SYSTEM RECONFIGURABILITY

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ABSTRACT

The plethora of radio access systems and therein the number of different terminals used to connect to them, have generated the need for simple to use 'any-standard' terminals. Such kind of terminals will be capable of reconfiguring themselves not just on the physical layer but also the system components on protocol stack and upper layers. A clear concept is needed to approach and eventually satisfy the requirements such terminals will have. To overcome the heterogeneity of the access systems, an approach introducing a reconfiguration plane, to support the modelling and implementation of a multi-layer reconfiguration system (physical- and upper system layers), had been proposed, the practical modelling of this plane is presented in this paper.

The paper also outlines the requirements and pitfalls that a functional implementation of a reconfigurable system can encounter. In addition, the a testbed implementation of a demonstrator of the reconfiguration plane (based on the Reconfiguration Management Architecture (RMA) [1] is described.

1. INTRODUCTION

The driving factors for reconfigurable solutions are not only emphasized by terminal manufacturers and network providers but also through the projected future needs of users. Requirements for user centric customisation of terminal features have to be addressed and tackled with a rather generic solution. Such a solution is provided by software reconfigurability, an important aspect of this solution, independent of the system (wired and wireless, mobile or stationary), will be the portability and the flexibility of the software entities implementing radio functionality. One of the challenges is contained in the problem of how well a particular system/platform will support them. These features can be extended to - compatibility, openness and ability to support multiple software and hardware vendors (involvement of 3rd party providers). Eventually, this will open the opportunity for new functionalities and reconfigurability of applications and services. Yet applications and services should not only be reconfigurable but they should be kept unaware of the underlying system implementation details. Thus, a homogeneous provision of access means will need to be ensured, even in a heterogeneous access environment. Hence, the terminals will need a degree of reconfigurability support well beyond the mere communication parts. A reconfiguration plane is required to provide this support whenever a reconfiguration is needed or triggered by different system components and modules. Albeit this reconfiguration plane aims to support mainly future reconfigurable systems, it is important that the reconfiguration support plane also supports and complements existing networks.

The key problem in the design of such reconfiguration support plane is to enable conformity with the specifics of the actual system layer, of the way the target system is set up and in the mechanisms to maintain the current system functionalities in case a fallback is required. Applying a modular architecture for reconfigurable systems together with a script based approach for the definition of a target configuration provides the possibility for simple identification of the different elements within the different layers of a system and it also provides a structural representation which facilitates the rapid implementation of different configurations.

The paper describes how to determine the design aspects and the details of run-time implementation of different layer system configurations (i.e. reconfiguration of execution environment, of user interface, etc.) in reconfigurable terminals. It also provides the details of the reconfiguration plane and how this complements the RMA towards reconfiguration of higher layer system components.

Finally, the paper discusses the use and handling of system components that can be downloaded from the network with the support of network resident download control, and describes the mechanisms to facilitate inclusion of third party software providers. The mechanisms a terminal requires to facilitate configuration of system components at all different layers of the protocol stack are shown and the complete demonstrator is illustrated.

2. RECONFIGURATION PLANE FOR RECONFIGURABLE SYSTEMS

The basic notion for communication in the existing wireless systems is based on the concept of splitting functionality into different 'planes', which for e.g. in GSM include user-, control- and management planes. However, in the world of software radio these three planes do not suffice for the support of the reconfiguration requirements, which the software radio systems encompass. So, the introduction of a new 'reconfiguration (support) plane' becomes obligatory. This additional functional plane, is distributed between terminal and network, and supports a strong reconfiguration management within the terminal but also the ability to interact with the responsible (and authorized) management units within the network environment. Architecture able to cope with these situations require an open programmable platform for the reconfigurable radio and distributed configuration management architecture to control the reconfigurable radio and system i.e. RMA of MVCE [1]. This functional plane is at the core of the Reconfiguration Management Architecture [2], see figure 1.

The RMA had been designed to enable, manage and support secure and reliable reconfiguration of terminals and network nodes, and also to facilitate the download of trusted and approved reconfiguration software. The main objective of the RMA is to prevent unsolicited radio access scheme configurations in Software Radio Equipment [3]. Research into software radio technology has come to age and there are configurable hardware platforms solutions already available [4] and [5], in which the RMA can potentially be integrated.

The configuration capabilities of these software radio platforms do currently not include the functionality of the reconfiguration plane. Yet, this touches an important issue when it comes to reliability and trustworthiness of configurations and to the portability, openness, flexibility and availability of reconfiguration support.

