

IEEE 802.22: Cognitive Radio Wireless Regional Area Networks

Wendong Hu, Ph.D.

Chair, IEEE 802.22 Working Group

whu@ieee.org

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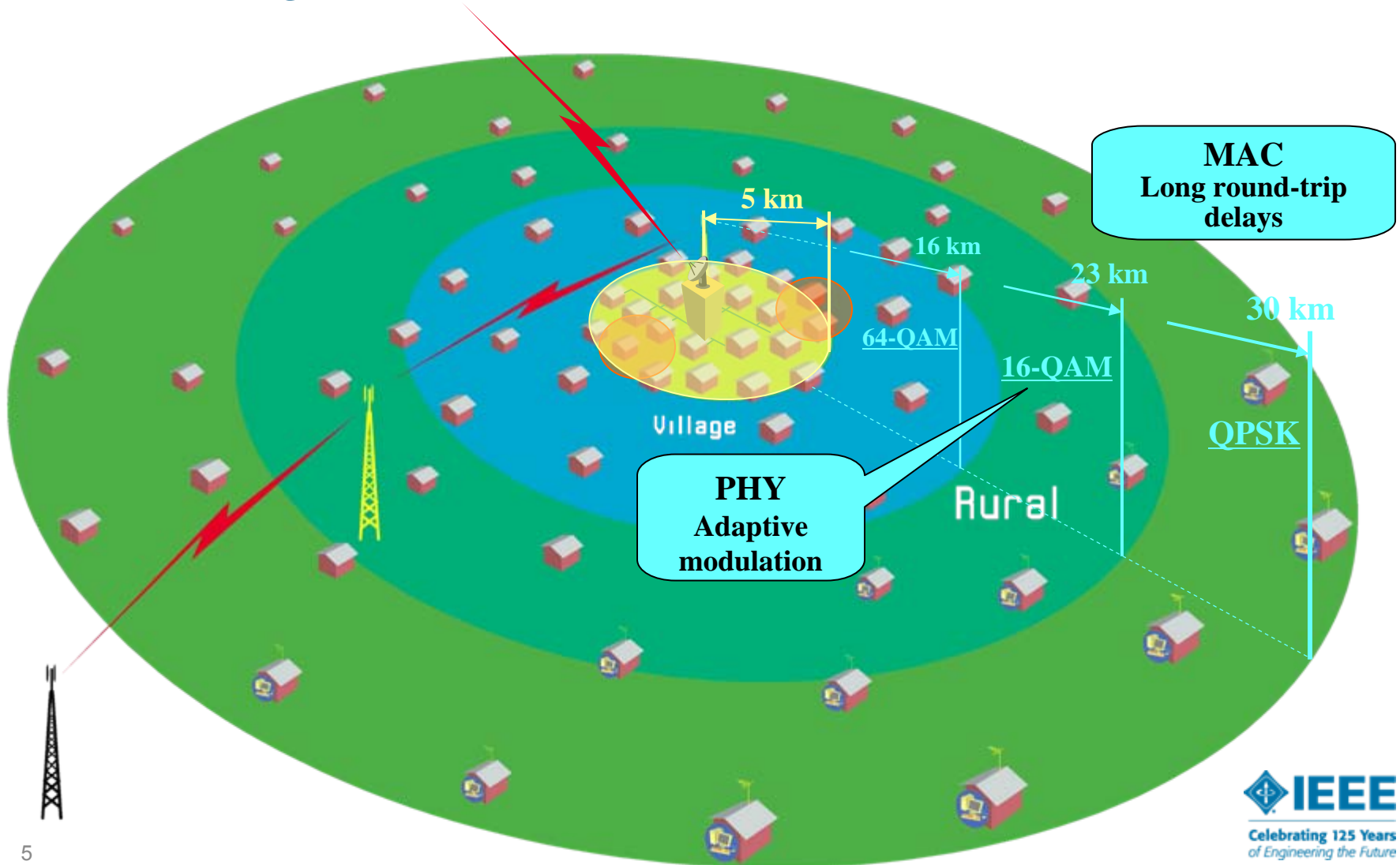
Outline

- Background
- Reference System Architecture
- Key Technological Features
- Further Observations
- Conclusion, Q&A

IEEE 802.22 Standard Project

- **IEEE P802.22** specifies the air interface, including the **cognitive** medium access control layer (**MAC**) and physical layer (**PHY**), for **unlicensed point-to-multipoint** wireless regional area networks operating in the **VHF/UHF TV broadcast bands** between 54 MHz and 862 MHz, **without disrupting the incumbent services.**

Long-range Wireless Broadband Access: Currently Focused Application of WRAN



Why TV Broadcast Bands?

