Two approaches were taken in ETSI BRAN [2] for the provision of system integration between HIPERLAN/2 (H/2) and UMTS depending on the requirements and the feasibility of deployment: loose coupling and tight coupling. The *loose approach* is simple to implement without major modifications of the systems. It allows centralized *authentication and signaling* information related to a user, independent of the radio access network of attachment. However, it does not allow for seamless handover between the systems since the local IP address needs to be changed and the QoS for each connection has to be renegotiated.

The *tight approach*, on the other hand, allows for seamless interworking, reusing the mechanisms for mobility, QoS and security of the UMTS core network for H/2. Furthermore certain addresses and identifiers of UMTS are used by H/2. However this increases the system complexity and signaling. The standardization work carried out in ETSI BRAN/3GPP provides a good overview of the variety of approaches that can be adopted, but several aspects in mobility and handover are still open.

### B. Wireless IP NEtwork as a Generic platform for Location Aware Service Support (WINE GLASS)

The objective of WINE GLASS [3] was to exploit enhanced IP-based techniques to support mobility and soft-guaranteed QoS in a wireless IPv6 Internet architecture incorporating UMTS and WLAN, and to explore their potential


[1] *This work has been produced in the framework of the project ANWIRE (www.anwire.org), which is funded by the European Community under the contract IST-2001-38835.*



0-7803-8256-0/04/$20.00 (C) 2004 IEEE

in enabling location- and QoS-aware application services for wireless mobile users. The project does not provide any QoS architecture in the WLAN access network.

### C. Mobility and Differentiated Services in a Future IP Network (MOBY DICK)

The general purpose of the MOBY DICK [4] is to establish if the IPv6 is able to replace the existing connection-oriented infrastructure in mobile networks. It targets a QoS-enabled and Authentication, Authorization, and Accounting (AAA) supported mobility on a heterogeneous network infrastructure. It merges mechanisms of these three different research areas.

### D. Multi-Segment System for Broadband Ubiquitous Access to Internet Services and Demonstrator (SUITED)

The framework of SUITED [5] consists of an integrated system, the Global Mobile Broadband System (GMBS). This is an IP-based mobile network comprising both, satellite and terrestrial (UMTS, GPRS, WLAN) components. A prototype of the GMBS was tested consisting of a multi-segment infrastructure and a multi-mode mobile terminal, capable of operating seamlessly with satellite and terrestrial networks. Navigation capabilities were integrated into the user terminal in order to enhance the performance of personal communication services.

### E. Broadband Radio Access for IP based Networks (BRAIN) and Mobile IP based Network Developments (MIND)

The projects BRAIN and MIND [6] had the overall aim to provide customized broadband multimedia services to mobile users from a wide range of wireless access technologies such as GPRS/UMTS, WLANs (mainly based on H/2), PANs and also ad hoc networks. BRAIN/MIND projects introduce a “flexible” and “open” framework allowing the use of any kind of mobility management protocol, QoS, AAA and security solutions inside each access network based on ongoing efforts at the IP level in the IETF. The projects had developed their own “scalable” and “robust” micro-mobility protocol, mechanisms for end-to-end QoS support over heterogeneous networks, seamless horizontal/vertical handovers and “adaptation” of multimedia services to the terminal and network conditions.

### F. Transparently Re-configurable Ubiquitous Terminal (TRUST) and Smart User-centric Communication environment (SCOUT)

The main feature of TRUST and SCOUT projects [7] is the use of reconfigurability in wireless access networks providing a high level of integration (by very tight coupling). This approach provides seamless interworking, better radio network planning and design, improved QoS and mobility support. The major drawbacks in this method are higher levels of signaling between the entities as well as requirement for definitions of suitable interfaces.

### G. Mobile Value-Added Services (MOBIVAS)

The MOBIVAS project developed a middleware platform for flexible delivery of value-added services (VAS) over disparate reconfigurable network infrastructures [8]. A loose-coupling approach is adopted, with the middleware platform residing in the IP backbone, outside a particular access network (e.g. GPRS, UMTS). VAS are automatically deployed on multiple networks, based on intelligent interpretation of service and network profiles, and identification and actuation of appropriate reconfiguration actions. Independently of which operator provides them with connectivity, mobile users are offered personalized, context-aware discovery and delivery of downloadable application from a single portal, which acts as a one-stop-shop. Terminal-, user- and network profile management are important enablers for these tasks. Moreover, charging, billing and accounting are handled in a unified manner.

