PAPER

Interference-Aware Channel Segregation Based Dynamic Channel Assignment for Wireless Networks

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SUMMARY Recently, we proposed an interference-aware channel segregation based dynamic channel assignment (IACS-DCA). In IACS-DCA, each base station (BS) measures the instantaneous co-channel interference (CCI) power on each available channel, computes the moving average CCI power using past CCI measurement results, and selects the channel having the lowest moving average CCI power. In this way, the CCI-minimized channel reuse pattern can be formed. In this paper, we introduce the autocorrelation function of channel reuse pattern, the fairness of channel reuse, and the minimum co-channel BS distance to quantitatively examine the channel reuse pattern formed by the IACS-DCA. It is shown that the IACS-DCA can form a CCI-minimized channel reuse pattern in a distributed manner and that it improves the signal-to-interference ratio (SIR) compared to the other channel assignment schemes.

key words: *channel segregation, dynamic channel assignment, co-channel interference*

1. Introduction

Since the number of available channels is limited, the same channel must be reused by geographically separated base stations (BSs). Therefore, the co-channel interference (CCI) limits the transmission quality. In any cellular system, careful channel assignment is necessary. If the same channel is reused by every BS, a sophisticated multi-user scheduling among all mobile terminals (MTs) is necessary. This problem can be separated into two problems: channel assignment over BSs in a network and multi-access within each BS. In this paper, the problem of how to assign the limited number of channels over BSs in a network is considered. Note that, how to share assigned set of channels among MTs belonging to each BS is the multiple access problem. As for multiple access within each BS, frequency division multiple access (FDMA), time division multiple access (TDMA), ALOHA, or carrier sense multiple access (CSMA) can be used. As a duplex scheme, either frequency-division duplex (FDD) or time-division duplex (TDD) can be applied. In this paper, a generic cellular system using time-division duplex (TDD) based FDMA is assumed.

There are basically two channel assignment schemes: fixed and dynamic. In this paper, dynamic channel assignment (DCA) is considered. In general, DCA can be classified into two types [1]–[3]: centralized DCA and distributed DCA. The centralized DCA finds the channel reuse pattern that minimizes the CCI by taking into account all the CCI information of all BSs; however, its drawback is high computational complexity [4]. Recent study on DCA is found in [5], which considers a heterogeneous network (HetNet) consisting of femto-cells and macro-cells. The DCA proposed in Ref. [5] is a type of centralized DCA based on the graph approach. On the other hand, in the distributed DCA, the channel selection is determined in a distributed manner based on own CCI information of each BS. Hence, distributed DCA is inherently computationally efficient. The application of distributed DCA to cellular networks and WLANs is studied extensively in the literature [6]–[8].

One promising distributed DCA is channel segregation based DCA (CS-DCA) [9], [10]. In CS-DCA of [9], [10], the priority order of each channel is stored in the priority table at each BS. When the channel is requested, the channel having the highest priority among idle channels is used. The priority is updated by measuring the signal-to-interference-plus-noise ratio (SINR) at every time when the channel is requested. The priority of a channel is increased when the SINR of that channel exceeds the threshold, otherwise the priority is decreased. In this way, the same channel is reused in different BSs, depending on the threshold SINR.

The aim of this paper is to propose a distributed DCA scheme which can form the CCI-minimizing channel reuse pattern in a distributed manner which requires no information exchange among BSs and less computational power than the centralized DCA. Recently, we proposed an interference-aware CS-DCA (IACS-DCA) [11]. Each BS measures the instantaneous CCIs on all available channels, computes the moving average CCI power using past CCI measurement results, and selects the channel having the lowest moving average CCI power. In a real situation, the traffic distribution is not uniform and varies over time. IACS-DCA forms the channel reuse pattern based on the average CCI information and hence, is able to track variations in the traffic distribution averaged over the CCI averaging interval. In this way, the same channel is reused in different BSs so as to minimize the CCI without exchanging the CCI information among BSs. However, in [11], the quantitative examination of channel reuse pattern formed by IACS-DCA was not discussed.

