CENTER FOR SOFTWARE DEFINED RADIO

Software Defined Radio

Application, trends and standardisation

White Paper, October 2008

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Why this document?

Software Defined Radio (SDR), is it a buzz-word or are we close to the commercial mass market? This white paper has been created to provide an easy readable status on the development of SDR and its introduction in the commercial market.

It starts with a brief overview of the application areas for SDR, followed by a short description of the development path, and finally it sums up on the identified challenges with respect to development and standardisation work.

The previous white paper from CSDR "Software Defined Radio – Terms, Trends and Perspectives" [1] provides a deeper focus of the SDR components.

SDR – always best connected

As an example, the modern cell phone, or let us define it as the modern personal communication device, provides access to a wide range of wireless technologies, such as Bluetooth, UMTS/ HSDPA, WiMAX and WLAN/DECT. The selection of the applicable technology depends on the actual application, whether there is a need for bandwidth, mobility or communication range.

The modern personal communication device supports the different wireless technologies in terms of individual radio systems for each of the mentioned technologies. Except for the automatic selection between equivalent technologies like GSM and UMTS due to insufficient signal level, the selection of the technology is mostly made by the end-user.

These technologies are not the only ones. In principle, there are several new technologies that have to be taken into consideration in order to ensure that the terminal is always best connected to one of the available access technologies in a global information community.

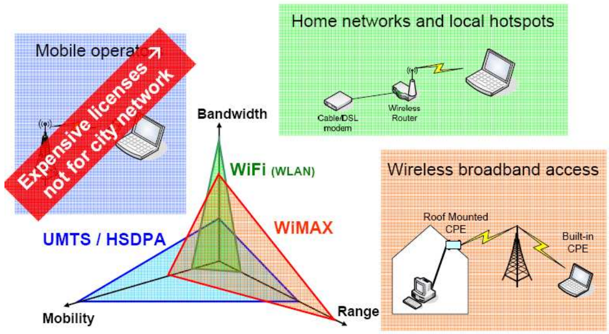

Figure 1: Technology versus demands [4]

The global information community consists of a pamphlet of different network technologies, each of them optimised to provide the right combination of mobility, bandwidth and communication range for their proper usage. An example of this is shown in Figure 1 with UMTS/HSDPA, Wi-Fi and WiMAX.

The overall network infrastructure in the global information community will be a heterogeneous environment where information sharing between different systems is required to facilitate joint network management and allow utilisation of several disjoint frequency bands.

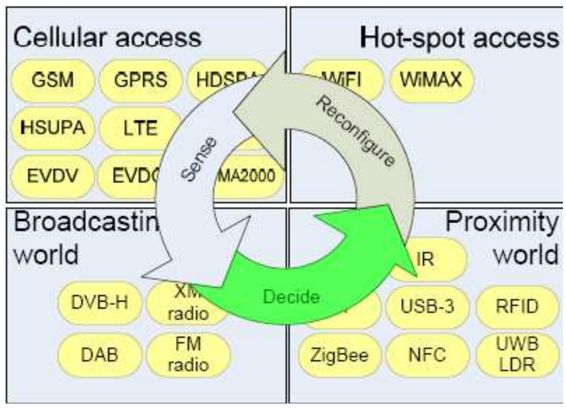

Figure 2: Cellular, hot-spot, broadcasting - they are all part of the global communication network [5].

The pamphlet of wireless technologies can be separated in cellular access, hotspot access, broadcasting world and the proximity world as shown in Figure 2.

The locally deployed network will only be a subset of what is shown in Figure 2 with at least a cellular network combined with a hot-spot network and one or two technologies from the proximity world.

The end-user will have different service demands depending on whether he is on the move or back in the office. When on the move, mobility is important while the bandwidth demands are typically limited. In the opposite, when the user is in the office bandwidth is a necessity while the requirements to mobility are less important.
This means that the available resources, like capacity and spectrum, can be used more optimally by allowing the end-user (or more precisely the end-user's device) to connect to the most suitable technology depending on the current demands and at the same time be economical beneficial for both the operator and the end-user.

What is most the "appropriate" access technology depends on the requirements for capacity, quality, mobility and communication range and must be evaluated continuously in order for the end-user to be at the "right" technology.

The selection of the proper network technology can either be made by the end-user or the terminal. The on-going trend shows that the end-user wants the technology to decide on "always best connected" as long as the shifting of technology does not affect the user perception of the provided services.

In order for the devices to make seamless inter-technology handover we need to integrate multiple radio systems in the end-user devices. We can do this by adding several RF modules, each for every technology, or using SDR.

In principle, a SDR consists of a hardware front-end and a software based base-band platform. The hardware front-end includes an antenna, an amplifier/filter, a down/up-converter and an AD/DA converter all supporting the necessary carrier frequencies and the band-width. The base-band part is built up by e.g. reconfigurable FPGA that can be re-loaded with the appropriate waveforms, e.g. LTE or WiMAX. The long term goal for SDR is to extend the AD/DA to the antenna, speaker and microphone (the ideal software radio).

