

Frontiers in Advanced Spectrum Sharing



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WinComm
San Diego
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Note: The views expressed in this presentation are those of the author and may not necessarily represent the views of the Federal Communications Commission

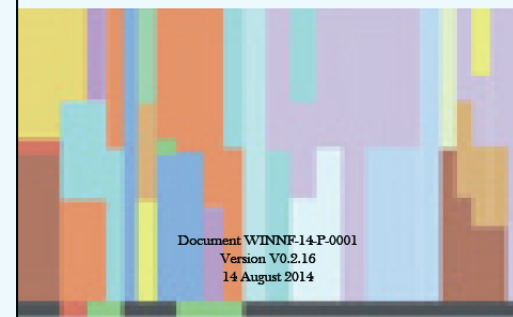
Great to be Here!

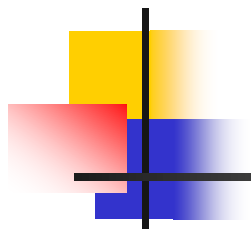
**Software Defined Radio Forum/Wireless Innovation Forum
Were Working on Spectrum Sharing Before it Was Cool!**

FCC and the Wireless Innovation Forum have worked collaboratively through many Commission proceedings dating back to 2000 as detailed in your Annual Report



Dynamic Spectrum Sharing
Annual Report - 2014





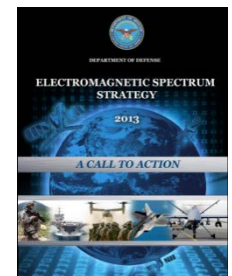
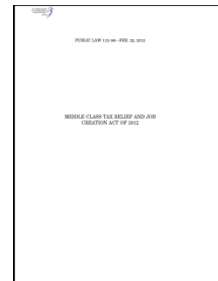
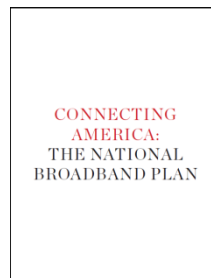
Overview of Spectrum Strategy

Spectrum Strategy

- Driver: Continued growth of mobile & other services

- Key Milestones:

- National Broadband Plan
- Middle Class Tax Relief & Jobs Creation Act of 2012
- Presidential Memos
- NTIA ten year plan
- PCAST Report
- Department of Defense Spectrum Strategy



- Strategy:

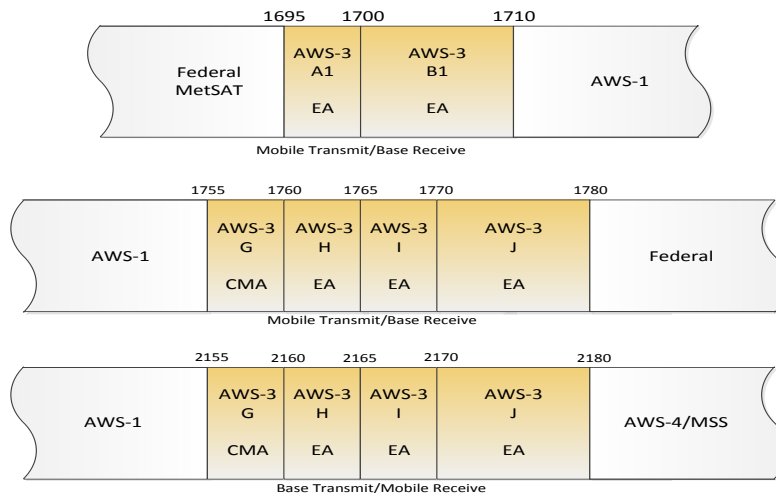
- Consider potential reallocations, but becoming more difficult
- Develop advanced spectrum sharing techniques
- Continue to advance efficient use of the spectrum (flexibility)



Spectrum Reallocations: Advanced Wireless Service-3

Advanced Wireless Service-3 (AWS-3)

- Recently concluded AWS-3 auction:
 - Paired 2110 MHz - 2155 MHz with 1755 - 1780 MHz;
 - Unpaired 1695 – 1710 MHz
- Why valuable: Adjacent to AWS-1



- Relocation or sharing with numerous federal operations
- “Heavy Duty” engineering
 - Identify relocation bands
 - Sharing: Realistic vs. Worst case
- Required close collaboration

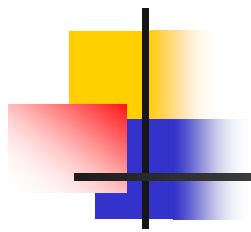
Federal Incumbent Systems:

- Fixed Point-to Point Microwave
- Military Tactical Radio relay
- Air Combat Training System
- Precision Guided Munitions
- Tracking, Telemetry & Commanding
- Aeronautical Mobile Telemetry
- Video Surveillance
- Unmanned Aerial Systems
- Other Systems



AWS-3 Auction Results

Date	Auction 97 began on 11/13/2014 and closed on 1/29/2015.
Licenses	1,614 licenses total Block A1: 176 Economic Area (EA) licenses Block B1: 176 EA licenses Block G: 734 Cellular Market Area (CMA) licenses Block H: 176 EA licenses Block I: 176 EA licenses Block J: 176 EA licenses
Spectrum	1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz bands ("AWS-3" bands)
Bandwidth	65 megahertz total Block A1: 1695-1700 MHz (5 MHz) Block B1: 1700-1710 MHz (10 MHz) Block G: 1755-1760/2155-2160 MHz (10 MHz) Block H: 1760-1765/2160-2165 MHz (10 MHz) Block I: 1765-1770/2165-2170 MHz (10 MHz) Block J: 1770-1780/2170-2180 MHz (20MHz)
Winning Bidders	31
Rounds	341
Qualified Bidders	70
Licenses Won	1611
Licenses Held By FCC	3
Net Bids	\$41,329,673,325
Gross Bids	\$44,899,451,600



Spectrum Reallocations: Incentive Auction in TV Band

Available at:

