

The RAINBOW Concept for the UMTS Access Network

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ABSTRACT

This paper presents an overview of the ACTS project RAINBOW which demonstrates a generic UMTS network architecture which is able to handle different radio access techniques. The approach pursued within the project is to develop a generic interface between the UMTS core network and the radio access parts. The basic concepts of the project are described, as well as the demonstrator built to evaluate these concepts and the services supported. Results from conceptual studies are also provided, which have been undertaken to further explore the project concepts and to evaluate alternative approaches.

- Definition of the boundaries, within the UMTS Radio Access System, between radio independent and radio dependent components.
- The integration of UMTS radio access system in B-ISDN and IN contexts for both transport and control procedures.

The RAINBOW project tackles many of these architectural issues by developing a demonstrator which can be used to prove the feasibility and evaluate the complexity of the solutions. In parallel to this demonstrator implementation, conceptual studies are performed to further explore the project concepts and to evaluate alternative approaches.

I. INTRODUCTION

The European Telecommunications Standards Institute (ETSI) and the International Telecommunications Union (ITU) are both defining a framework for future mobile networks, known as UMTS and IMT-2000, respectively. These systems need to be flexible enough to meet a wide range of differing operator and user requirements, and generic enough to support a family of both second and third generation radio interfaces.

In this paper, an overview of the work performed in the European ACTS project RAINBOW (Radio Access INdependent Broadband on Wireless) is presented. The central objective of the RAINBOW project is to specify and implement a generic UMTS access infrastructure which can be used to investigate key architectural issues of third generation mobile systems. These issues are:

- The design of a generic UMTS access infrastructure able to cope with different UMTS innovative radio access techniques and with different propagation environments.
- Develop solutions for the migration from second generation mobile systems (GSM/DCS1800 and DECT) to UMTS.

In the remainder, the two basic concepts of the project are first discussed in Section 2. Then, the demonstrator itself is briefly described in Section 4 in terms of the network architecture, network entities, functionality and services being demonstrated. Next, the results of additional system concept studies are presented in Section 6. In that section, the project concepts are further explored and alternative approaches to the ones implemented in the demonstrator are evaluated. Finally, some initial conclusions are provided.

II. RAINBOW CONCEPTS

In the last few years it has become clear that there will be more than one innovative radio interface used to access the UMTS/IMT-2000 system(s). This is particularly true for the recent twin track approach chosen in ETSI for the UMTS radio interface (i.e. both TD/CDMA and WB-CDMA). In addition to this, UMTS/IMT-2000 will have to support regional variations of second generation radio interfaces. This results in a scenario where UMTS/IMT-2000 will have to support a set of second and third generation radio interfaces. On the network side of UMTS/IMT-2000, there is a large number of core networks to which different UMTS access networks should be connected. Considering these aspects, the fundamental concepts of the RAINBOW project [1,2] are:

- A single generic interface between the UMTS access and core networks.
- A split between radio technology dependent and independent parts.

A generic interface between the UMTS core network and the radio access parts effectively decouples the radio access from the core network and enables the connection of different radio access modules (second or third generation) to the same network infrastructure via a unique interface. By decoupling the radio access from the core network, these two parts of the system can be designed and enhanced independently of each other. This also allows more than one radio interface to be used at the same time, each optimised for a different environment. It provides operators with a generic platform which can be tailored to their needs.

Manufacturers will also benefit from a generic and modular hardware platform which only requires a specific software change (e.g., plug-in software) to meet a given customer's needs [3]. The generic interface also facilitates the evolution of second generation mobile systems to UMTS, enabling the second generation base and mobile stations to be reused. However, in this case some interworking functions are required to map second generation protocols to the generic interface.

As can be seen in Figure 1, the generic interface not only has the ability to combine different radio access modules with the same core network but also to combine different core networks with the same radio access module. This gives operators the freedom to select their own evolution path towards UMTS, and still ensure a convergent solution which maintains a high degree of compatibility and interoperability.

The benefits of adopting a generic interface are the following:

- It assists a "modular" and "future-proof" design methodology for the UMTS system.
- It allows the radio modules to be "plug-replaceable" in their interconnection to UMTS core networks.
- It clearly delimits the border between radio access and the core network [4].
- It "naturally" drives the evolution from GSM and from a fixed network towards a "convergent" yet flexible UMTS solution.