There are further research efforts to model a reconfiguration plane of complete end-to-end systems [6] by the E^2R project [7]. The basic idea is to have a completely reconfigurable node between all the layers of the system. This approach is not dissimilar to the RMA's reconfiguration plane. The fundamental conceptual difference between the E^2R approach and the RMA is due to the fact that RMA's reconfiguration plane has been design to be complementary to the functionality of the existing systems which do not have at present – reconfigurability potential. It also tries to be generically designed so that its complementary functions can be made fit to future radio technologies. This reconfiguration plane is represented with distinct properties and protocols compared to the other planes that describe the functional parts of radio access systems. It ensures a high level of security and service support of nodes, full coexistence and availability on demand of reconfiguration management and control.

With the future provision of open programmable and software implementation of radio platforms and systems, software will be offered by many players, the possibility to combine various (software) implementations, from different sources, within one configuration will arise and the management of such scenarios will be rather challenging. To enforce regulation in such situations, a policy-based approach where rules are used to define system preferences, requirements and control [8] will need to be implemented.

The RMA reconfiguration plane at the core of the reconfiguration management and control services does

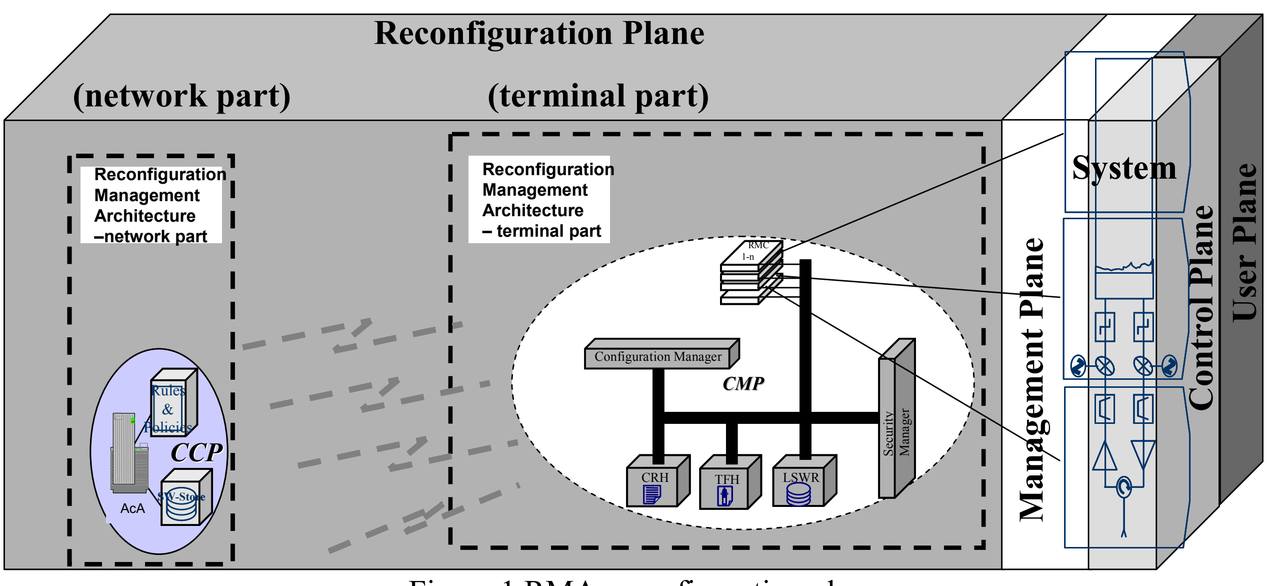

Figure 1 RMA reconfiguration plane

facilitate such means for reconfiguration management. The principles and mechanisms described enable the reconfigurable system's operations as well as the adequate network provisioning and terminals' standard compliance.

3. RECONFIGURABLE SYSTEM – FUNCTIONAL IMPLEMENTATION

There are some specific requirements needed to be met in the testbed implementation of the reconfiguration plane – irrespective of reconfigurable terminals type or network support functions implemented:

- Reconfiguration management is an additional platform capability to support multiplicity of system configuration replacements (system software modules);
- Reconfiguration control provides its services to all reconfigurable nodes within the network.

The simplicity of the concept is that the reconfiguration services have to become part of different systems to complement the functionality of these systems without introducing modifications and bringing higher complexity to the existing ones from the way they usually work. This makes the approach suitable to fit into the frame of existing business models and prevents the need for expensive modifications to the existing network (wireless and wired) infrastructures.

The main functions of the reconfiguration entities still relies on the provision of reconfiguration context upon the primary access technology, which core will continue to be based on IP networks. However, if the terminal requires modifying the system configuration it will interact with the reconfiguration management part of the terminal, and then using the underlying transport will follow the message to the reconfiguration management part in the network [10]. Another part of the reconfiguration plane component chain is the execution environment, which on its own may also be reconfigurable. It provides the means through which the reconfiguration plane operates and also facilitates general I/O communication with and between the remaining parts of the reconfiguration platform. In addition, it has the capability to generate the connectivity between different execution parts of the reconfiguration plane (network and terminal). At the interface between reconfiguration plane and reconfigurable platform, a set of reconfiguration controllers provides well-defined interfaces to implement the communication between management part and hardware specific interfaces from the platform side [11].

