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OFDM-based Dynamic Spectrum Access

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***Abstract*—Optimal utilization of radio resources (bandwidth, transmit power) in multicarrier based systems becomes very challenging due to coexistence of various wireless standards within the same frequency band. One possible solution is dynamic spectrum access (DSA) approach that allows several standards or users to opportunistically share the available spectrum resources without introducing mutual interference. Proposed demonstration, implemented in GNU Radio framework, enables interference-free coexistence of two OFDM-based systems within a common frequency band with optimally configured transmission parameters for given system constraints. Furthermore, a highly reconfigurable framework allows for implementation and evaluation of various transmission strategies for different DSA scenarios, different classes of given requirements and various sets of controllable parameters.**

I. Introduction and motivation

According to actual measurements, most of the licensed frequency spectrum is severely underutilized in both the time and spatial domain. Spectrum efficiency can be significantly increased by giving the access of frequency bands not used by primary (licensed) users (PU) to a group of secondary (unlicensed) users (SU). Dynamic spectrum access (DSA) is the novel approach that enables flexible, efficient and reliable spectrum use by adapting the radios operating characteristics to the dynamically changing environments. By observing the spectrum of interest SU are able to cleverly detect the unused spectrum and determine transmission characteristics (power, bandwidth, symbol rate) for efficient resource allocation for different classes of given requirements.

A possible candidate for the implementation of DSA is Orthogonal Frequency Division Multiplexing (OFDM) [1], a multicarrier modulation scheme which divides broadband channel into many orthogonal narrowband subchannels in such a way that attenuation across each subchannel stays flat. By leaving a set of subchannels unused, OFDM provides a flexible spectral shape that fills the spectral gaps without interfering with the PU. An important task in the design of future OFDM based systems in DSA scenarios is to exploit frequency diversity provided by broadband channel using adaptable transmission parameters (bandwidth, coding/data rate, power) in order to preserve power and bandwidth efficiency according to subchannel conditions at the receiver.

The demonstration will showcase interference-free coexistence of two OFDM-based systems within a common frequency band. The first system is PU transmitter-receiver pair which operates in narrowband randomly changing the portion of occupied spectrum. Accordingly, SU pair operating within the whole available band, continuously monitors and detects parts of non-used spectrum and performs capacity achieving OFDM transmission with optimal rate and power allocation over subchannels for given system constraints. Underlying framework extends PHY layer functionalities of current wireless standards and offers control and feedback mechanisms for easy reconfiguration of transmission parameters allowing evaluation of different DSA strategies in either simulation or real-time scenarios.

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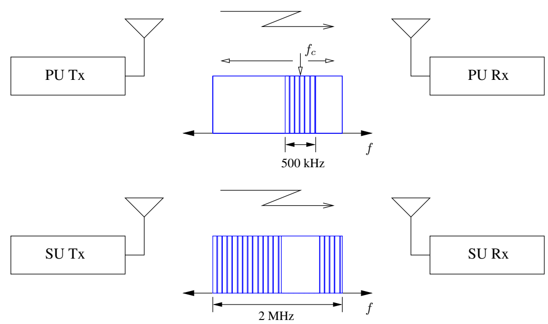
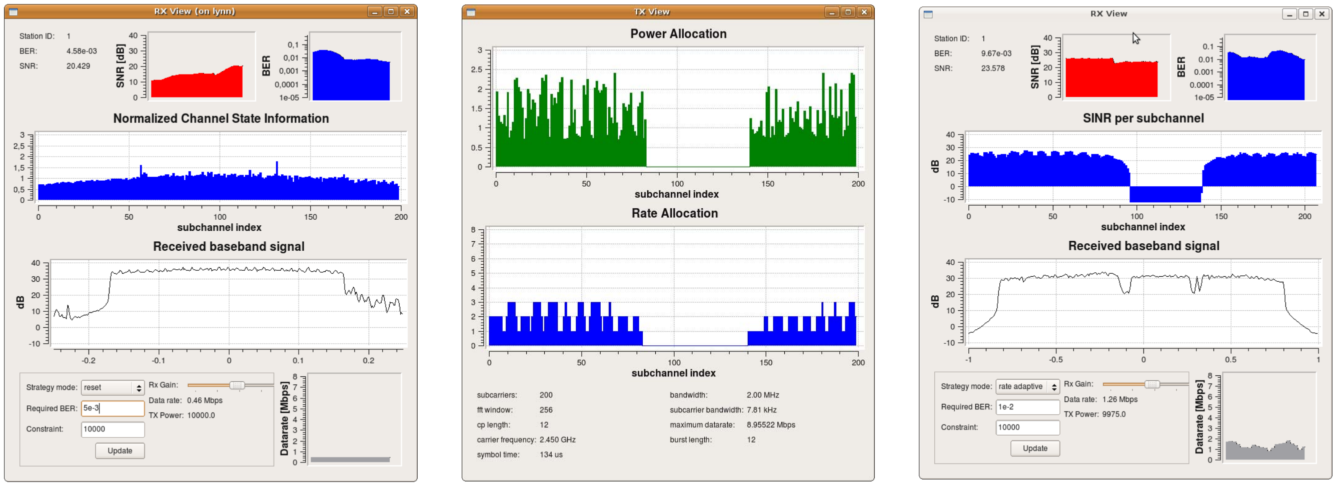


