

Vision and Regulatory Framework to Promote Evolution of Dynamic Spectrum Access



Regulatory Workshop Presentation

Peter A. Tenhula
Shared Spectrum Company (USA)
Chair, Wireless Innovation
Forum Regulatory Committee

Presentation Outline

- Background
 - U.S. and International Regulatory Efforts
 - Various Visions for Regulatory Evolution/Market Deployment
- SSC's Outlook
 - Three Overlapping Stages
 - Regulatory Steps
- Recommendation: “policy-based” regulatory framework
 - What types of spectrum sharing policy rules are necessary to take into account incumbent protection requirements and incentives?

Summary

- Long-term visions are becoming clouded by short-term reality
- Near-Term opportunities are in TVWS and U.S. Federal Bands
- Regulators are trying to fit DSA round pegs into square holes of legacy regulatory models
- Long-Term opportunity is policy-based regulatory framework overlaying legacy models
- Missing ingredient: Incentives

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Background

- U.S. Efforts
 - FCC SDR, Cog. Radio, 2ndary Markets & TVWS
 - FCC Broadband Plan & DSA Notice of Inquiry
 - President Obama's Spectrum Memo & Implementation
- International Efforts (primarily in Europe)
 - U.K. OFCOM cog. devices in TVWS/interleaved bands, secondary trading initiative
 - EU Radio Spectrum Policy Group (RSPG) Cog. Radio and Spectrum Sharing Initiatives
 - EU COST-TERRA Initiative
 - Industry Canada TVWS Consultation
 - Asia/Pacific Rim TVWS Trials (Singapore, Japan, Korea)

Background – Winn Forum Initiative

Forum's Roadmap Committee project to identify major innovations needed to create foundation for next generation of wireless devices

- Oct. 2011 Report created first list of “Top 10 Most Wanted Wireless Innovations”
 - #10: A new flexible regulatory framework to enable the operation of advanced wireless devices and systems that meet certain reconfigurability requirements across multiple bands and wireless services on a temporary, cooperative or opportunistic basis.
 - lower regulatory barriers to entry
 - promote technological innovation
 - easier and faster access to spectrum
 - enable incumbents and entrepreneurs to pursue new business opportunities throughout the wireless value chain
 - Examples (SSC, RSPG, COST-TERRA)

Various Perspectives/Taxonomies

- Peha Spectrum Sharing Taxonomy
- EU-RSPG Proposed Regulatory Framework
- Zhao et. al DSA Taxonomy
- Chapin and Lehr value chains for DSA-based wireless services
- FCC-SPTF Interference Temperature Approach
- Tenhula's Interdisciplinary/Cross Cross-Layer Regulatory Approaches
- DISA Spectrum Management and Spectrum Access Transformation
- Matheson and Morris Licensed Electrospace Rights (LERs)

Peha Taxonomy (1)

Figure 1: Examples of spectrum-sharing models of each type.
(References to Sections of Paper)

	Sharing Among Equals [Horizontal]	Primary-Secondary Sharing [Vertical]
Coexistence	<ul style="list-style-type: none"> - All devices share unlicensed bands. (3.1) - Unlicensed secondary devices share with each other when & where not used by primary users. (3.3) - LMR public safety systems share through distributed [decentralized] trunking. (3.4) 	<ul style="list-style-type: none"> - Secondary devices use cognitive radio to opportunistically share with primary spectrum users. (3.2) - Secondary devices use GPS and a database of transmitter locations to access spectrum where primary users do not operate. (3.2) - Secondary devices use ultrawideband technology to share spectrum with primary users. (3.2)
Cooperation	<ul style="list-style-type: none"> - Unlicensed devices all use prescribed common protocols and carry each other's traffic in a cooperative commons managed by a regulator or license-holder. (3.1) - Unlicensed secondary devices all communicate and cooperate to prevent interference to primary spectrum users and each other. (3.3) - LMR public safety communications systems share spectrum through centralized trunking (3.4) 	<ul style="list-style-type: none"> - Secondary devices explicitly request permission from a license-holder whenever they wish to transmit in a real-time secondary market. (3.2) - An interruptible system has exclusive rights to spectrum until or unless a primary user (such as public safety) temporarily preempts this system. (3.2) - One cellular carrier experiencing excessive call volume coordinates with another to briefly use the latter's spectrum for a fee. (3.4)

Peha Taxonomy (2)

Figure 2: Examples of licensed and unlicensed secondary systems

	Secondary is unlicensed	Secondary is licensed
Coexistence between primary and secondary	Primary system: Licensed TV broadcasters. Secondary systems: Opportunistic devices with no quality of service guarantees	Primary System: Licensed TV broadcasters Secondary system: Microcellular or cellular network which defers to primary, but does not share with other secondaries.
Cooperation between primary and secondary	Primary system: Cellular Secondary systems: Devices that get temporary quality of service guarantees in a real-time secondary market	Primary system: Public safety Secondary system: Cellular network with exclusive but interruptible access to spectrum

EU-RSPG Proposed Framework

- “vertical sharing” – cognitive radios share spectrum with existing users
- “horizontal sharing” – cognitive radio technologies have same rights to access spectrum as existing users
- “collective use of spectrum” (CUS) – allows undetermined/unlimited number of independent users and/or devices to access spectrum in same range of frequencies at same time and place under “well-defined set of conditions”
- “Licensed Shared Access” (LSA) – individual licensed regime of limited number of licensees in a frequency band already allocated to incumbent users for which additional users allowed to use spectrum in accordance with sharing rules thereby allowing all licensees to provide a “certain level of QoS”

EU-RSPG Summary (1)

