Demonstration of a cognitive radio waveform

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Abstract

Cognitive Radio is a paradigm for wireless communication in which a wireless node (or a network) can change its transmission and reception parameters according to the user needs and the wireless environment. A cognitive radio transceiver is able to sense, learn, decide and react adaptively to avoid interference with licensed or unlicensed users and to achieve greater spectrum efficiency compared to existing systems. Cognitive radio opens a new era in digital communications involving numerous topics, such as spectrum sensing and dynamic spectrum management. In the scope of the study C4/19, a new cognitive radio waveform for tactical mobile ad hoc networks has been proposed and implemented in software using Qt4, IT++ and universal software radio peripheral (USRP) hardware driver (UHD).

1. Context & State-of-the-art

Military tactical networks are being required to support a greater number of services than ever before. In addition, the bandwidth requirements associated with many of the new services are also rapidly increasing. The combination of these two factors means that we are nearing a time when there will be insufficient spectrum to support the services required for future military operations. Todays military operations are also typically undertaken by multiple nations cooperating in a coalition force. The spectrum and frequency planning activities associated with the deployment of a large multi-national coalition force are extremely complex and unacceptably long and can delay the start of an operation. Both of the aforementioned problems, spectrum scarcity and deployment burden, are to a large degree consequences of the centralized and static nature of current spectrum management.
Dynamic spectrum management (DSM) is a process where cognitive radios (CR) seek out and use a part of the electromagnetic spectrum in ways that are not predictable, so that it is not generally known which set of frequencies that the radio will use at any given time. The DSM process may be seen as a harmonization of, and dynamic interaction between, both a human element in the form of spectrum regulators and spectrum planners or managers and an autonomous element in the form of one or more cognitive radio networks. DSM represents a fundamental change from existing spectrum management procedures in the way that spectrum is allocated and used for both civilian and military domains.
A common strategy for DSM is to use iterative waterfilling which leads to a sub-optimal solution. Simulation results have been performed with the scenario shown in Figure 1. Two coalition nations are competing for four sub-channels, leading to a FDMA solution, where Tx1 is only using sub-channel 2 and 3, and Tx2 only sub-channel 1 and 4.

