END-TO-END RECONFIGURABILITY II: TOWARDS SEAMLESS EXPERIENCE

Didier Bourse, Karim El-Khazen, David Bateman (Motorola Labs, France)
Marylin Arndt (France Telecom, France)
Nancy Alonistioti (University of Athens, Greece)
Klaus Moessner (University of Surrey, UK)
Eric Nicollet (Thales Communications, France)
Enrico Buracchini (Telecom Italia Lab, Italy)
Panagiotis Demestichas (University of Piraeus, Greece)

ABSTRACT

The End-to-End Reconfigurability (E^2R) project aims at realising the full benefits of the diversity within the radio eco-space, composed of wide range of systems such as cellular, fixed, wireless local area and broadcast. The key objective of the E^2R project is to devise, develop, trial and showcase architectural design of reconfigurable devices and supporting system functions to offer an extensive set of operational choices to the users, application and service providers, operators, and regulators in the context of heterogeneous systems. Building on the successful developments of the first phase, E^2R II will demonstrate and validate technologies that enable a true seamless experience based on reconfigurable heterogeneous systems. The project will pursue research into the most promising directions towards removing walls (current technical and regulatory limitations) and building bridges (technical) in order to facilitate the vision of true end-to-end connectivity. This paper presents the E^2R II research project ambitions as well as each of the technical areas that will be tackled.

1. INTRODUCTION

Within the End-to-End Reconfigurability (E^2R) [1], innovative research, development and proof of concept are sought 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. End-to-end reconfigurability systems will provide common platforms and associated execution environments for multiple air interfaces, protocols and applications, which will yield to scalable and reconfigurable infrastructure that optimize resource usage, increased network and equipment capability and versatility by software modifications. The users will benefit from these capabilities by reaching the required service at times and places when and where needed at affordable cost.

Launched within the 6th Framework Programme (FP6) [2] of the European Commission (EC), the End-to-End Reconfigurability (E^2R) project is undertaking a long-term 6-year lifetime with ultimate goals of research, design and proof of concept of reconfigurability and is articulated in three major phases:

- Phase 1 (E^2R I) (2004-05) is a definition phase identifying stumbling blocks, consolidating the heritage of former work, and further developing concepts and solutions. The brand-new concept of this first phase was to bring together some key independent research activities initiated in former EC 5th Framework Programme (FP5) and to assess the feasibility of an integrated system for the support and provision of reconfigurability,
- Phase 2 (E^2R II) (2006-07) is concentrating on most promising solutions identified in E^2R I and will assess any emerging new technologies, while in parallel evolving towards integrated framework,
- Phase 3 (2008-2009) will complete the proof of concept evolutionary environment by demonstrating that reconfigurability could be implemented. Future research themes will be prepared to help the European Research Area (ERA) to pursue his research within the 7th Framework Programme (FP7).

This project is including major key European players in the domain of Reconfigurability, Software Defined Radio and Cognitive Radio, who have an accurate understanding of the state-of-the-art from various projects and bodies [3]. These previous initiatives of course motivated the E^2R project, but today's ambitions go further to the end-to-end aspect and reconfigurability support aiming at providing the seamless experience to the users, enabled by the end-to-end reconfigurability. This paper is presenting the E^2R II research project ambitions in Section 2 as well as each of the technical areas that will be tackled from Section 3 to Section 10. Finally, in Section 11, a short summary concludes the paper.

2. E^{2}R II AMBITIONS

Building on the successful development of the project, the next steps of E^{2}R would demonstrate technologies that enable a true seamless experience based on reconfigurable heterogeneous systems. Next steps would pursue research in the most promising directions towards removing walls (current technical and regulatory limitations) and building bridges (technical) in order to facilitate the development of the true end-to-end connectivity.

As already expressed, the charter of E^{2}R II project 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, manufacturers, and regulators in the context of heterogeneous mobile radio systems.

