Resource Management for Seamless Mobile Services

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Abstract

The seamless provisioning of services and applications across heterogeneous wireless systems will play a key role in future communication systems. While each individual enabling wireless technology is advanced and stable, or is expected to become mature in the near future, a framework for enabling the management of this heterogeneous infrastructure efficiently and user-friendly, does not exist yet.

We address these challenges within the SMART project with the invention of a novel architecture for seamless provision of mobile services over heterogeneous wireless networks. The SMART architecture is scalable, is able to use the available resources efficiently (like network, energy, and money), and makes the heterogeneous network transparent to, but nevertheless under control of the user. User-friendliness, security, and efficiency are the key goals of the architecture. In SMART all these issues are being dealt with in an integrated, coherent way.

***Keywords**: wireless Internet, Quality of Service, heterogeneous networks, multimedia, seamless services.*

1 Visions of the future wireless world

Electronic communication has proliferated deeply into our daily life, and it is becoming common to have several e-mail accounts, a wired phone at home and at work, a cellular phone, a workstation at home and in the office, a Personal Digital Assistant (PDA), and the list can go on and on. Recent advances in wireless networking technology and the exponential development of semiconductor technology have engendered a new paradigm of computing, called *personal mobile computing*. In this paradigm, the basic personal computing device will be an integrated, battery-operated device, small enough to be carried with you all the time. These future mobile devices will be always switched on, ready for service, and constantly connected to the Internet. As these mobile devices become more popular, the demand for anytime/anywhere connectivity for these devices increases, and the requirements on that connectivity become more stringent.

Moreover, it is expected that in future scenarios users will be able to choose from an even more wider range of services from various wireless access networks that each have their own characteristics, cost and ownership. Connectivity for mobile devices is governed by the communication technology on the device, its transmission characteristics, and the coverage area of that technology. To add versatility to these devices, they can include multiple communication technologies. With the growing demand for mobility support, coverage areas for wireless connectivity are growing and overlapping.

A principal goal of providing mobile services should be *user satisfaction*. In recent years, a major shift can be observed from a technology centred world to a service and experience centred world. It will become more and more important how users perceive the service and the emotional impact and pleasure that the service creates and maintains. Driving forces of user level interaction are rich digital content, universal availability, and seamless and personalized services. Personal service means taking into account personal preferences, needs and capabilities. The devices and services need to integrate in our current situation and mode of behaviour. The services should be flexible, cost effective, reliable, and make our business and private life less hectic and complex.

1.1 Multimedia content

The various types of media carried over the Internet have each specific characteristics and transmission requirements. In the current, rich multimedia content era, text and images remains significant and has some important applications. Most types of one-way text traffic (e.g. news, stock market information) usually pose no serious demands for transmission, except for some cases where immediate delivery is critical. Rich content applications like e-mail and ftp are not time-critical and the user is expected a fair delay during downloading. For interactive applications (like web browsing) critical parameters are the end-to-end delay, and the available bandwidth (at least a few tens of Kbits/s). Audio streams have moderate bandwidth requirements (8 Kb/s for telephone quality to 256Kb/s for CD quality). Timely and reliable delivery is very important. Buffering provides robustness and relaxes timing requirements. Interactive audio cannot use significant amounts of buffering, and therefore timing considerations are of equal, or even higher importance than bandwidth requirements. Timing and reliability constraints can be more relaxed for video. Streaming video has significantly higher bandwidth requirements than audio. It can range from 50 Kb/s to 1.5 Mb/s.

1.2 Access networks

In recent years, the Internet scenery has changed dramatically and a broad spectrum of access technologies has been introduced. Wireless access to the Internet is gaining momentum.

Future mobile terminals will be used in several different environments and locations (home, office, car, train, sea, wilderness, etc.). High altitude base stations (providing multimedia communication with large bandwidth and large coverage areas), high-speed local media points (providing digital broadcasting systems such as DAB), or dedicated road technologies might augment current wireless infrastructures that is largely based on cellular communication (GSM with low link quality data services, and UMTS that should provide higher bandwidths), wireless LANs (HIPERLAN/2, 802.11, etc. that can offer data rates of up to 11 Mb/s and low error rates), and personal area networks like Bluetooth, DECT, and

IEEE802.15.3. One might expect more special-purpose access networks to become operational in the future.

