A Study of Interference-Aware Channel Segregation for HetNet Using Time-Division Channels

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***Abstract*—One of the problem in heterogeneous networks (HetNets), i.e., a combination of several small cell base stations (SBSs) and an overlaid macro cell base station (MBS), is the co-channel interference (CCI) between BSs when MBS and SBSs share the same radio resource. Using interference-aware channel segregation based dynamic channel assignment (IACS-DCA), each BS periodically measures the average CCI power on all available channels. The channel with the lowest average CCI power is not being used by neighboring BSs and hence, this channel can be selected to use. In this way, IACS-DCA forms a channel reuse pattern with low CCI in a distributed manner. In this paper, we apply the IACS-DCA to HetNet using time-division channels. We show by computer simulation that the IACS-DCA is able to form a channel reuse pattern with low CCI.**

Keywords-channel segregation; dynamic channel assignment; co-channel interference; heterogeneous network

I. INTRODUCTION

Due to scarce spectrum resources, the number of available channels is limited in wireless networks and hence, the same channel must be reused by different base stations (BSs). Since the co-channel interference (CCI) limits the transmission quality, the channels must be reused so as to minimize the CCI at every BS. In addition, CCI environment changes over time when new BS appears or user equipment (UE) moves. Therefore, the channels should be properly re-allocated according to change of CCI environment. To remedy this problem, dynamic channel assignment (DCA) has been studied [1]-[3]. There are two types of DCA: centralized and distributed. The centralized DCA may not be practical due to its prohibitively high computational complexity [4]-[5]. We have been studying an interference-aware channel segregation based DCA (IACS-DCA) [6]-[8], which falls in the type of distributed DCA. We have shown that in the network using frequency division channels, IACS-DCA can form a channel reuse pattern with low CCI in a distributed manner [6]-[8]. In IACS-DCA, each BS periodically measures the average CCI powers on all available channels to select the best channel having the lowest average CCI power to use.

Heterogeneous networks (HetNets), which consist of several small cell BSs (SBSs) and an overlaid macro cell BS (MBS), are capable to deal with exponential increase in wireless data traffic [9]. One major problem in HetNets is the CCI between BSs when MBS and SBSs share the same radio resource. In this paper, we apply IACS-DCA to HetNet using time-division channels. We show by computer simulation that a channel reuse pattern with low CCI is formed by IACS-DCA in HetNet using time-division channels.

II. IACS-DCA

IACS-DCA flowchart is shown in Figure 1. Each BS is equipped with channel priority table. It periodically (i) measures the instantaneous CCI powers by monitoring the beacon signal on all available channels. The beacon signal is designed to be periodically transmitted from each BS. Then, each BS (ii) computes the average CCI power on all available channels by using past CCI measurement results and (iii) updates the channel priority table to (iv) select the best channel having the lowest average CCI power. After the channel selection, it (v) broadcasts the beacon signal on the selected channel. Each BS periodically repeats the procedure of (i) ~ (v).

The average CCI power measured at the m-th BS, BS(m), on the c-th channel at time t is denoted by $\bar{I}_{\mathrm{BS}(m)}(t;c)$. Using the average CCI powers on all available channels, the channel priority table is updated for all available channels (c=0~C−1). The channel having the lowest average CCI power is selected according to:

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

which is used until the next channel priority table updating time t+1.

The channel with the lowest average CCI power is considered not to be used by neighboring BSs and hence, the impact of causing interference to other BSs by using this channel is expected to be small. Therefore, a channel reuse pattern with low CCI can be formed by IACS-DCA.

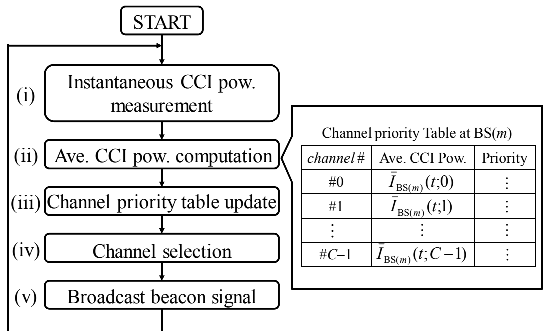

Figure 1. Flowchart of IACS-DCA.

III. COMPUTER SIMULATION

A. Simulation model

An example of HetNet model is illustrated in Figure 2. An MBS is located at the center of hexagonal macro cell. N_{SBS} SBSs are distributed uniformly within one MBS and a static UE is assumed to be uniformly located within each cell. The simulation parameters are summarized in Table I. We show that the channel reuse pattern formed by IACS-DCA can reduce the CCI which originates from macro cell and is received by small cell. As shown in Figure 3, we assume C time-division channels (i.e., C timeslots within one timeframe). For the measurement of the average CCI power, the first order filtering with forgetting factor β is used. If a too small β is used, the measured average CCI tends to follow the instantaneous CCI and the channel segregation cannot be done. Hence, β=0.99 is used [7].

