European Research in End-to-End Reconfigurability

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ABSTRACT

The End-to-End Reconfigurability (E²R) research [1], aims at bringing the full benefits of the valuable diversity within the radio eco-space, composed of a wide range of systems such as cellular, wireless local area and broadcast. The key objective of E²R is to devise, develop and trial architectural design of reconfigurable devices and supporting system functions to offer an expanded set of operational choices to the users, applications and service providers, operators, regulators in the context of heterogeneous mobile radio systems. Innovative research, development and proof of concept is sought over six years in an end-to-end aspect, stretching from user device all the way up to Internet protocol, and services, and in reconfigurability support, intrinsic functionalities such as management and control, download support, spectrum management, regulatory framework and business models. This paper presents the E²R project research approach and the main fields of investigations across the different workpackages in the first 2-year phase of the project that started in January 2004.

1. INTRODUCTION

Reconfigurable equipments and systems will generally provide much higher flexibility, scalability, configurability and interoperability than currently existing mobile communications systems. Reconfiguration will stretch over all OSI layers, on open platforms where the complete protocol stack will be subject to reconfiguration. To achieve the E²R project ambitions three major challenges were identified:

- Transforming embedded flexibility into end-to-end reconfigurability,
- Capturing the newly enabled functionalities of E²R into valuable benefits,
- Finding right balance between integrated versus distributed approaches.

These axes are driving the definition of an architecture and design of reconfigurable and flexible system concepts that enable seamless and transparent communication across these heterogeneous environments. An active cooperation between end-users, operators, service providers and new comers is needed to firm up the definition of the most appropriate distribution of intelligence between reconfigurable terminals and networks. In order to drive the E²R research work to success, the following approach is adopted over the whole duration of the project (initially planned for 6 years):

- Capture compelling use cases, establish a model architecture of the E²R system and define an overall end-to-end reconfiguration framework,
- Design and prove the concepts of technical solutions to implement reconfigurability in all the layers of an end-to-end wireless communications system,
- Develop a flexible, modular and evolutionary proof of concept environment for validation purposes,
- Disseminate, contribute to related standardisation bodies, organize training sessions and ensure worldwide recognition of the E²R research and its results.

The E²R consortium gathers 28 participants over 10 countries, from highly representative manufacturers, operators, academics and regulators within the mobile radio communications industry, and has an accurate understanding of the state of the art from various projects and bodies. These previous initiatives of course motivated the E²R project, but today's ambitions go further to the end-to-end aspect and reconfigurability support aiming at a truly integrated, flexible, and intelligent heterogeneous mobile communications environment.

This paper is presenting the E²R project, introducing in Section 2 the state of the art (SOTA) on SDR and Reconfigurability, the overall research approach in Section 3, the architectural visions in Section 4 and the project structure and research fields in Section 5. Finally

Section 6 is presenting the main expected impacts of the E²R developments.

II. STATE OF THE ART ON RECONFIGURABILITY

Since the late nineteen eighties, several initiatives, projects and project frameworks pursuing SDR and reconfigurability research have been initiated (SDR Forum, MVCE, EU ACTS, ESPRIT, IST Projects [2]…). While early efforts concentrated on the facilitation of multimode terminals and base stations and had a clear military focus, later initiatives discovered the importance of Software Definable Equipment for the commercial arena. Early initiatives aimed for the 'cheap' platform wherein Velcro styles multiple terminals were integrated together implementing as many air interfaces. Terminals that are "in-as-much-as-possible" defined in software followed this. A very strong heritage in reconfigurability was gained through former FP5 IST projects [3] like TRUST, SCOUT, MOBIVAS and CAST where expertise in the functions offered to user terminals, applications and services was capitalized. Each of these projects concentrated on a variety of different technical aspects such as terminals, value-added service provision, enabling technologies, applications, reconfigurable devices, network provisions, security, and proof of concept of reconfigurability.

The E²R project research scope is set to create opportunities across entire value chain. The provision of protocols stacks, applications and services which are flexible, sharable and adaptable in a heterogeneous radio network environment will bridge the gap between hardware/software technologies on one side and applications and services on the other side.