5.3 Summary of Regulatory Intervention

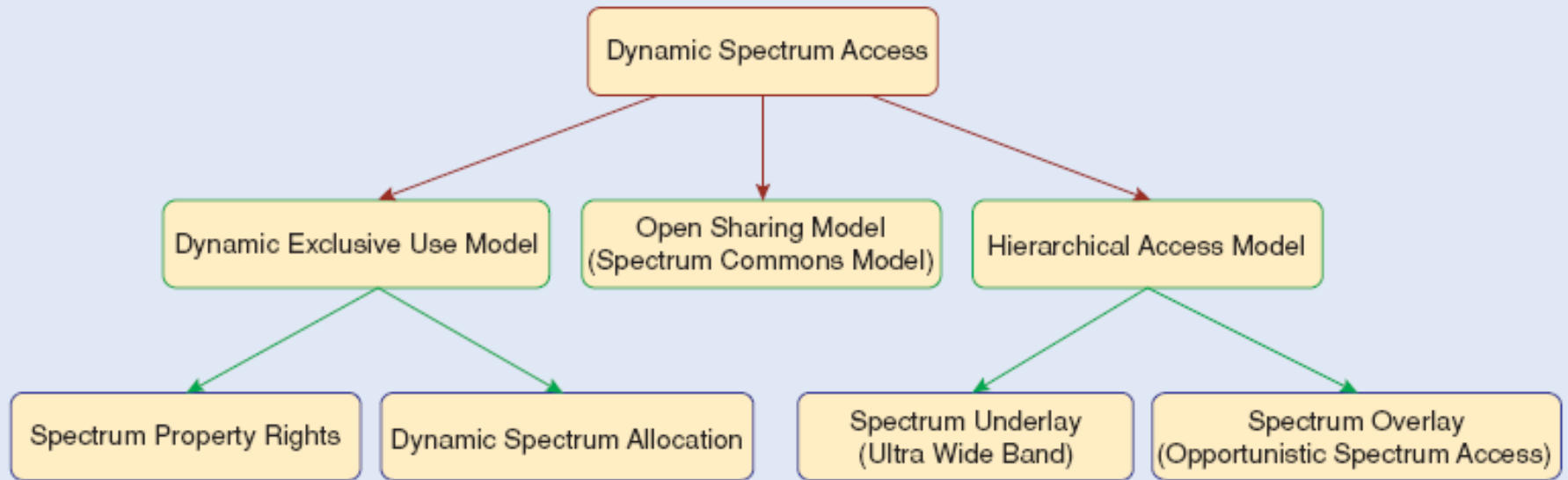
Regulatory Intervention	Vertical Sharing	Horizontal Sharing
Collective Use of Spectrum (CUS) Model (license-exempt use, light licensing and private commons)	<ul style="list-style-type: none">• Designate the frequency band where cognitive radio could share spectrum with existing users on an opportunistic basis.• Define the appropriate technical conditions for the cognitive devices.	<ul style="list-style-type: none">• Designate the frequency band to allow usage on a cognitive basis which does not interfere with existing users;• Define technical conditions for the block of spectrum where cognitive radio will operate within.
	<ul style="list-style-type: none">• Cognitive Technology (CT) devices will need to be able to adapt to new sharing conditions in line with evolution of other radio systems;• Sharing between cognitive radios could be set between themselves through industry standardisation or negotiated access between the spectrum users;• Ensure equitable and non-discriminatory access to spectrum for all the cognitive users and to ensure competition.	

EU-RSPG Summary (2)

5.3 Summary of Regulatory Intervention (ctd.)

Regulatory Intervention	Vertical Sharing	Horizontal Sharing
Rights of spectrum usage could be tradable or leased	<ul style="list-style-type: none">• Define the framework for trading or leasing of rights of spectrum usage (including, where needed, QoS requirements);• Assess the results of negotiations between market parties and their effects on e.g., competition and approve them.	<ul style="list-style-type: none">• Define the framework for trading and leasing of rights of spectrum usage;• Provide defined mechanisms in case of disputes and interferences issues and in case of not fulfilling the conditions of use.
	<ul style="list-style-type: none">• Ensure that the rights of spectrum usage are tradable or could be leased and are flexible <p>Identification of spectrum for cognitive access lies with the existing licensed holders and not with regulators.</p>	

Zhao et. al DSA Taxonomy



[FIG1] A taxonomy of dynamic spectrum access.

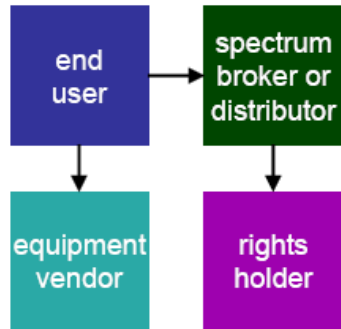
cross-layer approach that integrates signal processing and networking with regulatory policy making

Zhao et. al Opportunistic Spectrum Access (OSA)

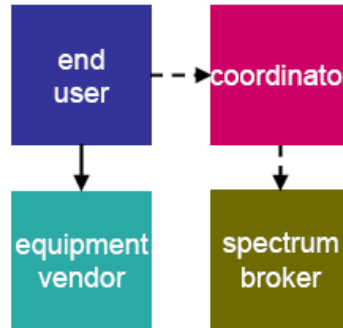
Basic Components of OSA Overlay Approach

- spectrum opportunity identification
 - module responsible for accurately identifying and intelligently tracking idle frequency bands that are dynamic in both time and space
- spectrum opportunity exploitation
 - module takes input from the opportunity identification module and decides whether and how a transmission should take place
- regulatory policy
 - defines the basic etiquette for secondary users to ensure compatibility with legacy systems
 - Fixed vs. Dynamic/Open
 - Centralized vs. Decentralized
 - Implemented on radio devices

