An Activation Management Method for Cognitive Radios Based on Human Activities

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1 Introduction

There are regional disparities in communication services between city areas and rural areas. Radio communication can provide information services with persons in rural areas at a lower cost, but almost of all radio frequencies for radio communication are fully-used by various existence systems. Therefore, cognitive radio as a method for alleviating regional disparities in information services has been paid attention. Cognitive radio cognizes radio-frequency usage and sets the appropriate parameters such as frequency, modulation, and coding autonomously so as to coexistent with other radio systems, and therefore it can produces new frequency resources [1].

These underlay techniques are employed in part by IEEE 802.22 standardization [2], and the techniques have considered in television (TV) and cellular bands [3] and in U.S. unlicensed TV broadcasting bands [4]. Adaptive inter-system handover, software radios, and dynamic spectrum access techniques have been proposed to alleviate interference with coexistence systems. An inter-system handover testbed was developed [5], and dynamic spectrum access techniques are of interest in researchers [6–8].

In this paper, an activation management method for cognitive radios is proposed to further alleviate interference with other radio systems. The idea is based on differences in radio frequency usage as human activities that weather, temperature, hours of a day, and days of a week effect on. Radio propagation simulation is carried out to estimate interference on the assumptions that cognitive radios operate at the same frequency of existing digital TV broadcasting. Result showed that coexistence of cognitive radios with TV broadcasting was possible in mountainous areas.

2 Differences in Radio Frequency Usage Due to Human Activities

Meteorological conditions, as well as hours of a day and days of a week, characterize communication traffic for data transmission. In rainy days, for example, communication traffic tends to burst such as a use of e-mail, rather than a use of cellular communication. Comparing it with softly rain, showery weather could concentrate on communication traffic in a place in a short time (Fig. 1). Most of origination and Internet access for personal use are from residential areas on weekdays, in contrast with holidays where they tends to use outdoors. Meteorological conditions and time effect on human activities, and it leads to differences in radio frequency usage.

Observation of hour by hour radio frequency usage shows spatial characteristics as seen in Fig. 2: in morning, peoples incline to watch TV in city areas, rather than data communications. Traffic in data communications increases in city areas during the daytime. In evening peoples in residential areas may watch TV rather than data communications, and tend to use data communications during midnight. Demands for watching TV and for data communications are independent among city areas and residential areas. If we consider the secondary use of cognitive radios in residential areas where TV broadcasting is the primary system, demand for cognitive radios activation is in early morning, evening, and midnight, if the radios do not interfere with existing TV receivers significantly.

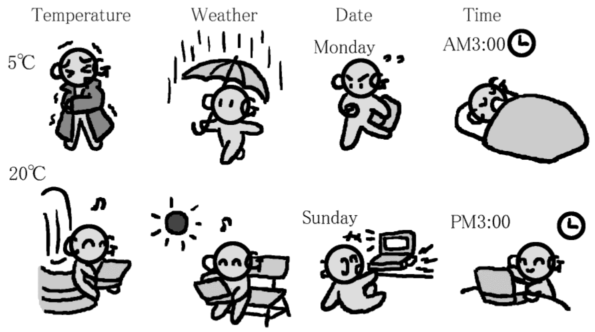

Fig. 1. Radio frequency usage differences due to meteorological conditions.

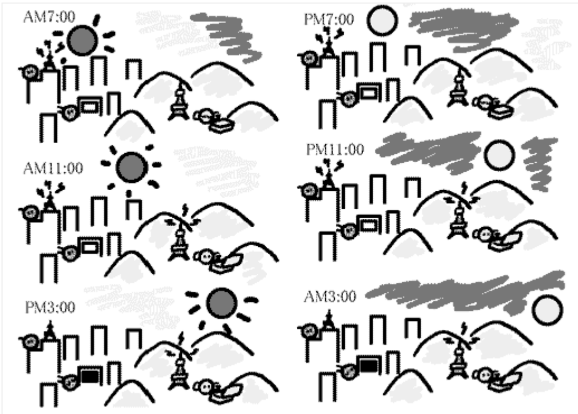

Fig. 2. Hour by hour radio frequency usage differences in a day.

3 Impact of Cognitive Radios on Existing TV Broadcasting Services

Radio propagation simulation is carried out to estimate how cognitive radios interfere with existence radio systems. Here, we consider cognitive radios operating at the same frequency as existing TV broadcasting stations use. We assume information on terrain and use locations of the digital TV broadcasting stations in Hiroshima City, Japan. There are 3 TV broadcasting stations in this area: on the top of Mt. Gongen (the output power is 3 kW), Mt. Yasumi (the output power is 30 W), and Mt. Ege (the output power is 3 W). A frequency of 471 MHz, an output power of 20 mW for cognitive radios, free space propagation for both TV broadcasting signal and cognitive radio signal, a mountain obstruction loss of 40 dB, a thermal noise power associated with 6 MHz bandwidth, and a required signal-to-noise power ratio (SNR) of 55 dB for TV signal reception are assumed in this simulation. Mountain ridges are approximated by lines, the number of mountain that obstruct a radiowave path between transmission and reception points are obtained, and path loss is calculated using Friis' transmission equation with the 2-dimensional distance and losses due to obstruction. Several TV broadcasting stations are available for some locations, and then we choose the strongest one. Radio propagation simulation is done within 37-km lengthwise and breadthwise.

First of all, we evaluate TV broadcasting coverage without any cognitive radios operated in the same frequency and the result is shown in Fig. 3. In this and following figures, grey hatching (low chromaticness) stands for unavailable areas of this TV broadcasting services that do not meet with the required SNR for the TV broadcasting signal reception. Except for some north region, TV broadcasting signal is available.