Fig. 1. The demonstration scenario

II. Demonstration description

The system overview of proposed demonstration is shown in Fig. 1. The scenario involves one PU and one SU entity, both transmitting OFDM waveform within a common frequency band of 2 MHz. The PU transmitter-receiver pair in general operates with narrower bandwidth (e.g. 500 kHz) and has a higher priority in a given frequency band. PU nodes randomly occupy the certain parts of a common band by changing the carrier frequency f_c without exchanging that information with SU nodes. The SU system, whose OFDM waveform can occupy the whole available band, continuously monitors and detects parts of non-used spectrum by means of interference measurement and adapts transmission parameters (used subchannels, rate and power allocation) according to given system requirements enabling interference-free coexistence with PU entity.

The system diagram of underlying framework used for proposed demonstration is shown in Fig. 3 [2]. Each transmitter and receiver node are composed of a host commodity computer and general purpose RF hardware, Universal Software Radio Peripheral (USRP) [3]. Baseband signal processing at host computers is implemented in GNU Radio framework [4], an open source, free software toolkit that provides library of signal processing blocks for developing communications systems and conducting experiments. The USRP performs computationally intensive operations as filtering, up- and



(a) The PU receiver's GUI

(b) The SU transmitter's GUI

(c) The SU receiver's GUI

Fig. 2. The GUIs with interactive control interface

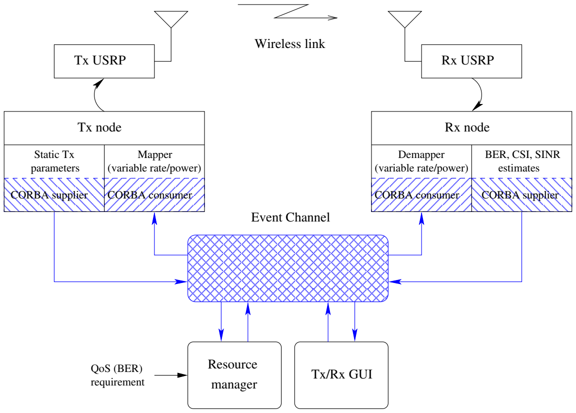


Fig. 3. The framework overview

down-conversion controlled through a robust application programming interface (API) provided by GNU Radio.

Within the framework, additional OFDM specific blocks are implemented where the main capacity achieving functionality is performed in blocks for adaptive mapping and demapping of various rates (taken from set of available modulations given in Table I) and power levels across subchannels. Algorithms for estimation of link quality, expressed through average signal-to-interference-plus-noise-ratio (SINR) and channel state information (CSI) over subchannels, are extensively studied and implemented at the receiver. The communication between transmit and receive node is organized as reconfigurable continuous one-way transmission of OFDM symbol frames. As shown in Table I, the set of input configuration parameters can be divided into two classes. The set of *static parameters* containing FFT size, number of subchannels, frame size, etc., is initialized at transmission start and is known to both nodes. The set of *dynamic parameters* which are reconfigurable at run-time includes total transmit power and allocated rate and power over subchannels.

TABLE I
OFDM SYMBOL PARAMETERS

Bandwidth (*static*)	Variable, up to $2MHz$
FFT length (*static*)	$64 - 1024$
Frame length (*static*)	Variable
Carrier frequency (*dynamic*)	$2400 - 2483MHz$
Modulations (*dynamic*)	BPSK, QPSK, 8-PSK, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM
Power (*dynamic*)	Up to 20 mW

The backbone of the system is realized over local Ethernet network by CORBA *event service* [5], a distributed communication model that allows an application to send an event that will be received by any number of objects located in different logical and/or physical entities. Estimated parameters that indicate link quality (average SINR, CSI, and BER) and current static transmitter's parameters are supplied as CORBA events to *event channel* which allows other components (consumers) within the system to register their interests in events. The central control unit that determines optimal input transmission parameters for given requirements is *resource manager*. Controlled by interactive GUI it consumes supplied events forwarded from *event channel*, performs allocation in an optimal manner, and supplies new transmission parameters, i.e. total transmit power and power/rate per subchannel, which are finally consumed by other components in the system.

GUI, facilitating the demonstration, is developed in Qt/C++ framework. The transmitter's GUI contains static transmission parameters and current allocation of rate and power over subchannels, as shown in Fig. 2(b). Furthermore, the receiver's GUI, given in Fig. 2(a) and Fig. 2(c), contains interactive interface for controlling allocation strategy in *resource manager* and dynamically shows estimated channel parameters (average SINR, CSI, BER) and achieved data rate.

Due to high modularity and distributed nature of the system supported by generalized interface, dedicated *resource manager* can be easily reconfigured for different DSA scenarios with arbitrary number of PU, different classes of given requirements and various sets of controllable parameters.

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