In order to be always best connected, the personal communication device has to go through a selection process. This process includes continuous radio channel sensing, deciding and reconfiguring of the end-user terminal including physical layer adaptation, as shown in Figure 2:

- **Sense**: spectrum sensing, ID existing services, estimate duration of availability + cost of usage

- **Decide**: how many users, what duration is required, bandwidth required, destination informed, conflict resolution

- **Reconfigure**:
  - Use: Spectrum still available? Possible interference event?
  - Release: Handle difference in usage duration

To some extent, intelligent selection of the appropriate network technology can be made today, but by SDR the intuitiveness in the selection becomes clearer as SDR provides software controllable support for multiple access technology using a common base-band platform and a single RF front-end with only one antenna.

As discussed later there are still several challenges that have to be alleviated in order to have a competitive solution for SDR as compared to today's implementation of multiple radio-systems that supports individual network technologies like GSM, UMTS, Wi-Fi and Bluetooth.

SDR provides more flexibility in network topologies due to the easier re-configurability, but it requires also more data to be collected in data-bases for network management, radio resource management and mobility management. These data are needed in order to guide the terminal to the proper access technology, an issue that is important especially when the personal device is turned on and the device starts searching for available wireless networks.

Commercial application with SDR and roadmap (past and future)

Military communication equipment must provide continuous access connectivity independent on the physical location.

In order to support this today, a number of different devices have to be on-board in military vehicles. The individual devices provide access to the individual radio communication system and thereby taking up significant amount of physical space. SDR, and hence only one physical communication platform, is a way to limit the physical space requirements. Furthermore, SDR provides a sufficient flexibility for providing access to locally available communication systems as well as an easy upgrade as new standards for access technologies are released.

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The research activities related to a future communication system based on SDR for military use started in 1996 and has evolved since then:

- **1996**: launch of the project Joint Tactical Radio System (JTRS). The focus of the project is to provide a SDR based solution for ground and air communication of voice, video and data.
- **2001**: release of the version 2.2 of the Software Communication Architecture (SCA). SCA is used in the JTRS project and it is expected also to be the basis for commercial standard for SDR.
- **2008**: narrow the scope of the JTRS project to a SDR based Ground Mobile Radio that can be applied to Marine and Army vehicles as well as Army helicopters. The SDR shall work with many existing military and civilian radios and include encryption and support for creation of mobile ad-hoc network. The current time frame for military use is 2010.
- **2010**: the European Defence Agency (EDA) is expected to release the Euro-SDR prototype providing a European secured software-defined radio referential (ESSOR).

In parallel to the projects JTRS and ESSOR, there are a number of activities focusing purely on commercial use.

The initial focus of the commercial use of SDR has been cellular base stations, satellite communication, solutions for intelligent transport systems, and public safety, basically because they represent a fairly expensive entity with a longer life cycle than e.g. personal handheld devices.

The current releases of SDR based base-stations support a relative narrow frequency band. Base stations are normally either purely for WiMAX (fixed or mobile) or for a combination of GSM, CDMA and iDEN. Within a couple of years, SDR based base stations with support for LTE-Advanced and WiMAX-Advanced will be released [2].

As the underlying hardware platform evolves and supports wider frequency range, more cellular access technologies will be added in the future and thereby provide a single base station solution for UMTS/HSPA, LTE and WiMAX. Whether or not the 2G technologies GSM and GPRS/EGDE will be supported in the base station depends on the foreseen release date of the base stations as these networks may begin to be faced out from 2012. Introducing SDR does not only provide a platform for easy upgradeability, but it has also the advantage that it reduces the required floor space.

As SDR becomes more mature, it will naturally be included in mass-market products like mobile terminals. The life-time for a terminal is roughly 1-2 years and is by no mean a high price product, but the benefits of streamlining the development process are significant compared to the short life-time.

SDR soft upgrade for mobile devices covering multiple standards including WiMAX, GPS, 3G and Wi-Fi are foreseen in 2011 – 2013, and it is expected that the market for SDR is mature in 2015 with the release of the commercial mobile phone implementation (see Figure 3).

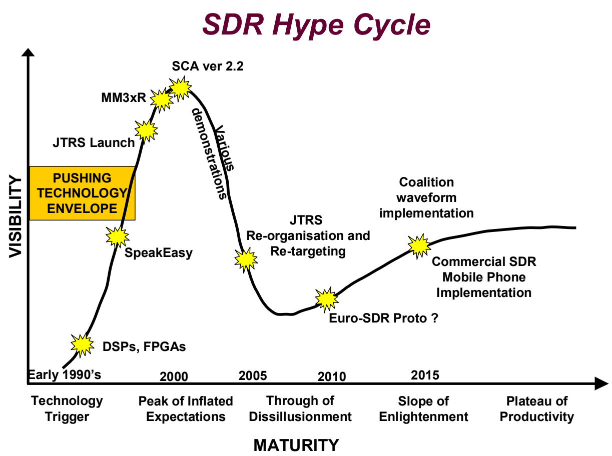

Figure 3: Hype cycle for SDR and CR [3]

According to [2] and [3], SDR will be applied in Intelligent Transport Systems as there is an increasing demand for keeping track of goods. This requires continuously monitoring of the container's content (e.g. by RFID) and location tracking (by GPS). The information has to be forwarded to the right entities which require connection to the available access technology.

