Trends in Research and Development of Software Defined Radio

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Abstract

Software defined radio, which is constructed with programmable devices such as digital signal processors and field programmable gate arrays, is an attractive technology that enables a single terminal to handle various kinds of wireless systems: the terminal's software is simply changed to reconfigure its functions. This paper reviews the background and trends in the research and development of software defined radio and introduces NTT's recent activities.

1. Introduction

Recent technical progress and cost-reductions in digital signal processing devices and urgent demands for seamless mobile communications are driving the research and development of software defined radio (SDR), which enables a single terminal to handle various kinds of wireless systems through a simple change in software to reconfigure the terminal's functions. Its application areas include military use, home networks, intelligent transport systems, and broadcasting, as well as cellular communications. The SDR terminal is constructed with programmable devices, such as digital signal processors (DSPs) and field programmable gate arrays (FPGAs), and employs multiband radio frequency (RF) circuits (Fig. 1). Japan currently uses second-generation (2G) mobile systems such as PDC (Personal Digital Cellular) and PHS (Personal Handy-phone System), and a third-generation (3G) mobile system, W-CDMA. In addition, next-generation mobile systems that can offer higher data-rates up to 100 Mbit/s are being developed [1]. This complex situation is mirrored overseas where many kinds of mobile systems (GSM, AMPS,

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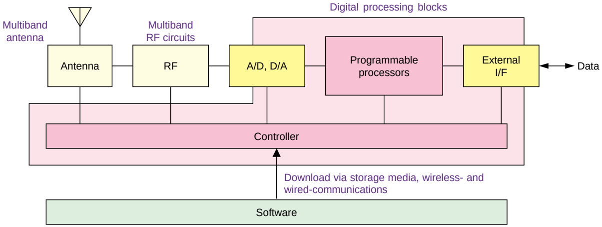

Fig. 1. Typical SDR architecture.

etc.) are in use. In addition to these public mobile services, many private systems such as IEEE802.11x wireless local area networks (WLANs) and Bluetooth have become popular. Users need to buy a dedicated terminal for each system because these systems have their own specifications in terms of frequency, modulation and demodulation schemes, and communication protocol. Furthermore, the coverage of these systems is restricted to specific areas. SDR is seen as the best way to achieve seamless mobile communication. This paper reviews trends in the research and development of the software defined radio and introduces NTT's recent activities.

2. Features of SDR

Figure 2 schematically illustrates some of the future possibilities that could be enabled by SDR technology. Seamless ubiquitous communication could be possible by selecting the wireless system corresponding to the location and the user's requirements. You can access the best system available. Overseas travelers simply download the software of the system used in the country they are visiting. Moreover, the desired quality of service can be maintained while improving service economy according to the data-rate and fee [2]. Over-the-air downloading lets you upgrade your terminal as new functions become available or bug-fixes are released even when you are at home (Fig. 3). SDR technology is also very attractive for operators. Conventionally, many workers are needed for time-consuming work to upgrade or bug-fix the enormous number of cellular base stations. SDR base stations can be remotely bug-fixed quickly by downloading new software via the network (Fig. 4). SDR technology also brings benefits to manufacturers. They no longer need to develop specific chips for each system in a very short time. All they have to do is develop software, so this can reduce development time and cost. This scheme allows new technologies to be commercially introduced much more quickly than the conventional one, so it may be possible to alleviate the recent shortage of frequency resources by quickly utilizing future technologies and systems that have greater spectral efficiency.

3. Trends in SDR

The R&D of SDR was originally started in the 1980s to develop a US military communication system. It has been continuing as the JTRS (Joint Tactical Radio System) project. In the 1990s, it was driven by rapid progress in technologies and cost-reductions in digital signal processing devices, such as DSPs and FPGAs [3]. In 1996, the SDR forum (formerly the MMITS forum) was established and it currently has more than 100 members worldwide [4]. The SDR architecture and program download schemes have been discussed in the SDR forum and at many conferences [5]-[7]. In June 2000, Motorola announced

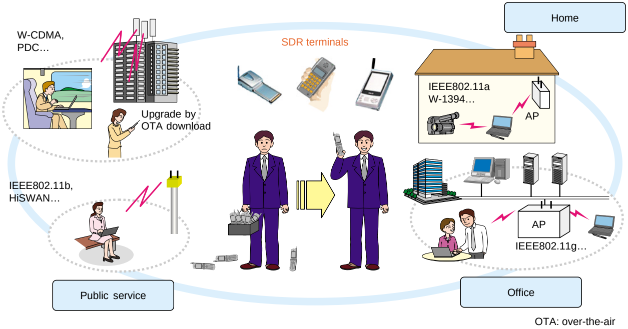

Fig. 2. Possibilities enabled by SDR technology.

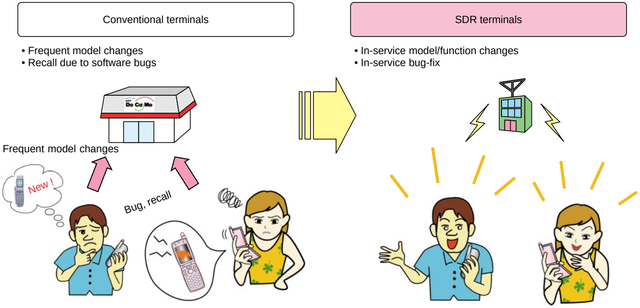

Fig. 3. Simple upgrading of user terminals by over-the-air downloading.