The Reconfiguration Controllers, are from a functional prospective the most sophisticated elements of the reconfiguration plane chain. Beside their main tasks they provide the connectivity between the reconfiguration management part and reconfigurable platform. Also, they incorporate a variety of functions to perform the reconfiguration procedure addressing interpretation of the information contained within a policy-file and then to implement the complete configuration of the reconfigurable module part – involves installation of the software specified within the policy-file and basic functional testing of the module. These controllers are instantiated during run-time, upon instantiation. each controller connects the neighbouring modules and verifies the new configuration.

Each of these reconfiguration controllers implements a dual state machine structure – on one side, one of the machines (toward the management part) has a predefined open interfaces, which allows standardisation and openness to 3rd parties software developers; on the other side, second machine towards the hardware platform, could have proprietary or open interfaces. This will depend on the design of the hardware platform by the manufacture. This has an implication that in the beginning for reconfigurable terminals these interfaces and communication may be restricted only to knowledge of the manufacture. However, in the later stages these interfaces and communication will inevitable be open due to the competition in this niche. Nevertheless, the functional implementations of the reconfiguration controllers by RMA's plane support both approaches. Another important issue is the inter module communication. This can be related to the particular access technology implementation and its software partitioning [12] with respect to the particular interfaces that have to be configured between the software modules. However, in general, their configuration is done by the reconfiguration controllers on the basis of the initial policy script. The whole process is initiated and coordinated by the reconfiguration management entity of the terminal part of the reconfiguration plane.

The afore described implementation of the reconfiguration plane shows its complementarity to any current an dpossible future access technologies. The scheme is used only when reconfiguration is triggered and does not affect the 'communication' functionality.

4. RECONFIGURABLE SYSTEM – DEMONSTRATING

The requirements of the system described above are closely related to the main design objectives of the RMA reconfiguration plane demonstrator. The reconfiguration management system operates alongside yet interacts with all other parts of the terminal (i.e. network node) and also with the other network entities (AcA – Authentication/ authorisation virtual Configuration Accounting/billing server). In this distributed structure, different parties are involved – operators, users, software providers, manufactures, or service providers, when providing new system software (like RF, Baseband components). The RMA runs in a distributed execution environment, which allows the download, configuration and execution of new modules, whenever a new or specific (software-) module is needed. The demonstrator described uses and implements this approach.

The demonstrator (see Figure 2) includes the implementation of the signalling and messaging procedures as well as a graphical user interface to demonstrate the run time reconfiguration of different system components.

The reconfiguration management (RM) of the terminal implements an additional security framework over and above the underlying security. It is based on a PKI, implemented to ensure security and identification for communication between network and terminal node. Finally, the reconfiguration plane contains additional procedures for system initiation where the downloaded component is locally stored and checked for completeness. Once all previously described procedures are completed, the actual configuration of the system whereby the ‘old’ system components are replaced with the ‘new’ ones and properly connected to the existing system components takes place.

The key new features are that the internal system has the means and permission to be reconfigurable to a new configuration without the need for a re-boot of the terminal.

The demonstrator implements the controllers’ state machines and performs the replacement of system components (codecs), i.e. run time replacement of H261 - 15kbps codec with a MPEG1 – 900kbps codec, and then with a hardware component into Xilinx XC4010XL FPGA and vice versa over a 1Mps wireless link.

The reconfigurable terminal, shown in figure 2 as a laptop together with the AcA (displayed as PC), they both contain the implementation of the distributed reconfigurable plane. The AcA implementation is connected to facilitate the download of the system–software (if necessary even from a third party provider (software, manufacture, service providers)). There is a ‘Streaming Server’ within the set up which is used as source for streaming of the video feds (via a wireless link) to the terminal (i.e. providing feds in two formats; these are H261 and MPEG1 at 15kbps and 900Kbps, respectively).

For the wireless connections a WLAN card is used for the client and an access point (IEEE 802.11b) for the AcA and traffic connection. The system setup demonstrates a boot up of the terminal and reconfigurable platform and initialisation of their internal functional entities. This initial setting does not contain the necessary system components (i.e. codecs), only the protocols for initial communication with the AcA. The RM receives a request from the user to download a particular video file (stream) from an internet location. The RMS then analyses and discovers the necessary component(s) needed to process the user request, checks then for the (local) availability of the software and if this is not the case, a request for download is sent to the AcA for the required component(s).

As next step, the AcA checks its inherent database for the availability of the system module(s) and forwards them to the terminal. If the required components are not present they can be downloaded from third parties through GAcA (gateway AcA). In addition, the AcA makes sure that everything that is downloaded is free of bugs and will not harm the terminal configuration. This applies for software that is part of the AcA database as well as the one that is received from other parties.

