IEEE COMMUNICATIONS SOCIETY

ICUFN 2010

June 16-18, 2010

ShineVille Luxury Resort, Jeju Island, Korea

Final Program

IEEE

Springer

KICS
Korea Information and Communications Society

Sponsored by

KCC NIA ETRI olleh kt SK telecom LG Telecom

SAMSUNG ELECTRONICS LG Electronics LG-NORTEL MODACOM

[3C-4] Downstream Backhaul Packet Control for Mobile Wireless Networks
Young-June Choi (Ajou University, Korea), Kyungtae Kim (NEC Labs America, Inc., USA), Kang G. Shin (University of Michigan, USA)

[3C-5] Drop Rate Optimization by Tuning Time to Trigger for WCDMA Systems
Shu-Ming Tseng, Wei-Zhe Tseng (National Taipei University of Technology, Taiwan)

June 17, 2010 (Thursday)

16:00-18:00

Session 4A: Resource Allocation and Network Management

Chair: Tapio Frantti (VTT Technical Research Centre of Finland, Finland)

[4A-1] Adjacent Channel Interference Aware Channel Assignment Scheme for WLANs
Yong Hyu Kim, Jiwoong Jeong, Chong-kwon Kim (Seoul National University, Korea)

[4A-2] Channel Allocation Scheme for Cognitive Radio Systems
Gun Woo Lee, Woong Soo Na, Lai Hyuk Park, Sungrae Cho (Chungang University, Korea), Sungho Hwang (Samsung Electro-Mechanics, Korea), Kihong Kim (Samsung Electro-Mechanics, USA)

[4A-3] Priority-Based Resource Allocation Scheme for Visible Light Communication
Muhammad Shahin Uddin, Mostafa Zaman Chowdhury, Yeong Min Jang (Kookmin Unversity, Korea)

[4A-4] Automatic Neighboring BS List Generation Scheme for Femtocell Network
Kwanghun Han, Seungmin Woo, Duho Kang, Sunghyun Choi (Seoul National University, Korea)

[4A-5] Interference Mitigation Using Dynamic Frequency Re-use for Dense Femtocell Network Architectures
Mostafa Zaman Chowdhury, Yeong Min Jang (Kookmin University, Korea), Zygmunt J. Haas (Cornell University, USA)

Session 4B: ITS & Vehicular Ad-hoc networks (1)

Chair: Juan Carlos Cano (Universidad Politecnica de Valencia, Spain)

[4B-1] Control of Transmission Timing Using Information on Predicted Movement in Opportunistic Roadside-to-Vehicle Communication
Ryo Aoki, Hiroyuki Kubo, Ryoichi Shinkuma, Tatsuro Takahashi (Kyoto University, Japan)

[4B-2] Intersection-Based Routing Protocol for VANET
Li-Der Chou, Jyun-Yan Yang, Ying-Cheng Hsieh and Chi-Feng Tung (National Central University, Taiwan)

[4B-3] Design and Implementation of Distributed and Scalable Multimedia Signage System
Miyuru Dayarathna, Anusha Withana, Kazunori Sugiura (Keio University, Japan)

[4B-4] Extension of Hierarchical Mobile IPv6 with Parallel Distribution Tunnels over Dual Wireless Network Interfaces
Jong-Tae Park, Seung-Man Chun, Jae-Wook Nah (Kyungpook National University, Korea)

[4B-5] Information Sharing in Sparse Traffic Area by Low Level Carrier Sense for VANET
Hoa Tung Le, Takeo Fujii (The University of Electro-Communications, Japan)

Session 4C: Future Internet and Network Architecture

Chair: Sven van der Meer (Waterford Institute of Technology, Ireland)

[4C-1] Management and Semantic Description of Objects for the Future Internet
Eric Renault, Wassim Drira, Houssem Medhioub, Djamal Zeghlache (Institut TELECOM-TELECOM SudParis, France)

[4C-2] A Multi-Objective Utility-based Approach for Service-Oriented Network Construction
Wei-Tsung Su (Aletheia University, Taiwan), Yen-Chieh Tseng, Yau-Hwang Kuo (National Cheng Kung University, Tainan, Taiwan, R.O.C., Taiwan), Kuan-Rong Lee (Kun Shan University of Technology, Taiwan), Yau-Hwang Kuo (National Cheng Kung University, Taiwan)

