Re-configurable Terminals Beyond 3G

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Abstract *- This paper presents some of the main fields of research for Software Defined Radio and re-configurable terminals beyond 3G and summarizes the associated solutions proposed and investigated inside the IST TRUST (Transparently Reconfigurable UbiquitouS Terminal) project. Terminal re-configuration, system level modeling, system and network architectures and configuration management are detailed. More information on studies and results in the frame of user perspective, enabling technologies and system research can be found in additional submitted papers.*

I. Introduction

As technology rapidly evolves the likelihood of many standards and proprietary enhancements covering all protocol layers increase. Standardisation effort is currently concentrating on compatibility questions and mostly precludes mechanisms on negotiations between terminal and network. With a greater variety on networks in the future, standardisation must be shifted to standardised protocol negotiations which provide the mechanisms to enable standardised and possibly new communication protocols being communicated and agreed between terminal and network. This could also imply the introduction of etiquettes between communicating entities.

Main advantages of re-configurable terminals are illustrated in Figure 1:

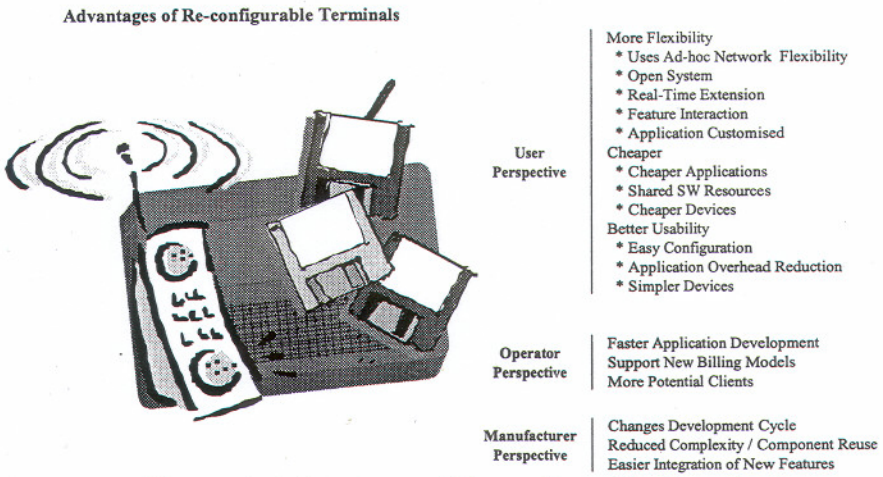

Figure 1: Advantages of Re-configurable Terminals

This stringent demand must be seen on the background that the internet paradigm moves to the mobile networks and this synergy of re-configuration principles and IP paradigm will eventually lead to an evolution of mobile networks.

The evolution of telecommunications in the next decade will be characterized by the convergence toward an IP-based core network and ubiquitous seamless access (2G, 3G, broadband, broadcast…) in a context of hierarchical and self-organizing networks (Figure 2).

