"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

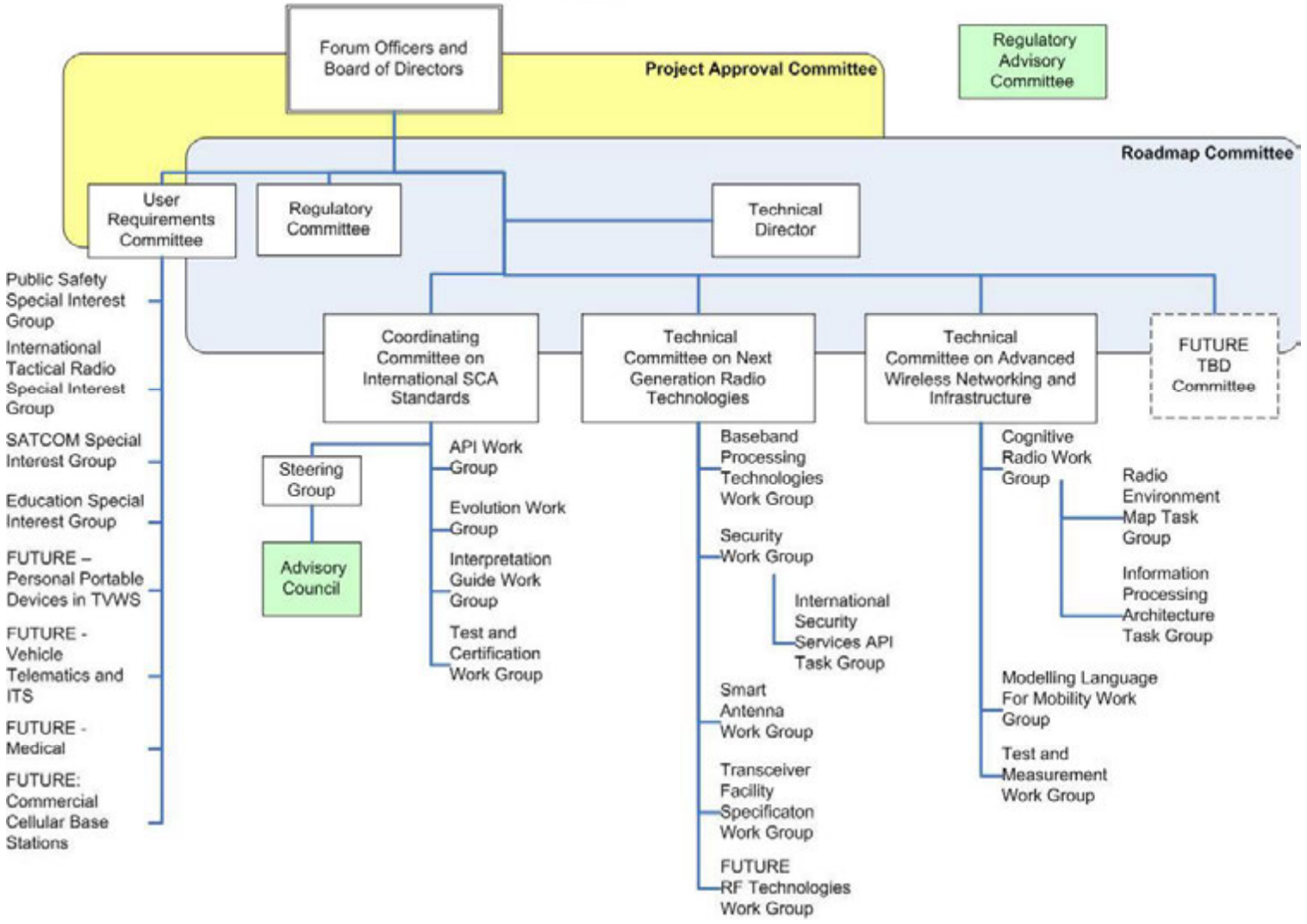
Through this collaboration, the Forum should help its members to:

- 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 …

Organizational Structure for The Wireless Innovation Forum

6/14/2010



Memberships and Partnerships

Wireless Innovation Forum Memberships and Partnerships

Benefits of Cognitive Radio

Presented by James Neel

President Cognitive Radio Technologies

Chair, Wireless Innovation Forum Cognitive Radio Work Group

Contributors

Ihsan Akbar, *Harris*

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Bruce Fette, *General Dynamics C4S*

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Jim Rodenkirch, *Diversified Technology Incorporated / OmegaTek*

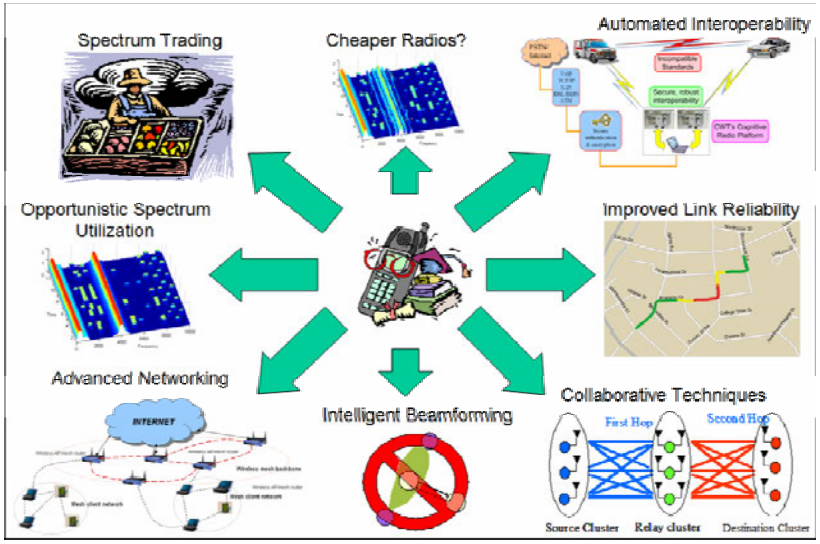
Qun Shi, *ITT*

Richard Taylor, *Harris*

Dandan Wang, *Huawei*

Motivation

- **Hype versus reality**
- **Some structure to burgeoning field**
- **Promote understanding and use of CR and SDR**



Proposed New Applications Enabled by CR	Performance Metrics Improved by CR
• Dynamic spectrum access • Self-organizing networks • Cognitive jamming systems • Cognitive gateways / bridges • Real-time spectrum markets • Synthetic (Cooperative) MIMO • Cognitive spectrum management • Cognitive routing	• Improving spectrum utilization & efficiency • Improving interoperability between legacy and emerging systems • Improving link reliability • Less expensive radios • Enhancing SDR techniques • Extended battery life • Extended coverage

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**

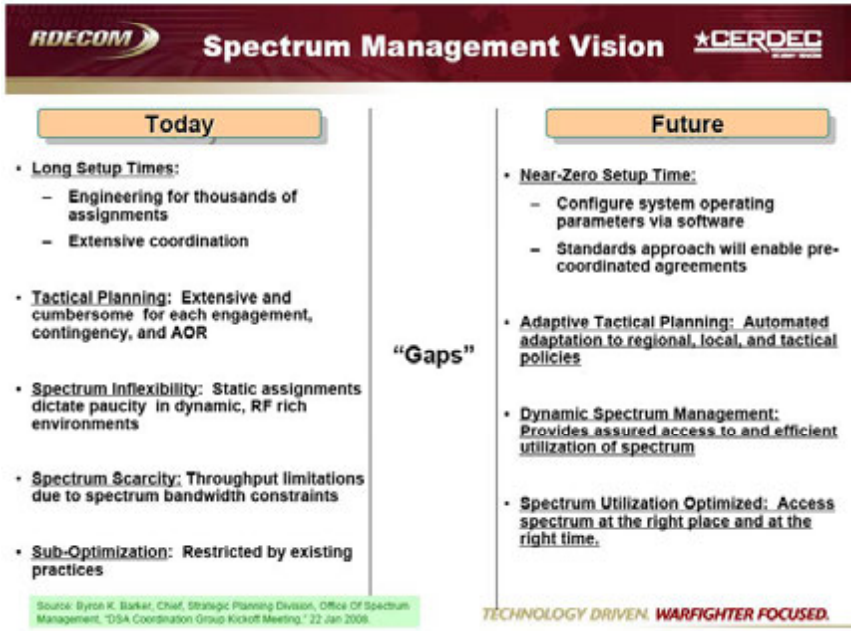


Figure 34: Issues in current military radio systems and desired functions identified by CERDEC. [Hoppe_09]

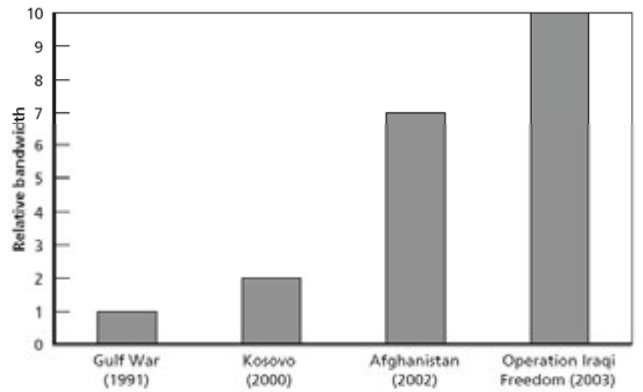


Figure 35: Increase in Bandwidth Demand by US Military Bandwidth Relative to Gulf War [Joe_04]

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]

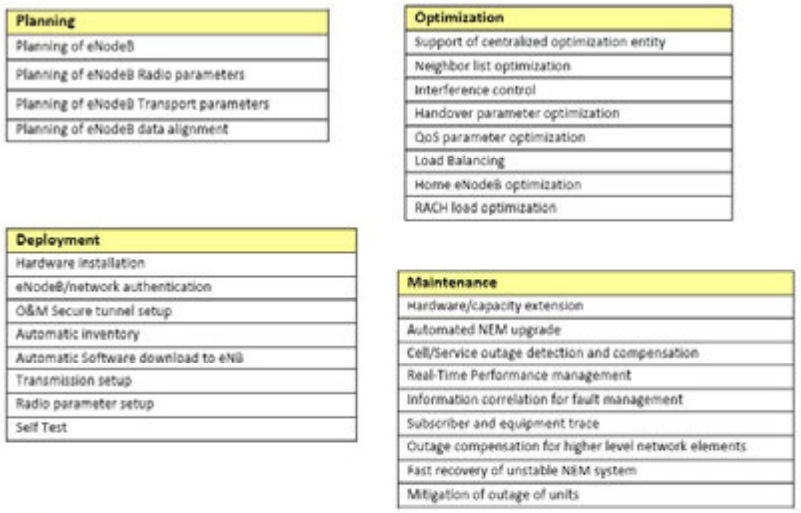
Metric	Threshold	Results
Channel Abandon Time	500 ms	100% in 465 ms
Interference Limit	3 dB	Mean 0.16 dB, Max 0.49 dB
Net Formation	30 s with 6 nodes	90% 3.5 s, 100% 8.68 s
Net Join	5 s	90% 2.07s, 100% 4.36s
Net Re=establish	500 ms	100% 165 ms
Spectrum occupancy	60% with 6 nodes	85% Occupancy @ 83% Confidence