- TV broadcast Bands – **Ideal for covering large area in a variety of environments**
 - Low inherent free space propagation loss
 - Excellent foliage and building penetration
 - Desirable non-line-of-sight (NLOS) propagation characteristics

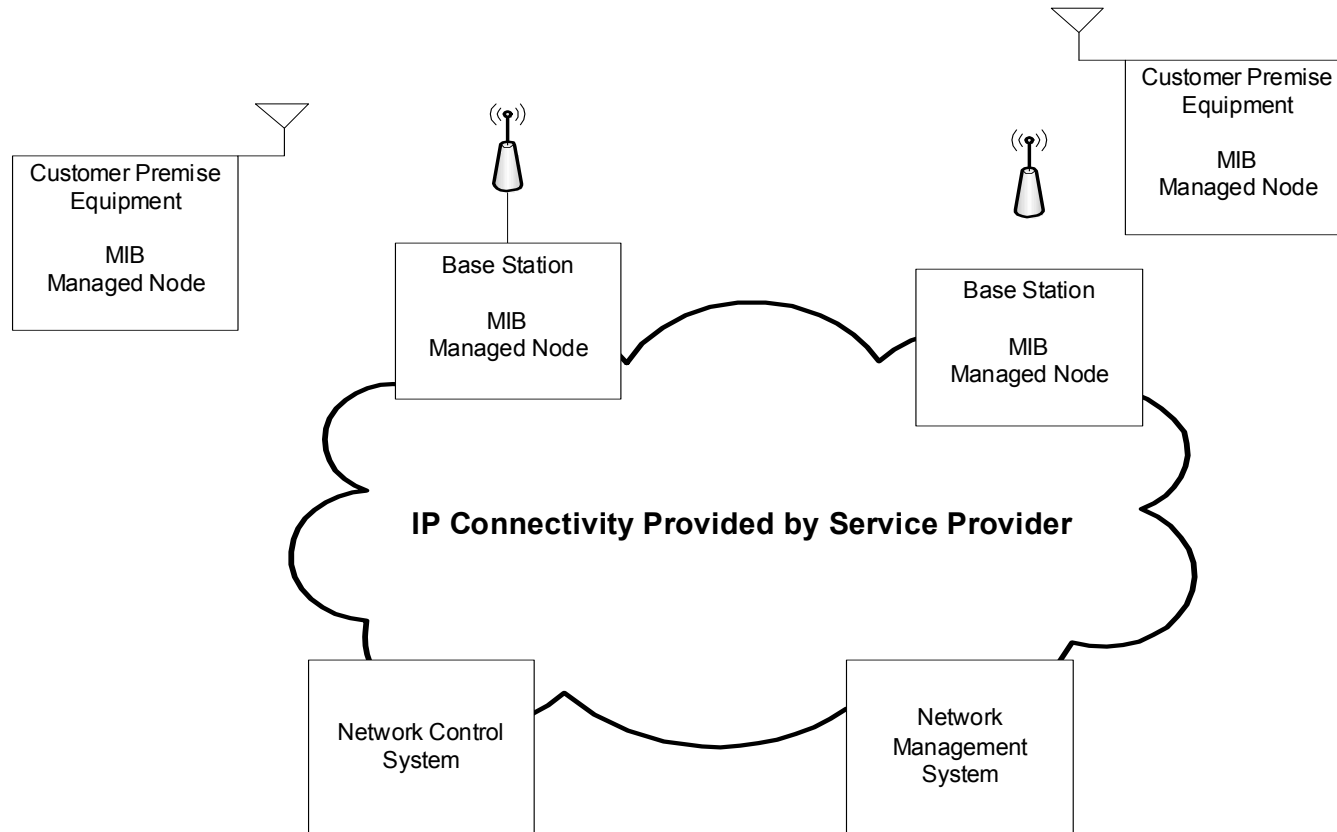
- **They're available!**
 - So called "TV Band White Spaces"
 - TV spectrum not being used by licensed services
 - Amount available will increase with Digital TV transitions

