E 8 Spectrum Sharing System of TDMA/W-CDMA with Interference Cancellation

Jie Zhou, Hisakazu Kikuchi, Shigenobu Sasaki and Shogo Muramatsu

†Dept. of Electrical and Electronic Engineering, Niigata University, 950-2181, Japan
URL: http://telecom0.eng.niigata-u.ac.jp/klab/

Abstract

In this paper, the co-existence of TDMA and W-CDMA spectrum sharing system with cellular architecture is discussed. W-CDMA applying interference cancellation (IC) shows a substantial difference in spectrum efficiency, the overlaid system can provide a greater overall rate and higher spectrum efficiency than a single multiple access-based system such as TDMA system or W-CDMA system.

1. Introduction

In this paper, the behavior and performance of the TDMA/W-CDMA overlaid system are completely investigated in detail. For this goal, the co-existence of TDMA and W-CDMA spectrum sharing system[1][2] with cellular architecture is discussed. In this system, both systems share the same frequency band to improve the spectrum efficiency. Overall rate and spectrum efficiency of the system are calculated for the forward link (down-link). Taking into account the path loss and shadow fading loss in this system with cellular architecture, W-CDMA applying interference cancellation shows a substantial difference in spectrum efficiency. The overlaid system can provide a greater overall rate and higher spectrum efficiency than a single multiple access-based system such as TDMA system or W-CDMA system.

2. Cellular System Models and Interference Cancellation

Figure 1 shows a traditional cellular system, where each cell consists of TDMA users and W-CDMA users in TDMA/W-CDMA overlaid system[2]. For the TDMA system, we assign the same channels to each cell with the cluster size, K, where K cells form a cluster and share the entire spectral bandwidth. For the W-CDMA system, we assign the entire bandwidth to each cell, using the pseudonoise (PN) codes, which are uncorrelated, and absolutely to separate the desired signal.

As shown in Fig.1(b) for the bandwidth allocation, where the ordinate is the power spectral density and the abscissa is the frequency axis. The idea behind the spread spectrum is to transform a signal with narrow-bandwidth into a noise-like signal of much wide-bandwidth W in W-CDMA system. One of the most attractive characteristics of adopting spread spectrum in wireless cellular system is the ability to overlay wide-band CDMA system, on top of existing narrow-band CDMA or TDMA systems.

Due to the low-power spectrum density, W-CDMA signals cause relatively little interference to TDMA system. On the other hand, TDMA system cause high interference to the W-CDMA system if without any interference suppressions, which limits the uses of overlaid system. Then, in order to suppress the multi-interference, the notch filter is introduced in the W-CDMA. The notch filter is the limited spectrum filter used in W-CDMA receiver for filtering the part of the overlaid bandwidth of TDMA with the higher signal level. As shown in Fig.1(b), only W_T is filtering out in one cell. Notch filter is also used in W-CDMA transmitter for filtering some portion of the overlaid bandwidth in order to reduce some multi-cross interference from the W-CDMA system to the TDMA. Based on Ref.[2], in the overlaid system, the performance could not improved greatly only dependent on the notch filter, so the signal level clipper is used. The signal level clipper is a kind of signal level limiter used for suppressing the higher signal level of interference. In order to understand easily, here we define the clipper scope, δ as the permitted range of signal level in the receiver that means δ times S_c/W of W-CDMA to be remained as interference generated from TDMA to W-CDMA.

3. Performance Evaluation

To delineate the spectrum efficiency, we simply define the spectrum efficiency as the overall rate (total bit rate) carried in one cell for one MHz. A convenient measure of the spectrum efficiency of the overlaid system is in terms of kbps/MHz/cell[2]. The overall rate of the overlaid system is given by the sum of the bit rates of all systems as $A_c + A_t$ for the TDMA/W-CDMA overlaid system, where A_c, and A_t are the overall rate of the W-CDMA and TDMA systems, respectively. $\eta_{t/c}$ is given by the following equation according to the above description as

$$\eta_{t/c} = \frac{A_c + A_t}{W} \tag{1}$$

4. Numerical Results

In order to derive some numerical results, we set the following parameters:
· Allocated bandwidth of W-CDMA $W = 25MHz$;
· Allocated bandwidth of TDMA $W_T = 1.25MHz$;
· Clipper scope $0 \leq \delta \leq 20$;
· Voice activity factor $\mu = 0.375$;
· Path loss exponent $\gamma = 4.0$;
· Standard variance $\sigma = 6, 7, 8, 9dB$;

- Cell radius $R = 10km$;
- Bandwidth of one channel in TDMA $W_t = 30kHz$ (U.S. standard);
- Full rate channels in TDMA $n_t = 6$ (U.S. standard)

