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MULTI-GROUP INTERFERENCE-AWARE CHANNEL SEGREGATION BASED DYNAMIC CHANNEL ASSIGNMENT

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Abstract: Our recently proposed interference-aware channel segregation based dynamic channel assignment (IACS-DCA) forms a channel reuse pattern with low co-channel interference (CCI) in a distributed manner. In IACS-DCA, each access point (AP) has channel-priority table, in which the channels are listed by the ascending order of average CCI power. Original IACS-DCA is designed to use the best channel among the available channels. If more-than-one channels are necessary at each AP, multiple channels can be chosen according to their priority information stored in channel-priority table. However, the use of lower-priority channels makes the channel reuse pattern unstable. Therefore, in this paper, we propose multi-group IACS-DCA which divides the available channels into multiple groups and applies IACS-DCA to each channel group. We show, by computer simulation, that multi-group IACS-DCA provides more stable channel reuse pattern and improves the signal-to-interference power ratio (SIR).

Keywords: channel segregation, dynamic channel assignment, co-channel interference, multi-channel assignment

1 Introduction

The number of available channels is limited in wireless networks. Hence, the same channel needs to be reused by spatially separated access points (APs) or base stations (BSs). In this paper, the terminology AP is used. Since the co-channel interference (CCI) limits the network capacity, it is necessary to minimize the total CCI which is caused by all APs and mobile terminals (MTs) in a network.

To reuse the channels more effectively, dynamic channel assignment (DCA) [1]-[3] has been studied extensively in the literature [4]-[8]. Recently, we proposed an interference-aware channel segregation based DCA (IACS-DCA) [9], in which each AP periodically monitors the CCI environment and computes the moving average CCI powers (obtained from past CCI measurements) of all available channels. Each AP has single channel-priority table, in which the channels are listed with the descending priority order (i.e., increasing order of CCI power). AP selects the best channel having the lowest average CCI power. It has been shown that IACS-DCA can form a channel reuse pattern with low CCI in a distributed manner [10].

Recently, the number of wireless terminals has been increasing rapidly. Therefore, the limited number of channels must be reused more efficiently. If more-than-one channels are necessary at each AP, the multiple channels can be used according to their priority information stored in channel-priority table of IACS-DCA. However, the use of lower-priority channels makes the channel reuse pattern unstable [11].

In this paper, we propose multi-group IACS-DCA. The original IACS-DCA is called single-group IACS-DCA. In multi-group IACS-DCA, the available channels are divided into multiple groups and single-group IACS-DCA is applied to each channel group. We show, by computer simulation, that multi-group IACS-DCA provides more stable channel reuse pattern and improves the signal-to-interference power ratio (SIR) compared with conventional single-group IACS-DCA when multiple channels need to be used at each AP.

The rest of the paper is organized as follows. Section 2 overviews single-group IACS-DCA and presents multi-group IACS-DCA. In Section 3, we examine the stability of channel reuse pattern and the SIR distribution by computer simulation. Section 4 offers some concluding remarks.

2 Multi-group IACS-DCA

In this paper, we consider a wireless network using time division duplex (TDD) and orthogonal frequency division multiplexing (OFDM) [12]. Perfectly synchronized TDD timing is assumed among APs and MTs in the network.

2.1 Single-group IACS-DCA

Single-group IACS-DCA [10] flowchart is shown in Fig. 1. Each AP is designed to periodically measure the CCI power and to compute the moving average CCI power on all available channels by using the first order filtering. Then, the channel-priority table is updated in which the channels are listed in ascending order of the average CCI power.

In this paper, discrete time normalized by the CCI measurement time interval is used. There are *C* available

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channels and each available channel uses OFDM with N_c subcarriers. We assume an interference-limited channel and a frequency-selective channel which is composed of L distinct paths. The impulse response of the propagation channel between transmitter and receiver at CCI measurement time t can be modeled as

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

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

Since the synchronous TDD transmission is assumed, the CCI measured at m-th AP, AP(m), comes from the MTs communicating with their corresponding other co-channel APs. The instantaneous CCI power $I_{\mathrm{AP}(m)}(t;c)$ measured at AP(m) on the c-th channel at time t is represented as

