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Compressive Spectrum Sensing for MIMO OFDM based Cognitive Radio Network

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Abstract **— Multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) is considered to be one of the most promising technologies for further generation mobile communication systems like 3GPP LTE in recent years. At the same time, as a smart spectrum sharing technology, Cognitive Radio (CR) was also proposed to enhance the utilization of the spectrum usage. Thus, the combination of MIMO-OFDM and Cognitive Radio, MIMO-OFDM based Cognitive Radio technology is treated as a prospect scheme for future dynamic spectrum access network or spectrum sharing system. Our proposed scheme can detect the spectrum usage without the prior information of sparsity, which is also suitable for the real wireless application environment. MIMO-OFDM with a massive number of transmit antennas (MIMO-OFDM) promises to increase the spectrum efficiency or reduce the transmission energy per bit. The performance of MIMO-OFDM is strongly influenced by the method used to estimate the channel state information (CSI) at the transmitter. The number of transmit antennas and training frames needed for CSI estimation which decreases MAC efficiency and increases the cost of estimating CSI at a user station (STA).**

Keyword- **Fading channel, OFDM, performance optimization, Broadband Wireless Access (BWA) Cognitive Radio Compressive sensing MIMO-OFDM Spectrum Sensing, CSI (channel state information), quantization.**

I. INTRODUCTION

OFDM is especially suitable for high speed communication due to its resistance to ISI. ISI occurs when a transmitter interferes with itself and the receiver cannot decode the transmission correctly. Because the signal reflects from large objects such as mountains or buildings, the receiver sees more than one copy of the signal. In communication technology, this is called multipath. Since the indirect paths take more time to travel to the receiver, the delayed copies of the signal interferes with the direct signal causing ISI. In the OFDM the transmitter, the signal is defined in the frequency domain. It is a sampled signal, and it is defined such that the discrete Fourier spectrum exists only at distinct frequencies. Each OFDM carriers corresponds to one element of this discrete Fourier spectrum.

MIMO-OFDM based Cognitive Radio technology is treated as a prospect scheme for future dynamic spectrum access network or spectrum sharing system. Since only a finite number of subcarriers are occupied by the primary users (PUs) in CR networks, the secondary users (SUs) can detect the spectrum holes (the unoccupied subcarriers) and opportunistically access those unoccupied spectrum subcarriers. Thus, spectrum sensing or detection is an important component for the implementation of CR. However, in traditional MIMO-OFDM system, the signals received in each antenna are sampled by an individual analog-to-digital converter (ADC), which will lead to a significantly increase of front-end cost for the whole system since multiple ADCs need to be adopted by corresponding to the multiple receiving antennas. Thus, the problem is how to design efficient receiving scheme for reducing the power consume and hardware cost in MIMO system. Considering the sparsity property of the received signals, we proposed a novel spectrum sensing scheme for the MIMO-OFDM based CR network by exploiting compressive sensing technology in this paper. Simulation results also show the effectiveness of our proposed scheme.

Now let $x_{i,j}$ be the complex-valued path gain from transmit antenna to receive antenna **i** (the fading coefficient). If at a certain time instant the complex-valued signals $\{s1\ldots\ldots\ldots s_{nT}\}$ are transmitted via the $\boldsymbol{n_T}$ antennas, respectively, the received signal at antenna i can be expressed as

$$y_i = \sum_{j=1}^{nr} x_{i,j}\ s_j + n_i \qquad (1)$$

Where n_i represents additive noise this linear relation can be easily written in a matrix framework. Thus, let s be a vector of size n_T containing the transmitted values, and y be a vector of size $\boldsymbol{n_R}$ containing the received values, respectively. We have $s \in C^{nT}, y \in C^{nR}$ [3].