Potential Solutions: Self Organizing Networks

[Brown_08]

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]



Planning
Planning of eNodeB
Planning of eNodeB Radio parameters
Planning of eNodeB Transport parameters
Planning of eNodeB data alignment

Optimization
Support of centralized optimization entity
Neighbor list optimization
Interference control
Handover parameter optimization
QoS parameter optimization
Load Balancing
Home eNodeB optimization
RACH load optimization

Deployment
Hardware installation
eNodeB/network authentication
O&M Secure tunnel setup
Automatic inventory
Automatic Software download to eNB
Transmission setup
Radio parameter setup
Self Test

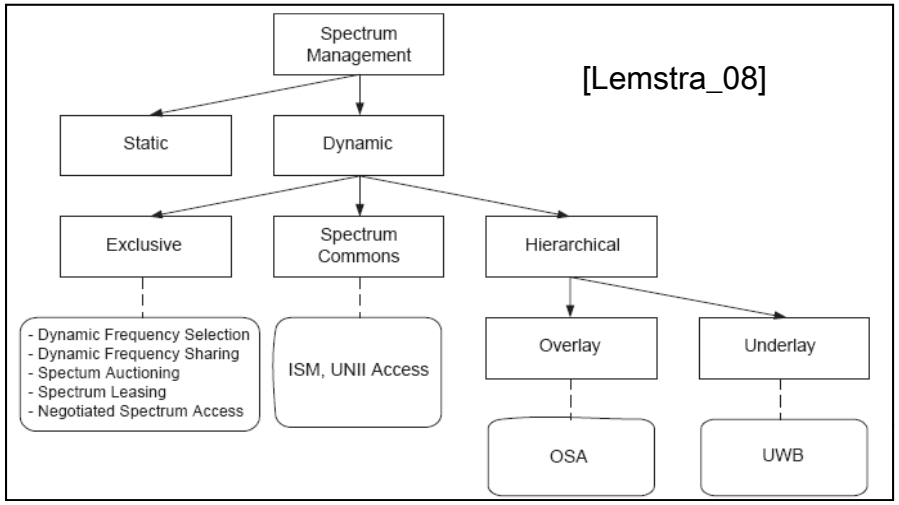
Maintenance
Hardware/capacity extension
Automated NEM upgrade
Cell/Service outage detection and compensation
Real-Time Performance management
Information correlation for fault management
Subscriber and equipment trace
Outage compensation for higher level network elements
Fast recovery of unstable NEM system
Mitigation of outage of units

Figure 32: Optimization use cases for SONs. From Table 1 in [3G Americas_09]

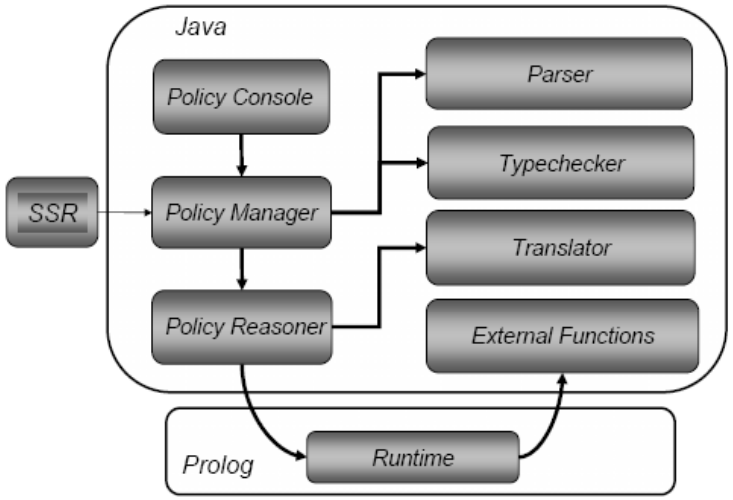
- **3GPP Release 8**
  - automatic inventory, automatic software download, Automatic Neighbor Relation, Automatic Physical Cell ID (PCI) assignment
- **3GPP Release 9**
  - Coverage & Capacity Optimization, Mobility optimization, RACH optimization, and Load Balancing Optimization

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]**



[Lemstra_08]



[Denkar_07]

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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

Selected Cognitive Radio Capabilities and Missions

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

- **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

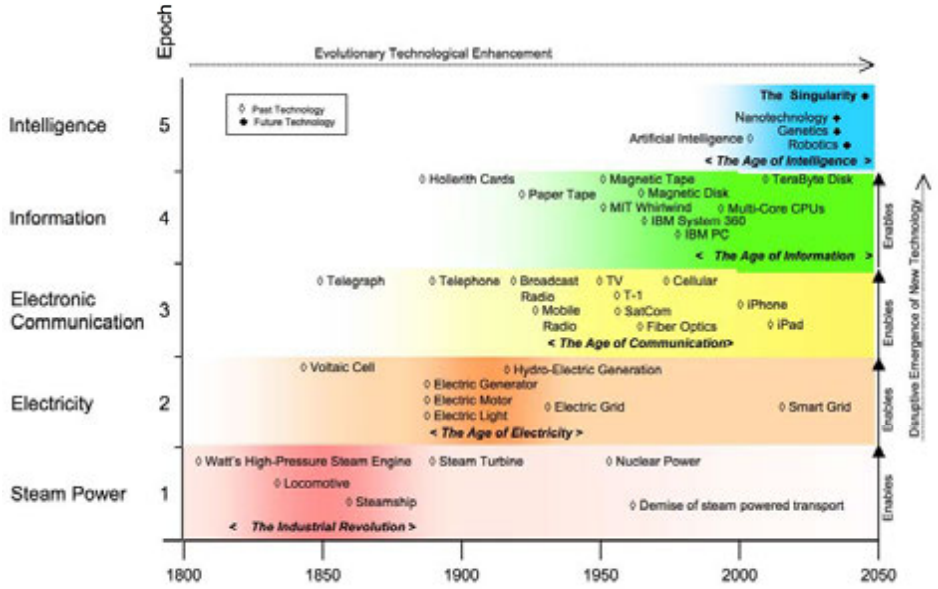
Document Organization

- **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



Technology Epochs and Innovations

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

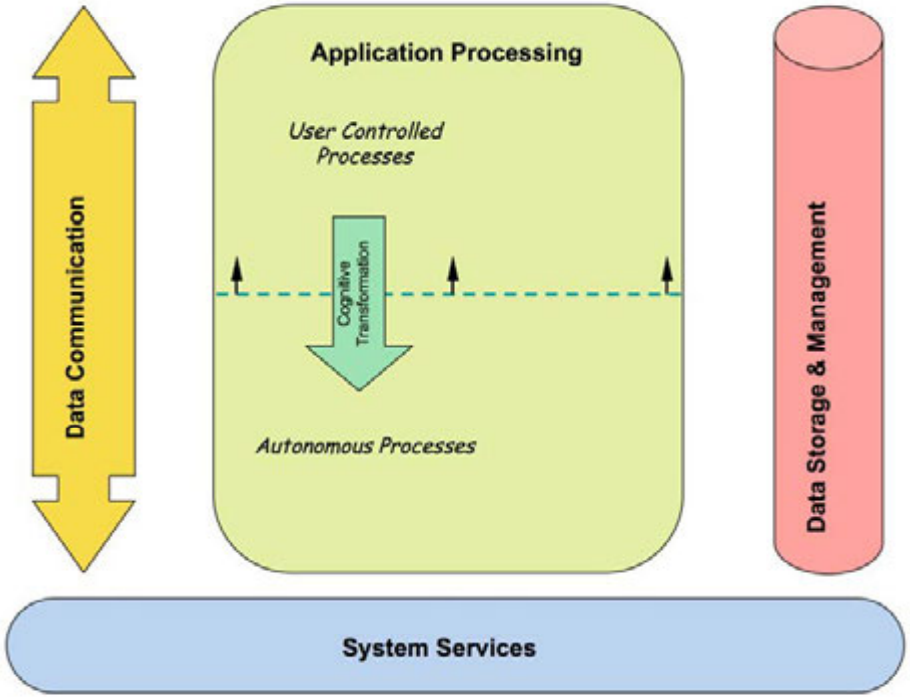
Information System Framework (Section 3)

- **Understanding an Information System is a multi-faceted problem**
- **Hardware consciously excluded to focus on processes**
- **Examples in Appendix**
  - Kindle, LMR, Cellular, TV Broadcast, Inventory Mgmt, Air Traffic Control

Purpose	Application area, motivation, goals, requirements, and preconditions under which the system operates
Scope	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
Technology	Underlying technology that enables the System and is used by it, level of technology maturity, evolutionary or disruptive
Economics	Business case for the System, Revenues, Cost structure, who pays, who profits
Politics	Regulatory considerations, public funding, benefits, legislative support, popular support, volatility of support
Structure	Identification of higher-level System, interfaces to and interaction with sibling Systems, process structure, precursor to System design

Information System Structure (Section 4)

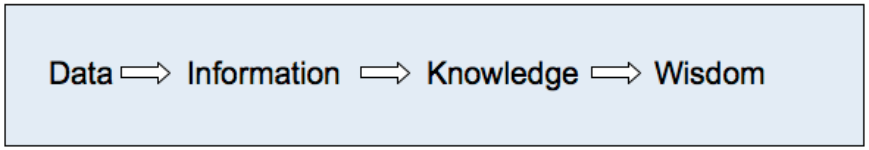
- **System Services**
  - Functions and processes provided by operating systems and other system functions to support system operation
- **Data Storage & Management**
  - Storing, , safeguarding, organizing and retrieving
- **Data Communication**
  - Transfer of data
  - Emphasis on replication
- **Application Processing**
  - Use, transform, combine, compute, create, present information to advancessystem goals.
  - Application dependent

