“State of the Art” in Spectrum Sharing

Presented by the Wireless Innovation Forum
27 July 2010
Agenda

Introduction to the Wireless Innovation Forum Overview
Benefits of Cognitive Radio
Information Processing Architecture
Modeling Language for Mobility and DSA Policy Languages
Radio Environment Map and Spectrum Databases
Standards
Projects and Programs:
- ITU
- US
- APAC
- Europe

Wrap up
Driving the Future of Radio Communications and Systems World Wide

The Role of the Wireless Innovation Forum
What is the Wireless Innovation Forum

A nonprofit “mutual benefit corporation” dedicated to:

“Driving the Future of Radio Communications and Systems World Wide”
The Role of “the Forum”

The Role of the Forum is to help representatives from its 115 member organizations to collaborate

• With each other
• With others in the industry

Through this collaboration, the Forum should help its members to:

• Expand opportunities
• Improve service
• Reduce cost (development, production, maintenance)
• Reduce time to market/time to deployment

In short, the organization is a “tool” to be used by its members’ representatives to achieve their objectives …
Memberships and Partnerships

Wireless Innovation Forum Memberships and Partnerships

Slide 7
Benefits of Cognitive Radio

Presented by James Neel
President Cognitive Radio Technologies
Chair, Wireless Innovation Forum Cognitive Radio Work Group
Contributors

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Rekha Menon, *Harris*

Joe Mitola, *Stevens Institute*
James Neel, *Cognitive Radio Technologies*
John Polson, *General Dynamics C4S*
Jim Rodenkirch, *Diversified Technology Incorporated / OmegaTek*
Qun Shi, *ITT*
Richard Taylor, *Harris*
Dandan Wang, *Huawei*
Motivation

• Hype versus reality
• Some structure to burgeoning field
• Promote understanding and use of CR and SDR
Document Organization

- Introduction
- Benefits
  - DSA
  - MIMO
  - RRM
  - Markets
  - Single Link Adaptations
  - Business Models
- Application Areas
  - Commercial
  - Public Safety
  - Military
- Risks / Issues
  - Implementation
  - Testing / Verification
  - Security
  - Regulatory
- Conclusions
- Appendices
  - Paper Summaries
  - CR Definitions
Military Issues

• Significant effort to plan and deploy network
  • Selecting frequencies, waveforms, and power levels consistent with the radio and antenna characteristics of the assigned units’ equipment
  • Identifying and planning for all tactical communication networks, and requesting the necessary TRANSEC and COMSEC key material
    • simultaneously managing de-confliction/coordination with all systems in the operational area, including those of coalition forces.

• Exponentially increasing spectrum demand

• Need to establish “spectral dominance” in hostile environment
Reducing Planning and Configuration

• Automated spectrum management [Neel_06]
• Intelligent policy reasoning [Perich_08] and [Lechowicz_07].
• Similar technologies for automated network setup are being explored in the commercial domain to help realize “Self-Organizing Networks” (See Section 3.1.2.3).

• Non xG DSA examples
  • [Seidel_05] mesh secondary networks with heteromorphic waveforms and discontiguous narrow bandwidth spectrum holes to be integrated into a single wideband logical channel. Around 70% of the spectrum is used as compared to 2-10% without DSA.
  • [Mody_07] machine-learning based DSA with zero interference with the legacy system and a modest increase in spectrum utilization. >90% spectrum with predictive utilization at the expense of some interference due to errors in prediction.
  • [Zekavat_05] multiple distinct PU sources, improves blocking rate and spectrum-efficiency by 23% and 8%, respectively.

Table 3: xG Test Results and Evaluation Thresholds From [Marshall_06]

<table>
<thead>
<tr>
<th>Metric</th>
<th>Threshold</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Abandon Time</td>
<td>500 ms</td>
<td>100% in 465 ms</td>
</tr>
<tr>
<td>Interference Limit</td>
<td>3 dB</td>
<td>Mean 0.16 dB, Max 0.49 dB</td>
</tr>
<tr>
<td>Net Formation</td>
<td>30 s with 6 nodes</td>
<td>90% 3.5 s, 100% 8.68 s</td>
</tr>
<tr>
<td>Net Join</td>
<td>5 s</td>
<td>90% 2.07s, 100% 4.36s</td>
</tr>
<tr>
<td>Net Re-establish</td>
<td>500 ms</td>
<td>100% 165 ms</td>
</tr>
<tr>
<td>Spectrum occupancy</td>
<td>60% with 6 nodes</td>
<td>85% Occupancy @ 83% Confidence</td>
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The belief among operators is that 3G represents a missed opportunity to automate network processes, and that much of the ongoing cost to configure and manage Node Bs, radio network controllers, and core network elements is accounted for by the need to allocate expensive technicians to mundane, yet cumbersome, tasks.

- Organizing Groups
  - 3GPP
  - Next Generation Mobile Networks

- Many cellular vendors focusing on reducing OPEX
  - See Motorola_09b], [NEC_09], and [Nokia Siemens_09]

- 3GPP Release 8
  - automatic inventory, automatic software download, Automatic Neighbor Relation, Automatic Physical Cell ID (PCI) assignment

- 3GPP Release 9
  - Coverage & Capacity Optimization, Mobility optimization, RACH optimization, and Load Balancing Optimization
Regulatory Issues

- **Difficult balancing act**
  - New services versus Incumbents
  - More regulatory models to consider
  - Greater number of interactions => more complicated balance
  - International harmonization versus experimentation
  - Block D example of mismatch

- **Regime uncertainty** [Higgs_97]
  - Current TVWS delays

- **Value to policy engines**
  - 1900.5, MLM, xG

- **Liability issues more complicated** [SDRF_08]
Reducing Planning and Configuration

