Ultra-wideband Coexistence with WiBro

Young-Keun Yoon, Heon-Jin Hong, and Ik-Guen Choi

ABSTRACT—Interference effects of ultra-wideband devices using the frequency band from 3.1 to 10.6 GHz on wireless broadband are evaluated. The ultra-wideband emission power spectral density that would be necessary to protect a wireless broadband station is considered. Also, an analytic scheme based on a system level simulation of a WiBro system is proposed.

Keywords—UWB, WiBro, PSD, OFDMA, TDD.

I. Introduction

Ultra-wideband (UWB) requires access to a very wide-range spectrum which is already used by many other radio-communication systems, and therefore cannot be allocated exclusively to UWB. However, the shared use of the spectrum by UWB and other systems has the potential for interference impact. In this letter, a theoretical model and analytic scheme based on a system level simulation of a wireless broadband (WiBro) system are proposed. As a conclusion of this study, the maximum emission power spectral density (PDS) values of UWB communication applications should be limited.

II. Proposed Analytic Modeling Approach

The analytic modeling is composed of three parts; a geometric model, an interference estimation, and a system level simulation.

1. Geometric Model

Figure 1 illustrates the proposed geometric model. In Fig. 1(a), “desired WiBro link” means the communication link between the WiBro base station (BS) and the WiBro terminal station (TS). In Fig. 1(b), “interfering UWB link” means the interfering link between the multiple UWB transmitters and the WiBro TS. In Fig. 1, the deployed UWB distributed area with the radius of R is the distributed area of UWB communication applications operating in various indoor environments, such as homes, offices, businesses, and so on. In addition, it is assumed that multiple UWB transmitters are randomly located within this UWB distributed area.

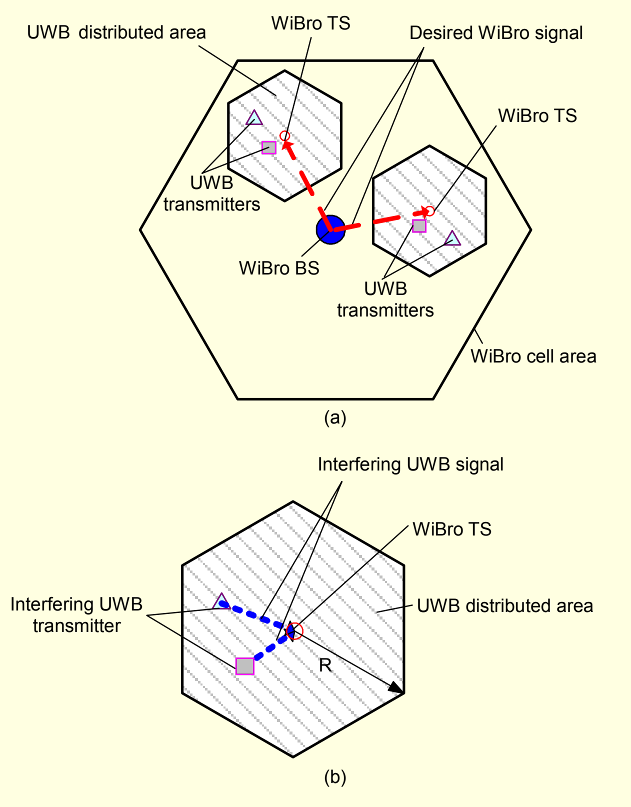

Fig. 1. Geometric model for WiBro forward link: (a) desired WiBro link and (b) interfering UWB link into WiBro terminal station.

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2. Interference Estimation

The coexistence of UWB with WiBro is dependent upon UWB interference effects on WiBro; therefore, the sum of the received UWB interfering signal powers to a WiBro station should be estimated for the protection of WiBro. As in [1], they can be given as

$$iR_j = 10\log_{10}\sum_{k=1}^{K}10^{\frac{p_k}{10}}, \qquad (1)$$

where p_k in dBw is the received UWB interfering signal power to the j-th WiBro station from the k-th UWB transmitter. In this letter, p_k is proposed to describe the interference effect by UWB activity as

$$p_k = 10^{*}\log_{10}(\beta) + P_{\max}(f_j) - \Gamma_{k\to j}(f_j) + G_{k\to j}(f_j) + G_{j\to k}(f_j). \qquad (2)$$

In (2), $P_{\max}(f_j)$ in dBw is the maximum emission power of the k-th UWB transmitter at the center frequency of f_j, G in dBi is the antenna gain of zero value, Γ in dB is the median path loss between the k-th UWB transmitter and the j-th WiBro station, and β is UWB activity.