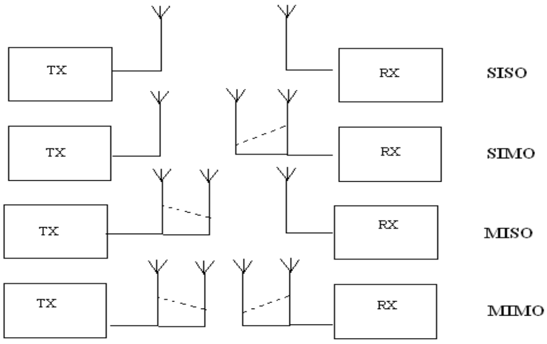

Figure 1: MIMO channel model

Here in this figure we have explained four channel models. First, in SISO there is one transmitting antenna and one receiving antenna, means single input and single output. Secondly, in SIMO there is one transmitting antenna and multiple receiving antenna, means single input and multiple output. Thirdly, in MISO there is two transmitting antenna and one receiving antenna, means multiple input and single output. Fourthly, in MIMO there is two transmitting antenna and two receiving antenna, means multiple input and multiple output.

We consider a MIMO-OFDM broadcast channel with one base station (BS), equipped with M antennas, and K ≥ M single-antenna user terminals (UT). MIMO broadcast channels have been widely studied in the recent past (see for example [1], [2], [3], [4], [5]). Under perfect transmitter channel state information (CSIT) at the BS and receiver channel state information (CSIR) at the UTs, its capacity was fully characterized in [5] and efficient resource allocation algorithms have been proposed in order to operate at desired points in the capacity region (e.g., [6], [7], [8]). In the current standardization of the 4-th Generation of wireless communication systems (e.g., IEEE802.16m), MIMO broadcast schemes are going to play a fundamental role in order to achieve high data rates in the downlink. In practice, CSIT must be provided to the BS by some form of feedback.

II. OFDM WITH SYSTEM MODEL

In the OFDM transmitter, the signal is defined in the frequency domain. It is a sampled signal, and it is defined such that the discrete Fourier spectrum exists only at distinct frequencies. Each OFDM carriers corresponds to one element of this discrete Fourier spectrum.

The amplitudes and phases of the carriers depend on the data to be transmitted. The data transitions are synchronized at the carriers, and can be processed together, symbol by symbol as shown in diagram be figure 2.

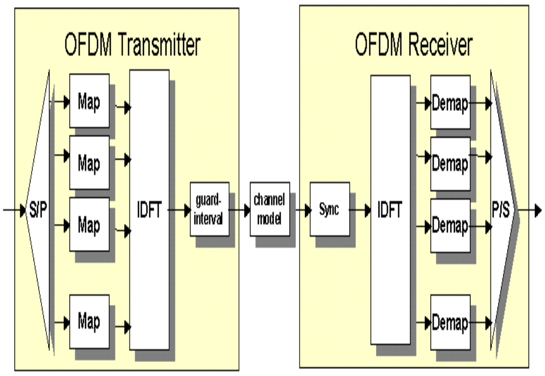

Figure 2: OFDM system model

In these model data coming from the input are arranged into vectors with number of components equal to the number $\widetilde{N}$ of carriers. Each component is composed by a number of bits depending on the alphabet of the modulation scheme used on the next stage. For example, if we use a 1536 carriers system with BPSK, we'll have vectors of 1536 component each one composed by 1 bit (BPSK is 2-ary). Each component (group of bits) is mapped into a complex symbol depending on the alphabet of the modulation scheme used. For example, with BPSK the alphabet is{ -1 ; +1 }.In order to obtain real samples after IFFT, a 2*Number of carrier points IFFT is done with :

The Inverse Fast Fourier Transform algorithm (IFFT) is applied to the vector giving a real samples vector. The guard interval is added at the beginning of the vector by repeating the components of the end. Vectors are concatenated to form a time signal (parallel/serial conversion) Windowing the signal is necessary to limit the bandwidth. Most used window is the raised cosine. The signal is then passed through the channel. Channel is modelled by a linear system with frequency response c(t) together with a source of additive Gaussian noise. At the reception, signal is rearranged again into vectors (serial/parallel conversion) and guard interval is dropped.

