Reconfigurable Framework for Adaptive OFDM Transmission *

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

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. Proposed demonstration, implemented in GNU Radio framework, enables capacity achieving OFDM-based data transmission between two network nodes 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 classes of given requirements and various sets of controllable parameters.

Categories and Subject Descriptors: C.2.1 [Network Architecture and Design]: Wireless communication; C.4 [Performance of Systems]: Measurement techniques

General Terms: Algorithms, Design, Experimentation, Measurement.

Keywords: OFDM, Rate and power allocation, GNU Radio, CORBA.

1. INTRODUCTION AND MOTIVATION

Current broadband wireless standards are based on Orthogonal Frequency Division Multiplexing (OFDM), a multicarrier modulation scheme which provides strong robustness against intersymbol interference (ISI) by dividing the broadband channel into many orthogonal narrowband subchannels in such a way that attenuation across each subchannel stays flat.

An important task in the design of future OFDM based system is to exploit frequency diversity offered by broadband channel by adaptable transmission parameters (bandwidth, coding/data rate, power) in order to preserve power and bandwidth efficiency according to subchannel conditions at the receiver. For given Quality of Service (QoS) demands, usually determined by target Bit Error Rate (BER), this can be formulated as an optimization problem which can be solved by designing an efficient resource allocation algorithm. There are basically two approaches which bring an optimal solution to this problem [1]

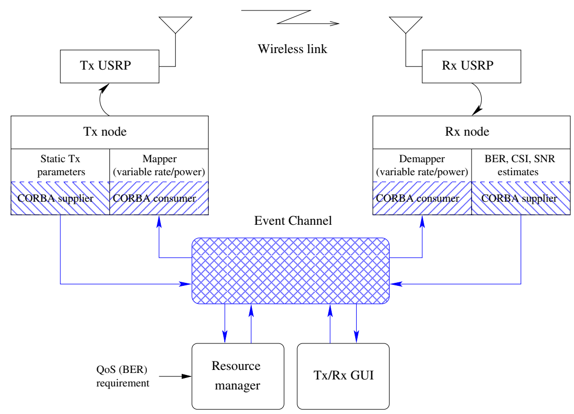

Figure 1: The system overview

- Rate adaptive (RA) optimization, which maximizes the overall rate given a fixed total power,
- Margin adaptive (MA) optimization, where the total transmitted power is minimized maintaining certain service rate demand.

The demonstration will showcase continuous capacity achieving OFDM transmission with optimal rate and power allocation over subchannels for given system constraints. Proposed system extends PHY layer functionalities of current wireless standards and offers control and feedback mechanisms for easy reconfiguration of transmission parameters allowing evaluation of different strategies in either simulation or real-time scenarios.

2. DEMONSTRATION DESCRIPTION

The investigation and assessment of information theoretic concepts for wireless resource management in real-world scenarios requires flexible testbeds with wide range of reconfigurable parameters. These functionalities are currently offered only in Software Defined Radio (SDR) technology based on general purpose hardware. We designed a modular, SDR based reconfigurable framework which treats OFDM transmission link as a black box. The control and feedback mechanism provided by framework allows for optimal assignment of predefined transmission parameters at the input and estimation of link quality at the output. High flexibility, provided by large set of reconfigurable parameters, which are normally static in real systems, enables implementation and assessment of different resource allocation strategies for various classes of system requirements.

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Figure 2: The transmitter's GUI

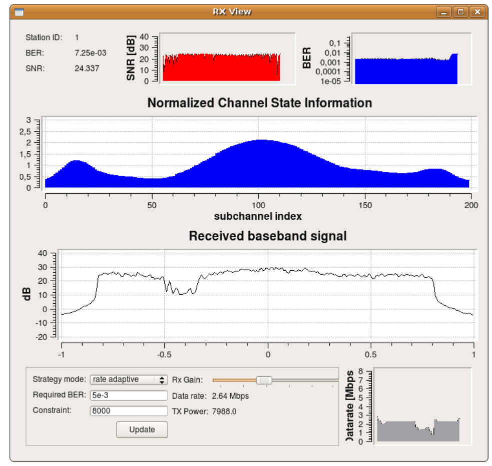

Figure 3: The receiver's GUI with interactive control interface

System diagram of demonstration developed in above mentioned framework is shown in Fig. 1. Transmitter and receiver node are composed of a host commodity computer and general purpose RF hardware, Universal Software Radio Peripheral (USRP)[2]. Baseband signal processing at host computers is implemented in GNU Radio framework [3], an open source 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 down-conversion controlled through a robust application programming interface (API) provided by GNU Radio.

Within the framework, additional OFDM specific blocks are implemented, particularly at receiver's synchronization stage, since OFDM system is highly sensitive to time offsets and oscillators' mismatch between transmitter and receiver due to necessity for subchannel orthogonality. 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 1) and power levels across subchannels.

Algorithms for estimation of link quality, expressed through average signal to noise ratio (SNR) and channel state information (CSI) over subchannels, are extensively studied [4] and implemented at the receiver. Furthermore, in order to assess system performance, receiver implementation contains blocks for BER measurement.

The communication between transmit and receive node is organized as reconfigurable continuous one-way transmission of OFDM symbol frames. As shown in Table 1, 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.

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 SNR, 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.

Table 1: OFDM symbol parameters

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

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. Furthermore, the receiver's GUI, given in Fig. 3, dynamically shows estimated channel parameters (average SNR, CSI, BER) and contains interactive interface for controlling allocation strategy (RA or MA approach) in *resource manager*.

The demonstration can also run in simulation mode on a single PC, without the RF interface (USRP boards), where transmitter and receiver "communicate" over an artificial channel. A set of channel models available through IT++ libraries [6] is ported to GNU Radio framework in order to evaluate system performance excluding hardware impairments.

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

3. REFERENCES

[1] Y. G. Li and G. L. Stuber, *Orthogonal Frequency Division Multiplexing for Wireless Communications*, Springer, 2006.
[2] "USRP," http://gnuradio.org/trac/wiki/USRP.
[3] "GNU Radio," http://gnuradio.org/trac.
[4] M. Zivkovic and R. Mathar, "Preamble-based SNR estimation in frequency selective channels for wireless OFDM systems," *Proc. of IEEE VTC 2009 Spring*, 2009.
[5] "Object Management Group," http://www.omg.org/.
[6] "IT++," http://sourceforge.net/apps/wordpress/itpp.