3. System Level Simulation

The transmission of WiBro signal is based on the orthogonal frequency division multiplexing access (OFDMA) and time division duplex (TDD). The modulation and coding rate (MC) are given in [2] and can be adaptively used. In [2], the minimum modulation and coding rate are QPSK and 1/2, respectively. Generally, the conventional derived process [1] is used as a basis of system level simulation to evaluate the interference impact. However, this scheme cannot describe the effects on system capacity which are caused by interference. Therefore, we propose the derived process as given in Fig. 2 with which it is possible to evaluate the effect of UWB interference on WiBro system throughput. Also, the averaged throughput, DR_{ave}, is given as

$$DR_{ave} = \{DR_1 \cdot A_1 + \sum_{i=1}^{I-1} DR_{i+1}\cdot(A_{i+1} - A_i)\}/A_I, \qquad (3)$$

In (3), DR is the throughput in a geometric area, A is the geometric area, and i is the index of the geometric area. In addition, the fallback method as given in [3] to manage the multiple modulation modes is used.

The throughput calculation process as shown in Fig. 2 is composed of seven steps.

Step 1. Set the modulation and coding rate (maximum 3/4 64 QAM, minimum 1/2 QPSK as in [1]).
Step 2. Derive the current required CNIR, B.
Step 3. Calculate the received CNIR, A.
Step 4. Compare A with B.
Step 5. If A is larger than B, then WiBro throughput is calculated and stored. Otherwise, step 6 is performed.
Step 6. Reduce the current required CNIR, B, through changing the coding/modulation scheme accordingly. The required CNIR in 3/4 64 QAM is set initially, which then could be lowered by changing the coding/ modulation scheme to 2/3 64 QAM and so on, down to the minimum coding/modulation scheme. Go to step 4.

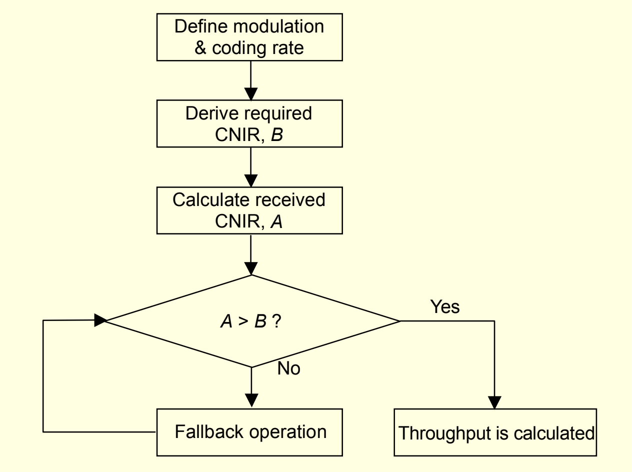

Fig. 2. Throughput calculation steps.

III. Results

The major parameters for evaluation are the following: a center frequency of 2.3 GHz; an occupied WiBro channel bandwidth of 9 MHz; a UWB protection criteria of – 6 dB; a UWB density N of 40, 80, and 120 devices/km^2; a UWB distributed area with the radius R of 5 m and 10 m; a UWB activity β of 10%, 50%, and 100%; and 16 WiBro terminal stations as shown in Fig. 1. The number of UWB areas is the same as the number of WiBro terminal stations. Also, the median path loss model is defined as a modified Hata model [1] in the case of the desired WiBro link and as a free space model in an interfering UWB link.

1. WiBro Performance Effects Considering UWB Density

Figure 3 shows the WiBro performance degradation in terms of UWB density. Here, UWB activity of 100% is assumed. The UWB density means the number of total UWB devices per unit of 1 km^2, and several UWB devices are located in a UWB distributed area. Figure 3 compares the UWB distributed area having a radius R of 5 m as shown in Fig. 3(a) with that of 10 m shown in Fig. 3(b). First, the results show that the WiBro capacity is drastically decreased by the higher emission PSD of