The approach adopted by the consortium in E^{2}R II project is depicted in Figure 1. The E^{2}R II is structured around two main research components, building on E^{2}R I and other FP6 projects and initiatives, and targeting the E^{2}R Beyond 3G System enabling the seamless experience to the users:

- "E^{2}R II Research Challenges" will focus on progressing the challenges that the E^{2}R project is addressing, such as enabling the sustainable business development of reconfigurable systems, the end-to-end reconfiguration management and control architectural framework, the efficiency enhancement of radio resource and spectrum, and the end-to-end seamless connectivity as well as building the European reference prototyping environment for end-to-end reconfigurable systems and solutions.
- "E^{2}R II Research Domain Skills" will bring the expertise within the cognitive networks, reconfigurable equipment and proof-of-concept research domains, serving the different challenges, and targeting standardisation and regulatory contributions.
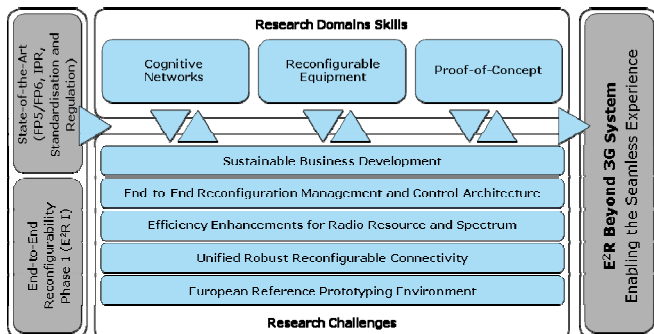
As initially planned, synchronisation points with time intervals (during the 6-year lifetime) between the different components will establish the convergence to a set of common functionalities to be deployed on the E^{2}R Beyond 3G System. The adopted approach for E^{2}R II is emphasising the synchronisations between the different research areas of the project. At the beginning of the E^{2}R II project, both research components of the proposed approach will assimilate the technical information in the different areas in order to define inter-dependencies between the constituent technical areas within the radio eco-space. In addition, it will help define the yet non-researched technical areas, which are appropriate to the development of the E^{2}R charter.

The E^{2}R II project will contribute to the specification and implementation of reconfiguration management functionality devised to operate end-to-end and to account for multiple actors, diverse Radio Access Technologies (RAT), equipment capabilities, and network infrastructures, driven by service-specific and resource-aware strategies, seamless user experience. This E^{2}R II approach results in a natural cycle of continuous technology watch and short-medium-long term conceptual research while guaranteeing the development and delivery of enabling technologies realising the Beyond 3G Seamless Experience.

In order to fully satisfy the objectives, the project structure of E^{2}R II has been devised as depicted in Figure 2, based on a clear matricial organisation of the E^{2}R II in challenges ("horizontal WPs") and domains skills ("verticals WPs). The intention in building the new structure of E^{2}R II was to develop a tighter integration of the various research tracks (WPs) and a stronger interoperation between the different technical and technological facilitators under investigation in E^{2}R.
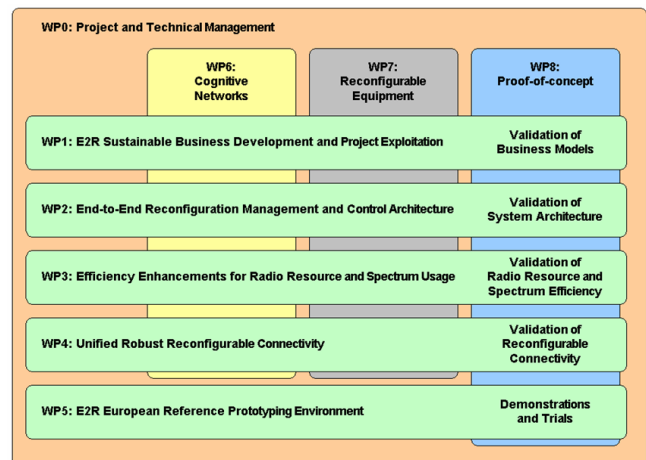

Fig. 1: E²R II Research Components

Fig. 2: E²R II Project Structure

The proposed structure will enable the achievements of the following objectives of E^{2}R II:

1. Enabling sustainable business development of reconfigurable systems in a multi-access / multi-owner environment,
2. Enabling end-to-end reconfiguration management and control architecture and devising optimal split of intelligence between network elements and end-user equipment,
3. Enabling efficiency enhancements for radio resource and spectrum management,
4. Enabling unified stable, secure and reliable reconfigurable connectivity in a multi-access / multi-owner situation,
5. Building the European reference prototyping environment for end-to-end reconfigurable systems and solutions.

