IEEE DySPAN 2008 Demonstration Proposal

Contact Information

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Abstract

Provide a concise (300 words) summary of the proposed demonstration and its technical significance.

A Heterogeneous Cognitive Radio Network Enabling Dissimilar Cooperative Spectrum Sensing, Dynamic Spectrum Access, and Interoperability

In this demonstration, the Center for Wireless Telecommunications (CWT) will build and operate a heterogeneous cognitive radio (CR) network which enables dissimilar cooperative spectrum sensing, dynamic spectrum access (DSA), and interoperability among legacy radios and a Wi-Fi network.

First, the CWT uses four different sensors to build an ad-hoc network for cooperative spectrum sensing. The first sensor utilizes cyclostationary features based signal detection on a PlayStation 3 connected to a Universal Software Radio Peripheral (USRP). The second sensor uses energy detection followed by a *k-nearest neighbor* (K-NN) algorithm classifying signal features on a laptop with a USRP. The third and fourth sensor utilizes energy detection followed by Euclidean distance-based signal feature classification using an Anritsu spectrum analyzer and a Lyrtech “Small Form Factor” SDR board respectively. The CWT employs Wi-Fi adapter cards to connect these sensors into an ad-hoc network. The CWT can then boost the overall spectrum sensing performance by fusing each sensor’s results into a single spectral map of the entire radio environment. For example, cyclostationary features together with other signal features such as phase and magnitude can both identify low SNR signals and distinguish high order modulations from QPSK.

Second, two CWT reconfigurable CR nodes communicate with each other using vacant channels obtained from the fused spectral map. The above four sensors continuously update this spectral map which informs both CR nodes to immediately switch to other vacant spectrum upon the primary signal’s return.

Third, in the aforementioned CR nodes, the CWT also developed three gateway functions based on GNU Radio and USRP to demonstrate interoperability in a heterogeneous network. These functions can: (1) bridge a Family Radio Service (FRS) radio to a Motorola Radius P110 police hand-held radio, (2) bridge the above police radio to Wi-Fi network through VoIP and (3) bridge a P25 digital radio to the police radio. In (2) and (3), the Wi-Fi network serves as a backhaul and sensor nodes with operating systems become network nodes.

Description

The description should include sufficient detail such that the evaluators can understand the purpose, configuration, design, and conduct of the demonstration/experiment.

Primary technical goals

The purpose of this demonstration is to showcase the capabilities of a heterogeneous cognitive radio network enabling DSA application based on dissimilar cooperative spectrum sensing, as well as interoperability among different legacy radios and a Wi-Fi network. Four different signal sensors with different algorithms and radio platforms are deployed, and their results are fused to complement each other. The demo develops data fusion algorithms for a variety of sensing results with different confidence and performance. A DSA protocol directed communication link is established between two cognitive radios. Gateway functions on reconfigurable cognitive radios are developed to achieve interoperability among different public radios and a backhaul network.

Description

Pictures, screen shots, and system drawings are encouraged (attach as necessary)

Please see attachments.

Operational parameters

Frequency Ranges	150.79 - 159.195MHz, 462.5625 - 467.7125MHz, 764 - 776 MHz, 794 - 825 MHz, 851 - 870 MHz, 2.4GHz ISM band
Bandwidth	25KHz (FM), 12.5KHz(C4FM), 6.25KHz(CQPSK), WiFi band, 300KHz (BPSK, QPSK, 8PSK)
Peak Input Power to Antenna	0.5 w
Antenna polarization and gain	Linear polarization, 3 dB gain
Waveforms (modulation type)	FM, BPSK, C4FM, CQPSK, QPSK, 8PSK, OFDM/CDMA (WiFi)

Technical Significance

Address the technical significance of the demonstration/experiment.