Next, thee cognitive radios are randomly placed and then we evaluate again (Fig. 4). In contrast with previous one, reception of TV broadcasting is unavailable for most of all locations. This is because TV signal reception requires the high SNR, and cognitive radios interfere with TV signal reception in city and mountainous areas.

Provided that we give up to use some TV broadcasting stations with low output power and cognitive radios would alternatively provide the programs with data transmission, cognitive radios would coexist with TV broadcasting. Because a TV broadcasting station with low output power have a smaller coverage. Figure 5 shows TV broadcasting coverage on the assumption that the station at the top of Mt. Gongen (upper north station) is unavailable. Comparing it with Fig. 3, Fig. 5 implies a use of cognitive radios are possible within the hatching area within specific durations that have higher demands for data communications and lower demands for watching TV. Agreements between primary and secondary provider at the frequency and demand analysis are a key for information services in rural areas with underlying cognitive radios.

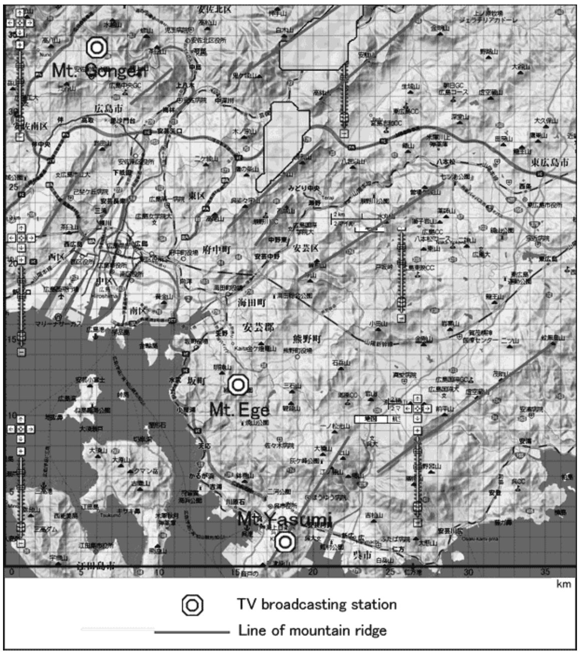

Fig. 3. TV broadcasting coverage without any cognitive radios.

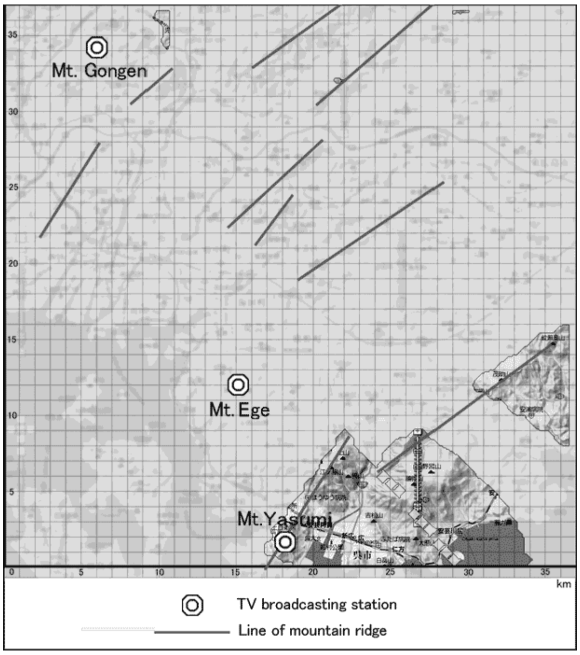

Fig. 4. An example of TV broadcasting coverage with three randomly located cognitive radios.

4 Conclusion

An activation management method for cognitive radios was proposed to further alleviate interference with other radio systems. Meteorological conditions, as well as hours of a day and days of a week, characterize communication traffic for data transmission, and demands for watching TV and for data communications are independent. Demands for cognitive radios operating in residential areas are in early morning, evening, and midnight. In these duration, cognitive radios in rural areas can provide the data communications if we give up to use some TV broadcasting stations with low output power and cognitive radios would alternatively provide the programs with data transmission.

Quantitative analysis of radio frequency usage under specific meteorological conditions, hours in a day, days in a week, as well as the dynamic radio propagation simulation are left for further study.

Acknowledgments

The authors would like to thank members of the Information Networks Laboratory at Hiroshima City University for valuable suggestions. This work was supported in part by a Hiroshima City University Grant for Special Academic Research under Grant No. 7112.

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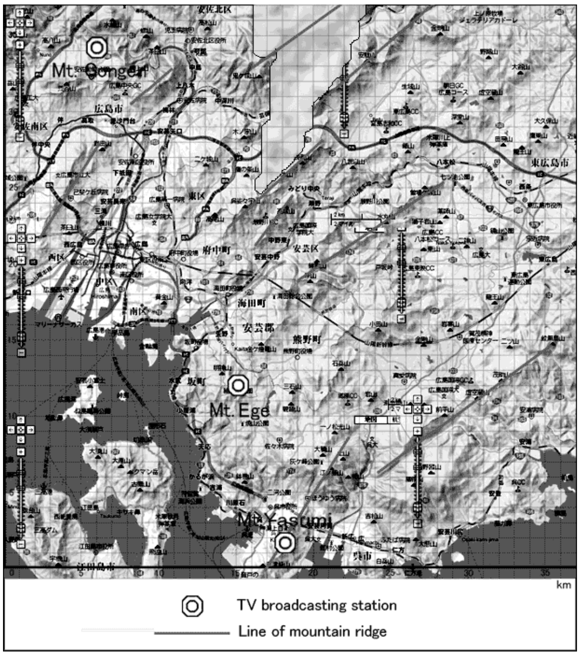

Fig. 5. TV broadcasting coverage when we give up to use a TV broadcasting station with low output power.

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