DySPAN 2008 Demonstration Proposal

Complete the following form with as much detail as possible. This information will be used to evaluate suitability of admission into the DySPAN Demonstration Session based on the technical significance to the symposium, demonstration maturity, and demonstration supportability.

Contact Information

Primary Contact Name	Ying Wang, Charles W. Bostian
Organization	Center for Wireless Telecommunications, Electrical and Computer Engineering Virginia Tech
Address	436 Whittemore Hall-MC 0111 Blacksburg, VA, 24061
Phone Number	(540) 231-5096, (540)231-2558
Email Address	ywang06@vt.edu, bostian@vt.edu

Abstract

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

We propose to demonstrate a Dynamic Cellular Cognitive System (DCCS) in DySPAN 2008. DCCS is designed to self-organize cognitive radios and other communication devices to automatically form a dynamic cellular structured network. Dynamic Spectrum Accessing (DSA) is achieved in DCCS based on multiple nodes cooperation. Nodes in DCCS cooperate to sense the spectrum and optimally allocate to achieve the spectrum efficiency for a whole network. It considers the varying spectrum condition in different locations of the network and uses cellular structure to increase the frequency reuse factor. Because of the designed universal classification technology, DCCS is able to change the cellular structure dynamically. It supports multi-band multi-mode communications and provides an interoperable platform for multiple types of devices. The computation complexity is relatively low.

In the demonstration, we will exhibit the main concepts of DCCS by using 5 cognitive nodes designed in Center for Wireless Telecommunications (CWT) at Virginia Tech. Further more, by agreement with other team, we would like to demonstrate how DCCS organizes and interoperates with other cognitive radios in the demonstration room and enables them to communicate with each other through multiple modulation types. We will also demonstrate how DCCS connects all the cognitive radios to form an island, and bridge to the internet if at least one node is able to access the internet, so that every cognitive node in it will be able to access the internet.

Other features of DCCS we would like to demonstrate include: the size of the network is dynamically adjusted according to communication requirements; fairness for cognitive radio nodes is guaranteed and interference is maximally avoided by cellular based design. The system regulates the behaviour of multiple cognitive radios to achieve system level efficiency. It supports individual cognitive radio node to achieve the required Quality of Service by a knowledge sharing scheme.

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

We plan to achieve 4 primary technical goals.

1. DCCS organizes multiple cognitive radios to dynamically set up a cellular based communication network. Each node can communicate with each other node.
2. Nodes within a cell will cooperate on DSA and share the spectrum information; available spectrum will be managed and allocated in a way to utilize the resource efficiently. Power control is applied to maximize the frequency reuse factor.
3. DCCS is able to accommodate multiple types of devices, including cognitive and non-cognitive devices. Based on the universal classification technology, newly arrived devices can be added to the network

automatically.

4. DCCS provides multi-band multi-mode modulations and satisfies the different QoS levels for different users and applications.

Description

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

There are three main concepts we would like to demonstrate through DCCS:

1. When multiple cognitive nodes coexist in a certain frequency range, DSA — with some regulation — will achieve higher spectrum efficiency for the whole system.
2. A cognitive radio network can be regulated and organized without losing the cognitive nature. In DCCS, radios are cognitive as individual nodes, and operate as a cooperative, efficient network as the system level.
3. Cognitive radio networks can interoperate with multiple types of devices with our Universal Classifier, Synchronizer and Demodulator (UCSD) installed in the Picocell Cognitive Nodes (PCNs.) Because of UCSD, PCN can always auto configure itself to the modulation type of a device and help devices communicate with other nodes in the network.

In the demonstration, we will use 5 cognitive radios designed in CWT lab to demonstrate our primary technical goals. We will employ these 5 nodes as PCNs, which are similar to base stations in a cellular network and add other nodes cooperatively. We will demonstrate how these nodes are able to reach each other using multiple modulation types.

There are 4 steps in demonstration:

1. 5 nodes are deployed to demonstrate the primary technical goals. The structure is shown in Figure 1.

