



NIST
**National Institute of
Standards and Technology**
U.S. Department of Commerce

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)

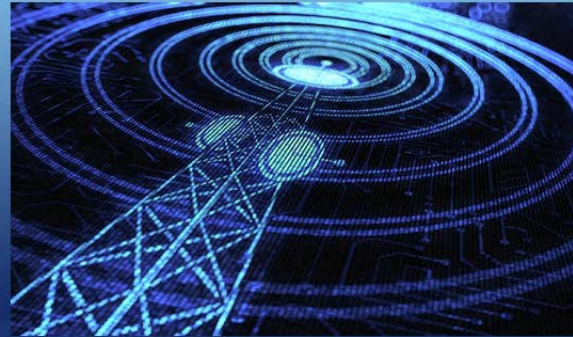
Moderator: Peter Tenhula (NTIA)



Wireless Spectrum Research and Development (WSRD)

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.

[More ▶](#)



Wireless Spectrum Research and Development (WSRD)

Contents

- 1 Overview
- 2 Scope
- 3 Functions
- 4 WSRD Co-Chairs
- 5 Wireless Spectrum Research & Development Senior Steering Group's Testbed Information Portal
- 6 Workshops and Reports
- 7 Events

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 shortcomings 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



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.

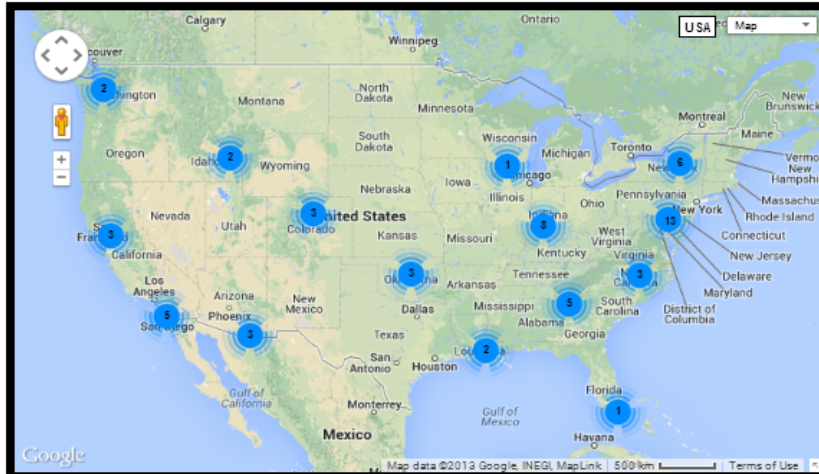
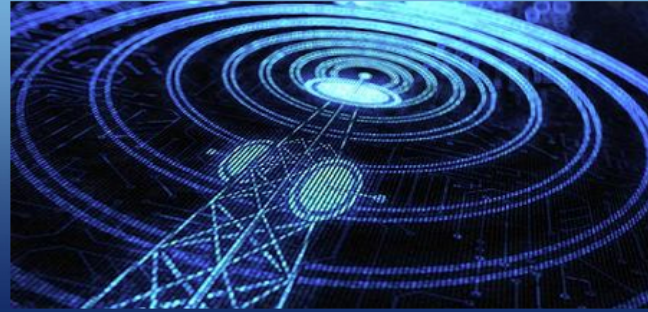
We invite you to contribute information on testing facilities that are not currently listed, and that are available for use. Please contact wigen@nitrd.gov for more information.



Wireless Spectrum Research and Development (WSRD)

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[More ▶](#)



- Aberdeen Test Center (US Army Test Ranges)
- AFRL Aerial Layer Networking Facilities
- BGPMux, DTunnels
- Calit2 Ericsson Wireless Access Network Research Test-bed
- CLOUD-CTL, ViSE
- CMUlab
- Cognitive Radio Network Testbed (CORNET)
- CR-GENI
- CRON-T
- D Meas, LEARN
- Design of Information Subs

Welcome to the 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.