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

where APG denotes a group of the APs and MTG(n;c) denotes a group of MTs communicating with AP(n) using the same c-th channel. $p_{\mathrm{MT}(n,u)}=P_{\mathrm{MT}(n,u)}R^{-\alpha}$ is the normalized transmit power of the u-th MT, MT(n,u), communicating with AP(n) with R being the reference distance and α being the path-loss exponent. $r_{\mathrm{AP}(m),\mathrm{MT}(n,u)}$ and $\eta_{\mathrm{AP}(m),\mathrm{MT}(n,u)}$ are the normalized distance and the shadowing loss in dB between AP(m) and MT(n,u), respectively. $H_{\mathrm{AP}(m),\mathrm{MT}(n,u)}(k)$ is obtained by the Fourier transform of the channel impulse response between AP(m) and MT(n,u) at time t.

The average CCI power on the c-th channel at time t is computed by using the first order filtering as

$$\bar{I}_{\mathrm{AP}(m)}(t;c)=(1-\beta)\cdot I_{\mathrm{AP}(m)}(t;c)+\beta\cdot\bar{I}_{\mathrm{AP}(m)}(t-1;c) \quad (3)$$

where β (0≤β<1) denotes the forgetting factor. Using the average CCI powers on all available channels, the channel-priority table is updated. If the value of β is set to too small, the average CCI power is strongly affected by the instantaneous CCI power. Hence, β≈1 is required for constructing a stable channel reuse pattern [10].

Although the original single-group IACS-DCA is designed to choose the best channel experiencing the lowest CCI, multiple channels can be assigned to MTs based on the channel-priority table as shown in Fig. 2(a). However, when lower-priority channels are used, the channel reuse pattern may become unstable [11].

2.2 Multi-group IACS-DCA

Fig. 2(b) illustrates the multi-group IACS-DCA which divides the available C=4 channels into two groups, each group having two channels. In each channel group, single-group IACS-DCA is applied and the best channel having the lowest average CCI power is chosen in each group. It has been shown in Ref. [10] that original single-group IACS-DCA can form a stable channel reuse pattern. Hence, it is expected that multi-group IACS-DCA produces much stable channel reuse pattern than single-group IACS-DCA in the case of multi-channel use.

3 Computer simulation

We evaluate the stability of the channel reuse pattern and the SIR distribution by means of computer simulation. The stability of channel reuse pattern is represented by the autocorrelation function of channel reuse pattern [10].

The cellular network model of A_{all}=100 cells is considered for computer simulation, as illustrated in