Fig.2 shows the overall rate of W-CDMA system and

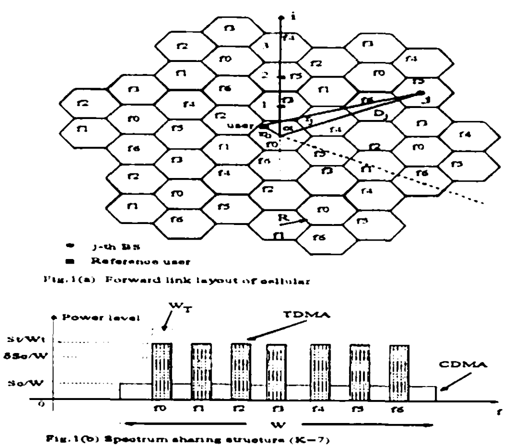

Fig. 1 Cellular geometry of TDMA/W-CDMA overlaid system in (a) Forward link layout of cellular, (b) Spectrum sharing structure ($K = 7$)

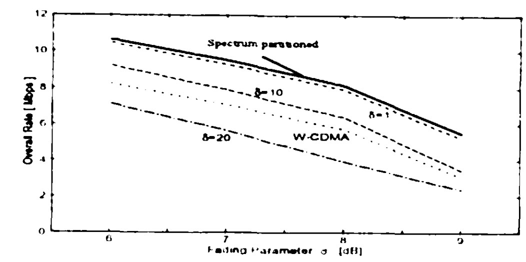

Fig. 2 Overall rate versus the fading parameter σ with diverse δ ($S_c/S_t = 0.01$)

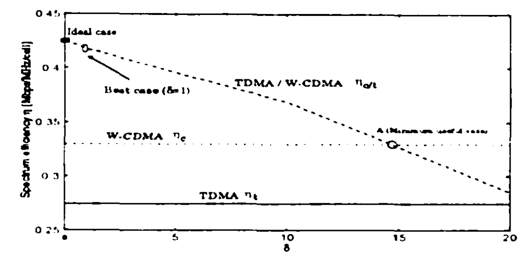

Fig. 3 Spectrum efficiency η of the TDMA/W-CDMA overlaid system versus δ when $\sigma = 6dB$ ($N_t = 250$ users/cell, $S_c/S_t = 0.01$)

the overall rate of the TDMA/W-CDMA overlaid system with different clipper scope, δ for σ. From this figure, we know when σ increases, the overall rate monotonically decreases. The overall of the system is very sensitive to δ. If δ is less than 10, the overall rate of TDMA/W-CDMA overlaid system is larger than that of W-CDMA, otherwise, it is worse. According to the features of forward link, that is not enough only dependent on notch filter to reject interference for improving the system performance, we must adopt signal clipper and set $\delta \leq 10$ in order to ensure higher overall rate and higher spectrum efficiency.

Fig.3 shows the spectrum efficiency of the TDMA/W-CDMA overlaid system with the notch filter and signal clipper by various clipper scope, δ. We calculated the spectrum efficiency of TDMA system, W-CDMA system and the proposed TDMA/W-CDMA overlaid system, respectively when $\sigma = 6dB$. From this figure, we see the spectrum efficiency of W-CDMA is larger than that of TDMA. When the two systems are sharing the same spectrum, theoretically the best ideal case is occurred as shown in this figure that means the multi-cross interference can be entirely rejected. It is impossible to achieve this case. In practice, after introducing some interference rejection technologies, we see the spectrum efficiency of TDMA/W-CDMA overlaid system is largest among three systems, especially when $\delta \leq 15$. It shows the more users can be supported in the TDMA/W-CDMA overlaid system that also means system capacity is increased. For the numerical results, the spectrum efficiency will be 27.3 percents higher than that of W-CDMA when $\delta = 1$ (Best case in practice) and nearly equal to that of when $\delta = 15$ (referred to the minimum useful case in Fig.3). When $\delta \geqq 15$, it will be less than that of W-CDMA system, but higher than that of TDMA system.

5. Conclusions

According to the numerical results, the analysis shows the followings. (1) Without notch filter and signal clipper, any overlaid systems by employing bandwidth sharing can not be achieved in practical situation because of significant multi-cross interference problems between TDMA system and W-CDMA system. (2) In order to decrease this interference, signal clipper must be introduced with the clipper scope, δ, especially, δ must be less than 15, the higher the spectrum efficiency is gotten for the system.

References

[1] D.G.Jeong, I.G.Kim and D.W.Kim, "Capacity Analysis of Spectrally Overlaid Multiband CDMA Mobile Networks," IEEE Trans. on Veh. Technol., Vol.47, No.3, pp.798-807, Aug. 1998

[2] J.Zhou, U.Yamamoto and Y.Onozato, "Impact of Interference Suppression Techniques on Spectrum Overlaid Systems of TDMA/W-CDMA and N-CDMA/W-CDMA," IEICE Transaction on Communications, Vol.E84-B, No.3, pp.539-550, March 2001.