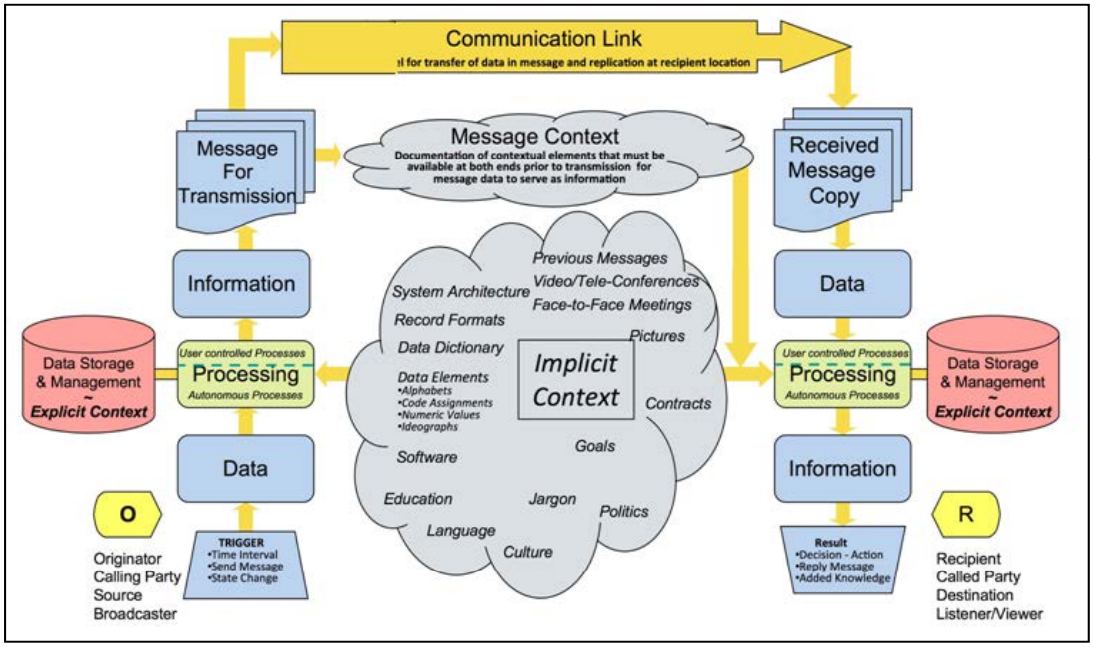


- **"Cognitizing" by transition from user controlled to autonomous processes**

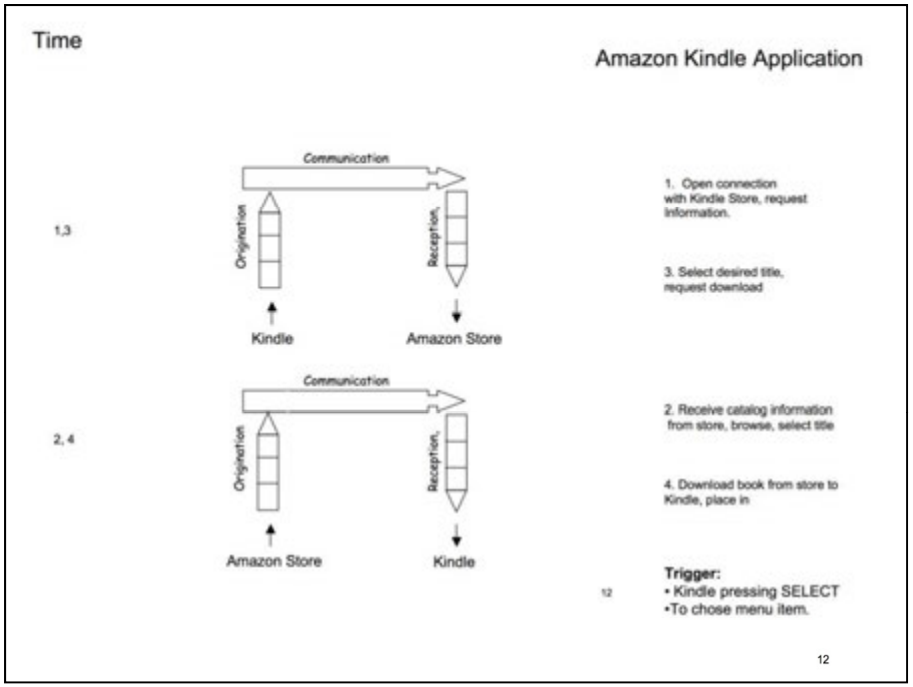
Information System and Context (Section 5)

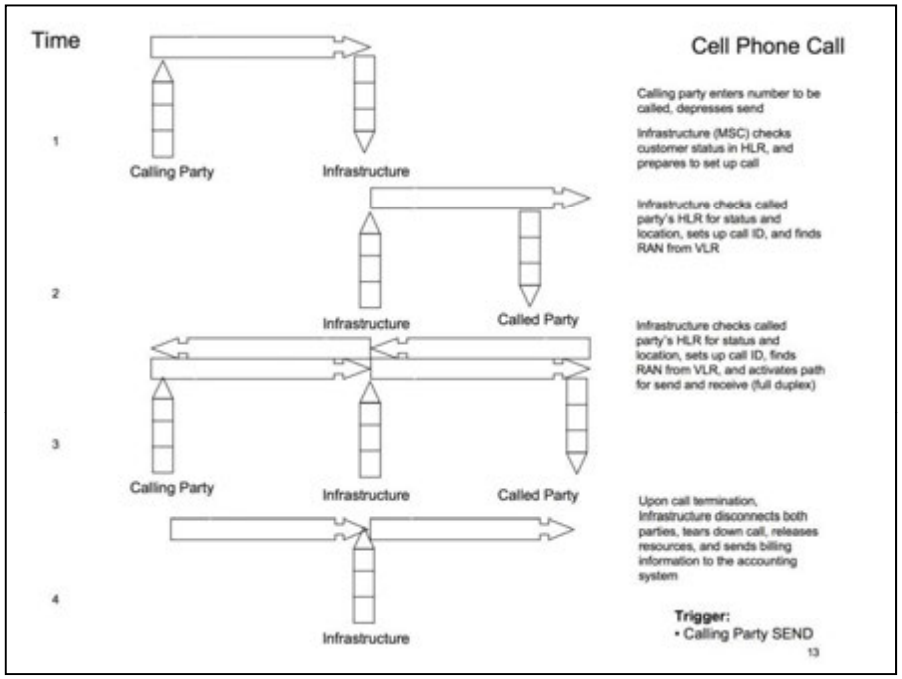
- **How do intelligent agents share information?**
- **Fundamental communications processes**
- **Sharing of data and context for actionable information**





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:**
  - http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-09-2479A1.pdf
- **Rules:**
  - http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-08-260A1.pdf
    - Graphs 201-225
  - 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)]**
4. **KB Enterprises LLC and LS Telcom [Proposal Part 1, Proposal Part 2, Proposal Part 3]**
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

Y. Zhao, B. Le, J. Reed, “Network Support: The Radio Environment Map,” in B. Fette, ed., **Cognitive Radio Technology** Elsivier 2009, ed. 2.

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

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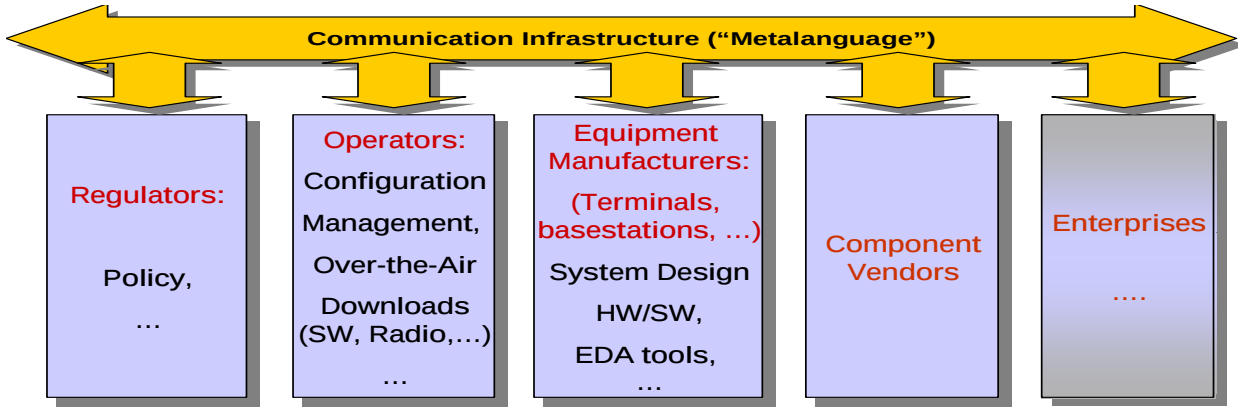
Project Motivation

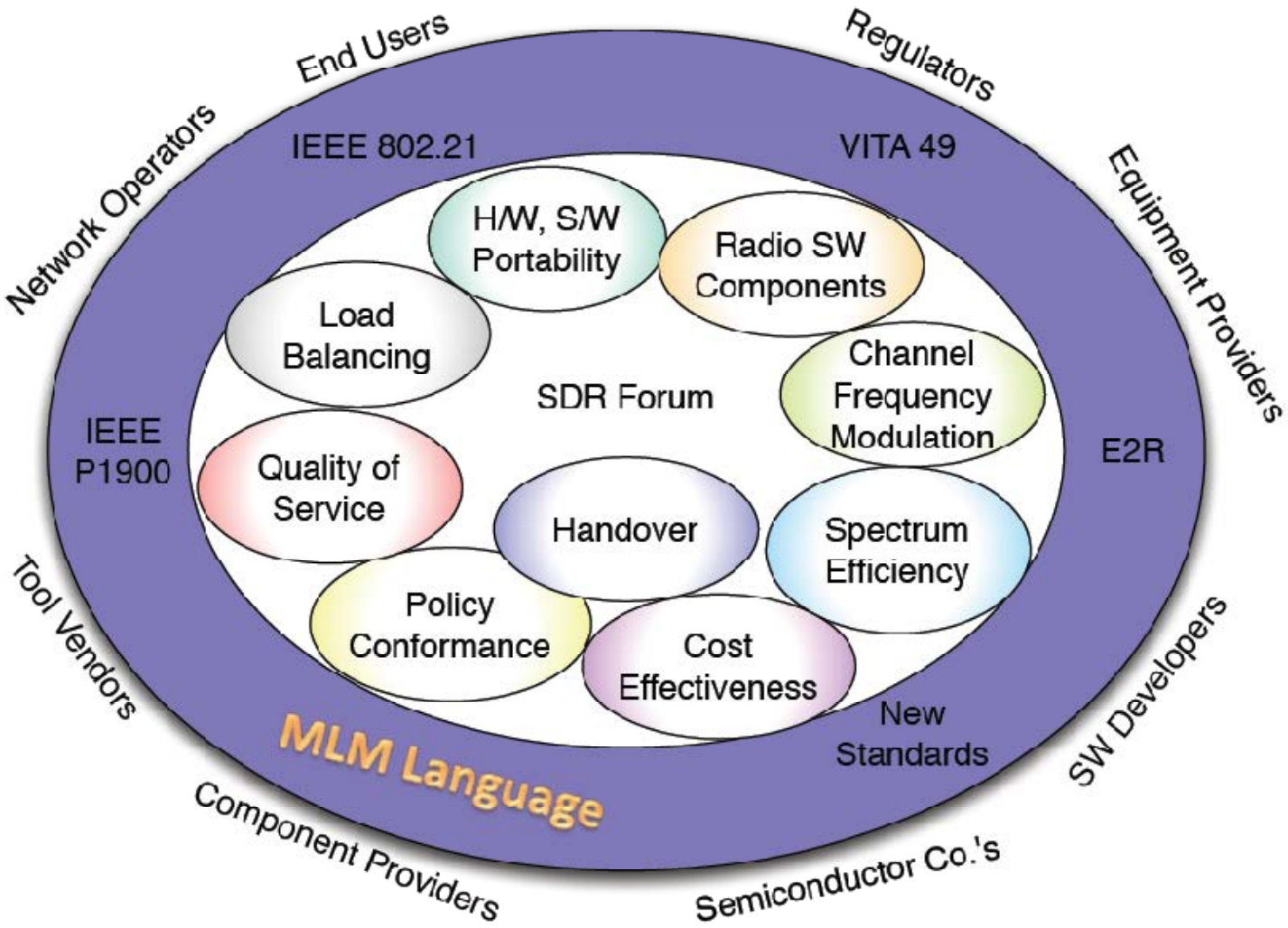
- **The evolution of SDR is leading to reconfigurable networks creating new opportunities and challenges**
- **A language for representing node/network information provides the ability to negotiate and control these reconfigurable networks**
- **All members of the value chain ('actors') have a role**