Fast Fourier Transform (FFT) is computed in order to get back the complex vector of symbols. Mapping of digital signal is performed by the DFT in OFDM in to complex signal and reverse mapping is performed by IDFT.

Let consider K be the size of IDFT and extended cyclically to include a cyclic prefix (CP) of length N_{cp}

$$x[n] = \sum_{k \in SA} s[k] e^{\frac{i2\pi\, nk}{K}}, n = -Ncp, \ldots\ldots, K-1.$$

Sets of all inputs of IDFT is

$$S \in \{-\frac{K}{2}, \ldots\ldots, \frac{K}{2} - 1\}$$

III. SPECTRUM SENSING

Spectrum sensing is a key technology to detect spectrum holes in cognitive network. Cognitive radio (CR) users must be able to determine spectrum bands available for transmission. Spectrum sensing enables CR users to detect the primary user's signal in licensed bands. In a opportunistic spectrum access paradigm, where CR users must avoid conflict with primary users by determining their transmission activity in a band, CR users periodically monitor spectrum bands to find spectrum holes. Energy detection, matched filter detection, and feature based detection are the three most commonly used transmitter detection techniques . Energy detection is easy to implement, but has low resolution compared to matched filter and feature based techniques. Matched filter and feature based detection are computationally complex and require a priori knowledge of primary signal characteristics. Since sensing is performed on the primary transmitter, the primary receiver is vulnerable to interference. The hidden/exposed terminal problem refers to the hidden receiver problem, the hidden transmitter problem, or the exposed transmitter problem.

In the hidden receiver problem a primary receiver (Rx), within range of a CR transmitter (Tx), experience interference if the CR Tx is out of range of the primary Tx (fading) or if some obstacle between the CR Tx and the primary Tx obscures the primary signal (shadowing). The hidden transmitter problems occur if the primary Tx is in the range of CR Rx but not the CR Tx and the exposed transmitter problems occur if the primary Tx is in the range of the CR Tx but not the CR Rx. Transmitter detection can be enhanced by cooperative sensing where CR users exchange local sensing information. Cooperative sensing solve the hidden receiver problem since fading and shadowing of primary signal are resolved due to spatial diversity.

Although the probability of primary signal detection can be enhanced through cooperation, exchange of local sensing data increase the communication overhead. To protect the receiver from interference, the FCC proposed interference temperature metric and limit. Interference temperature is measured as the RF power per unit bandwidth at the receiver. CR users must stay below the interference limit determined by the FCC in order to access licensed spectrum. The interference temperature has been shown hard to determine due to, for example, aggregate co-channel and adjacent channel interference at the licensed receiver. Geolocation techniques have been proposed to enhance or replace sensing, where the distance to the licensed user is known.

Hence, the technique enhances the utilization of the spectrum usage. MIMO-OFDM based CR network used spectrum sensing scheme by exploiting compressive sensing technology. The hardware cost and energy consumption can be significantly reduced in our scheme. And it can detect the spectrum usage without the prior information of sparsity, which is also suitable for the real wireless application environment. Improve the performance in multipath channel.

VI. CONCLUSION

Each CR has a limited reach, and channel scan is time consuming. Inspired by compressive sensing, a collaborative spectrum sensing method was proposed in to resolve these problems. The dogma of signal processing maintains that a signal must be sampled at a Nyquist rate at least twice its bandwidth in order to be represented without error. However, in practice, we often compress the data soon after sensing, trading off signal representation complexity (bits) for some error (consider JPEG image compression in digital cameras, for example). The major problem for spectrum sensing arises in wideband radio, when the radio is not able to acquire signals at the Nyquist sampling rate due to the current limitations in Analog-to-Digital Converter (ADC) technology Compressive sensing makes it possible to reconstruct a sparse signal by taking less samples than Nyquist sampling, and thus wideband spectrum sensing is doable by compressed sensing (CS). A sparse signal or a compressible signal is a signal that is essentially dependent on a number of degrees of freedom which is smaller than the dimension of the signal sampled at Nyquist rate. Our proposed scheme will detect the spectrum usage without the prior information of sparsity. Simulation results will also show the effectiveness of our proposed scheme.