Global Regulatory Rulings for unlicensed TV Bands Operations

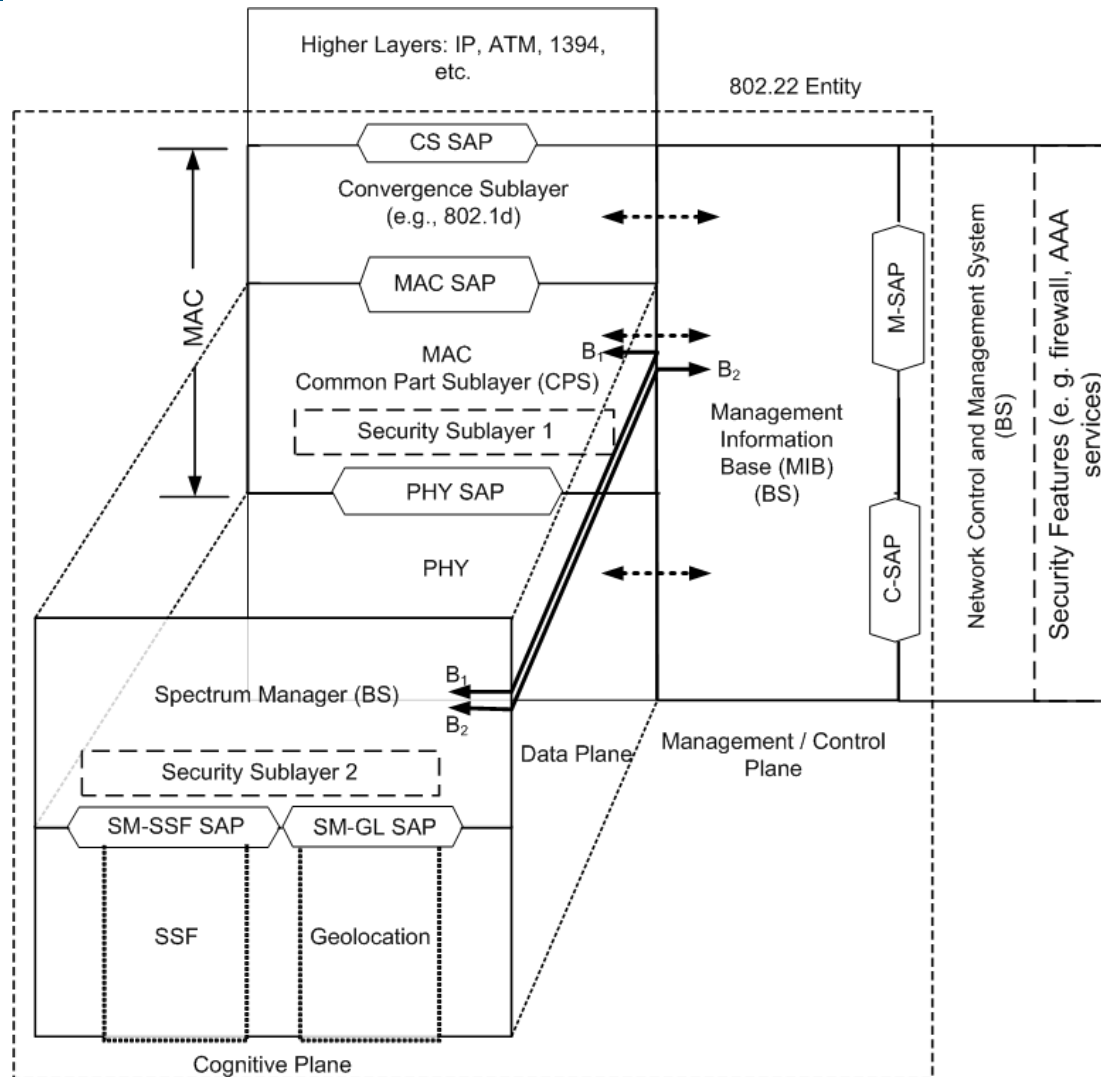
- **Regulatory bodies around the world are exploring and adopting rules for unlicensed operation in TV bands**
 - United States, FCC [1]
 - Canada, Industry Canada [2]
 - United Kingdom, OfCom [3]
 - European Union