### H. Flexible Convergence of Wireless Standards and Services (FLOWS)

As the previous projects, FLOWS [9] uses a common access network based on IP. Onto this common network a variety of wireless access points is deployed by using GSM, UMTS or H/2. The project attempts to ensure that the impact of using multiple standards takes into account the business needs of users. Additionally, key issues are the exploitation of the flexibility offered by Multiple Input/Multiple Output (MIMO) techniques to achieve convergence of wireless standards. The proposed architecture is more focused on terminal and radio access system issues, thus it cannot be seen as a global architecture for a “convergent” system.

### I. Future Technology for Universal Radio Environment (FuTURE)

FuTURE is a key project in wireless communication branch of the National High Technology Research and Development Program of China (863 Program) [10]. The technology objective of FuTURE is to carry out investigations on key technologies for air interface of Beyond 3G mobile communication, Beyond 3G radio access techniques; WLAN and ad hoc; MIMO and RF; also key topics as IPv6-based mobile core network.

The FuTURE project focuses on the physical layer architecture of future wireless system, providing a spectrum distribution for universal radio environment and an integrated architecture of a future wireless system. Some new network concepts, sub-system structures, handover methods and access schemes have been proposed. For instance, a new multiple access scheme LAS-CDMA (Large Area Synchronized CDMA) has been accepted by 3GPP2 as one candidate for Beyond 3G standard. It is compatible with future all-IP networks and current wireless communication standards.

## III. Comparisson of Different Integration Approaches

The international research projects described in the previous section represent a significant source of ideas and inspiration in considering an integrated 4G system and service design. In this section similarities and divergences in the used approaches are identified.

With respect to the integrated access networks, apart from SUITED, which is the only project incorporating also satellite network, these projects largely consider the integration of several terrestrial access networks (Figure 1). Along these ad hoc networks are only considered in the projects MIND, FuTURE and ANWIRE.

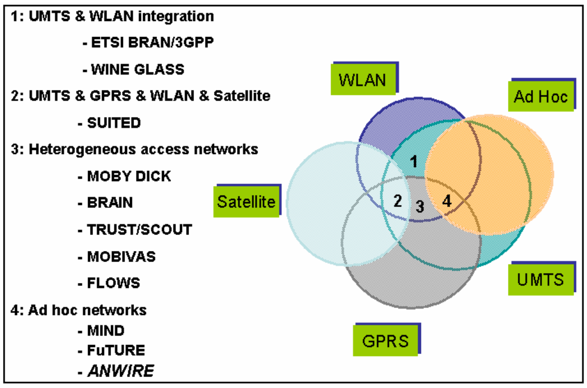


Figure 1. Access network technologies integration efforts.

Other differences and commonalities were found for the integration efforts in the control and management planes of each project (Figure 2). For instance, in ETSI BRAN, BRAIN/MIND and WINE GLASS, the vertical handover (VHO) process was achieved at a higher layer (i.e. session or network layer), which could be considered as a low integration VHO method, in contrast with the VHO managed at link layer or physical layer to be considered as a high integration method (used in ANWIRE, FuTURE, TRUST/SCOUT, SUITED, FLOWS). Some approaches, such as FuTURE, ETSI BRAN, SUITED, BRAIN/MIND, WINE GLASS and MOBIVAS, use a low integration strategy for QoS support over heterogeneous networks through QoS parameters *mapping*; others like TRUST/SCOUT and MOBY DICK use a high integration strategy with a common set of QoS classes.