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Information Processing Architecture

Presented by James Neel
President Cognitive Radio Technologies
Chair, Wireless Innovation Forum Cognitive Radio Work Group
Information Process Architecture

• World evolving to intelligent information processing systems

• Understand information process systems:
  • Operation
  • Interaction
  • Intelligence Incorporation
  • Impact

• Contributors
  • Peter G. Cook  Hypres
  • Ihsan Akbar Harris
  • Fred Frantz  L-3
  • Neal Mellen  TDK
  • Rekha Menon Harris
  • James Neel  CRT
  • James Rodenkirch  DTI
  • Rick Taylor  Harris
  • Roger Webb DGI

Selected Cognitive Radio Capabilities and Missions

<table>
<thead>
<tr>
<th>CR Capabilities</th>
<th>CR Missions and Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Spectrum Access</td>
<td>Cognitive (intelligent) Electronic Warfare</td>
</tr>
<tr>
<td>Cooperative Relaying (Synthetic MIMO)</td>
<td>Joint Component/Waveform Optimization</td>
</tr>
<tr>
<td>Concurrent Processing</td>
<td>Role-based (Mission-goal) Reconfiguration</td>
</tr>
<tr>
<td>Cross-network Cooperation/Coexistence</td>
<td>Dynamic Policy Compliance</td>
</tr>
<tr>
<td>Radio Resource Management</td>
<td>Power Optimization and Management</td>
</tr>
<tr>
<td>Self Healing Networks</td>
<td>Spectrum Auctions/Markets</td>
</tr>
<tr>
<td>Interference Suppression (Self, External)</td>
<td>Dynamic Network (Vendor) Selection</td>
</tr>
</tbody>
</table>
Document Organization

• Two Volumes
  • Context and Conceptual Overview
  • Use cases and refinements

• Status:
  • Focus of discussion with PSSIG
  • Volume I completing
  • Current Draft:

• Volume I Outline
  • Introduction
  • Innovation Context
  • Initial Framework
  • Information System Elements
    • Role of autonomous processes
  • Data & Information Flow
  • Preview for Vol 2
Innovation Context (Section 2)

• Progression from Manual
  • Design, Implementation, Operation
• To Automated
  • Design, Implementation, Operation
• CR is part of the current trend to automation

• Innovations can be both evolutionary and disruptive
• Understanding next generation communications requires complex systems

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Understanding an Information System is a multi-faceted problem.

Hardware is consciously excluded to focus on processes.

Examples in Appendix:
- Kindle, LMR, Cellular, TV Broadcast, Inventory Mgmt, Air Traffic Control

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Application area, motivation, goals, requirements, and preconditions under which the system operates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>For the target system, define the higher-level overarching system of which it is a component, its own lower-level component systems, and relationship to peer systems</td>
</tr>
<tr>
<td>Technology</td>
<td>Underlying technology that enables the System and is used by it, level of technology maturity, evolutionary or disruptive</td>
</tr>
<tr>
<td>Economics</td>
<td>Business case for the System, Revenues, Cost structure, who pays, who profits</td>
</tr>
<tr>
<td>Politics</td>
<td>Regulatory considerations, public funding, benefits, legislative support, popular support, volatility of support</td>
</tr>
<tr>
<td>Structure</td>
<td>Identification of higher-level System, interfaces to and interaction with sibling Systems, process structure, precursor to System design</td>
</tr>
</tbody>
</table>
Information System Structure (Section 4)

• **System Services**
  • Functions and processes provided by operating systems and other system functions to support system operation

• **Data Storage & Management**
  • Storing, safeguarding, organizing and retrieving

• **Data Communication**
  • Transfer of data
  • Emphasis on replication

• **Application Processing**
  • Use, transform, combine, compute, create, present information to advance system goals.
  • Application dependent

• “Cognitizing” by transition from user controlled to autonomous processes
Information System and Context (Section 5)

- How do intelligent agents share information?
- Fundamental communications processes
- Sharing of data and context for actionable information

Slide 23
Example Mappings from Section 5

- Other mappings: LMR, TV Broadcast
- Initial Diagrams for Volume 2
- In context of OODA Loop
Radio Environment Map and Spectrum Databases

Presented by James Neel
President Cognitive Radio Technologies
Chair, Wireless Innovation Forum Cognitive Radio Work Group
Radio Environment Map: Project Overview

**Objectives:**
- Anticipate the future development of cognitive radio databases, identify use cases and make recommendations for implementation
- Promote the use of cognitive radio

**Volume 1**
- Intro / motivation
- Review of current regs and proposals
- New applications
- Enhancing Spectrum Availability
- Promoting Public / Private Spectrum Sharing

**Volume 2: Roadmap, technical requirements...**
Current Usage and Proposals

- **Proposal Solicitation:**

- **Rules:**
    - Possibly more than one provider
    - Protected devices
      - TV, Point-to-point, PLMRS / CMRS on 14-20, offshore radiotelephone service, cable headends + low power TV receive sites, registered wireless mics
    - Record and share TVBD registration
    - Autonomous connection
    - May charge fees to register fixed
    - Provide lists of available channels to TV band devices
    - Access daily(ish) and when powered on or “move”
    - Minimal collected information on devices and protected services
    - Resolve claims of interference
    - Service for 5 years
    - Synchronize other providers