<http://wireless.fcc.gov/incentiveauctions/learn-program/>

Incentive Auction Opportunities for Broadcasters

Prepared for the Federal Communications Commission by

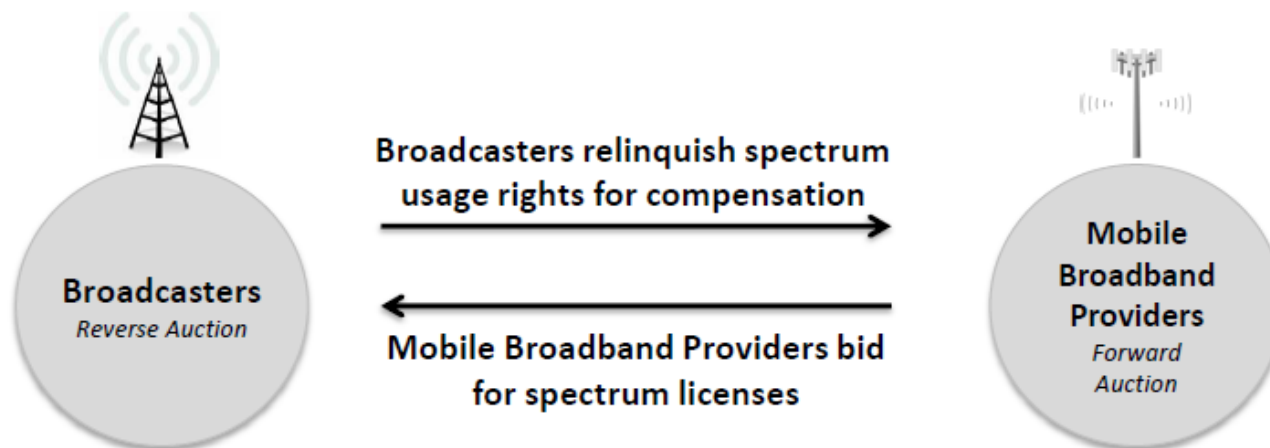
Greenhill

February 2015

What is the Incentive Auction?

The Incentive Auction Represents a Unique Opportunity for Broadcasters to Monetize the Value of their Spectrum

- The Incentive Auction is a market-based approach to repurposing the 600 MHz spectrum band that will provide Broadcasters the opportunity to sell their spectrum usage rights while retaining the flexibility to remain on the air
- The Incentive Auction is comprised of a Reverse Auction and a Forward Auction, which together will create a structured spectrum marketplace for Broadcasters and Mobile Broadband Providers
- The FCC has the unique ability to unlock value for Broadcasters by reorganizing the 600 MHz spectrum band into contiguous blocks on a nationwide basis and reallocating it for wireless use

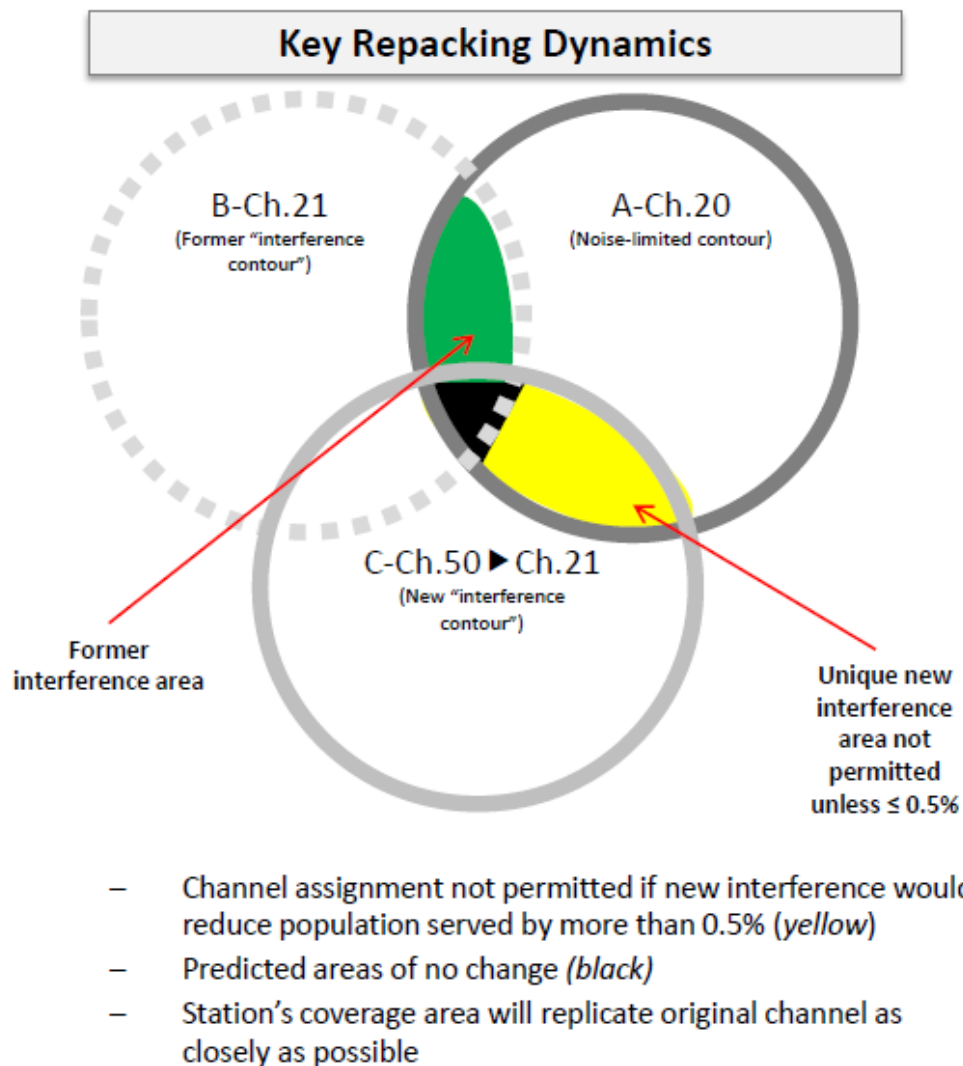


Source: FCC

Note: These slides present an unofficial summary of the Incentive Auction Report and Order and Rules dated May 15, 2014 and the Broadcast Incentive Auction Comment Public Notice dated December 17, 2014. Should this summary vary from the Report and Order, Rules or Comment Public Notice as released, the official documents govern. Final auction procedures have not yet been adopted by the Commission.