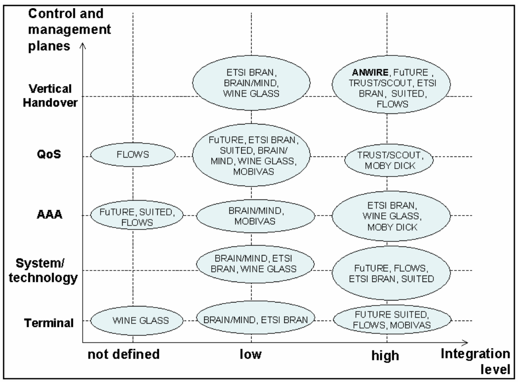


Figure 2. Control and management integration levels.

Concerning Authentication, Authorization and Accounting (AAA) issues, certain initiatives like BRAIN/MIND and MOBIVAS use different AAA systems in each access network that exchange database information (low AAA integration), whereas a higher integration was achieved by ETSI BRAN, WINE GLASS and MOBY DICK (these establish common AAA databases and associated protocols over their frameworks). Also, the integration of radio access technologies at link layer or physical layer marks differences with respect to the achieved level of system/technology integration among the projects. Most of the projects (e.g. FuTURE, FLOWS, ETSI BRAN, SUITED) achieve high level of integration; however BRAIN/MIND, ETSI BRAN and WINE GLASS use the required signaling between different radio access technologies for the exchange of information. Finally, the terminal architecture at lower layers differentiated the initiatives in two groups: i) BRAIN/MIND and ETSI BRAN using multimode terminals with different interfaces for each radio access technology (low integration system), and ii) FuTURE, SUITED, FLOWS and MOBIVAS defining multimode terminals using the same interface for different radio access technologies (high integration).

The *seamless horizontal handover (HHO)* is an important aspect of mobility management considered in most of the projects. The seamless HHO provides both fast HHO, which offers the minimum handover delay, and smooth HHO, which mainly reduces the lost of packets. Only, the FuTURE project introduces a mechanism for *smooth HHO*. An additional key aspect is the QoS awareness during the HHO process. Tighter coupling between QoS management and mobility management is achieved in most of the projects. Only BRAIN/MIND and WINE GLASS provide low level of QoS awareness. Figure 3a illustrates the HHO approaches used in different projects.

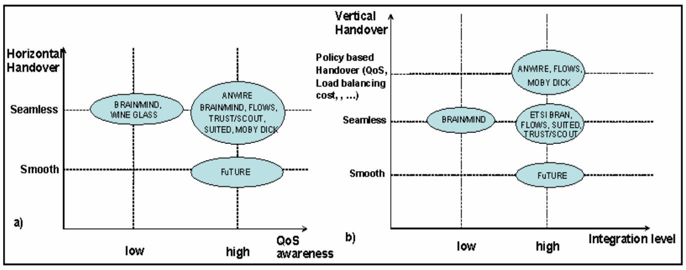


Figure 3. Handover and QoS efforts.

Figure 3b gathers the projects in terms of their efforts to achieve VHO. The *Policy Based VHO* [11] has attracted special attention recently as providing ability for mobile nodes to handoff from one technology to another based on constraints like the user preferences for cost/performance, or network related ones such as load balancing or QoS requirements. These constraints differ from the sole cell-based radio reception conditions, which is the main reason for 'classical' VHO execution [15].

Figure 4 finally groups the projects with respect to their efforts in adaptability and reconfigurability. Some projects like WINE GLASS and MOBY DICK do not consider these issues. Others like ETSI BRAN, BRAIN/MIND and FLOWS introduce *adaptability*, as a method to overcome service conditions changing (experienced during terminal movement) by providing ability for the communication nodes (access points, handsets etc) to dynamically change their configuration between predefined states. On the other hand, *reconfigurability* is a capability of the communication nodes to dynamically change their configuration from one state to a new one not reachable (not existing) before. The transition relies on advanced profile interpretation and management and is accomplished through appropriated signaling interactions. Such limited functionality has been demonstrated in SUITED. Other projects like ANWIRE, MOBIVAS, FuTURE and TRUST/SCOUT concern with both adaptability and reconfigurability issues.

