一般社団法人 電子情報通信学会
THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

信学技報
IEICE Technical Report

[Poster Presentation]A Study on Adaptability of Interference-Aware Channel Segregation To Varying CCI Environment

Katsuhiro TEMMA† and Fumiyuki ADACHI‡

†‡Dept. of Communications Engineering, Graduate School of Engineering, Tohoku University
6-6-05, Aza-Aoba, Aramaki, Aoba-ku, Sendai, Miyagi, 980-8579, Japan
E-mail: †tenma@mobile.ecei.tohoku.ac.jp, ‡adachi@ecei.tohoku.ac.jp

Abstract By applying interference-aware channel segregation based dynamic channel assignment (IACS-DCA) algorithm, each access point (AP) can use a channel with low co-channel interference (CCI) in a distributed manner. Interference environment may vary due to e.g., switching on/off of APs. Its adaptability to varying CCI environment has been left as an interesting study. In this paper, we investigate the adaptability of IACS-DCA to varying CCI environment. Assuming the CCI limited environment, we evaluate by computer simulation that IACS-DCA can form a channel reuse pattern according to varying CCI environment and improve the signal-to-interference power ratio (SIR).

Keywords Channel segregation, Dynamic channel assignment, Co-channel interference

1. Introduction

In the wireless communications networks, the co-channel interference (CCI) limits the transmission quality, e.g., signal-to-interference power ratio (SIR). The CCI environment may vary according to e.g., switching on/off of access points (APs) and/or installation of new APs. Dynamic channel assignment (DCA) [1]-[3] has been studied extensively in the literature [4]-[8] to cope with varying CCI environment.

Recently, we proposed an interference-aware channel segregation based DCA (IACS-DCA) [9]. In IACS-DCA, each AP periodically monitors CCI powers and computes the average CCI powers on all available channels to select the best channel having the lowest average CCI power to use. It has been shown that IACS-DCA can form a channel reuse pattern with low CCI in a distributed manner [10]. However, its adaptability to varying CCI environment has been left as an interesting study. An important parameter that controls the adaptability of IACS-DCA to varying CCI environment is the interference averaging interval. When using the first order filter for the interference averaging, the control parameter is the filter forgetting factor. In this paper, using a simple model of varying CCI environment, the adaptability of IACS-DCA is discussed in terms of uplink SIR.

The rest of the paper is organized as follows. Section 2 overviews IACS-DCA and discusses how the filter forgetting factor affects the IACS-DCA. In Section 3, we examine by computer simulation the distribution of uplink SIR achievable with IACS-DCA and discuss the adaptability of IACS-DCA. Section 4 offers some concluding remarks.

2. Overview of IACS-DCA

2.1. Algorithm

IACS-DCA flowchart is shown in Fig. 1. Each AP periodically measures the instantaneous CCI power and computes the moving average CCI power on all available channels. Then, the channel-priority table is updated in which the channels are listed in ascending order of the average CCI power. In this paper, the first order filtering is used to compute the average CCI power. The average CCI power $\bar{I}_{\mathrm{AP}(m)}(t;c)$ measured at the m-th AP AP(m) on the c-th channel at updating time t is given as

$$\bar{I}_{\mathrm{AP}(m)}(t;c) = (1-\beta)\cdot I_{\mathrm{AP}(m)}(t;c) + \beta\cdot \bar{I}_{\mathrm{AP}(m)}(t-1;c)\ , \qquad (1)$$

where $I_{\mathrm{AP}(m)}(t;c)$ and β (0<β<1) denote the instantaneous CCI power measured at AP(m) on the c-th channel at time t and the forgetting factor, respectively. Using the average CCI powers on all available channels, the CCI table is updated for all available channels (c=0~C−1). The channel having the lowest average CCI power is selected as

$$c(m) = \underset{c\in[0,C-1]}{\arg\min}\, \bar{I}_{\mathrm{AP}(m)}(t;c)\ . \qquad (2)$$

The channel selected by Eq. (2) may give strong interference to neighboring APs and hence, surrounding APs may select other channels except the case of sufficiently high shadowing loss (or penetration loss into a building). Consequently, a channel reuse pattern with low CCI can be formed by IACS-DCA.