There are several ways of finding the right facility for your needs:

- 1) search geographically using the map,
- 2) search using full-text search:

- 3) find labs by a particular characteristic that you require using the drop-downs:

*Available to:

Indoor/Outdoor

Frequency

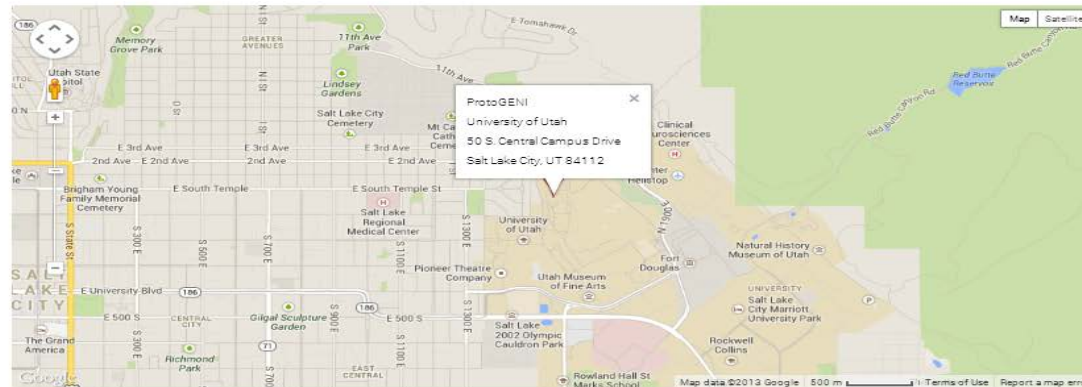
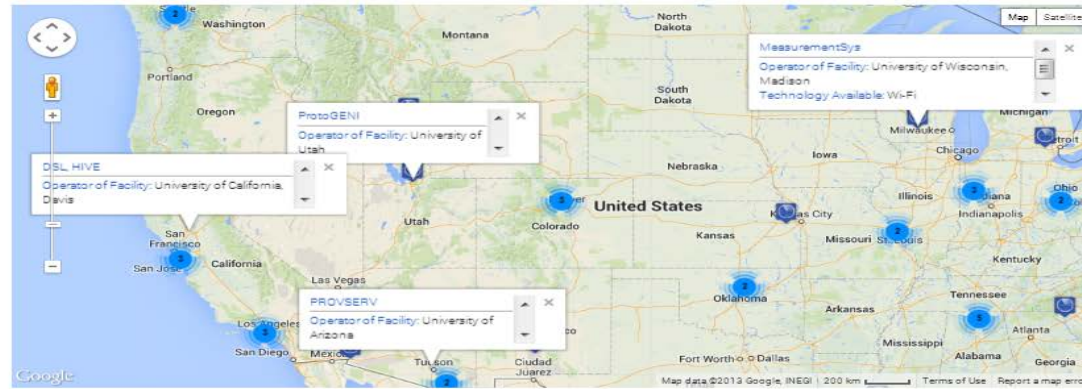
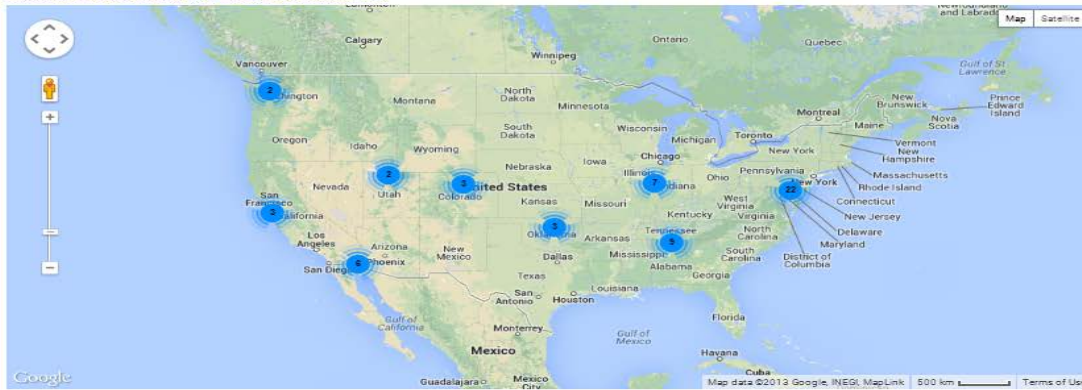
Available Technology

GENI/others

We invite you to contribute information on testing facilities that are not currently listed, and that are available for use. Please contact wisen@nitrd.gov for more information.

