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Reconfigurable simulator using graphical user interface (GUI) and object-oriented design for OFDM systems

Nabih Jaber, Kemal E. Tepe *, Esam Abdel-Raheem

Department of Electrical and Computer Engineering, University of Windsor, Windsor, ON, Canada

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ABSTRACT

In this paper, a design of a new object-oriented simulation environment and graphical user interface (GUI) for versatile orthogonal frequency division multiplexing (OFDM) systems is presented. This is achieved using high-level design, parallelism and usability for the simulation environment. GUI interface can serve as a learning/research tool for students or practiced professionals to investigate particular designs. It is evident that OFDM systems intended to be used in dynamic environments must be tested under various conditions in order to be designed for optimality. Hence, a simulation design is proposed coupling the GUI, parallelism, and high-level object-oriented design techniques to be beneficial to the researcher. A high-level design and GUI layouts of the proposed simulator is shown in details. Important OFDM parameters needed for reconfiguration of transmitter components, channel condition parameters, and receiver components are discussed. In addition, this paper provides a simple technique to implement simulation partitioning for increased parallel performance of reconfigurable object-oriented OFDM simulators. This simple technique applies to scenarios where there is disproportionate simulation duration between different OFDM configurations. It is shown to decrease total simulation time considerably.
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1. Introduction

In the development of any new communication technology, either a full prototype or a simulation must be modelled and developed alongside analytical/theoretical models. Prototyping is time consuming and costly, especially during the research and development stage where simulation is more attractive.

Object-oriented simulation environments have modularity, abstraction, re-usability and encapsulation features [14]. These features can for example, allow for a fair comparison for multiple receiver designs in a communication system to be tested under the same transmission conditions. In object-oriented simulation environments, the objects interact with each other at different states of the simulation. This makes object-oriented simulation more useful for getting reliable estimates of performance once all simulation components have been verified.

Orthogonal frequency division multiplexing (OFDM) systems were first proposed by Chang and Gibby for digital communications [10]. It has been used in wireless local area network (WLAN) standards (IEEE 802.11a/g and HIPERLAN/2), digital video broadcasting (DVB), digital audio broadcasting (DAB), new broadband wireless access standard WiMax (IEEE 802.16e), and now dedicated short range communication systems (DSRC) [18,34]. OFDM wireless communication physical layer (PHY) is a versatile communication model [10,18]. This is due to the OFDM PHY having multistage components that share

* Corresponding author. Address: Department of Electrical and Computer Engineering, University of Windsor, 401 Sunset Avenue, Windsor, ON, Canada N9B 3P4. Tel.: +1 5192533000x3426; fax: +1 5199713695.

E-mail address: ktepe@uwindsor.ca (K.E. Tepe).

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dependent symmetrical parameters/settings on each side of the communication channel [17], which is capable of being used in many different configurations within one or more technologies, such as in [8,3,16,31]. Testing various OFDM receiver designs under various levels of strain is important because it gives a more objective analysis of a particular implementation. In other words, OFDM PHY receivers have to be optimized and compared to one another in different environments, and hence is a useful candidate for object-oriented simulation analysis.

OFDM communication systems have different configurations depending on different applications, and can also have different performance characteristics. Hence, the OFDM communication systems are required to operate in different operating modes, and having a simulator with a modular structure, capable of reconfiguring on demand is desirable as it gives the ability to test full system performance. Object-oriented simulators can be made compatible with other object-oriented simulators, and hence can be deployed as subsystems [25] when simulating other aspects/layers of a communication system. An example would be for use in cross-layer analysis at different levels such as network layer or Medium Access Control (MAC) layer [17].

The majority of the simulation designs focus on simulation of higher layers of the open systems interconnection (OSI) communication stack, such as the ones shown in [28]. It is shown that changes in the physical layer or the channel of a communication system can have great repercussions in the higher layers [38]. In addition, other layers require information from the PHY to perform optimally. For example, a more realistic PHY implementation is important when it comes to a dynamic MAC layer design [41]. Due to this fact, and with the PHY being the lowest part of the OSI Model in a communication system, it is very important to have a well optimized and accurate PHY model for simulations.