Repacking Process is Designed to Preserve Population and Coverage Area

- Non-participating Broadcasters and those that do not have bids accepted will continue to operate in their pre-auction spectrum bands following the Incentive Auction
- The FCC will “repack” Broadcasters so that television stations occupy a smaller portion of the UHF band
- This will allow the FCC to reconfigure a portion of the UHF band into contiguous blocks of spectrum suitable for wireless use
- In carrying out the repacking, the Spectrum Act requires the FCC to make “all reasonable efforts” to preserve broadcast station “coverage area” and “population served” as of February 22, 2012 (the date of enactment)

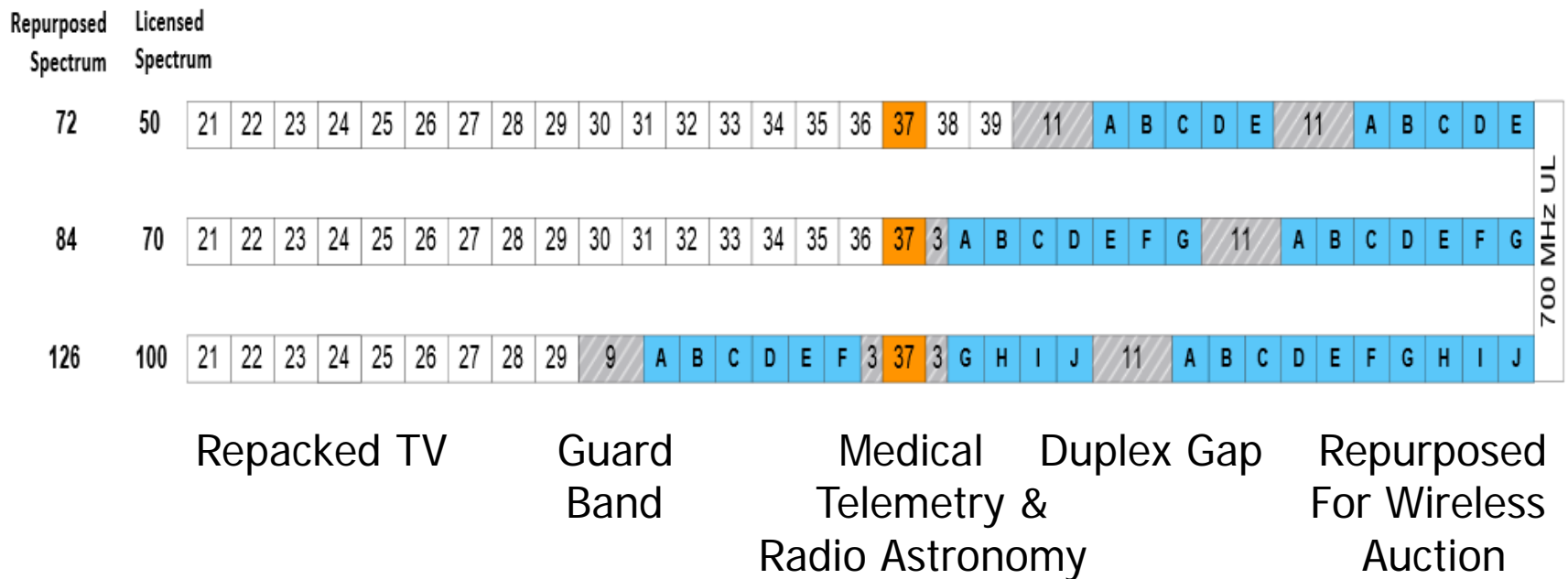


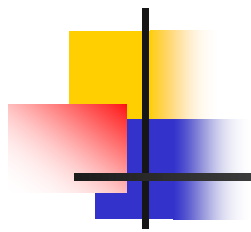
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TV Incentive Auction 600 MHz Band Plan

First time the Commission has needed to develop band plans without knowing how much spectrum will be available!





Spectrum Sharing: Unlicensed in the 600 MHz Band

Progress on White Space in the TV Bands (Unlicensed)

- Adopted final rules in 2012
- Nine devices approved:
 - Adaptrum, Koos Technical Services, Meld, Carlson, Redline and 6harmonix
 - All fixed devices, designed for professional installation - location entered manually
 - All are generic boxes with an input for a digital signal (voice, video, data).
- Data bases approved:
 - Spectrum Bridge, iconectiv (formerly Telcordia), Google, Key Bridge Global and KB/LS Telcom
- IEEE developing "af" standard
- Strong international interest



