Needs, research and development on software defined cognitive radio technology

Hiroshi Harada

National Institute of Information and Communications Technology (NICT)
3-4 Hikarino-oka, Yokosuka, 239-0847, Japan, E-mail: harada@nict.go.jp

Abstract

This paper summarizes needs of cognitive radio on the basis of latest Japanese frequency allocation environment. To realize the technology, National Institute of Information and Communications Technology (NICT) and a Japanese operator and some manufacturers have a project supported by Ministry of Internal Affairs and Communications (MIC) to research and develop enabling technologies on cognitive radio/dynamic spectrum access (CR/DSA) equipments. This paper also summarizes the projects briefly and also introduces research projects in NICT internally. Especially, this paper introduces a user-centric cognitive wireless network over multiple wireless operators: cognitive wireless clouds (CWC) proposed by NICT internal project.

1. Introduction

Currently, a number of wireless access systems have been available to users. Especially, several new systems can be used on not only 800-6000MHz band that is suitable for cellular communications and broadband wireless access systems but also the lower frequency band such as VHF and UHF bands and the most frequency bands adequate for mobile communication systems have been assigned to the services that will be started in 2010-2015.This means that there are no frequency bands to assign such newly standardized radio access technologies (RATs) and we need to consider solutions to secure frequency bands. We can come up with four solutions as shown in Figure 1. The first solution (a) is a conventional method that re-allocates the frequency band for conventional systems and secure new vacant frequency band. The method may sounds logical, but it takes very long time to mover frequency bands for conventional systems from one place to the other places. Currently, for example in IEEE, new wireless communication systems have been standardized every approximately two years. So we need to do so many re-allocations. This looks like unrealistic. The second solution (b) is underlay approach that used for ultra wideband (UWB) systems. To secure broadband, the newly assigned wireless systems reduce its operational transmission power and co-exist with conventional wireless communication systems. This approach also looks good but the method is not good for the systems that cover large area like cellular phone. The third and fourth approaches ((c) and (d) in Figure 1) are based on "Cognitive Radio/Dynamic Spectrum Access (CR/DSA)" technology [1][2]. In the both approaches, radio equipment needs to have a function to sense its operational environment. The third approach needs to find vacant frequency bands and/or vacant time slots. Once the vacant frequency bands and/or the vacant time slots are found, the users will use the bands and slots to communicate each other and realize broadband communications without moving any frequency band of conventional communication systems and without frequency re-allocation. On the other hand, the fourth approach needs to sense conventional communication systems. Once the systems are found, by bundling several communication systems, a broadband communication will be realized without moving any frequency band of conventional communication systems and without frequency re-allocation.

The introduction of CR/DSR is dependent on policy of frequency assignment of each country. Especially, in Japan, there is no auction to assign new frequency bands to the users (operators). The procedures to assign new frequency band are managed by Ministry of Internal Affairs and Communications (MIC). When MIC would like to proceed a new frequency assignment, MIC firstly shows the detail of new frequency band to be allocated to new application and calls for the proposal of necessary bandwidth and usage model. Then, a committee based on open discussion decides fundamental technical requirement included bandwidth, frequency mask, interference level and so on, usage model, and conditions for the operators (if needed) and the results are returned to the MIC. Then MIC decides the fundamental technical requirement and operators (not mandatory, dependent on usage model), and amends the Radio Law (if needed). Moreover, the standardization body (not managed by MIC) decides the detailed technical requirement. If an operator stops the service or breaks the service, the operators must return the frequency back to the MIC. Currently, in Japan, secondary use by operators for the allocated frequency band on the basis of CR/DSR technology has not been permitted. However it is very important to consider the introduction scenario of the CR/DSA technologies to the future wireless network.