Chapin & Lehr: Potential value chains for DSA-based wireless services

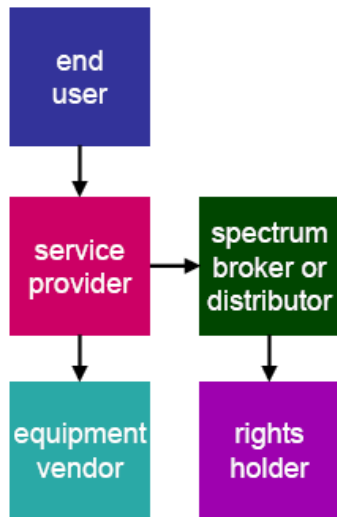


User acquires spectrum to support their network

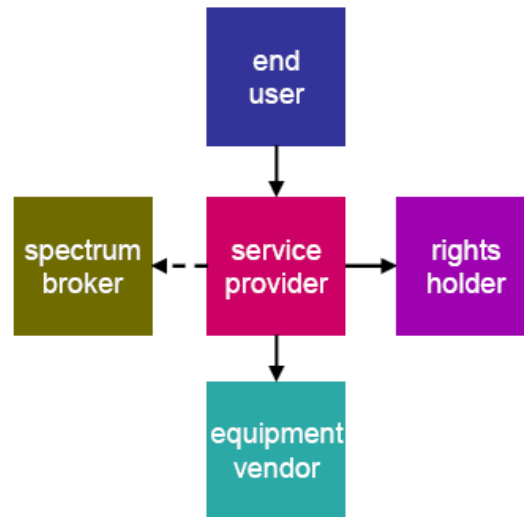


Viral network

In case of noncooperative DSA, rights holder is removed but the rest of the chain is unchanged.



New entrant service provider



Sophisticated service provider
(incumbent using DSA for peak loads)

Dotted arrows indicate small revenue flows.

Chapin & Lehr: Potential role of spectrum brokers/distributors

New intermediaries created by DSA that specialize in spectrum trading

- ensure adequate market liquidity
- lower transaction costs

Simple spectrum broker

- Matches buyers and sellers

Spectrum distributor

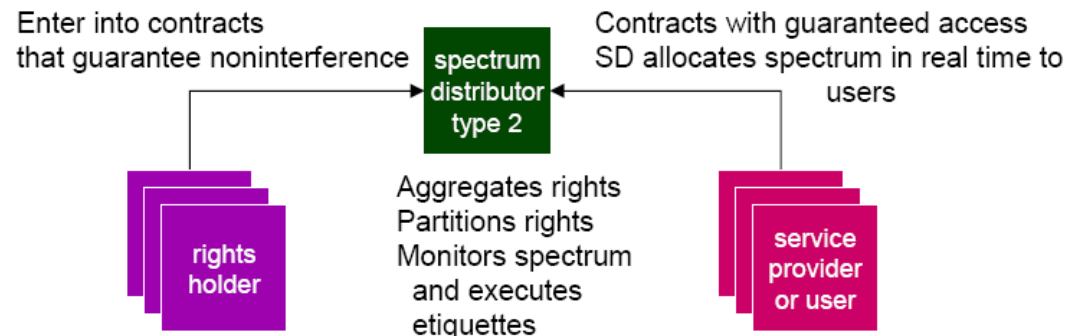
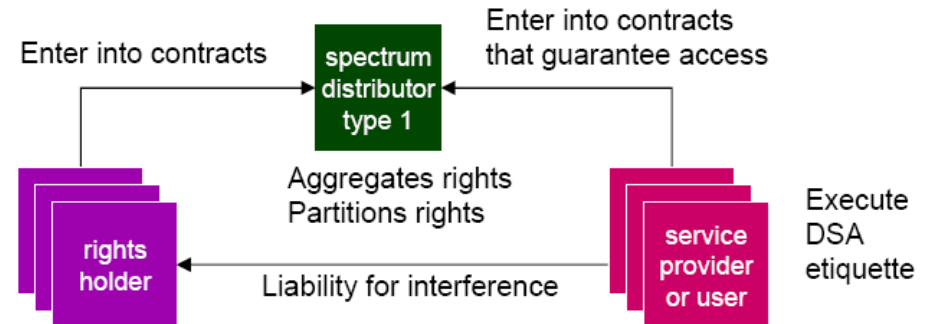
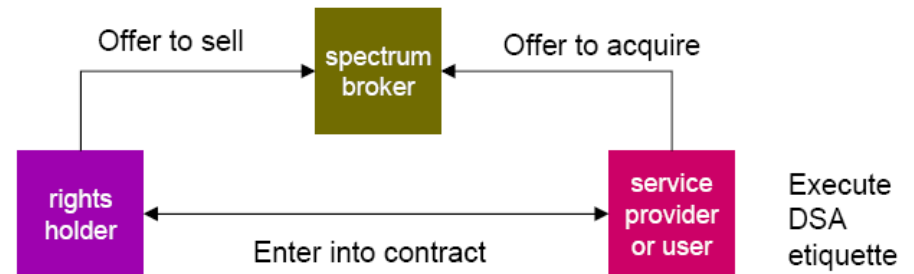
- Adds value by aggregating and partitioning spectrum access rights