The main challenges of E^{2}R II will be to develop and demonstrate solutions for interoperability, scalability and flexibility, enabling efficient support of ubiquitous access, pervasive services and dynamic resources management in the radio environment of the future. These research areas will drive the definition of system reference models and the distributed demonstration of resource management across multiple wireless/wireline access networks and multiple operators, with support of legacy architectures, thereby enabling seamless and transparent communication across these heterogeneous environments. Each of the eight technical workpackages is briefly described in the following paragraphs.

3. E2R SUSTAINABLE BUSINESS DEVELOPMENT AND PROJECT EXPLOITATION

WP1 will develop and analyze business models and roadmaps for end-to-end reconfigurable systems. It will aim to match these with a clear understanding of the different stakeholders including the user at the centre, as well as the business value of reconfigurability solutions. Regulatory enablers and constraints will be analyzed and the E^{2}R I regulatory framework proposal will be furthered to be capable of supporting reconfigurable systems and to allow their deployment as well as to allow a more flexible use of spectrum to gain higher efficiency. The WP1 will set the parameters for the validation of the E^{2}R business models. Next to elaborating exploitation and dissemination plans, the WP1 will also further build and implement coordinated standardisation and regulation plans.
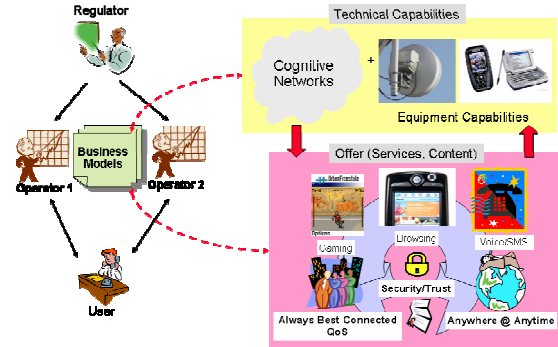

Fig. 6: E²R II WP1 Technical Scope

4. END-TO-END RECONFIGURATION MANAGEMENT AND CONTROL ARCHITECTURE

WP2 aims at devising end-to-end reconfiguration management and control architecture together with optimal split of intelligence and functionalities between cognitive network elements and reconfigurable end-user equipment. Building on the work of E^{2}R I, WP2 will define and validate the end-to-end system architecture, evolving the system capabilities and designating logical entities responsible for accomplishing such capabilities. The derived system architecture will be mapped to legacy as well as to evolved physical configurations, yielding the network architecture that presents optimal split of intelligence and functionalities between network elements and end-user equipment. Specific end-to-end mobility and Quality of Service (QoS) protocols and mechanisms will be explored for achieving software downloads and flexible traffic exchange, as well as component-based techniques on the reconfigurable equipment side. The developed protocols and mechanisms will exploit emerging concepts of autonomous systems as an evolutionary step from reconfigurable towards cognitive communications, characterized by self-learning, self-configuring, and self-managing attributes.
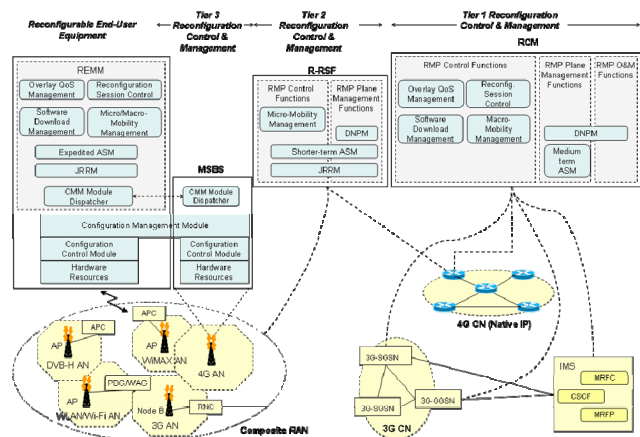

