Wireless World Research Forum (WWRF)

Review of SDR: past, present and future initiatives

Title of research item

Review of SDR: past, present and future initiatives

Contact details of author/submitter

Authors:
A. Delautre[1] antoine.delautre@fr.thalesgroup.com
JE. Goubard[1] Jean-Etienne.GOUBARD@fr.thalesgroup.com
N. Alonistioti[2] nancy@di.uoa.gr
M. Stamatelatos[2] g.stamatelatos@di.uoa.gr
A. Kaloxylos[2] agk@di.uoa.gr
P. Leaves[3] p.leaves@eim.surrey.ac.uk
G. Vivier[4] Guillaume.Vivier@crm.mot.com
M. Alvarez[5] macalvo@tid.es

[1]Thales, 160 Bd de valmy, BP 82, 92704 Colombes Cedex France

[2]University of Athens, 30 Panepistimiou Str., 10679 Athens, Greece

[3]The University of Surrey, Guildford GU2 7XH, UK

[4]Motorola Labs ECR Parc des Algorithmes Saint-Aubin, 91193 Gif-sur-Yvette, France

[5]Telefonica I+D, Calle Emilio Vargas 6, 28043 Madrid, SPAIN

Subject area: WG 6 Reconfigurability

Relevance of the topic to the above subject area

This contribution aims at being a high-level paper giving the reader some perspectives and detachments to the technology, in order to capture the already covered parts of the way towards Software Radio. The paper also aims at giving the reader a vision and trends of the radio-communications, according to our way of thinking and the impact on our way of life.

This contribution is candidate to help in the elaboration of WG6 white paper.

Abstract

Future of mobile communications have been studied for a long time, leading to the emergence of various cheap and efficient communications devices: GSM/GPRS, UMTS, 802.11 (soup), DVB-T, Bluetooth… Integration of those various protocols into a global framework, enabling a transparent seamless diagonal handover, is a key objective of the End-to-End Reconfigurability Integrated Project (E2R IP [8]). We propose to consider the technology improvements and the works done towards reconfigurability, demonstrating the technical feasibility of the Software Radio. FP5 projects have been selected to show the extent of the addressed domain. A business model is described to support the vision. The available technology is reviewed to exhibit available devices and services.

Firstly we will have a look on the work done during the last decades to capture the evolution of the radio-communications as well as in general the communications trends:
- The first steps of Software Radio
- The PC paradigm
- Mobile phones are person extensions

- The World Wide Web

Then we will make a tour of the major software radio projects on both side of the sea which have contribute to reconfigurability:
- SPEAKeasy
- JTRS program
- DRIVE / OVERDRIVE
- TRUST / SCOUT
- CREDO
- MOBIVAS

Finally we will propose and describe a business model which aims at enabling 4G Mobile Telecommunications Evolution:
- Business Models for 4G Mobile Telecommunications Evolution
- Involved Actors and their roles

Based on a parallel of the wired and unwired communication evolution, we will give some trends supporting our proposed business model as well as beyond 3G mobile radio communications.
- Available devices
- Available Communications
- Available Applications and services

I. INTRODUCTION

Future of mobile communications have been studied for a long time, leading to the emergence of various cheap and efficient communications devices: GSM/GPRS, UMTS, 802.11 (soup), DVB-T, Bluetooth… Integration of those various protocols into a global framework, enabling a transparent seamless diagonal handover, is a key objective of the End-to-End Reconfigurability Integrated Project (E2R IP [8]). We propose to consider the technology improvements and the works done towards reconfigurability, demonstrating the technical feasibility of the Software Radio. FP5 projects have been selected to show the extent of the addressed domain. A business model is described to support the vision? The available technology is reviewed to exhibit available devices and services.

II. Thinkings about the last decades

A. The first steps of Software Radio

During the last decade, reconfigurability has been evangelized by techno-addicts advocating that technology could achieve radio reconfigurability. Let us remember the vision of Joe Mitola [1] about Software Radio: "A software radio is a radio whose channel modulation waveforms are defined in software". Such approach was techno-oriented because it refers to digital converter and processing power enhancement

Since this 1st proposal, processing power and silicon integration have wonderfully progressed as well as digital converters. Evangelists have advocated Software Radio advent using comparison with the PC concept: standard hardware, "de facto" standard Operating Systems (OS) enabling the generation of a mass of cheap or free useful programs.