In this paper, to quantitatively examine the channel reuse pattern formed by IACS-DCA, we introduce the autocorrelation function of channel reuse pattern, the fairness

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of channel reuse, and the minimum co-channel BS distance. We show that the IACS-DCA can form a CCI-minimized channel reuse pattern in a distributed manner and that it improves the signal-to-interference ratio (SIR) compared to the other channel assignment schemes.

The rest of this paper is organized as follows. Section 2 describes the IACS-DCA. In Sect. 3, three indicators for examining the channel reuse pattern are introduced. In Sect. 4, we examine, by computer simulation, the channel reuse pattern to confirm that the IACS-DCA is able to form a CCI-minimized channel reuse pattern and improves the SIR compared to the other channel assignment schemes. Section 5 gives some concluding remarks and future works.

2. Overview of IACS-DCA [11]

Figure 1 shows a flowchart of the IACS-DCA [11]. In our proposed IACS-DCA, every BS 1) periodically measures the its instantaneous received CCI powers on all available channels, 2) computes the moving average CCI powers using past CCI measurements, 3) updates the CCI table, and 4) chooses the best channel experiencing the smallest average CCI.

To compute the moving average CCI powers for all available channels, the first order filtering [12] is used. The number of available channels is denoted by N_{ch}. The moving average CCI power of the m-th BS (BS_m) on the ch-th channel ($ch = 0 \sim N_{ch} - 1$) at time-slot t is given as

$$\begin{aligned}\bar{I}_{\mathrm{BS}_m,ch}(t) &= (1-\beta)\cdot I_{\mathrm{BS}_m,ch}(t) + \beta \cdot \bar{I}_{\mathrm{BS}_m,ch}(t-1) \\ &= (1-\beta)\cdot \sum_{i=0}^{t} \beta^i \cdot I_{\mathrm{BS}_m,ch}(t-i),\end{aligned} \quad (1)$$

where $I_{\mathrm{BS}_m,ch}(t)$ and β ($0 \le \beta < 1$) are respectively the instantaneous CCI power at time-slot t and the filter forgetting factor. BS looks up the CCI table and chooses the ch_{use}-th channel having the lowest moving average CCI power as

$$ch_{use} = \underset{ch\in[0,N_{ch}-1]}{\arg\min}\ \{\bar{I}_{\mathrm{BS}_m,ch}(t)\}. \quad (2)$$

In a real situation, the traffic distribution varies over time. Therefore, the channel reuse pattern should track the time-varying traffic. The filter forgetting factor β is an important

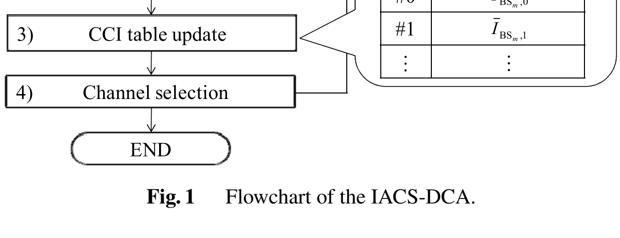


Fig. 1 Flowchart of the IACS-DCA.

parameter which controls the tracking ability of IACS-DCA against time-varying traffic. The averaging interval of first order filtering is given as $1/(1-\beta)$ time-slots. Therefore, IACS-DCA can track time-varying traffic variations slower than $1/(1-\beta)$ time-slots. By appropriately setting the value of β, IACS-DCA can be used in any time-varying traffic environment. For example, let's assume $\beta = 0.99$ and the CCI measurement and CCI table updating of every minute. Our proposed IACS-DCA can track time-varying traffic variations slower than 100-minute period.

In this paper, assuming the time-invariant uniform traffic distribution, we investigate if our proposed IACS-DCA based on CCI measurement can form a CCI-minimized stable channel reuse pattern.

3. Channel Reuse Pattern Evaluation

In this paper, we show that our proposed IACS-DCA can form a CCI-minimized channel reuse pattern in a distributed manner. In this section, to quantitatively examine the channel reuse pattern formed by IACS-DCA, we introduce the autocorrelation function of channel reuse pattern, the fairness of channel reuse, and the minimum co-channel BS distance.