Fig. 7: E²R II WP2 Technical Scope

5. EFFICIENCY ENHANCEMENTS FOR RADIO RESOURCE AND SPECTRUM

WP3 aims for further enabling and broadening the range of mechanisms available to increase the efficiency of radio resource usage. The theoretical tools, algorithms and mechanisms that will be investigated include the whole range from reconfigurability enabled service independent allocation of spectrum to joint radio resource management in single and multi-operator scenarios with heterogeneous access systems. This contribution will be made in varying forms as one of the drivers for the development of sensing and detection mechanisms for cognitive resource allocation. A spectrum occupancy measurements campaign at different sites of the 2006 FIFA World Cup Germany^{TM} will be undertaken before, during and after events. The findings and analysis of measurements will form the basis for algorithms development.
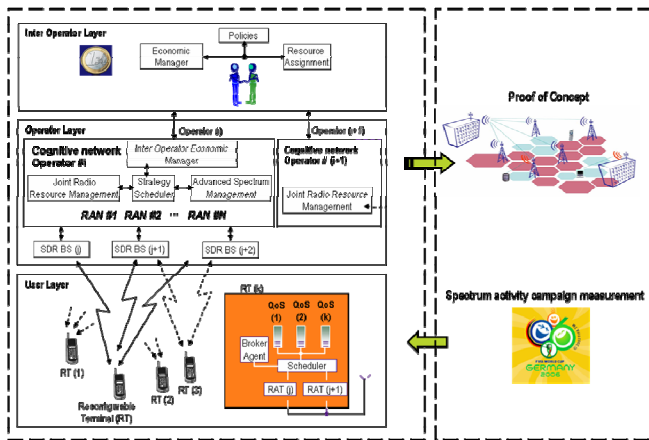

Fig. 8: E²R II WP3 Technical Scope

6. UNIFIED ROBUST RECONFIGURABLE CONNECTIVITY

WP4 enables robust (stable, secure, reliable) end-to-end connectivity in a multi-access/multi-owner environment. The key for accomplishing this objective is a unified management and control framework, which takes into account the interworking with distributed functionalities across the complete system emphasizing support for cognitive networks. Trade-offs amongst power efficiency, timing constraints and resource sharing have to be determined, which result in a cost function optimisation of the mentioned factors. Dependencies for sequencing the reconfiguration process across various system layers will be determined and synchronized in order to enable vertical and horizontal handover. Implementation aspects of reconfigurable equipment management and control will be demonstrated on a local prototyping platform. Validated reconfiguration processes and interfaces will be prepared for standardisation.
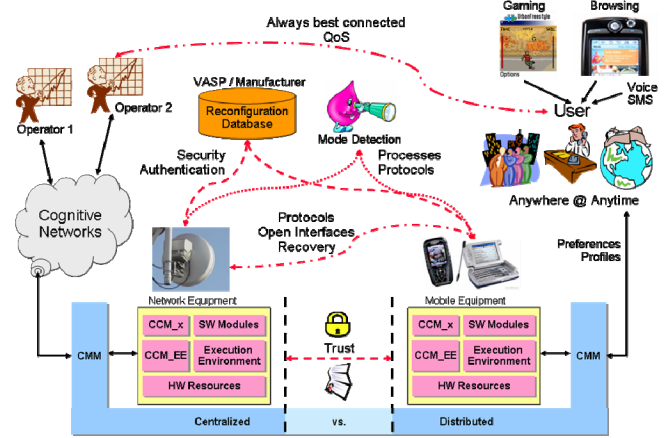