MLM Project Objectives

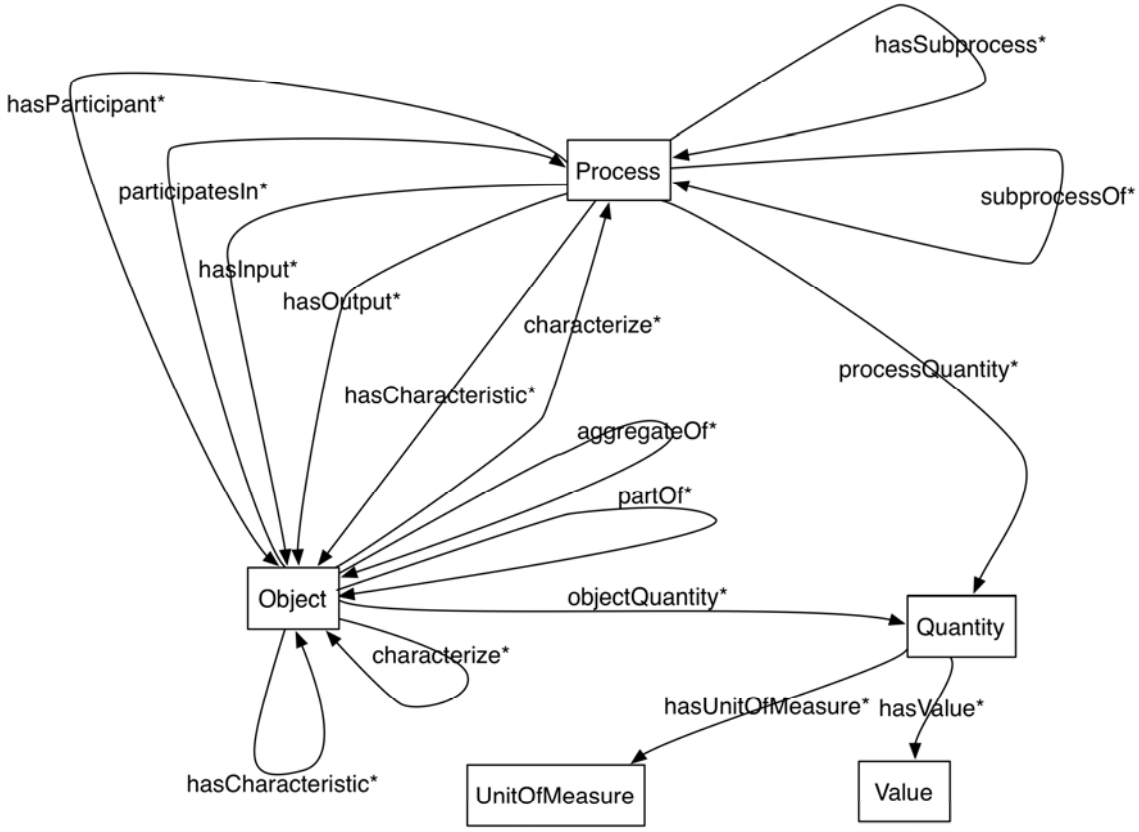
- ***Development of use cases for wireless communication in which the MLM language can facilitate flexible communication,***
- ***Development of Cognitive Radio Ontology (CRO) that is capable of expressing structural, functional and behavioral aspects of models for wireless communication,***
- ***Corresponding 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

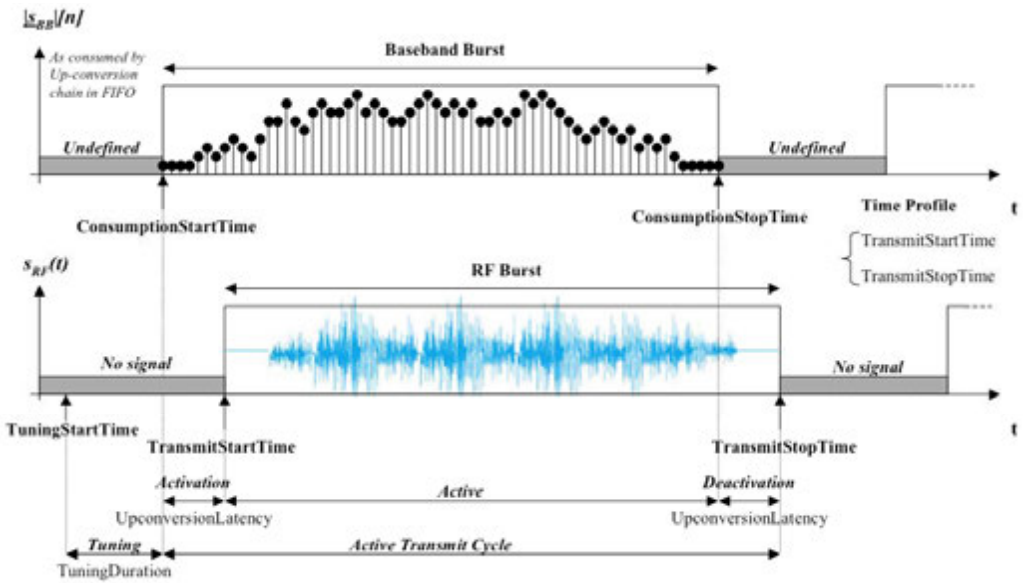


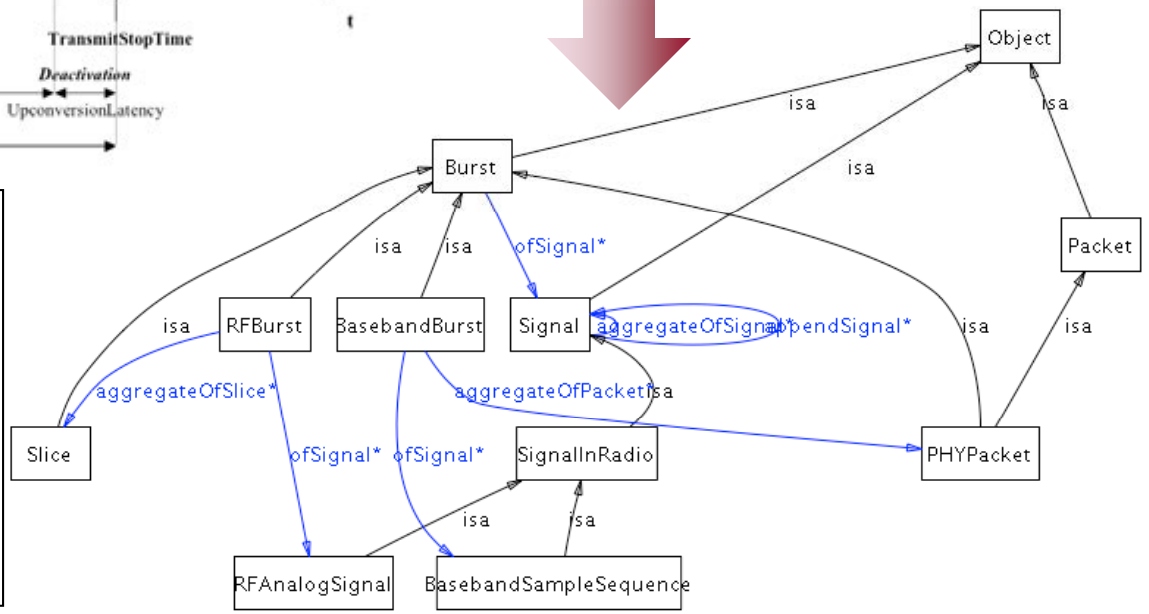
Base Model Concepts

- **Ontology model approach based on concept of *Objects* and *Processes***
  - *Derived from DOLCE*
  - *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.**



Representing Broadband and RF Burst





- **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

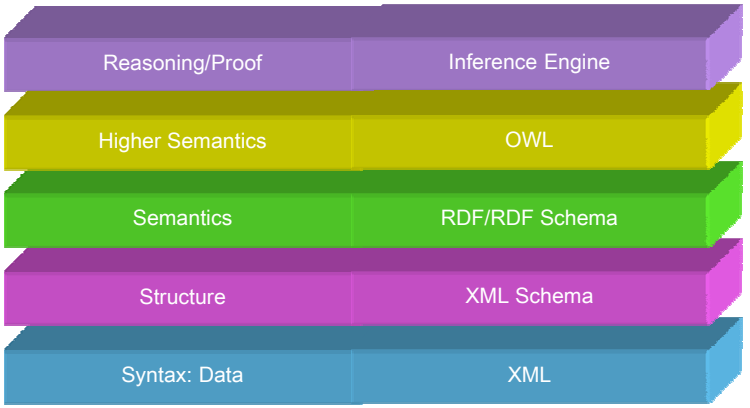
Some Related Efforts

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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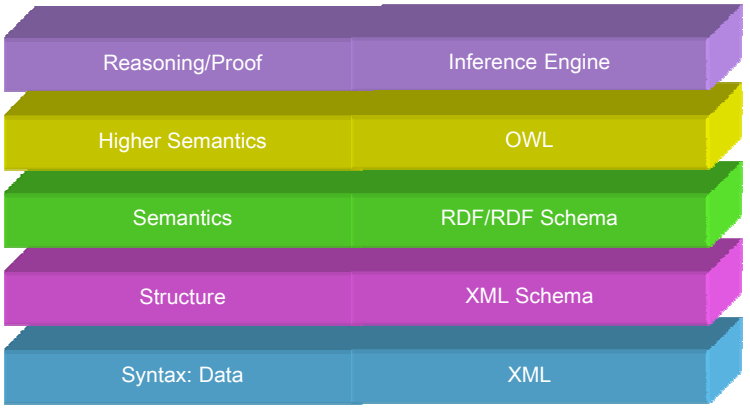


Cognitive Radio Standards

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**
  - http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-08-260A1.pdf
  - 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

TV Channel	Frequency Band	Frequency (MHz)	Allowed Devices
2	VHF	54 – 60	Fixed
5 – 6	VHF	76 – 88	Fixed
7 – 13	VHF	174 – 216	Fixed
14 – 20	UHF	470 – 512	Fixed
21 – 35	UHF	512 – 602	Fixed & Portable
36	UHF	602 – 608	Portable
38	UHF	614 – 620	Portable
39 – 51	UHF	620 – 698	Fixed & Portable