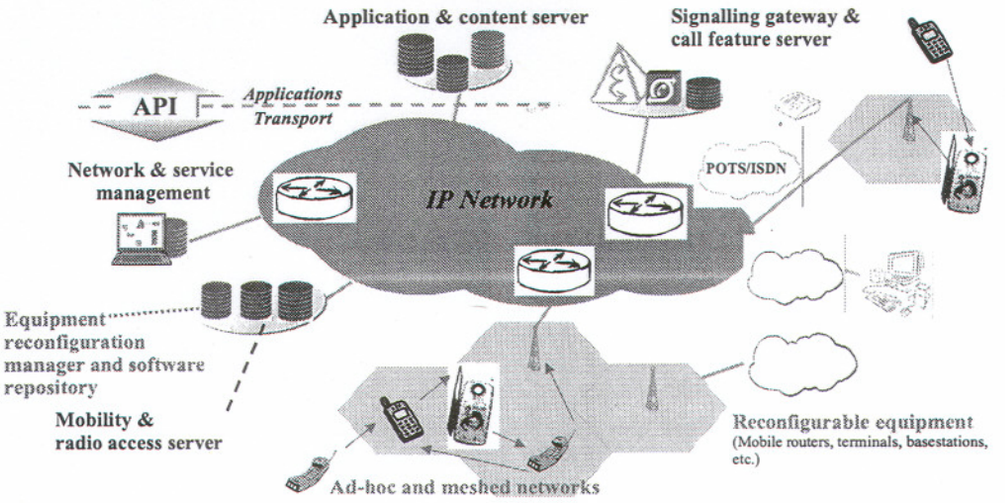

Figure 2: Convergence in Telecommunications

The interworking, mobility management and roaming will be handled via the medium access systems and the IP based core network. Re-configurable radio terminals and new appliances will be the key components of such a seamless network convergence.

II. State of the Art in SDR Research

Research in SDR has been dominated both in military and civilian communications [1]. In 1996, a non-profit organization called the SDR Forum [2] (ex Modular Multifunction Information Transfer System MMITS Forum) was set-up to develop technical specifications and standards requirements for the realization of SDR. Representatives from defence, commercial wireless, and civil government are present in this forum. In addition, membership includes service providers, network operators, equipment manufacturers, component manufacturers, regulatory authorities, and academia and research organisations. The activities of the SDR Forum have help raise the awareness of this emerging technology.

In addition, European Commission [3] sponsored research in SDR has also been significant. Examples of past and present projects include, the 4th generation ACTS and ESPRIT initiatives such as FIRST (Flexible Integrated Radio Systems Technology), SORT (SOftware Radio Technology), and SLATS (Software Libraries for Advanced Terminal Solutions) and the current wave of 5th framework projects such as TRUST (Transparently Re-configurable UbiquitouS Terminal), CAST (Configurable radio with Advanced Software Technology), MOBIVAS (downloadable MOBIle Value Added Services through software radio & switching integrated platforms), SODERA (re-configurable radio for SOftware DEfined RAdio for 3rd generation mobile terminals), and PASTORAL (Platform And Software for Terminals Operationally Re-configurAbLe), and so on.

The majority of the published papers on SDR technology were originally focused on aspects related to the digital front-end of the SDR terminals and functionalities of the radio interface. This was (and still is) largely due to the difficult problems that are still open in this field. On the other hand, very important and interesting issues such as the co-operation of the SDR terminal with the supporting networks were scarcely covered by the international bibliography.

The IST project TRUST [4] attempts to rationalize the "seamless wireless utopia" by studying the real user requirements for re-configurable terminals and then creating realistic working scenarios. Technology and system/network researches identify the system support concepts, enabling technologies and standardization required to realize the scenarios, and through subjective evaluation, system modeling and simulation, evaluate the feasibility of the proposed solutions.

III. Main TRUST Technical Achievements

The main fields of investigations, in the context of SDR and re-configurable terminals beyond 3G, identified and treated in the TRUST project are:

- User perspective: user and operator requirements, scalable application,
- System level issues: interactions between terminal and network, system architectures, mode switching negotiations, software downloading traffic impact, radio resource management (spectrum and vertical handover),
- Enabling technologies: RF hardware architectures, RF bottlenecks, re-configurable baseband software architecture, re-configurable signal processing algorithms, power management, scalable video.

The system research in TRUST is focused on the terminal re-configuration management following a top-down approach, from a conceptual perspective up to the potential terminal implementation solutions. Some of the main issues of this system analysis are presented hereafter. More details on studies and results in the frame of user perspective, enabling technologies and system can be found in additional submitted paper.

III.I. Terminal Re-configuration

System and technical analysis realized in the field of the terminal re-configuration address mainly:

- Blind and assisted radio access mode identification,
- Radio access mode negotiation and switching management or vertical handover,
- Secure software download including authentication, capability exchange, software integrity assurance and controllability of the terminal,
- Radio resource dedicated to software download,
- Negotiations methods between user, terminal and network,
- Minimal set of terminal and network functionalities to be standardised as e.g. reset and recovery procedures for terminals.