3.1 Autocorrelation of Channel Reuse Pattern

In the IACS-DCA, each BS measures the instantaneous CCI power on each available channel, computes the moving average CCI powers using past CCI measurement results, and selects the channel having the lowest moving average CCI power. Assuming the time-invariant uniform traffic distribution, IACS-DCA based on CCI measurement is expected to form a CCI-minimized stable channel reuse pattern. In this paper, we examine the stability of channel reuse pattern by using the autocorrelation function of channel reuse pattern. Then, we discuss if our proposed IACS-DCA based on CCI measurement can form a stable channel reuse pattern under the time-invariant uniform traffic distribution.

The autocorrelation function $\Phi(n)$ of channel reuse pattern is defined as the average number of BSs which continuously use the same channel at time-slot t and time-slot $t-n$, normalized by the total number of BSs. $\Phi(n)$ is given by

$$\Phi(n) \equiv E\left[\frac{1}{N_{bs}}\sum_{m=0}^{N_{bs}-1}\sum_{ch=0}^{N_{ch}-1} c_{ch}(m,t)\cdot c_{ch}(m,t-n)\right], \quad (3)$$

where $E[.]$ denotes the ensemble average operation, N_{bs} represents the total number of BSs and $c_{ch}(m,t)$ is a function that gives 1 when BS_m uses ch-th channel on time t otherwise it gives 0. As the channel reuse pattern approaches a stable condition, $\Phi(n)$ approaches to 1.

3.2 Fairness Index

Assuming the time-invariant uniform traffic distribution, the statistical properties of propagation path loss, shadowing loss, and fading are equally likely for all channels (this assumption holds in present wireless systems), the channel utilization can be highest if all channels are reused equally likely. If a certain channel is reused more frequently in different BSs, the reuse distance of that channel is shorter than those of others (or equivalently, the utilization efficiency of that channel is lower than other channels). Based on this consideration, the idea of fairness index is introduced. We evaluate the spectral efficiency by examining the fairness of channel reuse. In this paper, a modified Jain's fairness index proposed in [13] is used to examine the fairness of channel reuse. The fairness index $F(t)$ is defined as the fairness averaged over all BSs (or over channels used in all BSs) in an area of interest at time-slot t and is given as

$$F(t) \equiv E\left[\frac{\left(\sum_{ch=0}^{N_{ch}-1} u_{ch}(t)\right)^2}{N_{ch}\cdot\sum_{ch=0}^{N_{ch}-1}\{u_{ch}(t)\}^2}\right], \tag{4}$$

where $u_{ch}(t)$ represents the number of BSs using the same ch-th channel in an area of interest at time-slot t. $F(t)$ is defined over the range of $[1/N_{ch}, 1]$. $F(t)$ takes a value of 1 when all available channels are used equally likely while it takes a value of $1/N_{ch}$ when the same channel is used at all BSs. In this paper, an uniform traffic distribution is considered. In this case, the co-channel BS distance should be almost the same for all available channels, i.e., all available channels should be used equally likely, and consequently, $F(t)$ takes a value close to 1.

3.3 Minimum Co-channel BS Distance

In the channel reuse wireless networks, the transmission quality is affected by the CCI power. The minimum co-channel BS distance, i.e., the distance between BSs which use the same channel, is an important factor which indicates how closely the same channel is reused. The minimum co-channel BS distance $D(t)$ is defined as

$$D(t) \equiv E\left[\frac{1}{N_{bs}}\sum_{m=0}^{N_{bs}-1}\left(\min_{v\in[0,N_{bs}-1]} d_{m,v}(t)\right)\right], \tag{5}$$

where $d_{m,v}(t)$ represents the distance between BS_m and BS_v which use the same channel at time-slot t. As the minimum co-channel BS distance gets longer, the CCI gets weaker.

