Policy-Based Spectrum Access Control for Public Safety Cognitive Radio Systems

NPSTC Software Defined Radio Working Group
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Agenda

• About SSC and NetCity

• Review of SSC’s Cognitive Radio Technology

• Overview of SSC’s NIJ-CommTech Project

• Focus on “Policy” Based Spectrum Access Control for Public Safety Cognitive Radio Systems

• Request for Feedback – Q&A
Disclaimer

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The opinions, findings, and conclusions or recommendations expressed in this presentation are those of the presenters and do not necessarily reflect the views of the Department of Justice.
About SSC

• Dr. Mark McHenry, CEO & Founder
  – Former DARPA Program Manager
  – Engineer of the Year Award for DC Area (2006)
  – Member, Dept. of Commerce Spectrum Mgt Advisory Committee
• Team of 26+ engineers focused on spectrum access and software defined radio solutions
  – IEEE DySPAN 2007: Best paper and demonstration awards
• Built 1st deployable cognitive radio system
  – Prototype hardware units field tested and being sold
  – High power (10 W), Multi-Band (174-2680 MHz) transceiver
  – Modem based on IEEE 802.16d (WiMAX)
  – 100,000 lines of embedded software code
  – Policy-based, command and control software

• Partners integrating SSC technology & software for DoD
Achievements

• DARPA XG Phase III and other programs
  – Spectrum occupancy measurements
  – DSA algorithm and spectrum access rule development
  – DSA-based transceiver test bed
  – Interference avoidance field testing
  – DSA software-only upgrades to Harris and Thales hand-held radios

• 2002-2008, $24M DoD investment

• Field-tested in military environments

• Selected for NTIA/FCC Spectrum Sharing Innovation Test-Bed
About NetCity

• Established in 2001 to assist local governments with advanced communications technology planning and deployment
• Have assisted several local and state governments assess fiber optic, wireless, wi-fi and other business models for both public safety and general government networks
• Provide governance, economic, strategic and operational modeling and assessment
• Have worked with SSC since 2005
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Cognitive Radio Technology

- SSC has developed software-defined, cognitive radios that sense and detect available spectrum through user-defined policies

  - Increase link range by selecting “best” frequency that minimizes propagation loss & interference
  - Improve the capacity of wireless systems
    - Enable robust spectrum pooling with peers
    - High communication availability and reliability
  - Avoid intended/unintended interferers
  - Obtain additional spectrum quickly
    - Efficiently and safely use licensed spectrum without displacing legacy systems
    - Pool spectrum resources with other licensees
    - Lease from other spectrum “owners”

Dynamic Spectrum Access (DSA)
Multi-Band Radio System

<table>
<thead>
<tr>
<th>DoD RF Board (MHz)</th>
<th>Public Safety RF Board (MHz)</th>
<th>Wireless (TV) RF Board (MHz)</th>
<th>Commercial RF Board (MHz)</th>
<th>Small Form Factor RF Board (MHz)</th>
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</thead>
<tbody>
<tr>
<td>1215 – 1390</td>
<td>220 – 512</td>
<td>516 – 806</td>
<td>1390 – 1435</td>
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<td>1435 – 1525</td>
<td>764 – 869</td>
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<td>1670 – 2680</td>
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<td>1755 – 1850</td>
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<td>2200 – 2290</td>
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DSA 1000 / DSA 2000 / DSA 2100

- **DSA 1000**
  - 10 W (1 dB compression)
  - 20-1000 MHz
  - Antenna diversity

- **DSA 2100**
  - High Power, Long Range

The first affordable, fieldable DSA radio development platform!
Software Architecture

- **XML-based Policy Language**
- **Policy Analyzer** validates externally created spectrum access policies for consistency and accuracy.
- **Policy Administrator** securely disseminates policies using PKI.
- **Policy Enforcer** ensures that each DSA radio adheres to the policy rules.
- **Ultra-sensitive detectors** identify unused spectrum.
- **Rendezvous** and **Frequency Selection** algorithms select which channels to use.
- **Scheduler** manages which detectors are used, what frequency the devices use, and when the detectors and tuner/modems operate.
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Project Objectives