WSRD Testbed Inventory

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INL Wireless Testbed

Name of Testbed Facility	Idaho National Laboratory Wireless National Testbed
Operator of Facility	Department of Energy's Idaho National Laboratory
Location (mailing address)	Idaho National Laboratory Attn: Wireless NSLP P.O. Box 1625 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 exemplary tradition of facilitating innovative research in the nation, Idaho National Laboratory has been engaged in integrated wireless and cyber research, development, integration, testing and demonstration for more than a decade. INL provides an ideal large-scale wireless spectrum sharing testing and experimentation range for research, development and integrated interoperability evaluations. INL can also deliver wireless and wireless cyber evaluation and assessments that are key to spectrum sharing environments. INL capabilities and expertise can help bridge a large cross section of the government, industry and academia, using both open-air field and controlled laboratory environments. INL has 2100 square kilometers of wireless testing range, providing a controlled, isolated radio frequency (RF) spectrum experimentation environment, with minimal interference from rural/urban areas, airports or military test ranges. INL forms a unique national asset for integrated wireless testing of networks, hardware, sensors and applications, with possible nation-wide remote connectivity for research and experimentation. INL's Telecommunications research and experimentation team with private industry experience, deliver in-depth technical expertise and support. Current ground and aerial wireless experimentation capabilities at INL include carrier class networks such as GSM, UMTS, Fixed WiMAX, Mobile WiMAX, CDMA, 4G, Microwave, Wi-Fi and VSAT terminals. INL also has UGV and limited UAV testing range for integrated testing and validation. INL testbed has hardware and software from more than 50 leading vendors.
Website	http://www.inl.gov @ http://www.inl.gov/research/wireless-research-center @

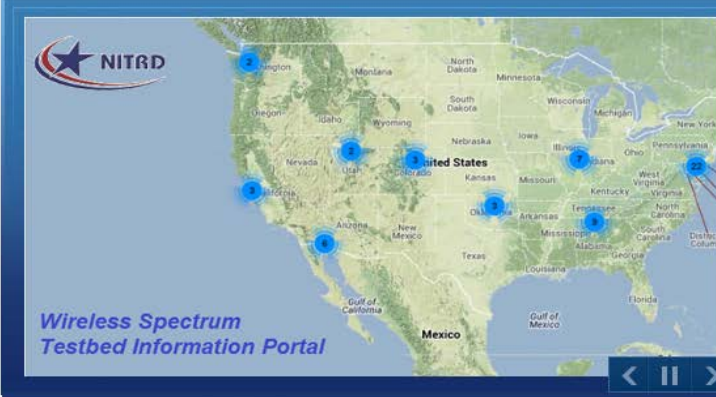
Main contact for further inquiries	
Main Contact Name	Dr. Rangam Subramanian
Main Contact Email	Rangam.Subramanian@inl.gov @
Main Contact Phone	(208) 226-0870

Frequency Range	0.000002 MHz - 60000 MHz/Extremely Low Frequency (ELF) to 60 GHz and beyond
Available to Federal Agencies	Yes *Note: Has been serving more than 50 different government offices under NTIA authorities.
Available to Academia	Yes *Note: Pilot demonstration for remotely enabled outdoor academic research experimentation also conducted.
Available to Industry	Yes *Note: Currently available for industry on government agency request or directly for industry with an FCC STA request. FCC licensing (pending new rule making on experimentation) will be required for wider industry availability.
Indoor	Yes
Outdoor	Yes
Technology Available	Extensive set of isolated, commercial-grade Tier-1 cellular equipment GSM UMTS CDMA Wi-Fi 4G 5G LME Project 25 SATCOM

Backbone networks include SONET, 60 miles of optical fiber, microwave and satellite networks.

Additional UAV and UGV test facilities. *Note: In planning 1) LTE and 802.22 WIRELAN networks, 2) Wireless security testing infrastructure, 3) Wireless IPv6 test and integration infrastructure.





Latest Datasets

- AMS Market News Historical Annual Su...
- Average historical annual temperature...
- Average historical total precipitatio...
- Extraction of lakes from an IfSAR DSM...
- Average historical annual total preci...
- Average historical annual temperature...
- Average historical temperature (degre...
- Average historical annual total preci...
- Average historical total precipitatio...
- Average historical annual temperature...

DATA AND TOOLS



- 91,071 datasets
- 349 citizen-developed apps
- 137 mobile apps
- 175 agencies and subagencies
- 87 galleries

COMMUNITIES



Come explore, discuss field, and develop the d community that you ca discussions by going to

OPEN GOVERNMENT



WELCOME TO THE RESEARCH COMMUNITY

Explore Federal Research Data

Research Apps

Mobile Apps

Web Apps

DATA.CATALOG

/ Organizations / Networking and Information ... / Wireless Spectrum Research & ...

Dataset Activity Stream Related

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

This application contains a list of Federal R&D sites that are available for public-private collaborative research efforts in the field of spectrum and wireless technology. For each site, there is a description of the features of the site, so that folks involved in spectrum R&D can find the site that is right for their particular project. The audiences most interested would be researchers and developers in these fields, including at companies that make and sell wireless products and services (e.g., Cisco, Qualcomm, Verizon Wireless, Boeing) and academic researchers.