Spectrum distributor type 1

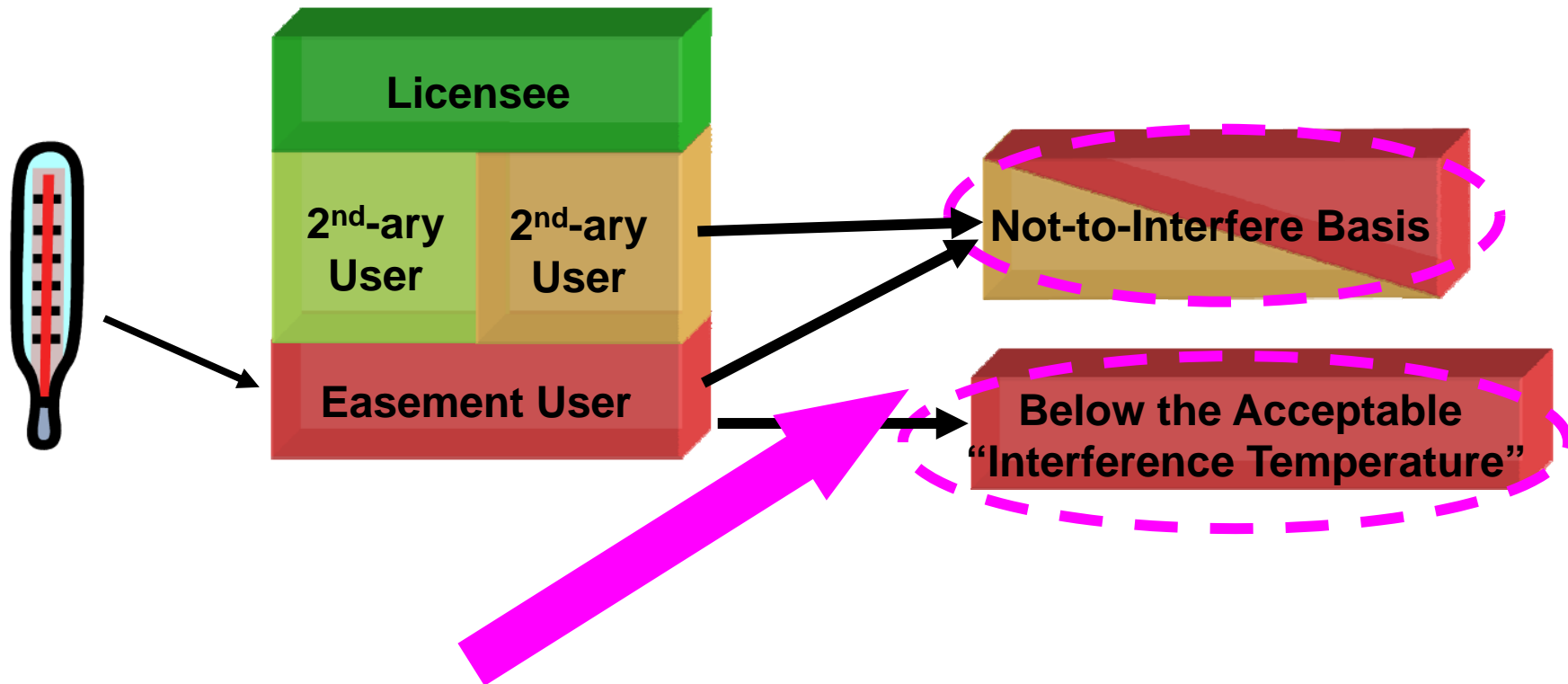
- Contracts with end-users to deliver QOS-differentiated spectrum access
- Acquires spectrum rights through contracts with primary rights holders
- Exploits easements

Spectrum distributor type 2

- Trusted third party between primary and secondary users
- Might install and operate monitoring and analysis systems
- Could also set and enforce standards for secondary user devices.