Fig. 9: E²R II WP4 Technical Scope

7. E2R EUROPEAN REFERENCE PROTOTYPING ENVIRONMENT

WP5 will build a reference prototyping environment for end-to-end reconfigurable systems and solutions, thus enabling the validation of the reconfigurability vision developed in the overall E^{2}R project. The reference prototyping environment will consist of terminal systems and a powerful all-IP network infrastructure, where different radio access technologies are available including both heterogeneous and multi-mode aspects. The prototype network infrastructure will consist of GSM/GPRS, UMTS, WLAN (IEEE 802.11x), DVB, WMAN (WiMax) segments. The network infrastructure enables the emulation of reconfigurable elements. The prototype terminal systems will include reconfigurable hardware necessary to demonstrate the E^{2}R scenarios. Terminals will be multi-mode and capable of multi-homing. WP5 will have the responsibility for the adaptations of RATs to the needs of E^{2}R II, including the convergence to a common IP layer.
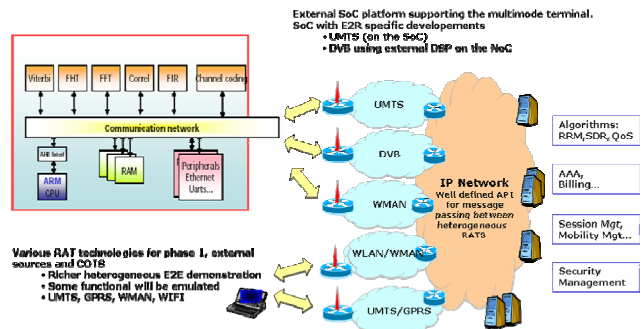

Fig. 10: E²R II WP5 Technical Scope

8. COGNITIVE NETWORKS

WP6 aims to establish a common framework in the European R&D area of cognitive radios and networks, contributing to their definition and future role. The far future self-healing network could be able to perceive radio, service, location and user contexts by interpreting the radio environment and reacting to its changes. The involved functional entities could be distributed over the architecture of the future telecommunication network, e.g. over radio, switching and O&M sub-systems. In this context, reconfigurable and adaptive evolved network nodes, and reconfigurable and self-adaptive resources and related algorithms on the basis of dynamic evolution of radio channel conditions and usage, traffic conditions, are fundamental for the realization of the above concepts. WP6 will study and analyze architecture and network mechanisms for reconfigurable and cognitive network components and assess reconfigurable and self-adaptive resources (both radio and core network ones) and related algorithms on the basis of dynamic evolution of radio channel, traffic conditions and usage.

9. RECONFIGURABLE EQUIPMENT

WP7 aims to develop a detailed knowledge about how reconfigurable equipment, both in the network and in the terminal, can be used in a commercially viable end-to-end reconfigurable system. Business models will be developed, that will support the introduction of reconfigurable equipment given the constraints of power consumption, cost and reliability. The work will then focus on demonstrating how, through the use of a proof of concept environment, equipment can be configured at all levels of the protocol stack and application layer. Novel mechanisms and algorithms will be developed to support configuration management techniques and hardware resource allocation. Through this work, WP7 will identify and highlight interfaces and methods, associated with reconfigurable equipment, that can be standardized and then initiate the standardization process.

10. PROOF-OF-CONCEPT

WP8 is targeted to the validation of business models, system architecture, mechanisms for radio resource and spectrum efficiency, and platform for dynamic and robust reconfigurable connectivity. More specifically, WP8 aims at defining criteria for the validation of the aforementioned work areas. Furthermore, WP8 is targeted to the definition of test-cases (scenarios) that will ensure the realization of comprehensive studies of all the features of the E^2R II Challenges (horizontal WPs), which will be demonstrated through the reference prototyping environment. WP8 will also address the integration of these features with the reference prototyping environment. Finally, an important goal of WP8 is to realize demonstrations and trials, according to the specified test cases, and to assess the degree of compliance with respect to the validation criteria. Corresponding results will be exploited for the refinement and fine-tuning of the E^2R components, as well as for dissemination purposes.

11. CONCLUSIONS

This paper has presented the ambitions of the E^2R II research project, that will be partly funded by the European Commission, and the main fields of research to be investigated over its whole duration (2006-2007). The E^2R project aims at bringing full benefits of the radio eco-space diversity making heterogeneous environments transparent, flexible and intelligent. The ultimate vision of the E^2R research is to reach an all-IP fully integrated networks with reconfigurable equipment 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.

ACKNOWLEDGMENTS

REFERENCES

[1] FP6 End-to-End Reconfigurability (E^2R) Integrated Project (IP), http://www.e2r.motlabs.com
[2] Community Research & Development Information Service (CORDIS), 6th Framework Programme, http://fp6.cordis.lu/
[3] Software Defined Radio Forum (SDR Forum), http://www.sdrforum.org