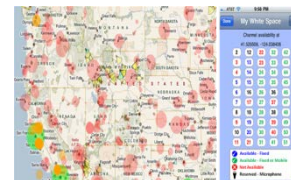
Meld



Carlson



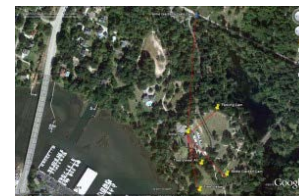
Adaptrum



Spectrum
Bridge



iconectiv



Wireless Cameras Cover Park
in Wilmington NC

Data Base Administrator Approval Process

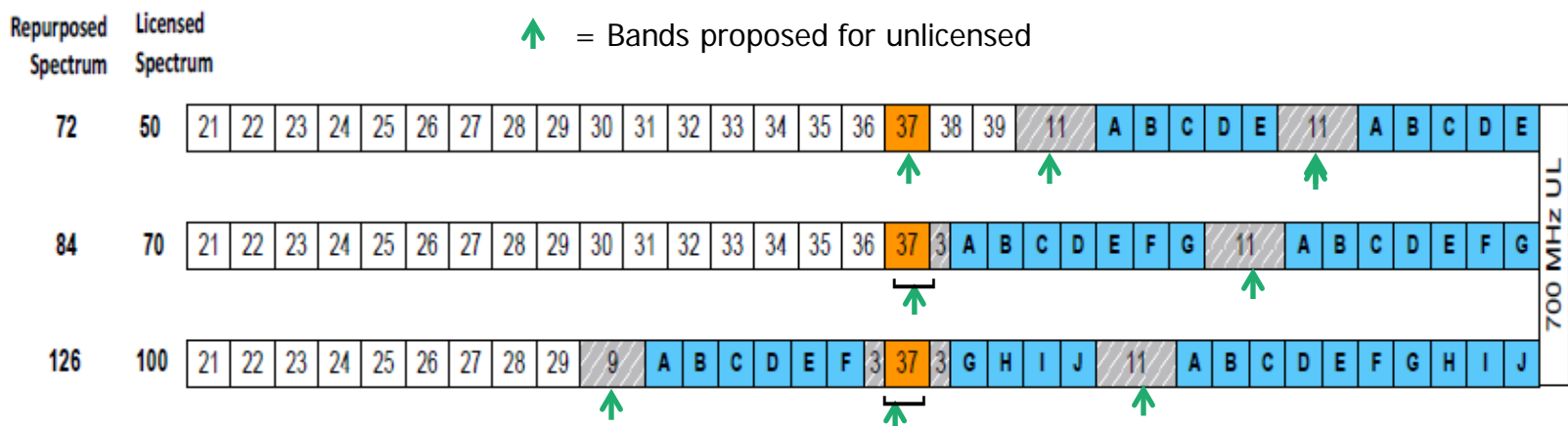
- File application
- Workshops
- Submit data base
- FCC Review
- Public beta test
- Final report
- Public comment
- Final approval
- Maintenance: Q&A's

White Space Database Administrators

Administrator Name	Contact Information	Approval Status
Airity, Inc. (formerly WSdb LLC)		Pending
Comsearch	H. Mark Gibson, 19700 Janelia Farm Boulevard, Ashburn, VA 20147 mgibson@comsearch.com	Pending
Frequency Finder, Inc.	Peter Moncure, 8910 Dick's Hill Parkway, Toccoa, GA 30557 pmoncure@radiosoft.com	Pending
Google Inc.	Alan.Norman, 1600 Amphitheatre Parkway, Mountain View, CA 94043 alannorman@google.com	Approved
KB Enterprises LLC and LS Telcom	Dr. Georg Schöne, Im Gewerbegebiet 31-33, D-77839 Lichtenau, Deutschland GSchoene@LStelcom.com	Approved
Key Bridge Global LLC	Jesse Caulfield, 1600 Tysons Blvd., Suite 1100, McLean, VA 22102 jesse.caulfield@keybridgeglobal.com	Approved
NeuStar, Inc.	Brian Rosen, 1775 Pennsylvania Ave., NW, Washington, DC 20006 brian.rosen@neustar.biz	Pending
Spectrum Bridge, Inc.	Peter Stanforth, 1064 Greenwood Blvd, Lake Mary, FL 32746 peter@spectrumbridge.com	Approved
iconectiv	John P. Malyar, 1 Telcordia Dr., Piscataway, NJ 08854 jmalyar@iconectiv.com	Approved
Microsoft Corporation	Ian Ferrell, One Microsoft Way, Redmond, WA 98052, ianf@microsoft.com	Pending

Proposed Rule Changes

- NPRM adopted Sept. 30, 2104
- Proposed unlicensed operation in:
 - Remaining white space
 - Duplex gap
 - Guard bands
 - Channel 37 – Shared non-Ix to medical telemetry and astronomy
 - Recovered spectrum until wireless operation commences





Spectrum Sharing: Wireless Microphones

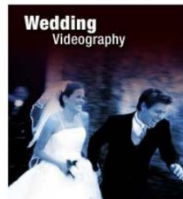
Wide Variety of Wireless Microphone Applications

Small Wireless Venues

School Performances



Event Videography



Medium Wireless Venues

Music Tours



Corporate Meetings



Large Wireless Venues

Houses of Worship



Theater Productions



Extreme Wireless Venues

Global Sporting Events



Political Conventions



Auto Shows





Proposed New Provisions for Wireless Microphones

- Many operate in the TV spectrum
 - Incentive auction will reduce TV spectrum
 - Insufficient for some applications
 - IA order expanded license eligibility
- NPRM adopted Sept. 30, 2014 proposed:
 - Access to new spectrum for major users
 - Increased flexibility under existing rules

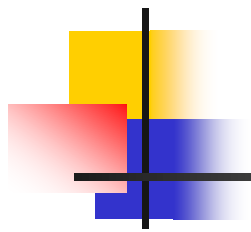


Low Power TV & Translators



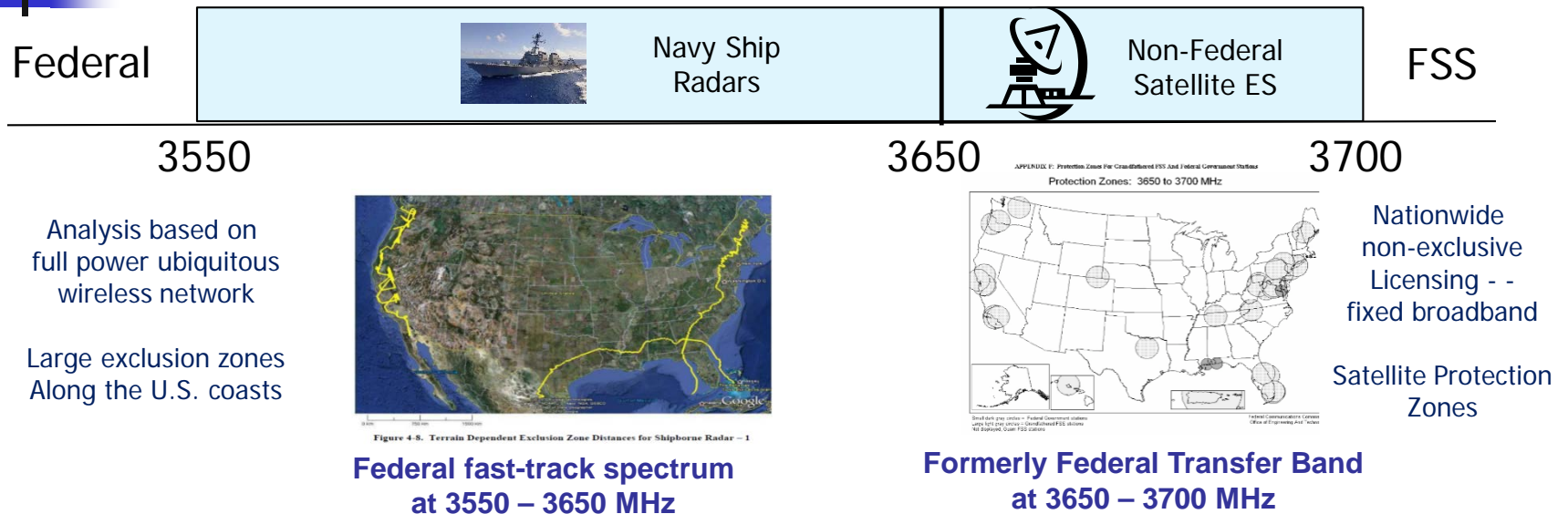
Low Power Television (LPTV) & Translators