B. The PC paradigm

In its beginning, Software Radio used to be compared to the PC concept: a standard platform composed of cheap boards provided by multiple companies. This paradigm has been observed on the PDA emergence and success. Palm has introduced the concept of Personal Digital Assistant and has created a market corresponding to the need of the "easy to use" and "easy to transport" "computer". The PDA concept has introduced an orthogonal way of using computer without keyboard & mouse but with a stylus ! The success of PDA remains on a common hardware and software platform; generally speaking Palm OS or Windows Pocket, since competitors platforms have disappeared or remain marginal . As soon as a platform has been stable and opened to

software developers, software programs have created enabling value added services. Thus, new companies have emerged to create markets.

In spite of the 1st thinkings on Software radio, the PC paradigm has not yet been applied to the mobile phones because this market remains a recent one: exploding markets do not need rationalization. The mobile phone market is now facing a new phase of its development.

C. Mobile phones are person extensions

Let's remember the market of mobile communications is only an 10 years old one. Within the last decade, every consumer or nearly, have, at least, changed their mobile 3, 4 or 5 times. Why? Because it is a belonging sign , a way to prove its membership to the up-to-date family. It became more than an useful communication mean. It became an identity sign, an ethnic symbol, an image media for anyone. Therefore, the personalization market of this device emerged, exploded and diversify itself into various markets, such as:

- packaging differentiations,
- screen saver proposals,
- personalized ringings.

To some extends, the PDA market have the same evolution, including various software solutions, according to each one need: addresses, agenda and many other soft applications. Mobile phones became more or less part of ourselves. This anthropological, psychological or marketing issue is not of importance for this paper. But as part of our person, the mobile phone, is required to be used where ever we are: going skiing or being on a strand, in Italy or Canada.

D. The World Wide Web

"To be connected or not to exist !" How to contact a business relation? Mobile phone or e-mail? Any company shall have a website. A data shall be disseminated and searched on the World Wide Web (WWW). A recent study of Microsoft stated that each purchase of more than $25 will be soon challenged on the WWW. Internet research is even used as a metric. Recently a well-known US singer woman has shown some part of its anatomy. The impact of this "pseudo-event" was compared to the September 11, in terms of number of search request on the Web demonstrating the preeminence of the WWW over the TV for the collective unconscious.

The wonderful progress of the technology has changed our life, enabling ubiquity, at least through communication media.

II. US DoD Initiative

A. SPEAKeasy the initiator

The US Department of Defense (DoD) can be considered as the initiator of the Software Radio because it has crystallized the available techniques by founding a major project demonstrating the reality of Multi-mode radio-communications.

In the late 1970's, the Air Force began working on a system known as the Integrated Communications Navigation, Identification and Avionics system (ICNIA) which used a DSP based programmable and control function to achieve a full integrated platform. At the heart of ICNIA was a 6800-series General Purpose Processor (GPP). This effort captured the attention of other military services and quickly developed into a tri-service programmable radio program called SPEAKeasy.

The phase 1 demonstrator was a 4 channel wideband capable architecture (HF, VHF, UHF), demonstrated during the Joint Warrior Interoperability Demonstration (JWID-95) in June 1995, based on multi DSP module and a RF up/down converter. The SPEAKeasy phase 2 expanded the modem-only approach (phase 1) to encompass the entire radio system, from I/O to RF and encouraged a COTS based design and use of commercial standards. It was demonstrated in March 1997.

SPEAKeasy program can be consider as the 1st Software Radio research program that have demonstrated the possibility to develop a multi-band and multi-mode software reconfigurable radio.

B. JTRS program

The Joint Tactical Radio Systems (JTRS) [2] program is an extension and an industrialisation of SPEAKeasy that keeps its architectural choices. JTRS would have found its genesis in learning from inter-service communication problems, during the Grenada Operation and Desert Storm :

- army troops forced to use personal calling cards,
- use of HF due to satellite communications over-loading.