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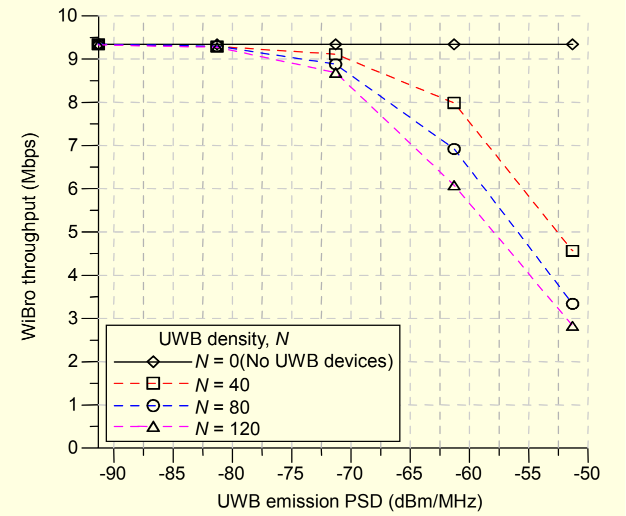
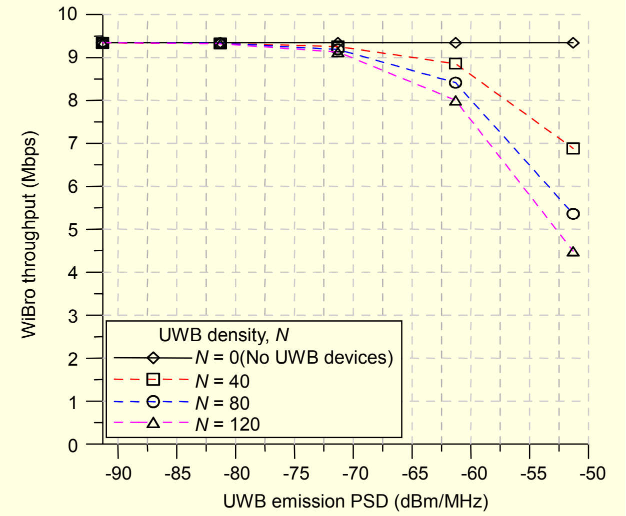


(a) *R* = 5 m



(b) *R* = 10 m

Fig. 3. WiBro throughput according to UWB density.

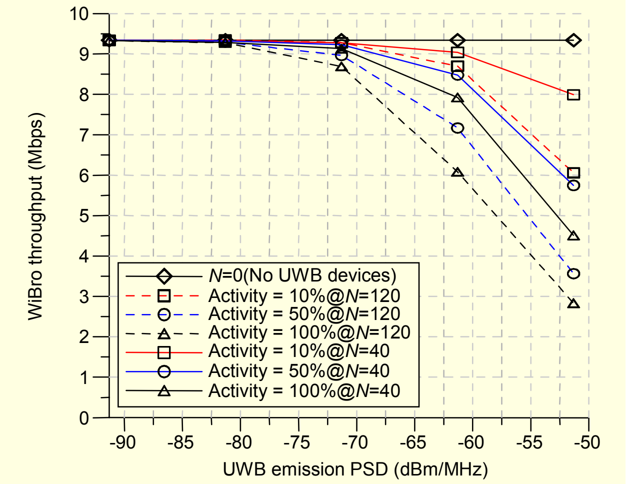


Fig. 4. WiBro throughput according to UWB activity (R = 5 m).

the UWB transmitter and the number of UWB devices. Second, the UWB devices when R = 5 m are aggregated more than those when R = 10 m. Therefore, the UWB interfering powers received by the WiBro station in the case of the 5 m radius produce a critical effect on WiBro performance.

2. WiBro Performance Effects Considering UWB Activity

Figure 4 shows the WiBro performance degradation in terms of UWB activity. Here, UWB densities of 120 devices/km^2 and 40 devices/km^2 with R = 5 m are assumed and compared. Results show that critical performance degradation of WiBro is produced by higher UWB activity.

IV. Conclusion

In conclusion, the simulation described in this letter showed that UWB interference in terms of UWB activity or UWB density is a critical problem in protecting WiBro performance. Therefore, the maximum emission PSD of UWB communication applications should be limited. In this letter, we proposed a novel analytic modeling approach based on a system level simulation of a WiBro (OFDMA) system. This scheme is useful to evaluate not only the outage probability as in conventional methods but also the capacity loss of systems due to interference from short range radio devices like UWB.

References

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