Data and Resources

Web Page map.aspx

testbed inventory wireless spectrum testing frequency technology radio communication satcom dama mini-odl ttnt qnt legacy hf vhf uhf 117g handheld radios wlan radios wimax microwave optical wi-fi gnu radios gsm lte qnt sdr bluetooth

Additional Info

Field	Value
Resource Type	Dataset
Metadata Date	10/31/2013

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

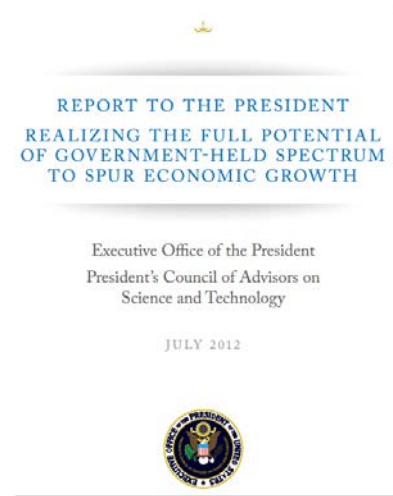
- *“...provide test services to support the development of the policies, underlying technologies, and system capabilities required to support dynamic spectrum sharing.”*

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 24th, 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.

Spectrum Sharing Policy and Research Initiatives

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Andrew Clegg (NSF)

Moderator: Peter Tenhula (NTIA)

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



Authentication manager

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

Customer master

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

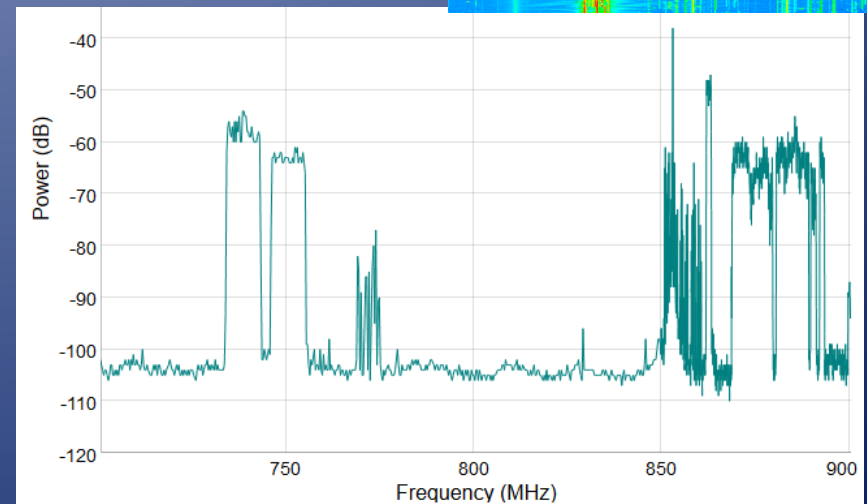
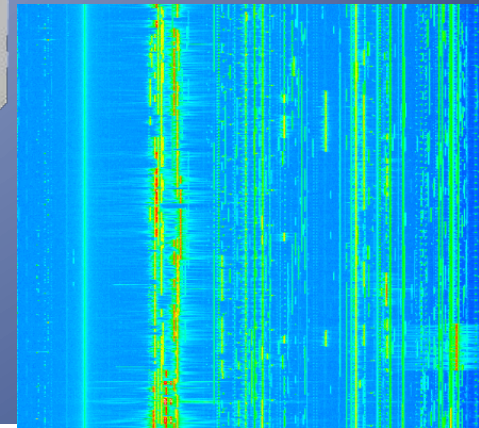
Security master