Today, users are able to select among a great variety of access networks and services. This contributes towards an extremely heterogeneous Internet infrastructure, where the transmission characteristics cover a broad range of values. This heterogeneity builds up as new technologies are introduced to cover parts of the domain, and stresses the need for provisioning ubiquitous and seamless access to Internet multimedia content.

All these access systems have very different characteristics in terms of bandwidth, cost per bit, energy consumption, coverage, as well as service mechanisms for mobility, roaming, and available services (e.g. data, voice, broadcasting). Consequently, the services and applications these networks work with most efficiently are also diverse. Intuitively, combining various access networks can provide a far better efficiency and performance. For example, digital broadcasting systems can be used as a broadband downlink channel to provide, for instance, fast Internet content. Other access systems may be used as return channels for data requests and acknowledgement signalling in such highly asymmetric services.

1.3 Outline

This position paper describes an architecture that is able to seamlessly provide a broad mix of services over a heterogeneous wireless network. Work on this architecture is performed within the SMART project, which integrates research of the MIRAI project (Japanese for *future*, and an acronym of ‘Multimedia Integrated network by Radio Access Innovation’) at the Communications Research Laboratory in Yokosuka, Japan, and the “Seamless Services” project, involving several Norwegian partners, Norut IT and the University of Twente in the Netherlands.

This document is structured as follows. First we introduce the SMART objectives and approach. Then, we present the state-of-the-art in the field of micro-mobility, and seamless services. In Section 4 we present the main concepts and innovations of our architecture, followed by a conclusion in Section 5.

2 SMART

The seamless provisioning of services and applications across heterogeneous wireless systems will play a key role in future communication systems.

The overall objective of SMART is to study, develop and validate heterogeneous wireless network architectures, where the user is unbothered, but can have full control, of the transport mechanisms and infrastructures used to access and deliver the services requested, while the available resources are used efficiently.

The seamless use of all these communication infrastructures will greatly benefit to user satisfaction. To be able to achieve this, future terminals need to be able to support simultaneously different access technologies. How all these systems should be integrated into the wireless Internet world and the backbone structures will be one of the critical issues. Adaptability to the various infrastructures and environmental conditions, as well as an easy addition into the global infrastructure, low cost, user-friendly operation, reliability, and security will be key issues.

2.1 Approach

The success of mobile communications so far has been made possible only by shared and stable visions and principles, at the system level and among a wide set of players. Standardisation organisations have done a good job so far. Currently, mobility and roaming is in general only possible within a common platform (horizontal handover). Co-operation and mobility between different platforms (vertical handover) is technically not efficient, and requires that the user have service contracts between several service providers to allow roaming. While each individual enabling technology is advanced and stable, or is expected to become mature in the near future (due to the current effort put in research and development on wireless Internet infrastructures), a framework for enabling the management of this heterogeneous infrastructure efficiently and user-friendly, does not exist yet.

A key contribution of our research is the aggregation of resources across multiple heterogeneous wireless networks. The simultaneous use of communication channels from multiple technologies enhances mobile communication in several ways.

First of all, there is the obvious increase in bandwidth, which will reduce the bottleneck for most wireless communication. Second, it relieves the system/user from choosing a single access network. By having information about the currently available channels, the system can choose some subset of these channels to fulfill the communication needs. The choice of which channel(s) to use depends on constraints set by the service, the user, and the system. Third, the simultaneous use of multiple channels makes it less sensitive to performance and quality fluctuations on individual channels. Finally, seamless handovers are eased with the use of multiple access networks, since a connection is not switched from one point to another. With overlapping coverage areas, the aggregated channels appear continuous.