   As we can see in Figure 1, there are two types of connections: intercell connections and intracell connections. Inter cell communication is relatively wider band communications compared to intracell communications. By these two connections, we are able to set up the connection between any two nodes using multiple modulation types.

   In the middle, an Anritsu MS 2781A signal analyzer servers as the UCSD. It will detect the signals, extract the demodulation information and send this to the PCN to which it is connected. In the demonstration, we will see that the network is automatically set up. When the cognitive radios exist, the network is automatically created. When new cognitive radios arrive, they can be automatically added based on mutual agreement.

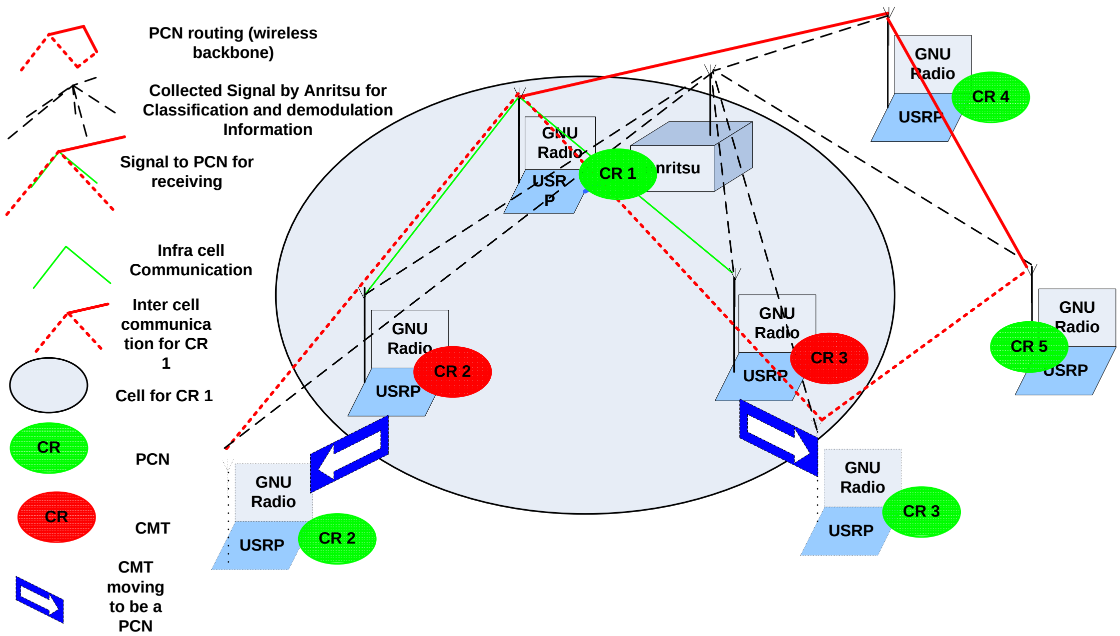

Figure 1: Proof of Concept of DCCS based on 5 nodes

2. In the Dyspan demonstration, we would like to take this invaluable opportunity to prove that DCCS can connect other teams' radios to make the demonstration area a whole network based on the agreement. Different devices or systems which are normally incompatible can now communicate with each other through different modulation types, using PCNs as the central gateways. To have so many cognitive raidos gathered together in one location is an excellent opportunity to demonstrate DCCS's adaptability.

3. DSA is an important feature for DCCS. In contrast to other DSA, in DCCS we solve the problem of how the vacant spectrum resources can be utilized for a whole group of cognitive radios in the most efficient way, when that group coexists in a system as secondary users. Our solution to this problem will include three aspects: spectrum sensing pooling technology, spectrum distribution among intercell and intracell communication, and power control to increase the frequency reuse.

4. A dynamic cellular structure will be shown. Wireless backbone technology is used for PCN connections. In DCCS development. WiMAX is used for wireless backbone. DCCS is dynamically changing the cellular structure, when the nodes move. Varying power consumption and reserve levels in a PCN will also change the structure.