[4C-3] Pricing Broadband: Survey and Open Problems
Mung Chiang, Prashanth Hande, Hongseok Kim, Sangtae Ha, Robert Calderbank (Princeton University, USA)

[4C-4] ActiveCast - a Network and User Aware Mobile Content Delivery System
Pietro Lungaro, Zary Segall, Jens Zander(The Royal Institute of Technology Electrum, Sweden)

[4C-5] Energy Efficiency in the Load-Balanced Switch
Qin Jia, Shuang Yang, Xin Wang, Jin Zhao (Fudan University, China)

June 18, 2010 (Friday)

10:20-12:00

Session 5A: Network Control and Analysis

Chair: Yonghoon Choi (Kwangwoon Univ., Korea)

[5A-1] Transport Protocol for Smart Grid Infrastructure
Tarek Khalifa, Kshirasagar Naik, Maazen Alsabaan (University of Waterloo, Canada), Amiya Nayak (University of Ottawa, Canada), Nishith Goel (Cistel, Canada)

[5A-2] OMG: An Ontology-based Group Mobility Generator
Hyungbae Park, Sunae Shin, Baek-Young Choi, Yugyung Lee (University of Missouri-Kansas City, USA)

[5A-3] Delay Based Packet Size Control in Wireless Local Area Networks
Tapio Frantti, Mikko Majanen, Timo Sukuvaara (VTT Technical Research Centre of Finland Oulu, Finland)

Channel Allocation Scheme for Cognitive Radio Systems

Gunwoo Lee, Woongsoo Na,
Laihyuk Park, Sungrae Cho
School of Computer Science and Engineering,
Chung-Ang University, South Korea
gwlee@uclab.re.kr

Kihong Kim, and Sungho Hwang
Samsung Electro-Mechanics Co.,LTD,
314, Maetan3-Dong, Yeongtong-Gu
Suwon, Gyunggi-Do, South Korea
sungho717.hwang@samsung.com

***Abstract*— Cognitive radio (CR) technology has attracted dramatic attentions recently because it has an ability to dynamically adapt to local spectrum availability and improves the radio spectrum utilization. In this paper, we propose a channel allocation algorithm where the base station allocates a channel to the secondary user by using the primary user arrival pattern. The proposed scheme selects a channel where the primary user arrives least frequently and limits the secondary user's allocation time to reduce interference to the primary user. Performance analysis shows that the proposed channel allocation algorithm can limit the secondary users' interference to the primary user up to 80%.**

***Keywords*—** *Cognative radio, CR, channel allocation algorithm, base station, primary user, and secondary user.*

I. INTRODUCTION

Radio resource allocation policies in the world including the United States have issued the spectrum right referred to as *license* by which licensed users can be protected from interference since only the licensed users can use the allocated spectrum band. Since currently most of spectrum bands have license, it is inevitable to compete unlicensed spectrum bands for new wireless technologies.

Recently, J. Mitola [1] has proposed cognitive radio (CR) concept where a CR user share its own spectrum resources with other users by switching its frequency band through SDR (Software Defined Radio). The SDR technique controls communication parameters in radio devices using software. In the CR networks, the licensed user is referred to as primary while unlicensed user is called as secondary. The secondary user monitors spectrum environment timely and spatially, senses idle spectrum holes, and then communicates through the spectrum holes. If the secondary user detects the primary user, the secondary user must move from its spectrum bands to other within the pre-specified time. Since the cognitive radio can reuse the radio spectrum multi-dimensionally, it is taken into account as a solution to unequal spectrum allocation. Consequently, various research organizations and industries pose great efforts on cognitive radio technology [1][2]. Although the research topics and organizations are different, the basic concept is same as follows:

- When a wireless device wants to communicate, it searches spectrum opportunity in frequency bands.
- If there is an idle frequency channel, the secondary user may use the channel under the condition that the secondary user should not interfere with the primary user.

The cognitive radio technology will lead wireless device revolution and it will improve the inefficient allocation of wireless resources. Through radio regulative relaxation of various groups such as FCC of the United States, the cognitive radio technology will play an important role and will lead a radio communication market[1][2].

Although various research groups have researched on various topics of cognitive radio technique, there are few research proposals of channel allocation aiming primary user's seamless services. In this paper, we propose cognitive radio channel allocation scheme which aims primary user's seamless services by monitoring the primary user arrival pattern. The proposed scheme selects a channel where the primary user arrives least frequently and limits the secondary user's allocation time to reduce interference to the primary user.