- Offer diverse and local programming, especially rural/remote areas
- Initiated NPRM to:
 - Facilitate the final conversion to digital
 - Mitigate potential impact of incentive auction and the repacking
- Proposed several actions to:
 - Extend the Sept. 1, 2015 LPTV & translator digital transition deadline
 - Extend channel sharing to LPTV & translators
 - Create a new Digital to digital replacement translator service
 - Provide for processing priority
 - Provide assistance to LPTV and TV translator stations in finding displacement channels after the incentive auction



Spectrum Sharing: Small Cells @ 3.5 GHz

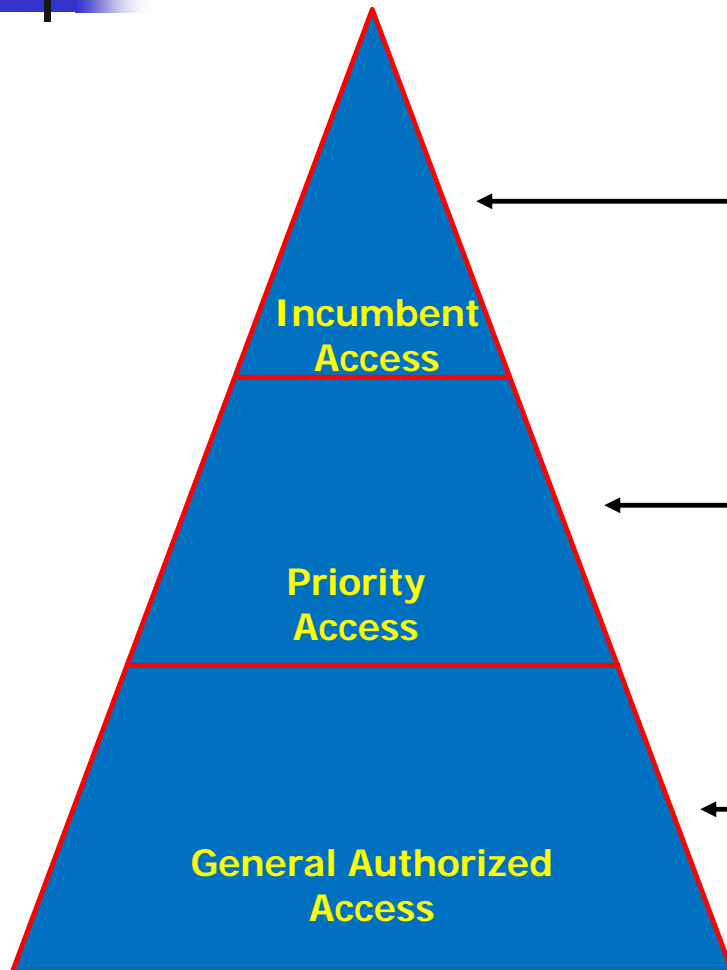
3.5 GHz Proceeding



- FCC Proceeding would provide for small cells and other uses through data base access / dynamic spectrum access - - reduce exclusion zones
- A small cell is a low power access point that operates in licensed spectrum
- A spectrum access system, incorporating a geo-location enabled dynamic database, would govern access to the 3.5 GHz Band
- Proposal also considers including 3650 – 3700 MHz



3.5 GHz Spectrum Access Tiers



Incumbent Access: Includes authorized federal and grandfathered Fixed Satellite Service (FSS) users currently operating in the 3.5 GHz Band.

Priority Access: Authorize certain users to operate with some interference protection in portions of the 3.5 GHz Band at specific locations

General Authorized Access: Users would be authorized to use the 3.5 GHz Band opportunistically within designated geographic areas. GAA users would be required to accept interference from Incumbent and Priority Access tier users.

Spectrum Access System (SAS)