Description of the technologies

First, cooperative spectrum sensing is widely endorsed by cognitive radio researchers for Dynamic Spectrum Access (DSA) implementation. Current related research mainly focuses on homogeneous sensor networks which deploy special DSA sensors; not only might these be costly, but adjacent sensors can only moderately complement each other. More practically, we may integrate available non-special sensors together with a variety of special ones. As a consequence, these sensors will have a wide range of performance and data confidence. This variety comes not only from different algorithms, but also a diverse array of radio platforms. Our demo is able to illustrate the benefits of dissimilar cooperative spectrum sensing in DSA applications.

Second, currently various incompatible public safety waveforms cannot communicate with each other, which sometimes results in huge economic and life loss. We achieve some public safety communication interoperability through three gateway functions which can bridge different legacy radios and also interoperate them with a Wi-Fi network through VoIP.

Detailed main technologies:

1. Sensors (see attached demo diagram)
    a. Sensor-1: energy detection followed signal feature (magnitude, bandwidth, phase, etc.) classification through Euclidean distance based decision. It runs on a Lyrtech board for carrier frequency, modulation type, and symbol timing identification. The board has a DaVinci DSP, a Virtex-4 FPGA, and an RF front end with antenna covering 450 MHz to 490 MHz.
    b. Sensor-2: energy detector and signal classifier. The signal classifier is based on a k-nearest neighbor (K-NN) algorithm, which classifies signals based on their time domain characteristics (the average of the standard deviation of a waveform's complex envelope at a given SNR is distinctive).
    c. Sensor-3: cyclostationary feature based signal detection running on a PS3 powered by a Cell Broad Engine.
    d. Sensor-4: same algorithms as Sensor-1 but running on an Anritsu receiver.
2. Sensor data fusion: includes both spatial fusion and feature fusion.
3. Ad hoc network: Wi-Fi based ad hoc network formed by an Ubuntu Linux Operating System running ad hoc protocols of MobileMesh (see reference 7)
4. DSA protocols: channel switching algorithms based on sensing results.
5. Gateway functions: these will bridge two incompatible analog radios to each other, an analog radio to a Wi-Fi network, and a P25 digital radio to a Wi-Fi network, using VoIP.
6. Reconfigurable Cognitive Radio: it reconfigures itself for multiple functions including signal sensing, different radio functions within multiple bands and possible modes, and functions as a gateway to achieve interoperability.

A discussion of the perceived impact of the demonstration to dynamic spectrum in general and the DySPAN audience in particular

- As the first critical step in DSA implementation, signal detection (and classification) detects the presence of primary signals and makes spectrum sharing without interference of primary users feasible. It is an important element of cognitive radio and DSA research. We provide four signal detection and classification methods based on different algorithms and platforms; we believe that other researchers will find them very valuable.
- Cooperative spectrum sensing can significantly boost signal detection performance in DSA applications; our heterogeneous cooperative sensor network also reveals a new perspective in cooperative spectrum sensing.
- As the final goal in DSA, spectrum sharing among secondary users relies on sensing results, communicating networks, and reliable DSA protocols. Our system demonstrates all above technologies.
- The primary goal of DSA is to enhance spectrum utilization efficiency. There are many different radio networks currently statically occupying different spectrum bands. It is very important to enable interoperability among all of the aforementioned radio networks. We developed reconfigurable cognitive radios which bridge communications among these different networks.

Technical Maturity and Operational Capabilities

Provide sufficient detail regarding the maturity of the demonstration/experimentation.

Current state of the technology, hardware, and software

Software and technology

- Sensor-2 (see attached demo diagram) has already been demonstrated on the Center for Wireless Telecommunications (CWT) Public Safety Cognitive Radio (PSCR), a reconfigurable cognitive radio for public safety communications. Sensor-4 too has been successfully demonstrated on several occasions. Sensor-1 and Sensor-3 are still partly under development. (See attached references.)
- Existing CWT DSA protocol helped CWT’s Smart Radio win the Grand Prize in Smart Radio Challenge 2007. The Smart Radio also enables GNU Radio based VoIP with home-made CVSD vocoder.
- Gateway functions Bridge-2 (see attached demo diagram) was widely demonstrated with PSCR. The other two gateway functions are currently under development
- The WiFi ad hoc network has worked well in a lab environment without attached sensors.
- The Data fusion algorithm is currently under development. Java based

GUI is available for one single sensor, the PSCR node.

