Reconfigurability for Satellite Terminals: Feasibility and Convenience

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Abstract. The reasons for the growing interest in reconfigurability is motivated and supported by a technology evolution of signal processing components, such as analog-to-digital and digital-to-analog converters, signal processors and FPGAs, available in the market with ever increasing performances and lower power consumptions. Reconfigurability however is expensive, in terms of development costs, power consumption, computational efficiency of devices, so not all radio systems may benefit from this innovative design. The selection of convenience areas is a tough task. Each communication context, satellites being one, has to be properly analyzed before making the decisions. We try in this paper to analyze the potentials of Software Radio for space applications, where large investments but also large risks are present.

1 The Silent Revolution

Some years ago, a silent revolution has initiated in the design of radio devices. Driven by the anticipated enormous potentials, the transformation of signal processing functions into software modules, which is at the basis of the *Software Radio* concept, has gained more and more attention from radio industry, operators and research institutions [1]. The reasons for this interest is motivated and supported by a technology evolution of signal processing components, such as analog-to-digital and digital-to-analog converters, signal processors and FPGAs, available in the market with ever increasing performances and lower power consumptions. ADC market is characterized by a constant growth of performances in terms of processing speed and dissipated power: an example is the Analog Device AD9461 ADC operating at 130 Msamples/s with 16 bits of resolution and 2.4 W of power consumption, or the ADS5546 from Texas Instruments producing 190 Msamples/s with 14 bits of resolution and 1.1 W of power. If we target an hand-held device, a more constrained energy consumption is required at frontend, so we could chose the AD9215 at 105 Msamples/s with 10 bits of resolution which dissipated at most 145 mW.

Data acquisition is fundamental to digital signal processing, but when high sample streams are produced by the front-ends, suitable processing cores must be present, to fully exploit the potential of software radio concept. FPGA, DSP and GPP are the leading processing solutions for digital radio implementation. Fast computing devices are present in the market, but the design of a digital radio change substantially when a fast reconfiguration capability is required: single mode signal processing can be optimized at low level on the selected set of signal processors, but if several standards have to be accomplished by the same device, abstraction of functions will reduce the effect of optimization efforts, requiring powerful devices for relatively simple functions.

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The selection of convenience areas is a tough task. Each communication context, satellites being one, has to be properly analyzed before making the decisions. If in the mid-term, reconfiguration and software radio are likely to be widely adopted by manufacturers also for space related products, in the near-term the injection of this new design paradigm may appear objectionable.

We try in the following paragraphs to analyze the potentials of Software Radio for space applications, where large investments but also large risks are present.

2 Terminals and Services

Satellite systems differ substantially from terrestrial ones in terms of number and diffusion of adopted standards, type of offered services, and latency of technology innovations. An accurate analysis must be carried out to evaluate the effective impact of software radio technology on space segments.

Satellite terminals may be roughly classified depending on a set of common characteristics:

***Adopted satellite access standard*:** receiving only DVB-S/S2, interactive DVB-RCS, S-UMTS or proprietary access;

***Power and size availability*:** battery powered hand-held, battery powered portable, AC powered fixed terminal;

***Access modes*:** single standard access, multi-standard access with user selection, multi-standard access with automatic selection;

***User mobility*:** stationary, slow intra-spot motion, fast inter-spot motion.

Under this incomplete classification, we can assert that software signal processing can be successfully applied to stationary AC powered receiving only fixed terminals. This is a feasible application of software radio, but it is not convenient, since the benefits from reconfiguration in this case are marginal. A portable or hand-held terminal will get a significant benefit in terms of usage and offered services from the ability to switch between different access modes. In this case the technological effort is consistent for the limitations on power and terminal size, but the convenience is high.

The main issues affecting the design of new generation satellite terminals can be simplified in three key points: the terminal size and portability, the accessed bandwith and the integration with other communication systems.