A major fact is an existing stock of 750,000 radio sets corresponding to 200 radio types and over 40 waveforms. Consequently, logistics support systems are expensive and complex. Inter-communications inside a Force needs specific bridges between WFs.

The Mission Need Statement for the Joint Tactical Radio was published on August 21st, 1997. And a DoD directive, August 1998, established JTRS Joint Program Office to oversee development of the JTRS Architecture.

C. JTRS User oriented market approach

For the military market, it is noticed that the user is unique and is also the provider and the network operator. Therefore the Total Ownership Cost (TOC) is a major criteria, conducting to initiate new research program in various domains, from antenna to software metrics.

The power of this "unique" user is enormous: JTRS is 2 Bn $US class program, enabling the creation of new standards and inducing the reorganization of the market. Taking into account that the military US markets represent 50% of the world market, JTRS program can be considered as "de facto" standard for the military industry. For the time being, this initiative has aroused the interest of the major industrialized countries: UK, Japan, France, Germany, Finland, …

Compared to the civilian market, the JTRS program is relatively small. But it concentrates in one direction and it aims at having access to civilian technology or COTS which is cheaper, because produced in larger quantities.

The US-DARPA has launched a new initiative XG for Next Generation Communication [6], which aims at creating a set of abstract behaviours for managing and coordinating Spectrum access. Indeed, spectrum management rules differ from countries. Fixed spectrum assignment leads to inefficient spectrum utilization. XG propose to investigate the usage of a policy-based "Metalanguage".

III. Analysis of FP5 Scenarios

A very strong heritage in reconfigurability was gained through former FP5 IST projects like DRIVE, OVERDRIVE, TRUST, SCOUT, CREDO and MOBIVAS, where the 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, proof of concept of reconfigurability.

A. DRIVE / OVERDRIVE

The scenarios written for the DRiVE and OverDRiVE projects focused around the delivery of seamless multimedia services in vehicular environments. Specifically, this describes aspects whereby the user is being delivered a variety of different services, using different modes such as unicast, multicast and broadcast, through several different access network types. The user traverses a variety of different vehicular environments, such as a multimedia equipped car, as well as public transportation, such as trains and busses. The user delivered wide variety of services, such as voice, music, information, email, and interactive gaming, through many different access modes and infrastructures, without user awareness of the underlying technical issues involved.

Another main characteristic of the DRiVE and OverDRiVE scenarios is the inclusion of dynamic spectrum allocation methods. It was a new concept at the beginning of the DRiVE project that focused on the idea of sharing spectrum sharing between the multiple cooperative radio access

networks delivering the services. These aspects are generally hidden for the user, and thus do not feature strongly in user-driven scenarios. However, from a technical point of view, these concepts are prominent.

B. TRUST / SCOUT

The TRUST /SCOUT scenarios were used to obtain detailed end user and operator requirements through the use of interactive storyboards. Initial requirements and scenarios were elicited from 'Lead Users', using questionnaires, interviews and focus groups. This resulted in a summary of initial requirements together with a number of high level user scenarios for SDR [3]. Later, detailed narratives and storyboards for four core users scenarios were developed, in order to provide a link between the end users, operators and system architecture research.

An example of these scenarios and the associated requirements can be found in [4]. An UK Sales Manager is traveling to the US. Since he is waiting for an important call, he wishes to be available anytime. In this situation he is able to set his terminal profile so that he is able anytime to make and receive voice calls (as a minimum) with the best available coverage. Upon arrival to the US, a new radio interface is downloaded and installed in the terminal. As he drives across the country, the terminal reconfigures itself to make use of the best available network. If a new radio interface needs to be downloaded, in order to get a better coverage in certain areas, the user is informed and can accept the download and subsequent reconfiguration. As a result of this process, he is able to receive his important call, even when he is traveling through a sparsely populated area, with less available network coverage.

C. CREDO

The context of the CREDO project is related to the Athens Olympic Games (2004). The user can be a professional (i.e. journalist) wishing to have access to the wide range of services provided at the Olympic stadium. These services would allow the user to have real-time information about sport events that are taking place, even in a remote location (i.e. sailing events occurring far from the Athens Olympic Stadium).