A next generation sharing system building on white spaces

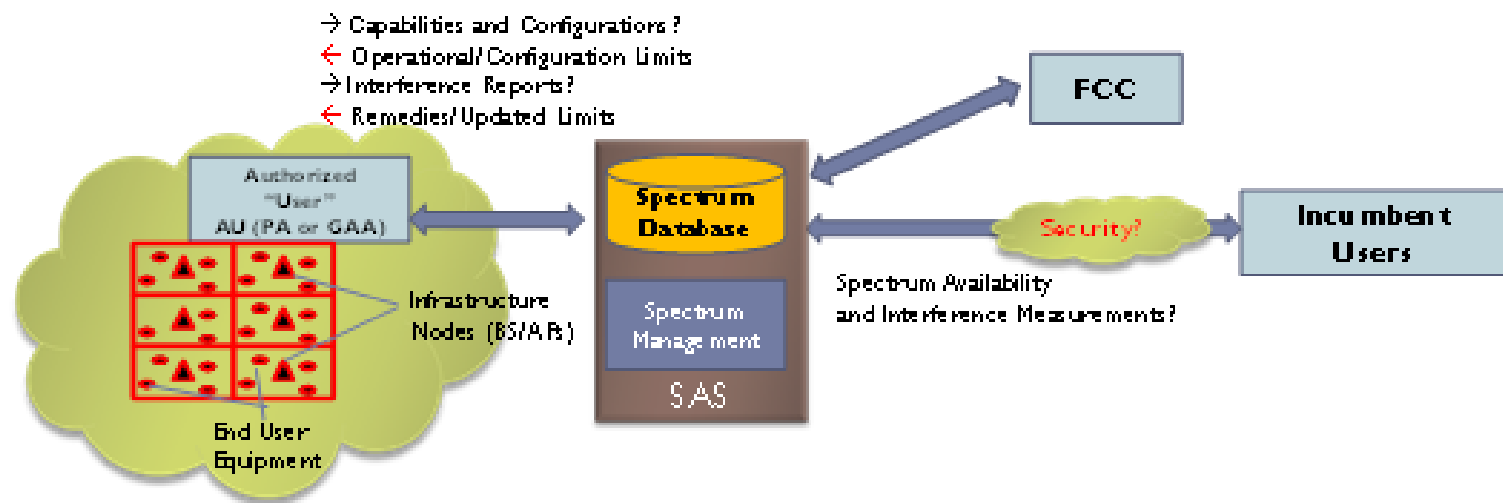


Figure 1: Spectrum Access System



Progress on 3.5 GHz

Commission Decision Soon:

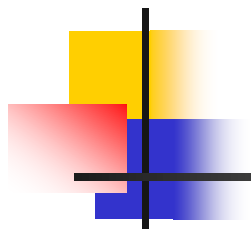
- Access Model (Tiers)
- PAL/GAA spectrum
- Protections for:
 - DoD
 - Existing 3.65 users
 - Satellite
- Technical requirements
- SAS:
 - Functions
 - Approval Process

Exclusion Zones:

FCC has worked extensively with NTIA/DoD to reduce exclusion zones and establish way forward towards dynamic sharing to increase access

Multi-stakeholder (MSH) process:

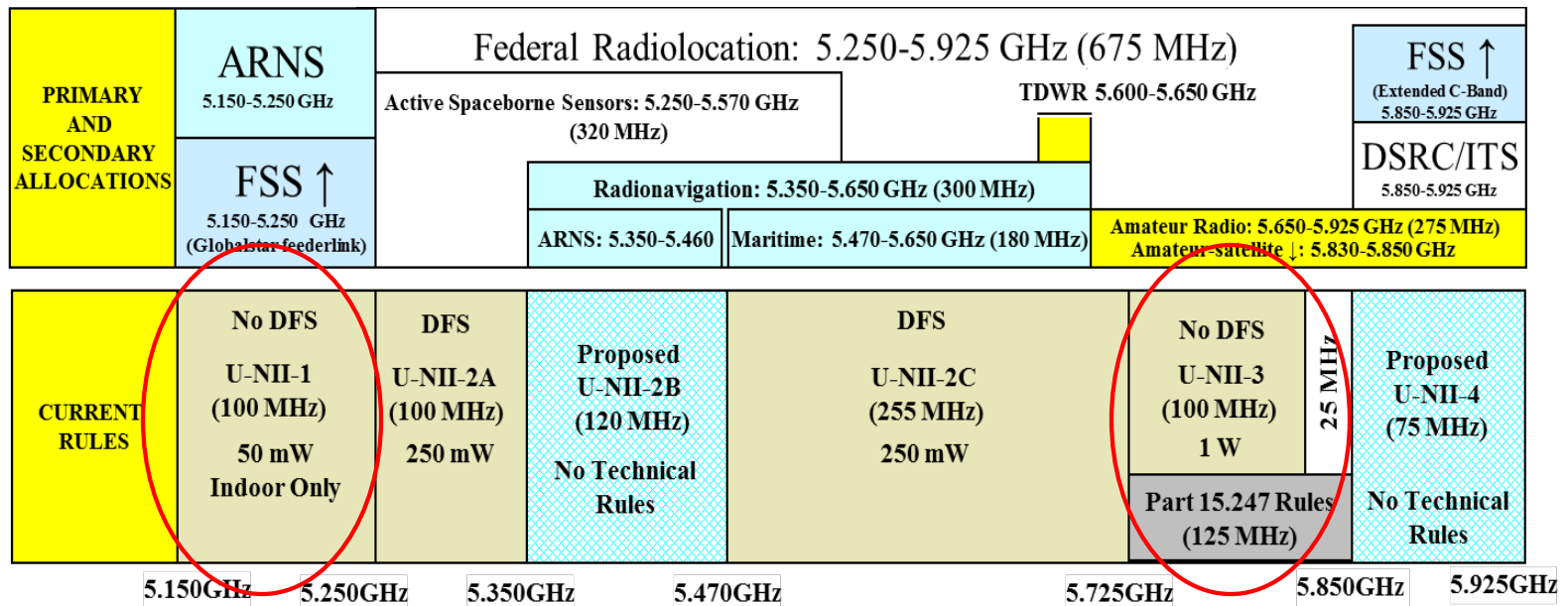
- FCC appreciates industry establishing MSH process
- Regulations will set framework
- Industry collaboration will be key to successful implementation



Spectrum Sharing: Unlicensed at 5 GHz

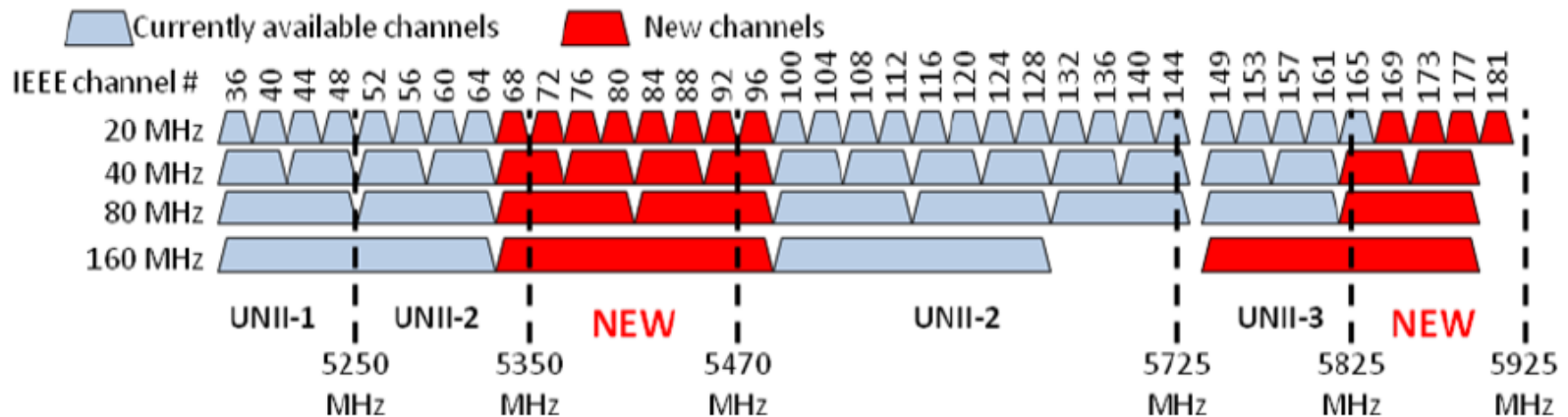
Expanding Spectrum for Unlicensed at 5 GHz