1. NeuStar, Inc. (with Shared Spectrum Co.) [Cover Letter, Proposal, Appendix A, Appendix B]
2. Spectrum Bridge [Cover Letter, Proposal]
3. WSdb, LLC [Proposal, Index of Attachments and Figures, Attachments 1(a), 1(b) and 1(c), Attachment 2(a), Attachments 3(a) and 3(b), Attachments 5(a), 5(b) and 5(c)]
5. Telecordia [Proposal]
6. Google Inc. [Proposal]
7. Frequency Finder, Inc. (with Mountain Tower, Ltd., d/b/a RadioSoft) [Proposal]
8. Comsearch [Proposal]
9. Key Bridge Global LLC [Cover Letter, Proposal Summary]
More Expansive Uses

- **Coexistence**
  - Improved coexistence in Block D
  - Support TVWS coexistence

- **Radio Resource Management**
  - Improved Spectral Efficiency
  - Traffic loading
  - “Fair” Spectral Access
  - Continual Improvement

- **Extend to Military Settings**
  - Support DSA Applications
  - Deconflict MANETs

- **Intelligent Transportations Systems**
  - Locations of vehicles, incidents, critical users (or cargos)
  - Support self-organizing networks
  - Organize distributed computing
  - Facilitate spectrum brokering

- **Monitoring**
  - Real-time Spectrum Dashboard
  - Data mining
  - Catch and fix 5,6-sigma events
  - Policy conformance

Others: FARAMIR: [www.ict-faramir.eu](http://www.ict-faramir.eu)

Schedule and Upcoming Activities

• TVWS Summit 2
  • Sep 16, Schaumburg, IL

• Afternoon 1
  • University Research
    • FARAMIR / VT
  • Public Safety Apps
    • Harris
  • Military Apps
    • GDC4S
  • Commercial Apps
    • Commsearch
    • SpectrumBridge
    • WSdB

• Panel Discussion
  • Common needs / issues?
  • Role for the Forum / WG

• Document timeline:
  • Q3 2010
    • Initial Review of Regs / Proposals
    • Short summary of applications
  • Q4 2010
    • Analysis of updated rules??
    • Use Case 1
  • Q1 2011
    • Use Case 2
Modeling Language for Mobility and DSA Policy Languages

Presented by James Neel
President Cognitive Radio Technologies
Chair, Wireless Innovation Forum Cognitive Radio Work Group
Project Motivation

- The evolution of SDR is leading to reconfigurable networks creating new opportunities and challenges.
- A language for representing node/network information provides the ability to negotiate and control these reconfigurable networks.
- All members of the value chain (‘actors’) have a role.
MLM Project Objectives

- Development of use cases for wireless communication in which the MLM language can facilitate flexible communication,
- Development of Cognitive Radio Ontology (CRO) that is capable of expressing structural, functional and behavioral aspects of models for wireless communication,
- Corresponding signaling plan, requirements and technical analysis of the information exchanges that enable these next generation features,
- Policies and rules for policy based radio control,
- Ontology extensions needed to support policy based radio control.
MLM Addresses Interoperability

SDR Forum

Channel Frequency Modulation

IEEE 802.21

H/W, S/W Portability

Load Balancing

End Users

Quality of Service

IEEE P1900

Policy Conformance

Network Operators

Handover

Component Providers

Cost Effectiveness

Regulators

New Standards

IEEE 802.21

VITA 49

Radio SW Components

SDR Forum

Spectrum Efficiency

Cost Effectiveness

between SW Developers

MLM Language

WIRELESS

Semiconductor Co.'s

E2R

Slide 33
Base Model Concepts

- Ontology model approach based on concept of **Objects** and **Processes**
  - Derived from DOLCE
  - [http://www.loa-cnr.it/DOLCE.html](http://www.loa-cnr.it/DOLCE.html)

- Objects represent entities that have state

- Processes represent events or actions that perform a transformation or state change on one or more objects.
Elements of an RF Burst are represented as entities in OWL

Process entities capture transformations and changes in state

Relationships represent decomposition, temporal order and context
Policy Language

• Genesis in Dynamic Spectrum Access (DSA) work to ensure DSA radios remained within allowable operational limits and frequencies.
  • e.g. DARPA neXt Generation (XG) project
• IEEE P1900.5 is developing policy language and architecture requirements.
• In the context of MLM, extended policy language attributes being considered include:
  • Spectrum management
  • Spectrum lease negotiation
  • Multiple user roles and associated capabilities
  • User authentication
Some Related Efforts

End-to-End Reconfigurability (E2R) activities include:

• Advanced Spectrum Management (ASM)
• Dynamic Network Planning and Management (DNPM)
• Joint Radio Resource Management (JRRM);

IEEE 802.21 is creating a ‘media independent handover’ capability;

• W3C has standardized OWL
• The W3C Rules Interchange Format working group aims to facilitate machine-to-machine exchange of rules.

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Some Related Efforts

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Cognitive Radio Standards

Presented by James Neel
President Cognitive Radio Technologies
Chair, Wireless Innovation Forum Cognitive Radio Work Group
Commercial Cognitive Radio Efforts

PHY / MAC Protocols

- TVWS
  - 802.22 (CR for rural)
  - 802.16h (CR WiMAX)
  - 802.11af (WhiteFi)
  - CogNeA
- Other bands
  - 802.11h
  - 802.11y

Supporting Standards

- 1900
- WinnForum MLM
- 802.19.1
- 802.21
- Self-organizing networks
TV White Space Overview

- Allows use of TV Bands (UHF / VHF) if not otherwise used
- Initial regulations in FCC-08-260
  - November 2008
  - Regs likely finalized in Q3-Q4 2010
    - Responding to comments
    - Delayed by broadband plan
- Key features of regs
  - Detection:
    - Sensing (needed for mics – for now)
    - Geolocation + look up database of protected transmitters
      - Check database daily
  - Multiple classes of devices
    - Allowable channels
    - Power limits
    - Direct / indirect database access
  - Protect border
  - Lower power on adjacent channels
- Protection for other bands, services
  - PLMRS / CMRS on 14-20, offshore radiotelephone service, cable headends + low power TV receive sites, registered wireless mics
- 6 MHz channels
- Availability subject to population paradox
- Allowed first in US
  - Later Canada, UK, Singapore, Finland
  - Different bandwidths