- **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

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

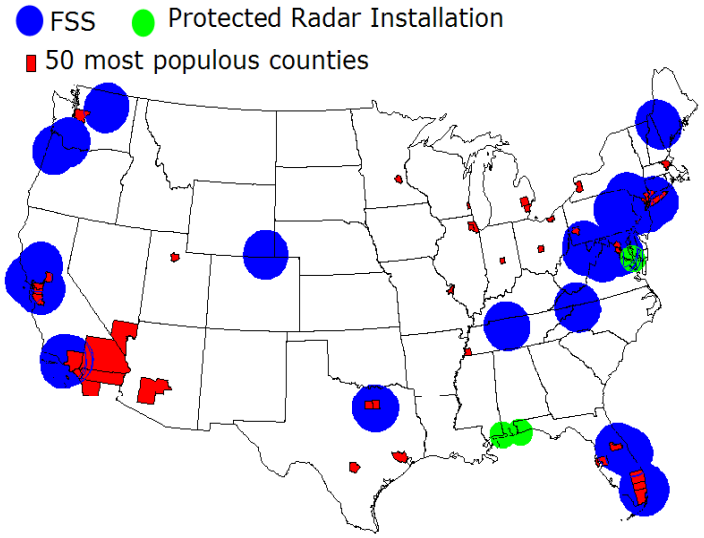
Basis for 802.11af

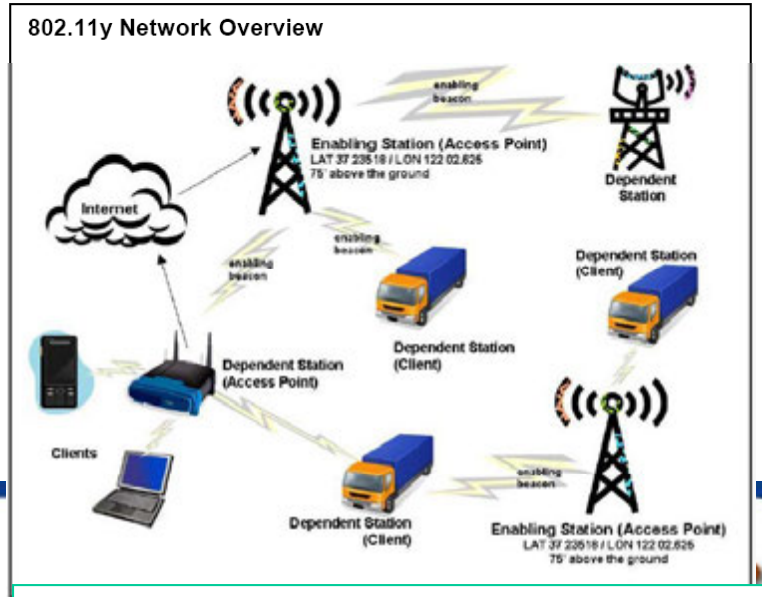
Incumbents

- 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

Source: IEEE 802.11-06/0YYYr0



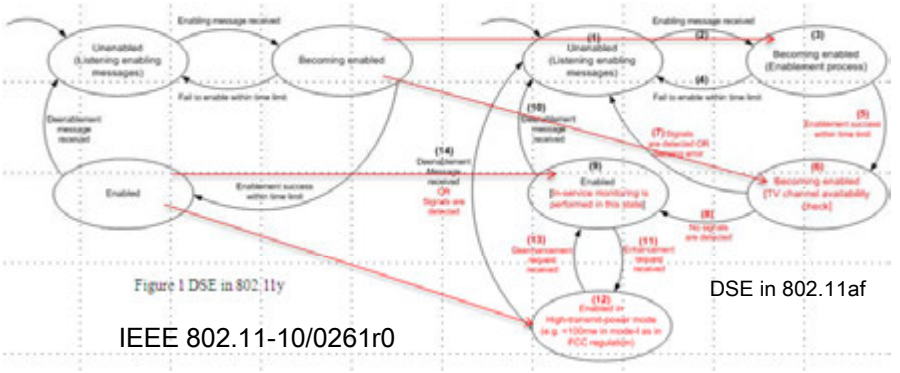


WiFi Alliance, "A New Regulatory and Technical Environment for Wireless Broadband: A Primer on the IEEE 802.11y Amendment,"

802.11af

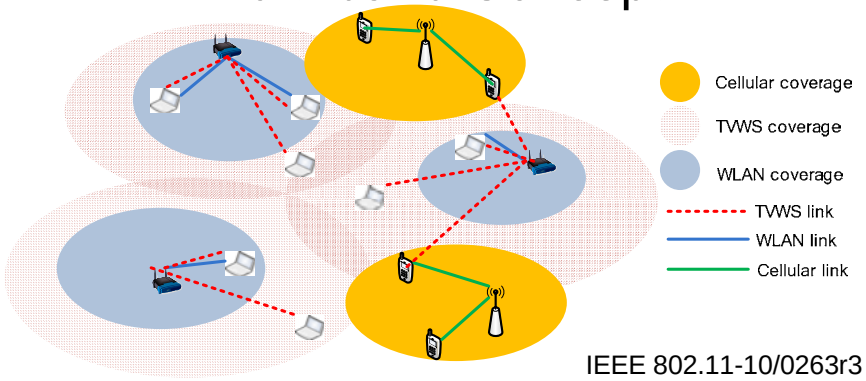
- **Builds on 802.11y**
  - DFS, TPC, quiet periods, policy enabling
  - Hope to be done in two years
  - Maybe only 15 pages…
  - Started in January 2010
- **Initially considered non-contiguous channels**
  - Not in other TVWS proposals
- **Multiband support**
- **Looking for techniques to speed up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

Building on 802.11y (Engagement State machine)



IEEE 802.11-10/0261r0

Multi-band Concept

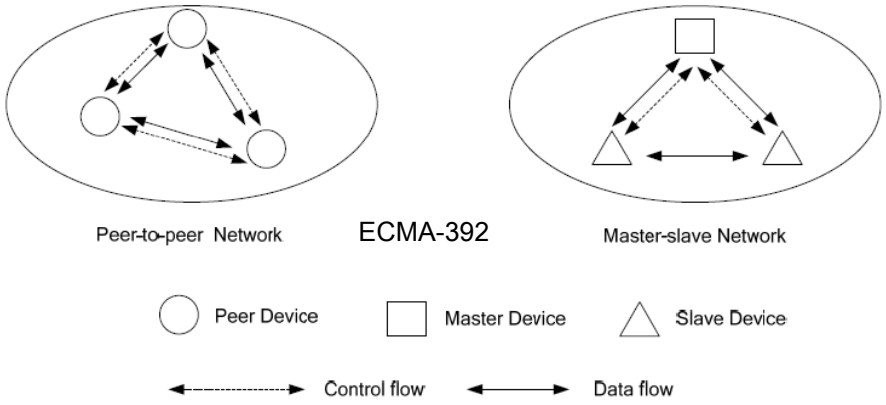


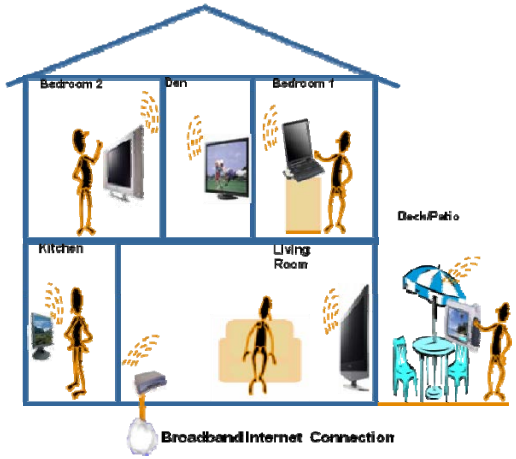
IEEE 802.11-10/0263r3

CogNeA: Cognitive Networking Alliance

- **Industry Alliance formed in 2007**
  - 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**
  - http://www.ecma-international.org/publications/standards/Ecma-392.htm
  - PHY/MAC
  - Bluetooth-like
- **Features:**
  - DFS, TPC, scheduled quiet periods, beacons, geo-location, sensing

Supported Topologies





Ecma/TC48-TG1/2009/017

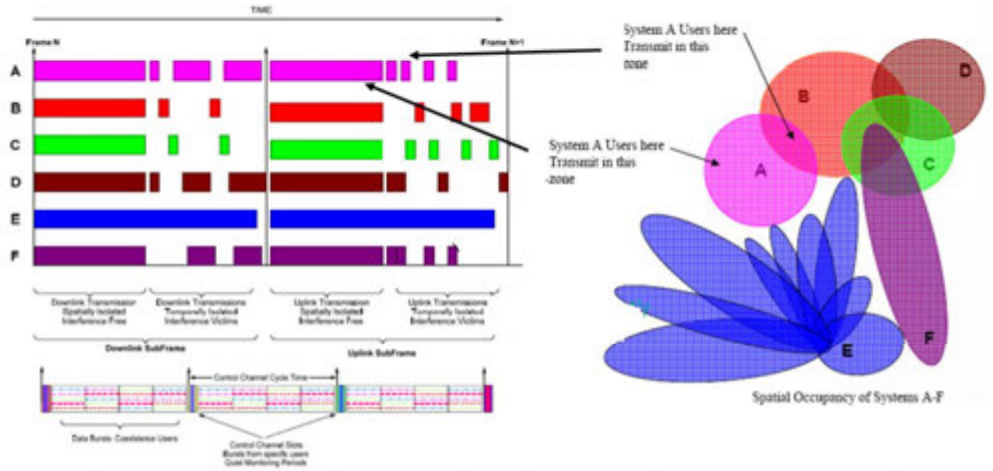
802.16h

- **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

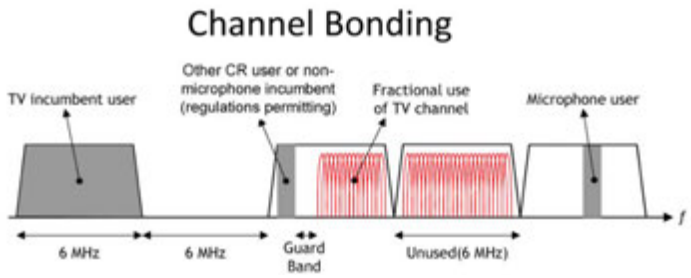
non-collaborative mechanism	*(CXCC:) dynamic frequency selection (DFS) *6.4.2.2*
	*(CXCC:) GPS timing recovery (GPS/UTC) *15.2.1*
	Extended quiet periods (EQP) *6.4.3.3*
	Adaptive EQP *6.4.3.4*
	Listen before talk *6.4.3.5*
	Uncoordinated Coexistence Protocol (UCP) *6.4.2.4*
collaborative mechanism	IP network message (CXP message) *15.5.2*
	coexistence proxy (CXPRX) *15.1.6*
	*(CXCC:) coexistence signaling (CSI/ radio signature) *15.3.1*
	*(CXCC:) coexistence messaging (CMI/CCD) *15.3.2*
	sub frame sharing (master sub frame) *15.4.2*
	channel reallocation (ACS) *15.4.1*
	Subframe Reallocation (ASFA) *15.4.2.2*
	credit token *15.4.2.5*

From: M. Goldhamer, "Main concepts of IEEE P802.16h / D1," Document Number: IEEE C802.16h-06/121r1, November 13-16, 2006.