The second basic concept in RAINBOW is the division of the radio access network into radio technology dependent (RD) and radio technology independent (RI) functionality, also illustrated in Figure 1. This concept facilitates the generic interface discussed previously and is in line with the work performed in ITU-R [5]. It provides a modular approach (separate RI and RD modules) which maximises the commonality within the access network when supporting several innovative radio access techniques. This is particularly relevant when multiple radio interfaces are needed to satisfy requirements of the different application and propagation environments in which UMTS will be used.

The division of radio independent and radio dependent functionality "future proofs" the design of the UMTS access network, by allowing new or unforeseen radio technology to be adopted with minimal modifications to the radio independent components.

A similar approach could be used to develop the GSM and DECT access interworking, required to ensure second generation access segments conform to the single generic interface for UMTS. This is possible because the GSM and DECT interworking towards that interface are naturally composed of radio dependent and radio independent parts.

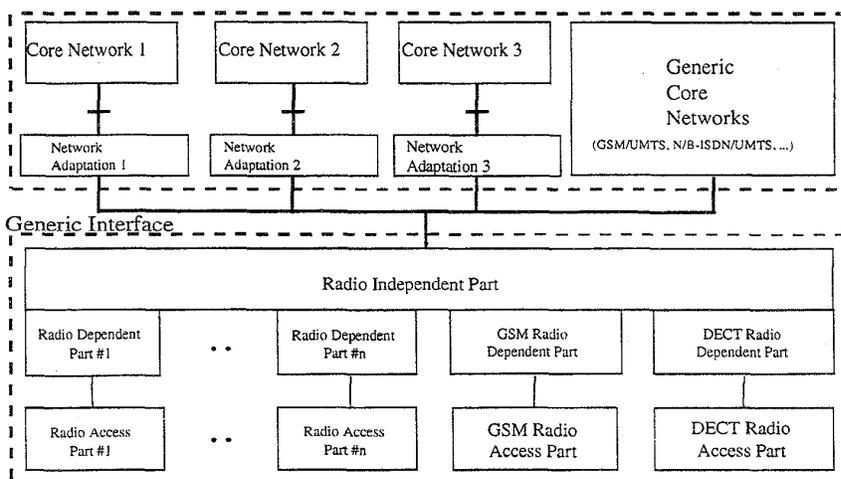


Figure 1. Fundamental RAINBOW System Concept.

III. RAINBOW TARGET ARCHITECTURE

The UMTS architecture adopted in RAINBOW is the generic UMTS architecture proposed by RACE project MONET and depicted in Figure 2 [6]. To support different levels of handover and roaming the architecture of the system is divided into core and access network components. The Cell Site Switch (CSS) and Local Exchange (LE) are considered respectively as the access and core network components of standard fixed network switching infrastructure. The Mobile Service Control Points (MSCPa/c) [7] are the nodes encompassing the intelligence of the system by supporting service control functions (i.e. mobility management, location determination, handover initiation) in the access and core network. The UMTS Mobility Server (UMSa/c) [8] is introduced in both the access and core network to cater for functions required by mobile networks which cannot be easily provided within a standard switching network (e.g. ATM). The UMS supports the mobility related transport features (handover, macro-diversity and related buffering functions, combining, multicasting, transcoding, rate adaptation, interworking functions) as well as the UMTS call control functions.

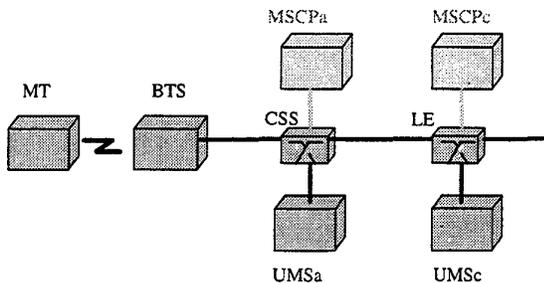


Figure 2. Generic UMTS Architecture.

Within RAINBOW this architecture is adopted and modified to develop a demonstrator.