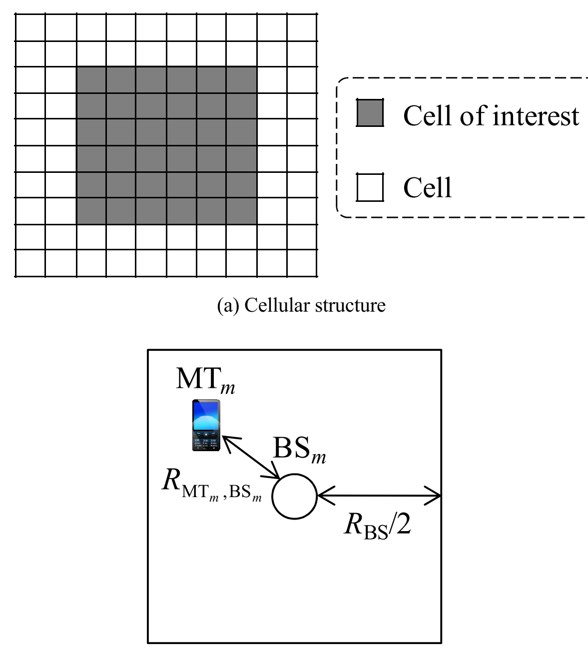
4. Computer Simulation

Computer simulation was done to examine the channel reuse pattern formed by IACS-DCA and to evaluate the SIR distribution in the network.

Table 1 summarizes the simulation condition. The MTs are assumed to be stationary. BS measures the uplink instantaneous CCI power from other MTs and updates the CCI table and the channel at every time-slot. The perfect measurement of the instantaneous CCI power on each BS

Table 1 Computer simulation condition.

System	No. of co-channel cells	N_{all}=100
	No. of channels	N_{ch}=4
	No. of MTs per cell	U=1
	Transmission probability	p=1
	Normalized transmit SNR	∞
Channel	Fading type	Frequency-selective block Rayleigh
	Power delay profile	Sampling interval-spaced L=16-path uniform
	Path loss exponent	α=3.5
	Shadowing loss standard deviation	σ=5.0 (dB)
IACS-DCA	Forgetting factor of first order filtering	β=0.5, 0.9, 0.99, 0.999
	CCI power measurement	Ideal



(a) Cellular structure

(b) Geometry of BS and MT

Fig. 2 Network model.

is assumed. We consider the TDD system using orthogonal frequency division multiplexing (OFDM) [14]. All MTs transmit packets with a probability of $p = 1$ for uplink and all BSs transmit packet with $p = 1$ for downlink, i.e., the time-invariant uniform traffic distribution is assumed.

4.1 Network Model

Figure 2 illustrates the network model. $N_{\mathrm{all}} = 100$ cells are considered and $N_{\mathrm{int.}} = 36$ cells (shadowed region in Fig. 2(a)) are the cells of interest to examine the channel reuse pattern and SIR distribution. As shown in Fig. 2(b), a BS equipped with single antenna is located at the center of each cell. In this paper, for examining if IACS-DCA forms the channel reuse pattern that minimizes the CCI, it is assumed that the single MT equipped with single antenna exists in each cell. $R_{\mathrm{MT}_m,\mathrm{BS}_m}$ denote the distance between the

m-th MT (MT_m) and the BS_m. If more than one user exist, an introduction of multiple access scheme and/or call admission control is necessary. Regarding cell selection, the distance-based cell selection is assumed. The distance between adjacent BSs is denoted by R_{BS}.

4.2 Propagation Channel Model

We assume a frequency-selective block Rayleigh fading channel which is composed of L distinct paths. The channel impulse response between BS_m and $\mathrm{MT}_{m'}$ is given by

$$h_{\mathrm{MT}_{m'},\mathrm{BS}_m}(\tau) = \sum_{l=0}^{L-1} h^{(l)}_{\mathrm{MT}_{m'},\mathrm{BS}_m} \cdot \delta(\tau - \tau^{(l)}_{\mathrm{MT}_{m'},\mathrm{BS}_m}) \qquad (6)$$

with

$$h^{(l)}_{\mathrm{MT}_{m'},\mathrm{BS}_m} = \sqrt{R^{-\alpha}_{\mathrm{MT}_{m'},\mathrm{BS}_m} \cdot 10^{-\frac{\eta_{\mathrm{MT}_{m'},\mathrm{BS}_m}}{10}}} \cdot \tilde{h}^{(l)}_{\mathrm{MT}_{m'},\mathrm{BS}_m}, \qquad (7)$$