REFERENCES

[1] Yang Wen Liang "Ergodic and OutageCapacity of Narrowband MIMO Gaussian Channels"2004.

[2] MIMO Wireless Communications by Ezio Biglier, Robert Calder bank, Anthony constantinides, Andrea Goldsmith, Arogyaswami Paulraj, H. Vincent Poor Cambridge University Press 2007.

[3] Martin Wrulich January 11, 2006 "Capacity Analysis of MIMO Systems".

[4] Gesualdo Scutari, Member, IEEE, Daniel P. Palomar, Member, IEEE, and Sergio Barbarossa, Member, IEEE "The MIMO Iterative Waterfilling Algorithm".

[5] A. Goldsmith, S A. Jafar, N. Jindal, and S. Vishwanath.Capacity Limits of MIMO Channels.IEEE J. Sel. Areas Commun. 21(5):684.702, June 2003.

[6] Kenneth W. Shum, Member IEEE, Kin-Kwong Leung, Member IEEE, and Chi Wan Sung, Member IEEE "Convergence of Iterative Waterfilling Algorithm or Gaussian Interference Channels 2007".

[7] Gesualdoscutari, member IEEE, Daniel P.Palomar, member, IEEE May 2009"Convergence of Iterative Water fillingAlgorithm for Gaussian Interference Channels''.

[8] Md. Noor-A-Rahim1, Md. SaifulIslam"Performance Analysis of MIMO-OFDM System Using Singular Value Decomposition and Water Filling Algorithm" International Journal of Advanced Computer Science and Applications 2011.

[9] Fundamentals of Wireless Communication by David Tse and PramodViswanath Cambridge University press 2005.

[10] Andrea Goldsmith "Wireless communication" 2005 Cambridge university press.

[11] Andreas F.Molisch "Wireless communication" 2005 Wiley India publication.

[12] Yong Soo Cho, Chung G. Kang MIMO OFDM Wireless Communications with MATLAB Wiley publication 2010

[13] Ezio Biglieri Robert Calder bank Anthony Constantinides Andrea Goldsmith MIMO Wireless Communications Cambridge University Press 2007.

[14] F.BoixaderaEspax, J. Boutros "Capacity considerations for wireless MIMO channels." ***http://www.com.enst.fr/publications/publi/MMT99_boixadera.ps. 2002-01-08***.

[15] T.Svantesson, A. Ranheim "Mutual coupling effects on the capacity of multielement antenna systems," Acoustics, Speech, and Signal Processing, 2001. Proceedings. 2001 IEEE International Conference on,Volume:4, 2001.

[16] John Proakis, Masoud Salehi "Digital communication" 5th edition 2007 McGraw-Hill Companies, Incorporated, 2007.

[17] Clint Smith and Daniel Collins, "3G Wireless Networks", 2nd edition, 2008.

[18] M. Mirahmadi, Member, IEEE, A.Al-Dweik, Senior Member, IEEE, and A.Shami, Senior Member, IEEE, "BER Reduction of OFDM Based Broadband Communication Systems over Multipath Channels with Impulsive Noise", IEEE Transactions on Communications, vol.61, No.11, November 2013.

[19] Ehab Salahat and Ibrahim Abualhaol, "General BER Analysis over Nakagami-m Fading Channels", IFIP Wireless and Mobile Networking Conference (WMNC), 2013.

[20] Bernard Skalar and Pabritra Kumar Ray, "Digital Communication: Fundamentals and Applications", Pearson, Edison 2, Jan.2009.

[21] Proakis John G., Salehi M., - Communication System Engineering, Prentice Hall of India, Edition 2, 2005.

[22] Orthogonal Frequency Division Multiplexing, U.S. Patent No. 3, 488, 4555, filed November14, 1996, issued Jan.6, 1970.

[23] Vendee-Ramjee, "OFDM for Wireless Multimedia Communications".