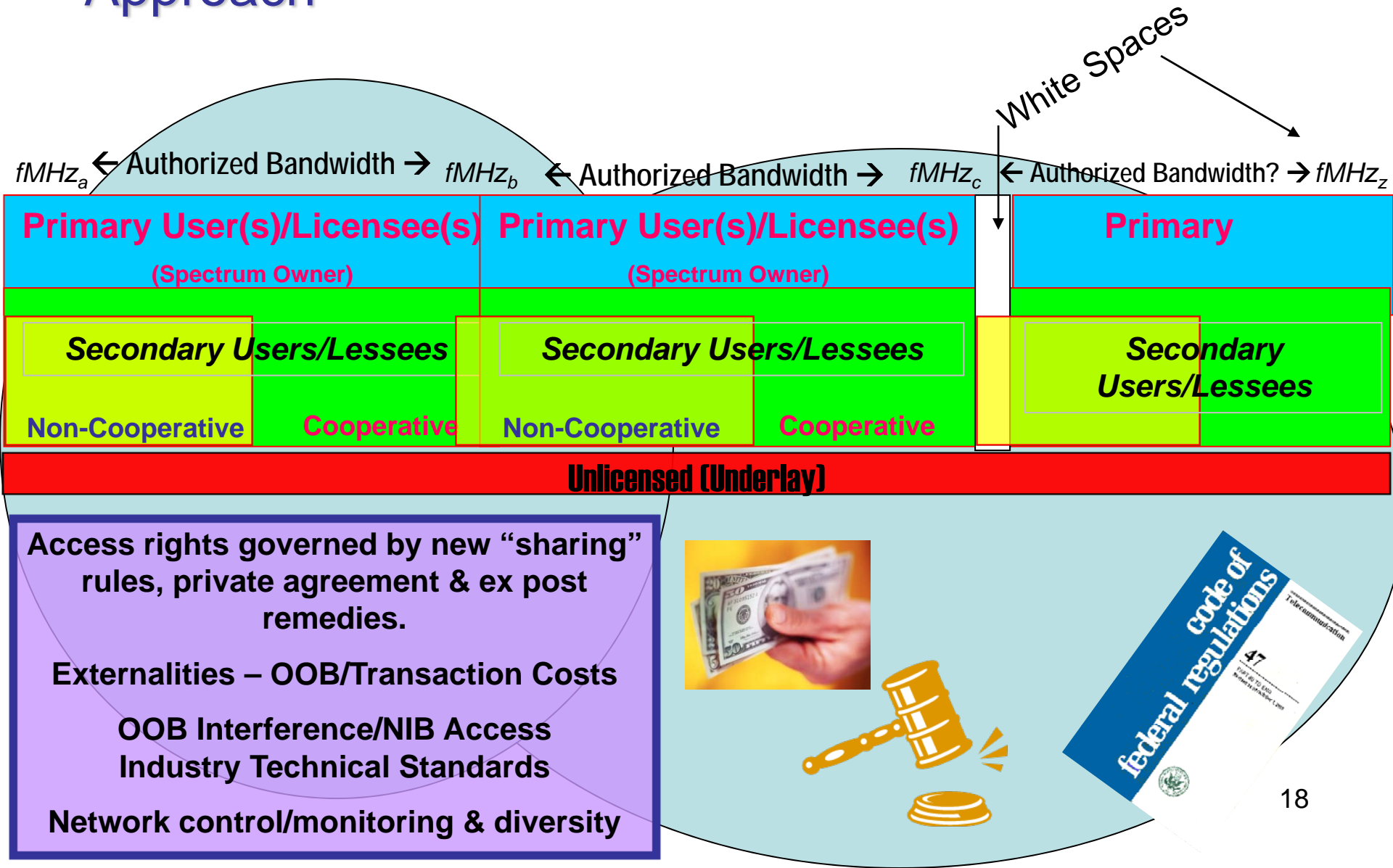


FCC SPTF Interference Temperature Model

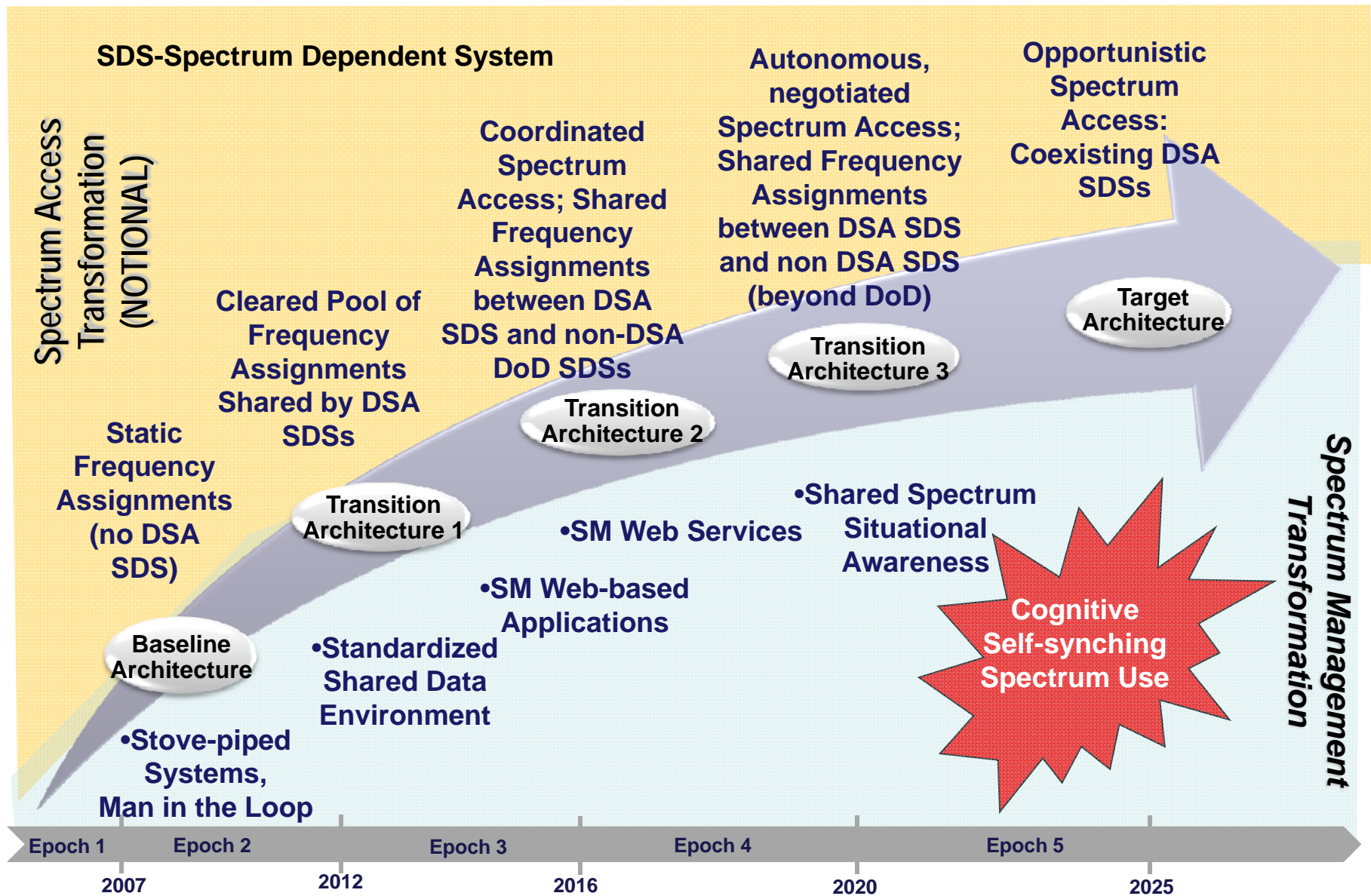


Cognitive Radios

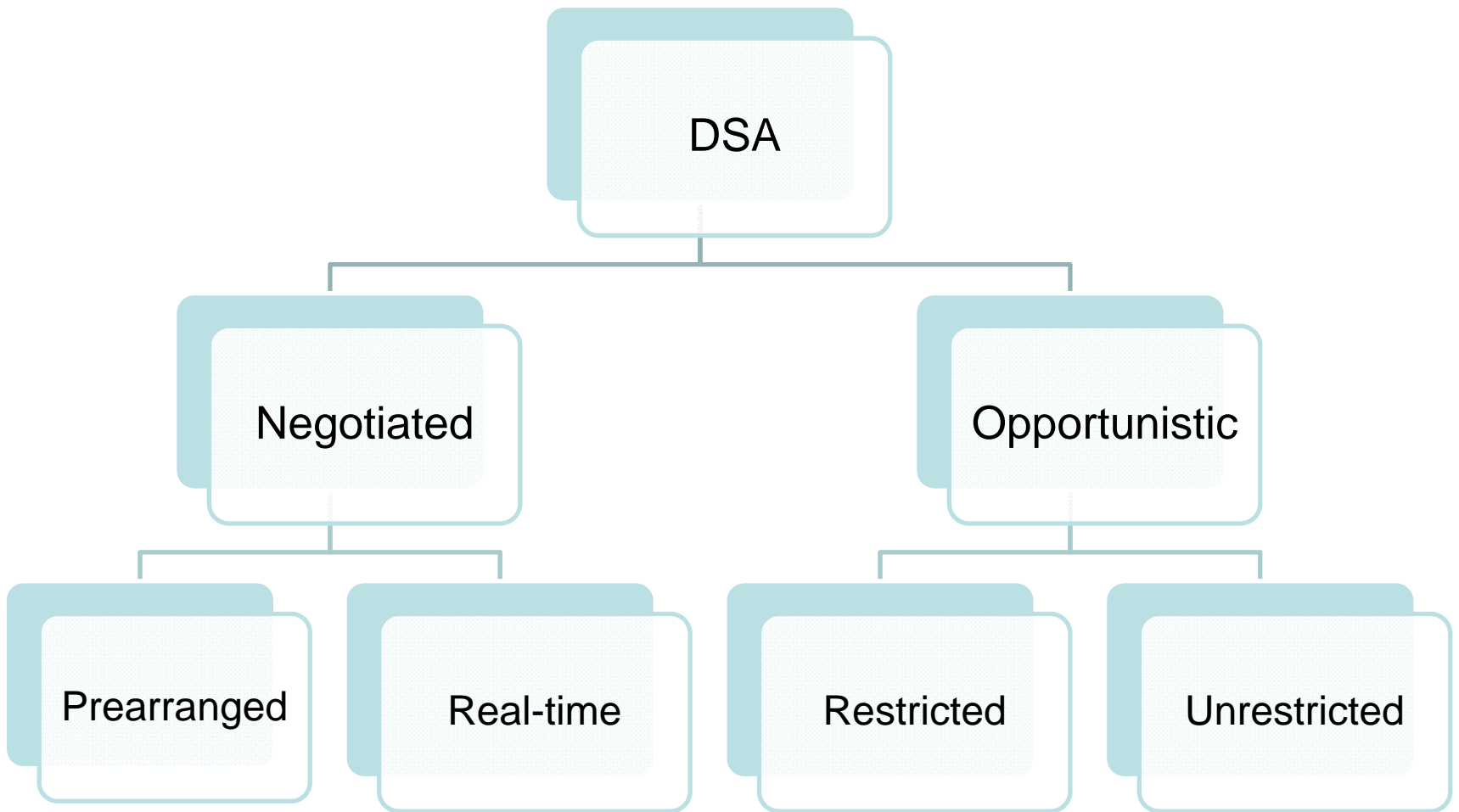
Tenhula's Interdisciplinary/Cross-Layer Regulatory Approach



DoD Spectrum Mgt/Access Transformation



Yet Another Taxonomy



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DSA Regulatory Evolution

How DSA and “opportunistic” sharing will likely evolve – Three Stages

- Stage 1: Internal & Unlicensed/Localized Deployment
(voluntary/no negotiation)
- Stage 2: Cooperative Access/Secondary Markets
(voluntary/negotiation/broker)
- Stage 3: “Opportunistic” Access
(involuntary/no negotiation)

DSA Regulatory Evolution – Stage 1

Internal & Unlicensed/Localized Deployment (voluntary/no negotiation)

- Examples: Military in Military Bands; Carrier X in Carrier X Bands; TV White Spaces, 5.8 GHz DFS and other low-power, unlicensed/lightly licensed bands
- Timing: Small scale deployments this year; larger-scale in 2-3 years (dependent on market forces & technology/device acceptance)