IV. RAINBOW DEMONSTRATOR ARCHITECTURE

The proposed demonstrator architecture is illustrated in Figure 3. This demonstrator currently utilises four different radio interfaces. The GSM and DECT radio interfaces are supported to investigate the issues arising from using existing second generation commercial terminals (either standard or enhanced versions) to access a UMTS infrastructure. Two innovative radio access techniques (one TDMA and one CDMA based) are emulated in real-time to allow some of the advanced features of UMTS to be accessed. The demonstrator is also currently being extended to support a fifth radio interface, developed in the European ACTS project FRAMES [9].

The lower layers of the innovative radio access techniques are emulated in the subsystem known as Real Time Emulator (RTE). The RTE [10] behaves as the real system from the

viewpoint of the external entities that interface with it. Its function is not to reproduce all the elements of the transmission chain, but only to emulate the input/output behaviour provided by the portion of the demonstrator it represents.

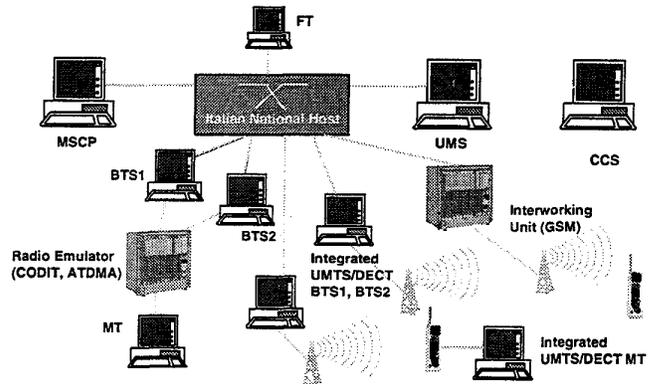


Figure 3. Implementation of the RAINBOW demonstrator.

The emulation model selected for the RTE is based on the Hidden Markov Model (HMM), which allows to reduce its complexity and operate in real time. For each radio access technique and each environment, the Markov chain is fed with a set of parameters that allows the RTE to behave as the real system from an input/output point of view. The radio emulator is made up of several boards interconnected by a back-plane bus (VME). The higher layers of third generation Mobile Stations (MS) and Base Transceiver Stations (BTS) are each implemented on a workstation.

In the case of second generation access techniques, the demonstrator uses actual GSM and DECT radio interfaces and equipment, enabling commercial terminals to access the UMTS infrastructure. For GSM, standard Mobile Terminals (MTs) and Base Transceiver Stations (BTSSs) are used, which are interworked to the UMTS access network. In the DECT case, UMTS enhanced MTs and BTSSs have been developed, which use the DECT radio lower layers but adopt the UMTS higher layers.

A Central Control Station (CCS) [11] is used for configuration set-up (booting process), debugging, monitoring, logging and post-processing purposes. It is connected to the RAINBOW demonstrator entities via separate Ethernet connections.

Workstations were selected as the hardware platform for implementing many of the nodes and components in the system. The UMS and MSCP are entirely implemented in workstations while the higher layer components of the third generation MT and BTS are also implemented on workstations. The vast majority of the protocols and functionality of the system is developed in software. The control software (i.e. state machine orientated logic) is developed in SDL while the transport software (i.e. data/packet processing) is developed in 'C'.

This demonstrator will be used to demonstrate various architectures and topology options and various functional allocation options using a flexible architecture which can be easily reconfigured. The generic architecture will also be evaluated in a joint demonstration with the FRAMES project, which provided the ETSI selected UMTS radio interface. The FRAMES radio interface will replace the RTE in the RAINBOW demonstrator. In the MT and BTS, the radio dependent parts will need to be adapted to the FRAMES radio interface.

V. DEMONSTRATIONS AND TRIALS

The generic UMTS demonstrator architecture will be used for trials which will demonstrate and evaluate the features of third generation mobile systems. A limited set of services, environments and radio access techniques have been selected to fully demonstrate the objectives of the project.