where $R_{\mathrm{MT}_{m'},\mathrm{BS}_m}$, α, and $\eta_{\mathrm{MT}_{m'},\mathrm{BS}_m}$ denote the distance between the $\mathrm{MT}_{m'}$ and the BS_m, the path-loss exponent, and the shadowing loss in dB having zero-mean and standard deviation σ, respectively. $\tilde{h}^{(l)}_{\mathrm{MT}_{m'},\mathrm{BS}_m}$ and $\tau^{(l)}_{\mathrm{MT}_{m'},\mathrm{BS}_m}$ are the complex-valued path gain with $E[\sum_{l=0}^{L-1} |\tilde{h}^{(l)}_{\mathrm{MT}_{m'},\mathrm{BS}_m}|^2] = 1$ and the time delay of the l-th path between $\mathrm{MT}_{m'}$ and BS_m, respectively. The average received signal power P_{r,BS_m} at BS_m from $\mathrm{MT}_{m'}$ is given as

$$P_{r,\mathrm{BS}_m} = P_{t,\mathrm{MT}_{m'}} \cdot R^{-\alpha}_{\mathrm{MT}_{m'},\mathrm{BS}_m} \cdot 10^{-\frac{\eta_{\mathrm{MT}_{m'},\mathrm{BS}_m}}{10}}, \qquad (8)$$

where $P_{t,\mathrm{MT}_{m'}}$ is the transmit power. By introducing the normalized distance $r_{\mathrm{MT}_{m'},\mathrm{BS}_m} = R_{\mathrm{MT}_{m'},\mathrm{BS}_m}/R_{\mathrm{BS}}$ and the normalized transmit power $\bar{P}_{t,\mathrm{MT}_{m'}} = P_{t,\mathrm{MT}_{m'}} \cdot R^{-\alpha}_{\mathrm{BS}}$, Eq. (8) can be rewritten as

$$P_{r,\mathrm{BS}_m} = \bar{P}_{t,\mathrm{MT}_{m'}} \cdot r^{-\alpha}_{\mathrm{MT}_{m'},\mathrm{BS}_m} \cdot 10^{-\frac{\eta_{\mathrm{MT}_{m'},\mathrm{BS}_m}}{10}}. \qquad (9)$$

4.3 Uplink Model

At the MT transmitter, the binary information sequence is data-modulated and then, the data-modulated symbol sequence is divided into a sequence of blocks of N_c symbols each. Then, N_c-point inverse discrete Fourier transform (IDFT) is applied to form the OFDM signal block. The last N_g samples in each block are copied and inserted as a cyclic prefix (CP) into the beginning of the signal block before transmission.

The transmitted OFDM signal block passes through a frequency-selective fading channel. At the BS receiver, after CP removal, the received signal block is decomposed by N_c-point DFT into the orthogonal subcarrier components. The frequency domain received signal on k-th subcarrier is expressed as

$$\begin{aligned} Y_{\mathrm{BS}_m}(k) = &\sqrt{2\bar{P}_{t,\mathrm{MT}_m}} \cdot H_{\mathrm{MT}_m,\mathrm{BS}_m}(k) \cdot x_{\mathrm{MT}_m}(k) \\ &+ I_{\mathrm{BS}_m}(k) + N_{\mathrm{BS}_m}(k), \end{aligned} \qquad (10)$$

where $H_{\mathrm{MT}_m,\mathrm{BS}_m}(k)$ and $N_{\mathrm{BS}_m}(k)$ represent the channel transfer function between MT_m and BS_m and the noise component on the k-th subcarrier, respectively. $x_{\mathrm{MT}_m}(k)$ is the data symbol transmitted on the k-th subcarrier. $I_{\mathrm{BS}_m}(k)$ is the CCI component received by BS_m and is expressed as

$$I_{\mathrm{BS}_m}(k) = \sum_{\{u \in U_{\mathrm{BS}_m}: u \neq m\}} \sqrt{2\bar{P}_{t,\mathrm{MT}_u}} \cdot H_{\mathrm{MT}_u,\mathrm{BS}_m}(k) \cdot x_{\mathrm{MT}_u}(k), \qquad (11)$$

where $U_{\mathrm{BS}_m} \in \{0, 1, \ldots, N_{\mathrm{all}} - 1\}$ is a set of interfering MTs which are communicating with their BSs using the same channel as BS_m. Then, the instantaneous CCI power of ch-th channel on BS_m at time-slot t is given by

$$I_{\mathrm{BS}_m,ch}(t) = \frac{1}{N_c} \sum_{k=0}^{N_c-1} \left| I_{\mathrm{BS}_m}(k) \right|^2. \qquad (12)$$

In this paper, ideal measurement of the instantaneous CCI power is assumed.

