Overview of the ARROWS Project

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Abstract

The main objective of the IST project ARROWS (Advanced Radio Resource Management for Wireless Services) is to develop, simulate, evaluate and validate advanced Radio Resource Management algorithms and procedures for an optimal and efficient use of the radio resources provided by UTRA (Universal Terrestrial Radio Access) to enable high capacity for multiservice applications for both TDD and FDD modes. The Project aims also to achieve a specific QoS for packet switched services in the UTRA Network through the use and optimisation of QoS Management Functions. The advanced Radio Resource Management (RRM) and Quality of Service (QoS) management solutions developed by the Project will be able to support integrated voice and data services, including packet access, asymmetrical traffic and high bitrate (2Mbit/s) services for multimedia IP based applications. An intelligent management of the radio resources is essential in order to fulfil the required QoS. The Project also intends to demonstrate the benefits of the developed RRM algorithms by means of a multimedia IP based applications over a testbed.

I. Introduction

In any wireless system there is clearly a very scarce resource, i.e., the available bandwidth. On the other hand, 3G systems intend to provide to the end user a variety of services also with high bit rates while assuring the desired Quality of Service (QoS) and supporting high capacity. The only way to harmonise these contradictory points (scarce bandwidth and high capacity of a variety of services with stringent QoS) is to be able to develop and exploit an intelligent management of the available radio resources, specifically studied for the UMTS case. This is why the primary goal of the ARROWS Project is to develop advanced algorithms and procedures for UMTS traffic control and dynamic bandwidth management. In order to evaluate and optimise the Radio Resource Management (RRM) and QoS Management algorithms and procedures, ARROWS will develop both link level and system level simulators (for both UMTS FDD and TDD mode). Also a real-time operation HW/SW platform will be developed to demonstrate the advantages of the designed algorithms. The considered UMTS reference architecture is an all-IP based Core Network architecture, in line with the current status of the work in the relevant Standardisation fora. The aim of this architecture is to allow operators to deploy IP technology to deliver 3G services.

In the preliminary phase of the Project **[Magnani01]**& **[Berberana01],** the key classes of services of 3G systems have been identified, with specific reference to the packet switched services, and the relevant QoS parameters have been addressed in terms of packet delay, jitters, loses, etc. Also the mapping of the selected services onto radio bearers was investigated, taking into account the specific features of the UMTS system. Different cases for the interaction between UMTS QoS management procedures for data services and IP-based QoS management procedures were analysed, taking as a basis the alternatives specified by the 3GP.

II. Radio Resource Management Algorithms

The main goal of the Radio Resource Management (RRM) algorithms is to harmonize the capability to provide the requested Quality of Service (QOS) for all the active users in the network with the scarcity of the bandwidth available. In that sense, the following partial goals must be achieved:

- Maximize the Spectral Efficiency
- Prevent the network Congestion
- Satisfy the required QoS for each active user
- To maintain the signalling load as low as possible.

As it is depicted in figure 1, the RRM algorithm can have different inputs, for instance: traffic volume measurements, system load measurements, current resource allocation, UE capabilities and QoS requirements etc. From these inputs, the actions of the RRM algorithms can be to (re) arrange:

- the physical channel parameters (Canalisation code, physical channel type, transport channel type, etc…)
- the transport channel parameters (Transport Format and Transport Format Combination Set)
- Radio Bearer parameters (MC Logical channel multiplexing)