- **Address** short- and long-term spectrum **access** problems that detract from core missions

- **Focus** on concerns about cognitive radio technologies
  (e.g., Interference, Device Integrity, Security, Authentication, Unproven and Untested Technology)

- **Gather** and **develop** communications, command and control requirements

- **Design** system for varied communications needs and applications
  (e.g., airborne surveillance; mobile voice, data, video)

- **Show** how end-to-end, multi-band cognitive radio system can be tailored, safely managed and effectively controlled **while experiencing** benefits of dynamic spectrum and bandwidth access

- **Enable** use for day-to-day activities and in rapid response to a threat, disaster or catastrophe
Team, Support & Outreach

Development process directly involves key stakeholders; addresses their requirements

➢ SSC Consultants:
  Nancy Jesuale (former Portland, OR Official)
  Prof. Dale Hatfield (former FCC Chief Engineer, Univ. of Colorado)

Supporters:

Outreach & Resources:
Project Overview
Cognitive Radio Access Management (CRAM) Subsystem

SSC’s dynamic spectrum access system meets wide variety of communications needs while giving users CRAM sub-system that provides ability to securely write and disseminate policies to cognitive radios.
## Project Tasks

### Phase I Tasks

<table>
<thead>
<tr>
<th>Task 1: Gather Data and Collect User Requirements</th>
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<tbody>
<tr>
<td>✓ Washington, DC Spectrum Occupancy Measurements</td>
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<tr>
<td>✓ Initial Requirements Collection</td>
</tr>
<tr>
<td>✓ Practitioner Outreach/Feedback – NIJ CommTech TWG</td>
</tr>
<tr>
<td>Regulatory Outreach/Feedback – ✓ NTIA and FCC</td>
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<tr>
<td>System Trade-Off Analysis (in progress)</td>
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<td>Stakeholder Feedback &amp; Focus Groups  [TONIGHT!!]</td>
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<tr>
<th>Task 2: Design CRAM System</th>
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<tr>
<td>Customize Software and Develop Policy Tools</td>
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| Task 3: Initial Lab Demonstration |
Follow-Up Opportunities

• Conduct live field demonstrations of CR system during first responder exercises in urban environments
  – Collaborate with Fed, State & Local Officials
  – Show how DSA radio/network policies provide secure and reliable command and control

• Leverage SSC’s 802.16-based multi-band radio platform for incident area test and evaluation of broadband applications
  – Prove interference avoidance and coexistence with legacy systems
  – Ensure building penetration and link range/quality
  – Rapidly deploy ad hoc network and backhaul

• Integrate DSA software in advanced military/public safety radios (e.g., Thales Liberty radio and Harris Unity radio)
  – Show interoperability with legacy systems with both waveform and frequency agility

• Use FCC/NTIA Test-Bed Frequencies
  – 410-420 MHz and 470-512 MHz
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Benefits

- **Flexibility**: High-level policies apply to multiple devices
- **Configuration ease**: Modify any configuration, setting, or rule; devices automatically adapt
- **Autonomy**: Devices autonomously balance resources and optimize network as permitted by policies
- **Assurance**: Policies from multiple stakeholders are enforced locally on every device
- **Transparency**: High-level specifications verified by theorem-proving systems for correctness at any time
- **Ease of policy authoring**: Declarative language creates a policy abstracting low-level requirements
- **Secure policy management and distribution**: Control of policies and monitor device’s behavior

- Spectrum Efficiency
- Rapid Network Set Up
- Multi-Band Devices
- Broadband Applications
- Flexibility for State & Local Governments
- Remote Spectrum & Network Management
- Multiple “Policy” Sources

- **Bottom Line**: TRUST in Policy-Controlled Cognitive Radio Devices for Public Safety
Regulators need assurance that devices access permitted spectrum only & “behave” according to rules.

Operators need assurance that they can configure devices properly to make most efficient use of spectrum/network resources.