Other works discuss OFDM simulators from different aspects, as heterogeneous simulation improvement, Network Simulator 2 (NS2) PHY accuracy improvement, model abstraction and approximation, Matlab and/or Simulink detailed modelling, and hardware accelerated simulation.

Authors in [39] study the effects of detailed modelling of OFDM PHY and focus on the integration between a Matlab/Simulink OFDM PHY simulator and a Qualnet Medium Access Control (MAC) layer simulator. They emphasise the importance of detailed modelling of the OFDM PHY and perform heterogeneous runtime performance study which resulted in improved simulation time. In [22], Network Simulator 2 (NS2) is used in conjunction with Qualnet with its proposed model, and studies the effects of accurate PHY modelling on higher layers, and shows upwards of six fold TCP/UDP throughput difference. Studies [35,24] investigate the use of hardware assisted OFDM simulation, showing that using field programmable gate arrays (FPGAs) programmed using Hardware Description Language (HDL) can improve simulation runtime performance over pure software simulation.

Some OFDM simulators use PHY abstraction to make approximations for parts of the OFDM PHY to improve simulator performance runtime and resource usage. For example, authors in [23] focused on OFDM channel realization in the frequency-domain for reducing complexity of simulation to increase simulation runtime performance. There are advantages to OFDM PHY abstraction, but this may not be accurate in all OFDM PHY scenarios.

In our OFDM PHY simulator model description, we use Unified Modelling Language (UML) diagrams to allow for understanding and implementation of the concepts we present regardless of platform choice or familiarity. The UML diagrams express and emphasise the building of our high-level objects that are inherently modular, flexible, and interactive. Consequently, the flexibility and interaction of our simulator's objects improve usability by introducing automatic reconfiguration, and parallel processing capabilities are improved through modularity of these objects. Although, the initial development time investment in a high level simulator designs, such as ours, is arguably higher than that of a purely functional implementation of a specific problem. This fact is mitigated by the re-usability of the object-oriented generic design, code modularity, and potential for rapid reconfiguration. We choose to illustrate the benefit of using an object-oriented design to improve parallel processing, and a graphical user interface (GUI) to control simulation parameters of a versatile/reconfigurable and complex OFDM PHY communication simulation system. Our object-oriented OFDM simulator allows for ideas to be expressed to others working in the same field through analysis of the simulation results.

High-level object-oriented design is a technique that is used to create flexible simulation objects. Parallel processing and distributed computing reduces overall time to complete a simulation by transferring process load in a simulation. Our work is based on the underlying complexity of designing OFDM PHY communication systems that need to be studied under various dynamic situations. The creation of a platform for rapid design and preliminary evaluation is studied and developed, building on existing software development techniques to apply them to OFDM PHY communication engineering problems. In addition, for explaining the development of our high level OFDM simulator, we are not focusing on any particular platform/programming language, such as Matlab, Simulink, IT++, Scilab, C++, Java.

The rest of the paper is organized as follows: Section 2 describes important aspects of modelling the OFDM PHY and the channel model. Sections 3 and 4 discuss the proposed GUI and simulator environment for OFDM PHY communication systems. More precisely, Section 4 starts with a highlight of the simulation design overview; in Section 4.1 the simulation environment overview is presented; in Section 4.2 descriptive Unified Modelling Language (UML) class diagrams for the simulator are shown, and the relationship between the high-level design and GUI is illustrated. Section 5 proposes using simulation partitioning for distributed and parallel simulation. An example case study is used to show the resulting improvement in simulation runtime for different OFDM PHY designs. In addition, a sequence diagram is used to highlight the flow between simulation processing units. Section 6 discusses our design in relation with previous related works. Finally, Section 7 provides the concluding remarks.

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