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 QPSK
- **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)



Status

- Finalized 2011

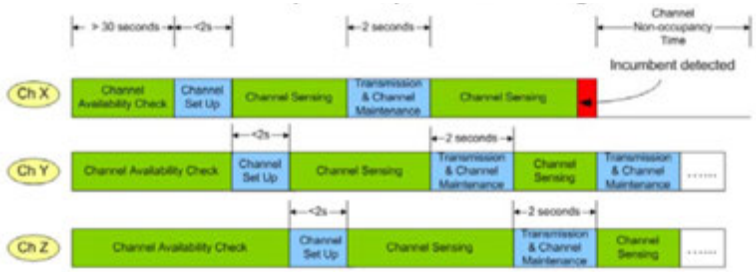
802.22.1

- Enhanced interference protection
- Particularly for mics

802.22.2

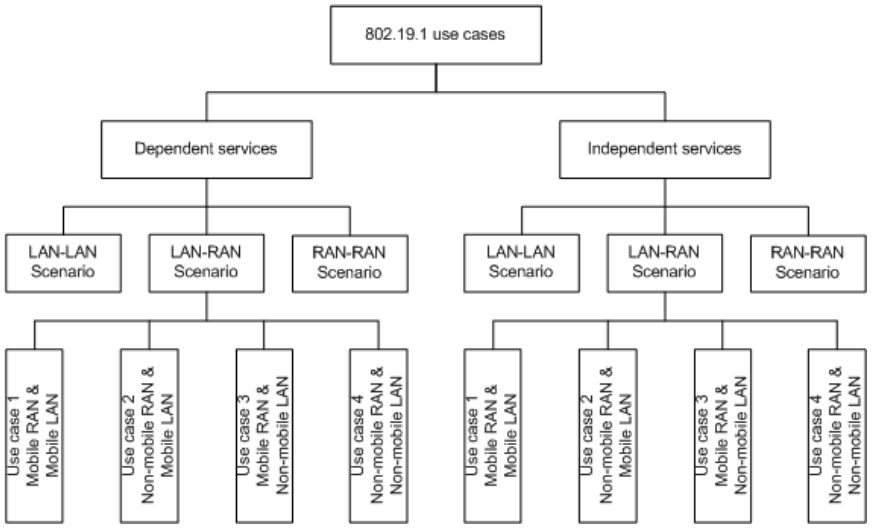
- Best practices for deployment

Scheduled and hopped quiet periods%

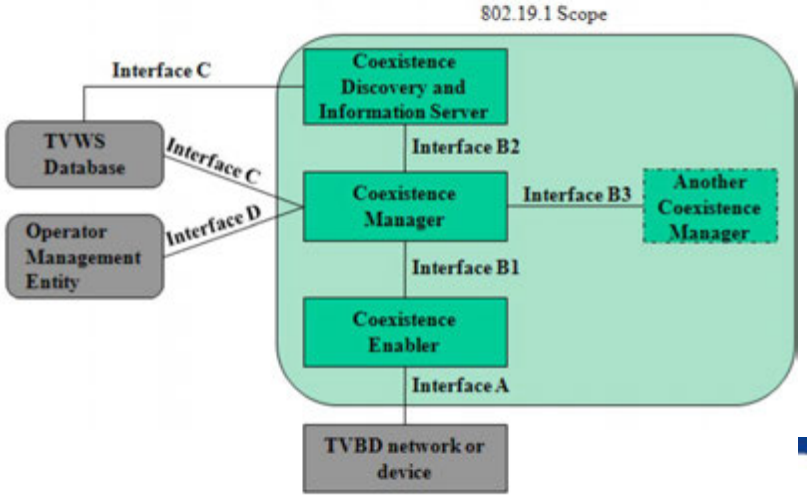


802.19.1 (TVWS Coexistence)

- **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/
  - 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

	1900.1	1900.2	1900.3	1900.4	1900.5	1900.6
PAR Approved	3/04/05	03/20/05	12/05/07	12/06/06	03/28/08	9/26/08
Initial Ballot - Open	9/07/07	07/02/07	Pending Withdrawal	9/08/08		
Initial Ballot – Close	10/07/07	08/03/07		10/08/08		
1st Recirc – Close	4/17/08	10/24/07		10/26/08		
2nd Recirc - Close		01/01/08		11/22/08		
RevCom Approval	4/10/08	1/08/08		1/19/09		
SASB Approval	6/12/08	3/28/08		1/29/09		
Published	9/26/08	7/29/08		2/27/09		

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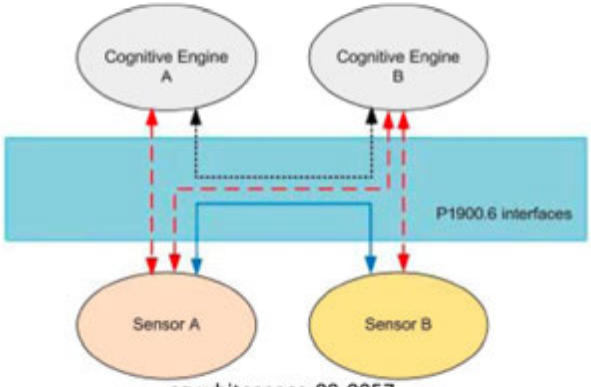

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Projects and Programs - ITU

Presented by Lee Pucker

Chief Executive Officer

Wireless Innovation Forum

WRC 2012

Geneva
23 January to 17 February 2012

WRC-2012 Relevant Agenda Items

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
ETARE
Waveforms Evolutions
Technologies Studies
Simulations and Demonstrations

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

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

EDA – 2009 / 2010
SDR Std & Certif
Process Description
Standardisation
Certification
Accreditation

EDA – 2009 / 2010
WF Dev tool
WF Dev Framework
Cial & Military WF
Recommendations
Roadmap and Shared View

Cross Fertilization

Public Safety

EC - 2007 / 2008
WINTSEC
Explore interoperability and SDR for HLS Applications
Recommendations
Roadmap and Shared View

EC – 2009 / 2011
EULER
Demonstrate Interoperability & WF Portability (WiMAX)
Initial Experimentation of SDR for HLS Applications

EC – 2008 / 2011
SECRICOM
Wireless Communication for Crisis Management
Network Interoperability

All inc. cial

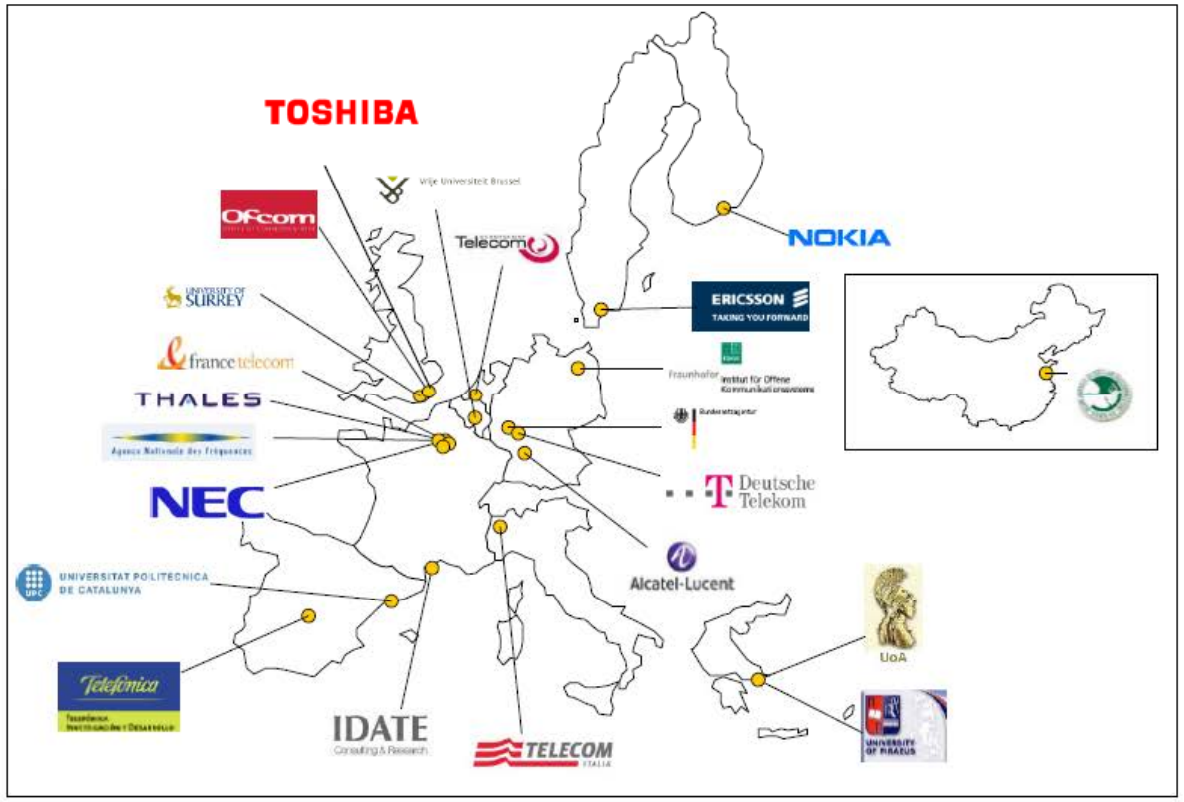
EC – 2004 / 2009
E2R/E3
Cognitive Radio System Reconfig. netw. And self adap.
Recommendations
Roadmap and Shared View

2010 European Reconfigurable Radio Technologies Workshop and Product Exposition
June 23-25, 2010 • Mainz, Germany

SDR Standards
WF Developments
Spectrum Efficiency
WF Portability
Interoperability

