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Multi-user detection for co-channel heterogeneous radio signals in ubiquitous antenna system

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Abstract: This letter newly proposes a new multi-user detection scheme for multiple users using co-channel heterogeneous radio signals in ubiquitous antenna system. The ubiquitous antenna system is composed of multiple radio base stations (RBSs), the central control station (CCS) which performs the multi-user detection, and radio-on-fiber (RoF) link which connects the RBSs to the CCS. Computer simulation results show that the multi-user detector exploiting the minimum mean square error (MMSE)-based combiner and the serial interference canceller (SIC) in combination can achieve the coexistence of coded orthogonal frequency division multiplexing (COFDM) and direct sequence spread spectrum (DSSS) signals.

Keywords: ubiquitous antennas, radio-on-fiber, multi-user detection

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

References

[1] M. Inoue, K. Mahmud, H. Murakami, M. Hasegawa, and H. Morikura, "Novel out-of-band signaling for seamless interworking between heterogeneous networks," *IEEE Wireless Commun.*, vol. 11, no. 2, pp. 56–63, April 2004.

[2] Y. Matsumoto, "Wireless LAN," *Journal IEICE*, vol. 87, no. 10, pp. 832–834, Oct. 2004.

[3] M. Toyama, M. Okada, and S. Komaki, "Maximal Ratio Combining Macro Diversity for Micro-Cellular Slotted ALOHA," *IEICE Trans. Commun.*, vol. J79-B-I, no. 5, pp. 271–277, May 1996.

[4] S. Okamura, M. Okada, and S. Komaki, "Ubiquitous Antenna System for Joint Detection of COFDM Signals," *IEICE Trans. Fundamentals*, vol. E85-A, no. 7, pp. 1685–1692, July 2002.

[5] R. Katayama, K. Tsukamoto, and S. Komaki, "Multi-user Detection Schemes for Co-channel Heterogeneous Radio Signals Based on Ubiquitous Antennas," *Proc. ISCIT2004*, pp. 714–719, Sapporo, Japan, Oct. 2004.

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[6] J. G. Proakis, *Digital Communications*, 4th ed., McGraw-Hill, New York, 2000.

1 Introduction

In recent broadband wireless communication networks, there coexist various wireless access method with different air interfaces. This is called "heterogeneous wireless network" or "heterogeneous signal environment" [1]. Each of different wireless access systems is usually operated in different frequency band, but some systems use the same band, especially in unlicensed band. For example, with spread of IEEE 802.11 wireless local area network (WLAN), there have been many instances that IEEE 802.11b, g, Bluetooth, and others share the same 2.4 GHz industrial, scientific, and medical (ISM) band. In this band, the interference among the systems leads to degradation of throughput [2]. Therefore, the simultaneous reception of co-channel heterogeneous signals would be an important technique to reduce the co-channel interference, and consequently achieve that various wireless services can share the same frequency band.

In order to improve frequency utilization efficiency for cellular or WLAN systems, we have previously proposed a ubiquitous antenna system, which is composed of multiple radio base stations (RBSs) deployed over the service area, a central control station (CCS) and radio-on-fiber (RoF) link that connects the RBSs to the CCS [3, 4]. In this system, all the signal processing and modulation/demodulation are performed at the CCS, and the RBSs distributed over the service area equip only electrical-to-optical (E/O) and optical-to-electrical (O/E) converters. Since all the signals received at the RBSs are transfered to the CCS with their formats kept, we can employ more sophisticated signal processing such as macro diversity, co-channel interference cancellation and multi-user detection [4].

In this letter, we propose a multi-user detection scheme for multiple users using co-channel heterogeneous radio signals in ubiquitous antenna system [5], in order to achieve the coexistance of different wireless services in the same frequency band, exploiting the minimum mean square error (MMSE)-based combiner and the serial interference canceller (SIC) in combination. Computer simulation investigates the achieved BER and effective data rate for the coexistance of COFDM and DSSS signals.

2 Multi-user detection scheme for heterogeneous wireless signals

We assume that each of mobile terminals (MTs) in the service area simultaneously sends a direct sequence spread spectrum (DSSS) signal specified in IEEE 802.11b or a coded orthogonal frequency division multiplexing (COFDM) signal specified in IEEE 802.11g in the identical frequency band. We consider the uplink of the ubiquitous antenna system. Fig. 1 shows the