In the Stadium environment, a wide range of RAT (Radio Access Technologies) are available (i.e. GPRS, UMTS, WLAN, DVB..) in order to guarantee coverage, capacity and service delivery, via the most appropriate RAT. This is necessary in this particular traffic-demanding context.

The user is equipped with a terminal with multiple transmission/reception capabilities, possibly GPRS, UMTS, WLAN, DVB, etc.: ideally, the terminal radio capabilities would match the available RATs.

When the user logs onto the system, terminal discovers automatically the available networks, selects one of them (the first option can be GPRS, the second UMTS and the third WLAN, for instance.) and performs registration (in terms of authentication, mobile IP…). The terminal intelligence and the peer network supporting functions exchange Service Contract related information (transparent to the user) that allow the network to register the user profile and to prepare to grant service delivery, in conformity with the user profile (e;g. subscription, terminal capabilities, etc.). Upon user request, terminal ensures the delivery by choosing the most appropriate transport network. If a congestion or a QoS (Quality of Service) degradation occurs at a particular wireless network segment, a handover is decided, for the benefit of the user, in conformance with his subscription.

D. MOBIVAS

The scenario of MOBIVAS [5] (Mobile Value Added Services) is related to end users equipped with advanced terminal providing the user customized transparent service provision.

The user request for a Value Added Service (VAS) which will be negotiated by a VAS Manager (VASM) and provided by a VAS Provider (VASP). This exhibits various functionalities needed in the system:
- capability and content negotiation,

- service configuration,
- user profile personalization,
- service selection,
- service downloading.

This simple scenario focusing on services successfully demonstrate the necessity to address business economics, security and billing issues. Not really perceived from the user point of view, various actors and entities are needed to make service delivery a reality.

IV. Enabling Business Model

A. Business Models for 4G Mobile Telecommunications Evolution

The vision of the 4G wireless/mobile systems will be the provision of broadband access, seamless global roaming and Internet/Data/Voice everywhere, utilizing each time the most "appropriate" technology. 4G will be characterized by an horizontal communication model, where many different access technologies, such as cellular, cordless, wireless LAN, short range connectivity and even wired systems, will interface to a common platform, over the IP protocol, complementing each other in an optimal way, for different service requirements and radio environments. In this context, reconfigurability is a critical enabler for the introduction of ubiquitous services and applications. The business models to be adopted are encompassing the active participation of third party Value Added Service Providers (VASPs), which will be able to offer their Value Added Services (VASs) either through operator's network (Network Operator Centric Model) or through a new business actor which would be called Service Platform Operator/Provider or Service Aggregator or Service Integrator (Service Platform Operator/Provider Centric Model), or directly to the users. Adopting the second model (Figure 1), we propose the introduction of this new business actor.

B. Involved Actors and their roles

The (Mobile) User/Subscriber is the actual consumer of the available services. He is likely to request the provision of value added services and applications from a service platform operator entity. To formulate and manifest these requests, the user employs a communication and computing infrastructure contributed by another entity in the business model, the mobile network operator, with whom the user maintains a business relationship such as subscription.

The Mobile network operator provides the network infrastructure and transport medium for authenticated and authorized mobile subscriber access to standardized circuit-switched and packet-switched services (e.g., voice telephony, Internet connectivity). It maintains the customer relationship with the user via a subscription arrangement. The network operator would also typically provide independent software vendors with access to network functionality, through open, standardized APIs (e.g., OSA/Parlay).

The Service platform operator/provider mediates between service developers/providers, network providers and end-users. It is a middleware that keeps users/subscribers aware of the available services, categorizes services depending on their content, localization, terminal capabilities and subscriber profile, by operating a software platform for service, reconfiguration management and provision. The platform operator comes into business level agreements with network operators and VASPs. These agreements concern the provision of services and applications owned by the latter, to subscribers of the network operator.

The Value-Added Service Provider (VASP) administers the computational infrastructure (e.g. software implementation) that constitutes the realization of a value-added service. Such services can range from VoIP and videoconferencing to mobile commerce and virtual presence. Service providers establish business level agreements with platform operators, outsourcing to them the deployment and provisioning of their services to various 4G networks. Business-level agreements between VASPs and users are not required. However, they are not precluded.