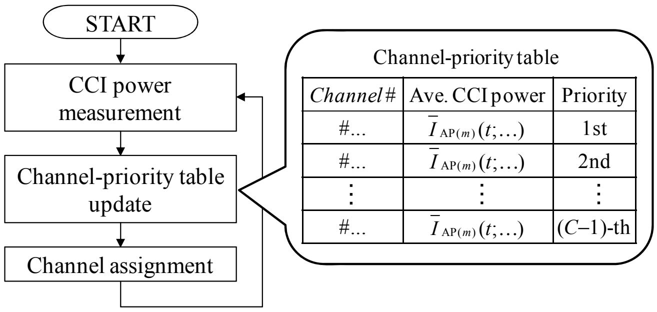


Fig. 1 Flowchart of IACS-DCA.

2.2. Forgetting Factor of First Order Filter

The forgetting factor β of Eq. (1) controls the adaptability of IACS-DCA. The interference averaging interval is equivalent to 1/(1−β) times the updating interval.

If β is set to be too small, the measured average CCI tends to follow the instantaneous CCI and the channel segregation cannot be done [7]. Hence, β≈1 is recommended to segregate available channels and to form a stable channel reuse pattern.

3. Computer Simulation

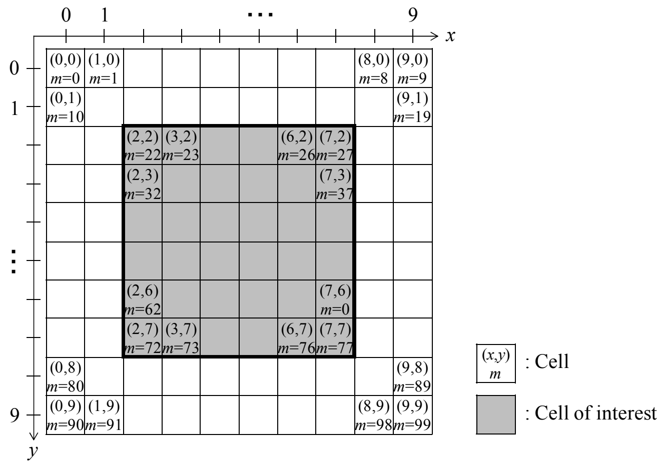
3.1. Network Model

Figure 2 shows the network model assumed in this paper for computer simulation. An area consisting of 100 cells is considered and 36 cells in the center area are the cells of interest to evaluate the SIR distribution as illustrated in Fig. 2(a). Each AP is located at the center of each cell as shown in Fig. 2(b). The distance between adjacent APs is used as the reference distance *R*. We assume that each AP is designed to periodically transmit the beacon signal on the selected channel and to measure the instantaneous beacon signal power on each of available channels as the instantaneous CCI power for IACS-DCA.

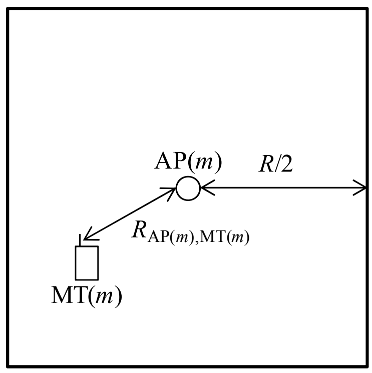
Table 1 summarizes the simulation condition. In this paper, we consider the orthogonal frequency division multiplexing (OFDM) using N_c=64 subcarriers and synchronous time division duplex (TDD) over all APs. The number of available channels is assumed to be *C*=4. An interference-limited environment is assumed and the short term SIR averaged over fading is measured.