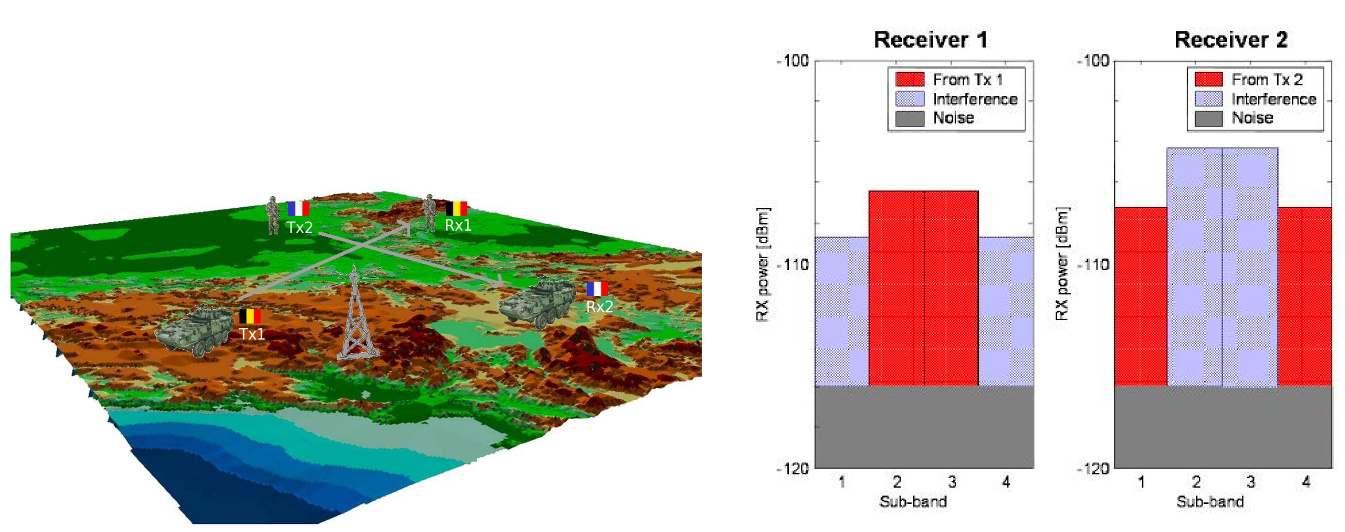

Figure 1: *Iterative waterfilling algorithm and simulation results*

2. Implementation of a new DSM strategy and cognitive radio waveform

A new algorithm has been proposed in the study C4/19 to improve the convergence of iterative waterfilling by adding a constraint on the number of sub-channels that can be used for transmission. Simulations in the discrete event simulator OMNeT++/MiXiM have shown no errors of convergence with a single sub-channel constraint.
Following the previous contributions to DSM for cognitive radio, a new waveform design has been proposed in C4/19. The waveform is an orthogonal frequency division multiplexing (OFDM)-based waveform with a spectrum sensing block based on energy detection to determine the best sub-channel for transmission. Multiple users are handled by orthogonal frequency division multiple access (OFDMA) and full-duplex is enabled either by time division duplexing (TDD) or frequency division duplexing (FDD). A complete OFDM blind receiver which does not require the use of pilot symbols is used for time, frequency, and phase offset estimation as well as channel estimation. Based on channel and noise estimation, adaptive modulation is used to improve the link throughput. Cyclic redundancy check (CRC) and forward error correction (FEC) are used to detect and correct errors within a frame's preamble and postamble.
The proposed waveform has been implemented in software using Qt4, IT++ and UHD. Qt4 is a cross-platform application framework that is widely used for developing application software with a graphical user interface (GUI). IT++ is a C++ library of mathematical, signal processing and communication classes and functions. Its main use is in simulation of communication systems and for performing research in the area of communication. The USRP products are software radios which connect to a host computer through a high-speed USB or Gigabit Ethernet link, which the host-based software uses to control the USRP hardware and transmit/receive data. Some USRP models also integrate the general functionality of a host computer with an embedded processor that allows the USRP Embedded Series to operate in a standalone fashion. The goal of the UHD is to provide a host driver and application programming interface (API) for current and future USRP products.

3. Demonstrator setup

Figure 2 shows the demonstrator setup of 2 host PCs connected to 2 USRPs and exchanging data with the proposed waveform in TDD mode. The band of interest is divided into 4 sub-channels and the waveform automatically selects the best sub-channel according to the measured noise. The sampling rates and carrier frequencies in Tx and Rx for both USRPs are 2 Msps and 433.92MHz respectively, the OFDM has 512 sub-carriers and 128 samples for the cyclic prefix. The third computer and USRP is used as a jammer sweeping the whole bandwidth.