It has become clear that the development of a purely technical vision for future mobile communications will not be sufficient to achieve good user satisfaction. Rather, such a technical view must be complemented by:

- an user centric approach, looking at the ways users will interact with the wireless systems,
- new services and applications that will become feasible with the new technologies, and
- new business models, in which the user is placed central.

The innovative approach of SMART is that it proposes to design a framework and architecture, which deals with all these issues at the same level. The goal is to provide a good user-satisfaction by designing an efficient and cost-effective communication infrastructure, that can be used to provide seamless and secure services. In SMART the wireless access networks will be co-operating and complementary components, all operating at the network layer (IP). The different access systems are organised in a layered structure. This concept facilitates an optimum system design for different application areas, cell ranges, and radio environments, since a variety of access technologies complement each other on a common platform. The provision of seamless services includes security and privacy mechanisms, interworking mechanisms, and resource management strategies.

2.2 Requirements

A fundamental goal is to *make the heterogeneous network transparent to the user*. This means that the user is less bothered of the wireless access network(s) he/she is using, and can trust that an efficient configuration is being used. In addition, a goal is to design the system architecture such that it is independent of the wireless access technology. To achieve these goals we have the following requirements:

- *Different access technologies*. In a heterogeneous network it should be possible to use a *combination* of several networks, each of which is optimised for some particular service. Multiple differentiated flows can then be used to achieve better and/or cheaper connectivity. Software-defined radio technology will play a significant role in providing the versatile communication platform. Since it should be possible to use multiple wireless access networks 'simultaneously', the software-defined radio must be able to switch quickly between the various wireless subsystems (or be equipped with multiple radios).
- *Mobility management.* Seamless handovers within the same network or between different access networks and technologies should be provided.
- *Wireless system discovery*. We expect that there will be a widespread adoption of wireless access technologies, ranging from local point-to-point connections like Bluetooth, via wireless local area networks, to first, second and third generation cellular systems. Discovering which wireless systems are available might become a difficult, time and energy-consuming process. Efficient support for wireless system discovery is therefore essential.
- *Efficient configuration selection*. An important motivation of a heterogeneous network is that it is possible to use a combination of several wireless systems. The decision of selecting the most appropriate network(s) could be based on aspects like available bandwidth, energy consumption needed to perform the service, service classification, and cost. The result is that each service is delivered via the network, which is most efficient to support this service.
- *Simple, efficient, scalable, low cost*. All these requirements are closely related to each other. These requirements are of particular importance in the future pico-cellular networks in which access point offers tens to hundreds of megabits per second. It is not affordable to have many complex access points.
- *Energy efficient*. We expect that wireless IP communicators will be switched on, ready for service, constantly reachable by the wireless Internet. This implies that mechanisms for services like maintaining location information and wireless system discovery should be energy-efficient (and bandwidth efficient as well).
- *Secure and private*. Mobile systems are susceptible to a number of security problems that do not exist in their stationary counterparts. Mobile hosts must update their location while moving. These location messages make impersonation possible unless properly secured. In systems and applications where seamless handoff is of primary importance, session keys used by the mobile hosts must be promptly available at the new base station during handoff. Privacy becomes very important when a mobile user is constantly 'on-line' and can be traced wherever he/she moves.
- *Quality of Service support.* End-to-end QoS mechanisms should be available. Since the wireless access networks provide special services, QoS aspects in heterogeneous networks are of prominent importance. End-to-end QoS implies that interoperation with local QoS mechanisms should be possible, but also that lower layer protocols (link and physical layer) should be aware of the traffic characteristics and so be able to meet the different requirements of QoS. Bridges to existing solutions (e.g. IP control concepts like Differentiated or Integrated Services) will be required to address transition from today's solution.

3 State of the art

Today, global roaming between dissimilar networks is difficult by the virtue of the fact that three components need to be tied together before a service can be executed. These are the *User*, the *Service Provider*, and the *Access Provider*. Dissimilar networks often have dissimilar IP tunnelling protocols, dissimilar authentication and authorisation mechanisms, dissimilar service definitions, and dissimilar Quality of Service mappings. Many hurdles need to be overcome before global roaming becomes feasible.