Other users need assurance that their systems are not harmed.

Policy Control

Provides Necessary Trust, Security and Assurance
End-to-End Policy System

User Space:
- SSC User Console
  - Monitor, Download Logs
  - Request Update
  - Turn On/Off Emergency
- Device
- Device
- Device

Operator Space:
- SSC Policy Administration Console
  - Monitor, Download Logs
  - Push Updates, Switch Modes
- SSC Policy Automated Update Service
  - Synchronize, Download Updates
  - Upload Logs
- XG Policy Configuration Database
  - Check, Download Updates
  - Upload Logs
- Plan Configurations Per Radio Group
- Assign Membership
- Check, Download Updates
- Plan Configurations Per Radio Group
- Assign Membership
- Upload Policy Updates
- Add, Overwrite, Delete Policy

Regulator Space:
- SSC Policy Authoring Suite
  - Check, Download Updates
  - Add, Overwrite, Delete Policy
- Operator’s XG Policy Repository
- Regulator A’s Policy Repository
- Regulator B’s Policy Repository
Cog Radio just one component in the policy framework
- Includes policy enforcer, reasoner, manager, database library, security library, geographical library, compression library, and remote control
- Prototypes and reference designs available now

Web User Interface
- Off-line policy configuration for groups of radios
- On-line policy management of one or more radios
- On-line performance querying of each radio
- Customizing for public safety

Administration Console
- Includes policy enforcer, reasoner, manager, database library, security library, geographical library, compression library, and remote control
- Prototypes and reference designs available now

Authoring Tool
- Wizard and expert mode for writing/editing policies
- Customizing for public safety
Cog Radio Device

Multi-band cognitive device includes Cognitive Controller and Conformance Enforcer

Cognitive Controller
- Monitors and dynamically adjusts device configuration in order to optimize its and network performance
- Guards cognitive controller to ensure the device does not enter an invalid state
- Suggests valid states to controller by computing constrained opportunities
- Monitors and reconfigures device parameters

Conformance Enforcer
- Ensures that the cognitive controller does not violate constraints set forth by user, network, and regulators.
- Monitors the device and notifies “authority” if policies are violated

User-Specific RF Front End for Public Safety Bands:
- 138-174, 225-512 & 764-869 MHz
- Integrated 802.16-based modem, SSC Detector & CPU

- RF Interfaces:
  - 1 or 2 Antenna Ports
  - External PA for > 100mW
- Control interfaces:
  - 1 Ethernet Port
  - GPS Timing Port
- Power: 12V (~15W w/o PA)
### Spectrum Access Policy Types

#### Enable Interference-Free and Frequency-Agile Operation

<table>
<thead>
<tr>
<th><strong>Listen-Before-Talk (LBT) based types</strong></th>
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<tbody>
<tr>
<td>Same up and downlink frequencies</td>
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<tr>
<td>Different, but known, up and downlink frequencies</td>
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<tr>
<td>Different, but unknown, up and downlink frequencies, band plan known</td>
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<td>TV band (TV detector)</td>
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<table>
<thead>
<tr>
<th><strong>Connectivity based types</strong></th>
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<tbody>
<tr>
<td>Beacon signal reception required to use band</td>
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<tr>
<td>Connectivity requirement for any policy (can use certain bands only if connected to Spectrum Manager)</td>
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<tr>
<th><strong>Group Behavior based types</strong></th>
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<tbody>
<tr>
<td>Type 1 - Abandon channel if any node within certain range detects Non-cooperative signal</td>
</tr>
<tr>
<td>Type 2 - Determine TX power based on estimated interference probability (Belief, Disbelief, and Ignorance estimates fused)</td>
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<tr>
<td>Node Identify restrictions (e.g., use while airborne prohibited, use only in fixed applications)</td>
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<tr>
<th><strong>Spatial types</strong></th>
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<tbody>
<tr>
<td>Geographic border field strength limits</td>
</tr>
<tr>
<td>Database geographic/TV coverage area based</td>
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<tr>
<th><strong>Temporal types</strong></th>
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<tr>
<td>Time of Day restrictions</td>
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<tr>
<td>Authorization for finite time duration (with periodic renewals)</td>
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<tr>
<th><strong>Device based types</strong></th>
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<tbody>
<tr>
<td>Ability to measure second and third harmonic</td>
</tr>
<tr>
<td>TX power spectrum density limit</td>
</tr>
<tr>
<td>Geo-location capability</td>
</tr>
<tr>
<td>Adjustable I/N Limit for any policy</td>
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<tr>
<th><strong>Distributed Control based types</strong></th>
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<tbody>
<tr>
<td>Automated policy updates if feedback indicates that existing policy is insufficient for non-interference operations</td>
</tr>
<tr>
<td>Automated policy updates notification of policy revocation or update by policy authority</td>
</tr>
</tbody>
</table>
Multiple Policy Sources