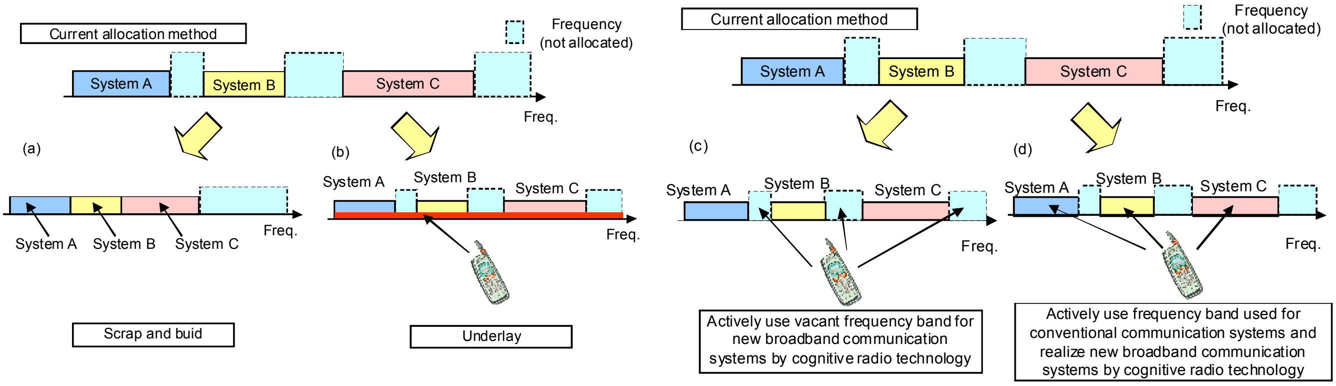

Fig. 1: Four solutions to secure frequency band.

This paper firstly explains some scenarios to introduce the CR/DSA technology to the network and introduces research projects funded by MIC and managed by NICT. This paper moreover introduces a user-centric cognitive wireless network over multiple wireless operators: cognitive wireless clouds (CWC) proposed by NICT internal project to realize the introduction scenario based on common wireless network platform.

2. Concept of Cognitive Wireless Network

In this paper, CR/DSA technology is defined as a radio or system that senses, and is aware of, its operational environment and can dynamically and autonomously adjust its radio operating parameters accordingly by collaborating wireless and wired networks [2][3] as shown in Figure 1. To introduce CR/DSA technologies to the wireless network and configure the network as cognitive wireless network, three steps must be needed by considering current status of frequency allocation plan in Japan as shown in Figure 2.

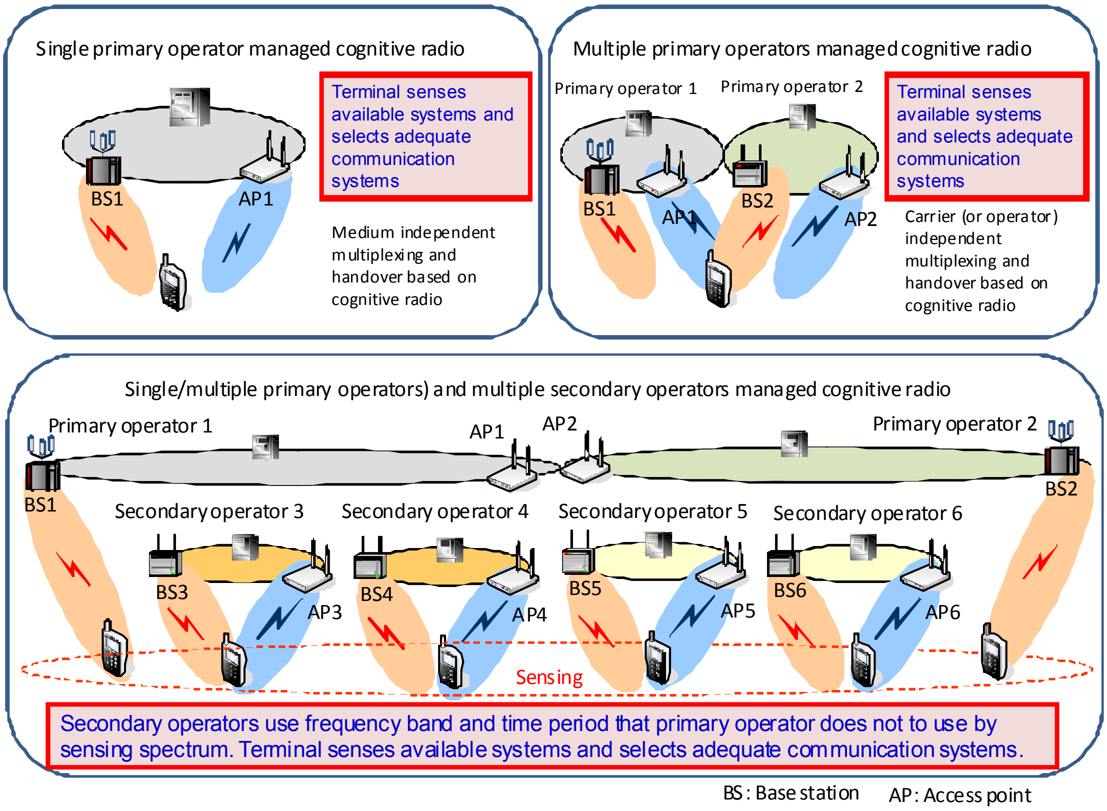

Fig. 2: Three scenarios to introduce CR/DSA technologies to wireless networks.