- U.S. regulatory status: Allowed so long as operations consistent with service rules, Parts 2, 15, 22, 24, 27, 90, *etc.* or NTIA Manual (Non-Fed & Fed)

DSA Regulatory Evolution – Stage 2

Cooperative Access/Secondary Markets (voluntary/negotiation/broker)

- Examples: secondary market leasing/brokers; Fed/non-Fed sharing/leasing arrangements; adjacent band/area interference resolution; private commons
- Timing: 3-5 years (dependent on market forces, technology acceptance & some regulatory)
- U.S. regulatory status:
 - Leasing allowed (non-Fed only)
 - case-by-case interference resolution/deconfliction
 - new law/regulations for coordination incentives/re-allocation (Fed/non-Fed sharing/leasing)

DSA Regulatory Evolution – Stage 3

Opportunistic Access

(involuntary/no negotiation)

–Examples:

- vacant, non-licensed bands (e.g., other white space “sandboxes”, auction left-overs, un-assigned Federal bands)
- potential non-cooperative, forced sharing of licensed bands

–Timing:

- could be part of Stage 1 unlicensed/light licensing, but only on localized basis
- only after many years of experience with other dynamic sharing approaches

–U.S. regulatory status: New rulemaking(s) required

Regulatory Steps (U.S.)