<table>
<thead>
<tr>
<th>TV Channel</th>
<th>Frequency Band</th>
<th>Frequency (MHz)</th>
<th>Allowed Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>VHF</td>
<td>54 - 60</td>
<td>Fixed</td>
</tr>
<tr>
<td>5 - 6</td>
<td>VHF</td>
<td>76 - 88</td>
<td>Fixed</td>
</tr>
<tr>
<td>7 - 13</td>
<td>VHF</td>
<td>174 - 216</td>
<td>Fixed</td>
</tr>
<tr>
<td>14 - 20</td>
<td>UHF</td>
<td>470 - 512</td>
<td>Fixed</td>
</tr>
<tr>
<td>21 - 35</td>
<td>UHF</td>
<td>512 - 602</td>
<td>Fixed &amp; Portable</td>
</tr>
<tr>
<td>36</td>
<td>UHF</td>
<td>602 - 608</td>
<td>Portable</td>
</tr>
<tr>
<td>38</td>
<td>UHF</td>
<td>614 - 620</td>
<td>Portable</td>
</tr>
<tr>
<td>39 - 51</td>
<td>UHF</td>
<td>620 - 698</td>
<td>Fixed &amp; Portable</td>
</tr>
</tbody>
</table>
802.11y

Ports 802.11a to 3.65 GHz – 3.7 GHz (US Only)
- FCC opened up band in July 2005
- Completed 2008

Intended to provide rural broadband access

Basis for 802.11af

Incumbents
- Band previously reserved for fixed satellite service (FSS) and radar installations – including offshore
- Must protect 3650 MHz (radar)
- Not permitted within 80km of inband government radar
- Specialized requirements near Mexico/Canada and other incumbent users

Key features:
- Database of existing devices
  - Access nodes register at http://wireless.fcc.gov/uls
  - Must check for existing devices at same site
- “Light” licensing
  - Right to transmit, but not protected
- Automatic policy recognition
  - Varies by channel location
- Tiered policy enforcement
  - Enabling – determines operating regs
  - Dependent – follows instructions
**802.11af**

- **Builds on 802.11y**
  - DFS, TPC, quiet periods, policy enabling
  - Hope to be done in two years
  - Maybe only 15 pages...
  - Started in January 2010
- **Initially considered non-contiguous channels**
  - Not in other TVWS proposals
- **Multiband support**
- **Looking for techniques to speed up channel sensing**
- **Sharing MAP information**

Building on 802.11y (Engagement State machine)

Multiband Concept
CogNeA: Cognitive Networking Alliance

- **Industry Alliance formed in 2007**
  - [http://www.cognea.org/](http://www.cognea.org/)
    - looks like a bad blog, but that’s the website
  - BT, Cambridge Consultants, ETRI, Philips, Samsung Electro-Mechanics, MaxLinear, Georgia Electronic Design Center (GEDC) at Georgia Institute of Technology and Motorola

- **Use cases more focused on internet and whole-home networks**

- **Approved draft**
  - PHY/MAC
  - Bluetooth-like

- **Features:**
  - DFS, TPC, scheduled quiet periods, beacons, geo-location, sensing
802.16h

- Started as WiMAX for unlicensed
  - Focus on 3.65 GHz
- Migrated to TVWS
- Draft 15(!) March 2010
- Improved Coexistence Mechanisms for License-Exempt Operation
- Explicitly, a cognitive radio standard
- Incorporates many of the hot topics in cognitive radio
  - Token based negotiation
  - Interference avoidance
  - Network collaboration
  - RRM databases
- Coexistence with non 802.16h systems
  - Regular quiet times for other systems to transmit
- Location-aware, time-aware scheduling to allow non-interfering parallel transmissions, and sequential transmissions of transmissions that would interferer

**Cognitive Techniques in 802.16h**

<table>
<thead>
<tr>
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<th>Collaborative Mechanism</th>
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<tbody>
<tr>
<td><em>(CXCC)</em> dynamic frequency selection (DFS) 6.4.2.3</td>
<td>IP network message (CNP message) 15.5.2</td>
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<td><em>(CXCC)</em> GPS tuning recovery (GPS/UTC) 15.2.1</td>
<td>Coexistence proxy (CXP proxy) 15.1.5</td>
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<td>Extended quiet periods (EQP) 6.4.3.3</td>
<td><em>(CXCC)</em> coexistence signaling (CPS) radio signature) 15.3.1</td>
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<td><em>(CXCC)</em> coexistence messaging (CM/CCD) 15.3.2</td>
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<tr>
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<td>Subframe sharing (master sub frame) 15.4.2</td>
</tr>
<tr>
<td>Uncordinated Coexistence Protocol (UCP) 6.4.2.4</td>
<td>Channel reallocation (ACS) 15.4.1</td>
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<tr>
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<td>Subframe Reallocation (ASFA) 15.4.2.2</td>
</tr>
<tr>
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<td>Credit token 15.4.2.3</td>
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802.22

- 100 km range
- Data Rates 5 Mbps – 70 Mbps
- Point-to-multipoint TDD/FDD
- DFS, TPC
- Adaptive Modulation
  - QPSK, 16, 64-QAM, Spread
- OFDMA on uplink and downlink
- Collaborative Sensing
- Self-coexistence
- Use multiple contiguous TV channels when available
- Fractional channels (adapting around microphones)
- Space Time Block Codes
- Beam Forming
  - No feedback for TDD (assumes channel reciprocity)