III. E²R RESEARCH APPROACH

The approach adopted by the E²R project research is depicted in Figure 1, wherein three main components are depicted:

(1) *E²R System Research, Business Path and Technology Roadmaps* is focusing towards compelling scenarios and user requirements of the Radio Eco-System, building on FP5 projects and interacting with other ongoing research initiatives. In addition, the corresponding roadmap of the identified key enabling technologies within an overall architecture, re-enforced by regulatory rules, will help to set out a clear path of End-to-End reconfigurability within the Radio Eco-Space,

(2) *Core Technology Research, Design and Proof of Concept* constitutes another area of work within the E²R research charter. Research work encompasses the technologies needed to transform embedded flexibility into end-to-end reconfigurability, while finding the right balance between integrated versus distributed approaches. This would yield the optimization of resources (spectrum, radio, network and equipment) and reconfiguration functions (discovery, negotiations, control and triggering),

(3) *E²R Proof of Concept Evolutionary Platform* enables the validation of the charter of E²R research as a whole, thus establishing the proof of concept of the overall system within the Radio Eco-Space.

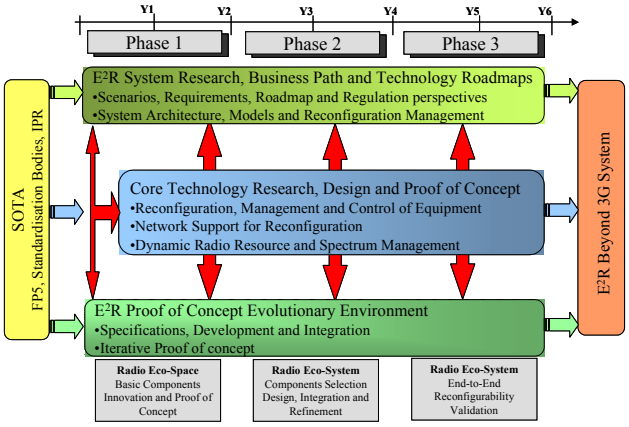

Figure 1: E²R Research Approach

IV. E²R ARCHITECTURAL PERSPECTIVES

Referring to the state of the art and more specifically to FP5 projects on heterogeneous access network environment, huge amount of work has been done on the inter-working and interoperability at the networking layer within an all-IP based framework as depicted in Figure 2. Moreover, within this pool of projects there are also some projects, which have addressed:

- Interoperability issues at the networking layer,
- Reconfigurability issues linked to agile radio spectrum usage with assumption of either multimode or reconfigurable terminals,
- Versatility of terminal and network enabling new services and new billing schemes.

In parallel, there have been also several projects, such as TRUST, SCOUT, MOBIVAS, CAST… addressing reconfigurability issues from SDR enabling technologies (radio modem) and also initial software architectures for terminals and their support for reconfiguration from the network. In medium term architecture, it is envisaged that several capabilities in dynamically reconfiguring the radio access systems will be amenable. The radio access network topology could be dynamically reconfigured with equipment - such as reconfigurable terminals, base stations/Node Bs, gateways - and related reconfiguration support entities in the core network and internet/intranet.

E²R project expects that the topology presented in Figure 3 will correspond to the transition from multi-mode to smart reconfigurable equipments and related reconfiguration support. Several extrinsic important aspects to this vision are being investigated, such as dynamic spectrum allocation, regulatory issues, and business models.

