Innovative Spectrum Sharing Technology Day

Co-hosted by

U.S. Commerce Department’s National Telecommunications and Information Administration and the National Institute of Standards and Technology

November 5, 2013
Welcome and Introductory Remarks

Speakers

The Honorable Patrick D. Gallagher
Acting Deputy Secretary of Commerce, Under Secretary of Commerce for Standards and Technology, and Director of NIST

The Honorable Lawrence E. Strickling
Assistant Secretary of Commerce for Communications and Information and Administrator of NTIA

Dr. Jason Furman
Chairman, Council of Economic Advisers, Executive Office of the President
Spectrum Sharing Policy and Research Initiatives

Panelists

Tom Power (OSTP)  Byron Barker (NTIA)
John Quinlan (OMB)  Jason Boehm (NIST)
Karl Nebbia (NTIA)  John Chapin (DARPA)
Julius Knapp (FCC)  Andrew Clegg (NSF)

Moderator: Peter Tenhula (NTIA)
Wireless Spectrum Research and Development (WSRD)

Overview

The Wireless Spectrum R&D (WSRD) Senior Steering Group (SSG) has been formed to coordinate spectrum-related research and development activities across the Federal government. The purpose is two-fold: to help coordinate and inform ongoing activities across Federal agencies; and to facilitate the identification of shortfalls in the Government's R&D portfolio with respect to technologies that allow a more efficient use of spectrum. These activities are consistent with the guiding principles of WSRD, which are transparency, smart investment, and the solicitation of opportunities for technology transfer across and beyond the Federal government.

Wireless Spectrum Research & Development Senior Steering Group's Testbed Information Portal

Designed for the purposes of information exchange, it is our hope that this will prove useful for government, academic, and industry researchers in need of spectrum testing facilities.

We invite you to contribute information on testing facilities that are not currently listed, and that are available for use. Please contact wireless@nirf.gov for more information.
WSRD Testbed Inventory

Welcome to the Wireless Spectrum Research & Development Senior Stealing Group’s Testbed Information Portal. Designed for the purposes of information exchange, it is our hope that this will prove useful for government, academic, and industry researchers in need of spectrum testing facilities. We invite you to contribute information on testing facilities that are not currently listed, and that are available for use. Please contact vander@cs.wisc.edu for more information.
# INL Wireless Testbed

**Name of Testbed Facility**: Idaho National Laboratory Wireless Testbed  
**Operator of Facility**: Idaho National Laboratory  
**Location (mailing address)**: Idaho National Laboratory  
**Address**:  
1901 Industrial Drive  
P.O. Box 1824  
Idaho Falls, ID 83401  

**About**  
Idaho National Laboratory (INL) is a Department of Energy (DOE) national laboratory and a Federally Funded Research and Development Center (FFRDC). Built on the foundation of pioneering research in the nuclear, Idaho National Laboratory has been engaged in integrated science and cyber research, development, integration, training, and demonstration for more than a decade. INL’s unique approach to achieving high-performance computing and scientific research focuses on validated interdisciplinary science and technology. INL’s unique infrastructure includes a wide range of supercomputers and high-performance computing resources to support the full spectrum of scientific research and development. INL’s Testbeds are designed to support a wide range of scientific research and development, including advanced applications and technologies. INL’s Testbeds are designed to support a wide range of scientific research and development, including advanced applications and technologies.

**Website**  
[www.inl.gov](http://www.inl.gov)  

**Main contact for further inquiries**  
**Main Contact Name**: Dr. Ranjan Subramanian  
**Main Contact Email**: Ranjan.Subramanian@inl.gov  
**Main Contact Phone**: (208) 526-0610

**Frequency Range**: 6.7380 MHz to 5.5 GHz and beyond  
**Available to Federal Agencies**: Yes  
**Available to Academics**: Yes  
**Available to Industry**: Yes  
**Technology Available**: Extensive set of advanced, commercial-grade TDD-L cellular equipment  
**Bandwidth**: 40 miles of optical fiber, microwave and satellite networks

**Additional notes and restrictions**:  
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**Map Image**: A map showing the location and surrounding area of the INL Wireless Testbed.
DOC Center for Advanced Communications

Innovative Spectrum Sharing Technology Day

Jason Boehm
Director, Program Coordination Office
National Institute of Standards and Technology
Policy Drivers for a DOC Role

PCAST Spectrum Report

• “...provide test services to support the development of the policies, underlying technologies, and system capabilities required to support dynamic spectrum sharing.”