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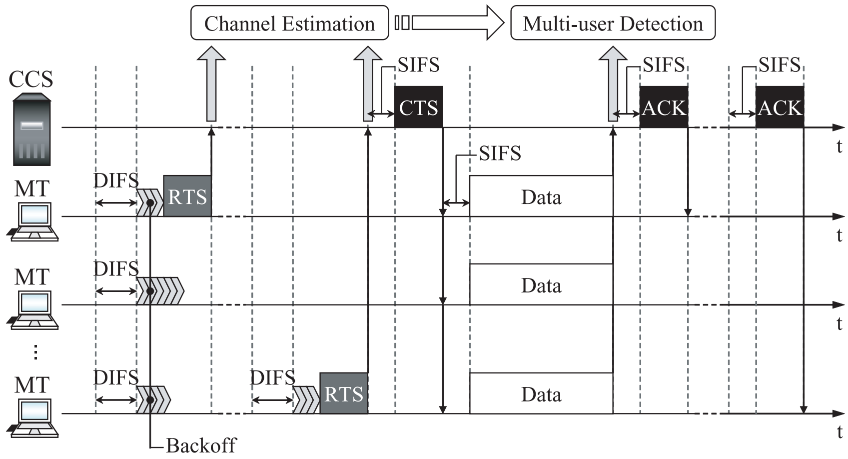

Fig. 1. Access control scheme of the proposed system.

access control scheme of the proposed system. In the proposed system, firstly, each MT sends RTS (Request To Send) signal after DIFS (Distributed Inter Frame Space) and backoff time in order to request a data transmission. Then CCS estimates channel parameters required for multi-user detection by using preamble data included in the RTS from each MT, and replies CTS (Clear To Send) signal to all MTs after SIFS (Short Inter Frame Space) time. After receiveing CTS, MTs send COFDM or DSSS signals simultaneously in the identical frequency band. These heterogeneous radio signals from multiple MTs are received by multiple RBSs, converted to an optical signal at an E/O converter, and sent to the CCS via RoF link. At the CCS, the optical signals from RBSs are converted to RF signals again by O/E converters. In order to simultaneously detect each user's signal, we propose two types of multi-user detection receiver using single-stage SIC and double-stage SIC.

In the single-stage SIC scheme, the post-DFT combiner is first applied to the received signals to detect COFDM signals. The post-DFT combiner which performs the MMSE-based optimum combining on the subcarrier-by-subcarrier basis, separates and detects co-channel COFDM signals [4]. The bit streams demodulated from the detected COFDM signals and the estimated channel parameters are used to generate a replica of the COFDM signal component at each RBS. Then, the replica signals are subtracted from the signal received at each RBS. After that, we can obtain DSSS signal components in the received signals. In order to separate and detect each of DSSS signals from multiple MTs, we apply the time-domain MMSE combiner to the DSSS signal components. Although the MMSE combiner can separate each of co-channel signals, we need more RBSs than MTs to more effectively reduce the interference from delay paths in the frequency-selective fading environment. So before applying the MMSE combiner, we despread the DSSS signal components. In order to obtain a path diversity gain, we employ RAKE receiver technique [6] at the despreader. Then the despread signals are input to the MMSE combiner. The bit stream for each MT can be obtained by demodulating the output signals of the MMSE combiner.

In the single-stage SIC, COFDM signals detected by the post-DFT com-

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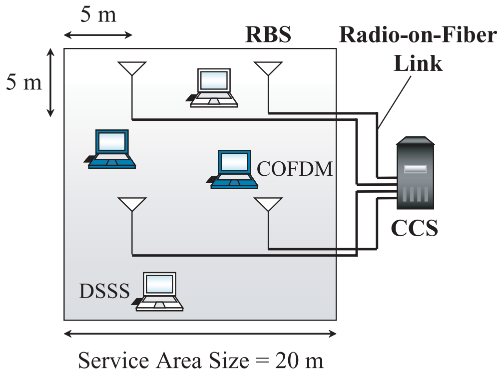

Fig. 2. The location of RBSs.

biner still suffer from the interference of DSSS signals [5]. In order to improve the quality of COFDM signals, we subtract the replica of DSSS signal components from the received signal with the double-stage SIC scheme. First, DSSS signals are demodulated by the 1st-stage SIC, and then the replicas of DSSS signal components generated by using the bit streams and the estimated channel parameters are subtracted from the received signals from RBSs. After that, we can obtain the COFDM signal components. Finally, the COFDM signal components are applied to the post-DFT combiner to detect each of MTs' signals.

3 Performance evaluation

In the following, we evaluate BER performance and effective data rate for the uplink of the proposed ubiquitous antenna system. We assume four RBSs and four MTs. The location of RBSs is shown in Fig. 2. The position of each MT is chosen randomly in the service area. Each MT transmits a DSSS-DQPSK signal with 2 Mbps data rate specified in IEEE 802.11b or a COFDM-QPSK signal with 12 Mbps data rate specified in IEEE 802.11g simultaneously in the identical frequency band. Which signal each of MTs transmits is chosen randomly. We assume Rayleigh fading channel according to the ITU-R indoor B model and path loss exponent of 3.0. We also assume the perfect channel parameter estimation and ignore the non-linear distortion and noise in the RoF link. For the following evaluation, we define that the nominal carrier-to-noise power ratio (CNR) is the received CNR at the RBS when the MT is located at the center of the service area. For comparison, we also evaluate the performance of single reception system, where a DSSS or COFDM signal from single MT is received by the nearest single RBS.