Scheduled and hopped quiet periods%

802.22.1
- Enhanced interference protection
- Particularly for mics

802.22.2
- Best practices for deployment

Status
- Finalized 2011
802.19.1 (TVWS Coexistence)

- Coexistence mechanisms for heterogeneous networks in TVWS
- Device discovery
- Manage coexistence info
  - Database, shared info
- Support reconfiguration requests
- Automate analysis of info
- Make coexistence decisions
- Support multiple topologies

IEEE 802.19 DCN 19-10-0008-01-0000

IEEE 802.19-10/0055r3
IEEE 1900 (SCC41)

- **IEEE 1900 (aka Standards Coordinating Committee 41 – Dynamic Spectrum Access Networks)**
  - [http://www.scc41.org/](http://www.scc41.org/)
  - 1900.1 – Terminology and Concepts
  - 1900.2 - Recommended Practice for Interference and Coexistence Analysis
  - 1900.3 – Conformance Evaluation for SDR modules
  - 1900.4 – Architectural Building Blocks
    - Network resource managers
    - Device resource managers
    - Information to be exchanged between the building blocks
  - 1900.5 – Policy Languages
    - Tie-ins with MLM group
  - 1900.6 – Spectrum Sensing
    - Information exchange
    - Went to ballot in April

<table>
<thead>
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<th></th>
<th>1900.1</th>
<th>1900.2</th>
<th>1900.3</th>
<th>1900.4</th>
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Projects and Programs - ITU

Presented by Lee Pucker
Chief Executive Officer
Wireless Innovation Forum
Geneva
23 January to 17 February 2012
1.7 to consider the results of ITU R studies in accordance with Resolution 222 (Rev.WRC 07) in order to ensure long-term spectrum availability and access to spectrum necessary to meet requirements for the aeronautical mobile-satellite (R) service, and to take appropriate action on this subject, while retaining unchanged the generic allocation to the mobile-satellite service in the bands 1 525 1 559 MHz and 1 626.5-1 660.5 MHz;

1.19 to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU R studies, in accordance with Resolution 956 (WRC 07)

1.20 to consider the results of ITU R studies and spectrum identification for gateway links for high altitude platform stations (HAPS) in the range 5 850 7 075 MHz in order to support operations in the fixed and mobile services, in accordance with Resolution 734 (Rev.WRC 07);
Projects and Programs – ITU Region 1

Presented by Lee Pucker
Chief Executive Officer
Wireless Innovation Forum
SDR European Projects Overview

**Defense**
- EDA – 2007 / 2008
  - SCORED: Complement WINTSEC on Military Applications
  - Recommendations: Roadmap and Shared View

- EDA – 2009 / 2010
  - WOLF: Soldier Communications in Urban environment
  - WF definition: Demonstrations

- EDA – 2009 / 2010
  - ETARE: Waveforms Evolutions Technologies Studies Simulations and Demonstrations

- EDA – 2010 / 2012
  - CORASMA: Cognitive Radio System Architecture Dynamic Spectrum Mangt Simulations & Demos

**Public Safety**
- EC – 2007 / 2008
  - WINTSEC: Explore interoperability and SDR for HLS Applications
  - Recommendations: Roadmap and Shared View

  - EULER: Demonstrate Interoperability & WF Portability (WiMAX)
  - Initial Experimentation of SDR for HLS Applications

**All incid. Public Safety**
  - Recommendations: Roadmap and Shared View

**Roadmap and Shared View**
- Cross Fertilization

**SDR Standards**

**WF Portability**

**Interoperability**

**Certification**

**Standardisation**

**Recommended**
Duration
Jan. 08 – Dec. 09

Consortium
22 Organizations
11 Countries

Budget
18.62 MEuros

EU Budget
11.16 MEuros

Resources
1386 PM (~58 PY/Y)

Contractual Outcomes: 43 Deliverables and 47 Milestones
E3 Challenges and Approach

Elaboration of a Technical Use Case Portfolio

Construction of a Unique Architectural Framework

Convergence of Wireless Systems and Related Harmonisation of Standards

Business Value Evaluation and Quantitative Analysis

Cognitive Radio Systems

Demonstrations of Cognitive Radio Features

Autonomic/Collaborative Optimisation of Spectrum and Radio Resources

Provision for Enablers for Reconfigurable and Cognitive Systems

Specification and Algorithms for Self-x Concepts

B3G Systems
Evolution of Decision Loop from E3

Managed System

Self-organizing System

Cognitive System

Network Operation

Traditional Management & Control

Autonomic Management & Control

Cognitive Management & Control

Context Acquisition

Decision

Policies

Profiles

Reconfiguration Decision

Optimization Engine

“Learning”

Targets

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Note: The Members of the SDR Forum have taken no official position on the CPC at this time.