Public Safety and FirstNet

• FirstNet – establishes a nationwide public safety broadband network (PSBN) based on a single, national network architecture
• Through auction of spectrum NIST will receive $100M to support R&D on next generation Public Safety Communications

Interference Issues

• Concerns over GPS interference clearly illustrates need for clearly defined testing and evaluation capabilities
Response – The Center for Advanced Communication

NIST and NTIA will work together to establish the Center for Advanced Communications

• MOU between NIST and NTIA to establish the Center signed on May 24\textsuperscript{th}, 2013

Planned Center Objectives:

• Enhancing mission effectiveness of both agencies by better coordinating research and testing functions of NIST and NTIA
• Promoting interdisciplinary research, development, and testing in advanced communication-related areas (radiofrequency technology, digital information processing, cybersecurity, etc.)
• Providing a single focal point for engaging both industry and other government agencies
Proposed CAC Organization and Functions

Examples of the specific types of research, facilities and other activities at the new center may include:

- Multiuser test beds that allow government and industry researchers to realistically measure and evaluate the performance of new advanced communications technologies;
- Targeted interdisciplinary research, development and testing projects in fields such as digital information processing, interoperability and quantum communications; and
- Outreach to international standards development organizations to help ensure compatibility of U.S. advanced communications efforts with the global marketplace.
Next Steps

• Establish transition team to begin finalizing organizational plans for the Center and complete the necessary approval steps.
• Initiate recruitment of the Center leadership.
• Begin coordinated industry and stakeholder outreach.
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Overview of Exhibits and Demonstrations

- Cantor Fitzgerald & Co.
- Illinois Institute of Technology Wireless Communications and Networks Research Center
- Idaho National Laboratory
- InterDigital Communications
- Google Inc.
- Dynamic Spectrum LLC/Stevens Institute of Technology
- xG Technology Inc.
- Polytechnic Institute of New York University
- Microsoft Corp./Adaptrum Inc.
- Qualcomm Inc./Nokia Solutions and Networks
- Shared Spectrum Company/Corning Inc.
- Silicon Image
CANTOR EXCHANGE’S SYSTEM ARCHITECTURE

**Matching engine**
- Central trading system is responsible for order management
- Matching orders by specified size/price (specified by algorithms)

**Gateway**
- Front-end trading system
- Presents view and point of connection

**Session manager**
- Interface to the customer
- Authenticates logins with upstream servers prior to connecting authorized traders to the trading systems via Gateway
- Can support thousands of requests

**API System Components**
- Provides market access via a low latency C/C+ and Java API offered on all major operating systems
- Use API to receive trades all through one application

**Customer master**
- Internal database that stores all customer information
- Unique storage facility that supports client functionality in any existing business area

**Authentication manager**
- Responsible for securely managing the username and login details for each authorized trader
- Assigning users specific Gateways for trading system connections

**Security master**
- Internal database that stores all security reference data
- Repository for all-static data concerning the underlying instrument which trade/record-keeping can reference
Low-cost portable spectrum sensing

Web-based live monitoring of spectrum measurements

Distributed systems for long-term spectrum observation
Spectrum Agile RF Cognitive Radio Platform Based on Filter Bank Multi-Carrier Spread Spectrum Technology

- Operates simultaneously in “underlay” and “overlay” modes
- Enables Spectrum Sharing with Dynamic Negotiation of Secondary Channels’ Spectral Positions
- Performs Robustly Under Jamming Condition, Partial / Full Band Interference, and Multipath Conditions
- Exhibits Low Probability of Detection (LPD), Interception (LPI) & Exploitation (LPE) in Underlay Mode
- Can co-exist with Legacy Wireless Communication Systems
- Performs robustly in high-speed mobility environments
- Adaptable to several applications such as Defense, Public Safety, Cellular, Energy, Transportation, Medical etc.
**Carrier Aggregation**
- Combines up to 4 non-contiguous channels
- “Quarter-clocked” operation of 20MHz 802.11n chipset

**Sensing enabled channel switching**
- Scans for interference, DTV, & microphones

**Agile Spectrum Allocation**
- Dynamically selects best available channels

**TVWS database**
- Identifies open channels and Primary Users

**Wideband radio**
- 200 MHz wide transceiver

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**DSM Wi-Fi Prototype**

**Standards-Based Spectrum Sharing for TVWS, 3.5 GHz, and Other Frequency Bands**

- Non-contiguous Channel Aggregation & Intelligence to Manage It
  - Aggregation efficiently combines channels wherever they are
  - Database Access
  - Spectrum Sensing
  - Channel Allocation
  - Co-existence Management