A terminal with reduced size, with the ability to access satellite services on the palm of one hand is one of the most complex challenges in the communication field. The main problem is characterized by the available power available at the terminal, which poses a serious budget link problem. In some scenarios link cooperation techniques [3, 4, 5] may represent the solution. Improvements are also obtained with the evolution of capacity approaching channel coding techniques (i.e. Turbo and LDPC alone or in combination). Moreover the ability to exploit all available service coverages (satellite, terrestrial, with or without fixed infrastructure) is another key resource. All the cited capabilities are possible through the adoption of reconfigurable architectures for terminals and systems, so in this case the benefit resulting from software radio is high.

As concerns the accessed bandwidth, the main limiting factors are power, processing complexity and spectrum. SDR platforms do not provide significant improvements in terms of processing complexity, and in some cases available complexity is even worse with DSP and FPGA. Spectrum can be better exploited by the adoption of more efficient techniques, but in the complex the SDR technology is not beneficial to bandwidth.

The situation changes with respect to the last issue: the integration with other communication systems. SDR provide an abstraction pillow between connection and transport, promoting the convergence of services at network layer (IP, IPv6). The ideal SDR platform accesses multiple communication standards, though radiofrequency sections are reasonably duplicated to avoid unnecessary waste of processing resources. The contribution from SDR technology is high.

3 Signal Processing Solutions and Evolutions

Signal processing in satellite air interfaces are usually represented as a cascade of processing blocks implemented into ASIC chipsets. The reconfiguration capability can be obtained with two main approaches: parametrization and SW reconfiguration. The former consists in a set of control registers passed to the various signal processing devices, in order to slightly modify their behavior. The latter implies a true software radio architecture where the processing is represented by segments of code for a single processing core.

SR concept by Mitola [6] is obtained by reducing the "parametrized" part to RF sampling and expanding the SW part to the rest of the access device.

Real SDR implementations consist of a variable balance between the two approaches.

Satellite reconfigurable SDR terminals will be probably designed by replicating antennas and RF sections (due to the wide frequency segment of satellite bands) controlled by parameters, while baseband processing can be easily implemented in software. The resultung general architecure, depicted in Fig. 1, can provide all the desired fetures: multistandard, multichannel, multiservice and multiband access to satellite services.

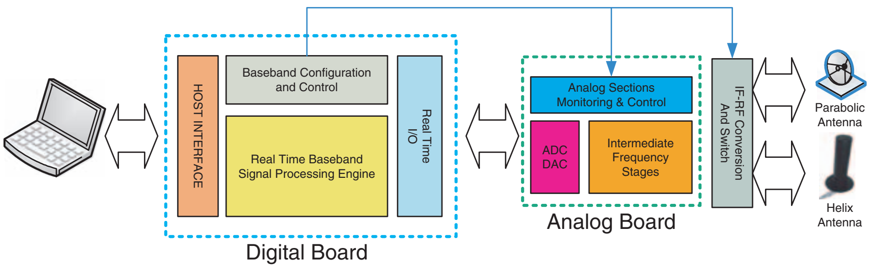

Fig. 1. Implemented SDR architecture for transportable satellite terminal.

Software reconfiguration levels enabled by SDR technology are:

– reconfiguration at commissioning
– with downtime
– on a per call (session) basis
– per timeslot.

The first kind of reconfiguration, provided by the manufacturers, defines the property of the device based on pricing profiles. It is issued once in the lifetime of the terminal, and allows opimization of the production lines, at the expense of a moderate waste of resources for low cost terminals.

The reconfiguration with downtime is performed to correct bugs and install upgrades of the terminal features. In some cases it prevents the factory recalls, which may reveal expensive especially in the case of large numbers of sold devices. Can be performed some times during the lifetime, it is operated by users or support centers after directives from the manufacturers.