The first step is to introduce the cognitive radio technology to primary operators. By collaborating between radio access networks (RANs) in each primary operator, the adequate frequency bands are secured over heterogeneous networks. The second step extends the concept of the first step to multiple primary operators. By collaborating between RANs in the multiple primary operators, the adequate frequency bands are secured over heterogeneous networks.

The third step is the final solution when the second step cannot fulfill the demand of users on broadband communication. In the third step, on the common frequency band with primary operators, the secondary operators exist. By collaborating RANs between multiple primary and secondary operators, the adequate frequency bands for users are secured over heterogeneous network.

To promote research and development of the cognitive radio technology, Ministry of Internal Affairs and Communications (MIC), JAPAN started a project regarding the method to improve spectrum utilization efficiency funded by spectrum usage fees in 2005 as shown in Figure 3. The project includes four research topics: (1) research and development on elemental technology for cognitive radio terminals, (2) research and development on cognitive radio communication technology [4], (3) research and development on improved technology of frequency utilization in space domain, and (4) research and development on super-semiconductor based filter technology. The first two research topics are closely related to the research of cognitive radio. Especially, NICT have researched and developed enabling technologies for the CR/DSA based radio equipments since 2005 and in addition, as shown in Figure 3, NICT has two more research projects on software defined cognitive radio (SDCR) equipment and software defined cognitive wireless networking and its related technologies. As for radio equipment related research results, References [3]-[6] explain them. The next section explains an original cognitive wireless network: cognitive wireless cloud.

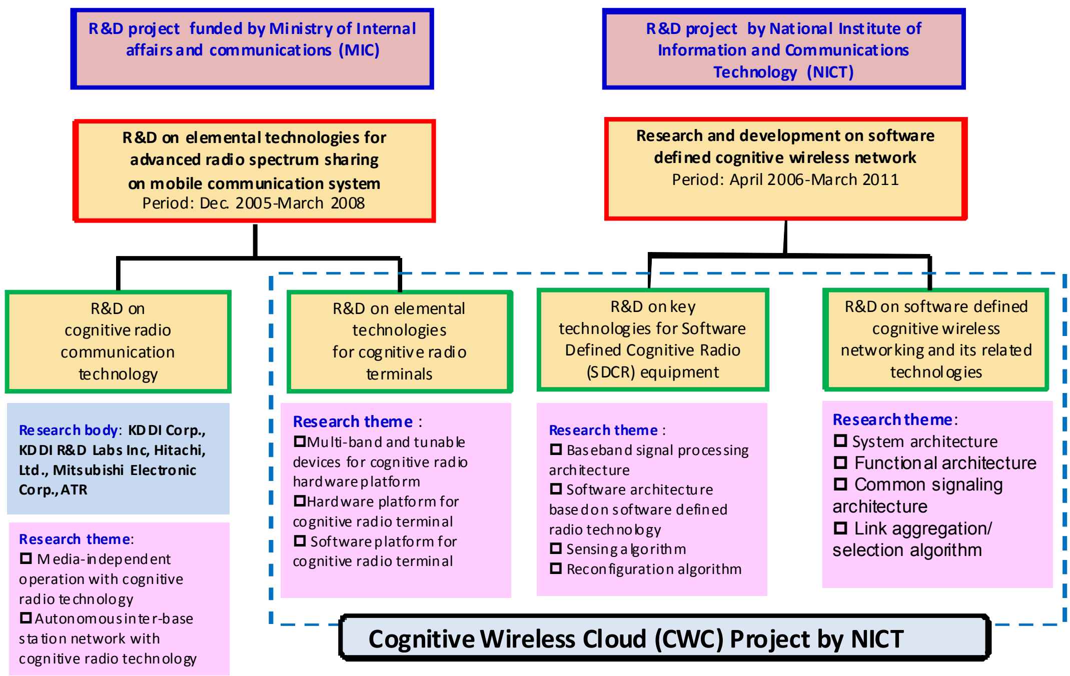

Fig. 3: Project overview related to CR/DSA technologies.