Network model

Currently, co-operation between different wireless access networks is based on a tunnelled network model [9]. In this model, a user of a mobile host has a service agreement with operators of several wireless access networks independently. Based on some policy, the optimal network for the requested service is selected. The hybrid core tunnels the traffic across the Internet and the selected access network to the mobile host. Roaming and mobility mechanisms are implemented at higher layers of the protocol stack, resulting in inefficiencies, performance degradation, and interworking problems. The advantage is that this system requires little modification to existing access networks. Roaming between common platforms (horizontal handover) is based on lower layers of the protocol stack (data link). However, because they all have their own infrastructure for e.g. signalling, handover, and billing, efficient co-operation between these existing networks systems is not possible. What lacks is a global view, both technically as in business models, that will allow these networks to co-operate to a much higher degree, thus allowing an efficient, and cost effective operation.

An innovative part of our approach is that in our architecture co-operation is at a lower layer of the protocol stack. In the SMART model there is a Common Core Network that deals with all network functionality and operates as a single network. The difference between horizontal and vertical handovers is diminished, because *all* mobility and roaming issues are being dealt with by the architecture in the same entity. Of course, the architecture still has to deal with the specific characteristics of the access networks, but it has a much higher freedom in selecting the most appropriate access network. Different radio access networks handle only the physical and link layer functions specifically related to a distinct radio access technology. The core network is IP based. This reduces the overhead, and improves performance. A major challenge of this model is that the different access networks must converge, which requires a standardisation effort and business commitment to support it.

Often, the various kinds of architectures that are able to deal with multiple networks are referred to as hybrid [9]. We prefer to call them *heterogeneous* to stress the fact that there can be multiple networks *simultaneously*, all working together. Hybrid networks describe the more traditional view of having multiple networks of which one can be chosen.

Routing

Future wireless network infrastructures will have to support a wide variety of users, applications, and access needs. High-speed access can be achieved by using small cell sizes. As base station density increases, however, so will handoff rates.

Currently, related work mainly is associated with routing and handoff aspects for wireless networks. The Mobile IP protocol [6] supports mobility transparently above the IP level and it allows the nodes to change their location. Mobile IP is generally seen as a *macro mobility* solution, it is less well suited for micro-mobility management, in which a mobile host moves within a sub network. A typical example of micro mobility is a handoff amongst neighbour wireless transceivers, each of which is covering a very small geographical area, so that handovers occur frequently (e.g. every few seconds). There have been quite a few proposals to support micro mobility (e.g. Cellular IP [3], HAWAII [7]). The differences among all these schemes are related to the mechanisms used to route the packets within a local (home or foreign) domain.

Traditionally, for efficiency reasons, micro mobility is dealt with at the link layer. However, in an architecture supporting various Radio Access Networks (RAN) a natural solution to roaming between these different RANs is IP mobility. It is of great interest to understand which role low-end and high-end routers should play in mobility management in a full IP architecture. Another important question is related to resource management. It is crucial to understand how resource management should be dealt with in the routers within the core network. This is in particular important to achieve end-to-end QoS – e.g. how should end-to-end QoS requirements be mapped to QoS requirements on the involved routers and which mechanisms should be used to satisfy those requirements?

Seamless services

The challenges to provide seamless services to users introduced with heterogeneous wireless architectures are huge. To effectively and efficiently overcome the problems involved, e.g. related to handovers, radical changes in network characteristics, etc., many researchers have proposed middleware techniques, in which the application and user is shielded from these impairments, in order to guarantee transparent operation of the service regardless of the working conditions.

In the SMART approach we take a different view, and try to establish a framework in which the operation of a service to a large extend is determined by user preferences, environmental conditions (available access networks and their characteristics), and the requirements and adaptability capabilities of the service itself. Interaction between services and communication mechanisms are a prerequisite to achieve such a seamless service. This will make user, service, and system aware, and not shield from the consequences of their choices. Security and privacy issues play a crucial role in this framework.