Available Hardware: six 2.0+GHz Dell Laptops, 1 Anritsu receiver (Anritsu Signature MS2781A Signal Analyzer), 1 Lyrtech board, 1 PS3, 16 USRPs, 3 FRS radios, 1 borrowed Motorola Radius P110, 1 rented Tyco P25 radio, above 10 antennas.

Amount and type of work yet to be done prior to DySPAN

- Sensor-1 needs finished signal classification algorithms based on accomplished spectral correlation function (SCF) algorithm running on the Cell Broad Engine. Estimated 3 months by the primary contact
- Sensor-3 needs to port existing Matlab algorithms in sensor-4 to the FPGA/DSP based Lyrtech board. Estimated 4 months by the 5th and 7th team members
- Wi-Fi ad hoc network attaching sensors need data fusion methods. Estimated 2 months by the 2nd and 6th team members
- Gateway functions Bridge-1 and Bridge-3 need signal modem development on GNU Radio. Estimated 3 months by the 1st, 8th, and 9th team members
- Whole system integration and test. Estimated 1 month by the whole team

Risk mitigation methods to be implemented to ensure proper operation within regulatory constraints

- We will use Wi-Fi channel to establish the ad hoc sensor network. The possible cloudy Wi-Fi environment may disable our network connection. Our backup plan is to replace Wi-Fi with Bluetooth tools in forming this network.
- We plan to use a police hand-held radio which we used in our lab several times; however, it might not be possible to bring this radio to Chicago. Our backup option is to demonstrate Bridge-2 through different channels of two FRS radios.
- We rented a Tyco P25 radio for interoperability development. Firstly we may not able to get the proprietary vocoder. Secondly, we may not be able to bring this radio either. Our backup is another cognitive radio designed to mimic a digital radio.

Previous experience and trials of demonstration equipment’s coexistence with other communication systems

Note that a summary of existing test results may be useful in conveying the operational readiness and stability of the demonstration/experiment

In our demo system,

- The Anritsu receiver (Anritsu Signature MS2781A Signal Analyzer) has frequently been used to communicate with USRP hosted by GNU Radio.
- Two different cognitive radio nodes have successfully communicated with each other in widely noted demonstrations. They are also able to reconfigure to communicate with FRS radios and Motorola P110 Radius police hand-held radios.
- The Wi-Fi enabled ad hoc network was tested and successfully connected 5 laptops in a lab environment.

Logistical Needs

Include the logistical needs for supporting the demonstration/experiment at DySPAN. These details allow the planners to properly acquire and allocate resources to support the demonstrations.

Amount of space required (sq. ft or sq. m)	10 x 3 ft
Number of demonstration tables required	2 tables
Input power requirements and number of outlets (note: US uses 120V, 60 Hz power with a NEMA 5 (flat 3-prong) plug)	9 outlets
Approximate power consumption	930 W
Storage and security requirements for equipment	Secured storage for 3 laptops, 1 PS3, 4 radio boards, and several hand-held radios.
Instrumentation and other support equipment requested of DySPAN	An Anritsu Receiver (e.g., An Anritsu Signature MS2781A Signal Analyzer)
Internet/network access (wireless, wired, number of ports, etc.)	5 wireless ports
Other needs	

Checklist

[x] Contact information is complete and accurate
[x] Abstract
[x] Description is complete, including all operation parameters requested
[x] Technical specification
[x] Technical maturity and operational capabilities
[x] Logistical needs described as fully as possible
[x] Attachment for description

[x] We grant permission to make the information in this proposal public.