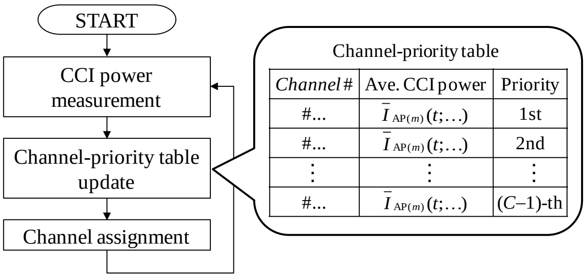


Figure 1 Flowchart of single-group IACS-DCA

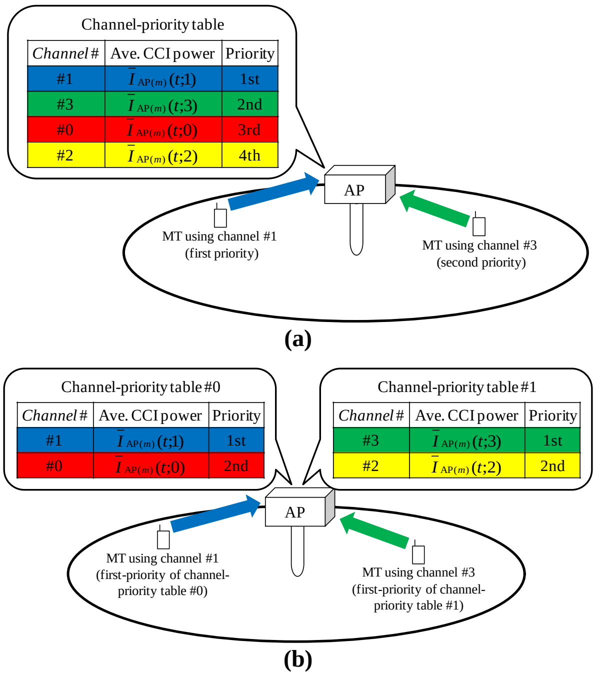
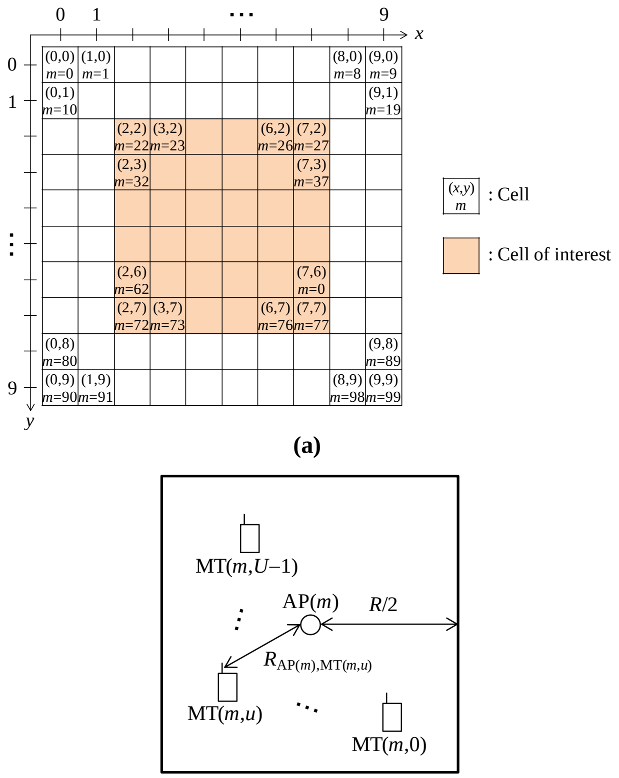


Figure 2 Multi-channel assignment using IACS-DCA
(a) Multi-channel use in single-group IACS-DCA
(b) Multi-group IACS-DCA

Fig. 3(a). Each AP is located at the center of each cell as shown in Fig. 3(b). The distance between adjacent APs is used as the reference distance *R*. Table I summarizes the simulation condition. The number of available channels and the number of OFDM subcarriers are assumed to be C=16 and N_c=64, respectively. If the forgetting factor β to be used for interference averaging is set to too close to 1, tracking ability against changing traffic distribution tends to be lost. In this paper, β=0.99 is used [10]. $A_{\text{int.}}$=36 cells in the center area shown in Fig. 3(a) are the cells of interest to evaluate the stability of the channel reuse pattern and the SIR distribution.

In each simulation run, MT locations and propagation channel are assumed to be static. The initial channel is generated randomly. The SIR measurement is done when *t*=2 000 (i.e., after the channel reuse pattern gets stable). The cumulative distribution function (CDF) of SIR and the autocorrelation of channel reuse pattern are obtained by conducting the simulation 1 000 times.



(a)

(b)

Figure 3 Network model
(a) Multi-channel use in single-group IACS-DCA
(b) Multi-group IACS-DCA

Stationary *U* MTs are assumed to be uniformly located in each cell. It is assumed that *U* MTs communicate with their corresponding AP. In single-group IACS-DCA, *U* channels are chosen in the descending priority order. On the other hand, in multi-group IACS-DCA, available *C* channels are divided into *U* channel group of *C*/*U* channels each and the best channel having the lowest average CCI power is chosen in each group.

Table I Computer simulation condition

Network model	No. of channels	C=16
	Signal transmission	OFDM using N_c=64 subcarriers
	No. of MTs per cell	U=2, 4, 8
Propagation channel	Fading	Static Rayleigh with L=16-path uniform power delay profile
	Path loss exponent	α=3.5
	Shadowing loss standard deviation	Log-normal with standard deviation σ=5 (dB)
IACS-DCA	Forgetting factor of first order filtering	β=0.99

The autocorrelation function of channel reuse pattern is defined as [10]

$$R(T)\equiv E\left[\frac{1}{A_{\text{int.}}}\sum_{m\in \mathrm{APG}_{\text{int.}}}\sum_{c=0}^{C-1}q(m,t;c)\cdot q(m,t-T;c)\right] \quad (4)$$

where $\mathrm{APG}_{\text{int.}}$ is a group of the cells of interest. *q*(*m*,*t*;*c*) is the function that gives 1 when AP(*m*) uses *c*-th channel on time *t* and 0 for otherwise. In fact, Eq. (4) compares the channel reuse pattern at time *t* with that at time *t*–*T* to count the number of APs which use the same channel. As the channel distribution pattern satisfies a stable condition, *R*(*T*) approaches to 1.