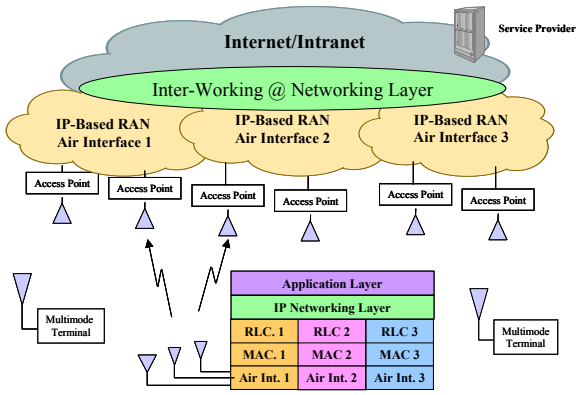

Figure 2: Short Term Architectural Perspective

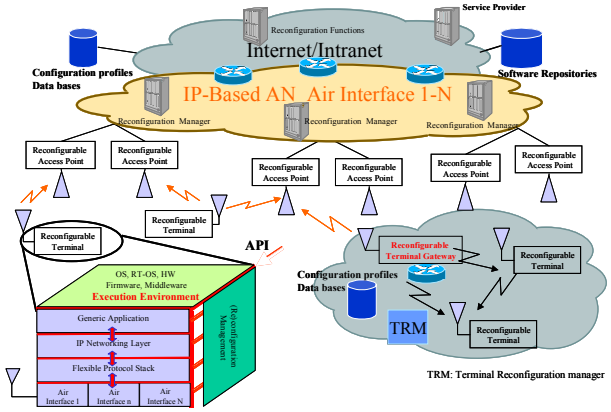

Figure 3: E²R Architectural Vision

V. E²R PROJECT STRUCTURE

The E²R Project is structured in six technical workpackages (WP), corresponding to six main research fields. Two additional workpackages are dedicated to project management and dissemination, standardisation and training:

- "E²R System Research" (WP1) aims to build and develop the system research for end-to-end reconfigurability, with the aim of aggregating the technical, business and regulatory visions from the different actors of the project and this, across the project WPs. The technical research is addressing the E²R scenarios and requirements, the E²R business path elaboration and road-map, the overall E²R architectures, reference models and reconfigurability management, and finally the E²R regulatory perspectives,
- "Equipment Management" (WP2) addresses the reconfiguration issues related to equipment, i.e. terminals and base-stations/access-points, which are capable of being reconfigured securely, reliably and seamlessly (Figure 4). Initially the focus is on the terminal centric development of the local (to the equipment) reconfiguration management, and the development of extensions for execution environments to provide the basic mechanisms supporting the needed reconfiguration capabilities for dynamic adaptation and secure/reliable operation. As progress in the aforementioned topics will be made, deeper integration and exploitation of reconfigurable and flexible protocol stacks will be pursued,

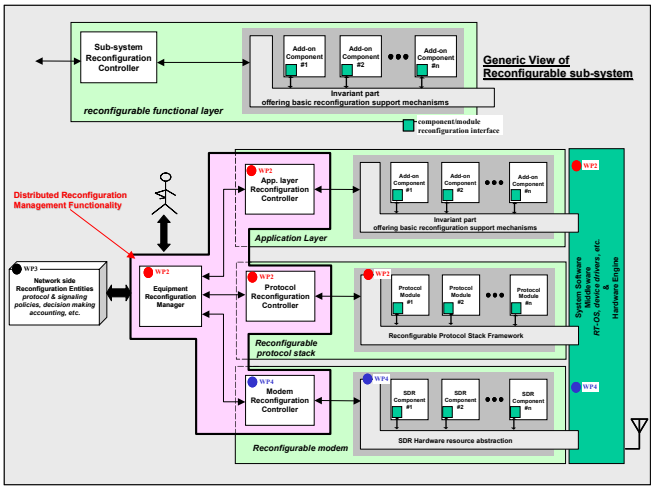

Figure 4: Equipment Management Research

- "Network Support for Reconfiguration" (WP3) concentrates on the support of reconfigurability of network entities and terminals by network functions for secure download, reconfiguration management and validation. This research is working closely with the research on equipment management to define a suitable reconfiguration management plane as another control plane stretching across users, services, networks and terminals. Concepts for end-to-end reconfigurations and its impact on end-user service provision management are developed and applied for the design of heterogeneous coupled multi-standard networks based on reconfigurable network elements (Figure 5). This will result in new architectures and signalling for network reconfiguration concepts and negotiations and trading services are partly validated. Reconfiguration

support architectures and mechanisms will be developed supporting security and safety concepts.