4.4 Simulation Results

4.4.1 Stability of the Channel Reuse Pattern

Figure 3 shows a one-shot observation of channel reuse pattern formed by IACS-DCA. MT location is shown in Fig. 3(a). The initial channel reuse pattern at time $t = 0$ was generated by assigning channel #0 to all BSs (see Fig. 3(b)). Figures 3(c) and (d) show one-shot observation of the channel reuse pattern at $t = 100$, 900, 1000 and 1100 for the case of $\beta = 0.999$ and $\beta = 0.5$, respectively. The number in the pattern represents the channel index. In the computer simulation, the BS indicated by bold square in Fig. 3(b) is set to always use channel #0. It can be seen from Fig. 3 that the

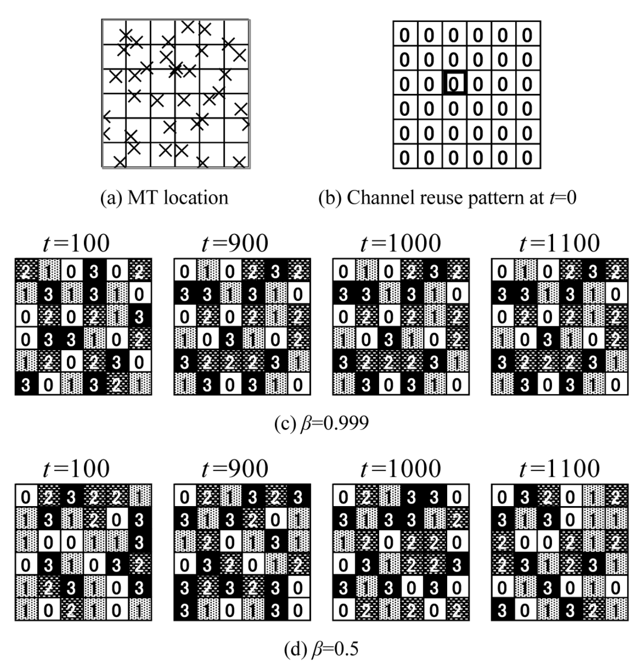


Fig. 3 One-shot observation of channel reuse pattern with IACS-DCA.

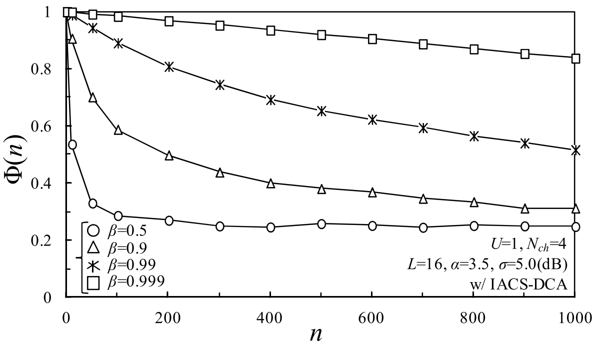


Fig. 4 Autocorrelation function $\Phi(n)$ of channel reuse pattern.

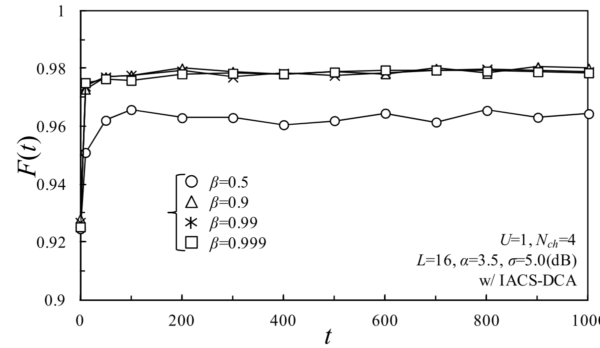


Fig. 5 Fairness index $F(t)$ of channel reuse.