For the transmission quality measure in this paper, the block-averaged SIR is used. Assuming the synchronous TDD system, the uplink CCI experienced at AP comes from MTs communicating with their corresponding other co-channel APs. The uplink instantaneous SIR $\lambda_{\mathrm{MT}(m,u)}(t)$ of MT(*m*,*u*) experienced at AP(*m*)'s antenna is given as

$$\lambda_{\mathrm{MT}(m,u)}(t)=\frac{\left|\sum_{k=0}^{N_c-1}\sqrt{\begin{array}{r}2p_{\mathrm{MT}(m,u)}\cdot r_{\mathrm{AP}(m),\mathrm{MT}(m,u)}^{-\alpha}\\ \times 10^{-\eta_{\mathrm{AP}(m),\mathrm{MT}(m,u)}/10}\end{array}}\times H_{\mathrm{AP}(m),\mathrm{MT}(m,u)}(k)\right|^{2}}{I_{\mathrm{AP}(m)}(t;c(\mathrm{MT}(m,u)))} \quad (5)$$

where $I_{\mathrm{AP}(m)}(t;c(\mathrm{MT}(m,u)))$ is the instantaneous CCI power measured at AP(*m*) on the *c*(MT(*m*,*u*))-th channel at time *t* and is given as

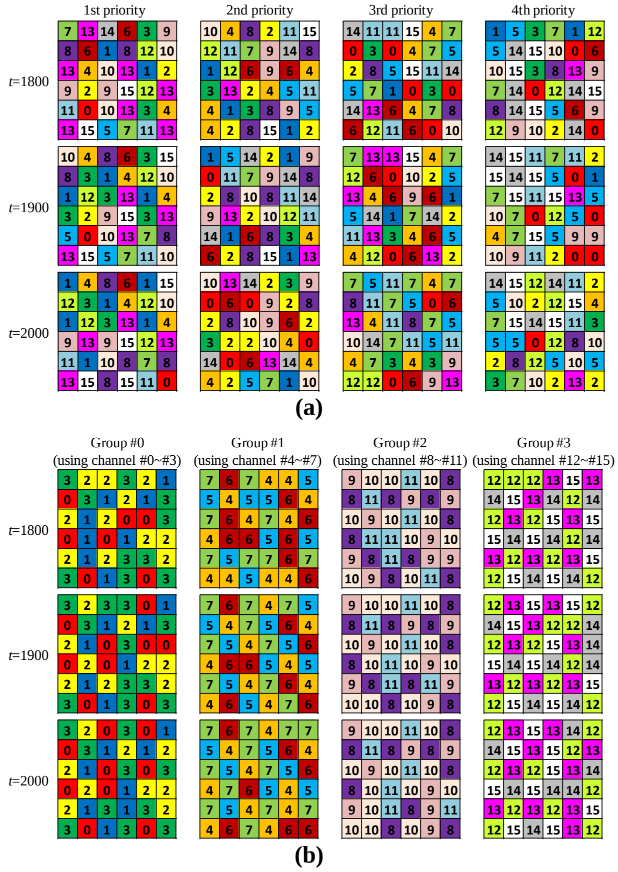
$$\begin{aligned}&I_{\mathrm{AP}(m)}(t;c(\mathrm{MT}(m,u)))\\&=\sum_{k=0}^{N_c-1}\left|\sum_{\substack{n\in\mathrm{APG}\\ \neq m}}\sum_{u'\in\mathrm{MTG}(n;c(\mathrm{MT}(m,u)))}\left\{\sqrt{\begin{array}{r}2p_{\mathrm{MT}(n,u')}\cdot r_{\mathrm{AP}(m),\mathrm{MT}(n,u')}^{-\alpha}\\ \times 10^{-\eta_{\mathrm{AP}(m),\mathrm{MT}(n,u')}/10}\end{array}}\times H_{\mathrm{AP}(m),\mathrm{MT}(n,u')}(k)\right\}\right|\end{aligned} \quad (6)$$

with *c*(MT(*m*,*u*)) being the channel which is assigned to MT(*m*,*u*).