The services that will be demonstrated are speech, MPEG sequence and Internet access. The list of major features to be demonstrated are:

- *radio independence*: the demonstrations will aim to prove that the RAINBOW infrastructure can handle, using the same or similar functionality and protocols, different radio access schemes, taken as examples of possible innovative UMTS radio interfaces.
- *migration*: the demonstrations will aim to prove the backward compatibility of the RAINBOW network infrastructure with a, possibly, evolved version of GSM and DECT equipment.
- *flexibility of the architecture (topology)*: the demonstrations should prove that this architecture can be adapted to cope with the requirements of different UMTS environments.
- *flexibility of the functional allocation*: this feature will be demonstrated by considering different solutions for the allocation of functional entities to network elements.
- *handover using ATM transport*: the different ways in which handovers can be performed in an ATM transport and switching environment will be demonstrated.
- *macro-diversity*: the support of macrodiversity with a maximum size of the active set of 2 will be demonstrated for the CDMA based radio access technique.
- *flexible (a)symmetric services*: several services, such as speech, MPEG stream and Internet access, will be demonstrated.

For each of these features at least one demonstration scenario has been defined by grouping together services, environments,

radio access techniques, bearer types and the network entities required at the same time in the RAINBOW demonstrator. The scope of each scenario is either to test the call set-up or to demonstrate the innovative features.

The aim followed in the definition of the trials was that each trial had to represent a family, grouping together all those scenarios having a set of common characteristics. Each trial is characterised, with respect to the demonstrator configuration, by a detailed description and the expected results (both qualitative and quantitative) in terms of features to be proven. This has led to the definition of 25 trials, which can be furthermore grouped in four sets according to the architectural configuration of the demonstration they require.

VI. SYSTEM CONCEPT STUDIES

In parallel with the work on the demonstrator, conceptual studies are being conducted to further explore the project concepts and to evaluate alternative approaches. This work has been established to identify alternative choices taken by RAINBOW project and to consolidate standardisation contributions made by RAINBOW partners. The topics studied in more detail are:

- The split between *radio technology dependent/independent* functions in the access network. This allows to identify those functionality which are part of the common infrastructure for several radio access techniques, and those functionality which needs to be added/replaced when introducing a new radio technology. It could be stated that the RI/RD classification reflects radio efficiency and network efficiency requirements in the access and network parts respectively. An RI/RD identification criterion has recently been studied [1]. This criterion allows to embody slightly different functions (in principle radio dependent) in a single radio independent function accepting a given overhead to fulfil its characterisation according to the radio interface.
- RAINBOW assumes IN functional model for mobility management based on the work carried out in the standardisation bodies as ETSI and ITU. Mobility management includes location management and handover control. This study analyses the existing solutions to cover these issues: a comparison is made of MAP versus INAP protocols for service and mobility provision. This study intends to analyse which protocol is more suitable to fulfil the requirements of UMTS network.
- An assessment is made of the advantages/disadvantages of ATM transport (for voice, data, multimedia) compared with other transport techniques (e.g., n*64 kbps, Frame Relay, IP). The main advantages of the use of ATM in the fixed access and core network are its flexibility, efficiency and future proofness. The QoS requirements can be guaranteed in ATM, while this is not the case in Frame Relay or IP

networks. A possible disadvantage for the use of ATM in the short term is the relatively low installed base of ATM infrastructure.

- Due to the increase in the relevance of Internet, access to Internet services through UMTS will be investigated. The project will focus on the detailed analysis of the relationship between IP technology and UMTS functionality, integrated solutions providing Internet and circuit-switched services over the same UMTS access network, and the impact of the radio environment on Internet protocol.
- Only intra-LE mobility is within the scope of the RAINBOW demonstrator. However, as inter-LE handover is an essential component of the real UMTS, studies on the handover control procedures required to handover a call between different environments will be conducted. Some effort will also be devoted to analyse the type of handover needed in a multi-bearer connection for multimedia calls.

VII. CONCLUSIONS

This paper has described the generic UMTS approach of the RAINBOW project. The main objectives are to define a single generic interface between the UMTS access part and the core network(s) and to model the access architecture according to the principle of separating the radio access dependent part from the independent ones.

Based upon basic concepts of RAINBOW, a demonstrator is being built to integrate several radio access schemes: second generation as GSM and DECT and third generation radio access techniques based on TDMA and CDMA. Demonstrated services will include a basic speech service and new wideband services as MPEG streams and Internet access for bursty and asymmetric type of traffic.

Beside the development of the demonstrator, the main achievement of the concept study work has been the acceptance in ITU-R of the definition of a generic interface between radio access part and network part. This concept has been integrated in the ITU.MOD [5] recommendation which will serve as a basis for IMT-2000.

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