- 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

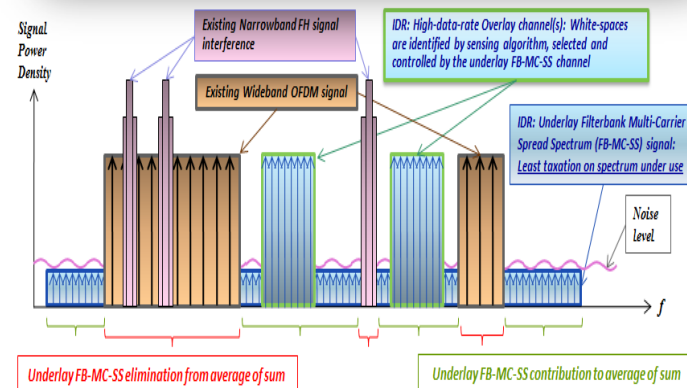
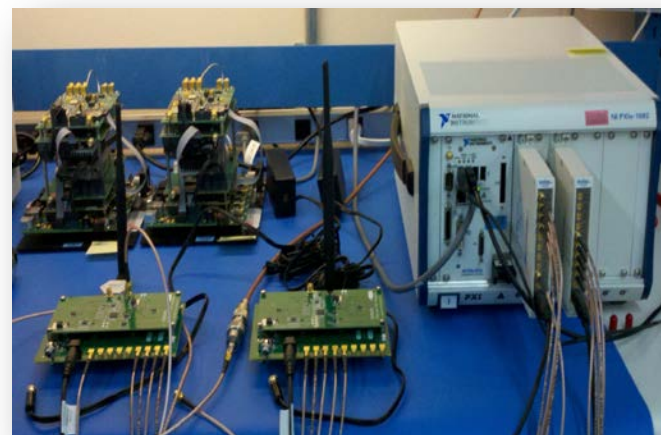
Web-based live
monitoring of spectrum
measurements

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.



DSM Wi-Fi Prototype

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

- 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

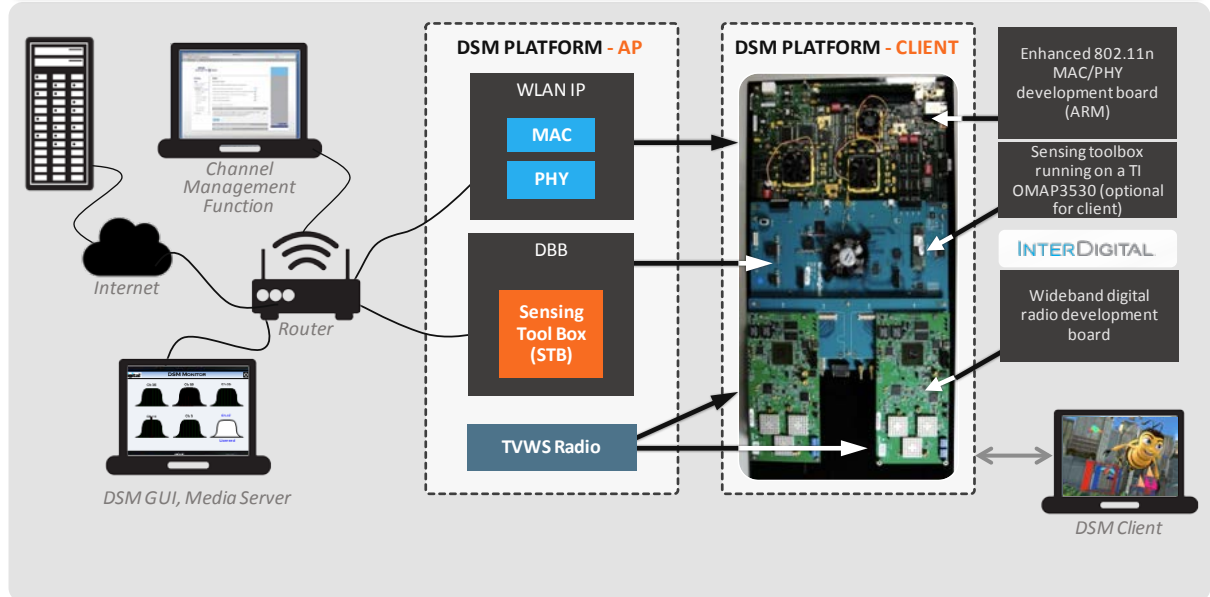
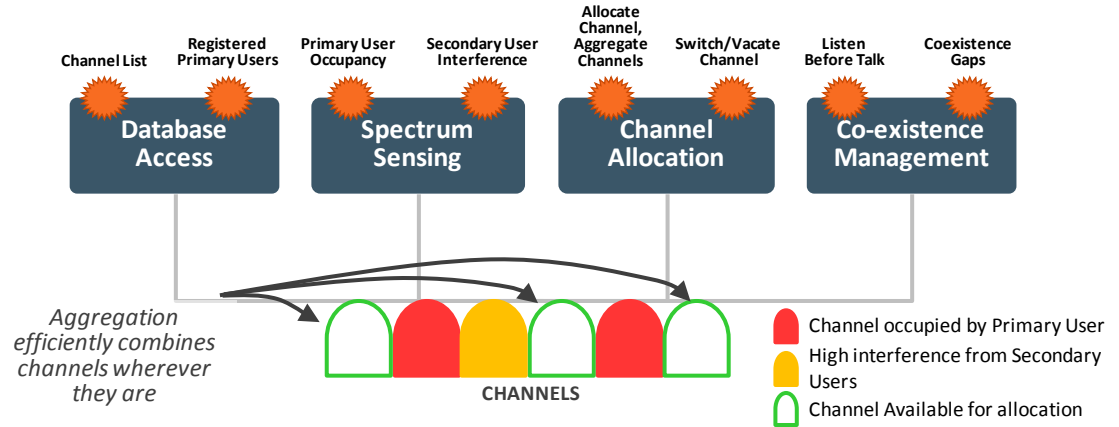
- TVWS database**