The design of UCSD is key technology to support a dynamic cellular structure for DCCS, because the PCN end of a communication pair always understands the communication and can set up the connection. Thus the structure can dynamically change, and the communication can always be resumed. When a new device joins the network and sends a signal that is received by a PCN using UCSD, it is the PCN's responsibility to detect, classify and demodulate the signal, using the same modulation type to communicate.

Operational parameters	
Frequency Ranges	(see table below)
Bandwidth	DCCS can work either as the primary user or the secondary user: Primary user: 3.5M Secondary user: No requirement
Peak Input Power to Antenna	6 Watts
Antenna polarization and gain	Vertical omnidirectional, Gain: 0dB
Waveforms (modulation type)	FM, AM, MPSK, QAM and OFDM, WiFi, WiMAX

Channel	Centre Freq. (MHz)	Max ERP	BW (MHz)	Mobile
1	231.2250	1 W (0dBW)	1.75	Yes
2	233.0250	1 W (0dBW)	1.75	Yes
3	234.8250	1 W (0dBW)	1.75	Yes
4	236.6250	1 W (0dBW)	1.75	Yes
5	238.4250	1 W (0dBW)	1.75	Yes
6	386.8750	1 W (0dBW)	1.75	Yes
7	396.8750	10 W (10dBW)	1.75	Yes
8	406.9750	1 W (0dBW)	1.75	Yes
9	408.7750	10 W (10dBW)	1.75	Yes
10	436.8750	1 W (0dBW)	1.75	Yes

Technical Significance

Address the technical significance of the demonstration/experiment.

Description of the technologies

The following are the key technologies.

1. DCCS
   A provisional patent application covering DCCS has been filed February 25, 2008 in US Patent and Trademark Office. Being able to demonstrate the concept of DCCS in DySPAN will be an excellent chance to test the feasibility of this technology in DSA and cognitive networking.

2. UCSD

   UCSD is filed as Virginia Tech Intellectual Property disclosure on February 18, 2008. A cognitive radio, when transmitting, changes its modulation type based on the sensed environment. This requires a cognitive radio receiver, which can detect, classify and demodulate signals in the physical layer automatically. UCSD is designed for this. In DCCS, the mobile terminals always directly communicate with a PCN that has UCSD installed. UCSD will guarantee that mobile terminals can always be understood, providing the freedom to change the network structure dynamically.

3. Spectrum Pooling Technology
   Within a cell, multiple nodes cooperate together on the spectrum sensing. A spectrum vector is distributed among all the nodes and updated by each node. Each node will be responsible for a certain range of spectrum. By negotiating among the adjacent PCNs and using power control, frequency is reused in different cells without interference.

4. Power control Algorithm
   PCN uses a power control optimization algorithm to control the power of each node within its cell to realize frequency reuse among different cells.

5. Wireless backbone and dynamic routing technology for PCNs
   The connections among PCNs are wideband. They are similar to a wireless backbone. Frequency distribution and power control are the two primary enabling technologies. A dynamic routing protocol is designed for forwarding data to the desired destination.

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

---

In general:

For cognitive radio dynamic spectrum sensing, there are three restrictions: hardware limitations, geographic limitations, and computational complexity.

Although DCCS is not specifically designed for DSA, DSA is an important part of DCCS. By using a dynamic cellular structure for communication over relatively large geographic areas, DCCS is also able to overcome these three restrictions for DSA. The detailed explanation is as follows:

1. Hardware limitations. For most SDR platforms, the spectrum range is specified. Different devices may have different frequency ranges. By accommodating multiple devices, DCCS also benefit from the diversity of the available spectrum sensing range. Within a cell, each node senses the spectrum, fills up the spectrum vector, and shares it with other nodes in a cell. PCN manages the spectrum allocation to optimize the spectrum efficiency. Among PCNs, spectrum allocation is negotiated to increase the frequency reuse factor.
2. Geographic limitations. " Unless a Cognitive Radio(CR) can measure the effect of its transmission on all possible receivers, taking a useful interference temperature measurement may not be feasible" [1] . When the transmitter and the receiver are far away from each other, a cognitive radio is not able to detect the spectrum around all possible receivers. There is a potential to interfere with these receivers. By using DCCS for intracell communication, power control will guarantee that the transmitted signal is limited to a single cell. Using DCCS for intercell communication, the PCNs topology information can be used to avoid interference. In other words, we are able to measure the effect of a transmission on all possible receivers. Therefore, we can make a useful measurement of interference temperature.
3. Computational complexity. In some DSA literature, the distribution algorithm for DSA is used. When the node number is relatively large, the complexity of the algorithm increases dramatically. By using the hierarchical structure of DCCS, the number of distribution nodes decreases relative to the number of PCNs. Within a cell, a PCN will gather the spectrum information and send it to other nodes. Because only local information needs to be sensed, an accurate sensing result can be achieved by using energy detection methods. Energy detection is preferred over cyclostationary methods due to reduced computational complexity.