3.2. Modeling of Varying CCI Environment

To generate the varying CCI environment, APs are switched on and off with a certain probability. In each simulation run, 27 of APs in the area of interest and 48 of APs in the surrounding area are randomly selected to be switched on and the other APs are switched off as shown in Fig. 3 (i.e., active AP density is 75% of the network). When the AP is switched off, its channel-priority table is reset (i.e., the average CCI powers on all available channels are set to be 0). For the active AP in the present simulation run, if it was also active in the previous simulation run, its channel-priority table is continuously used in the present simulation run.



(a) Cellular structure



(b) Geometry of AP and mobile terminal (MT)

Fig. 2 Network model.

Table 1 Computer simulation condition

Network model	No. of channels	*C*=4
	Signal transmission	OFDM using N_c=64 subcarriers
Channel model	Path-loss exponent	α=3.5
	Shadowing loss	Log-normal with standard deviation σ=5.0 (dB)
	Fading	Rayleigh with *L*=16-path uniform power delay profile
	Transmit SNR	∞ (Interference limited)
IACS-DCA	Forgetting factor of first order filtering	β=0.5, 0.9, 0.95

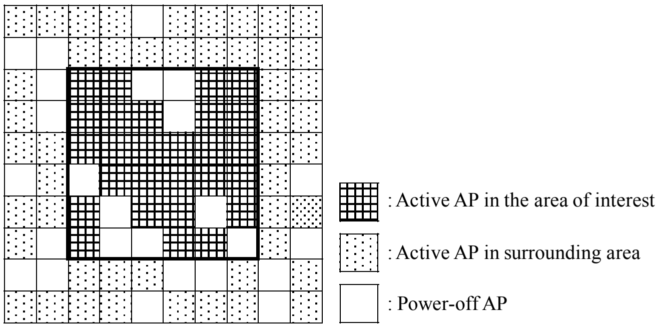


Fig. 3 One-shot view of active AP pattern.

In each simulation run, the uplink SIR measurement is done after T times updating of the priority table, where T is the AP on/off interval normalized by table updating interval. The uplink SIR measurement is done by randomly varying the user location in each active cell for the channel reuse pattern formed at updating time $t=T$ and cumulative distribution function (CDF) of SIR is obtained.

3.3. Computation of SIR

The instantaneous CCI power $I_{\mathrm{AP}(m)}(t;c)$ measured at AP(m) on the c-th channel (c=0~C−1) at updating time t is computed as

$$I_{\mathrm{AP}(m)}(t;c)=\sum_{k=0}^{N_c-1}\left|\sum_{\substack{n\in \mathrm{APG}(c)\\ n\neq m}}\left\{\sqrt{\begin{array}{l}2p_{\mathrm{AP}(n)}\cdot r_{\mathrm{AP}(m),\mathrm{AP}(n)}^{-\alpha}\\ \quad\times 10^{-\eta_{\mathrm{AP}(m),\mathrm{AP}(n)}/10}\end{array}}\times H_{\mathrm{AP}(m),\mathrm{AP}(n)}(k)\right\}\right|^2, \quad (3)$$

where APG(c) denotes the AP group which is using the same c-th channel, $p_{\mathrm{AP}(n)}=P_{\mathrm{AP}(n)}\cdot R^{-\alpha}$ is the normalized transmit power of beacon signal of AP(n) with R being the reference distance and α being the path-loss exponent. $r_{\mathrm{AP}(m),\mathrm{AP}(n)}$ and $\eta_{\mathrm{AP}(m),\mathrm{AP}(n)}$ are the normalized distance and the shadowing loss in dB between AP(m) and AP(n), respectively.