The rest of this paper is organized as follows. In section 2, we introduce the primary user arrival model. Section 3 presents a channel allocation algorithm, and in section 4 the throughput performance evaluation of our proposed algorithm is analyzed. Finally, we draw conclusions and suggest future directions in section 5.

II. THE CHANNEL OCCUPANCY MODELOF THE PRIMARY USER

In this section, we describe the channel occupancy model of the primary user.

A. Assumption

We assume here that the primary user exploits FDD (Frequency Division Duplexing) with N frequency bands and occupies each of the frequency band at random amount of time. We further assume that the occupancy time and arrival/departure times of the primary user at each of the frequency band are independent. Although the occupancy time of the primary users are continuous, we segment the time duration with very short time slot (it is referred to as mini-slot in this paper). Then, the continuous occupancy time can be modeled by discrete on/off model.

This work was supported by the IT R&D program of MKE/KEIT. [2009-F047-01, Development of Open mmWave Wireless Interface Platform Technology]

B. *The Primary User Arrival Model*

Fig. 1 depicts the discrete channel usage pattern of the primary user as an ON/OFF model where the primary user consecutively arrives or departs at the i th band among N frequency bands ($1 \le i \le N$). In the ON/OFF model, ON state represents occupancy of the channel while OFF state stands for vacancy from the channel by the primary user. At the OFF state, the secondary user can opportunistically occupy the channel. Let α_i denote the state transition probability from ON state to OFF state at the i th channel while β_i denote the state transition probability from OFF state to ON state. Fig. 2 represents state transition diagram using Markov chain model [3].

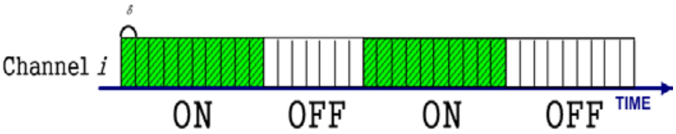

Figure 1. The i th seamless channel occupancy model of the primary user

C. *Probability of the primary user appearance*

Let T_B^i is sum of the primary user's occupancy times at channel i and let T_I^i is sum of the primary user's idle time. At channel i, the number of the primary user's occupied mini-slots (S_B^i) and the number of idle mini-slot (S_I^i) given by

$$S_B^i = \frac{T_B^i}{\delta} \tag{1}$$

and

$$S_I^i = \frac{T_I^i}{\delta} \quad . \tag{2}$$

Let μ_i denote the number of transitions from ON state to OFF state at the i th channel while λ_i denote the number of transitions form OFF state to ON state. Then, α_i and β_i in Figure 2 are given by

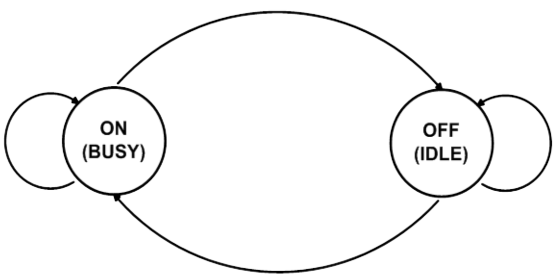

Figure 2. ON-OFF channel using model of the primary user

$$\alpha_i = \frac{\mu_i}{S_B^i} \tag{3}$$

and

$$\beta_i = \frac{\lambda_i}{S_I^i} \quad . \tag{4}$$

III. CHANNEL ALLOCATION ALGORITHM

In this section, we describe channel allocation algorithm for centralized cognitive radio system based on primary user's arrival pattern. If the base station allocates a channel to the secondary user without any policy, there would be more interference to the primary user and seamless communication of the primary user is not possible. So, we can utilize an efficient channel allocation technique using probability model as the above.

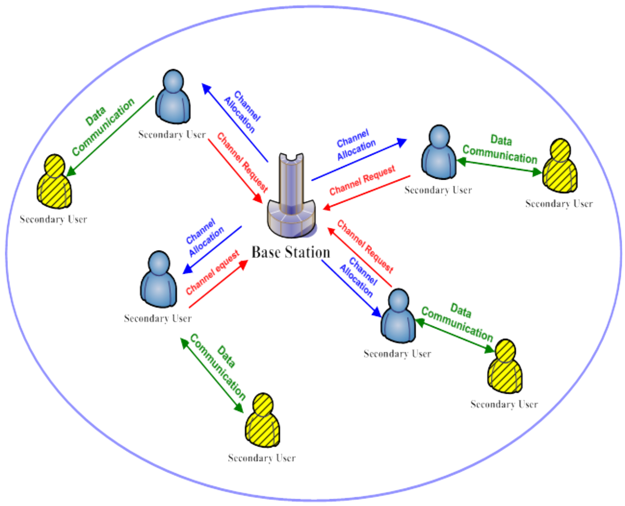

Figure 3. The secondary user structure of centralized cognitive radio.