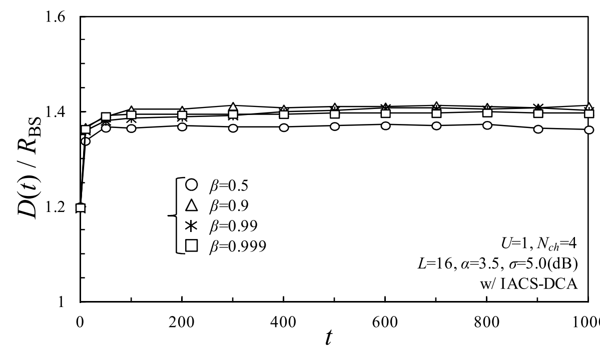


Fig. 6 Minimum co-channel BS distance $D(t)/R_{\mathrm{BS}}$.

stability of channel reuse pattern depends on β. The channel reuse pattern stays the same (stable) after $t = 900$ when $\beta = 0.999$ (see Fig. 3(c)) while it varies even after $t = 900$ when $\beta = 0.5$. This is because the CCI averaging interval of the first order filtering is $1/(1-\beta)$ time-slots. When $\beta = 0.999$, the channel reuse pattern changes slowly and becomes stable at around $t = 1000$. This is because when $\beta = 0.999$, the CCI is sufficiently averaged after $t = 1/(1-0.999) = 1000$ and therefore, the channel reuse pattern becomes almost stable after $t = 1000$. When $\beta = 0.5$, however, the channel reuse pattern is unstable. This is because the CCI averaging interval is only 2 time-slots and is not enough long; therefore, the measured average CCI power deviates from the ensemble average and it varies similar to the instantaneous CCI power. This suggests that β close to 1 should be used to form a stable channel reuse pattern.

Figure 4 plots the autocorrelation function $\Phi(n)$ of channel reuse pattern as a function of time separation n with β as a parameter. In Fig. 4, the channel reuse pattern at time-slot $t = 2000$ is used as the reference pattern. Assuming the time-invariant uniform traffic distribution, β of close to 1 is suitable because the filter output approaches the ensemble average of CCI. It can be seen from Fig. 4 that the channel reuse pattern becomes stable when larger β is used (note that this is true only for the time-invariant uniform traffic distribution case).

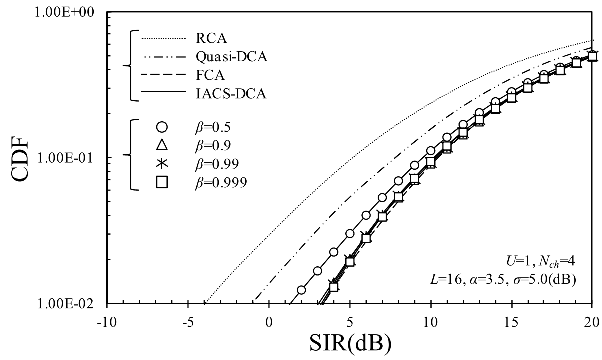
4.4.2 Fairness of Channel Reuse and the Minimum Co-channel BS Distance

Figures 5 and 6 show respectively the fairness index $F(t)$ for channel reuse and the minimum co-channel BS distance $D(t)$ normalized by R_{BS} as a function of time-slot t with β as a parameter. It can be seen from Fig. 5, when β closer to 1 is used, all the channels tend to be used equally at different BSs. The fairness index of 1 is desirable for the case of time-invariant uniform traffic distribution. However, IACS-DCA is a distributed algorithm and the channel reuse pattern fluctuates as indicated by Fig. 4. Accordingly, the highest fairness index achievable by IACS-DCA is found to be 0.98 as seen from Fig. 5.