III.II. System-Level Modeling

The overall coherence of these studies in ensured at system level by using Unified Modeling Language (UML) and Specification Description Language (SDL).

The top-level use-case diagram (UCD), capturing all systems interactions is depicted in Figure 3.

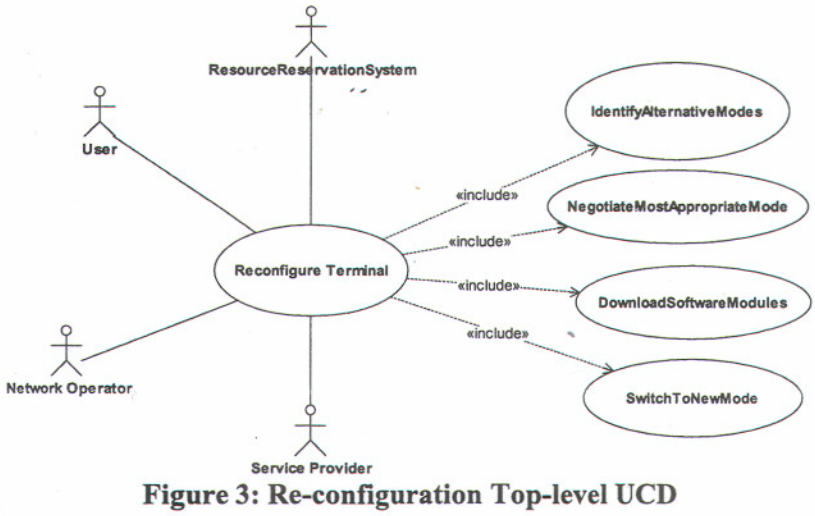

Figure 3: Re-configuration Top-level UCD

Derived from this top-level use-case diagram are defined detailed use-cases, class, collaboration, message sequence and state transition diagrams. UML is used to support the system architecture definition and the detailed design of modules in terms of functionalities and interactions. SDL is also used for specific modeling schemes.

III.III. System and Network Architectures

The architecture defined in TRUST project is based on a network-centric architecture (Figure 4) involving the association of Home Reconfiguration Manager (HRM), Serving Reconfiguration Manager (SRM) and Proxy Reconfiguration Manager (PRM). This architecture is useful for cellular networks and provides a centralized software distribution and TRUST has already developed concepts for supporting a de-centralized distribution from terminal to terminal suitable in ad-hoc networks.