3.1 Stability of the channel reuse pattern

Fig. 4 shows one-shot observation of channel reuse pattern variations (the number in the pattern denotes the channel index) formed by IACS-DCAs at time t=1 800, 1 900, and 2 000 for achieving sufficient CCI average. The number of MTs per cell is U=4 and the initial channel reuse pattern at time t=0 was generated randomly. In single-group IACS-DCA, the available C=16 channels are listed in channel-priority table and U=4 channels are assigned to each MT in descending priority order. In multi-group IACS-DCA, the available C=16 channels are divided into U=4 groups having C/U=4 channels each. The best channel in each channel group is assigned to one of four MTs. It can be seen from Fig. 4 that multi-group IACS-DCA seems to form more stable channel reuse pattern compared with single-group IACS-DCA.

Fig. 5 shows the autocorrelation of channel reuse pattern. The channel reuse pattern at time t=2 000 was used as the reference pattern. We can see from Fig. 5 that multi-group IACS-DCA provides more stable channel reuse pattern than single-group IACS-DCA. It is interesting to note that as U increases, the reuse pattern stability becomes higher for multi-group IACS-DCA while it becomes lower for single-group IACS-DCA. Any possible reason for this is left as our future study.



	1st priority						2nd priority						3rd priority						4th priority					
t=1800	7	13	14	6	3	9	10	4	8	2	11	15	14	11	11	15	4	7	1	5	3	7	1	12
	8	6	1	8	12	10	12	11	7	9	14	8	0	3	0	4	7	5	5	14	15	10	0	6
	13	4	10	13	1	2	1	12	6	9	6	4	2	8	5	15	11	14	10	15	3	8	13	9
	9	2	9	15	12	13	3	13	2	4	5	11	5	7	1	0	3	0	7	14	0	12	14	15
	11	0	10	13	3	4	4	1	3	8	9	5	14	13	6	4	7	8	8	14	15	5	6	9
	13	15	5	7	11	13	4	2	8	15	1	2	6	12	11	6	0	10	12	9	10	2	14	0
t=1900	10	4	8	6	3	15	1	5	14	2	1	9	7	13	13	15	4	7	14	15	11	7	11	2
	8	3	1	4	12	10	0	11	7	9	14	8	12	6	0	10	2	5	15	14	15	5	0	1
	1	12	3	13	1	4	2	8	10	8	11	14	13	4	6	9	6	1	7	15	11	15	13	5
	3	2	9	15	3	13	9	13	2	10	12	11	5	14	1	7	14	2	10	7	0	12	5	0
	5	0	10	13	7	8	14	1	6	8	3	4	11	13	3	4	6	5	4	7	15	5	9	9
	13	15	5	7	11	10	6	2	8	15	1	13	4	12	0	6	13	2	10	9	11	2	0	0
t=2000	1	4	8	6	1	15	10	13	14	2	3	9	7	5	11	7	4	7	14	15	12	14	11	2
	12	3	1	4	12	10	0	6	0	9	2	8	8	11	7	5	0	6	5	10	2	12	15	4
	1	12	3	13	1	4	2	8	10	9	6	2	13	4	11	8	7	5	7	15	14	15	11	3
	9	13	9	15	12	13	3	2	2	10	4	0	10	14	7	11	5	11	5	5	0	12	8	10
	11	1	10	8	7	8	14	0	6	13	14	4	4	7	3	4	3	9	2	8	12	5	10	5
	13	15	8	15	11	0	4	2	5	7	1	10	12	12	0	6	9	13	3	7	10	2	13	2

(a)

