End-to-End Reconfigurable System Architecture definition

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ABSTRACT

The End-to-End Reconfigurability (E^{2}R) 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 E^{2}R 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. This paper describes the High Level Scenario analysis process (or conceptualisation process) that produced the E^{2}R High Level System Requirements and how the E^{2}R System Architecture Model, following OMG [2] and MDA [3] guidelines, was derived from these requirements. Finally, it gives an overview of the UML [4] System Architecture Model for E^{2}R.

I. INTRODUCTION

The ultimate E^{2}R project's vision of reaching an all-IP fully integrated network of networks - with reconfigurable equipments and associated discovery, control and management mechanisms - requires 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).

The E^{2}R System Research Work-Package is responsible for providing the necessary high level system guidance, coordinating the project's other Work-Packages (figure 1. illustrates the E^{2}R system research methodology).

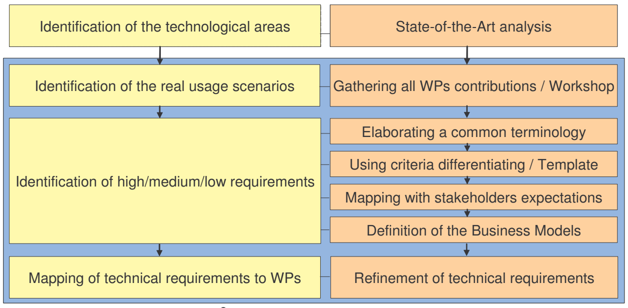

Figure 1.: E^{2}R system research methodology

The technical, business and regulatory visions from the different actors of the Project (from user to service provider) are collected and aggregated to elaborate the high level E^{2}R scenarios and requirements, the E^{2}R business path elaboration and road-map, the overall E^{2}R architectures, reference models and reconfigurability management, and finally the E^{2}R regulatory perspectives.

Overall, coordination with the other E^{2}R Work-Packages ensures a unified high level system vision across all the project's activities.

In effect, E^{2}R performs both a 'traditional' Top-Down system engineering approach (providing high level scenarios, requirements and architecture models) and the 'Bottom-Up' industry/device approach (embedded equipment flexibility).

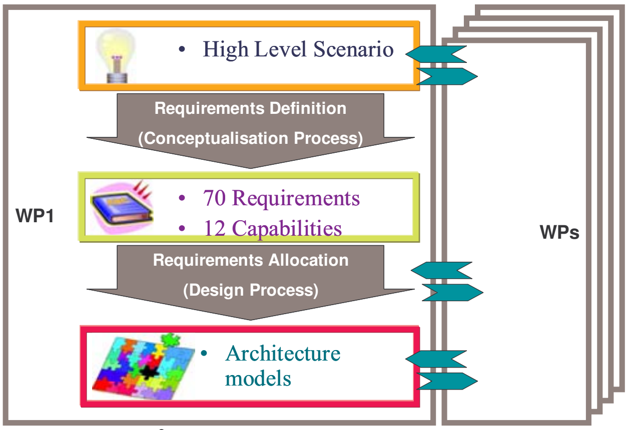

Figure 2.: E^{2}R iterative elaboration of joint system vision

By iteratively confronting these different approaches, the system vision is reinforced in many ways (Figure 2.):

- Consolidate the High Level Scenario definition,
- Consolidate the Requirements allocation,
- Consolidate the Architecture models (towards a Unified Architecture Model satisfying both approaches).

II. E^{2}R HIGH LEVEL SCENARIOS

The first step in the System Architecture definition process was to define high level scenarios describing, from a user perspective (but also taking into account other actors in the system such as operators), sequences of events where a reconfiguration of one or several parts of the system is required.
The scenarios are grouped into three families:

- Ubiquitous access
- Pervasive services
- Dynamic resource management

In the first family of scenarios (Figure 3.), Mr. X travels from Europe to USA (e.g. San Francisco) with his E^{2}R Device.
Before his departure, Mr. X was communicating using the European communication system standard.
Arriving at destination, Mr. X switches ON his E^{2}R Device and the local new communication system has to be activated and/or downloaded and configured on it. Mr. X or its equipment could for example discover the needed information (via Kiosk, Pilot Channel, WLAN, Bluetooth…) at the Airport.
The new communication system could be downloadable either through the device manufacturer or related operator services.