Two sides of Flexible Spectrum Management from E3

**Dynamic Spectrum Allocation (DSA)**
- Spectrum control entity in the network
- Radio Resource Optimization on the area and cross technology level
  - medium term processes
- Radio Resource Optimization on the regional and cross Operator domain level
  - long term processes

**Dynamic Spectrum Selection (DSS)**
- Spectrum control entity in the terminal
- Radio Resource Optimization on the local and per call level
  - short term processes
E3 Involvement

**Regulation:**
- ITU WP 1B on CR \textit{E3 monitors}
- ITU-R WP5A on CR \textit{E3 contributes}

**Autonomic and Cognitive Management:**
- ETSI RRS WG3 (CPC) \textit{E3 leads}
- IEEE SCC41 P1900.6 \textit{E3 contributes}

**System Architecture and Interfaces:**
- IEEE SCC41 P1900.4 \textit{E3 contributes}
- ETSI RRS WG3 (FA) \textit{E3 leads}

**Radio Equipment Architecture and Interfaces:**
- ETSI RRS WG2 \textit{E3 contributes}
- WINNF (Transceiver) \textit{E3 leads}

**Specification Techniques:**
- OMG, WINNF, OMA, \textit{E3 contributes}
ETSI RRS

RRS : Reconfigurable Radio Systems
- Completion of a phase of feasibility studies
- Press Release Nov 09 : ETSI's standardization of Reconfigurable Radio Systems gets underway
- ETSI Technical Reports on standardization needs and opportunities
  - Architectural and implementation aspects of RRS
  - Specific user requirements in the context of public safety
- Proposed Standardisation
  - SDR Architecture for terminals
  - Functionnal Architecture of CR
  - Cognitive Pilot Channel
  - System Architecture CR for public safety networks
- Potential application area
  - Usage of European TV bands White Space

ETSI RRS Technical Reports
TR 102 838  Summary of feasibility studies and potential standardization topics
TR 102 680  SDR Reference Architecture for Mobile Device
TR 102 681  Radio Base Station (RBS) Software Defined Radio (SDR) status, implementations and costs aspects, includin
TR 102 682  Functional Architecture (FA) for the Management and Control of Reconfigurable Radio Systems
TR 102 683  Cognitive Pilot Channel (CPC)
TR 102 745  User Requirements for Public Safety

http://www.etsi.org/WebSite/technologies/RSS.aspx
COST TERRA Program (Action IC0905)

COST = CO-operation in Science and Technology:
  • European Science Foundation (ESF) instrument
  • supports co-operation across Europe


Working groups:
  • WG1 "CR/SDR deployment scenarios“ – activated
  • WG2 "CR/SDR co-existence studies“ – activated
  • WG3 "Economic aspects of CR/SDR regulation“
  • WG4 "Impact assessment of CR/SDR regulation"
COST Action IC0902

“Cognitive Radio and Networking for Cooperative Coexistence of Heterogeneous Wireless Networks”

Work Groups

• WG1 - Definition of cognitive algorithms for adaptation and configuration of a single link according to the status of external environment.
• WG2 - Definition of cooperation-based cognitive algorithms, that take advantage of information exchange at a local level.
• WG3 - Definition of network-wide mechanisms for enabling the cognitive approach.
• WG4 - Definition of mechanisms for intersystem coexistence and cooperation.
• WG5 - Definition of a cross-layer cognitive engine

Special interest groups:

• SIG1: Information representation languages
• SIG2: Learning and artificial intelligence
• SIG3: Mobility management for cognitive wireless networks
Projects and Programs – ITU
Region 2

Presented by Lee Pucker
Chief Executive Officer
Wireless Innovation Forum
A sampling of Spectrum and SDR/CR/DSA activities in the Americas
Canada

Government of Canada Consults with Canadians on Foreign Investment in the Telecommunications Industry, describes how Canada compares with other countries and presents the following three options for consideration:

• Increase the limit for direct foreign investment in broadcasting and telecommunications common carriers to 49 percent;
• Lift restrictions on telecommunications common carriers with a 10-percent market share or less, by revenue; or
• Remove telecommunications restrictions completely.
Canada

**Comment Period Extended to 11 August 2010** on Decisions on the Transition to Broadband Radio Service (BRS) in the Band 2500-2690 MHz and Consultation on Changes Related to the Band Plan

**Radio Standards Specification 141 (RSS-141), Issue 2, Aeronautical**
Radiocommunication Equipment in the Frequency Band 117.975-137 MHz, which sets out certification requirements for radio transmitters and receivers in the aeronautical mobile (R) service operating in the band 117.975-137 MHz for communication.

**Standard Radio System Plan 301.4 (SRSP-301.4), Issue 5: Technical Requirements for Fixed Radio Systems Operating in the Bands 1427-1452 MHz and 1492-1518 MHz**, which sets out the minimum technical requirements for the efficient utilization of these bands;

**Radio Standards Specification 142 (RSS-142), Issue 4: Narrowband Multipoint Communication Systems in the Bands 1429.5-1432 MHz and 1493.5-1496.5 MHz**, which sets out certification requirements for radio transmitters and receivers of Narrowband Multipoint Communication Systems (N-MCS), including utility telemetry systems, in the bands 1429.5-1432 MHz and 1493.5-1496.5 MHz.
FCC UNLEASHES 25 MHz OF SPECTRUM FOR MOBILE BROADBAND USE IN 2.3 MHz BAND
- To co-exist with Satellite Digital Audio Radio Service (SDARS) licensees
- Reduced OOBE requirements with additional coordination necessary with AMTS sites

Inventory of Commercial Spectrum
- FCC Chairman pledges to begin process prior to enactment of “Radio Spectrum Inventory Act”

OET Requests Info on Use of 1675-1710 MHz Band
- 214 Comments received

FCC Spectrum Task Force Announces Initiative To Unleash Additional Spectrum For Mobile Broadband
- add co-primary fixed and mobile allocations to the 2 GHz band
- to expand existing secondary market policies and rules to address transactions involving the use of MSS bands for terrestrial services

Tech Industry Leaders form White Spaces Database Groups

• The Group submitted to FCC:
  • A set of diagrams setting forth a preliminary functional architecture for the database, and
  • A document outlining the terms and concepts used in describing the database architecture

Wfnn Forum Host TV White Spaces Summit

• 15 June 2010 Washington DC: “Maintain a spotlight on TV White Spaces progress” (successful)
• 16 Sept 2010 Schaumburg IL: “Going to Market with TV Band Devices: Long Term Promises, Near Term Actions”
Wireless Industry's First Private Spectrum Auction to Be Hosted by Spectrum Bridge (3/9/2010) – Date to be announced

1. (UHF) Part 22 spectrum licenses, covering Clark County, NV, which includes metro Las Vegas.
2. (VHF) spectrum licenses covering the state of Florida.