The communication is made via the secure connection and is terminated when interaction with the network is concluded. Once the software is downloaded it runs the reconfiguration procedure and configures the system to the new (requested) state and then executes the users request for connecting to the Internet site for receiving the video stream.

The demonstrator shows this procedure, it downloads first the MPEG1 codec and runs a streaming video from the local intranet. Then the terminal changes location and the whole procedure is repeated to replace the component (MPEG1 codec) with another, the H261 codec but this time from a remote site (AcA2), and a video stream is feed to the terminal from the Internet. In this way as using different locations, the demonstrator shows not only the functionality of the distributed plane but also the robustness and performance of the system as a whole as well as the innovativeness of the generic approach to be able to download and connect to foreign compatible networks for performing system reconfiguration .

The same (reconfiguration) procedures can also be used for a different demonstration scenario, whereby the hardware components are either remotely or locally stored. If it is the latter case (locally stored) at the terminal part and the RM will not need to download the required software modules, but only has to take care of the correct installation. The latter demonstration shows that the system components can be exchangeable since the reconfiguration plane contains the necessary mechanisms implemented to ensure functioning entirety of the terminal at all times. This also involves reconfiguration of hardware component into Xilinx XC4010XL FPGA.

The next steps of this work will include research into a system implementation and conformance to existing wireless standards. This will involve the demonstrating of a reconfigurable management system into a real implementation of a wireless standard into hardware and demonstrating a system reconfiguration with another wireless system both connected to a real networks to the testbed.

5. CONCLUSIONS

A key challenges for the future of the reconfigurable terminals and networks is the implementation of the reconfiguration plane, which contains a distributed reconfiguration management scheme, an execution environment as part of the OS where the RM is running as well as a middleware based messaging scheme for unified internal and external communication.

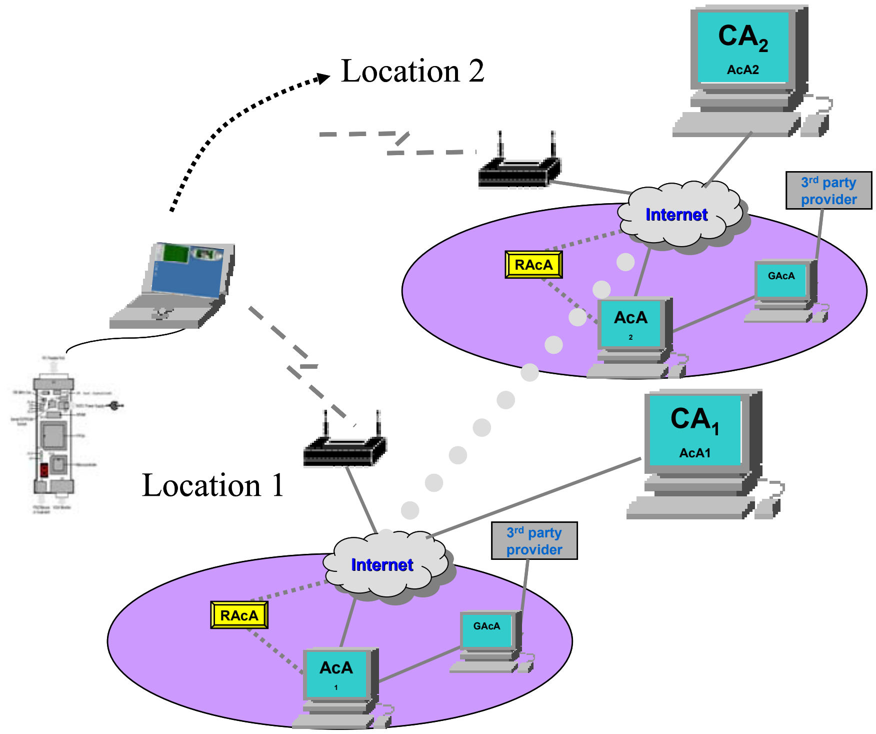

Figure 2 - RMA reconfiguration plane implementation

The paper described the reconfiguration plane and some of its key components and explained how runtime reconfiguration of software components can be performed using reconfiguration controllers. It presented a demonstrator that implements the RMA's reconfiguration plane and associated system components, and demonstrates/ performs system reconfiguration of a 'terminal' and described the network entities necessary to support reconfiguration processes.

While the reconfiguration management architecture provides the mechanisms necessary to support reconfiguration of software configurable communication nodes in wireless environments, it is in fact a complete proposal for a reconfiguration management scheme for secure reconfiguration of SDR equipment in reconfigurable radio communication networks at any location.

6. ACKNOWLEDGMENTS

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