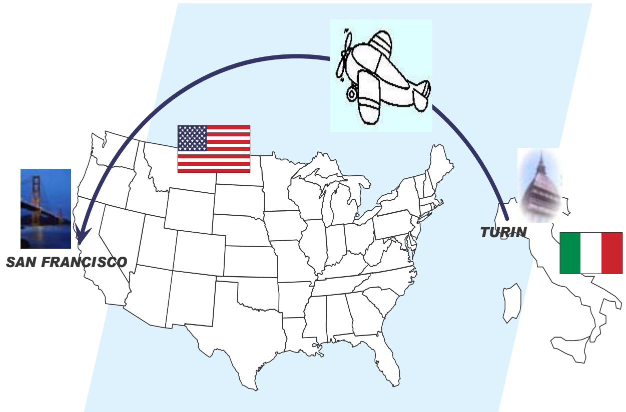

Figure 3.: Scenario Family #1 - Ubiquitous access

In this family of scenario, the traveller finds himself in a city where none of the radio access technologies currently available in his terminal are deployed. He needs to download the waveform used by the local network. The possibility of downloading new applications (not only waveforms) is also considered.

In the second family of scenarios (Figure 4.), Ms. Y is seated in a taxi, driving to the railway station. She is working using her Company groupware software; her E^{2}R Device is communicating to the Company Intranet.
When Ms. Y enters the railway station, her E^{2}R Device is maintaining the wireless communication to the Intranet.
Vertical handover to different access systems is possible during the journey. Services are dynamically adapted and her E^{2}R Device is reconfigured based on the availability of the access systems, its traffic load, user preferences, cost, and terminal static and dynamic capabilities.
The operator is able to load balance traffic in cases of congestion on specific access networks.

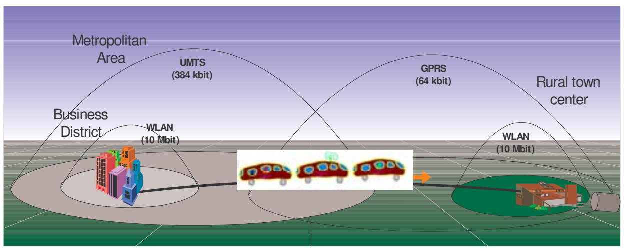

Figure 4.: Scenario Family #2 - Ubiquitous access

This second family of scenarios deals mainly with the possibility of handover between different radio access technologies, this process being transparent to the user, without any interruption of the service.

The third family of scenarios is more focused on network reconfiguration: during the day, hot spot traffic areas will move and services required by users will also evolve.
Moreover, in cases of unusual events (such as sporting event, accident, natural disaster…), the different communication systems covering such areas must adapt to these load and services variations.
To dynamically face theses changes of traffic and provide fast and cheap hot spot coverage to the E^2R Devices, the network operators would perform a spatial/temporal reconfiguration and/or redeployment of their networks capacities as well as a load balancing, based on different cooperation schemes.

In this family of scenario, an operator may want to adapt its network to variations in traffic conditions. To do this he may want to:

- Change the waveform in some channels; e.g. replace GSM by EDGE,
- Change the amount of spectrum allocated to different Radio Access Technologies in his own networks,
- Ask for more or less spectrum to another operator, or to a third party (e.g. spectrum broker, …) responsible for inter-operator spectrum allocation.

III. E^2R HIGH LEVEL SYSTEM REQUIREMENTS

High level scenarios were used for deriving high level system requirements grouped in twelve "capabilities" where each one represents a class of common characteristics or features that a system has to provide (for instance security, privacy, etc .).

These capabilities and requirements* are an identification of what is needed in technical terms to be able to run the high level scenarios.

The E^2R System Capabilities are summarised in the table below.