Fig. 3 (a) shows BER of COFDM and DSSS signals vs. nominal CNR for the single-stage SIC and the double-stage SIC. It is seen from Fig. 3 (a), the BER for both of COFDM and DSSS signals can be reduced as CNR increases, except the case of COFDM with the single-stage SIC in the CNR of more than 15 dB. These results confirm the simultaneous reception of co-channel heterogeneous wireless signals. The residual error seen for COFDM with the single-stage SIC is due to the interference from the DSSS signals at the post-DFT combiner. However, we can see no residual error for the double-stage

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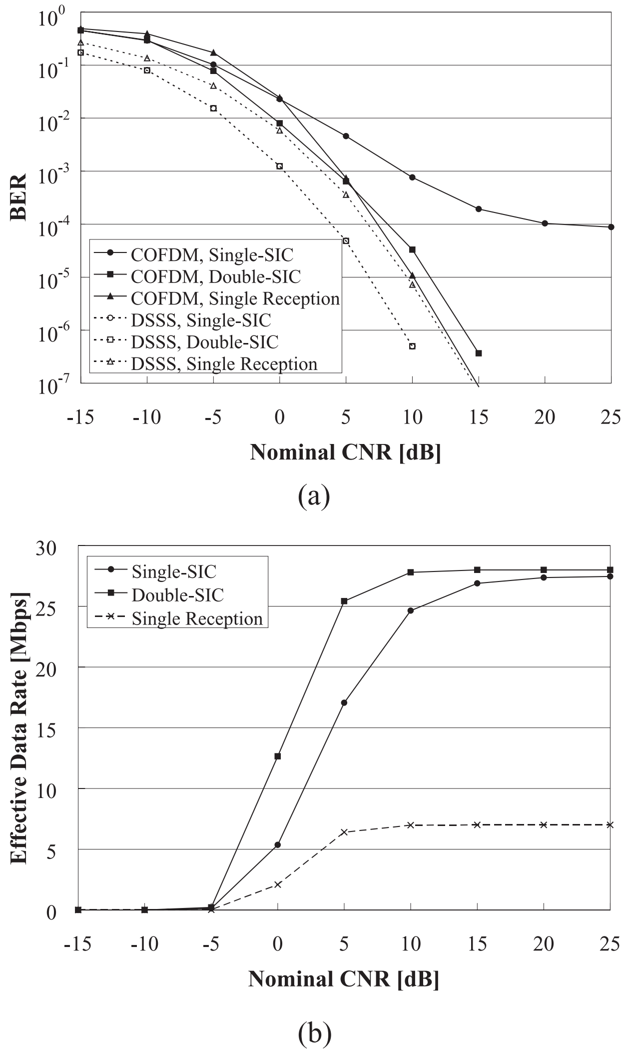

Fig. 3. (a) BER and (b) effective data rate of the proposed system vs. nominal CNR.

SIC at the high CNR by removing the DSSS signal components and nominal CNR penalty compared with single reception is about 2 dB at BER=10^{-6}. When comparing with single reception system, for the COFDM signal in case of the nominal CNR of less than 0 dB, both of the single-stage SIC and the double-stage SIC achieve better performance than the single reception. This improvement can be obtained from macro diversity effect with multiple RBSs.

For the DSSS signal, we can see that the single-stage SIC and the double-stage SIC achieve better BER performance than the single reception. This is also due to a macro diversity gain. We can also see that the single-stage SIC and the double-stage SIC can improve the required CNR for single reception system by 4 dB at BER=10^{-6}.

Fig. 3 (b) shows the effective data rate vs. nominal CNR. While the single reception achieves the effective data rate of 7 Mbps at high CNR, the proposed single-stage SIC and double-stage SIC can achieve the effective data rate of 27.5 Mbps and 28 Mbps, respectively. We can see that the double-

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stage SIC reduce the nominal CNR required to achieve the effective data rate of 25 Mbps by 6 dB comparing with the single-stage SIC.

4 Conclusion

In this letter, we have proposed multi-user detection schemes for simultaneous reception of co-channel heterogeneous signals for the uplink in a ubiquitous antenna system. As a multi-user detector, we have applied the single-stage SIC and the double-stage SIC with the MMSE-based combiner and the SIC. Computer simulation results show that both the single-stage SIC and the double-stage SIC can separate and detect the DSSS and COFDM signals transmitted in the identical frequency band and the double-stage SIC improves the nominal CNR for the effective data rate of 25 Mbps by 6 dB comparing with the single-stage SIC.

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