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New Course Development for 5G Wireless Communications - Challenges and Opportunities during Covid Pandemic

Christopher Zarod
Dr. Xingwu Wang, Alfred University

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Christopher Zarod, Xingwu Wang

Alfred University

Alfred, NY 14802

At the beginning of 2020, we intended to develop new tech elective courses in the areas of information-communication technologies (ICTs). Such courses should benefit both MSEE and BS REE (Renewable Energy Engineering) programs. When the Covid pandemic occurred in March, we modified our plans for actions. First action was to examine the inherent correlations between mobile ICTs and renewables, and second action was related to simulations. In this paper, we'll describe the lessons learned in the second endeavor, along with the software applications. For example, 5G connectivity introduces enhanced mobile broadband (eMBB) supporting high data rates and low latency, allowing large data flow instantaneously. Massive machine type communication (mMTC) supports a large number of connected devices including IoTs. Ultra-reliable and low latency communications (URLLC) provide reliability and latency characteristics for emerging wireless communication needs. 5G NR consists of two frequency bands for applications: FR1 (0.41-7.13GHz) and FR2 (24.25-40.00 GHz). Analysis of the FR2 band will be useful for applying 5G connectivity to various campus specific applications. For example, 5G FR2 connectivity can greatly increase data rates for wind/solar energy harvesting and consumption, thus creating relevance between existing REE courses and the proposed courses. Among available software packages for 5G wireless education, MATLAB packages was selected since all Alfred engineering students learn the simulations tools in their first-year course work. MATLAB codes are tested to illustrate initial planning steps to design new 5G courses and can provide simulated results for course development. These codes include the downlink and uplink functionality, in which uplink (downlink) refers to the transmission from the ground side to cell tower (from tower to ground). Advantages of such codes include "soft" spectrum analysis functionality to teach students the concept of communications. For example, students can analyze simulated interference with additive white Gaussian noise (AWGN), which is a basic noise model used in information theory to mimic effects of many random processes occurring naturally. AWGN impairments to communication are linear additions and produce simple and tractable mathematical models which are useful for learning the underlying behavior of a system before other, more complicated phenomena are considered. One of the key leaning objectives is to explore Shannon's Limits, i.e., maximum theoretical transmission capacities of a proposed configuration for FR2 applications. Comparisons are made between downlink and uplink peak data rates for a specific MIMO (multi-input multi-output) antenna arrangement. For classroom demonstrations, AWGN will then be added to visualize its effects on the transmitted signal waveforms. Different filters can be inserted to observe their effects by examining noise and comprehensible signals. Another key learning objective is related to the concept of constellation diagrams in digital communications. For example, using 64 QAM (quadrature amplitude modulation), students can visualize the effects of AWGN on the In-phase and Quadrature amplitudes. AWGN effects can be seen in the spectrum analyzer, in constellation diagrams and in mathematical approaches. In each of these cases, the level of complexity regarding analyzing and measuring AWGN effects can be manipulated resulting in the freedom to either incorporate all these cases in one course or create three separate and more advanced courses.

Regarding the educational approach, it is important to establish three main benefits of 5G, i.e., bandwidth parts, the ability to vary subcarrier spacings, and the ability to use the FR2 range. Please note that neither was available in earlier versions of wireless communications such as LTE. To teach such concepts, one can use 5G MATLAB codes. The first three code sections in a basic MATLAB code outline the waveform configuration, carrier configuration, and the bandwidth part configuration. In these sections channel bandwidths, frequency range, number of carriers and associated bandwidth parts are configured. In the carrier and bandwidth parts subcarrier spacings are configured. The computer codes can aid in relaying these important concepts to student. Please note that computerized approach may take advantage of the 5G Waveform Generator toolbox available in MATLAB. This toolbox, under the 5G test model application, uses frequency range, test model, channel bandwidth, subcarrier spacing, and duplex mode to generate a spectrum analyzer view. With this toolbox, impairments and various visualizations can be used to enhance the concept of communications. For example, signal transmission and noise impairments are important issues in communications. One can establish models which are useful for learning the underlying theory and practice by focusing on the key concepts, systems, and/or components.

To find support for this possible addition of curriculum at Alfred University, a preliminary survey was conducted with sophomore engineering students. The survey consisted of 4 questions. 1. Would you be interested in taking a class that deals with 5G Wireless Communication? 2. Would you be interested in learning basic 5G MATLAB coding? 3. Would you be interested in learning methods to generate, visualize and impair 5G Waveforms? 4. Would you be interested in learning basic mathematical equations and applying them to 5G connectivity? The results are as follows. When combining the yes and maybe categories, eighty percent of students would consider taking a class in 5G wireless communications for question 1, eighty-six percent of students would consider learning 5G MATLAB coding for question 2, seventy three percent of students would consider learning 5G based MATLAB apps for question 3, and eighty percent of students would consider learning 5G based mathematics for question 4. This survey can also serve as a gauge to understand student's levels of interest and their perceived knowledge of importance for this type of course development path. Future surveys would include more specific questions related to specific topics. In the presentation, we'll describe various options in course development.