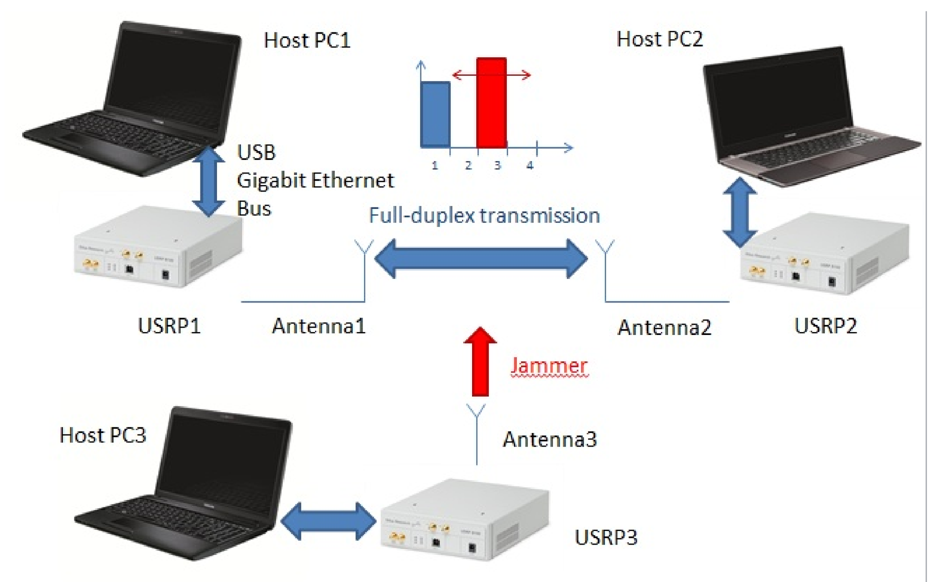

Figure 2: *Setup used for the demonstrator*

Figure 3 shows the spectrogram of the cognitive radio waveform in demonstration. The jammer in red sweeps the whole bandwidth and the cognitive waveform in yellow automatically changes its sub-channel whenever the jammer perturbs the transmission.

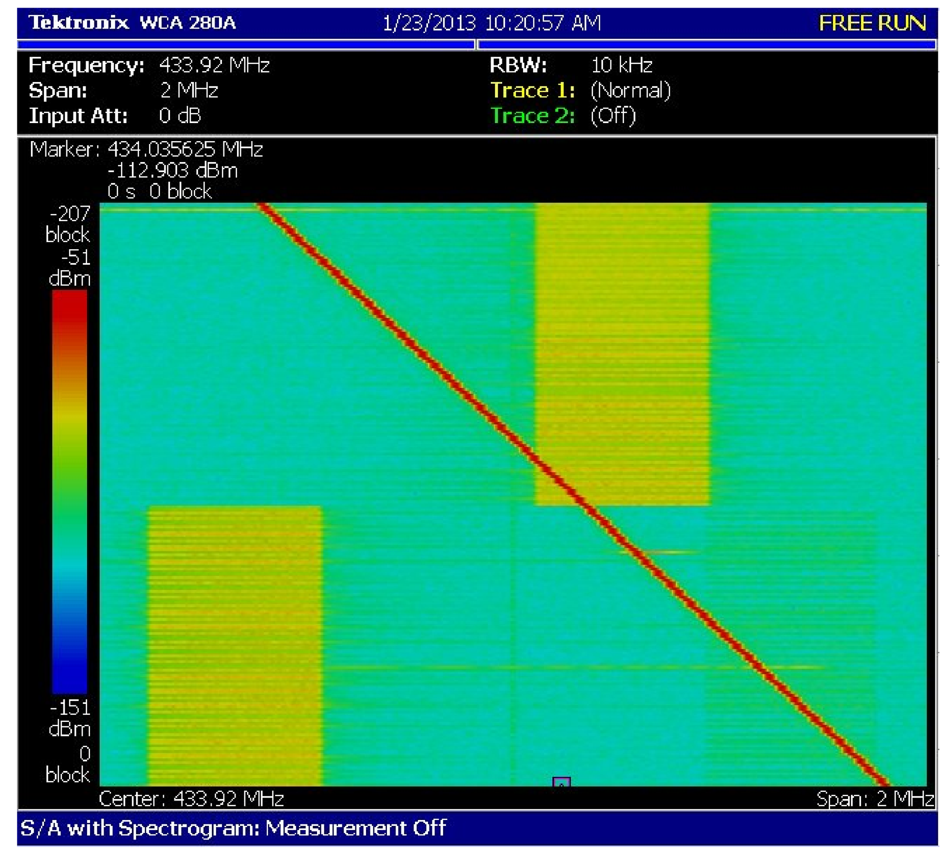

Figure 3: *Spectrogram showing the cognitive capability of the waveform*

Figure 4 shows the application's GUI of the two computers exchanging data. The implemented services are video, audio and text. Data can still be exchanged in the presence of a jammer or other radio networks.