The most dynamic reconfiguration levels, one on a per session basis and one during the sessions are the most attractive features expected from SDR platforms. They are characterized by a continuous service, and enable several service features. They are mainly operated by users or automated by procedures. The control of this two reconfiguration levels is supervised or instantiated by service operators, by adaptive decisional processes derived from the observation of communication and traffic parameters (i.e. congestion, load, link quality).

All the cited reconfiguration levels are possible with SDR architecture, but the last two levels require a consistent technological effort in order to be implemented with reasonable final costs for the device.

The reconfiguration is possible through software architectures, whose reference in the literature is represented by SCA (Software Communication Architecture) developed in the framework of the US'Army leaded JTRS project [7]. The Joint Tactical Radio System family of radios will range from low cost terminals with limited waveform support to multi-band, multi-mode, multiple channel radios supporting advanced narrowband and wideband waveform capabilities with integrated computer networking features. These radios shall conform to open physical and software architectures. The JTRS will develop a family of affordable, high-capacity tactical radios to provide both line-of-sight and beyond-line-of-sight C4I capabilities to the warfighters. This family of radios will cover an operating spectrum from 2 to 2000 MHz, and will be capable of transmitting voice, video and data.

Following this rationale, a series of research initiatives have been issued to prove the technical feasibility of software radio concepts to satellite communications with added value to offered services. As an example we can consider the context of fast deployable overlay networks. In this case the transportable satellite terminal acts as a service gateway between a local (wireless or wired) terrestrial network and a global satellite backbone. The ideal terminal is a transportable multi-standard terminal, able to select the suitable pair of satellite and terrestrial standards to bridge together. A prototype of this terminal has been designed and partially implemented at CNIT laboratories. The functional block diagram is in Fig. 2.

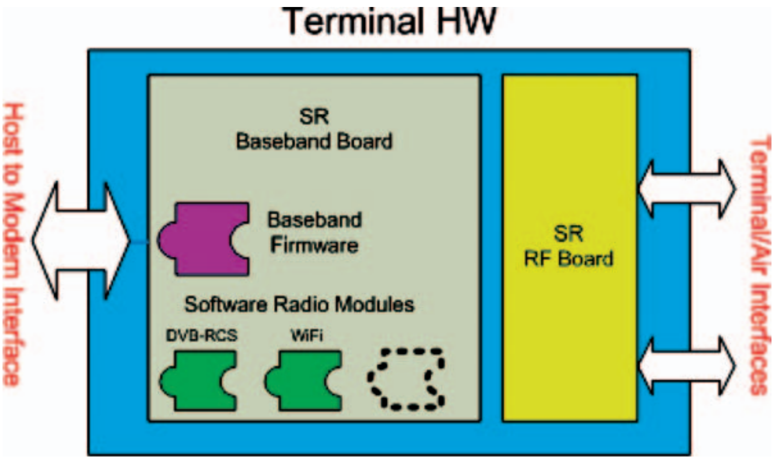

Fig. 2. Software-defined radio satellite terminal functional scheme.