$H_{\mathrm{AP}(m),\mathrm{AP}(n)}(t;k,c)$ in Eq. (3) is obtained by the Fourier transform of the channel impulse response between AP(m) and AP(n), where $E[|H_{\mathrm{AP}(m),\mathrm{AP}(n)}(t;k,c)|^2]=1$ (E[.] denotes the ensemble average operation). We assume a frequency-selective Rayleigh fading channel which is composed of L distinct paths. The impulse response of the propagation channel between AP(n) transmitter and AP(m) receiver is assumed to be the same for all m and n and is modeled as

$$h(\tau;t)=\sum_{l=0}^{L-1}h_l(t)\delta(\tau-\tau_l), \quad (4)$$

where $h_l(t)$ and τ_l denote the time-varying complex-valued path gain with $E[\sum_{l=0}^{L-1}|h_l(t)|^2]=1$ and the time delay of the l-th path, respectively.

Since the uplink CCI experienced at AP(m) is the sum of the CCI from all MTs in the co-channel cells, the CCI can be approximated as a complex-valued Gaussian variable. The CCI variance $2\sigma^2_{\mathrm{AP}(m)}$ is expressed as

$$2\sigma^2_{\mathrm{AP}(m)}=\sum_{\substack{n\in \mathrm{APG}(c(m))\\ n\neq m}}2p_{\mathrm{MT}(n)}\cdot r_{\mathrm{AP}(m),\mathrm{MT}(n)}^{-\alpha}\cdot 10^{-\eta_{\mathrm{AP}(m),\mathrm{MT}(n)}/10}, \quad (5)$$

where $p_{\mathrm{MT}(n)}=P_{\mathrm{MT}(n)}\cdot R^{-\alpha}$ is the normalized transmit power of MT(n) and $r_{\mathrm{AP}(m),\mathrm{MT}(n)}$ and $\eta_{\mathrm{AP}(m),\mathrm{MT}(n)}$ are the normalized distance and the shadowing loss in dB between MT(n) and AP(m), respectively. The uplink short term SIR $\lambda_{\mathrm{MT}(m)}(t)$ is computed using

$$\lambda_{\mathrm{MT}(m)}(t)=\frac{2p_{\mathrm{MT}(m)}\cdot r_{\mathrm{AP}(m),\mathrm{MT}(m)}^{-\alpha}\cdot 10^{-\eta_{\mathrm{AP}(m),\mathrm{MT}(m)}/10}}{2\sigma^2_{\mathrm{AP}(m)}}. \quad (6)$$

3.4. One-shot Observation of Channel Reuse Pattern

Figure 4 shows the one-shot observation of channel reuse pattern (the numbers in the pattern represent the channel index) formed by IACS-DCA. To investigate the influence of the path loss on the channel reuse pattern, the standard deviation σ of shadowing loss was set to 0 (dB). For comparison, the channel reuse pattern formed by quasi-DCA [10] is also shown. The quasi-DCA performs as follows. Every time an AP is switched on, it measures the instantaneous CCI power (beacon signal power) on each of available channels and selects the channel having the lowest instantaneous CCI power. In quasi-DCA, an active AP continues to use the same channel as far as it remains switched on and hence, it cannot adapted to the varying CCI environment. On the other hand, in IACS-DCA, every updating time, all APs try to adapt to varying CCI environment.

In quasi-DCA, an AP which was active in the previous simulation run continues to keep the same channel to use in the present simulation run and only newly active APs find channels having minimum CCI under the given channel reuse pattern formed in the previous simulation run. Therefore, some neighbor active APs use the same channel in the case of quasi-DCA (colored area in Fig. 4(b)). In IACS-DCA, all APs can select the best channel according to varying CCI environment as shown in Fig. 4(c).