FiberTower brokering 39 GHz spectrum

• FiberTower has listed its 39 GHz portfolio of nationwide area millimeter-wave spectrum on SpecEx, an online spectrum broker.
FCC Spectrum Dashboard

- Wireless broadband is increasingly essential to our economic success, as well as education, health care, energy, and public safety.
- Spectrum is the lifeblood of wireless, and clear information on spectrum management is essential for innovation.
- Spectrum Dashboard is the foundation for a comprehensive spectrum inventory.

Enhanced Mapping and Export of License Results

Spectrum Dashboard – Next Steps

- Launch Spectrum Dashboard 2.0 - 4th quarter of 2010
  - Include information on leases in the dashboard
  - Provide more information on geography and population
  - Allow overlay market areas and third party data
  - Improve attribution and counting of Cellular spectrum
  - Additional capabilities and options such as searches related to tribal lands
- Hold public forum - 4th quarter of 2010
- Further developments to complete inventory include additional bands, more licensing data and enhanced features with public input

- The Secretary of Commerce/NTIA, shall:
  - collaborate with the FCC to make available a total of 500 MHz of Federal and nonfederal spectrum over the next 10 years, suitable for both mobile and fixed wireless broadband use
  - convene the Policy and Plans Steering Group (PPSG) to advise NTIA on achieving the objectives

- The Director of OMB shall work with the Secretary of Commerce/NTIA to insure funding to execute this initiative

- The Secretary of Commerce/NTIA, in consultation with NIST, NSF, DoD, DoJ, NASA, and other agencies shall create and implement a plan to facilitate research, development, experimentation, and testing by researchers to explore innovative spectrum-sharing technologies, including those that are secure and resilient.
Mobile Apps for the Military

*Apps for the Army* competition, open to military and civilian Army employees

*Connecting Soldiers to Digital Applications* initiative to distribute smart phones with 50 test apps to 192 soldiers at Fort Bliss & White Sands Missile Range in New Mexico

The *Raytheon Android Tactical System (RATS)* app for the Android to track buddies on-screen – this is reminiscent of Garmin’s ability to do the same on their GPS devices

DARPA’s wants individuals and industry to develop apps → http://www.darpa.mil/newsroom.html
The fifth World Telecommunication Development Conference (WTDC-10), which met from 24 May until 4 June.

The Meeting Action Plan consists of a comprehensive package that will promote the equitable and sustainable development of telecommunication and ICT networks and services worldwide. The five Programmes identified are:

- Information and communication infrastructure and technology development
- Cybersecurity, ICT applications and IP-based network-related issues
- Enabling environment
- Capacity-building and digital inclusion
- Least developed countries, countries in special need, emergency telecommunications and adaptation to climate change

**ITU introduces Smart Grid standards initiative**

- A new ITU group has been tasked with identifying standards needs for the world’s new Smart Grid deployments
Region 2 – Standards (IEEE 802)

Mar 2010

• IEEE 802.19.1 call for proposals (presentations to be made at Sept. ’10 meeting)
• 802.11af presentation of proposals and straw poll voting to accept proposals

May 2010

• IEEE 802.11af technical review of draft solicited from .11WG
• 802.22 Letter Ballot #3

Planned July 2010

• IEEE 802.19.1 workshop on TVWS coexistence
• 802.11af addressing comments from WG technical review
• 802.22.1 recurs comment resolution
• 802.22 resolving comments from Letter Ballot #3
Projects and Programs – ITU Region 3

Presented by Lee Pucker
Chief Executive Officer
Wireless Innovation Forum
Asia-Pacific Telecommunity (APT)

ICT organizations of governments in Asia

- Established in 1979
- 34 member countries, 4 associate members and 122 affiliate members

Work program areas

- Policy and regulation
- Radio communication
- Standardization
- Human resource development
- ICT development
863 Project

- Since 2005, multiple projects about CR have been supported by 863 Project including:
  - Researches on key techniques of CR: Spectrum sensing, Spectrum allocation, etc
  - Hierarchical spectrum sharing network (HSSN): HSSN architecture, Cooperative spectrum sensing, Spectrum management, Spectrum allocation, Routing, Power control, etc
  - Dynamic spectrum sharing network (DyS2)
    - Support cooperative spectrum sensing and dynamic spectrum management
    - SDR-based nodes for dynamic spectrum sharing
    - Network and nodes with reconfigurability
      - Node: access point, gateway or terminal
      - Network: centralized, decentralized or hybrid architecture
    - Demonstration of DyS2 in 694-806MHz TV band

(Source: Huawei)
Other Projects related to CR in China

- 973 project
- Important National Science & Technology Specific Project
  - Researches and verification on key techniques for efficient spectrum utilization to WRC-11
    - Task 1: researches on special scenarios
    - Task 2: platform
    - Task 3: exploratory researches
    - Task 4: standardization
- Several CR projects funded from National Natural Science Fund

(Source: Huawei)
### Objectives
- Research and develop technologies to increase frequency utilization efficiency for next generation mobile communication system
- **Period:** 2008-2012