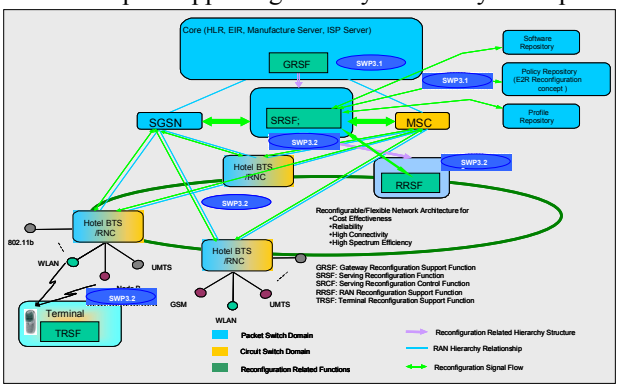

Figure 5: Network Support Research

- "Radio Modem Reconfigurability" (WP4) focuses on the development of local configuration control concepts and mechanisms for the physical layer resources, reconfiguration strategies and the development of the reconfigurable physical resources (Figure 6). This research is working closely with the research on equipment management to define the partitioning of configuration management and control function and their interfaces and capabilities towards the physical layer resources. The modem research will provide physical layer related reconfiguration capability information to the configuration management entity and will be responsible for reliable reconfiguration processes. Hardware architectural elements as well as operational software aspects will be considered. A common terminal and base station approach will be targeted, creating synergies between both as far as possible, nevertheless considering the need for specific variants due to different requirements,

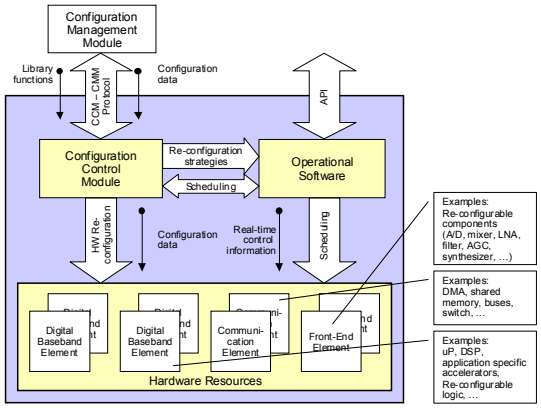

Figure 6: Radio Modem Reconfigurability Research

- "Evolution of Radio Resource and Spectrum Management" (WP5) aims at developing the mechanisms for dynamic allocation of radio resources. This requires research into combining reconfigurable technology and support structures (from pure terminal perspectives, e.g. Cognitive Radio, to network oriented perspectives, e.g. JRRM and flexible network planning) with novel resource management techniques that are capable to control the complete spectrum in a local area. Deployment of such technology requires a new approach to regulation and economics of spectrum. Hence the second major aim of this research is to develop, based on the results of the system research (which will be in tight collaboration with national regulatory bodies and operators), new options and mechanisms to enable more progressive spectrum regulation and market-based approaches, and to facilitate a more efficient resource usage (Figure 7),

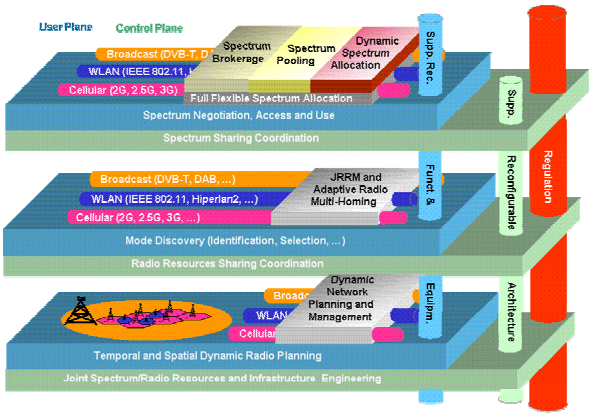

Figure 7: ARRM/ASM Research

- "E²R Proof of Concept Evolutionary Environment" (WP6) aims at integrating the results of the different E²R research fields, and validating the vision of the reconfigurability developed in the overall E²R project. The main expected outcome of WP6 is the development of an experimental proof of concept environment capable of demonstrating end-to-end reconfigurability features in an all-IP network architecture, where different radio access technologies are available (Figure 8). This flexible, scalable, and evolutionary environment will allow the validation of the system scenarios, in coordination with the rest of the WPs research.