- **Aim to promote both economic growth and more efficient and effective use of the TV spectrum**
 - Allow the development of new and innovative types of unlicensed devices that provide broadband data and other services for businesses and consumers without disrupting the incumbent services
 - Benefit wireless internet service providers (WISP) by extending the service range of their operations

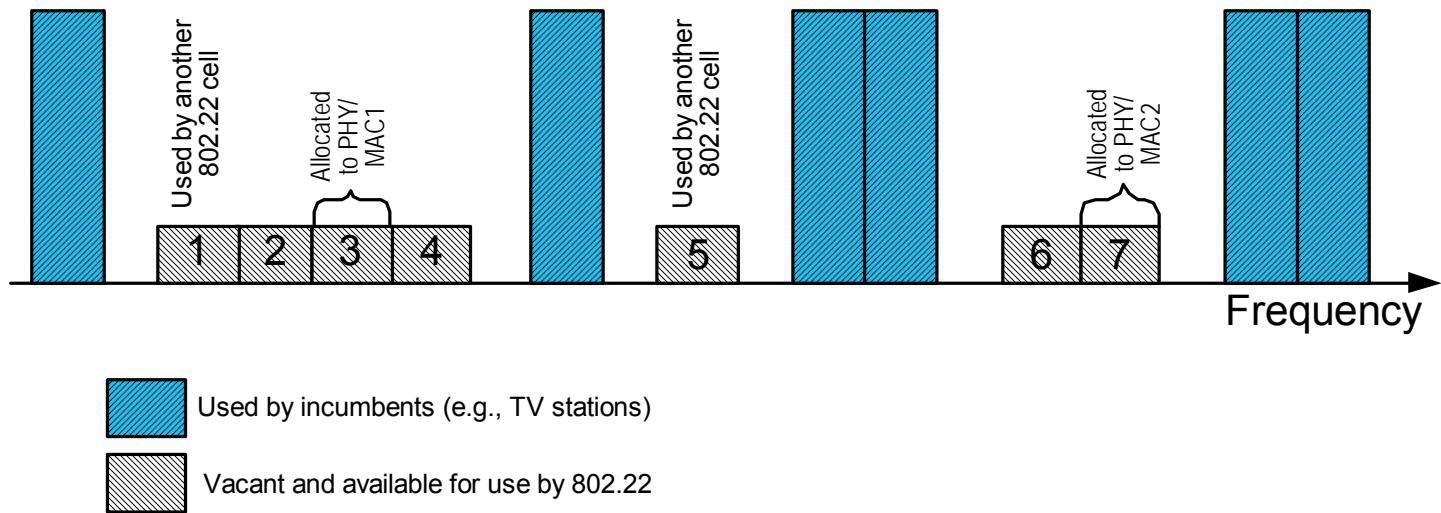
IEEE 802.22 Management Reference Model



IEEE 802.22 Protocol Reference Model



Frequency Agile Operations of IEEE 802.22 WRAN Systems



Key Technological Features of IEEE 802.22

- **Optimized air-interface for long-range TV Band operations**
- **Efficient use of the spectrum**
 - Cell-based centralized spectrum management
 - Collaborative self-coexistence mechanisms
- **Cognitive Capabilities** for
 - Identifying available TV channels
 - Protecting licensed incumbents

Optimized Air-interface for Long-range TV Band Operations

- Long-range operation
 - OFDMA-based PHY parameters are optimized to absorb longer multi-path excess delays up to 30km of coverage distance
 - TDMA-based MAC absorbs additional propagation delays for coverage distances of up to 100 km through intelligent scheduling
- TV band operation
 - Channel Bandwidth designed to be 6 MHz, 7 MHz or 8 MHz (same as TV channels) for frequency bands between 54 MHz and 862 MHz

Key OFDMA-based PHY Layer Parameters in IEEE 802.22

■ Sub-carrier Spacing

- 3.34 kHz (BW=6MHz); 3.90625 kHz (BW=7MHz) and 4.46 kHz (BW=8 MHz).
- Optimized for multi-path and Doppler effect in TV band channels

