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Frequency channel blocking for MMW entrance networks

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Abstract: This letter proposes a novel frequency channel blocking (FCB) scheme for millimeter-wave (MMW) entrance networks. In the FCB scheme, any frequency channel is determined to be blocked whether or not, based on not only the network throughput but also the newly defined fairness index. As the results, the FCB scheme yields better throughput and fairness performances with a little increase in computational complexity compared to the conventional scheme.

Keywords: MMW entrance networks, frequency channel blocking, fairness index

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

In Japan, the multihop wireless access with a mesh configuration is proposed for the broadband fixed wireless access (FWA) systems using millimeter-wave (MMW) and quasi-MMW bands (22, 26 and 38 GHz) in [1]. However, according to the tremendous increase of high-speed demand, a new system exploiting 32 GHz band has been developed from today FWA [2]. This system

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has a hierarchical network structure of access networks constructed with P-MP (Point-to-MultiPoint) links for customer premises equipments (CPEs) and a higher level mesh-topology entrance network constructed with Gbps P-P (Point-to-Point) links. The entrance network is used to relay traffic from several base stations (BSs) providing P-MP access links, to a center station (CS) connecting to backbone (BB) networks via P-P wireless links.

Reference [3] proposed the dynamic resource assignment (DRA) scheme performing the radio path allocation and the sub-optimum frequency channel assignment for mesh-topology MMW entrance networks. Nevertheless, in [3], the throughput degradation problem occurs when traffic load becomes heavy. This is because the heavier traffic load leads more share of any channel among different radio links, and thus interfere one another stronger. Therefore, to combat the above problem, we enhance the DRA scheme by using the frequency channel blocking (FCB) scheme proposed in this letter. The proposed FCB scheme blocks the use of frequency channel at any radio link in order to suppress interference level in other links. That is, the proposed FCB scheme sacrifices the throughput of any BS to improve the total network throughput performance. However, this may lead the unfairness problem, which is one of the most important issues in multihop mesh-topology networks [4]. Therefore, this letter proposes a novel frequency channel blocking criterion determining based on not only the network throughput but also the newly defined fairness index.

2 Frequency Channel Blocking

Let us first define network throughput and fairness index as follows:

Throughput, T, is the successful received traffic rate in network [bps]. If the number of error bits of the received packet, whose length is 1500 Bytes, is no more than 2 bits (maximum tolerable error bits in packet), it will be successfully received. In addition, the impact of retransmission when packet is unsuccessfully received is not considered.

Fairness index, F, is newly defined based on the definition shown in [4], and can be written as

$$F = \frac{\left(\sum_{i=1}^{N_{BS}} T_{norm,i}\right)^2}{N_{BS} \cdot \left(\sum_{i=1}^{N_{BS}} T_{norm,i}^2\right)}, \tag{1}$$

$$T_{norm,i} = \frac{T_i}{L_i}, \tag{2}$$

where T_i, L_i and $T_{norm,i}$ respectively denote the throughput, the input load and the normalized throughput of the ith BS. Moreover, from Eq. 1, we can observe that the fairness index is bounded between 0 and 1. A higher fairness index indicates better fairness between BSs.

The proposed frequency channel blocking is performed as detailed in the flowchart shown in Fig. 1. Let us define the parameters as follows:

N_{BS} : Number of BSs in network,

N_{bc} : Number of frequency channel blocking cancellations.

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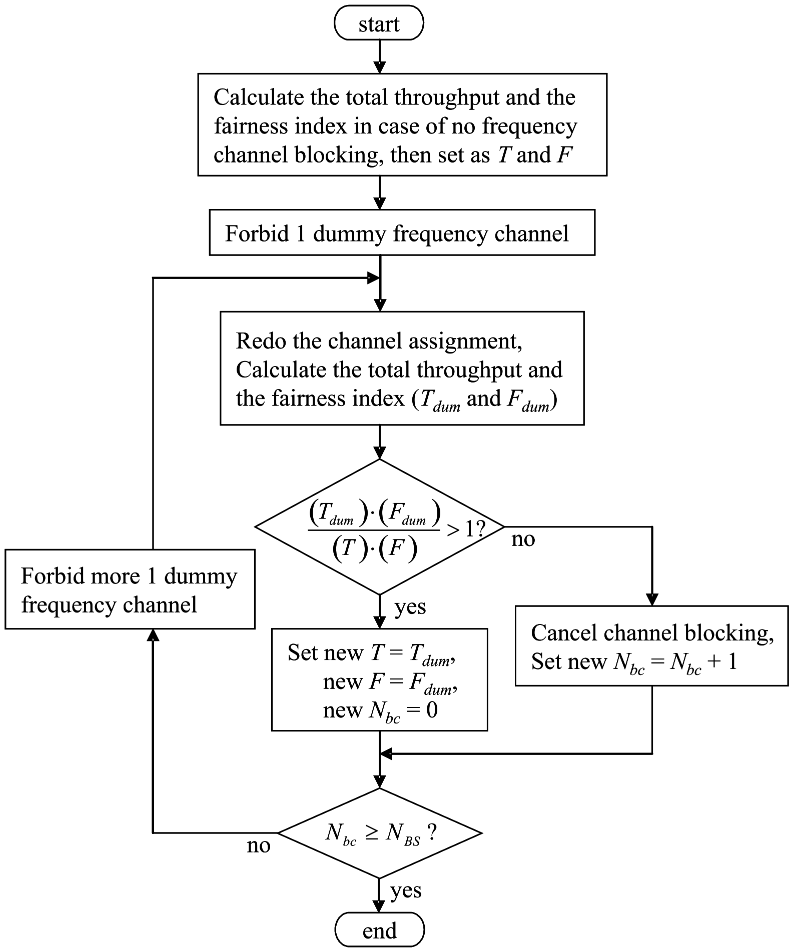