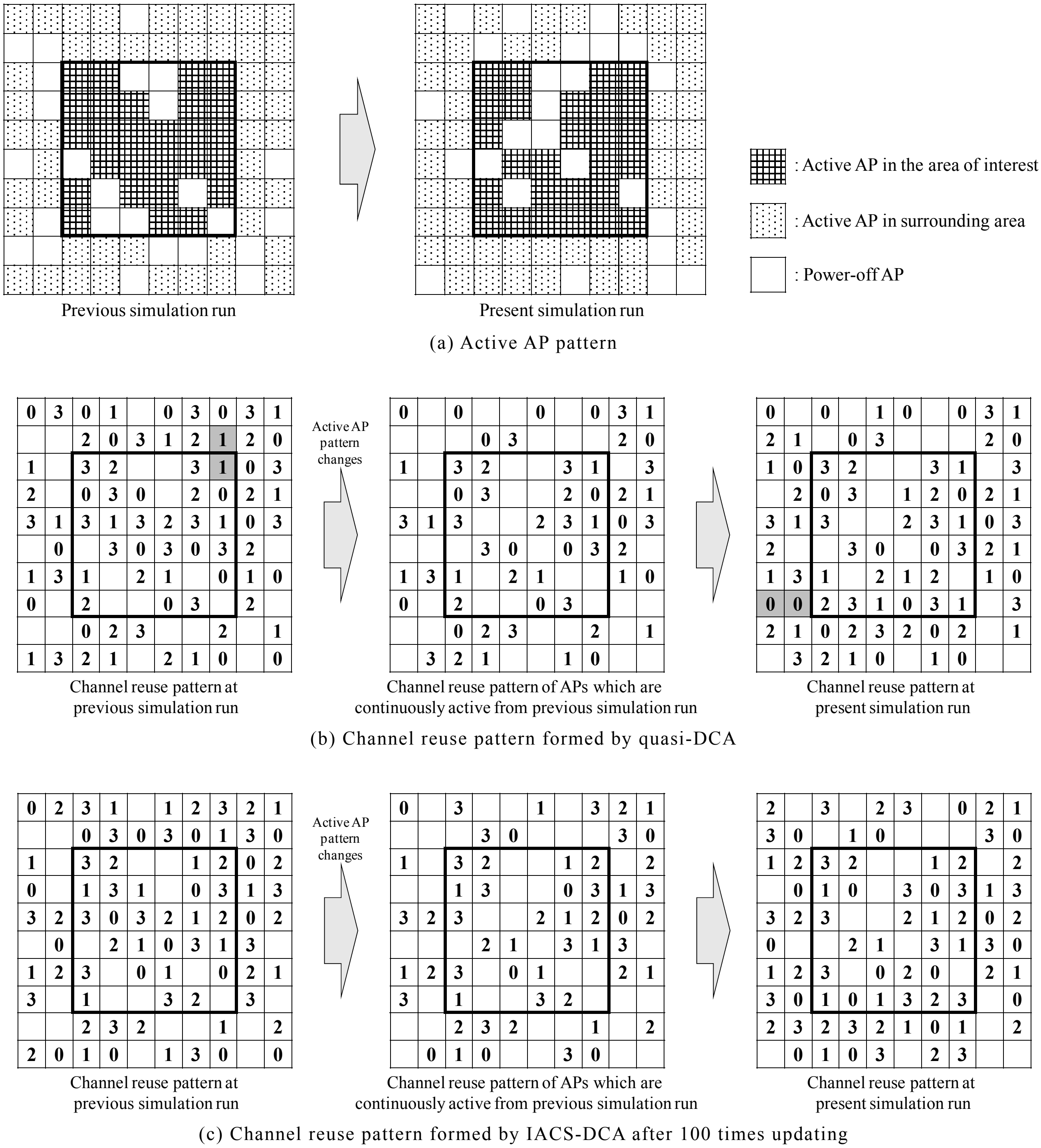


Fig. 4 One-shot view of channel reuse pattern when β=0.9 and σ=0 (dB).

3.5. Adaptability of IACS-DCA

The adaptability of IACS-DCA to varying CCI environment is discussed with respect to the uplink SIR. Figure 5 shows the 10%-outage SIR as a function of AP on/off interval normalized by table updating interval (the *x*%-outage SIR is defined as the SIR value below which the measured SIR falls with probability of *x*%). We compare three cases: β=0.5, 0.9, and 0.95 (corresponding to the averaging intervals of 2, 10 and 20 times the updating interval, respectively). From Fig. 5, it can be seen that IACS-DCA can adapt to varying CCI environment and achieve higher 10%-outage SIR than the quasi-DCA.