	Group #0 (using channel #0~#3)						Group #1 (using channel #4~#7)						Group #2 (using channel #8~#11)						Group #3 (using channel #12~#15)					
t=1800	3	2	2	3	2	1	7	6	7	4	4	5	9	10	10	11	10	8	12	12	12	13	15	13
	0	3	1	2	1	3	5	4	5	5	6	4	8	11	8	9	8	9	14	15	13	14	12	14
	2	1	2	0	0	3	7	6	4	7	4	6	10	9	10	11	10	8	12	13	12	15	13	15
	0	1	0	1	2	2	4	6	6	5	6	5	8	11	11	10	9	10	15	14	15	14	12	14
	2	1	2	3	3	2	7	5	7	7	6	7	9	8	11	8	9	9	13	12	13	12	13	15
	3	0	1	3	0	3	4	4	5	4	4	6	10	9	8	10	11	8	12	15	14	15	14	12
t=1900	3	2	3	3	0	1	7	6	7	4	7	5	9	10	10	11	10	8	12	13	15	13	15	12
	0	3	1	2	1	3	5	4	7	5	6	4	8	11	8	9	8	9	14	15	13	12	12	14
	2	1	0	3	0	0	7	5	4	7	5	6	10	9	10	11	10	8	12	13	12	15	13	14
	0	2	0	1	2	2	4	6	6	5	4	5	8	10	11	10	9	10	15	14	15	14	12	14
	2	1	2	3	3	2	7	5	4	7	6	4	9	8	11	8	11	9	13	12	13	12	13	15
	3	0	1	3	0	3	4	6	5	4	7	6	10	10	8	10	9	8	12	15	14	15	14	12
t=2000	3	2	0	3	0	1	7	6	7	4	7	7	9	10	10	11	10	8	12	13	15	13	14	12
	0	3	1	2	1	2	5	4	7	5	6	4	8	11	8	9	8	9	14	15	13	15	12	13
	2	1	0	3	0	3	7	5	4	7	5	6	10	9	10	11	10	8	12	13	12	15	13	14
	0	2	0	1	2	2	4	7	6	5	4	5	8	10	11	10	9	10	15	14	15	14	14	12
	2	1	3	1	3	2	7	5	4	7	4	7	9	10	11	8	9	11	13	12	13	12	13	15
	3	0	1	3	0	3	4	6	7	4	6	6	10	10	8	10	9	8	12	15	14	15	13	12

(b)

Figure 4 One-shot observation of channel reuse pattern variations when U=4
(a) Single-group IACS-DCA
(b) Multi-group IACS-DCA