Fig. 1. Frequency channel blocking algorithm.

At the beginning, the initial value of network throughput and fairness index, when the frequency channel blocking scheme is not performed, are calculated. The frequency channel blocking first tries to forbid one dummy frequency channel. Note that at each time in blocking one dummy frequency channel, the frequency channel assignment will be redone. After that, the total throughput and the fairness index of network are calculated, and thus respectively set as T_{dum} and F_{dum}.

Since both the network throughput and the fairness index are significant, in this letter, we propose a novel criterion determining whether the blocking is permitted or not by comparing the product of network throughput multiplied by fairness index before and after the blocking has been done. If the product after the blocking has been done is more than that before the blocking is done, the blocking will be permitted. That is, the latest blocking will be accepted if the following equation

$$\frac{(T_{dum}) \cdot (F_{dum})}{(T) \cdot (F)} > 1? \tag{3}$$

is satisfied, and cancelled in otherwise.

If the frequency channel blocking is accepted, the new value of T and F can be written as T_{dum} and F_{dum}, respectively. Moreover, the number of

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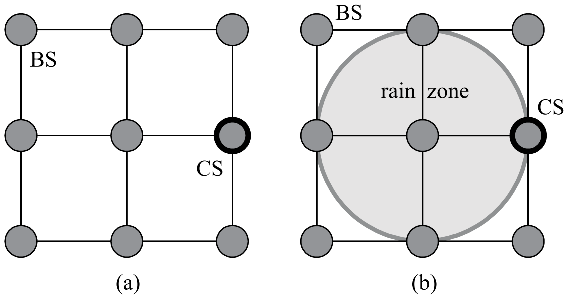

Fig. 2. Analysis model under (a) fine weather condition and (b) rainfall condition.

frequency channel blocking cancellations (N_{bc}) is set to be 0. On the other hand, if the frequency channel blocking is cancelled, the N_{bc} is added by 1.

If condition of $N_{bc} \geq N_{BS}$ is still not satisfied, algorithm tries to additionally forbid more one frequency channel at other one radio link. That is, in this proposed FCB algorithm, algorithm tries to forbid frequency channel until there is no one blocking acceptance for all BSs. Finally, plural frequency channels could be forbidden.

3 Performance Evaluations

Figure 2 shows the analysis model. The eight base stations (BSs) and one center station (CS) each, arranged into the 3×3 square mesh-topology, are established connections with P-P links using parabolic antennas as the wireless entrance network under the line-of-sight (LOS) and the adaptive white Gaussian noise (AWGN) environments. This square mesh-topology is considered in order to evaluate the performance in the severe interference condition. Assume model 2(a) is under the fine weather condition, and model 2(b) is under the rainfall condition that rain falls at the center of network. The rain rate in the rain zone is assumed to be the heavy flat rate of 45 mm/h, which causes the rain attenuation of 10 dB/km as the calculation from the power-law relationship by the ITU-R recommendation, $\gamma = k \cdot R^{\alpha}$ [dB/km] where R is the rain rate in mm/h, $k = 0.221$ and $\alpha = 1.003$ for 32 GHz band.

Parameters used in calculations are as follows. Carrier frequency, f_c, is 32 GHz. Total bandwidth, BW, is 720 MHz. Number of frequency channels, N_f, is 36. That is, channel bandwidth, B_f, becomes 20 MHz. Noise figure is 8 dB. Atmosphere absorption factor, γ_0, is 0.11 dB/km. The adaptive modulation (QPSK, 16QAM, 64QAM and 256QAM) is also performed based on the carrier-to-noise power ratio (CNR) to achieve the bit error rate (BER) of 10^{-4} with margin of 1 dB.

In addition, calculations are performed in two following systems:

1. System I is designed for small size network which is constructed with 1 km length P-P links using parabolic antennas whose gain, $G(o)$, is 28 dBi and front-to-back ratio, α_{fb}, is 15 dB. Transmitted power per channel is set to be 23.8 dBm.