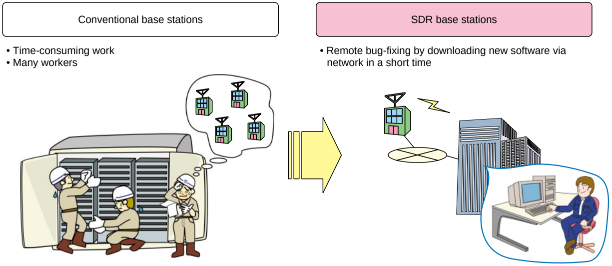

Fig. 4. Simple remote bug-fixing of base stations by downloading software.

that they had started to develop a cellular SDR terminal. In September 2001, the US Federal Communications Commission (FCC) adopted rule changes to accommodate the authorization and deployment of SDRs [8]. The new rules allow manufacturers and operators to reconfigure devices after they have been deployed in the field.

In Europe, there are many SDR-related co-projects, such as MMR (multi-mode multi-protocol radio), SORT (software radio technology), PROMURA (programmable multimode radio for multimedia wireless terminals), SLATS (software libraries for advanced terminal solutions), and TRUST (transparently reconfigurable ubiquitous terminal), under ACTS (Advanced Communications Technologies and Services), ESPRIT (European Strategic Program for R&D in Information Technology), and IST (Information Society Technologies) projects. They have mainly been making new concepts for SDR (some projects have already ended).

In Japan, a study group for software defined receivers was organized in the Association of Radio Industries and Businesses (ARIB) with the support of the Ministry of Post and Telecommunications (MPT) of Japan in 1996 and the final report was completed in 1999 after three years of study [9]. In December 1998, a software radio study group was organized in the Communication Society of the Institute of Electronics, Information, and Communication Engineers (IEICE), Japan. The group has been very active in discussing SDR issues including devices, algorithms, application programming interfaces, operating systems, software downloading, regulations, and so on [10]. In April 2000, the Telecom Engineering Center (TELEC) with support from the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT, formerly MPT) of Japan started three years of serious discussions towards accepting the SDR concept in the Japanese legal and regulatory environment, and the final report was made in March 2003.

The major technical issues for SDR mobile terminals include developing high-speed and low-power-consumption programmable devices, and small multiband RF circuits. Some R&D organizations including NTT have continued to study these technologies.

4. NTT's activities

In 1999, we developed the first SDR prototype that can support cellular systems such as Japanese PHS. It handled only narrow bandwidth (up to a few hundred kilohertz) wireless systems, which use the TDMA (Time Division Multiple Access) scheme [11]. It could not handle wireless LAN systems that use the DSSS (Direct Sequence Spread Spectrum) scheme because it cannot handle the required bandwidths of more than 20 MHz. In November 2001, NTT announced the successful development of an improved SDR prototype that can support both low-speed wireless systems such as PHS and high-speed, broadband wireless systems such as IEEE802.11 wireless LAN [12]. We developed a novel wideband flexible-rate pre-/post-processor (FR-PPP) to overcome the bandwidth restriction (Fig. 5) [13]. The FR-PPP consists of FPGAs and a direct digital synthesizer (DDS). Conventional pre-/post-processors (PPPs) have preset parameter hardwired circuits including various kinds of filters to support the targeted wireless systems. Therefore, their circuit scale is excessive. The FR-PPP is much smaller because the FPGA can flexibly act as whatever filters are needed for each system. In addition, while conventional PPPs use complicated interpolation circuits to support the various clock-rates of the targeted wireless systems, the DDS in the FR-PPP directly generates any clock-rate that is needed. This also reduces the circuit scale and offers high-speed operation. These breakthroughs make possible a wide-bandwidth and very flexible SDR that can support wireless LANs as well as 2G systems such as PHS. The processing power of the prototype can also support 3G systems such as W-CDMA. We also developed a multiband RF circuit that can cover the frequency bands from 900 MHz to 2.5 GHz by using direct conversion technology [14]. In addition, over-the-air downloading was success-

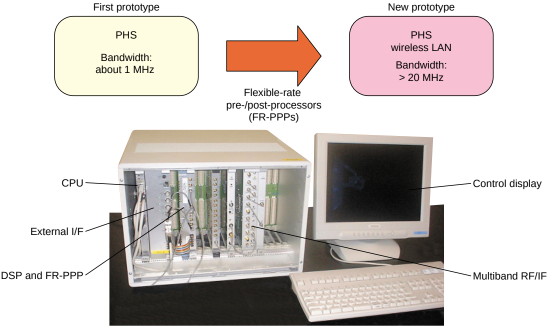

Fig. 5. NTT's new SDR prototype supporting PHS and IEEE802.11 wireless LAN.

fully implemented. Its protocol is very general and compact because it is based on TCP/IP and uses the physical layer of the active wireless system. To ensure that downloads are secure, the 128-bit next-generation block cipher "Camellia," which was co-developed by NTT and Mitsubishi Electric Corporation, was implemented in the protocol [15]. The following three selected papers in this issue describe these results in detail.

5. Conclusion and future plans

This paper reviewed trends in the research and development of software defined radio and introduced NTT's recent activities. The results of feasibility studies are showing that SDR technology will allow a single mobile terminal to cover second- and third-generation mobile systems, as well as higher-speed and broader-bandwidth wireless systems such as wireless LANs. However, in making compact, low-power-consumption equipment we must minimize hardware and software overheads. The processing power and power consumption of programmable processors needs to be greatly improved. Multiband RF circuits need to have a wider coverage: the broadcasting bands and 5-GHz bands. NTT Laboratories have been working hard to make an SDR mobile terminal whose size, cost, and power-consumption rival those of current mobile terminals.

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