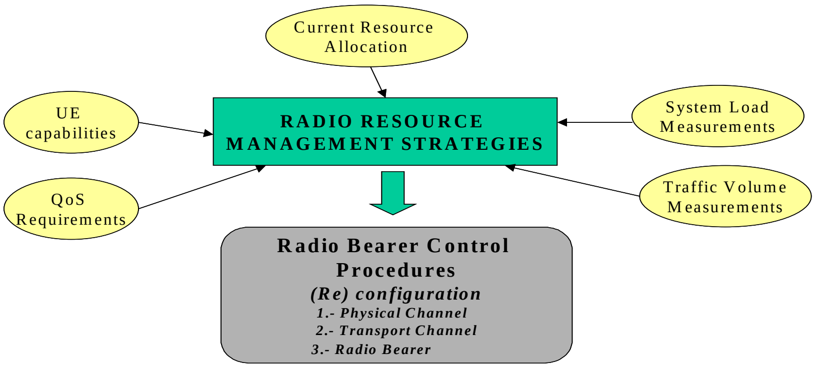

Figure 1.- RRM Control procedures

To achieve the mentioned objectives the following functional actions must be carried out:

- **Admission control** is in charge to accept the entrance of a new user in the network in light of the required QoS. In particular, the admission control functions allocated in the radio network controller must control requests for set-up/reconfiguration of radio resources. Arrows will develop proper algorithms taking into account following issues:
  - ❖ How to rearrange already assigned resources to handle a request to reconfiguration/reconfiguration.
  - ❖ Inter working with congestion control functions
  - ❖ Different admission control behaviour depending on QoS requirements, user profile and load state.

- **Congestion control** mechanisms should be devised to face situations in which the system has reached a congestion status and therefore the QoS guarantees are at risk due to the evolution of system dynamics (mobility aspects, increase in interference, etc.). To this end, Arrows will develop the following issues:
  - ❖ Design of criteria to decide that the system has reached the congestion status depending on different parameters such as performance and interference measurements.
  - ❖ Development of proper algorithms to counteract congestion by suitably combining different mechanisms such as limiting TFCS, inter-frequency handovers, etc.

- ***Transmission Parameter Management*** mechanisms are devoted to decide the suitable radio transmission parameters for each connection. It includes:
  - ❖ TFC selection.
  - ❖ Outer loop power control (SIRtarget definition)
  - ❖ Code management (downlink OVSF code selection)
  - ❖ Random access parameters management (for RACH and CPCH)
  - ❖ Time Slot selection for TDD case (Dynamic Channel Allocation)

More detailed information about the RRM mechanisms considered in the ARROWS project can be found in reference **[Agusti01].**

On the other hand, to develop and evaluate the proposed RRM algorithms the ARROWS project will use both Software Simulator and testbed Demostrators. In the next sections a brief description of their main characteristics is presented.

III. Simulators

With reference to the simulation models, they are envisaged, in a first step, for developing and testing innovative algorithms for RRM and QoS Management. In particular two sets of simulators are being developed, one set for UTRA/TDD and another one for UTRA/FDD. Each set consists of two simulators, link level simulator and system level simulator (see figure 2), each one addressing different views of the systems. The link level simulator has a resolution of one timeslot, both for TDD and FDD. It aims at simulating the air interface in environment. The Physical Layer (coding, spreading, rake receiver) is not simulated, but modelled in a simplified but accurate way. As a result of link level simulation, a characterization of the air interface behaviour (i.e., the interference) in a multicell, multi-user environment is obtained. Nevertheless, RRM and QoS Management algorithms are not analysed at this level. In fact, it is different problem from that of air interface characterization. So, a new tool -system level simulator- has been considered, in which a multicell, multi-user but also a multiservice environment with different algorithms is studied in a flexible way, in order to optimise the capacity. In this level, the previous results of the link level simulation characterizing the interference are employed for the air interface modelling, as this point is not addressed in this simulator. The combination of these two tools provides a complete platform for algorithm specification and test.

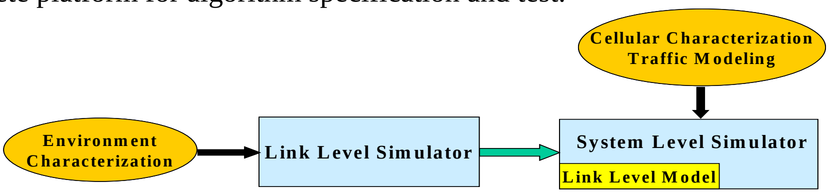

Figure 2. - Link and System level simulators.