2. System II is designed for larger network which is constructed with 3 km

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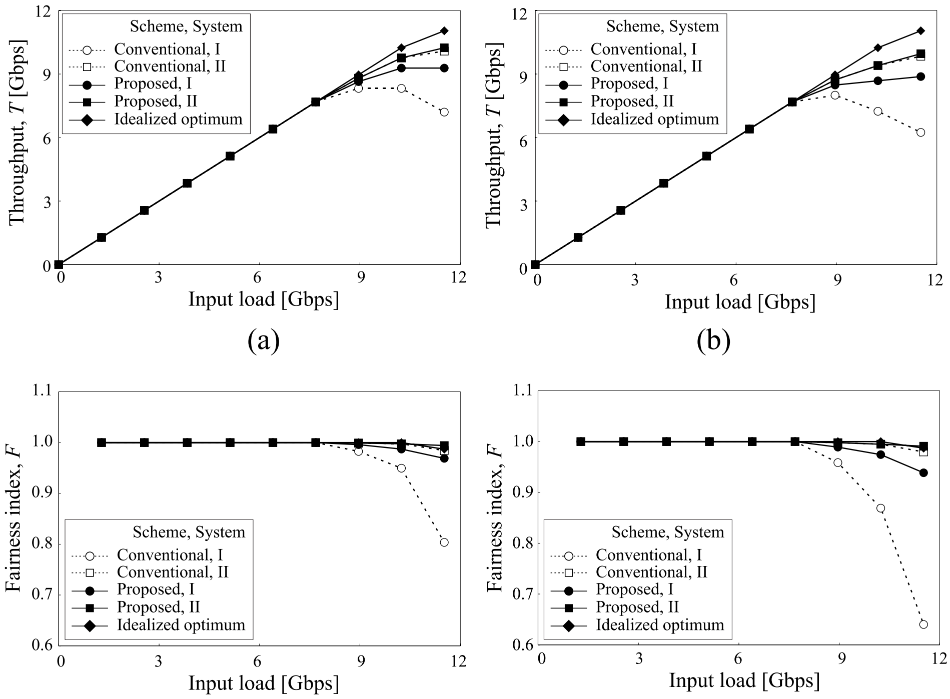

(a) (b)

(c) (d)

Fig. 3. Relationship between input load and (a) throughput under fine weather condition (b) throughput under rainfall condition (c) fairness index under fine weather condition (d) fairness index under rainfall condition.

length P-P links using parabolic antennas whose $G(o)$ is 42 dBi and α_{fb} is 30 dB. Transmitted power per channel is set to be 25.6 dBm.

Throughput and the fairness index performances of conventional scheme investigated in [3] are compared to those of case using the proposed FCB scheme. In addition, performances of case idealized optimum, searching the frequency channel assignment pattern that gives the best throughput, are also compared. The calculations of the case idealized optimum are performed in system II, but use different parabolic antennas whose beamwidth is close to 0 degree, and $G(o)$ and α_{fb} are respectively 42 dBi and ∞.

The relationships between total network throughput versus total input load in network are shown in Fig. 3 (a) and Fig. 3 (b). In the system II, it is obvious that the conventional scheme obtains a quite good throughput, which is a little degraded when compared to that of the idealized optimum, because the impact of interference can be well mitigated according to the use of well performance antennas. Moreover, the use of FCB scheme gives a very little improvement of throughput over the conventional scheme. In contrast, in the system I, the throughput of the conventional scheme first increases and reaches a peak at the input load of 9 Gbps and then starts to decrease little if the input load increases further. On the other hand, the FCB yields throughput improvement about 2–3 Gbps over the conventional scheme when input load is close to 12 Gbps.

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Moreover, the relationships between network fairness index versus total input load in network are shown in Fig. 3 (c) and Fig. 3 (d). It is obvious that in the system II, the fairness index of both conventional scheme and proposed scheme using FCB are almost the same which close to 1. In contrast, in the system I, we can observe that the conventional scheme starts to obtain the deteriorated fairness index when the input load exceeds 9 Gbps, which the fairness indexes become about 0.6–0.8 when the input load closes to 12 Gbps. On the other hand, the fairness index of the case using proposed FCB scheme closes to 1 even if the input load becomes more than 9 Gbps, which is almost the same as that of the idealized optimum.

Finally, we examine the computational complexity performance of case using proposed FCB scheme and case of idealized optimum, for example, are determined in the case that total input load in network is 10.25 Gbps, and then normalized by the computational complexity of conventional scheme proposed in [3]. The results are respectively about 13.6 and 10^{183} under fine weather condition, and respectively about 16 and 10^{197} under rainfall condition. It is clear that the addition of computational complexity by using proposed FCB scheme is very small compared to the case of idealized optimum.

4 Conclusion

This letter has proposed the FCB scheme, performed based on not only the network throughput but also the newly defined fairness index, for MMW entrance networks. As the results in the system I, when input load is close to 12 Gbps, the FCB scheme yields the network throughput improvement about 2–3 Gbps over the conventional scheme without FCB, and obtains fairness index nearly 1. Moreover, the use of FCB scheme leads a little increase in computational complexity over the conventional scheme.

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