The Content Provider provides some forms of content that can be of value to mobile users (e.g., stock prices, music, news). The content provider may establish business relationships with content

aggregators or directly with VASPs, in order that the content can be exploited in the context of mobile services.

Notably, in the proposed paradigm, there is not necessarily a one-to-one mapping between actors and real-life entities. A mobile operator could be, at the same time a service platform operator or a content provider. It could undertake the role of the service provider. These relationships can be analyzed in several scenarios, regarding the possible market dynamics in the mobile services industry.
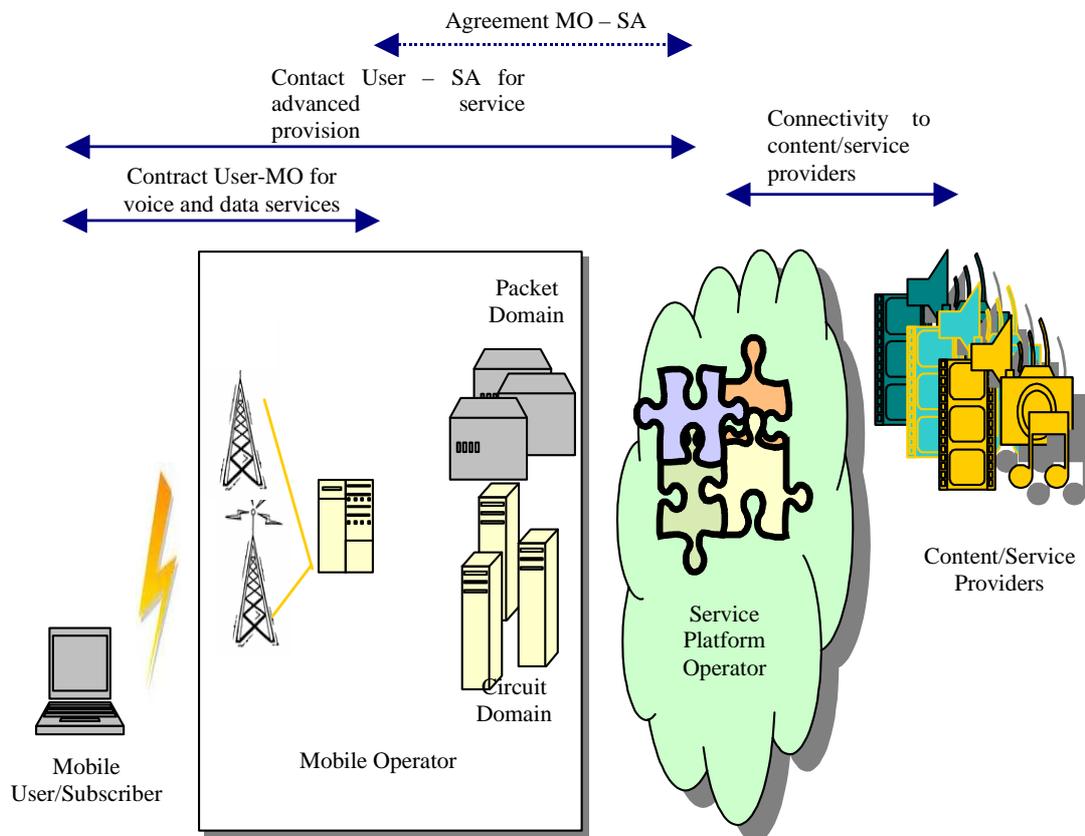

Figure 1. Involved Players and their roles

V. Already Available Technology

A. Available devices

Today mobile phones have Java Capabilities, Camera color screen and are more multimedia oriented than only voice communication oriented. As an example of the trend let's have a look to the Microsoft^{TM} O_2: it is a real computer equipped with 4 radio protocol stacks (3 GSM, GPRS, Bluetooth & 802.11). If we have an accurate view of 802.11, we could find at least 3 modes a, b & g, which means 8 potential radio communication modes.

Body or Personal Area Network (PAN) is a reality as PDA, Laptop, mobile phones and earpieces are equipped with Bluetooth capabilities enabling devices inter-communications.

Wireless Local Area Network (WLAN) becomes to be a reality at home for internet access and resource shearing.