The ultimate objective of simulation is to select a set of algorithms. These algorithms shall be able to manage the radio resources under some previously identified usage scenarios, so that the number of terminals using the air interface can be maximised while the quality contracted by each service utilization session can be assured. The simulation models are developed using the well-known OPNET simulation framework.

IV. The ARROWS Demonstrator

In order to demonstrate the advantages of the designed Radio Resource Management (RMM) algorithms, a real-time operation HW/SW platform including multimedia terminals, UMTS elements and IP connectivity, able to support real-time multimedia calls will be developed, **[Gelonch 01]**. The purpose of the UTRAN emulator is to reproduce the real behaviour of the single user with more accuracy than what would be obtained from the simulators (more suited for global systems performance analysis), but with less implementation complexity than the real system does. The philosophy used is to implement a "subset" of functionality, appropriate for emulation of the critical aspects related to QoS, rather then to realize a "one by one" representation of UTRAN specs. This approach leads to lighter implementation, suitable to assess new RRM algorithms easily, not considering parameters that do not relevant influence on them. That is, the ARROWS demonstrator is planed a flexible SW/HW platform that allows the experimental evaluation of new Radio Resource Management algorithms under controlled but realistic conditions. Then, the demonstrator will allow studying the impact on the system performance of a wide variety of advanced RRM algorithms, under different and selected traffic loads, with several service configurations and for different mobility characteristics. The demonstration of the selected strategies will be done by applying to the demonstrator some of the service mix scenarios used during the project simulation phase.

IV-I. Hardware Platform

Figure 3 shows the relevant blocks to consider in the testbed. Basically these blocks are the most relevant protocol layers defined for the radio and Iu interfaces. Both user and control transmission planes are included. RRM strategies to be implemented and analysed in the ARROWS project are located in the so-called RRC and RRC/RNSAP/RANAP modules represented in the Figure 3. These modules will interact with lower layers in order to configure and control them. Radio channel conditions will be obtained from a module (called Propagation scenario and Mobility conditions in the Figure 3) devoted to characterise the propagation environment, location of the Node-B cells and mobility pattern associated to the simulated mobile terminals. Finally, two modules named NAS Driver (Non-Access Stratum Driver) are included to provide the Access Stratum services to the Non-Access Stratum part of UMTS both in the terminal and in the UMTS Core Network Gateway. In particular, these NAS Drivers should translate application or higher layer requirements to UTRAN and also provide the transmission capabilities to be used for the application as well as Mobility Management and Call Control functionalities.

Mobility Management refers to the Mobility Management sub-layer, which is responsible for tracking the location of the UE. The ARROWS demonstrator Mobility Management software performs the decoding and encoding of Mobility Management messages, and runs the State Machine for elementary procedures for each Mobility Management context, handling Location Updates, Attach, Detach, Authentication/Ciphering, Identification and Paging. This entity receives incoming Mobility Management messages, performs error checking on the parameters and also error recovery as per specifications.

The Call control sub-layer is responsible for functions like call set-up, call release, call modification, supplementary services, etc., for the MS in the circuit switched mode. The ARROWS Call Control software performs the encoding, decoding, parsing of these Call Control messages and runs the state machine for elementary procedures for each Call Control context like call set-up, call release.