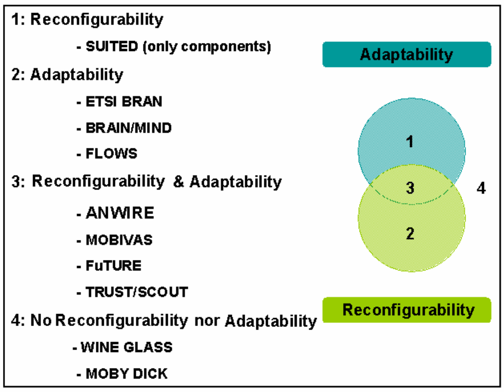


Figure 4. Adaptability and reconfigurability efforts.

## IV. REQUIREMENTS FOR INTEGRATED SYSTEM AND SERVICE 4G ARCHITECTURE

Through a deeper analysis of the system and services integration approaches used in the well-known international research projects, a number of which involve heterogeneous systems, as regards their commonalities and differences one can deduce the requirements and challenges for the design of an integrated system and service 4G architecture. In particular various issues related to the *network*, the *terminal*, the *user,* the *service,* and *security and privacy* need to be resolved. These are expanded on in the following. Some have been addressed in the literature from different viewpoints, e.g.[16].

From a *network* viewpoint, *high integration* could be regarded as possible if integration can be achieved at the link and the physical layers, while *low integration* is accomplished at higher layers. The former poses many difficult challenges. In the latter the unification of the following important system functions is highlighted:

- *Unified system management* of mobility and security, which will normally require interactions between the corresponding functional entities of different networks. Session continuation and service mobility, while roaming, are issues that need particular consideration and present major challenges.
- *End-to-end QoS negotiation and support:* For this, internetworking mechanisms involving network layer (or above) operations are needed [16]. To address this issue, internetworking with, and among, the most common QoS architectures is being studied within the 3G Partnership Project (3GPP), which initially proposed a comprehensive QoS architecture for UMTS.
- *Authentication, Authorization and Accounting (AAA)*: Multiple AAA systems existing in different networks need to co-operate through the exchange of appropriate information. ANWIRE suggests an alternative AAA approach, by introducing a third party AAA service provider. Through business agreements with the third party AAA service providers, all types of Service Providers (xSP) and Access Network providers (ANPs) will be able to offer their fee-based services to mobile users who have credit arrangements with one or more third party AAA service provider, just as they have one or more credit cards today, and through these entities will receive periodic itemized bills for all services used. Naturally new internationally agreed protocol structures would be required to support this approach to AAA.

In considering the integration process at the *network layer*, the following requirements and issues are among those needing careful study:

- *Mobility management:* needs to be highly sophisticated to enable seamless vertical handoff, VHO, without service interruption requiring a real or virtual network layer support for a 'connection' make before break among multiple co-existing heterogeneous networks of the 4G environment, [15]. For instance when VHO is user driven it may be possible to implement it such that from a network point of view it will simply appear as a normal connection termination activity on one network and connection initiation activity on the other. This would be occurring at the network layer and/or layer 2.5 (e.g. MPLS switched paths). However when it is network driven, the interworking will be more complex and development of standardized protocol would offset the growth of multiple bi-lateral propriety solutions.
- *Routing:* The implementation of the routing function poses different challenges depending on the type of network technologies being considered. Wired, mobile wireless and ad hoc networks all have diverse needs and requirements.

From a *terminal* viewpoint, the process of system and service integration needs to consider the following requirements:

- *Support for multiple communication modes:* Connectivity to different types of access networks shall be possible from a single terminal in evolving degrees of complexity, [15].
- *Adaptability and reconfigurability:* On-the-fly modification of the terminal logic in various layers (e.g. physical/link/network/application) is highly desirable in order that terminals may adapt to different access networks by reconfiguring themselves. Open software defined radio (SDR) frameworks [12] and standardized execution environments [13] are major enablers for the realization of this goal.
- *Always Best Connected (ABC):* The ABC enabled terminal will allow a mobile user to move seamlessly between different wireless access networks, while maintaining connections to application servers without losing data or needing to restart the application. This will allow the using of the most suitable network for each particular service leading to optimization of system performance and resource usage [16].