For DySPAN audience:

Instead of researching an individual system, DySPAN provides the opportunity for the interaction of various, independently-developed systems and networks; DCCS intends to organize the different types of cognitive radios nodes and cooperate with different networks. Each cognitive radio node will contribute spectrum information using its unique DSA technology. This information is shared and optimally allocated. Because the propagation of a signal is restricted to a relatively small area (a cell in DCCS), the frequency reuse factor is increased.

Technical Maturity and Operational Capabilities

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

Current state of the technology, hardware, and software

DCCS system technology is well designed. In DySPAN, we intend to show a proof of concept demonstration.

Hardware: Universal Software Radio Peripheral (USRP) boards are used as the radio platform. Laptops running GNU radio is used as the software platform.

Software:

1. PCN structure

In Figure 2, the PCN structure is shown.

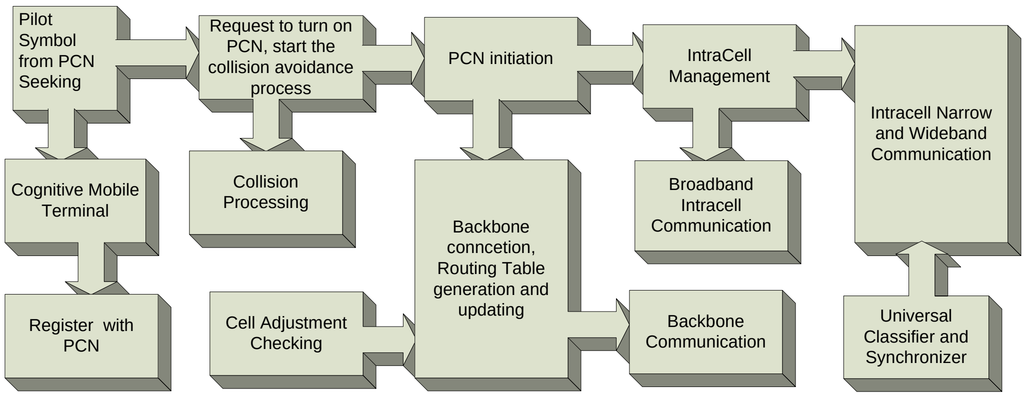

Figure 2: PCN structure

Currently, most of the intracell part is finished. Universal Classifier and Synchronizer, intracell narrow and wideband communication are already finished and tested. The testing scenario is shown in Figure 3. Testing result is shown in Figure 4. Coding for other parts is still under development.