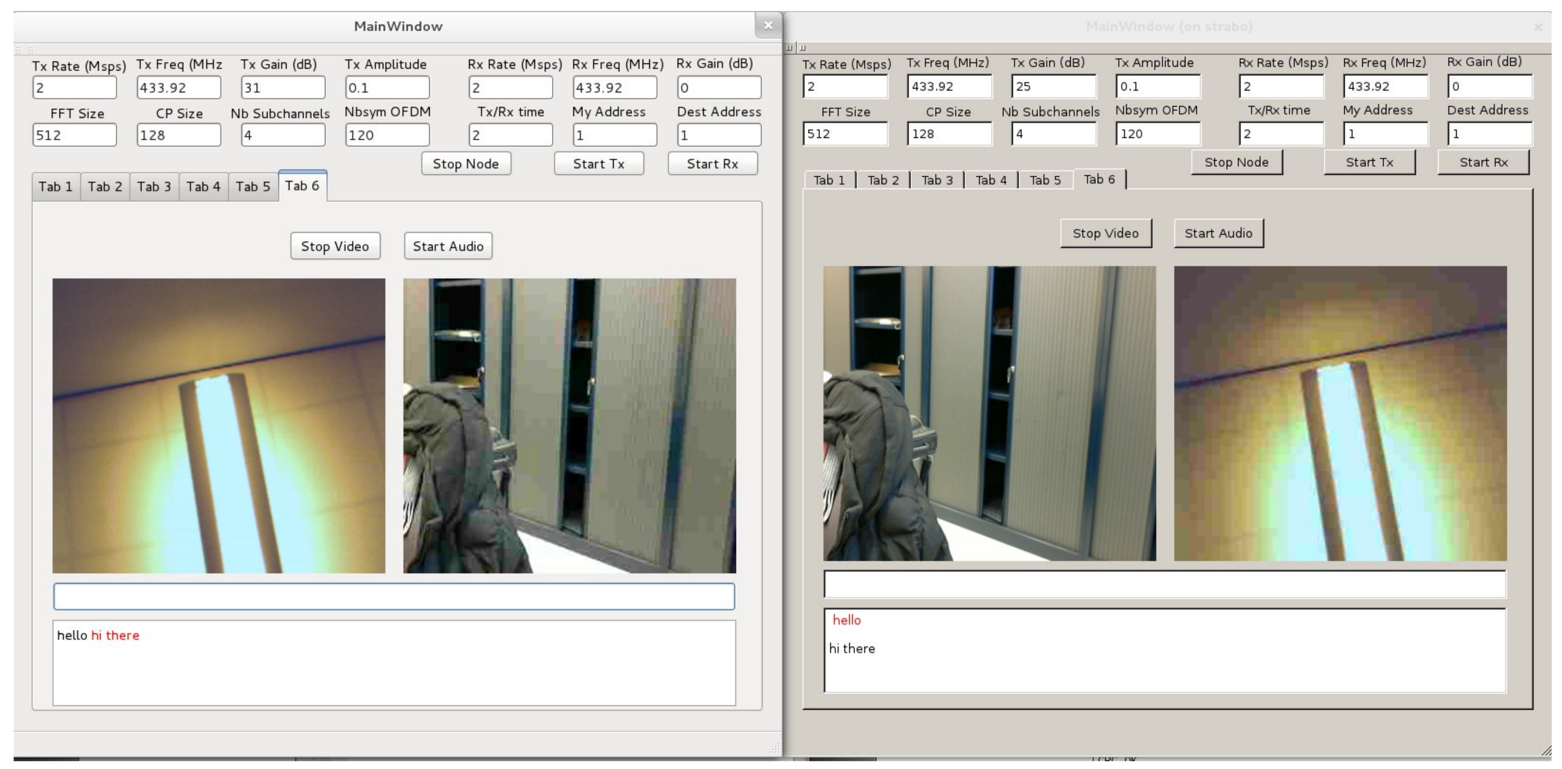

Figure 4: *Data transmission between 2 USRPs in presence of a jammer*

4. Conclusion

In the scope of the study C4/19, a new cognitive radio waveform for tactical mobile ad hoc networks has been proposed and implemented in software using Qt4, IT++ and UHD. The cognitive radio waveform allows the exchange of video, audio and text between 2 USRPs and is robust against jamming owing to the best sub-channel selection. These results will be used to develop a complete cognitive radio network in the future study SIC-10.