In each simulation run, the signal-to-interference power ratio (SIR) measurement is carried out when t=2000 (i.e., after the channel reuse pattern gets stable). The cumulative distribution function (CDF) of downlink SIR is obtained by conducting the simulation run 300 times. We only consider path loss in propagation loss. The initial channel is set to channel #0 (c=0) for all BSs.

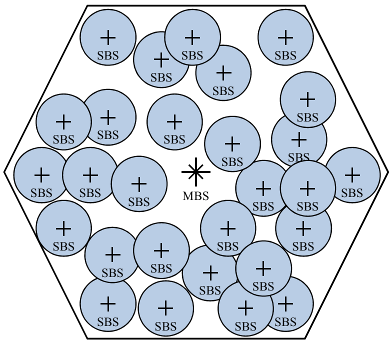

Figure 2. An example of HetNet model.

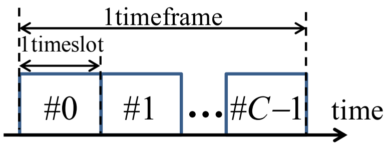

Figure 3. Timeframe structure.

TABLE I. TABLE TYPE STYLES

Network	No. of MBSs	N_{MBS}=1
	No. of SBSs	N_{SBS}=29
	No. of channels	C=8
	Carrier frequency	2 [GHz]
	Frequency bandwidth	10 [MHz]
	Noise power spectrum density [10]	−174 [dBm/Hz]
Macro cell	Radius	250 [m]
	Min. MBS-SBS distance	75 [m]
	Transmit power of MBS	46 [dBm]
Small cell	Radius	40 [m]
	Min. SBS-SBS distance	40 [m]
	Transmit power of SBS	30 [dBm]
Path loss [11]	MBS-SBS, MBS-UE	$15.3+37.6\log_{10}(d_{BS(m),BS(n)})$ [dB]
	SBS-SBS, SBS-UE	$27.6+37.6\log_{10}(d_{BS(m),BS(n)})$ [dB]
	$d_{BS(m),BS(n)}$: distance between BS(m) and BS(n) [m]	
IACS-DCA	Filter forgetting factor	β=0.99

B. Simulation result

Figure 4 plots the CDF of downlink SIR. For comparison, we also plot the downlink SIR when MBS is off after channel segregation is finished (there is no CCI from MBS to small cell when the SIR measurement is carried out). We observe that downlink SIR when MBS is on is almost equal to downlink SIR when MBS is off. This proves the effectiveness of our proposed IACS-DCA in reducing CCI between macro cell and small cells.

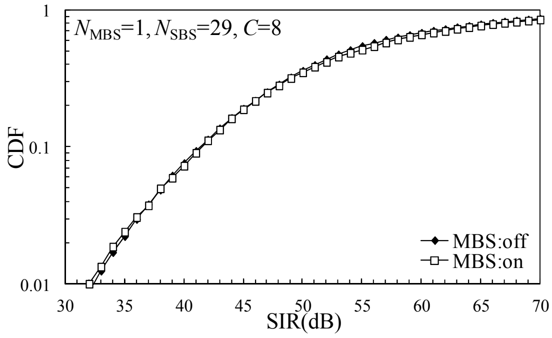

Figure 4. Downlink SIR distribution.

IV. COLCLUSION

In this paper, we studied the IACS-DCA in HetNet using time-division channels. We showed by computer simulation that the CCI from marco cell which is exposed to small cells can be avoided by IACS-DCA.

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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] 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. Magazine, vol. 45, no. 11, pp. 86-95, Nov. 2007.

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

[4] R. W. Nettleton, "A high capacity assignment method for cellular mobile telephone systems," Proc. IEEE 39th Vehicular Technology Conference (VTC1989-Spring), May 1989.

[5] G. F. Marias, D. Skyrianoglou, and L. Merakos, "A centralized approach to dynamic channel assignment in wireless ATM LANs," Proc. 18th Annual Joint Conference of the IEEE Computer and Communications Societies (Infocom'99), Mar. 1999.

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

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

[8] R. Sugai, M. T.H. Sirait, Y. Matsumura, K. Temma, and F. Adachi, "Impact of shadowing correlation on interference-aware channel segregation based DCA," Proc. 2014 IEEE 11th Vehicular Technology Society Asia Pacific Wireless Communications Symposium (APWCS2014), Aug. 2014.

[9] A. Damnjanovic, J. Montojo, Y. Wei, T. Ji, T. Luo, M. Vajapeyam, T. Yoo, O. Song, and D. Malladi, "A survey on 3GPP heterogeneous networks," IEEE Wireless Commun., vol. 18, no. 3, pp. 10-21, Jun. 2011.

[10] H.T. Friis, "Noise figures of radio receivers," Proc.of the IRE, pp. 419-422, July 1944.

[11] S. Samarakoon, M. Bennis, W. Saad and M. Latva-aho, "Opportunistic sleep mode strategies in wireless small cell networks," Proc. IEEE International Conference on Communications 2014 (ICC2014), pp.2707-2712, June 2014.