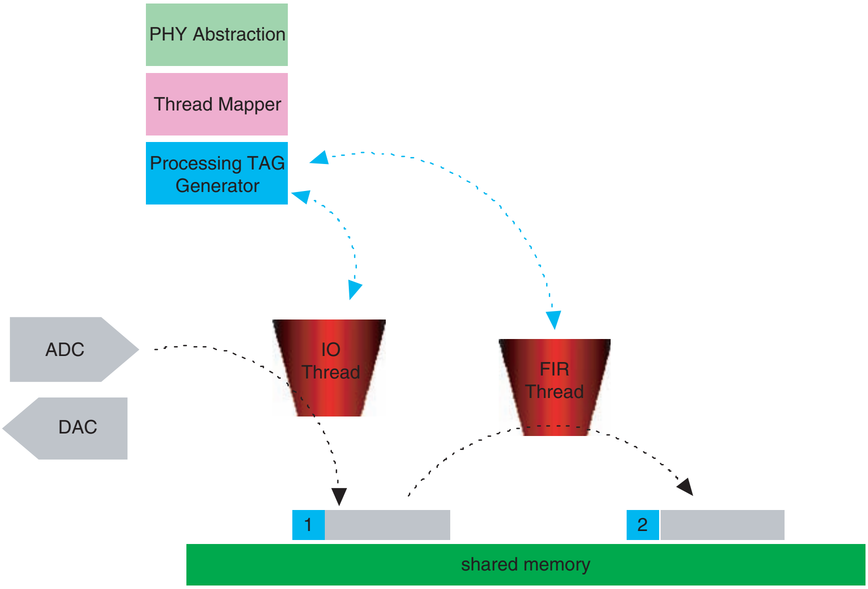

Fig. 3. Parcel processing for SDR computing.

The software definition of signal processing sections will also allow new approaches to signal processing design, removing the limitations imposed by real hardware devices [6]. The most relevant impact of this issue is the adoption on radio devices of processing schemes used by computing. Parallel processing, threads, pipelining are only a few examples of these schemes. Figure 3 shows a novel computing scheme for SDR satellite terminals called *parcel processing*. With this scheme a shared memory is accessed by parallel processing threads implemented on different hardware devices. The processing flow is regulated by labels attached to signal portions (e.g. parcels). This processing method is suitable for multi-hardware software radio terminals and allows complex architectures mixing general purpose and specialized signal processing devices.

4 Securing Devices

The software definition of complex processing functions represents a great opportunity but also exposes the terminal to new dangerous security treads. The most relevant security issues related to SDR platforms are:

Alteration of R-CFG file: event that occurs when an undesired entity substitutes the true configuration file with another one where malicious code is present. Securing the radio definition code downloaded from satellite implies a strong authentication of the source and a shared key mechanism to secure the download phase. In addition a tamper-proof HW is required, to be authenticated by the service provider.

Violation of user's privacy: usually managed by mechanism in upper layers, with the exception of the replacement of MAC address with a dynamical *Temporary Mobile Identifier* (TMI) to address the SDR device.

Terminal cloning: obtained through copies of R-CFG code on anonymous HW. The only solution is to insert a unique identifier on HW in order to authenticate the overall (SW+HW) terminal. This is a difficult task, however, on SDR platform where GPPs are employed.

HW tampering and cloning: is somewhat related to the previous item, and occurs when generic clones of HW platforms are released. A solution may be represented by the trusted computinh [8] (TC) paradigm, but it is still a controversial issue. TC in the personal computer field is considered a limiting factor to the freedom of the market.

5 Adding Intelligence to Communication Devices

The natural evolution of a dynamic HW satellite terminal is the adoption of intelligent decisional processes implemented in the terminal itself. When a complete cognitive cycle is adopted, we refers to it as *cognitive radio* [2].

The main objective of this features is the smart, dynamical distributed selection of communication resources through sensing and learning. The main advantages in the satellite context is similar to those in the terrestrial wireless: the coexistence of a primary communication service, like DVB-S downstream, with a secondary service without any perceived degradation in the performances of the primary service.

Cognitive radio features for the satelite terminal requires an additional technological effort in terms of integration with sensors (environmental, spectrum and terminal status) and the development of context-aware services. Moreover, the latencies experienced in GEO system represent heavy limitations to the processes involved in the cognitive cycle.

6 Conclusions

Satellite Terminal reconfigurability is a great opportunity for manufacturers and service operators both in terms of production efficiency and implementation of new services. The main enabling technology for reconfiguration is represented by software radio, which can improve size and mobility of terminals and their integration with other communication systems. The adoption of SDR technology on the design of mobile satellite terminals represents the most challenging and evolutionary scenario, at the same time, it is also a consistent technological effort for the scientific community and manufacturers. Many technological aspects still remain to be investigated in several areas: cognitive processes, security, and signal processing design.

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