- Identifies open channels and Primary Users

- Wideband radio**

- 200 MHz wide transceiver

Non-contiguous Channel Aggregation & Intelligence to Manage It



Spectrum Access System Revolutionizes Spectrum Management

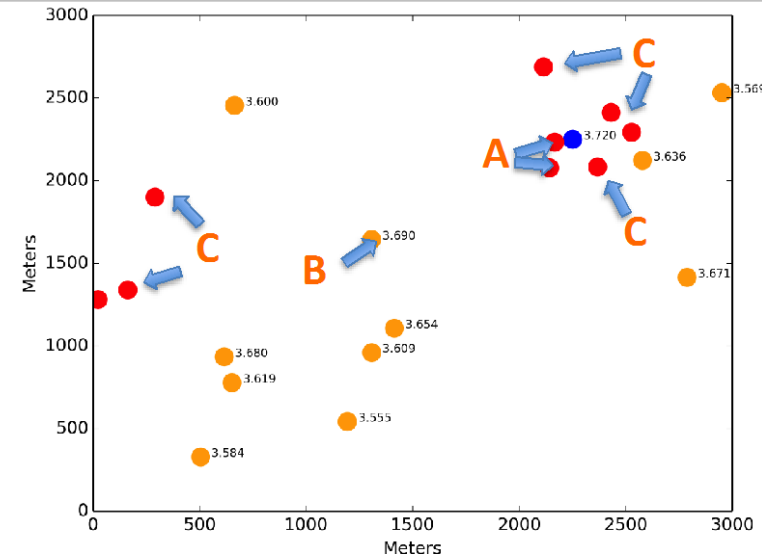


Demo a Spectrum Access System (SAS),
and how it:

- 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





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:

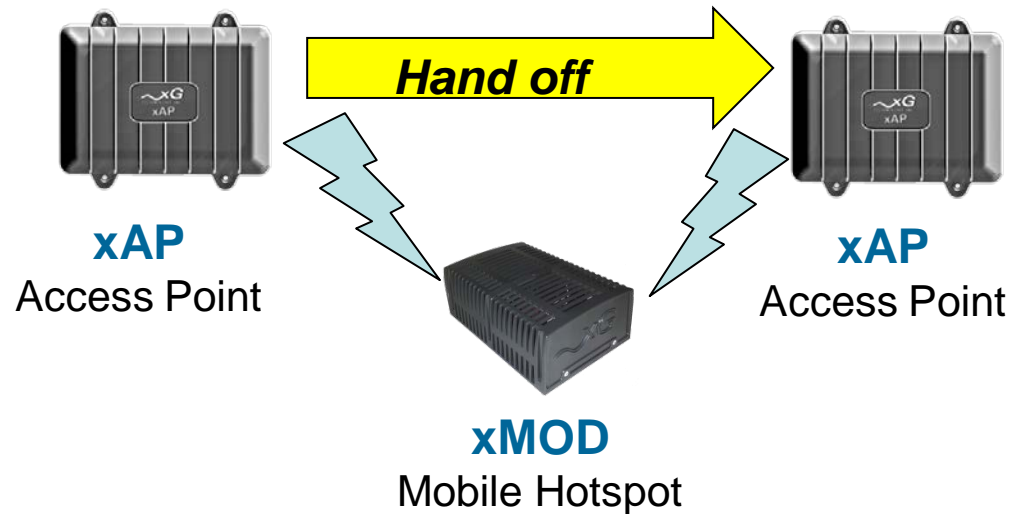
Dr. Vijay P. Kumar, Dynamic Spectrum, LLC

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!

Full Duplex Radios for LTE Networks

Sanjay Goyal, Pei Liu, Michael Knox and Shivendra Panwar

Department of Electrical and Computer Engineering, Polytechnic Institute of New York University

- 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.