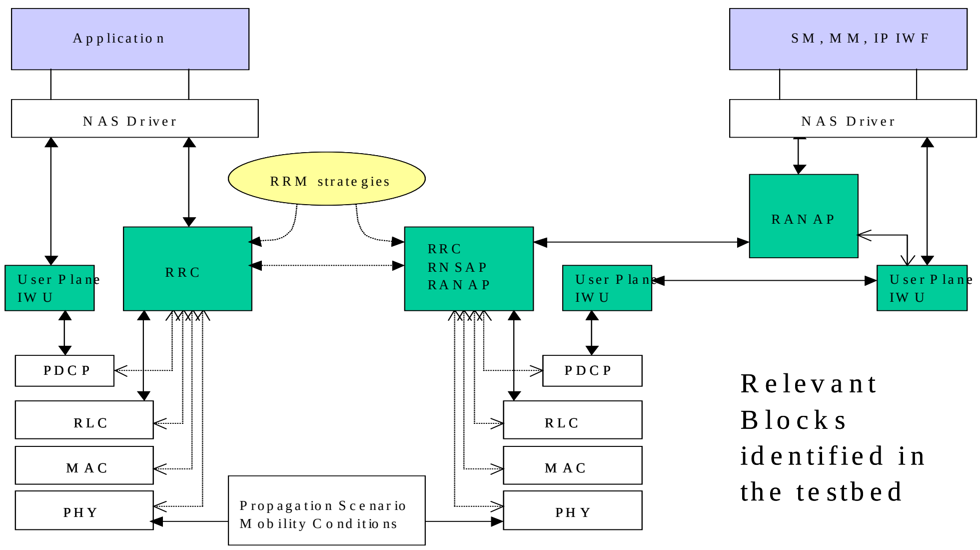

Figure 3. - UMTS functionalities included in the ARROWS testbed.

From the hardware implementation point of view, basically, three PC's are used to emulate the UTRAN radio access. The first one is used for emulating the multimedia terminal, which takes into account the IP based multimedia applications, the terminal non-access stratum functions, emulated by means of an appropriate Inter-Working Function (IWF), as well as the terminal part of the Radio Resource Controller (RRC). The second PC emulates the lower layers of the UTRAN access network, that is the PDCP, RLC/MAC and Physical layers, for both mobile and UTRAN network. This emulation takes into consideration the radio environment and traffic conditions of the emulated system. Moreover, this second PC also addresses the emulation of the Radio Resource Management RRM) functions as well as the RANAP and RNSAP protocols used for signalling purposes through the Iu and Iur interfaces. It is important to emphasise at this point that the proposed architecture is flexible enough to allow locating these RRM, RANAP & RSANP functions in a new PC, if their computing load is high enough to prevent the real time operator of the Demonstrator. Finally, a third PC is used to emulate the main functionalities of the UTRAN Core Network

The interconnection between UMTS Core Network PC and the Application Server PC will be done by means of an Ipv6 network that emulates the Internet cloud. In particular, for emulating the behaviour of the Internet Network in a controlled way, the ARROWS project will use the internal Intranet of TELEFONICA. In this way, it will be possible to study the behaviour of the proposed algorithms in a real but controlled environment.

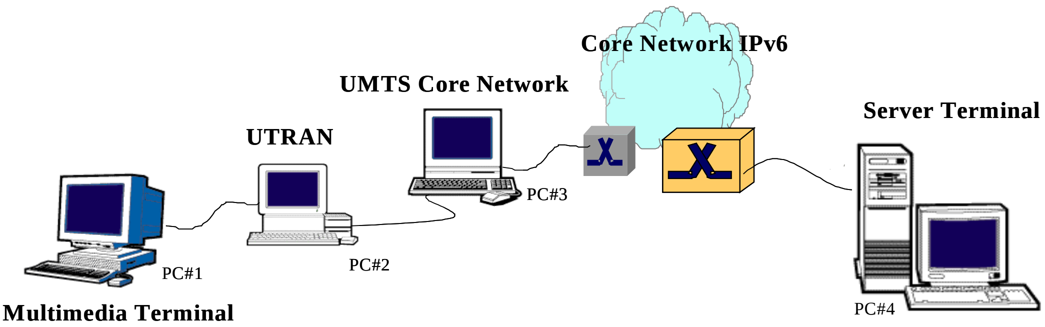

Figure 4.- Hardware architecture for the ARROWS testbed

Moreover, a Central Control Unit (CCU) responsible for the configuration of the other modules, as well as to support the trials of the Test and Validation activity in terms of measurements collection, production of reports and display of the results, is also included.