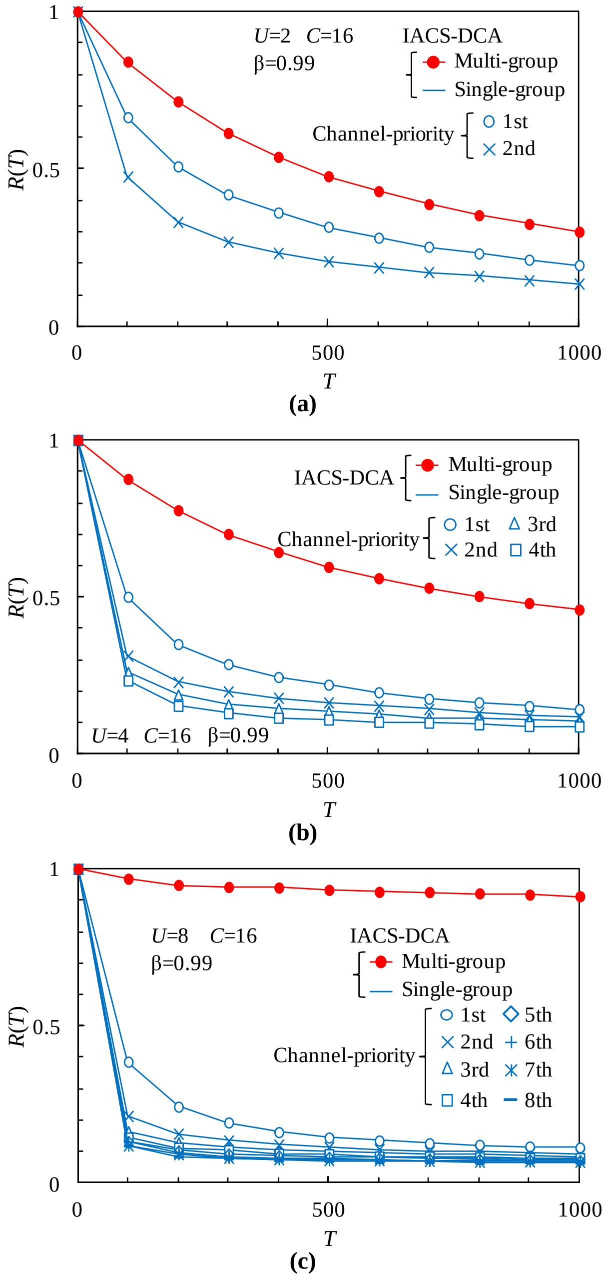


Figure 5 Autocorrelation of channel reuse pattern comparison
(a) U=2 **(b)** U=4 **(c)** U=8

3.2 SIR distribution

In the case of single-group IACS-DCA, SIR of MTs communicating using lower-priority channels degrades [11]. However, in the case of multi-group IACS-DCA, highest priority channel is always used and therefore, serious SIR degradation may not be caused. Fig. 6 plots the CDF of uplink SIR. As is expected, the multi-group IACS-DCA provides an improved SIR performance (although the performance improvement is small) compared with single-group IACS-DCA.

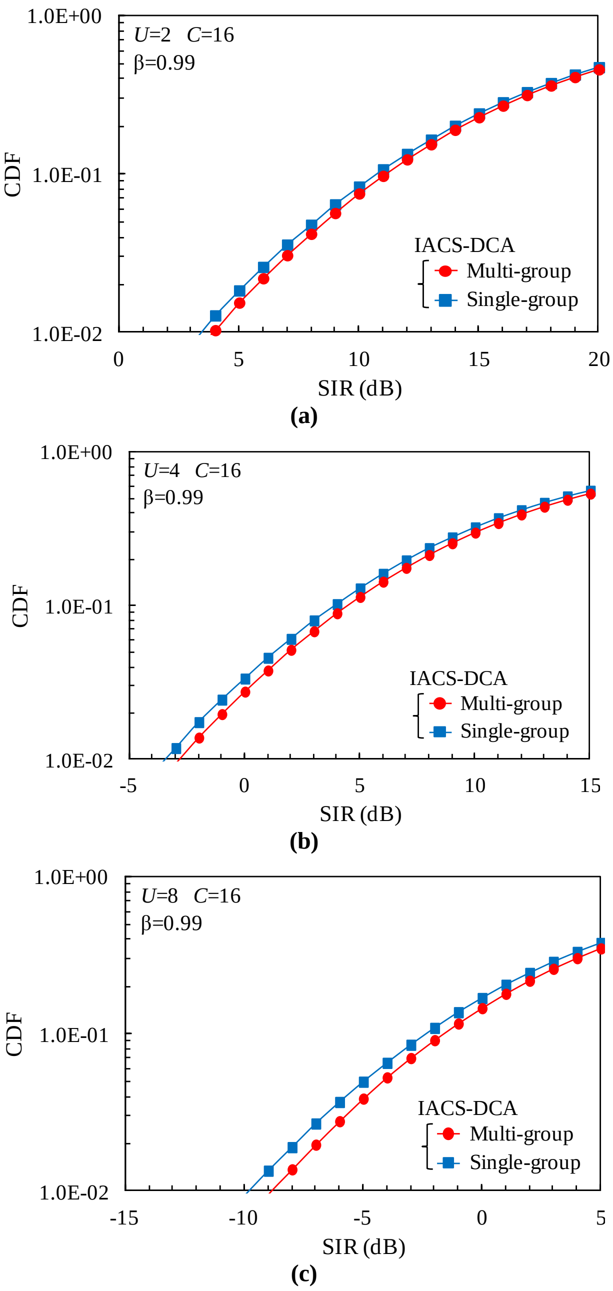


Figure 6 CDF of uplink SIR
(a) *U*=2 **(b)** *U*=4 **(b)** *U*=8

4 Conclusions

In this paper, we proposed multi-group IACS-DCA, in which the available channels are divided into multiple groups and single-group IACS-DCA is applied to each channel group. It was shown by computer simulation that multi-group IACS-DCA provides more stable channel reuse pattern and better SIR performance than single-group IACS-DCA.

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