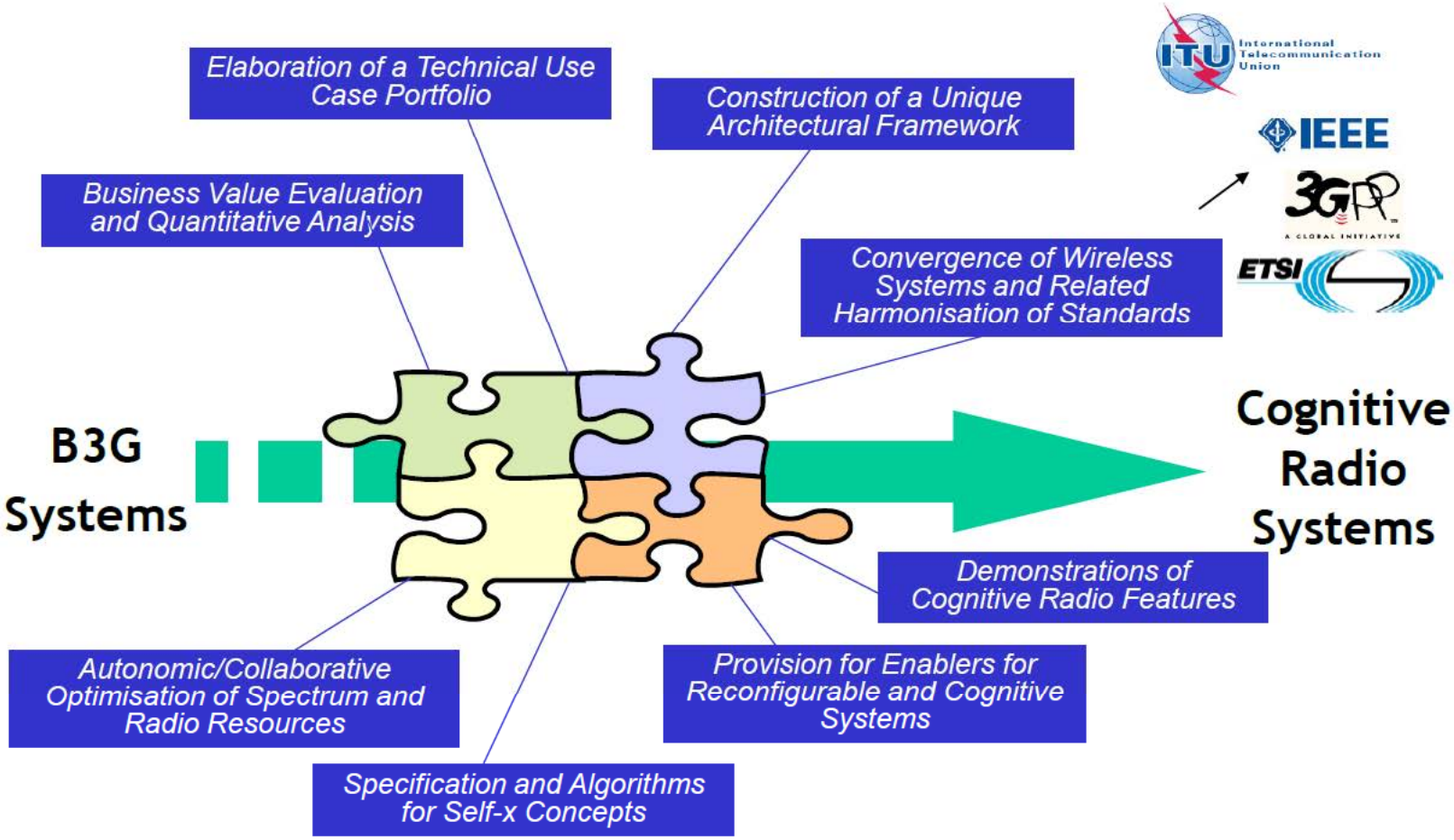
E3 Project Highlights

- ✓ **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)

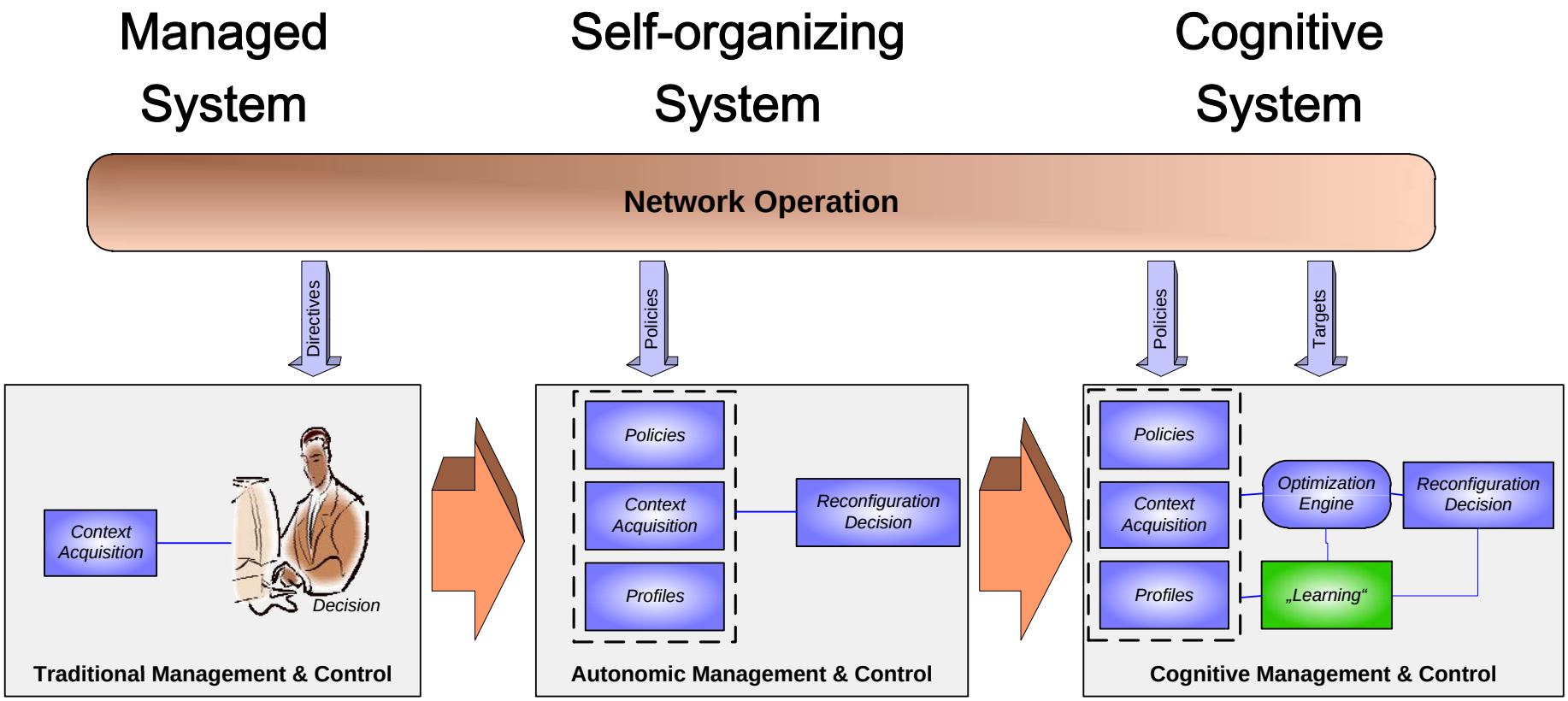


- ✓ **Contractual Outcomes: 43 Deliverables and 47 Milestones**

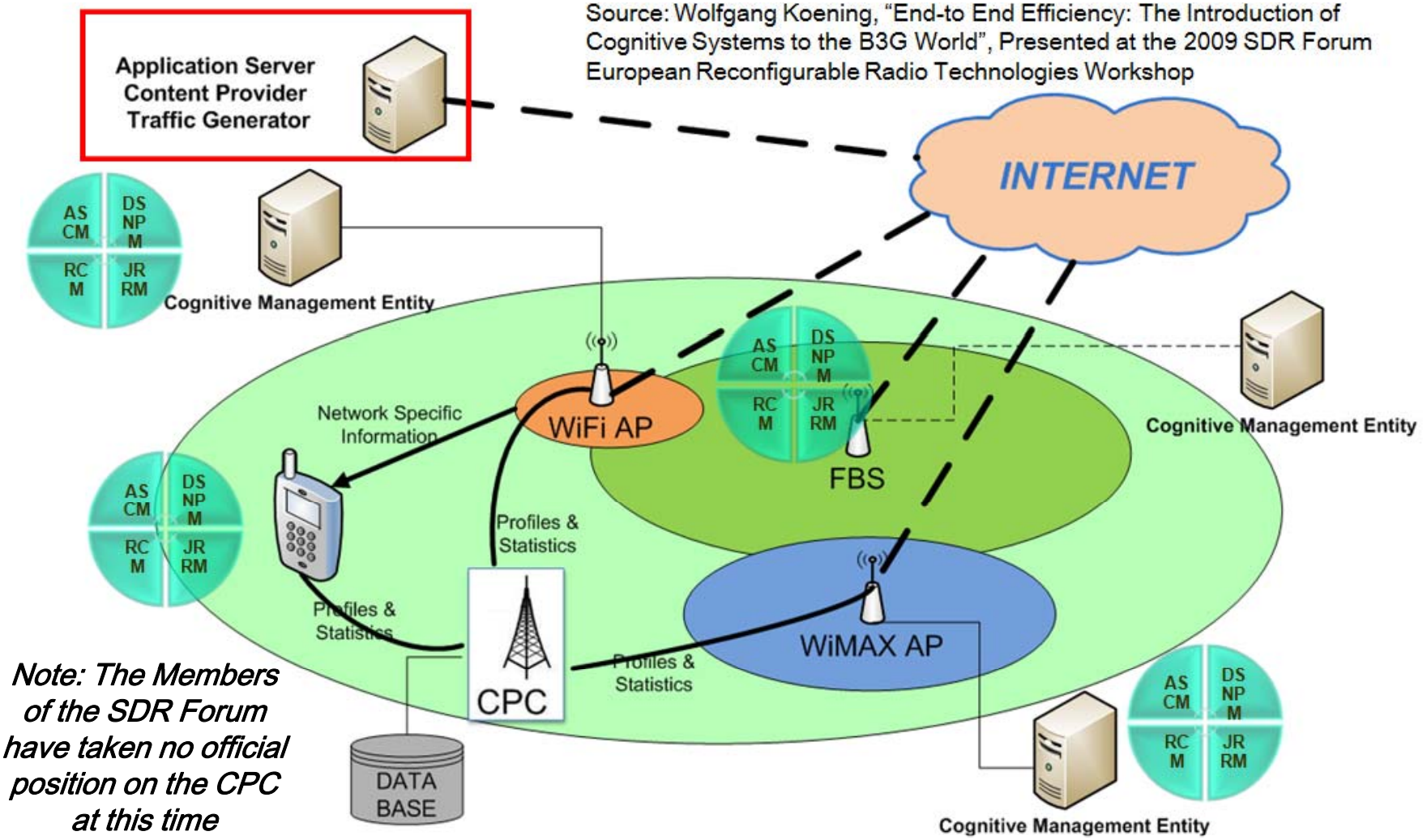
E3 Challenges and Approach



Evolution of Decision Loop from E3



E3 Prototype Target



Two sides of Flexible Spectrum Management from E3

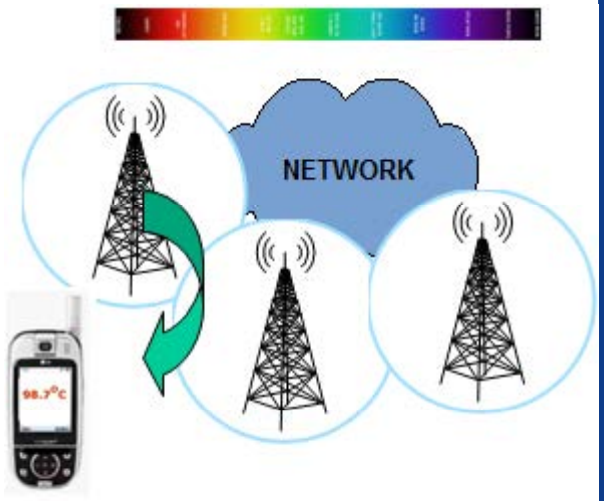
Dynamic Spectrum Allocation (DSA)