■ Cyclic Prefix

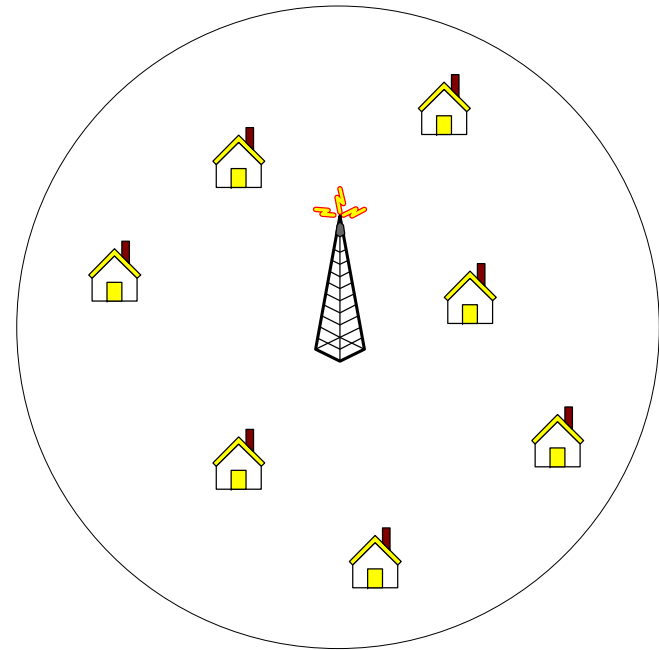
- 75, 38, 19 and 9 μ s (BW= 6 MHz), 64, 32, 16, 8 μ s (BW= 7 MHz), 55, 28, 14 and 7 (BW= 7 MHz).
- Four different lengths of CP are defined to allow for different channel delay spreads while utilizing the spectrum efficiently.

■ Advanced Modulation and Coding

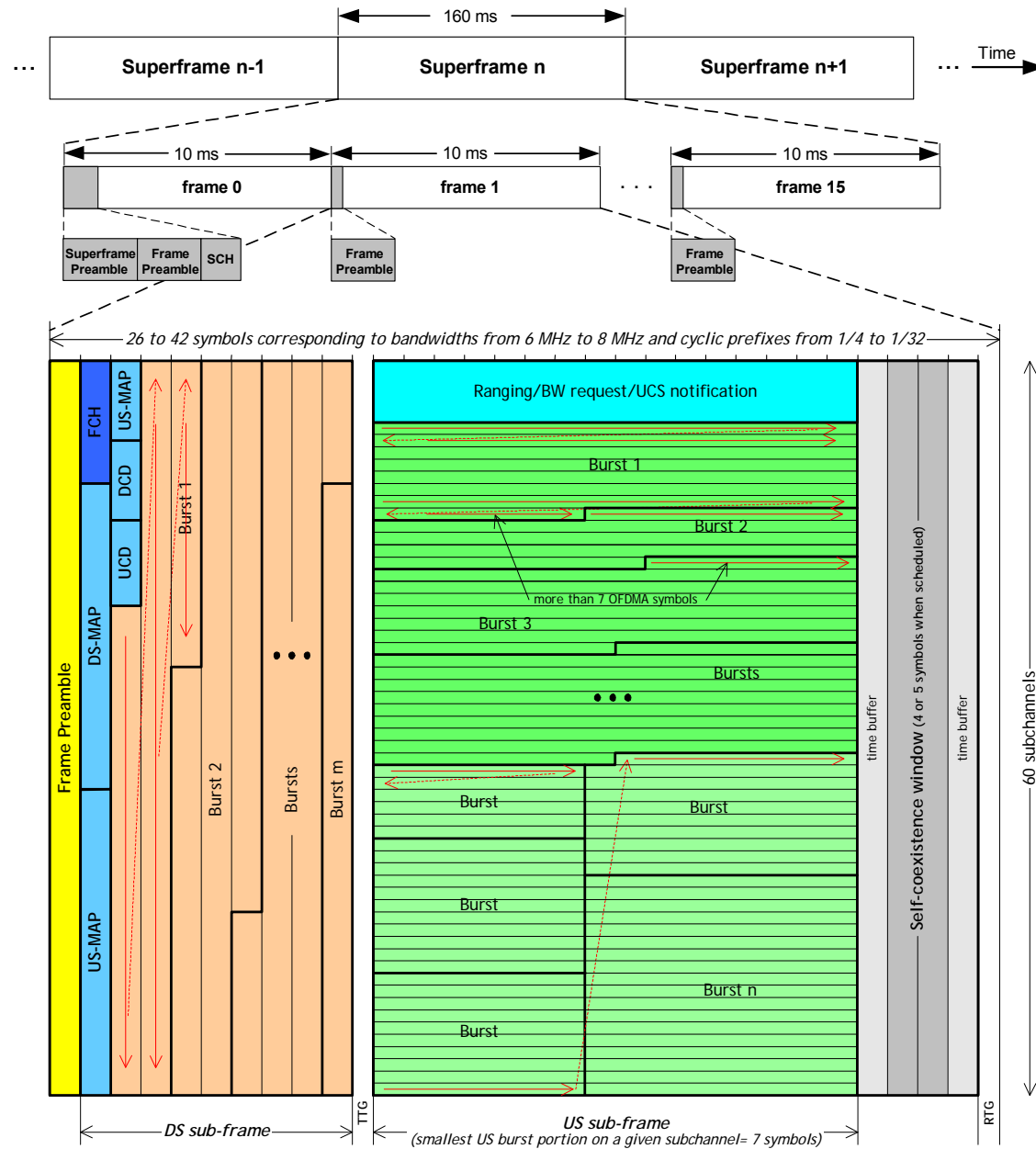
- Combinations of 3 modulation schemes (QPSK, 16QAM, 64QAM) and 4 code rates (1/2, 2/3, 3/4, and 5/6);
- Forward error codes: Mandatory convolutional codes and 3 optional advanced codes.