- ✓ FCC DSA NOI (Nov. 2010)
- ✓ FCC Spectrum Task Force PN on Sharing Federal Bands (Mar. 2011)
- NPRM(s) to kick off Stage 3 with new flexible policy-based regulatory framework proposal for “sandboxes” and Federal bands
 - Require RF devices to be reconfigurable to avoid squatters & previous (and ongoing) sharing issues
 - Establish minimum hardware/software capabilities for devices in multiple sandbox/opportunistic bands
 - Propose baseline operating parameters with flexibility to deviate via policy controls managed by third-party band managers based on changing circumstances over long- & short-term & in real time (depending on protected/adjacent systems)
 - Defer to standards development already underway (IEEE P1900.5 & P1900.6; WInn Forum MLM)
 - Build enforcement apparatus for interference deconfliction remedies (e.g., activity logs, OTA policy updates/renewals)

Other Proposals

- Leverage standardized approaches & other initiatives
 - policy repositories (e.g., MCEB Pub. 8/XML/OWL)
 - new Consolidated Licensing System (CLS) & TVBD Databases
 - Goal: easy/simultaneous approvals for spectrum access & equipment
- Facilitate acceptance of policy ontology with harmonized regulatory nomenclature for all flexible/sandbox bands (including new repurposed bands)
 - DSA-enabled RF devices can operate seamlessly across multiple bands/services
- Companion NOI for longer-term easement-based sharing of licensed & non-repurposed Federal bands
- Congress needs to pass improvements to the Commercial Spectrum Enhancement Act (CSEA) to provide Federal agencies greater flexibility for reimbursed sharing arrangements

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Overview

- **policy-Based Regulatory Framework**
 - Promotes an Evolution:
 - from static spectrum access to **DYNAMIC** spectrum access
 - from fixed operating parameters to reconfiguration capabilities for reconfigurable RF devices
 - from human-based rules to *machine-readable* rules (small “p” policies) that run on RF devices
 - Shifts focus to fair and efficient enforcement/dispute resolution and away from *ex ante* regulations.
 - Enables spectrum sharing criteria and arrangements that take into account incumbent requirements and incentives
- Use cases and near-term opportunities in shared Federal government bands:

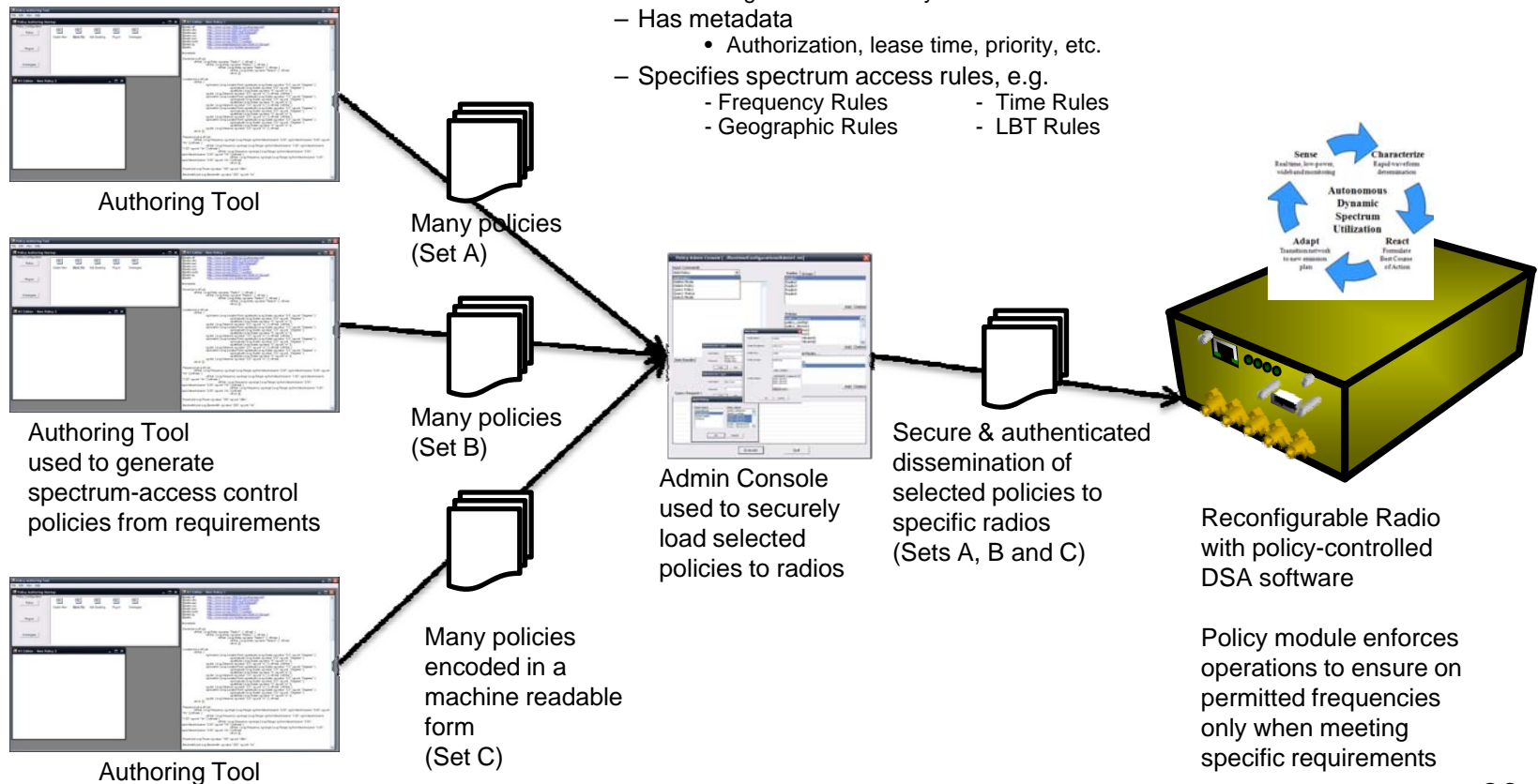
1695-1710 MHz	1710-1755 MHz
3550-3650 MHz	1755-1850 MHz