Security is considered an important aspect of IPv6, and will be integrated within the SMART architecture. Privacy is an often-neglected subject, but will be essential in SMART to provide seamless services in a heterogeneous environment while retaining the privacy of its users.

Currently, research and standardisation organisations are already working on the issue of application adaptability. For example, JPEG2000 provides scalable image compression and support many types of progressive transmission. This is highly desirable when transmitting image data over transmission links with varying characteristics. The rendering of an image can start when the first data is received and the quality of the image will just improve when more incoming data is processed. Another media-coding standard, MPEG-4, provides object-based transcoding suitable for adaptable video content delivery. While MPEG-1 and 2 used frame based coding methods, MPEG-4 introduce an object-based coding scheme where each object is described by texture and shape information, which provide individual object optimisation.

4 SMART Innovations

The major challenge for the future generation wireless Internet is that the architecture will have to be very flexible and open, capable of supporting various types of networks, terminals, services and applications.

The main innovation of SMART is that we *exploit the heterogeneous wireless world*, instead of trying to fight against it. Currently, wireless access systems are designed with the main focus on providing functionality. Efficiency, user-friendliness, and interoperability play a minor role. Instead, SMART aims at providing a user-friendly, efficient, and open infrastructure that *exploits* the opportunities of the future heterogeneous world. A fully Internet Protocol compatible solution (IPv6) is adopted, allowing for full multimedia capabilities, and a smooth integration and deployment current (fixed) Internet services. An overview of the architecture can be found in [4], and the architectural concept is depicted in Figure 1.

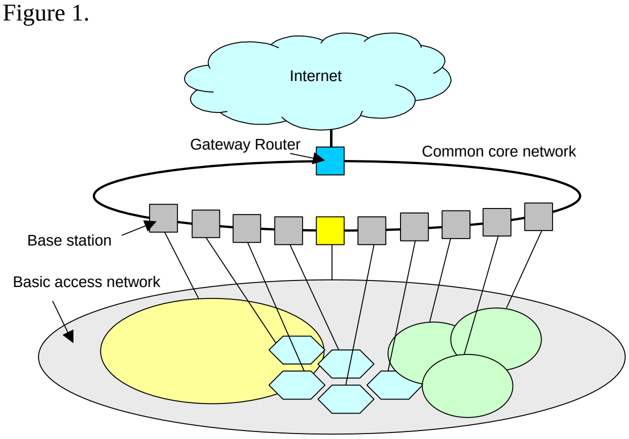

Figure 1: Architectural concept.

Below we will describe the major innovative subjects that will be explored and developed within SMART.

4.1 Efficient heterogeneous network support and resource management

The SMART architecture will be designed to ensure that a user can use the infrastructure efficiently, and can interwork with fixed Internet technologies. The wireless access networks will be co-operating and complementary components. Through this infrastructure operators will be enabled to provide users with efficient wireless access (in terms of cost and QoS), and service providers with the means for offering sophisticated services. To enable this, the SMART architecture is based on a unified, IP-based access and core network that can serve as a single, common network architecture for many different wireless access networks. Efficient resource usage is accomplished by having a distributed resource management entity that is able to configure the network for the requested service. The decision of selecting the most appropriate network(s) will be based on aspects like available bandwidth, energy consumption needed to perform the service, service classification, and cost. The result is that each service is delivered via the network, which is most efficient to support this service. Parallel IP streams over the core network will be essential.

Current research is still focussed on resource management that is located on the terminal. Although this is a very simple approach, the consequences are that many opportunities of efficient resource utilisation cannot be explored, either because the local terminal lacks the required information, or because the system does not allow changing the wireless access network, or using several networks simultaneously. Through our proposed distributed resource management architecture, we can achieve an efficient exploitation of the heterogeneous wireless networks.

4.2 Physical and logical separation of transport and signalling

The major purpose of logical separation of user transport and user control is to allow these functions *to scale independently of each other*. This issue is considered essential since user transport traffic may increase at a different rate from the signalling associated with that traffic. To this end, in the SMART architecture we use two distinct networks: the Basic Access Network (BAN) for all signalling related traffic, and the Common Core Network for the user traffic itself. The BAN is used for other services like paging, synchronisation, and wireless system discovery.