Cell-based Centralized Spectrum Management

- **Point-to-multipoint cell topology:** a central BS controls the medium access of a number of associated CPEs
- Facilitates flexible bandwidth allocation and QoS support, and ensures efficient (intra-cell) spectrum use for data delivery.



IEEE 802.22 Frame Structure



Collaborative Self-coexistence Mechanisms

■ Coexistence Beacons

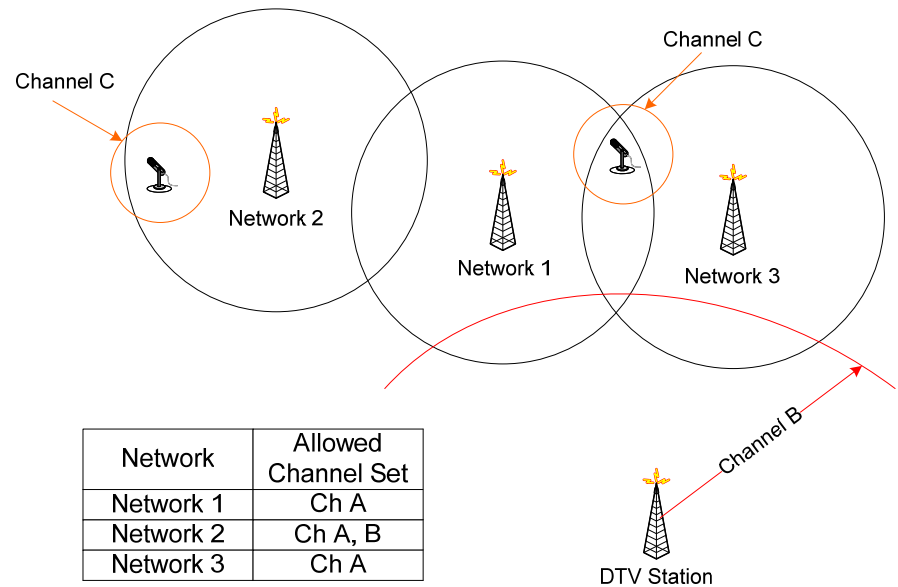
- Inter-WRAN communications

■ Spectrum etiquette

- Inter-WRAN channel selection (to avoid conflicting channel selection)