Photo of complete antenna

	Full Duplex LTE (85 dB Cancellation)
Downlink	69%
Uplink	81%

Capacity gain

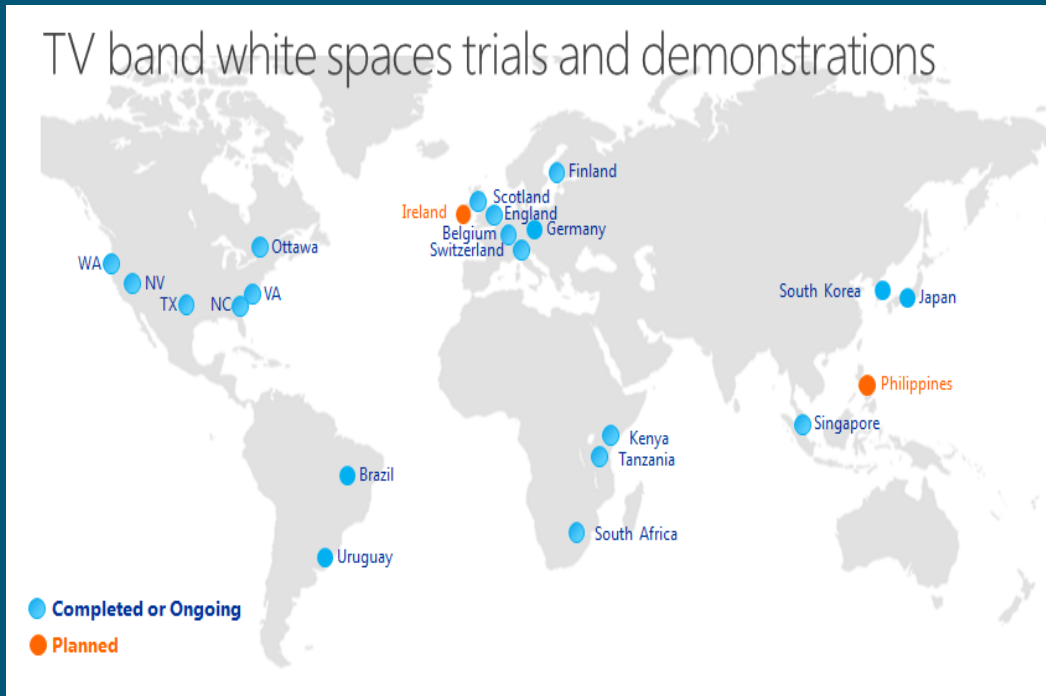
Streamloading: High-quality, low-cost, efficient video delivery for mobile users

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 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