4.3 Novel wireless system discovery

We expect that there will be a widespread adoption of wireless access technologies, ranging from local point-to-point connections like Bluetooth, via wireless local area networks, to first, second and third generation cellular systems. Discovering which wireless systems are available might become a difficult and resource consuming process (e.g. time, energy, bandwidth). Support for wireless system discovery is essential. In a mobile environment it is very important to be energy efficient since a terminal relies on its batteries to operate. We expect that the wireless IP communicators will be on-line continuously, although not be actively communicating most of the time. In essence, mobile hosts will be in an idle state, but passively connected to the network infrastructure. It is then extremely inefficient to have to scan all networks, and wait for a paging message. Moreover, since the wireless networks are optimised for some special services, it is very likely that they are not efficient for paging messages. The innovative approach to solve these problems is that we use a separate signalling network for this matter (the BAN). The network provides the terminal with information about the currently available wireless networks, and indicates which network to use, so that the terminal is not forced to scan all possible variants.

4.4 Rapid service creation

The SMART architecture will support the capability for rapid service creation by network operators, and service providers, independently of the equipment and network manufacturer. Rapid is considered from weeks, rather than many months to years. This is achieved by providing a framework that offers services to be used by wireless access manufactures, and can be used by service providers to offer sophisticated new services. Although beyond the scope of this project, the SMART architecture supports the separation of service provider from network provider, enabling different means of revenue generation for both service and network providers.

4.5 Quality of Service mechanisms

Enabling end-to-end QoS over Internet is a tough venture, because it introduces complexity starting from applications, different networking layers and network architectures, but also in network management and business models [8]. It becomes even more challenging when one is introducing QoS in an environment of mobile hosts, wireless networks, and different access technologies. Yet the need for QoS mechanisms in this environment is greater due to scarce resources, unpredictable available bandwidth and variable error rates. In a heterogeneous network in which we apply different wireless networks with different characteristics, the need for QoS mechanisms is evident. Within the fixed Internet there are several ways to enable end-to-end QoS. Current work on QoS over IP architectures, i.e. Integrated Services [2] and Differentiated Services [1] seems to leave out mobility support, despite its importance.

The high level of integration within the SMART architecture allows a much better and smooth QoS management than in current systems. Moreover, QoS requirements are much easier recognised and utilised at the lower layers of the communication protocol stack, thus allowing for a significant improvement in overall performance and efficiency. Traffic flows within the SMART Common Core Network are differentiated according to its service needs and QoS requirements. There are two main reasons for having such differentiated traffic flows: 1) to enable routing of multiple parallel traffic flows on several different wireless access networks, and 2) to enable cross-layer interaction. In a wireless environment it is essential that the lower layer protocols are aware of the traffic characteristics. The Internet is implemented on the basis of the ISO/OSI hierarchy architecture, where the protocols for different layers are independent of each other. Recent research has shown that for wireless Internet, information of other layers may be required in order to improve the overall performance and efficiency.

4.6 Seamless services and security

Traditionally, middleware is being used to hide the peculiarities of the underlying system. The traditional middleware is a horizontal layer below the service and application. In SMART we take a different approach, and establish a vertical layered framework in which the operation of a service to a large extend is determined by user preferences, environmental conditions, and the requirements and adaptability capabilities of the service itself.

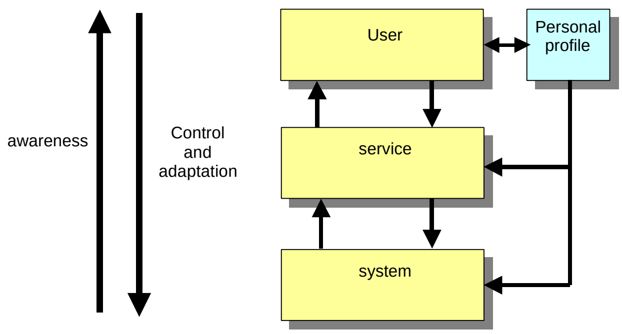

Figure 2: Seamless service concept.