Previous Rules



- NPRM proposed to expand access to spectrum for unlicensed at 5 GHz
- First R&O 3/31/14 - Removed indoor-only restriction & increased permitted power for U-NII 1
- Continuing to work on sharing in proposed U-NII-2B and U-NII-4

Implications for Wi-Fi



UNII-1: 5150-5250 MHz band

UNII-2: 5250-5350 MHz and 5470-5725 MHz band

UNII-3: 5725-5825 MHz band

Current 802.11ac and Potential New Usable Channels



Ongoing Work

U-NII-2B (120 MHz)

- Sharing with federal plane/ship/terrestrial radars & earth exploration satellite
- US proposing to continue international work for WRC-19
- Moving forward domestically
- Work group established:
 - FCC/NTIA/DoD/NASA
 - Considering 1x protection studies & developing ways to share
 - Evaluating sharing with indoor low power/then outdoor high power

U-NII – 4 (75 MHz)

- Sharing with Dedicated Short Range Communications
 - Vehicle to Vehicle
 - Vehicle to Infrastructure
- IEEE Tiger Team has been working on industry proposals
- FCC/NTIA/DoT collaborating
- Considerations:
 - Protect safety of life
 - Roads are everywhere
 - Wi-Fi & DSRC are similar



Millimeter Wave Spectrum



High Level Overview of US Table of Frequency Allocations

Frequency Range	Allocations	FCC Service Rules
9KHz – 95GHz	Various Allocations in Primary, Co-Primary, or Secondary	Various service rules for a given allocation
95GHz - 275GHz ¹	Various allocations (large amount of allocation for passive services)	No Service Rules
275GHz - 1000GHz ¹	No Allocation	No Service Rules

¹ Experimental Licensing Process supports various activities in these bands

Expanding Use of the Millimeter Wave Spectrum

- FCC Notice of Inquiry (NoI) adopted 10/17/14
- Examines new developments in technology that could dramatically expand the horizon for spectrum that could be used for mobile wireless service, faster broadband speeds
- Recommended by Technological Advisory Council
- NoI is beginning of Process

Federal Communications Commission		FCC 14-154
Before the Federal Communications Commission Washington, D.C. 20554		
In the Matter of)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services)	GN Docket No. 14-177
Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands)	ET Docket No. 95-183 (Terminated)
Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands)	PP Docket No. 93-253 (Terminated)
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band)	RM-11664
NOTICE OF INQUIRY		
Adopted: October 17, 2014		Released: October 17, 2014
Comment Date: December 16, 2014		
Reply Comment Date: January 15, 2015		
By the Commission: Chairman Wheeler and Commissioners Clyburn, Rosenworcel, Pai, and O'Rielly issuing separate statements.		
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<http://www.fcc.gov/document/noi-examine-use-bands-above-24-ghz-mobile-broadband>



NOI: 48 Comments; 18 Replies

Industry	Commenters
Manufacturers	Intel, Nokia, Samsung, Ericsson, ALU, Qualcomm, Huawei, Motorola Mobility, SiBeam, Bluwan, InterDigital
Fixed Wireless Industry	FiberTower, Straight Path, Vivint, XO, McKay Brothers, FWCC
Wireless Industry	Verizon, T-Mobile, CTIA, 4G America, Mobile Future
Satellite Industry	EchoStar, ViaSat, Inmarsat, Iridium, O3B, SIA, Avanti, Fixed Satellite Services Operators, European Satellite Operator's Association
Other Industry/ Standard Organizations	IEEE, WiFi Alliance, Wireless Innovation Forum, TIA, ARRL, CEA, NCTA, Committee on Radio Frequencies, Google, SpaceX
Academia	NYU, U of Wisconsin (Akbar Sayeed)
Others	Marcus Spectrum Solutions, James Whedbee



NoI: Technology

Smart Antennas	<ul style="list-style-type: none">• Base Station Antenna (32, 64 elements, patch antennas)• Handset Antenna (modular arrays of 4 elements or more)• Digital/Analog/hybrid beamforming/MIMO processing of array(s)• Modules comprising of a RFIC chip and beamforming unit
Bandwidth	<ul style="list-style-type: none">• Throughput is a function of available bandwidth• Large contiguous blocks of spectrum present certain advantages over multiband spectrum aggregation, particularly with respect to handsets• contiguous blocks of 500 MHz- 2GHz
Performance	<ul style="list-style-type: none">• Maximum throughput up to 10 Gbit/s and at least 100 Mbit/s at cell edge• end-to-end latency of < 5 milliseconds and air latency of < 1 millisecond• channel bandwidths in excess of 1-2 GHz
Backhaul	<ul style="list-style-type: none">• Integrated backhaul/access (multi-hop communication)• Inband/Outband options in the mmW bands; Fiber and other options
Deployment Scenarios	<ul style="list-style-type: none">• Initial deployment will be complementary as hotspot offloading• Eventually a standalone network, but one that is like a WiFi network rather than a ubiquitous nationwide system of mmW access points