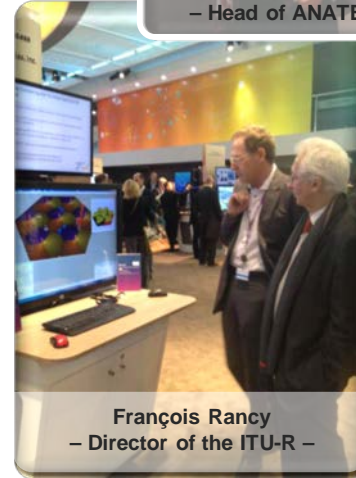


NSN's/Qualcomm's joint LSA demonstration at Mobile World Congress-2013

GSMA MOBILE™
WORLD CONGRESS
 Barcelona | 25 – 28 February 2013



Joao Batista De Rezende
 – Head of ANATEL –

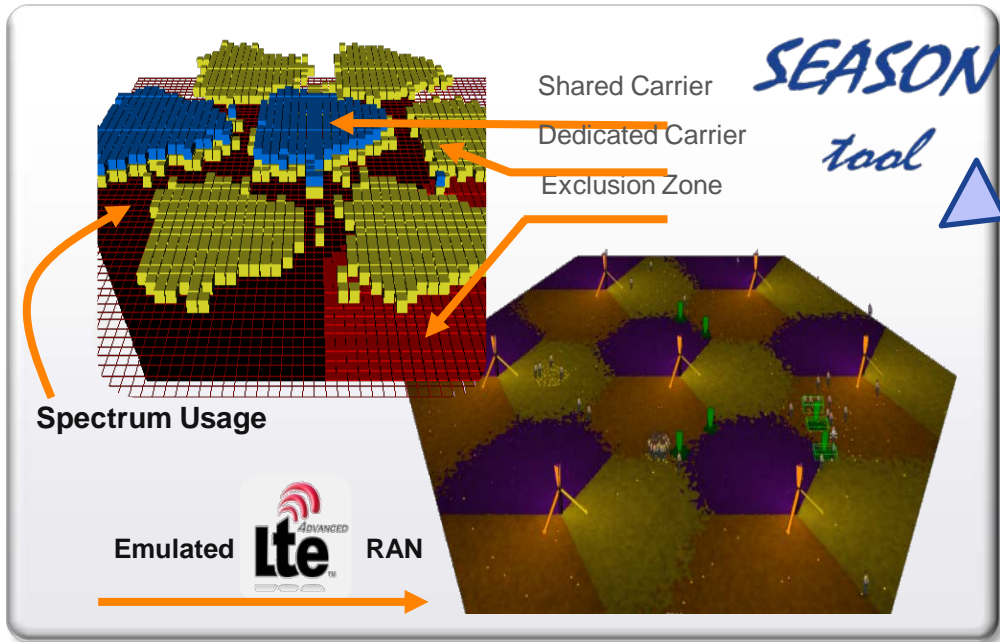


François Rancy
 – Director of the ITU-R –



Durga Prasad Malladi
 Vice President, Eng. QCOM

- 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



Shared Spectrum Company/Corning ONE™

Spectrum Sensing Improves Indoor Wireless Capacity



Indoor Multi-Band Optical Distributed Antenna Network

CORNING

MobileAccess
Wireless Solutions

Central Location

ICU with
Composite Cable
2 cables



OIU with
2xOIMs

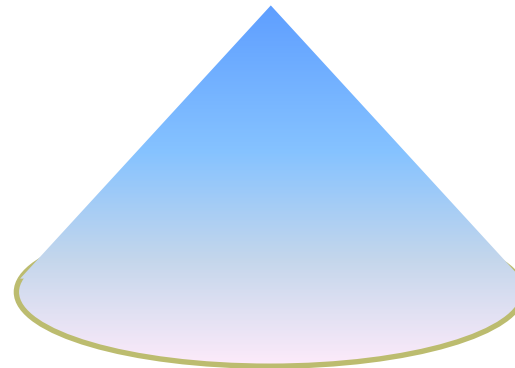


HEU with 2
sets of
RIMs
(8 total)



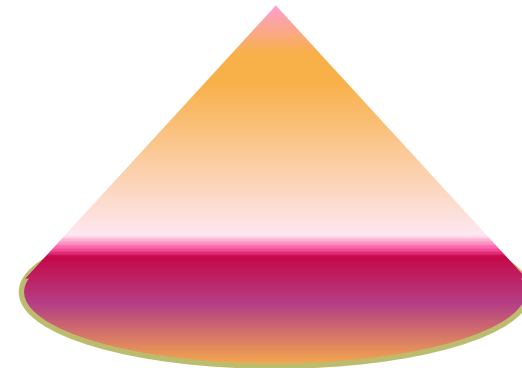
Spectrum
Monitoring

Remote Antenna Zone/Location 1



Quiet Spectrum Activity

Remote Antenna Zone/Location 2



High Spectrum Activity

Demo Overview:

- Industry leading, commercially deployed DAS system
- Demonstrates spectrum efficiency and capacity improvements
- Leverages spectrum sensing
- TV whitespace real-time spectrum sensing

Wireless HD[®] - 60GHz Multi-link Gaming Demo

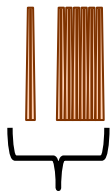
- ▶ Multi-gigabit data transmission of Full HD video with sub-frame latency
- ▶ Cost-effective standard CMOS ICs with embedded antenna arrays
- ▶ Adaptive, real-time beam forming algorithm insures robust connections
- ▶ Supports non-line-of-sight ranges up to 10 meters
- ▶ Channel and spatial isolation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

2.4GHz



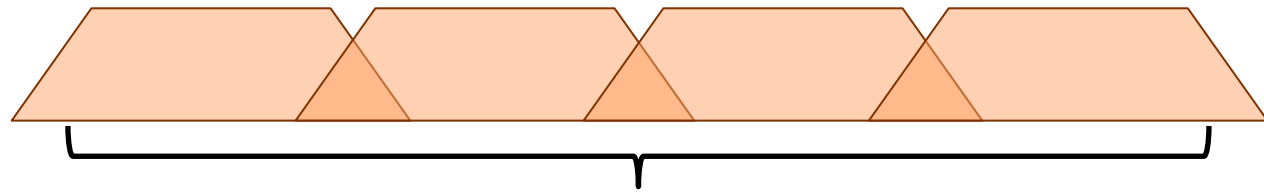
20-40 MHz

5GHz



20-160 MHz

60GHz



2000 MHz per channel

Overview of Exhibits and Demonstrations

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- 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