3. A Cognitive Wireless Network: Cognitive Wireless Cloud

In the research project on cognitive wireless network in NICT, a cognitive wireless network named cognitive wireless clouds (CWC) has been proposed [7]. Figure 4 shows the concept, briefly. First of all users sense RATs by using cognitive radio terminal and send the results to the cognitive network managers (CNMs). CNMs collect the sensing information from users, and analyze the information, and decide a recommended network policy. CNMs are distributed to the network and they work jointly to decide recommended RATs to the users. The recommended policy may be a list of recommended RATs that are dependent on each user's location. When users move from one place to the other, the users newly start to sense usable RATs and also request to CNMs to get network policies (or recommended RATs from the viewpoint of the networks). By using sensing information by users and the network policies and users' preference, users finally decide RATs to connect, where user's preference is very important because each user has some limitations to select RATs: in the case of students the most important preference may be cost to use RATs and in the case of business men it may be the speed of wireless network. As described in the above, CWC is user (terminal) centric network. It is therefore possible to be extended to a operator (carrier) independent networking. For optimization of radio resource management of such a scalable network having multiple operator networks and terminals, distributed optimization and management methods by using CNMs should be applied to keep using the most appropriate wireless configurations adaptively.

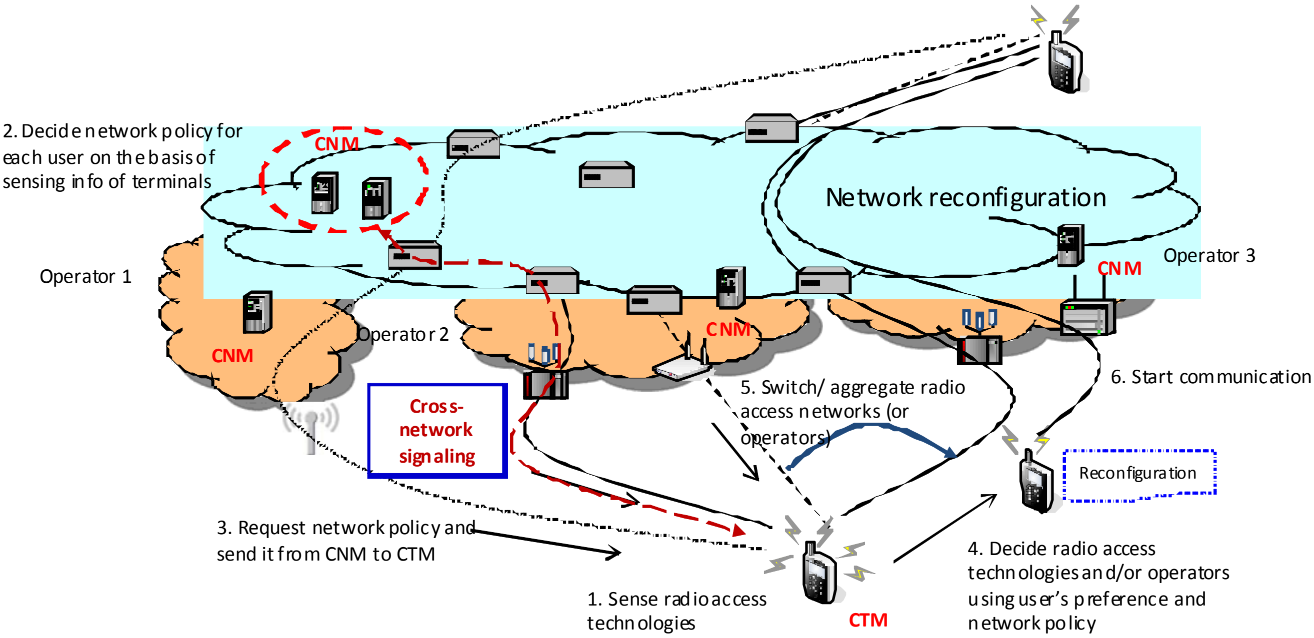

Fig. 4: Cognitive Wireless Cloud (CNM: Cognitive Network Manager, CTM: Cognitive Terminal Manager).

4. Conclusion

This paper summarized needs of cognitive radio on the basis of latest Japanese frequency allocation environment and also summarized the projects funded by MIC briefly and also introduced research projects in NICT internally. Especially, this paper introduced a user-centric cognitive wireless network over multiple wireless operators: cognitive wireless clouds (CWC) proposed by NICT internal project.

5. References

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