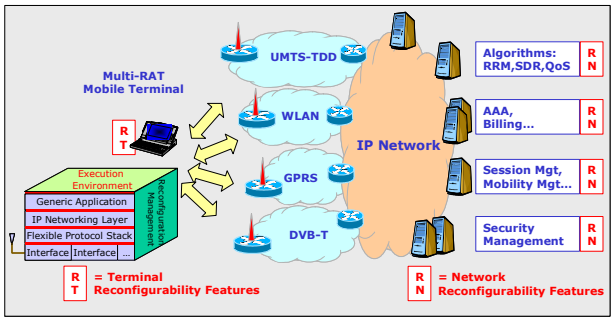

Figure 8: E²R Prototyping Environment

VI. EXPECTED RESULTS AND IMPACT

The advent of End-to-End reconfigurability will influence the structure of the industry, creating new markets and new employment opportunities, notably in the area of content creation, new services and service/content creation tools but also in wireless information technology administration (WIT). Thus impact on standards, industry and users can be identified as follows:

- Efficient, advanced & flexible end-user service provision. The reconfigurability management of the network and systems will be also serving the optimal provision of end-user services and applications. The aspect of end-to-end reconfigurability encompasses the tailoring of application and service provision to user preferences and profile, taking also into consideration the network/terminal capabilities, configuration and profile, as well as service/charging/security profiles and related context,
- Efficient spectrum, radio and equipment resources utilization. With close collaboration with the Regulations authorities and local regulators, enabling technologies for flexible spectrum resources and the associated security issues will be devised. The aftermaths of such a regulation would be to simplify the process of optimizing resource usage, in order to provide equipments and systems capable to operate in a situation where grant is given to private users to access to a portion of bandwidth that would be unlicensed,
- Reduced cost to upgrade fielded systems. The communications standard used by a device will be field upgradeable through software downloads e.g. over the air. The economics of expensive infrastructure systems will be improved, since the cost of the hardware and deployment can now be amortized over a longer lifetime,
- Multi-standard platforms. A single hardware platform will be shared dynamically amongst multiple applications, with channel resources shifting among different communications standards as the load shifts. This will significantly reduce the cost of infrastructure to support a mixture of legacy and newly deployed fixed-standard radio devices,
- Better support for customized solutions. A developer will be able to modify the communications standard of a device without investing in a new hardware design. Users who need relatively small volumes of devices, for whom the cost of custom hardware is prohibitive, will gain the ability to improve their operations with devices optimized to their special needs,
- Reduced standards risk. An operator will deploy expensive infrastructure or large numbers of mobile devices without locking in the communications standard that will be used. This insulates the operator from potential changes in the standard and from market uncertainty.

VII. CONCLUSIONS

This paper has presented the E²R project, partly funded by the European Commission, and the main fields of research to be investigated over its whole duration. The E²R project aims at bringing full benefits of the radio eco-space diversity making heterogeneous environments transparent, flexible and intelligent. The ultimate vision of the E²R research is to reach an all-IP fully integrated networks with reconfigurable equipments and associated discovery, control and management mechanisms. Therefore, research in the end-to-end aspect (stretching from user device all the way up to internet protocol and services) and in reconfigurability support (intrinsic functionalities such as management and control, download support, spectrum, regulatory issues and business models) is required to realize this vision.

Benefits of end-to-end reconfigurability could be enabled if and only if the reconfigurability is considered simultaneously at all layers, for all involved actors. Indeed, the most advanced reconfigurable equipments will bring very limited advanced features if the network or the services are not designed to support them. Similarly, reconfigurable networks will bring limited advantages if designed without considering reconfigurable equipment capabilities. E²R is seen by many actors of the wireless industry as a core technology to enable the full potential of beyond 3G systems. It has the potential to revolutionize wireless just as the PC revolutionized computing.

ACKNOWLEDGMENT

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