RF Devices Controlled by Policy-Based Reasoning

Policy-Based Controls Draw on Principles Currently Employed Manually by Spectrum Managers

Policy

- Is permissive or prohibitive
 - De-confliction rule favors prohibitive policy or higher-level authority
- Has metadata
 - Authorization, lease time, priority, etc.
- Specifies spectrum access rules, e.g.
 - Frequency Rules
 - Time Rules
 - Geographic Rules
 - LBT Rules



Spectrum Access Policy Types

Ensure Interference-Free Access with Frequency-Agility

Listen-Before-Talk (LBT) based types	Connectivity based types
Same up and downlink frequencies	Beacon signal reception required to use band
Different, but known, up and downlink frequencies (f1/f2)	Connectivity requirement for any policy (can use certain bands only if connected to data base)
Different, but unknown, up and downlink frequencies, band plan known	
TV band (ATSC signal feature detector)	
Spatial types	Group Behavior based types (distributed sensing)
Geographic border field strength limits	Type 1 - Abandon channel if any node within certain range detects Non-cooperative signal
Database geographic/TV coverage area based	Type 2 - Determine TX power based on estimated interference probability (Belief, Disbelief, and Ignorance estimates fused)
Temporal types	Distributed Control based types
Time of Day restrictions	Automated policy updates if feedback indicates that existing policy is insufficient for non-interference operations
Authorization for finite time duration (with periodic renewals)	Automated policy updates notification of policy revocation or update by policy authority
Device based types	Transaction /Permission Based Types
Ability to measure second and third harmonic	Spectrum lease verification and terms comparison
TX power spectral density limit	Node Identity restrictions (e.g., use while airborne prohibited, use only in fixed applications)
Geo-location capability	
Adjustable I/N Limit for any policy	

Proposed “Incumbent-Friendly” Features*

Sharing conditions/service rules necessary to protect Federal systems can be implemented with policy-based DSA solutions:

- enable Federal incumbents to change/upgrade their radio equipment or operating parameters;
- require new DSA-enabled systems to have backup bands and prohibit operations solely within a protected Federal band;
- provide Federal incumbents (or FCC/NTIA) capability to easily identify sources of harmful interference and/or quickly correct IX problems;
- require DSA systems to have a policy certificate management feature that prevents unauthorized/accidental access to restricted frequencies or geographic areas; and
- give Federal agencies greater flexibility to be reimbursed for spectrum sharing or leasing arrangements.

*SSC Comments in ET Docket No. 10-237 (Feb. 28, 2011)

Spectrum Sharing Criteria and Arrangements

- Spectrum sharing rights/responsibilities can be embodied in:
 - Rules & Regulations
 - User/System Requirements
 - Etiquettes, Standards, Best Practices
 - Machine-readable policies
 - Communications hardware/software protocols
 - Negotiated agreements (or through brokers/band managers)
- Mostly technical and operational sharing issues can be embodied in:
 - Sharing “criteria” (like rules & requirements) and
 - Sharing “agreements” (negotiated or brokered arrangements)
- Implemented/Enforced through:
 - Regulatory development & oversight of sharing criteria
 - Private negotiation by parties and/or brokers of sharing agreements to fill in any gaps and clarify expectations
 - DSA policies

Missing Ingredient: Incentives

3550-3650 MHz NTIA Exclusion Zones*



Defined by distance from coast line considering IX to/from commercial base/mobile systems.

Assumed shipborne radar operating 10 km from coast.

Exclusion zone distances could cover >50% of CONUS pops.

Proposed Alternative Impact/Exclusion Zones*



*SSC Comments in ET Docket No. 10-123 (Apr. 22, 2011)

Proposed Alternative Impact/Exclusion Zones

New wireless broadband systems (“WBS”) subject to minimally necessary, but more flexible exclusion and impact zones.

Advanced WBS (“AWBS”) operators using policy-based DSA could gain access to more spectrum-geography and more consumers.

Up to four different zones could be specified:

- **Impact Zone**

- WBS must accept harmful IX from Federal radar facilities; WBS expected, but not required to employ IX mitigation technology to operate in Impact Zone; could arrange to receive mandatory advisory notices of Federal exercises or expansion (permanent or temporary).
- AWBS would more rapidly and automatically detect IX, determine its location in zone and change operating freq to a “backup” without losing connectivity.

- **WBS Exclusion Zone**

- Only AWBS systems authorized to operate without any mandatory coordination requirements; regulations would mandate equipment capabilities that can be deployed in this zone.

- **AWBS Exclusion Zone**

- Where even AWBS operations are not permitted on or next to the same frequencies being used by the incumbent Federal systems in this area because the AWBS system will more than likely cause harmful interference to the protected Federal system.
- Voluntary coordination could be used to allow AWBS operations at certain times.

- **Occupied Zone**

- Area in which the incumbent Federal system’s signal is so strong that all channels in the shared band are not likely usable by the WBS or AWBS system when a legacy system is operating.
- WBS operators could arrange to receive voluntary advisory notices of Federal exercises or expansion of operations (permanent or temporary).

Summary

- Long-term visions are becoming clouded by short-term reality
- Near-Term opportunities are in TVWS and U.S. Federal Bands
- Regulators are trying to fit DSA round pegs into square holes of legacy regulatory models
- Long-Term opportunity is policy-based regulatory framework overlaying legacy models
- Missing ingredient: Incentives

Thanks!

Questions?