IV-II. Software Architecture

The UMTS functionalities retained in the ARROWS projects should be organised and distributed among the hardware platforms of the testbed. We have defined what we call modules that are basically pieces of software devoted to perform a set of the functionalities of the ARROWS testbed. All the modules follow a common specific programming philosophy (i.e. mono-task approach, common procedures to communicate with each other, etc.) and interfaces between them have been perfectly delimited. In order to hidden the time constrain granularity (10 milliseconds frame) to the functionalities performed in the modules a Communications Manager has been introduced. This module will concentrate all the communication functions required between modules and could provide a common framework to all the modules in order to access some specific operating system resources. Modules will use this layer to write/read messages to each other without worrying about the mechanism used to transfer the information and without knowing if the origin/target module is in the same machine or not

The Operating System selected is Linux. There exist different configurations of the operating system to achieve the time constrains requirements. The first one is the standard Linux running over the hardware platform using a optimised kernel for this precise hardware platform eliminating any useless modules for the application, the second one corresponds to a mixture of RED Linux kernel modification together with a set of Loadable Kernel Modules (LKM) to improve real-time behaviour and the third one corresponds to the RTAI (Real Time Application Interface) utilisation approach. With the first approach all the useful system calls available in Linux can be used without any special restriction. The second approach requires a more accurate management of process communication and the third one also requires an accurate partition of tasks. Obviously the most interesting option because of its simplicity is the first one, but probably the timing requirements cannot be achieved. In this case a migration to the second approach will be done.

IV-III. Applications

The applications main purpose is to let the user of an all-IP UMTS terminal to evaluate subjectively the adequateness of the ARROWS resource management solutions. In this approach, besides measuring the quality (delay and reliability) that the IP packets receive from the Radio Access Bearers (RAB) they use, applications will also handle these packets so that a degrading transport service can be felt by user as, for instance, degrading audio or video. Four main services were found representative for ARROWS: email, Web browsing, video streaming and videoconference. The applications implementing these services are required to execute in a Linux based UMTS terminal and to be based in widely used applications that, in turn, must be open source so that the ARROWS new functional blocks can be easily accommodated. Email and Web browsing are based on Mozilla. Video streaming and videoconference are based on Mbone tools (VIC and VAT).

Under the conditions defined by ARROWS, applications must expect end-to-end quality of the transport service. The IETF Integrated Services approach, along with RSVP, was selected as the solution providing QoS at the IP level. The major impact of this aspect is the modification of the applications selected. Nowadays, ports of Mozilla and Mbone tools can already be found for RSVP or IPv6, but not for both simultaneously. Another aspect addressed is the mapping of IP flows (and the QoS they demand) into QoS characterised RAB/ PDP contexts. During the establishment of a new QoS IP flow, RSVP at the terminal side, needs to establish one QoS characterised RAB. New functional blocks are required to support this mapping. At the control plane, RSVP needs to be extended towards the establishment and termination of QoS RABs. At the user plane, IP packets need to be classified into flows and made compliant to the QoS negotiated. Linux facilities for QoS IP are currently being used to implement the user plane functions. Examples of these facilities are the u32 and rsvp classifiers, the CBQ (Class Based Queueing) and the Token Buckets.

V. Trials and Envisaged Results

Once both the ARROWS Simulators and Demonstrator will be ready for trials, and after their validation, an exhaustive measurement campaign will be carried out. This campaign will be performed considering the service and system requirements defined in **[Magnani 01]** and **[Berberana 01]**. In particular this activity contemplates the evaluation of the Radio Resource Management algorithms in terms of aspects such as:

- QoS monitoring considering throughput, delay, level of user acceptance etc.
- Performance comparison of different Radio Resource Management strategies. Impact of the call-admission and scheduling algorithms
- Impact of the scenario characteristics (mobility, propagation characteristics, traffic density, etc.)
- Influence of the H.O. procedures in the grade of service provided

This validation procedure will be used to provide feedback to the RRM algorithms developed in order to tune them for improving their performance.

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