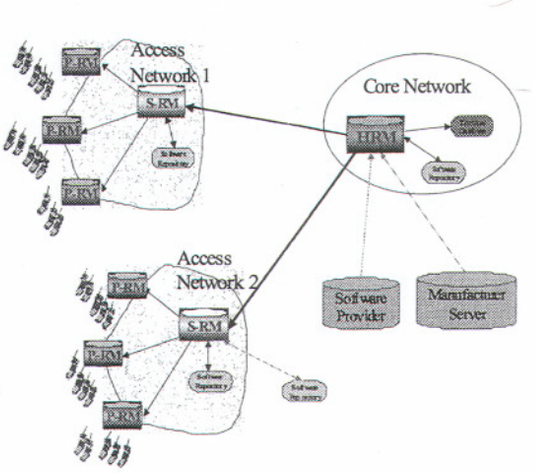

Figure 4: Network-Centric Architecture

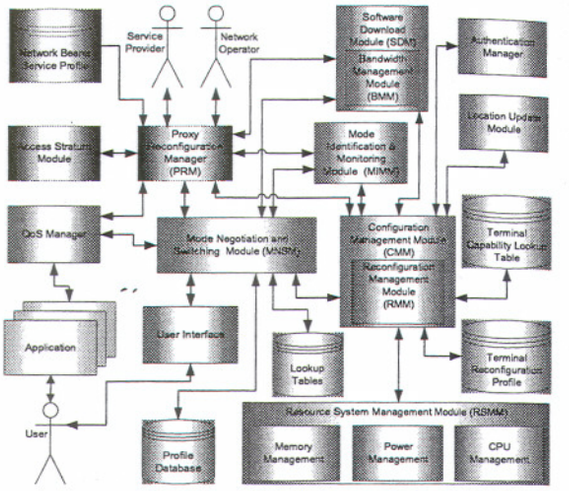

Figure 5: System Architecture

Interactions between terminal and network are crucial as the available bandwidth on the wireless link is a limited resource that should be used for services rather than negotiations. Furthermore, resources on the terminal itself are usually also limited. In order to relieve the terminal from the burden of frequent interactions with network entities, information from the network could be generally obtained via the PRM, which is located in the radio access network. It serves as a proxy instance for negotiations with other network entities, in particular the SRM and the HRM.

The system architecture is depicted in Figure 5. The system architecture definition is still under analysis, the distribution of functionalities across modules and the detailed interactions between modules being currently investigated.

III.IV. Terminal Configuration Management

TRUST considers one or more terminal agents per domain of responsibility representing the responsible organisation and act as the main method of interaction to perform re-configuration. Requests to re-configure the terminal originating from the user, network operator, manufacturer, service provider or possibly even third parties are sent to the corresponding terminal agents. Then the terminal agent performs the necessary re-configuration tasks. Each terminal agent has associated configuration data and the domain manager holds global configuration data corresponding to their domains of responsibility.

There are two basic kinds of interaction between the terminal agents in different domains. One is "re-configuration requests", which are mostly passed down the hierarchy of domains of responsibility – Service Provider -> Network Operator -> Manufacturer, another is "notifications", which are passed in most cases up the hierarchy of domains. The re-configuration requests can be categorised as request for changing "mode" and request for changing "configuration", where a mode is an abstract representation of the services provided and not the detail of how it is implemented. A configuration represents a set of software modules that are required for implement a particular mode of operation. Therefore, the mode can be translated into an actual configuration in order to hide the detail of the actual software configuration required to support the mode.

The direct interactions between the terminal agents (shown in black in Figure 6) can be standardised to enable agents in different domains of responsibility (that could be provided by different vendors), to notify each other of changes or request reconfiguration. Alternatively, all interaction could occur via the appropriate domain manager (as indicated in red in Figure 6). This second option is attractive from the point of view of security because the domain managers are best placed to authenticate and authorise the interactions and so it is logical to allow them to perform a proxy function for these interactions. Also, it is safer for terminal agents in one domain to not be aware of terminal agents in another domain if they do not need to. This approach with interaction being passed through the relevant domain manager is described using UML. Obviously, if there is a large volume of configuration management data that needs to be exchanged between terminal agents this would not be a good solution, however, for most operations there is only likely to be small amounts of information being passed.