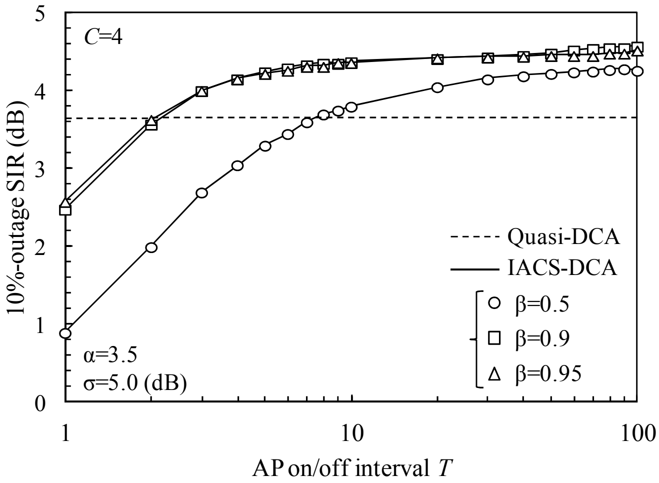


Fig. 5 10%-outage SIR as a function of AP on/off interval *T*.

4. Conclusion

In this paper, we investigated the adaptability of IACS-DCA to varying CCI environment with respect to the uplink SIR. In the computer simulation, the varying the CCI environment was generated by switching on and off APs with a certain probability. It was shown that IACS-DCA can adapt to varying CCI environment and achieve higher SIR than the quasi-DCA.

References

[1] I. Katzela and M. Naghshineh, "Channel assignment schemes for cellular mobile telecommunication systems: a comprehensive survey," *IEEE Personal Commun.*, vol. 3, no. 3, pp. 10-31, June 1996.

[2] A. Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.

[3] H. Skalli, S. Ghosh, S. K. Das, L. Lenzini and M. Conti, "Channel assignment strategies for multiradio wireless mesh networks: issues and solutions," *IEEE Commun. Mag.*, vol. 45, no. 11, pp. 86-95, Nov. 2007.

[4] D. Goodman, S. A. Grandhi and R. Vijayan, "Distributed dynamic channel assignment schemes," *in Proc. IEEE 43th Vehicular Technology Conference (VTC1993-Spring)*, May 1993.

[5] G. Cao and M. Singhal, "Distributed fault-tolerant channel allocation for cellular networks," *IEEE Journal on Selected Areas in Commun.*, vol. 18, no. 7, pp. 1326-1337, July 2000.

[6] H. Luo and N. K. Shankaranarayanan, "A distributed dynamic channel allocation technique for throughput improvement in a dense WLAN environment," *in Proc. IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP2004)*, vol. 5, pp. 345-8, May 2004.

[7] Y. Furuya and Y. Akaiwa, "Channel segregation, a distributed adaptive channel assignment scheme for mobile communication systems," *IEICE Trans. Commun.*, vol. E74-B, no. 6, pp. 1531-1537, June 1991.

[8] Y. Akaiwa and H. Andoh, "Channel segregation-a self-organized dynamic channel allocation method: application to TDMA/FDMA microcellular system," *IEEE Journal on Selected Areas in Commun.*, vol. 11, no. 6, pp. 949-954, Aug. 1993.

[9] R. Matsukawa, T. Obara and F. Adachi, "A dynamic channel assignment scheme for distributed antenna networks," *in Proc. IEEE 75th Vehicular Technology Conference (VTC2012-Spring)*, May 2012.

[10] Y. Matsumura, S. Kumagai, T. Obara, T. Yamamoto and F. Adachi, "Channel segregation based dynamic channel assignment for WLAN," *in Proc. IEEE The 13th International Conference on Communication Systems (ICCS2012)*, Nov. 2012.