**Enhanced 802.11n MAC/PHY development board (ARM)**

**Sensing toolbox running on a TI OMAP3530 (optional for client)**

**Wideband digital radio development board**

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Spectrum Access System Revolutionizes Spectrum Management

Demo a Spectrum Access System (SAS), and how it:

- Manages Multiple Tiers of Access
- Incentivizes Improved Hardware Performance through Increased Spectrum Opportunities
- Protects from Adjacent Channel, Out of Band Emissions, and Aggregation

Demo the SAS Controlling Multiple Operating, Carrier Grade, LTE micro-cells and User Equipment

- Requesting a spectrum grant
- Connecting to User Equipment
- Immediate Shutdown for Federal Preemption

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Google’s spectrum database opens television white spaces spectrum for broadband

Approach makes more spectrum available while protecting existing services

Incumbent users can continue to operate as-is

Databases enable devices that are simple yet dynamic

Regulator maintains incumbent user data set and has flexibility to adjust rules as necessary
Dynamic Spectrum Sharing and Management for Secure and Resilient Public Safety Communications Over 4G and WiFi Networks

Mitigating communications outages due to access network and/or core network breakdown (as in Hurricane Sandy and Boston Marathon bombing)

Presenters:

Dr. Vijay P. Kumar, Dynamic Spectrum, LLC

Mr. Vidya Sagar, Stevens Institute of Technology
Inside Table Top: Mobile handoff via commercially available, spectrum sensing/sharing xMax cognitive radio.

Outside H1 based COW: w/ integrated satcom

Ready to deploy spectrum sharing solution!
Recent advances in RF antenna and circuit designs enabled full-duplex communications operating using a common RF carrier, which has the potential to double spectrum efficiency and reduce network delay.

- Our team owns a US patent on a full duplex antenna feed network, and has built a prototype for LTE band.
- Our study shows over 80% capacity improvement for LTE-like systems with this design. At the mobile device side, no extra circuit is required.

<table>
<thead>
<tr>
<th></th>
<th>Full Duplex LTE (85 dB Cancellation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downlink</td>
<td>69%</td>
</tr>
<tr>
<td>Uplink</td>
<td>81%</td>
</tr>
</tbody>
</table>

Photo of complete antenna

Capacity gain
Streamloading: High-quality, low-cost, efficient video delivery for mobile users

Fraida Fund, S. Amir Hosseini, Shivendra Panwar
Department of Electrical and Computer Engineering, Polytechnic Institute of New York University

- Mobile video delivery method based on a hybrid access model that’s a win-win-win for content providers, wireless carriers and consumers
  - **Content providers** retain the same control over content as in the current streaming access model
  - **Wireless carriers** can deliver video more efficiently than in the streaming model
  - **Consumers** enjoy content that’s priced at streaming rates but with the high quality of downloaded video
Microsoft: Innovation in Spectrum Sharing

TV band white spaces trials and demonstrations

- TV White Space pilots on four continents
- Over a decade of leading-edge research

Visit our demo booth and learn more about Microsoft's projects and our Spectrum Observatory

For more information contact spectrumpolicy@microsoft.com
NSN’s/Qualcomm’s joint LSA demonstration at Mobile World Congress-2013

- Huge attention from vendors, telecom operators, device and chip set industry, regulatory bodies e.g. ITU-R and CEPT, national regulators e.g. Anatel, European Commission RSPG, representatives of ministries from several countries and press.
- In total > 200 visitors over 3½ days.

Real time Radio Access Network Emulation
- Multi-user, multi-cell radio network
- Suited for dozens of sites and 1000+ terminals
- Realistic propagation models also for 3D city models, shadowing and refraction
- Advanced 3D graphics, Interactive control
- Evaluation & visualization of advanced SON
**Demo Overview:**
- Industry leading, commercially deployed DAS system
- Demonstrates spectrum efficiency and capacity improvements
- Leverages spectrum sensing
- TV whitespace real-time spectrum sensing
WirelessHD® - 60GHz Multi-link Gaming Demo

- Multi-gigabit data transmission of Full HD video with sub-frame latency
- Cost-effective standard CMOS ICs with embedded antenna arrays
- Adaptive, real-time beam forming algorithm insures robust connections
- Supports non-line-of-sight ranges up to 10 meters
- Channel and spatial isolation supports multiple in-room connections

2.4GHz  5GHz  60GHz
20-40 MHz  20-160 MHz  2000 MHz per channel
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