Furthermore, there is a need for easy upgrade of the supported radio-access technologies. Hereby, a SDR based solution has its advantages compared to a traditional HW specific communication solution [3].

The introduction of SDR in both the terminals and the base stations will allow the equipment to have the necessary flexibility, especially when spectrum trading becomes fully available. Hereby, the same amount of spectrum can be used for a variety of wireless technologies without leaving the national telecom authorities with the control of spectrum. According to [2], spectrum trading will be a reality around 2013 starting with more intelligent band management techniques in 2009.

Challenges and Standardisation

Even though the development of SDR has now been going on for more than 10 years, there are still a number of challenges that has to be solved before the ideal software radio is available. Currently, the software reload-time of new waveforms, and thereby support for new access technologies, is too long. At the same time, the power consumption for a SDR based solution is higher than in non-SDR solution and hence provides an increase in power in a time where there is a strong focus on green technology and battery life-time.

Furthermore, research is on-going within broadband antennas, RF linearization and AD/DA conversion.
For the antennas, generations of re-configurable antennas will appear on the market in 2008-2012, some of those based on plasma. Antennas based on plasma and meta-materials are considered with an expected release in 2009-2013.

In order to support the multiple cellular access technologies, there is a need to develop an RF front-end that is sufficiently linear on the entire frequency band. Currently, only frequency-neighbouring access technologies are covered, but as the supported frequency band increases it will be possible to add technologies being frequency wise apart.

For the AD/DA conversion there is a need to increase the word-length to support the ever increasing bandwidth demands.

In parallel to the on-going research on SDR in general and more specifically on the HW challenges, there are a number of interest and standardisation bodies involved such as SDR-Forum, IEEE and ETSI:

- The standardisation of SCA takes place in the Open Management Group (OMG).
- ITU-R 8A focuses on a recommendation for allocation of the proper frequency band for SDR. The decision will be taken at the World Radio Conference in 2011 or alternatively in 2014/15.
- ETSI has created a sub-group in 2007 on SDR to put more attention on SDR
- 3GPP looks at the specification for LTE-Advanced
- IEEE focuses in on 802.21 and P1900.1-4. IEEE P1900 concerns the architecture as well as the protocols for optimising the radio resource usage. It is expected that the first IEEE P.1900.4 based devices will be available in 2011.
- The Open Management Alliance (OMA) looks at equipment management protocols
- IETF consider network capabilities and protocol enhancement, also for SDR.

To this list of organisation involved in SDR can be added OBSAI, CPRI and GNURadio.

Summary

The market for SDR is under development. The current applications of SDR are dedicated solutions like the US Military radio for ground-mobile communication as well as the development of SDR based base stations for CDMA1900 and GSM1900, and WiMAX.

One of the drivers for SDR is the continuous increase in spectrum demand with focus on spectrum efficiency (see IEEE P.1900.2). SDR, in itself, may not provide a solution for this, but its possibility to shift to other technologies provides an opportunistic spectrum use and spectrum sharing.

Future development will extend the number of applications with SDR for both military and commercial usage.
We will see an increased focus on standardisation for both software and the underlying hardware, e.g., via the focus from ETSI. There will, however, be acceptance of local request like local security applications.

SDR based solutions take less footprint due to the reduction of the number of individual RF systems that must be simultaneous present in e.g., the mobile terminals.
Furthermore, the available capacity will increase in both terminals and non-portable devices as the DSPs and the FPGAs become more powerful with lower power consumption and smaller size.

References:

[1] ”Software Defined Radio – Terms, Trends and Perspective” by Center for Software Defined Radio is available at http://www.csdr.dk/CSDR/Whitepaper.aspx

[2] “Military Applications of Software Defined Radios“ by LtCdr GS Topi TUUKKANE, Finnish Defence Forces CIS Centre, Development Division, E-mail: topi.tuukkanen@mil.fi

[3] http://www.sdrforum.org/uploads/news_441550Rome_2008_Meeting_synopsis.pdf

[4] Presentation by Bart Lannoo, Ingrid Moerman, Ghent University – IBBT, “Municipalities as a Driver for Wireless Broadband Access” given at the Strategic Workshop on the Global Information Multimedia Communication Village, Madeira 2008

[5] Presentation by Laurent HERAULT, CEA, ”Enabling technologies & convergence” given at the Strategic Workshop on the Global Information Multimedia Communication Village, Madeira 2008