B. Available Communications

Apart from "legacy" cellular operators, new operators appear offering 802.11 access. They mainly address business people traveling with their laptops, offering internet connections and e-mails. WLAN is now available on board (trains, aircrafts) as well as at the railway station and at the airport. WLAN access is a market differentiator for hotels. It is cheaper and faster than modem.

The Paris public transportation company has offered a free wireless access to internet along the bus line 38. Some initiatives have been created to create free WLAN access (Seattle). They face a major issue which is the management!

There are numerous offers of WLAN access. No one is transparent for the user who needs to establish explicit connections, without seamless roaming for the time being.

C. Available Applications and services

In spite of the non-success of WAP, services have been created for user and fruitful projects initiated.

One of the most known services for mobile users is AvantGO™ which provides a kind of personalized electronic news-paper. Microsoft™ MSN product enables the creation of virtual communities capable of chat, voice and video.

The Purdue University initiative, "e-Stadium" [7], investigates the proposal of a bunch of services associated to sport events in a stadium, distributed through a 802.11 network.

X. CONCLUSIONS

Private use of mobile phones and Internet are recent. It's already became part of our way of life, part of our way to communicate.

As previously shown, an huge amount of works has already be done at various levels demonstrating the technical feasibility of the Software Radio. Multimode advanced terminals are already on the market. Versatile advanced software radio prototype will be tested 2nd half of 2004 (JTRS).

We also have to mention the Mobile Virtual Centre of Excellence (MVCE) consortium which coordinates UK Mobile/Personal Communication research activities.

Various wireless networks are already available or will be shortly deployed offering from narrow bandwidth (GSM) to high bandwidth (802.11g) with corresponding range. The next generation of home appliances and media devices will be wireless enabled.

Numerous useful services are available on internet: news, weather, road traffic, search engines... Such services would be of great interest, if they were available on mobile at reasonable price and speed, since some of them are proposed on PDA format and WAP format.

All the various environmental components upon which FP5 project were based, are available today or will be tomorrow.

The presented FP5 projects have studied the multimedia delivery, across heterogeneous networks, in various cases taken into account various point of view:
- In vehicular (DRIVE/OVERDRIVE),
- Reconfigurability on layers of a terminal and spectrum sharing (TRUST/SCOUT)
- QoS for service continuity (CREDO),
- Reconfigurability management issues for intelligent service provision (MOBIVAS).

They have provided solutions to overcome the various issues, evangelizing the world about reconfigurability concepts. After the demonstration of the software radio feasibility and advantages, it is now time to move to a forwarding stage, taking in account some new "variables" such as: business models, legal frameworks as well as the interconnection of the various results in a global perspective, enabling diagonal seamless handover for the benefit of the user.

List of references

[1]   J. Mitola, "Software Radios: Wireless Architectures for the 21st Century", http://ourworld.compuserve.com/homepages/mitola/

[2]   http://jtrs.army.mil

[3]   D. Williams, E. Ballesteros, C. Martinez, E. Morata, "IST-1999-12070 TRUST D2.1. User Assessment: reconfiguration scenarios and requirements.", TRUST IST-Project, 2000.

[4]   M. Alvarez, K. Cook, C. Martinez, R. Navarro-Prieto, "End User and Operator Requirements for Software Reconfigurable Radio", SDR Forum Document Number SDRF-01-I-0049w, 2001

[5]   P. Marshall, "XG Next Generation Communications", Wireless World Research Forum, 10th Meeting, New York, NY, USA

[6]   "IST-1999-10026 MOBIVAS D2.1.3 Description of the pilot requirements & the user scenarios" MOBIVAS IST-Project, 2000

[7]   S. Koo, A. Adewunmi, J. Lee, Y. Lee, C. Rosenberg, "Graduate-UndergraduateInteraction in Wireless Applications Research and Development", 33rd ASEE/IEEE Frontiers in Education Conference, 2003, S2D-9.

[8]   End-to-End Reconfigurability (E²R), FP6 IST-2003-507995 E²R, http://www.e2r.motlabs.com.

[9]   Didier Bourse and al "The End-to-End Reconfigurability (E2R) Research", WWRF10 New-York Meeting – WG6.