### Current Status
- May 2008: Call for proposals for research topics provided from MIC
- Aug. 2008: Decided proposers

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<th>Selected proposers</th>
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<td>(1) R&amp;D on joint control technology between multiple base stations for various cellular zone</td>
<td>Softbank Mobile, Softbank telecom, Univ. of electro Communication</td>
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<td>(2) R&amp;D on reliability improvement technology by dynamic use of multiple radio communication system</td>
<td>NTT DoCoMo, ATR</td>
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<td>(3) R&amp;D on radio resource control technology between multiple radio access technologies on common frequency band</td>
<td>KDDI, ATR</td>
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<td>(4) R&amp;D on dynamic spectrum access networking technology in multiple wireless access networks</td>
<td>NICT, NTT Personal Communications</td>
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<td>(5) R&amp;D on dynamic spectrum access equipment in multiple wireless access networks</td>
<td>NICT</td>
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Other Programs in Japan

White space communication (spectrum sharing type cognitive radio)

- 2009/11/25: Task force to consider usage of white space were launched
- 2009/12/02: First task force meeting
- 2009/12/11-2010/01/12: Public comments on usage model in white space band was received and 102 usages from 53 entities
- 2010/03/01: International symposium was held in Tokyo managed by MIC
- 2010/04: Public hearing on public comments
- Still under discussion

(Source: NiCT)

- Research on cognitive radio technologies for providing best connectivity in multi-RAT (Radio Access Technology) environments
  - Universal Access based on CR/SDR technology
    - RAT discovery and RAT selection based on cognitive engine
    - Reconfiguration for adaptation
  - Digital RF techniques for SDR platform
    - Direct waveform synthesis for transmit signal processing
    - RF sub-sampling for receive signal processing
Objective: Development, proliferation, and standardization of CR/SDR technologies.

Organization:

- Chair
- Executive Office
  - Technical Committee
  - Standardization Committee
  - Service Committee
I²R TVWS Device

- Signal detection sensitivities: -114dBm ~ -125dBm
- Supported frequency range: 48MHz ~ 1000MHz
- Channel raster: 25kHz
- Supported signal type: DTV (ATSC-8VSB), Wireless microphone
Wrap Up

Presented by Lee Pucker
Chief Executive Officer
Wireless Innovation Forum
“Radio Environment Map” Projects

Projects defining the Radio Environment Map
- “Industry Database Project”
- E2R/E3 architecture and IEEE SCC41 P1900.4 Specification
- WInn Forum Cognitive Radio Database Project
- Multiple ITU WRC-12 Projects

Projects defining How to Distribute Radio Environment Map Information
- IEEE SCC41 P1900.6 Sensor Interface Specification
- E3 and IEEE SCC41 P1900.4 Cognitive Pilot Channel
- Remote Application Service

Projects Defining the “Language” Used for Distribution
- IEEE SCC41 P1900.4, WInnForum MLM, Others
Other Technology Developments

Air Interface Standards
  • IEEE 802, ECMA, others

Implementation Standards – Hpw
  • IEEE SCC41, ETSI TC RRS, WiNnForum

Coexistance Standards
  • IEEE 802, IEEE SCC41, COST, Others

Basic Research is Occurring in Funded Programs All Over the World
2010 Meetings and Events

65th General Meeting
• March 8 to 11, 2010, San Diego, California (Hosted by JTRS Science and Technology Forum)

66th General Meeting and 2nd Annual European Reconfigurable Radio Technologies Workshop
• June 21 to 24, 2010, Mainz, Germany (Hosted by BNetzA)

67th General Meeting
• September 13 to 17, 2010, Schaumberg, Illinois (Hosted by Motorola)
• Workshop: TVWS Communications (Tentative)
September Workshop

“Going to Market with TV Band Devices: Long Term Promises, Near Term Actions”
16 September 2010, Schaumburg, Illinois

In November, 2004 the Federal Communications Commission (FCC) announced landmark decision allowing the use of fixed and personal/intermittent devices in “unlicensed” TV Band spectrum, referred to as “white space.” Numerous parties are now developing devices that can be used in these bands. This workshop is designed to help them in the coming months. While awaiting the final rules and regulations, devices are being built and tested by multiple vendors and work continues on the development of standards supporting the use of TV Band Devices by multiple groups across the industry. This work has been bolstered by the National Broadcasters Plan recently announced by the FCC. This plan reinforces the use of Cognitive Radio and Dynamic Spectrum Access technologies by expanding opportunities for innovative spectrum access models by creating new avenues for responsible and innovative use of spectrum and increasing investment in new spectrum technologies.

The purpose of this workshop is to coordinate critical technical, business and regulatory “go to market” issues for TV Band Devices, and to develop a comprehensive action plan that addresses immediate needs while maximizing the possibilities for future innovation and access throughout the wireless value chain. This workshop will also define the next steps to be undertaken by the forum as a whole and the community as a whole, and will drive the work plans for longer term projects within the Forum’s Cognitive Radio Work Group, Test and Measures Group and the Regulatory Committee. These efforts will also help shape the Regulatory Workshop being held at SDR'10 in December.

Who should attend?
Equipment developers and manufacturers, test & measurement vendors, certification authorities, spectrum stakeholders, wireless service providers, national public database providers and end-users impacted by software defined Radio and cognitive radio (SDR/CR) systems technology developers being utilized for TV Band devices including dynamic waveform selection, opportunistic scheduling, dynamic spectrum access, secondary and unlicensed spectrum access and policy based operation.

www.WIRELESSINNOVATION.org
The premier event for bringing next generation radio technologies to life.

30 November - 3 December 2010 ● Washington, DC

Conference Chair: Dr. John Glossner

Program Committee: Over 70 of the World’s Leaders in SDR, CR and DSA

Over 145 Proposals Received from 22 Separate Countries

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