Capability	Definition
Service Level Agreement	*Service Level Agreement existence between the different parties involved*
Equipment Reconfiguration	*The equipment must be able to change its configuration by means of software*
Security	*The equipment reconfiguration must be performed securely.*
No Radio Interference	*Protection from the possible interference coming from badly reconfigured equipment must be provided.*
Download	*Existence of mechanisms to allow the equipment to download software modules for reconfiguration*
Reconfiguration Management	*Existence of an entity that manages the end to end reconfiguration process*
Service Adaptation	*Adaptation of services to network conditions.*
Vertical Handover	*Possibility of handover between different radio access technologies.*
Service Provision	*Service provision refers to basic telecommunication services as well as value added services offered by operators or independent VAPSs.*
System Monitoring	*The equipment and network must be able to monitor the current state of system operation.*
Dynamic Resource Management	*The network operator is able to dynamically assign its resources to the different tasks to be performed in order to make the best use of them.*
Spectrum Transfer	*The owners of the spectrum are able to transfer their spectrum to other parties through commercial agreements such as a re-sale or a lease. the regulator may decide to perform a reallocation of the spectrum assigned to communication systems.*

As an example, here is the list of the requirements for the capability "*Vertical Handover*" :

- Requirement identification: **VHO_Seamless**
  There SHALL exist mechanisms that enable the transfer of the context of the application/service for the seamless operation of 3rd party applications/services when performing a vertical HO between different NOs.

- Requirement identification: **VHO_RealTime**
  The handover process SHALL be completed in real time without delays that may be cause service interruption. Additionally, the packet loss must be minimized. To

* Note about E2R convention for naming requirements: "*Capability_Requirement*" where *Capability* is one word (or acronym) dedicated to express the corresponding capability, and *Requirement* is one word (or expression) dedicated to express the corresponding requirement (e.g. **VHO_Seamless** is a requirement related to the Capability "*Vertical Handover*»)

accomplish this, different handover algorithms may be available to be downloaded and executed.

- Requirement identification: **VHO_Personalized**
Handover decision SHOULD be based on contextual information (user/paying capabilities, user/QoS demands, system capabilities, system load) so that a compromise could be found among the various profile parameters.

IV. E^{2}R SYSTEM ARCHITECTURE

Therefore, each requirement was analysed to identify which were the data that the system had to handle and which were the functions associated with it (in other words, the main building blocks of the architecture).

Again, let's take for example the capability "*Vertical Handover*" and its related requirements:
"*Vertical Handover*" can be defined by the possibility of handover between different radio access technologies, equipments being able to move through different access networks without loosing their active connections. It can be equipment or network initiated. So the refinement process applied for the tree requirements of our example leads to the identification of data and functions that are able to realize it.

For the first requirement **VHO_Seamless**, three data have been identified to help performing this activity, that are :

- A Packet Data Protocol (PDP) describing the control plane (transport characteristics) of existing connections.
- Radio Access Bearer (RAB) Contexts describing radio connection characteristics of existing connections.
- A Session Context incorporating application / service related information.

And two functionalities have been likely to provide the processing part :

- PDP and RAB Management functions (cellular systems' legacy functions) providing mechanisms allowing the transfer of context along systems offering differing technologies.
- Direct service access point for the application layer, allowing exchange of primitives with the system function.

Performing the same exercise of analysis for the requirement **VHO_RealTime**, it appears their will exist some data that needs to be processed for real time operation during a vertical handover refers to synchronisation parameters specific to each technology.

The functional part of this requirement will be realized by some technologies such as :

- Session Initiation Protocol (SIP), GPRS Tunnelling and RANAP, RNSAP for tightly interworking RAN-s,
- Protocol functionalities that can serve as the basis for the real time management of vertical handovers.

Concerning the last requirement of the capability Vertical Handover, **VHO_Personalized**, three data appears to be necessary :

- key information for providing personalisation during the vertical handover (stored in a user profile) that range from preferences of displaying characteristics to the preferred technologies of connection.
- Applications to be used for particular services, the context of the user for dealing with billing and the terminal in use also have an impact in the final decision.
- Parameters belonging to another sphere of applicability, such as the available resources (i.e. radio, transport) of a network, the system capabilities, the system state...