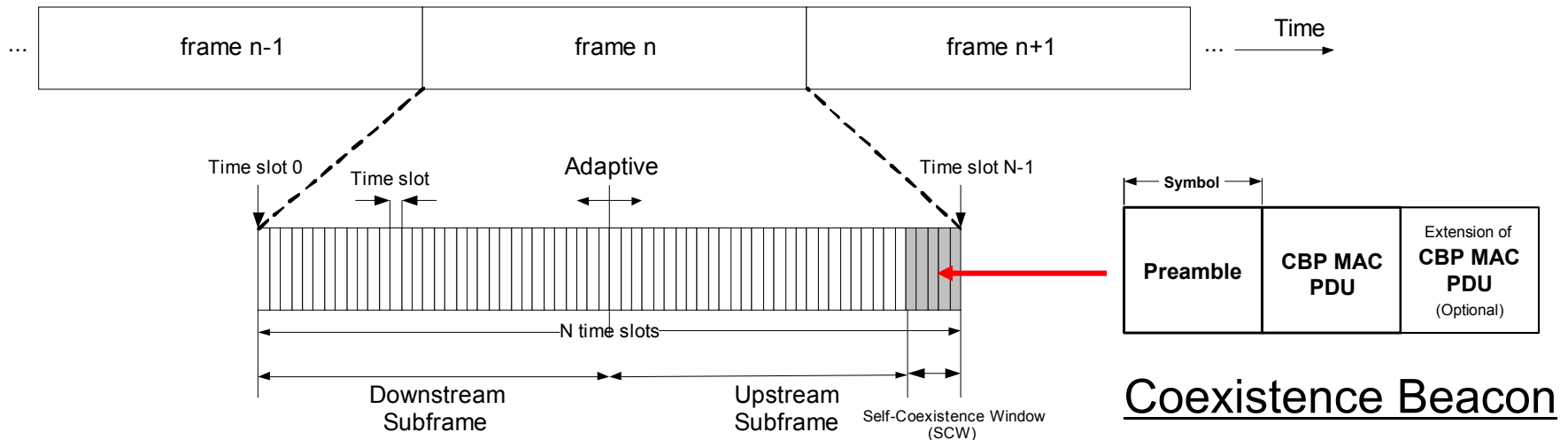
■ On-demand Frame Contention Protocol

- Inter-WRAN Co-Channel Spectrum Sharing



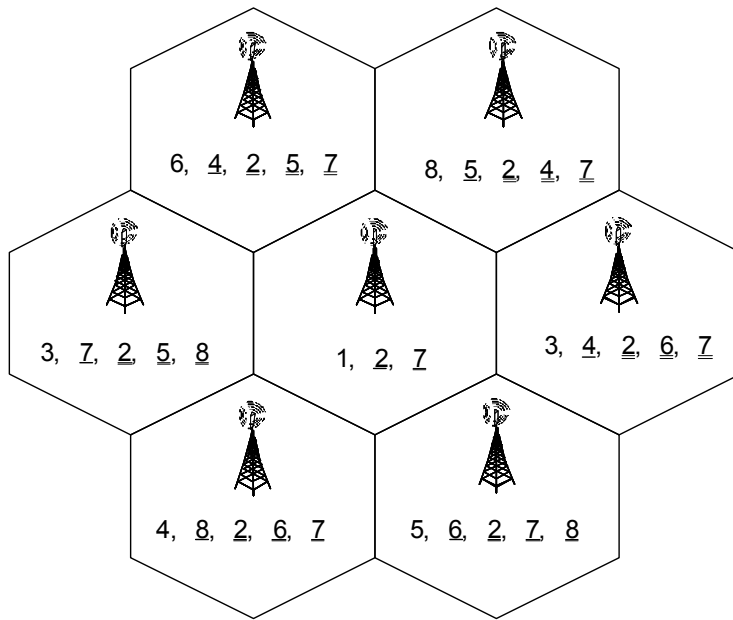
Coexistence Beacons

- To enable **over-the-air Inter-WRAN** communications.
- Transmitted during the **Self-coexistence Windows** at the end of data frames by the BS and/or some designated CPEs.