- 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

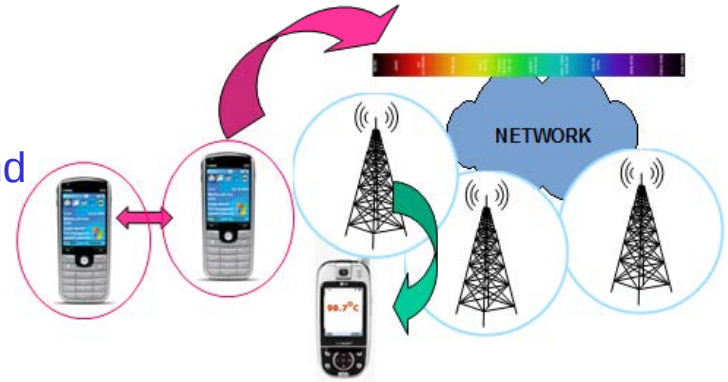
  → **long term processes**



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	*E³ monitors*
	ITU-R WP5A on CR	*E³ contributes*
Autonomic and Cognitive Management:		
	ETSI RRS WG3 (CPC)	*E³ leads*
	IEEE SCC41 P1900.6	*E³ contributes*
System Architecture and Interfaces:		
	IEEE SCC41 P1900.4	*E³ contributes*
	ETSI RRS WG3 (FA)	*E³ leads*
Radio Equipment Architecture and Interfaces:		
	ETSI RRS WG2	*E³ contributes*
	WINNF (Transceiver)	*E³ leads*
Specification Techniques:		
	OMG, WINNF, OMA,	*E³ contributes*

ETSI RRS

RRS : Reconfigurable Radio Systems

- Completion of a phase of feasability 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

http://www.etsi.org/WebSite/technologies/RRS.aspx

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, includir
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

COST TERRA Program (Action IC0905)

COST = CO-operation in Science and Technology:

- European Science Foundation (ESF) instrument
- supports co-operation across Europe

COST-TERRA: Techno-Economic Regulatory Framework for Spectrum Access for Cognitive Radio/Software Defined Radio

COST-TERRA
COST Action IC0905 TERRA
TECHNO-ECONOMIC REGULATORY FRAMEWORK FOR RADIO SPECTRUM ACCESS FOR COGNITIVE RADIO/SOFTWARE DEFINED RADIO

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

ITU Region 2 Report

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.

US FCC (July 2010)

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

US FCC – TV White Space

Unlicensed Operation in the TV Broadcast Bands (ET Docket No. 04–186 and 02–380; FCC 08–260) Published March 19, 2009.

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

WInn 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”

US Secondary Market

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.**

US – FCC Spectrum Dashboard

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.

More than 125,000 Hits

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

US – Administration

Presidential Memorandum: Unleashing the Wireless Broadband Revolution (28 June 2010)

- 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*.

US DoD

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

Region 2 Int'l Regulatory Activities - ITU

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

CR Activities in China

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)

CR Activities in China

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)

Programs in Japan – The MIC Program

- 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

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

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)

CR Activities in Korea

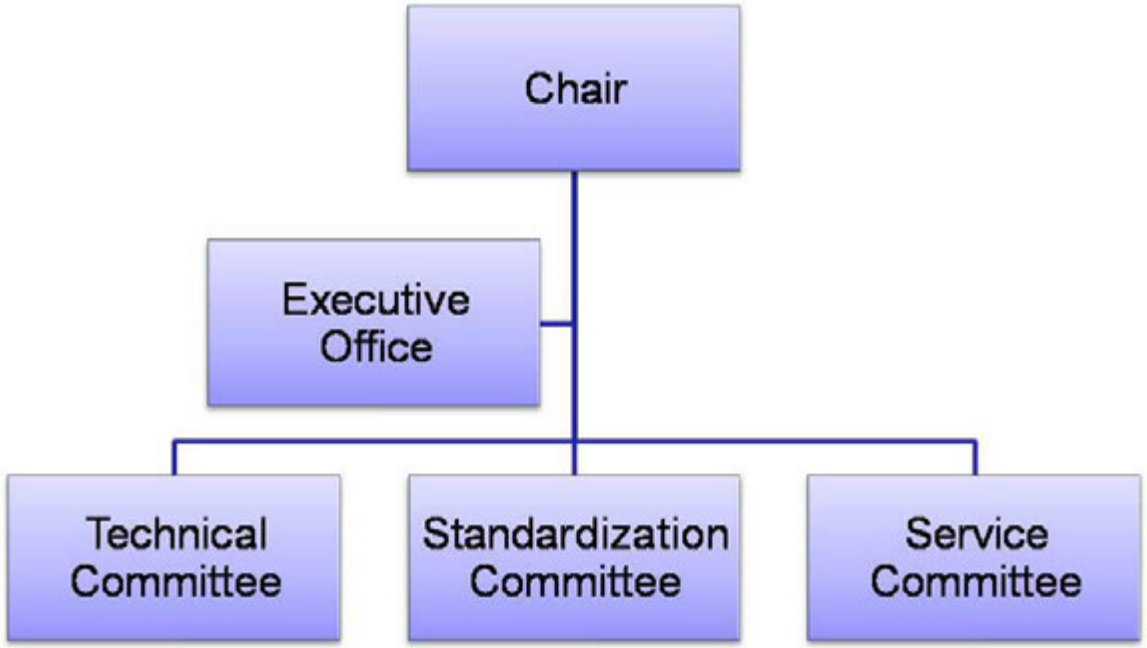
Cognitive Radio Systems (2008~2010) Project at ETRI

- 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

CR/SDR Forum in Korea

Objective : Development, proliferation, and standardization of CR/SDR technologies.

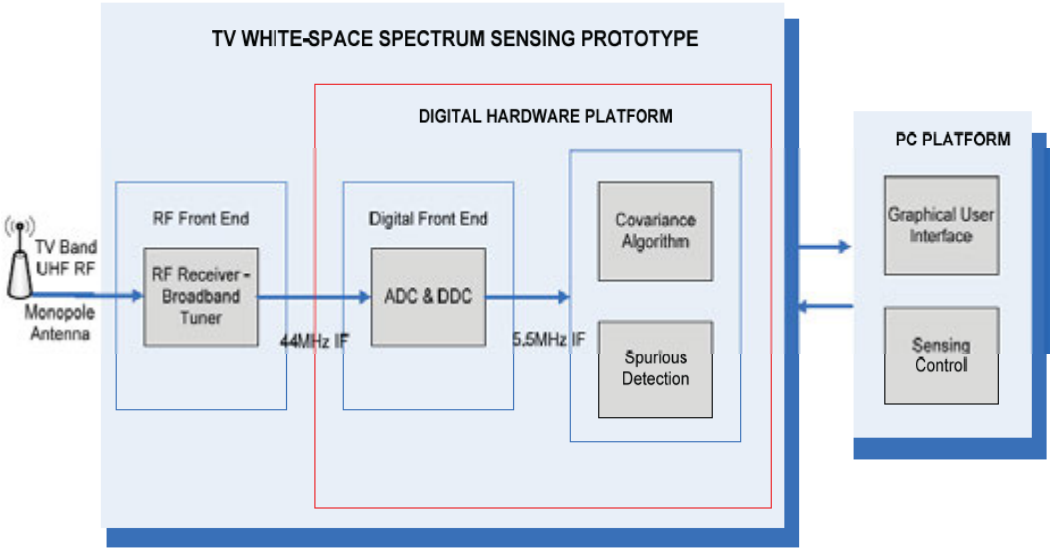
Organization



TV White Space in Singapore

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)

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September Workshop

WIRELESS INNOVATION FORUM

WInnForum Workshop:

"Going to Market with TV Band Devices:
Long Term Promises, Near Term Actions"

16 September 2010, Schaumberg, Illinois

In November, 2008 the U.S. Federal Communications Commission (FCC) announced a landmark decision allowing the use of fixed and personal/portable devices in "unused" TV Band spectrum, referred to as "white space." Numerous petitions for reconsideration were filed along with several database manager proposals and the FCC is expected to rule on them in the coming months. While awaiting the final rules and designations, first devices are being built and trialed 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 Broadband 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 opportunistic and unlicensed use of spectrum and increasing research into new spectrum technologies."

The purpose of this workshop is to explore the critical technical, business and regulatory "go to market" issues for TV Band Devices, and to develop a collaborative action plan that addresses immediate needs while maximizing the possibilities for future innovation and success throughout the wireless value chain. The output of this workshop will define short term actions to be taken by the Forum on behalf of its members 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 Measurements Group and the Regulatory Committee. These outputs will also help shape the Regulatory Workshop being held at SDR'10 in December.

Who should attend?

Equipment designers and manufacturers, test & measurement vendors, certification authorities, spectrum stakeholders, wireless service providers, third party database providers and end-users impacted by software defined Radio and cognitive radio (SDR/CR) system technology developments being utilized for TV Band devices including dynamic waveform activation, opportunistic scheduling, dynamic spectrum access, secondary and unlicensed spectrum access and policy based operation.

This workshop will be held in conjunction with The Wireless Innovation Forum (SDR Forum Version 2.0) working meeting 13-17 September, hosted by Motorola. This meeting will include working sessions advancing the Forum's 2010 operations plan in support of the commercial, public safety, satellite communications, and international tactical radio communities.

Wireless Innovation Forum groups that convene during the meeting may include the following:

* Public Safety Special Interest Group
* International Tactical Radio Special Interest Group
* Satellite Communications Special Interest Group
* Regulatory Committee
* Cognitive Radio Work Group
* Commercial Baseband Processing Technologies Work Group
* Modelling Language for Mobility Work Group
* SCA Next Task Group
* SCA API Work Group
* SCA Implementation Guide Work Group (SCA Users Group)
* SCA Test and Certification Work Group
* Security Work Group
* Smart Antenna Working Group
* International Security Services API Task Group
* Test and Measurement Work Group
* Transceiver System Interface Task Group

For a list of current projects, visit www.WirelessInnovation.org/page/Current_Projects.

To learn more, visit the calendar at www.WirelessInnovation.org.

WWW.WIRELESSINNOVATION.ORG

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

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http://conference.wirelessinnovation.org/

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