And four functions will ensure the processing capabilities :

- The network will always intend to control the final decision, aiming at getting the best possible connection, so that users' personalised needs are met.
- Personalization functionalities located either in terminal, or distributed in the network elements.
- The decision making functionalities within communication architectures do not locate in the same physical elements.
- Virtual Home Environment (VHE) considers the control of the terminal locally, as one of the several choices for personalization.

V. E^{2}R UML SYSTEM ARCHITECTURE MODEL

The next step of the analysis process of E^{2}R system leads naturally to the identification of the main building blocks of the architecture, with data and functions associated with each of these blocks, starting from the result of the previous analysis process described in the previous paragraph. UML [4] is well suited to represent the results of this analysis with class diagrams, since a class represents a set of data and functions having coherent relationships.

The choice for UML representation is amply justified by the three criteria necessary to efficiently coordinate with the other E²R Work-Packages and better ensure a unified high level system vision across all the project's activities :

- Representation of abstract concepts,
- Speak a common language,
- Facilitate the analysis.

In addition, the use of UML is a key foundation for OMG [2] MDA (Model Driven Architecture) [3] and gives E²R the opportunity to benefit from standard profiles (e.g. OMG's « PIM et PSM for SWRADIO Components » [2]) as far as the MDA approach by providing a way to elaborate models that are open, vendor neutral and clearly independent of any implementation technologies.

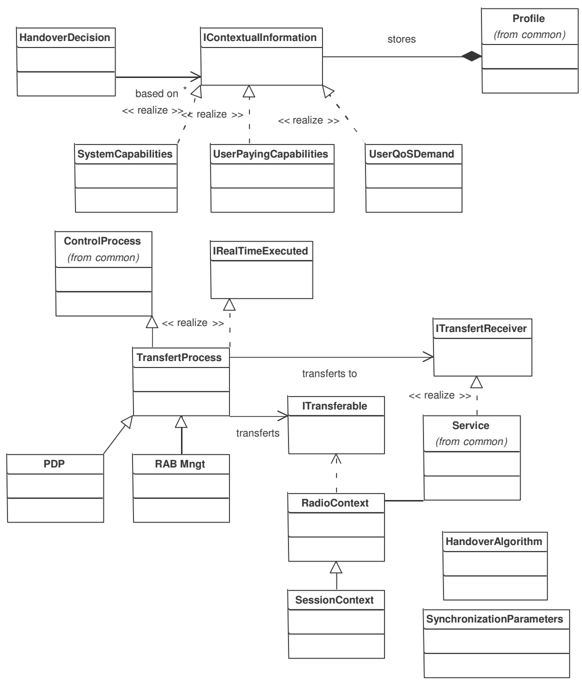

Figure 5.: example of UML E²R Architecture diagram ("*Vertical Handover*" Capability)

Note: a UML profile is a definition of stereotypes and relationships dedicated to a particular domain (software defined radio for instance in the case of the OMG's « PIM et PSM for SWRADIO Components » profile) facilitating the design of models belonging to this domain.

Figure 5. gives an example of the transcription's result of the data and functions identified in chapter IV. into an UML class diagram notation for the "*Vertical Handover*" Capability.

VI. CONCLUSIONS

This paper has presented the initial step of the E²R System Architecture Model definition.
So far, this is essentially the result of a Top-Down approach that derived from the High Level System Requirements (Design Process), themselves being derived from the High Level Scenarios (Conceptualisation process).

On-going confrontation of the E²R research achievements across the projects Work-Packages, at scenario, requirement and architecture levels, is making the current high level E²R vision of reconfigurability to evolve into a unified System vision.

In particular, the adoption of UML representation of the E²R System Architecture Model provides favourable grounds for interactions within E²R Work-Packages as well as with external entities such as standardisation bodies and various stakeholders in the context of heterogeneous mobile radio systems.

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