A. *Construction of networks*

The secondary user network is constructed from a base station (BS) and it forms a centralized cognitive radio system (see Figure 3[1][5] as an example). The secondary user is an entity which does not interfere with the primary user using cognitive radio technique. The base station manages the secondary users who participate in the network. The secondary user periodically collects information of frequency utilization, and it reports appearance of the primary user to the BS. The base station receives the condition of the spectrum from each secondary user, and it collects statistics of primary user's arrival pattern. In the centralized cognitive radio network, if the secondary user wants to use resources, they have to follow the next procedure:

- Step 1: The secondary user requests a channel for communication service to the base station.
- Step 2: The base station runs the channel allocation algorithm (in subsection B) and allocates a channel to the secondary user.

- Step 3: The secondary user starts communication using the allocated channel.

If the primary user wants to use the channel at which the secondary user communicates, the secondary user has to stop transmission and then to search other channels for data communication.

B. Channel allocation algorithm

The base station allocates a channel by forecasting when the primary user appears for each of frequency band. In this case, base station uses probability model mentioned in section 2. (5) calculates how long the ON period remains with respect to threshold ρ . τ_i denotes the number of consecutive mini-slots in OFF state at channel i . Since β_i represents transition probability from OFF state to ON state at channel i , $(1-\beta_i)$ denotes transition probability remaining in OFF state. From this reasoning, $(1-\beta_i)^{\tau_i}$ is the probability that τ_i mini-slots are idle at a certain point.

If we set a threshold ρ which satisfies the following:

$$\rho \le (1-\beta_i)^{\tau_i}, \tag{5}$$

we can obtain τ_i mini-slots which is available for secondary users. Then, the channel allocation algorithm converges to the solution to find

$$k = \arg\max_{\forall i} (\tau_i) \tag{6}$$

In other words, the channel allocation algorithm is to search the maximum number of OFF mini-slots for all channels.

By using (5) and (6), the base station can allocate anticipated number of channels to the secondary user to provide seamless communication of the secondary user.

IV. Performance Evaluation and Analysis

In this section, we evaluate and analyze the performance of the proposed channel allocation algorithm. This simulation performed using NS-2.

A. Simulation Setup

We develop simulation with event-driven method in C++ for evaluating performance. The major entities of the simulation are as follows:

- Frequency Channel: Composed with 5 frequency channels for communicating among other entities such as primary user, secondary user, and base station.
- Secondary user: We assume the secondary user arrives to the system whose inter-arrival time follows exponential distribution. It searches idle channel using frequency sensing, and requests channel allocation to the base station. If it could not sense any empty channels, it restarts next channel scan after exponentially distributed random amount of waiting time.

By continuous sensing for channel, the secondary user reports the primary user's appearance to the base station. If the primary user is detected at the channel at which the secondary user communicates, the secondary user has to stop transmission and then to search other channels for data communication after exponentially distributed random amount of waiting time.

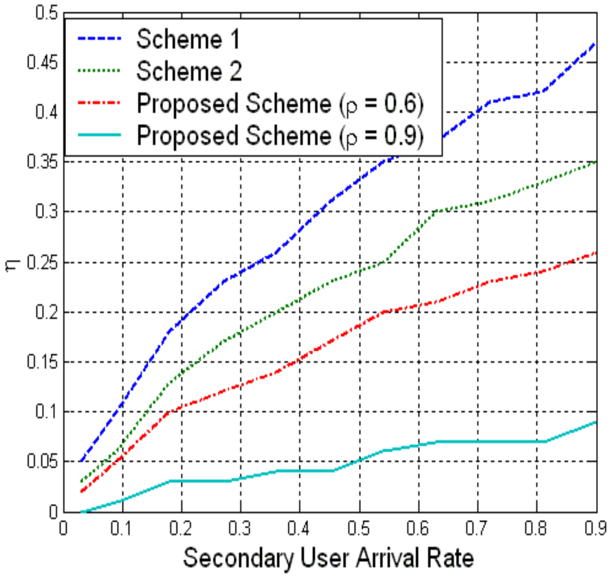

Figure 4. Performance evaluation graph of channel allocation algorithm.