Peer-to-Peer and Hierarchical Spectrum Control

**Equipment Data (DD1494 – NTIA/DoD) Policies**
- ~200 radio types
- Frequency range, TX power, NF, BW, ...
- Detection/false alarm rule sets – Radar pulse pattern, FM modulation, etc
- LBT rule threshold parameter spreadsheet
- Ex: RT-1107(V)/WSC-3(V) operates from 225-399 MHz, 5 kHz BW, ...

**Regional Policies (Assignment Database)**
- Limitations of frequency range, TX power, BW
- Service (Fixed, mobile, airborne, ...)
- Frequency range, TX power, NF, BW, ...
- LBT rule time parameters
- Geographic, time limitations
- Ex: AN/GRT-022 is used from 225-320 MHz only, -6 dB I/N

**Local Party-to-Party Policies**
- Geographic, time
- Spectrum leasing limitations
- User priority
- LBT threshold and time parameters
- Ex: 440 MHz is only used occasionally for radar testing. You can use this channel if you have a monitoring system with an elevated antenna within LOS of Andrews AFB is used to detect (every five minutes) if we are using the radar transmitter or not. Only groups that I provide a “certificate” to are allowed this privilege.

**National Rules Policies**
- Geographic, time
- Spectrum leasing limitations
- User priority
- LBT threshold and time parameters
- Policy dissemination limitations
- Ex: 243 MHz used only for emergency

**XML-Based high-level descriptive language**

**DSA System**
- DSA radio operates on all of the polices to decide “proper” operation
NIMs and ICS: Policy Sources?

- Incidents happen, grow, develop, and resolve
- Multiple jurisdictions may be involved
- National, state and local resources may be involved
- DSA radio systems can create tactical and operational networks on-the-fly
- Incident commanders can control radio resources (spectrum, capability, applications, etc.)

How can NIMs and ICS guide policy development?
A network in its “steady-state” prior to incident & follows static policies for radio operation, authentication, spectrum access, etc.
As incident begins, incident commander identified. As IC begins managing response resources, cog radios activate/receive new policies related to each user’s role in the incident.
Full Array of Ad-hoc Incident Communications Networks

As incident develops, many tactical networks established & radios are authenticated according to user’s role.
Conclusions

Cognitive Radio Technology:

1. Is here . . . Now

2. Must earn the trust of Public Safety users before wide-spread or mission-critical deployment

3. Can be safely and effectively deployed through policy-based control mechanisms . . . with policies based on current public safety best practices and existing rules
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Invitation

Cognitive Radios for Public Safety
Invitation to Stakeholders Focus Group

Tonight, Tuesday, September 16, 2008
5:45 – 7:30 pm
(Immediately following the NPSTC committee meetings)

Spring Room (4th Floor), Renaissance Seattle Hotel
Refreshments will be served
Please see or email Nancy Jesuale
njesuale@netcityengineering.com
Tonight’s Focus Group

Desired Outcomes:

– Validation and prioritization of public safety spectrum, network, authentication, security and bandwidth requirements

– Identification of reliable sources (e.g., rules, plans, agreements, etc.) from which to derive spectrum access “policies” for broadband public safety CR systems
Thanks!