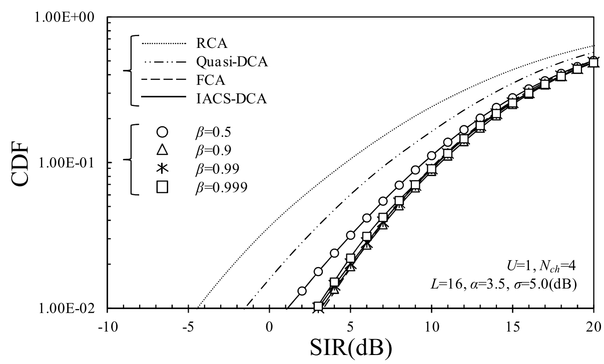
It can be also seen from Fig. 6 that the minimum co-channel BS distance gets longer and approaches $D(t)/R_{\mathrm{BS}} = 1.4$. Since a cellular system with square cells is assumed in this paper, the shortest distance between co-channel BSs is 1. This is the case if the same channel is reused by an immediately adjacent BS. However, this cannot happen unless a very large shadowing loss exists between two immediately adjacent BSs. The second shortest distance between co-channel BSs is $\sqrt{2} \approx 1.41$, which is the case if the same channel is reused by a diagonally opposite BS. Therefore, it is plausible that the achievable shortest distance is around 1.4.

4.4.3 SIR Distribution

Figure 7 plots the cumulative distribution function (CDF) of the SIR when using IACS-DCA. The SIR level was measured when $t = 2000$. For comparison, the SIR distributions of the random channel assignment (RCA), the fixed channel assignment (FCA) [15] and the quasi-DCA are also plotted. In the quasi-DCA, every time each BS is powered on, it measures the CCI power of all available channels, selects the channel having lowest CCI power. The selected channel does not change until $t = 2000$. It can be seen from Fig. 7 that the use of larger β improves the SIR performance. The IACS-DCA using $\beta \approx 1$ improves the SIR at CDF $= 10^{-1}$ by about 4.4 dB and 4.6 dB for uplink and downlink, respectively, compared to the quasi-DCA. Since we are assuming the time-invariant uniform traffic distribution, FCA should be the best in the minimum CCI sense. IACS-DCA achieves the SIR distribution close to FCA and a slight degradation



(a) Uplink



(b) Downlink

Fig. 7 CDF of SIR.

in SIR performance is due to the channel reuse pattern fluctuation as indicated by Figs. 4∼6.

The channel reuse pattern formed by our proposed IACS-DCA is examined from different viewpoints. Figure 4 examines the stability of channel reuse pattern by the autocorrelation function and Figs. 5 and 6 examine the channel reusing by the fairness index and the minimum co-channel BS distance. It can be seen from Fig. 4 that the use of smaller β makes the channel reuse pattern less stable. However, it is seen from Figs. 5 and 6 that if β is higher than 0.9, the fairness index does not differ so much and the minimum co-channel BS distance does not differ either. This observation is consistent with the result of SIR distribution plotted in Fig. 7. It should be noted that much clearer difference between the cases $\beta = 0.5$ and 0.9 is seen in the fairness than in the minimum co-channel BS distance. This suggests that a good indicator to examine the channel reuse pattern is the fairness index. What can be understood from Figs. 4∼7 is that the use of small β, e.g. $\beta = 0.5$, is not appropriate.

5. Conclusion

In this paper, we introduced the autocorrelation function of channel reuse pattern, the fairness of channel reuse, and the minimum co-channel BS distance and discussed the performance of our proposal, IACS-DCA. It was shown that IACS-DCA using $\beta \approx 1$ can form a stable channel reuse pattern in a distributed manner and that it almost matches the SIR performance of FCA in the case of a time-invariant uniform traffic distribution.

In this paper, MTs were assumed to be stationary. However, in practical situations, they move and the traffic distribution may dynamically change over time. How fast our proposed IACS-DCA is able to track the time-varying traffic is an important practical issue. The optimum forgetting factor β should be lower than 1 so that the channel reuse pattern can track the traffic variation (the use of $\beta \approx 1$ cannot track the traffic variation in practice). Tracking ability of IACS-DCA against changing traffic distribution pattern is an important future study. In the near future, small-cell structured networks will become popular. In small-cell networks, the traffic distribution varies more dynamically and rapidly. IACS-DCA may not be able to track such rapidly time-varying traffic. It is an interesting problem whether IACS-DCA is applicable to a small-cell network. This is left as our future study.

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