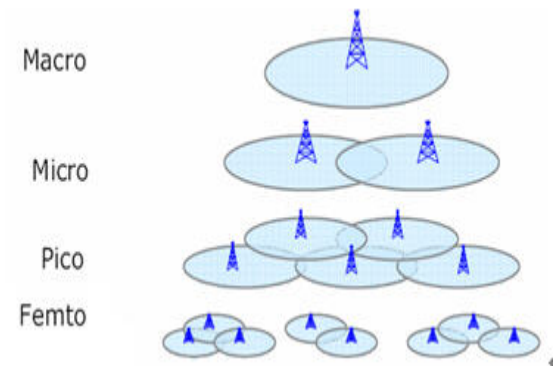


NoI Frequency Bands

LMDS	<ul style="list-style-type: none"> • Co-primary for fixed and mobile • Large contiguous bands 27.5-28.35 GHz, 29.1-29.25 GHz, 31-31.3 GHz, • Licensed on geographical basis, FSS sharing possible
39 GHz	<ul style="list-style-type: none"> • Co-primary for fixed and mobile; Large contiguous bands (1.4 GHz), • Licensed by Economic Area; May require exclusion zones
37/42 GHz	<ul style="list-style-type: none"> • Co-primary for fixed and mobile (but not authorized for mobile) • Large contiguous bands 37-38.6 (1.6 GHz) and 42-42.5 (0.5 GHz) • Larger contiguous block possible by combining with LMDS band • Federal use
60 GHz	<ul style="list-style-type: none"> • Co-primary for fixed and mobile • Large contiguous bands 57-64 (7 GHz) and 64-71 (7 GHz) • Unlicensed operation in the 57-64 GHz band (IEEE 802.11ad) • Potentially three 2.3 GHz block licensed operation in the 64-71 GHz band
70/80 GHz	<ul style="list-style-type: none"> • Co-primary for fixed and mobile • Large contiguous bands 71-76 (5 GHz) and 81-86 (5 GHz) • Non-exclusive licensed operation, Database aided spectrum coordination, • Does not support the concept of CMRS (service area-based)
24 GHz	<ul style="list-style-type: none"> • No Mobile allocation; licensed in geographic areas to fixed services

NoI: Licensing/Sharing Possibilities

- Nature of service may affect licensing:
 - In the past, services were generally ubiquitous
 - Business model lead to more localized installations
 - Service may be used for capacity where needed
- NOI Explores Several Options:
 - **Option 1:** Auction rights by service area
 - **Option 2:** Adopt nonexclusive licensing rules using automated frequency coordination
 - **Option 3:** Authorize under unlicensed rules
 - **Option 4:** Hybrid licensing involving sharing between licensed operations and either unlicensed operation or secondary licensed operations
 - **Other Options:** Open for suggestions
- Responses vary but there is support for both licensed and unlicensed models



Networks are Typically
Made Up Of a Combination
of Cell Sizes:

Macro: 1 km – 20 km

Micro: 500 m – 2 km

Pico: 50 m – 500 m

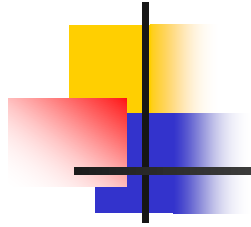
Femto: 4m – 10 m

5G: 200 m? Implications?



Next Steps

- Staff considering next steps in domestic proceeding
- WRC 15 is expected to frame future WRC agenda item to identify spectrum for advanced mobile services
- U.S. is developing its position
- We are working with other nations in multiple fora



Model City Program

Model City Program

- NTIA/FCC Model City Program for Demonstrating and Evaluating Advanced Wireless Spectrum Sharing Technologies
- Outgrowth of PCAST
- Comment invited last summer
- Workshop planned April 15-16 to explore concept, scope, governance, process, technical considerations and funding alternatives.

Some trade-offs to Consider

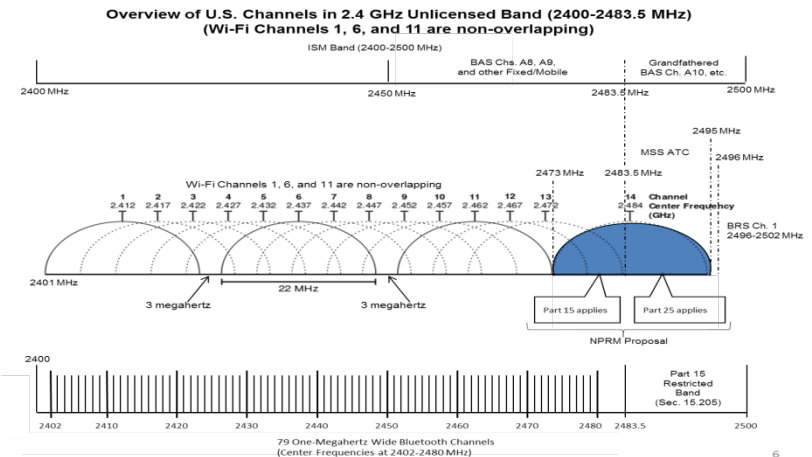
Urban Area:
A "Real Test"
but high risk



Remote Area:
More limited
demonstration
but low risk

Other "Sharing" Matters

- Proceeding on Globalstar's proposed Terrestrial Low Power Service (TLPS)



- Development of LTE-U initially planned for upper 5 GHz unlicensed band
http://www.3gpp.org/news-events/3gpp-news/1660-laa_ieee

IEEE 802 Interim Session
Atlanta, USA
Jan 11-16, 2015

3GPP
A GLOBAL INITIATIVE

3GPP & unlicensed spectrum

Dino Flore
Chairman of 3GPP TSG-RAN
(Qualcomm Technologies Inc.)

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1



Spectrum Sharing: Research and Development

- NTIA: Center for Advanced Communications
- National Information Technology R&D (NITRD)/
Wireless Spectrum R&D (WSRD)
- National Science Foundation
- Defense Applied Research and Development Program: Radars
- The Department of Defense (DOD) parties interested in establishing a
Section 845 Other Transaction (OTA) agreement to develop and
mature technologies and support policy development to enable
advanced approaches to electromagnetic spectrum use.
- Academic Work
- DySpan
- And YOU!



Conclusion

Questions?