- *Access networks discovery and association:* The GSM approach, which uses periodical broadcasting of signalling messages by base station to mobile terminals for service subscription, becomes complicated in 4G systems because of the heterogeneity of wireless technologies and access protocols. One approach is to use SDR enabled terminals that can scan available networks [16]. Within the ANWIRE we also consider another promising approach of using *wireless billboard channel* for advertisement of access networks through which terminals can discover the networks available in an area, choose and associate with one or (in the case of MAcWiNT[2]) more of them.

The integration system and services process needs to consider the following *user* aspects:

- *Management of user profiles,* that contain users' preferences needed to be taken into account for the ABC decision-making process. To advertise his/her profile the user could avail of the same *wireless billboard channel* used for advertisement and discovery of access networks, or of another reverse (i.e. user to network) channel organized along similar lines.
- *Single identification* is desirable so that the user is associated with a unique identifier, independent of his/her current terminal and access network or location, along with sophisticated dynamic hierarchical mobile IP address management (e.g. to facilitate inter-user interactive real-time communication sessions.
- *Single point of business contact*: Ideally, a single business relationship (e.g. subscription) should suffice for the user to have service access anywhere, anytime, anyhow. The level of the system integration is a decisive factor for the realization of this goal. In the business models used today the User Home Access Network Provider (UHANP) is placed at the center as both the effective manager of all the user's wireless communications activities and the supplier of part of these wireless communication services. This places the UHANPs in a uniquely strong position and one with an inherent conflict of interest when viewed from the user's perspective in consideration basically of their freedom and independence in seeking best value for money. Prospective UHANP entrants will be faced with having to have customer administrative and management support in place, plus most of the business agreements with the other parties before they might hope to start seeking 'home user accounts' and make inroads into the market. Naturally this will be a brake on fast deployment and flexible provision of new services, as well as a serious barrier to new ANP entrants.

  Within this context, ANWIRE suggests an alternative business model, one which separates out the administration and management of customers' one-stop-shop authentication and accounting system from the business of supplying an wireless access network service, and locates it with a third party AAA service provider.

From a *service* viewpoint, the following issues of particular importance can be identified:

- *Flexible and fast service creation.*
- *Service advertisement, discovery and association:* One approach here could be to use the same *wireless billboard channel* considered by ANWIRE for advertisement and discovery of access networks.
- *Service continuity:* Uninterrupted, optimal Always Best Service (ABS) delivery should be provided, efficiently coping with user mobility to different networks and terminals, [15].
- *Service adaptability* to constraints and limitations of the access networks and terminals currently in use.
- *Service deployment and delivery in diverse environments:* Services shall exploit reconfiguration capabilities of the underlying terminal and network infrastructure so that they can be optimally deployed and delivered over diverse infrastructures.

An additional critical concern is *security and privacy*, which needs to be considered in every layer of the overall integrated system. The concept for future 4G reconfigurable networks is based on spontaneous networking without prior relationship to the network operator. In this case the communicating parties have to provide credentials for authentication without knowing each other. A typical implementation approach is for the user to be identified by a portable and removable smart card (possibly with incorporated biometric user verification process, analogous to fingerprint recognition), which contains user's credit card details (or a specific authentication code acceptable, or even provided by, the third party AAA service provider) and is inserted in the terminal currently used, with a suitable public key encryption system. In this way each service charge (e.g. to ANP or xSP) may be paid directly to a third party AAA, indicated by the payee. Any xSP (VASP, CP, etc) charges may be similarly processed. Financial institutions, such as present day credit card companies would probably be the most suitable contenders for the third party AAA service provider business.

As more information of commercial value will be committed to the 4G networks, the users will require stronger *end-to-end security* services provided at the user application level. To achieve this, new robust, less 'power hungry' and flexible (in order to apply to different technologies and devices with different capabilities, processing power and security needs [16]) encryption techniques must be used for securing the communication as well as to provide content encryption of stored data and removable memory.

Another security service is to provide metadata protection, including confidentiality of identity, time and traffic. This raises a question of finding a compromise between *anonymity* and *accountability*. Therefore, easy-to-use mechanism for extra authorization, change of pseudonyms etc. have to be implemented, allowing users to adapt to more complex environment of multi-service 4G networks.