To effectively and efficiently overcome the problems related to heterogeneous networks, e.g. problems related to handovers, radical changes in network characteristics, etc., applications and services need awareness of consequences of choices imposed on the underlying system. Moreover, global co-operation is needed on requirement and the consequences of adaptations to varying conditions. Applications can then make decisions about how the protocols and mechanisms should be applied, in order to respond effectively to both application needs and the environmental characteristics. In addition, the variety of traffic types and quality of service requirements, which can be expected, clearly calls for adaptive solutions in which no design criteria can be decided a priory to fit all possible communication needs. Rather, the service should be smart enough to be able to build its own best scheme based on its own requirements, user preferences, and environmental conditions. Interaction between services and communication mechanisms are a prerequisite to achieve such a seamless service, and the active involvement of user and preset profile will make the service more seamless and convenient for the user.

4.7 User-centric management system

A major innovative part of SMART will be the user-centric management system, in which users to a large extend can control their preferred profile and account settings. In current solutions those profiles are usually stored locally, e.g. in the user's terminal (SIM card, PDA). There are no general solutions spanning different networks, services, and terminals. As a result, today's users have many personal profile databases that contain duplicate information. For example, users store their telephone numbers both in their cellular phone, PDA, and their desktop's address book. The need for the user to be able to fully control their own 'account' is mandatory in a future where mobile devices are not longer tied to a specific account of one network provider. The mobile device will be a customer of several different network providers, and a user of a large amount of mobile services in a global, distributed market place.

One innovation within SMART is the creation of a *personal profile home page* that is under control of the user, can be accessed by the system and is independent of the terminal, network and application.

In the network-accessible personal profile, users can configure application and network parameters, control, monitor and set cost parameters, configure media, shortcuts, filters, inter-working servers and services and so on. The most innovative part of this management system will be that it provides *immediate feedback* to the user on the selected preferences. When a user changes a particular setting, (e.g. it indicates that it allows the system to transmit full colour, high quality images over a GSM phone), the system will visually indicate the consequences of such a setting (e.g. it will show the quality of a picture, the cost associate with the communication (money, time, energy resources, etc.). The system will provide context aware configuration, which means that profiles can be tied to current or specific locations or situations. The vision of a network accessible central point of administration will add significant convenience to the user, ability to create a cost efficient profile and to select and configure services based on a personal choice. Security, high availability, trustiness, authentication and authorisation are of major importance for the management system.

5 Conclusion

The SMART architecture aims at providing seamless services over a heterogeneous wireless network efficiently. By design, the architecture enables the rapid creation of new business opportunities, allows the fast introduction of new wireless and mobile technologies, while efficiency, seamless services, user-friendliness and security are primary goals.

Efficient handover mechanisms are crucial in these systems. A major innovative part of our approach is that in our architecture the difference between horizontal and vertical handovers is diminished, because *all* mobility and roaming issues are being dealt with by the architecture in the same entity. Of course, the architecture still has to deal with the specific characteristics of the access networks, but it has a much higher freedom in selecting the access network to use. Different radio access networks handle only the physical and link layer functions specifically related to a distinct radio access technology. A Resource Manager is responsible for the efficient use of the wireless access networks. Scalability is ensured by virtue of distributed design, and decomposition of functionality. A Basic Access Network, physically and logically separated from other wireless access networks, is used as a means for wireless system discovery, signalling and paging. End-to-end Quality of Service mechanisms, in which all layers of the network protocol stack are aware of the traffic requirements of the traffic flow, are used to increase the efficiency of the wireless channel. The Personal Profile Home Page provides user the opportunity to configure services and network parameters, and provides *immediate feedback* to the user on the selected preferences. A framework will be developed to enable seamless services to interact with the lower layers of the communication system, in order to adapt the system to changing environment characteristics, and thus increasing the system-efficiency and user-satisfaction.

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