Acquisition and Identification of OFDM Signals using Cyclostationary Signatures *

Milan Zivkovic, Johannes Schmitz, Rudolf Mathar
Institute for Theoretical Information Technology
RWTH Aachen University
D-52056 Aachen, Germany
{zivkovic,schmitz,mathar}@ti.rwth-aachen.de

ABSTRACT

An effective solution for increasing spectrum efficiency in current networks assumes OFDM-based cognitive radio (CR) systems, which allow for reconfigurable activation and loading on specific group of subcarriers in locally available spectrum. However, each CR receiver should synchronize itself to appropriate carrier frequency and identify currently activated subcarriers and corresponding waveform parameters, i.e., applied modulation/coding scheme. Proposed demonstrator, showcases dynamic reconfiguration and identification of OFDM-based CR system utilizing the detection of cyclostationary signatures, intentionally embedded features that introduce certain periodicity exhibited by second order statistics. Presented framework additionally allows to easily extend given scenario to multiuser environment which assumes coexistence and identification of several CR transmitter/receiver pairs operating with different waveform parameters within the common dedicated bandwidth.

Categories and Subject Descriptors: C.2.1 [Network Architecture and Design]: Wireless communication

General Terms: Algorithms, Design, Experimentation.

Keywords: OFDM, Cognitive Radio, Cyclostationary Signal Analysis, GNU Radio

1. INTRODUCTION

By observing the spectrum of interest, cognitive radios (CRs) are able to detect the unused portions (*spectrum holes*) and adapt radio operation to dynamically changing environment without introducing harmful interference to the primary users (PU). Due to its flexibility in allocating resources among CRs, OFDM has been shown as a promising candidate for physical (PHY) layer in cognitive networks. OFDM is a multicarrier modulation scheme based on division of broadband channel into many narrowband subchannels modulated on different subcarriers. By leaving a set of subchannels unused and loading different waveforms on occupied subcarriers, OFDM provides a flexible spectral shape that fills spectral gaps without interfering with the PU and preserves power and bandwidth efficiency. However, there is a need for control channel which coordinates the operating parameters within the network, i.e., carrier frequency, occupied bandwidth, and modulation scheme. Since the presence of control channel significantly reduce the spectrum efficiency in cognitive radio scenario, there is a need to identify the waveform parameters at the receiver utilizing inherent characteristics contained in transmitted signal.

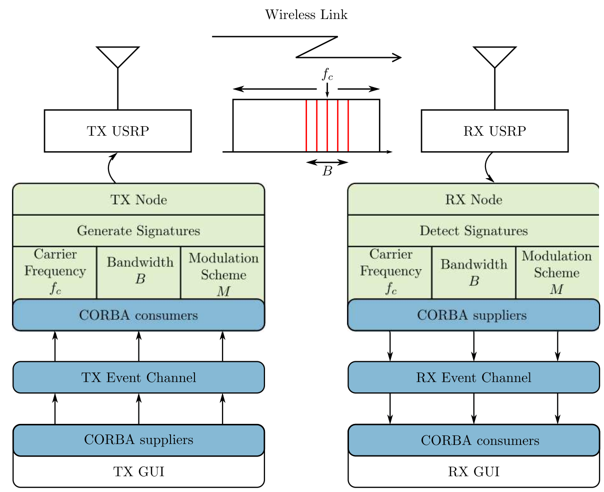

Figure 1: The System Overview

Cyclostationary signal analysis [1] was shown to be an efficient method for differentiation of signal energy from the local noise energy at low SNR values by exploiting certain periodicity exhibited by second order statistics of a modulated signal. At the CR transmitter, such periodicities can be intentionally inserted in the data payload by embedding cyclostationary signatures on specific sets of subcarriers, thus allowing for dynamic network coordination [2]. Applying this concept, OFDM signal parameters can be recognized dynamically by the CR receivers detector without any predetermined control channel while only requiring basic information on OFDM signal structure. The demonstration showcases bandwidth and rate adaptive OFDM transmission where CR transmitter embeds three signatures at different cyclic frequencies. By continuously sensing the available common spectrum, the detector, tuned on specific predetermined cyclic frequencies, extracts information about the currently used carrier frequency, occupied bandwidth (the number of loaded subcarriers) and the modulation scheme.

2. DEMONSTRATOR DESCRIPTION

The system overview of proposed demonstration and underlying framework is given in Fig. 1. The implementation is based on the reconfigurable platform for adaptive OFDM transmission (TIGR), developed at the Institute for Theoretical Information Technology (TI) [3]. Within the TIGR, the transmitter and receiver node are composed of a host

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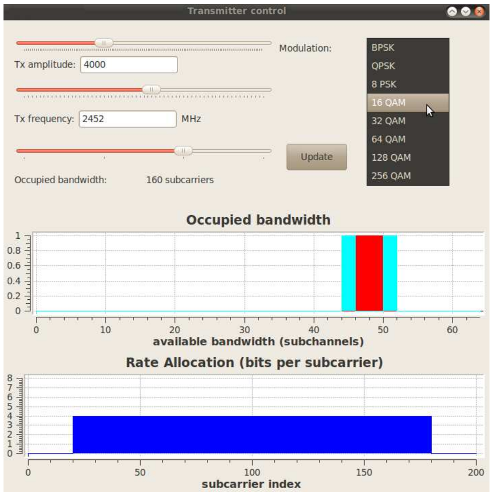