Also an essential service is to provide user controlled *location privacy*. Current standards for wireless/mobile

[2] Multi-Access Wireless Network Terminal

communications do not provide sufficient location privacy. Future standards will need to provide stronger levels of protection against eavesdropping and malicious actions likely to be encountered in an environment of a plethora of networks visitable by passing users.

Last but not least, more protection mechanisms against different types of *attacks* such as (distributed) denial of service, malicious calls and callers, non-forwarding, traffic deviations, route modification will need to evolve, becoming stronger and more sophisticated.

## V. CONCLUSION

A structured overview analysis of 4G system and service integration issues and challenges was presented based on a deep analysis of integration efforts done so far in well-known international, mainly EU IST, research projects. In the latter, commonalities and differences of the adopted system and services integration approaches are highlighted, and system and services integration requirements were identified. This has been treated within the context of the aim of this 4G integration being to provide an interconnection between heterogeneous wireless access technologies in order primarily to ensure seamless handover from one technology to another, thus to provide a continuous, and where possible always best service (ABS) to always best connected (ABC) users. A number of novel concepts were outlined and areas requiring attention of internationally agreed protocol development highlighted.

The ongoing research work within the ANWIRE project [1] intends to provide a complete 4G integrated systems and service framework architecture (called GAIA) along with an analysis of the signaling issues [17].

## ACKNOWLEDGMENT

The authors would like to acknowledge the support of ANWIRE, a EU FP5 Thematic NOE, IST-2002-38835 and their ANWIRE partners for their valuable inputs and fruitful discussions.

## REFERENCES

[1] ANWIRE homepage: http://www.anwire.org
[2] ETSI DTS/BRAN-0020003-2 v0.c: Broadband Radio Access Networks (BRAN); HIPERLAN Type2; Interworking between HIPERLAN/2 and 3rd Generation Cellular and other Public systems, V0.c (2001-12).
[3] WINE GLASS homepage: http://wineglass.tilab.com.
[4] MOBY DICK homepage: http://www.ist-mobydick.org/
[5] SUITED homepage: http://www.suited.it/
[6] BRAIN/MIND: http://www.ist-brain.org, http://www.ist-mind.org
[7] TRUST/SCOUT: http://www.ist-trust.org, http://www.ist-scout.org
[8] MOBIVAS homepage: http://mobivas.cnl.di.uoa.gr.
[9] FLOWS homepage: http://www.flows-ist.org/
[10] FuTURE: http://future.863.org.cn/future_e/future_e01_02.html
[11] H.Chaouchi, G. Pujolle. "Policy Based Management architecture for Always Best Connected users", DVD Proc. of the 1st International ANWIRE Workshop. Glasgow, Scotland. ISBN 0-9545660-0-9. April 2003.
[12] SDR Forum. http://www.sdrforum.org.
[13] 3G TS 23.057: "Mobile Station Application Execution Environment (MExE); Functional description".
[14] J. Pereira. "The Path to 4G" in Wireless, Mobile and Always Best Connected. DVD Proc. of the 1st International ANWIRE Workshop. Glasgow, Scotland. ISBN 0-9545660-0-9. April 2003.
[15] M.O'Droma, I.Ganchev, G.Morabito, R.Narcisi, N.Passas, S.Paskalis et al. "Always Best Connected Enabled 4G Wireless World". Proc. of the 12th European Union IST Summit on Mobile and Wireless Communications, Aveiro, Portugal. ISBN 972-98368-7. June 2003. Pp.710-716.
[16] S. Y. Hui and K. H. Yeung. "Challenges in the migration to 4G mobile systems". *IEEE Communocations*, vol. 41, No. 12, Dec. 2003.
[17] H. Chaouchi, G. Pujolle, I. Armuelles, M. Siebert, F. Bader, I. Ganchev, M. O'Droma, N. Houssos. "Policy Based Networking in the Integration Effort of 4G Networks and Services". IEEE VTC04 Spring, Milan, May 2004, 5pp.

0-7803-8256-0/04/$20.00 (C) 2004 IEEE