

Alternatives For Coexistence Mechanisms in White Space

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Authors:

Name	Company	Address	Phone	E-mail
Mark Cummings	SWIM	348 Camino al Lago Atherton, Ca. 94027	+1 650 854 4406	markcummings @envia.com

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Presentation Objectives

- **Outline The Alternatives**
- **Present a Framework For Discussion**
- **Assess The Forces At Work**
- **Recommend a General Way Forward**

Context

- **Existing Spectrum for 802 Products Is Becoming Congested**
- **White Space Provides An Opportunity For Congestion Relief**
- **TV White Space Is**
 - Not the First White Space Initiative
 - Will Not be the Last
 - Interacts With Other Related Trends
 - Growing Demand For Spectrum For All Types of Wireless
 - Emergence of Femtocells
 - Emergence of Self Organizing Networks

Coexistence Goals – Turn To Green

- **Maximize Coexistence**
 - While Requiring Minimum Re-Engineering of Existing Technology
 - Maximize the Ease With Which New Technology Can Be Introduced
 - Providing Best Possible User Experience
 - Maximize Efficiency

Matrix

		802.11			802.15			802.16			802.22		GSM		WCDMA		CDMA2000	
			UWB	Blue Tooth	Other		Low Power	High Power	Macro Cells	Femto Cells	Macro Cells	Femto Cells	Macro Cells	Femto Cells				
802.11																		
802.15	UWB																	
	Blue Tooth																	
	Other																	
802.16																		
802.22	Low Power																	
	High Power																	
GSM	Macro Cell																	
	Femto Cell																	
WCDMA	Macro Cell																	
	Femto Cell																	
CDMA 2000	Macro Cell																	
	Femto Cell																	

*Protected devices, as defined by the FCC are not listed. They are protected by procedures specified by the FCC.

**This Table is meant to be Representative, not complete

***It is Likely that a similar analysis be done for OFCOM, Industry Canada, Netherlands Antilles, etc. rules

Full Coexistence Without Cooperation
 Partial Coexistence Without Cooperation
 Coexistence Requires Cooperation



Tools

- **Available Vectors**
 - Frequency
 - Power
 - Time
 - < Second
 - > Second
 - >>Second
 - Modulation Scheme
 - To Avoid Mutual Interference
 - To ID “Signature”
 - Space
 - Space Division
 - Geographic Dispersion
 - Priority
 - Type of Information
 - Service Level Agreement
 - Law
- **Implementation Approaches**
 - Centralized
 - Distributed

Fully Centralized Example

- **TDMA Reservation Scheme**
 - Vector
 - Time & Time Slot
 - Algorithm
 - A Master Station Transmits Sync
 - Time Slot(s) Is(Are) Designated For Reserving Communication Time Slots
 - All Stations In the Neighborhood Use the Reservation Request Slot to Ask the Central Authority For Communications Slots
 - The Central Station Assigns Slots Based On

Fully Distributed Example

- **Autonomous Configuration Scheme Proposed In 3GPP**

- Vectors

- Type of Information

- Packets for streaming with demand for low latency and error rate have higher priority

- Power

- Sense the Power of adjacent Stations
 - Control Own Transmit Power

- Algorithm

- Exchange Sensed Power Levels and Priority of Packets in Output Buffer With Neighbors
 - Adjust Transmit Power To Achieve Optimal Performance of All

- References

- ftp://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_57/Docs/R1-092057.zip

- ftp://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_57/Docs/R1-092054.zip

Strengths And Weaknesses

- **Strengths**
 - Each Vector Works Well With Some Approaches To Implementation
 - Each Vector Works Well With Some Existing AIS's (Air Interface Standards)
- **Weaknesses**
 - No Single Vector Works Well With All
 - Approaches To Implementation
 - Existing AIS's

Observations

- **The larger the Number of Vectors Articulated, the Greater the Likelihood of AIS Coverage**
- **The November 2008 FCC Report & Order Specifies a Hybrid System**
 - Central Data Base
 - Local Sensing (Distributed)
- **Centralized Systems Are Limited By Concerns About**
 - Anti Competitive Effects
 - Limitations On Innovation
 - Privacy Concerns

Forces At Work

- **Who Is Going To Do What To My AIS?**
 - Desire To Maintain Control
- **Some Standards Poised For Early Move Into White Space Want Coexistence Mechanism That Are;**
 - Easy For Them to Implement
 - Minimum Rework
 - Don't Protect Other AIS's Likely to Enter Slightly Later
 - Analogous To US Military Comm's In First Gulf War

Similarity To Early History of IEEE 802

- **IEEE 802 Was Originally Organized to Develop a Single Standard for Wired LAN's**
- **Industry Players Wanted Each of Their Own Technologies Adopted As a Standard**
- **Innovation Created a Path To a Solution**
 - **MAC & Phy**
 - Each Player Could Have their Own Phy
 - A Standardized MAC Provided A Path To Wide Scale Adoption

Possible Way Forward

- **Develop An Approach Similar to MAC and Phy That Supports:**
 - Multiple Ad Hoc Solutions Driven By:
 - Desire of Each Group to Control It's Own Fate
 - Drivers in Different Market Segments
 - Competitive Landscape
 - Early Implementations
- **While Providing**
 - A Mechanism For Later Entrants
 - That Can Be Implemented With Software Upgrades
 - That Can Be Expanded To Include Other White Spaces
 - Is Compatible With Other Related Efforts Both
 - Inside 802
 - Outside 802
- **Harmonization of Resulting Standards**

Example Mechanism Approach

Add Frequency Vector

- **Very High Level Example - Just Meant to Be Illustrative**
 - Similar Results Could Be Achieved With Other Vectors
- **Example 802.11 & 802.16 Coexistence**
- **802.11 Moves Into TV White Space**
 - Simply Adds Capability to Access the White Space D/B
 - Makes Provision For Future S/W Upgrades To MAC
- **802.16 Role Out Proceeds To Point Where 802.16 is Ready to Take Advantage of White Space**
- **S/W Extensions to the MAC Are Downloaded**
 - Defines Sub Channels Within TV Channel
 - Provides Ability of 802.11 & 802.16 Radios To Move To Different Sub Channels

How To Get There

- **Maintain Open Communications Channels Between All Different Efforts**
 - Inside 802
 - Outside 802

What Is Necessary For Coexistence

- **How To Connect Two Overlapping Radio Nets**
 - WSD Access to D/B Implies Access to the Internet
 - Therefore two paths for inter technology communication for radios that check with the D/B
 - Back Haul Internet
 - Over The Air
- **What Data Should Be Exchanged**
- **How Should The Radios Cooperate**
 - Algorithm For Convergence
- **What Protocol Should Be Used**