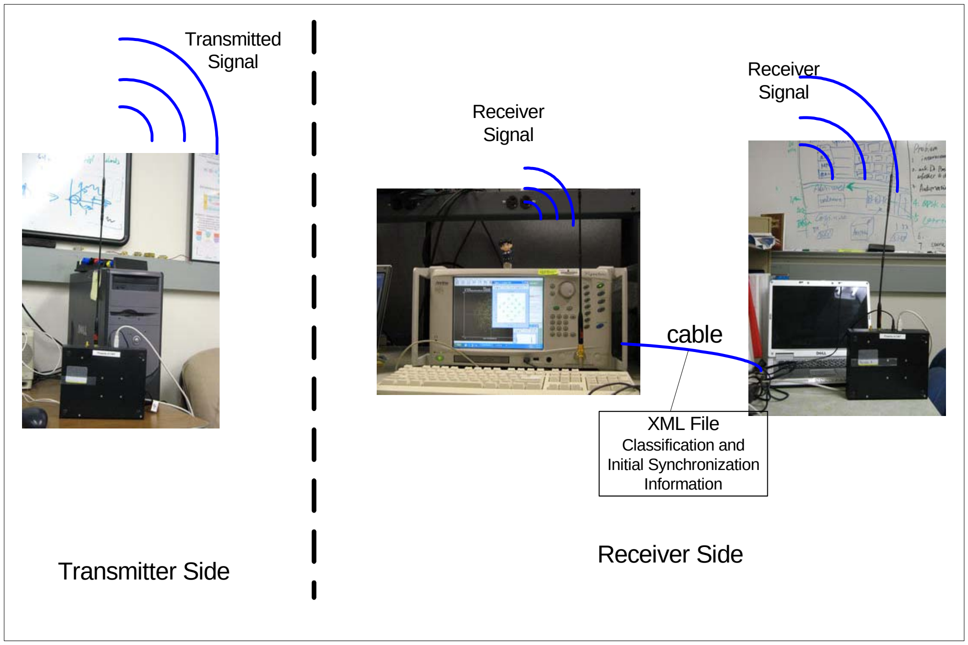

Figure3: Testing scenario for UCSD part of PCN

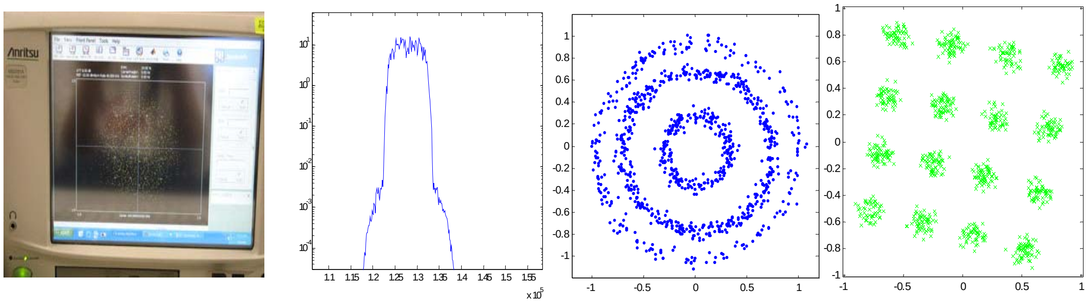

Figure 4: Testing result for UCSD part of PCN

2. Dynamic routing among PCNs and wireless backbone framework
The routing strategy is designed and under coding development. Wireless backbone framework is under coding development.

3. Policy and regulations for DCCS
This part will be based on the policy model already developed by CWT.

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

All the other parts shown in Figure 2 are yet to be done prior to DySPAN. Hardware and system testing are yet to be done prior to DySPAN. We are 50% finished.

Types of work yet to be done prior to DySPAN includes:

1. Hardware testing. USRP will have the new version prior be DySPAN, which will have positive impact on our system. The testing for new version USRP is necessary.
2. Software coding part. The PCN coding, dynamic routing and policy model need to be finished and tested.
3. System integration and testing will be done after items 1 and 2 are completed, prior to DySPAN.

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

Regulation constraints are imported to PCNs. When a PCN manages the resource within the cell and controls the power for each node, its behavior will be governed by the applicable regulations.

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

Currently not available.

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)	3 sq.m * 3 sq.m
Number of demonstration tables required	3 tables preferred
Input power requirements and number of outlets (note: US uses 120V, 60 Hz power with a NEMA 5 (flat 3-prong) plug)	120V, 60 Hz power with a NEMA 5 (flat 3-prong) plug, 20 outlets
Approximate power consumption	1000 watts in total

Storage and security requirements for equipment	NO Special Requirement
Instrumentation and other support equipment requested of DySPAN	Anritsu MS2781A SIGNAL ANALYZER preferred.
Internet/network access (wireless, wired, number of ports, etc.)	Wireless or wired, 1 port minimal
Other needs	N/A

Checklist

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

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