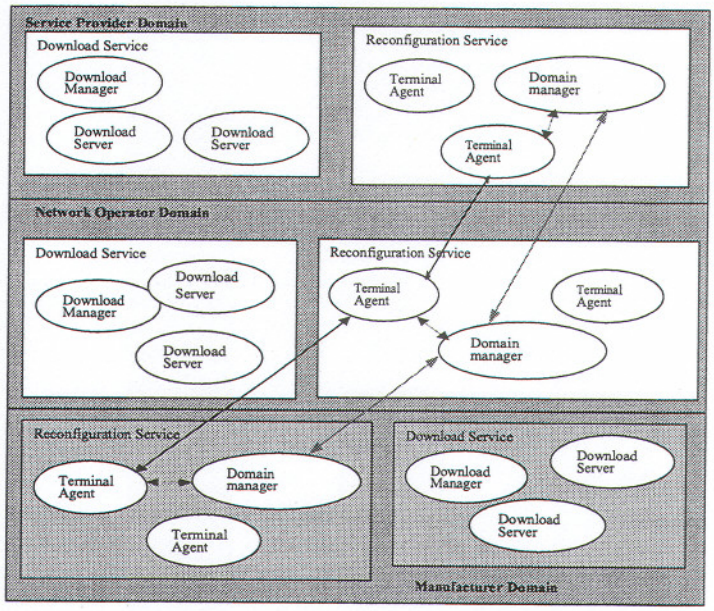

Figure 6: Configuration Management Framework

For configuration management of re-configurable terminals there will be some configuration data that is definitely required by all terminal agents – e.g. available battery power - and is most logically placed in a central repository with access controlled by the corresponding domain manager. In this way it is not necessary to have an open or standardised database access and replication mechanisms, but the data access occurs via the domain manager and this interaction must be standardised. This resembles to the previously mentioned etiquette for standardised negotiations between entities. The additional information that is not required to be accessible to all terminal agents could be stored in proprietary manner on a terminal agent basis. Also, replicating this data between terminal agents and terminal agent proxies will also need to be proprietary if the storage and access control mechanisms are proprietary. However, if proxy domain managers exist, the replication of data between the domain managers and their proxies will need to be standardised or mandated.

IV. Time Frame

The main expected results for the hot research topics, identified from the TRUST project perspective, in the frame of the re-configurable terminal beyond 3G are the following:

- Achievement of a user/operator requirement definition,
- Achievement of system analysis on terminal re-configuration,
- Definition of a potential system architecture supporting terminal re-configuration in hierarchical networks,
- Progress in research on enabling technologies and definition of solutions for some of the bottlenecks,
- Validation of concepts and demonstration of scalable service.

An evolution path for future developments has been identified in TRUST project. The vision (Figure 7) addresses terminals, networks and regulation issues.

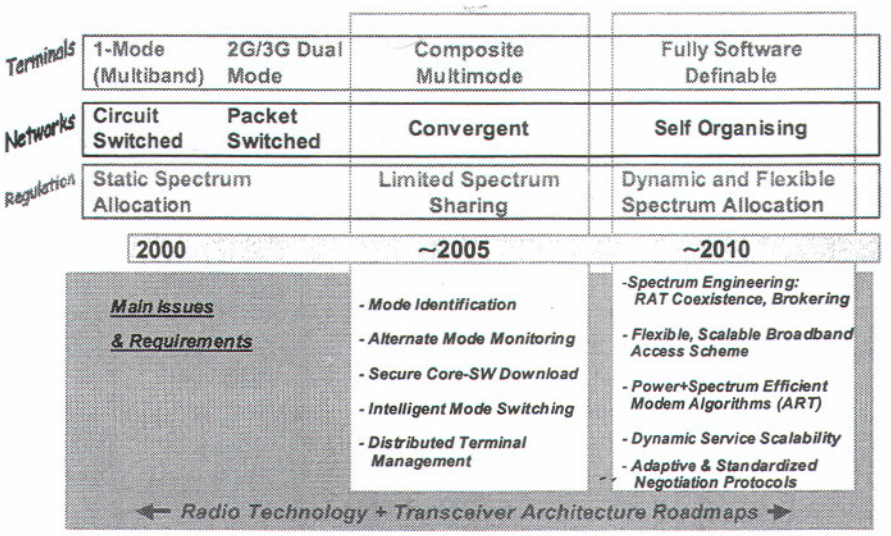

Figure 7: Time Frame for Re-configurable Equipments

This presents the medium term requirement for re-configurable terminals to address optimum service delivery and synergy in a composite radio environment, and the longer term view of dynamic spectrum access in a scalable communications environment.

V. Conclusions

This paper presented some of the main fields of research for SDR and re-configurable terminals beyond 3G and the associated solutions proposed and investigated inside the TRUST project. Major issues in system analysis were highlighted: terminal re-configuration, system-level modelling, overall system architecture and configuration management.

It is fundamental to realize that the SDR definition, design and development still require huge amount of efforts and research at all levels to achieve the success of the promising communications evolution.

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