- Primary user: Each channel has the only one primary user. The inter-arrival time of the primary user for each channel is exponentially distributed. When the channel is being used, the primary user measures statistics of the interference from the secondary user.
- Base Station: When receiving channel allocation request from the secondary user, the base station allocates a channel to the secondary user depending upon channel allocation policy. The base station collects information of the primary user's appearance from the secondary user's channel sensing report.

The proposed algorithm mentioned in section 3 is implemented at the base station entity, and then the base station reports statistics of the channel usage time to the secondary user after analyzing each channel status.

In this paper, we measure the secondary user’s interference frequency η from the perspective of the primary user's appearance. η is defined by the number of busy mini-slots when the primary user arrives, divided by the number of primary user’s arrivals.

B. Performance Comparison

We implement the following comparative models for analyzing performance of the proposed channel allocation algorithm.

- Scheme 1: When the base station allocates a channel, it allocates an idle channel randomly. The secondary user can use the channel until the primary user appears.
- Scheme 2: This scheme collects average idle time of each channel. When the base station receives a channel request, it allocates the longest average idle channel. The secondary user can use the channel for the average idle time of the channel.
- Proposed Scheme ($\rho = 0.6$): When the base station allocates channel, it allocates channel using proposed algorithm with threshold ρ of 0.6.
- Proposed Scheme ($\rho = 0.9$): When the base station allocates channel, it allocates channel using proposed algorithm with threshold ρ of 0.9.

C. Analysis

Figure 4 shows performance comparison of the proposed channel allocation algorithm with comparative models. The value of η varies with an appearance of the secondary user proportionately. We observe that scheme 1 shows the dramatic changes with respect to the secondary user arrival rate. The proposed scheme with $\rho = 0.6$ shows the value of η gives less changes than scheme 1 and scheme 2. The proposed scheme with $\rho = 0.9$ shows very slight changes with respective to value of η. The rationale for this can be interpreted as follows. As ρ increases, τ_i will decrease as in (5). The reduction of τ_i means that channels are allocated to the secondary user for shorter period of time. Hence, there will be more likelihood that the secondary user does less interfere with the primary user.

The value of η using the proposed channel allocation algorithm with $\rho = 0.6$ is reduced about 40% compared with scheme 1 and about 25% compared with scheme 2. The value of η using the proposed channel allocation algorithm with $\rho = 0.9$ is reduced about 80% compared with scheme 1 and about 75% compared with scheme 2.

V. CONCLUSION

To solve inefficient allocation problems of frequency bands, there have been huge demands for new radio technology to use radio resources efficiently. Cognitive radio is such a technology to bring significant attentions in area of wireless communication.

For this reason, various research groups have researched on various topics of cognitive radio technique; there are few research proposals of channel allocation aiming primary user's seamless services.

In this paper, we propose cognitive radio channel allocation scheme which aims primary user's seamless services by monitoring the primary user arrival pattern. The proposed scheme selects a channel where the primary user arrives least frequently and limits the secondary user’s allocation time to reduce interference to the primary user.

We have evaluated our proposed allocation scheme with existing techniques, and we show that the secondary user’s interference to the primary user can be reduced up to about 80%.

REFERENCES

[1] L. Park, S. Cho, S.-O. Lim, T.-G. Kwon, J.-W. Cho and Y. Li, “A Survey on MAC layer Techniques in Cognitive Radio System”, Journal of Webcasting, Internet Television and Telecommunication , 3(2), pp. 115-126, 2007.

[2] L. Park, S. Cho, S.-O. Lim, T.-G. Kwon, and J.-W. Cho, “MAC Layer Techniques for Cognitive Radio : A Survey,” in Proc. ICMOCCA 2007, (C), 3(2), pp. 115-126, 2007.

[3] H. Su and X. Zheng, “Cross-Layer Based Opportunistic MAC Protocols for QosS Provisionings Over Cognitive Radio Wireless Networks,” IEEE JSAC, Vol.26, No.1, pp. 118-129, 2008.

[4] IEEE802.22, “IEEE 802.22 Wireless Regional Area Networks Medium Access Control (MAC) and Physical layer (PHY) specification ”, 2006.

[5] I. F. Akyildiz , W.-Y. Lee, M. C. Vuran, S. Mohanty, “NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey,” Elesevier, pp. 2197-2159, January 2006.