Figure 2: The interactive GUI

commodity computer and general purpose RF hardware, Universal Software Radio Peripheral USRP [4]. Baseband signal processing at host computers is implemented in GNU Radio framework [5], an open source software toolkit that provides library of signal processing blocks for developing communications systems and conducting experiments. Additional flexibility and reconfigurability is enabled by Common Object Request Broker Architecture (CORBA) [6], an event-based communication model that allows interaction between software elements located in different logical and/or physical entities (e.g. communication among signal processing stage, control blocks and GUI). The communication between transmitter an receiver node in TIGR is organized as reconfigurable continuous one-way transmission of OFDM symbol frames. As shown in Table 1, the set of configuration parameters can be divided into two classes. The set of *static parameters* containing FFT size, frame length, and scanning bandwidth, is initialized at transmission start and is known to both nodes, while the *dynamic parameters* are reconfigurable at run-time. The demonstration scenario assumes that transmitter, controlled by interactive GUI, as shown in Fig. 2, changes its waveform parameters, such as carrier frequency f_c, bandwidth B, and modulation scheme M, and embeds appropriate signatures, SIG_c, SIG_B, and SIG_M, with cyclic frequencies, α_c, α_B, and α_M, respectively, which are taken from the predefined sets. In order to identify the transmitted waveform, the receiver, with architecture shown in Fig. 3, is switching between the *signature detector* and *core receiver* in order to save computational resources and operates in following steps:

1. The receiver starts signal acquisition in *signature detector* mode with detector tuned to α_c. It will scan the predefined bandwidth until finding the primary signature SIG_C at the transmitter's carrier frequency f_c.

2. The receiver tunes *signature detector* to α_B in order to detect the occupied bandwidth, determined by the predefined number of loaded subcarriers. As SIG_B is generated using subcarriers located at the edge of occupied bandwidth, the estimated offset Δf_B relative to the previously determined carrier frequency f_c is used to calculate the number of used subcarriers B.

3. The *signature detector* is tuned to α_M to find the appropriate offset Δf_M relative to carrier frequency f_c, where different offsets are mapped to different modulation schemes M given in Table 1.

4. After determining all three OFDM waveform parameters, i.e., carrier frequency f_c, bandwidth (number of used subcarriers) B, and modulation scheme M, the receiver reconfigures to *core receiver* and starts reception of the transmitted OFDM signal.

5. Whenever some of the transmitter's parameters are changed, the loss of synchronization in *core receiver* signals the controller thread to switch the system to *signature detector* mode to begin signal acquisition.

Table 1: Demonstration Setup parameters

FFT length	64 – 1024
Frame length	Variable, up to 50 payload symbols
Scanning Bandwidth	Variable, up to 83MHz
Carrier frequency	2400 – 2483MHz
Bandwidth	64 - 200 Subcarriers
Modulations	BPSK, QPSK, 8-PSK, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM
Power	Up to 20 mW

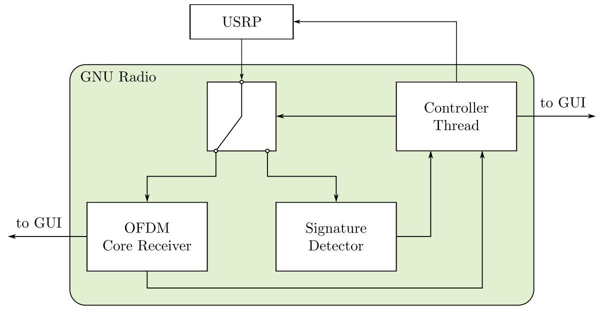

Figure 3: Receiver Architecture

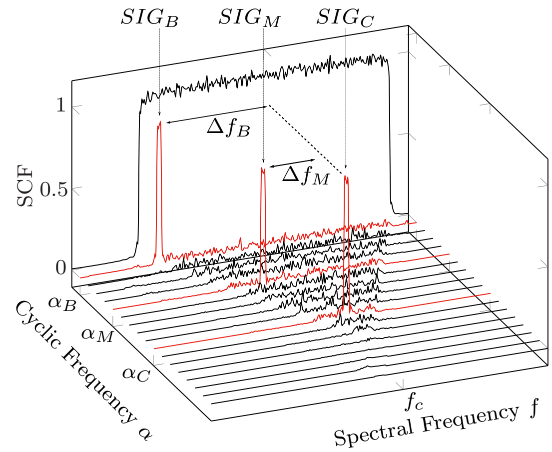

Figure 4: Spectral Correlation Function

By applying distinctive primary signatures, the demonstration can be extended to a scenario which involves two independent transmitter/receiver pairs sharing a common frequency band.

3. REFERENCES

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