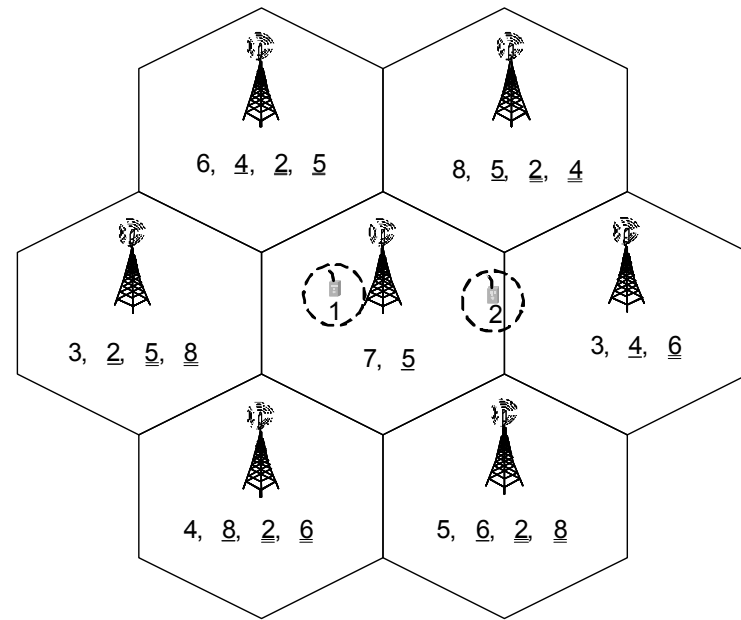


Spectrum Etiquette

- To enable least conflicting Inter-WRAN channel selection



(a)

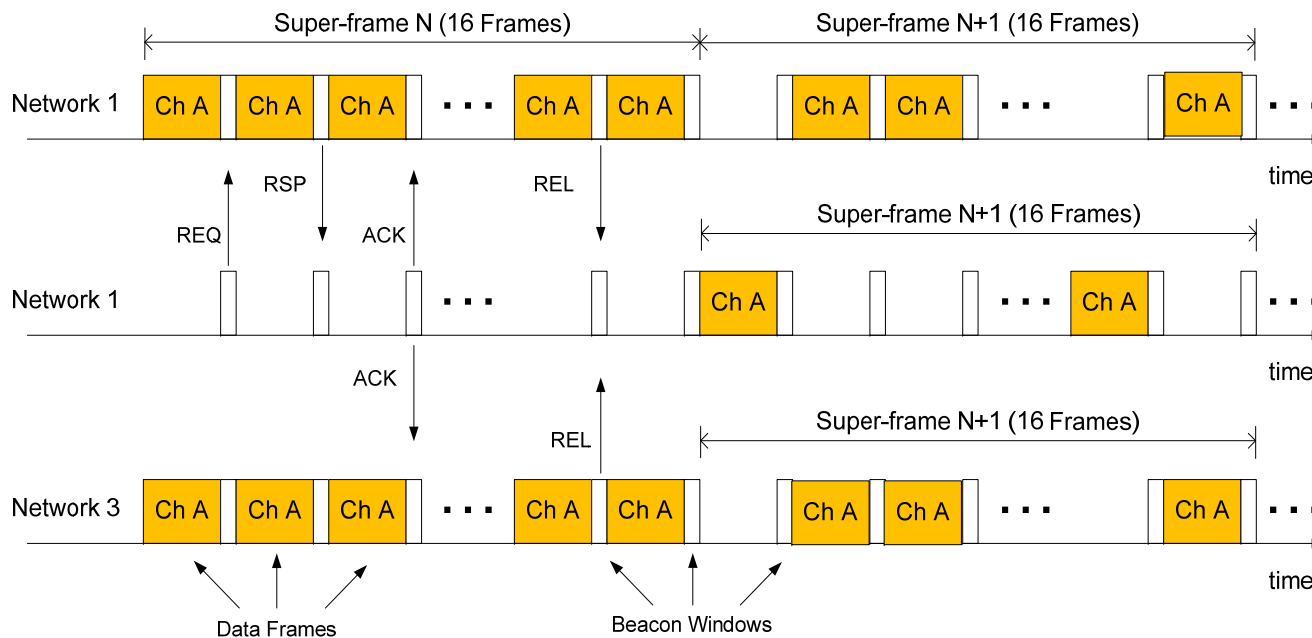
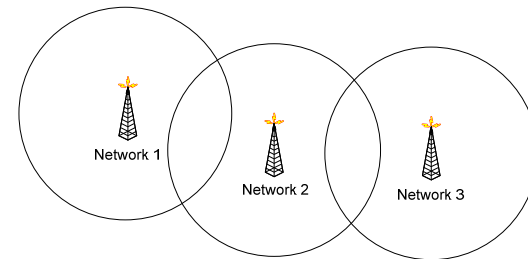


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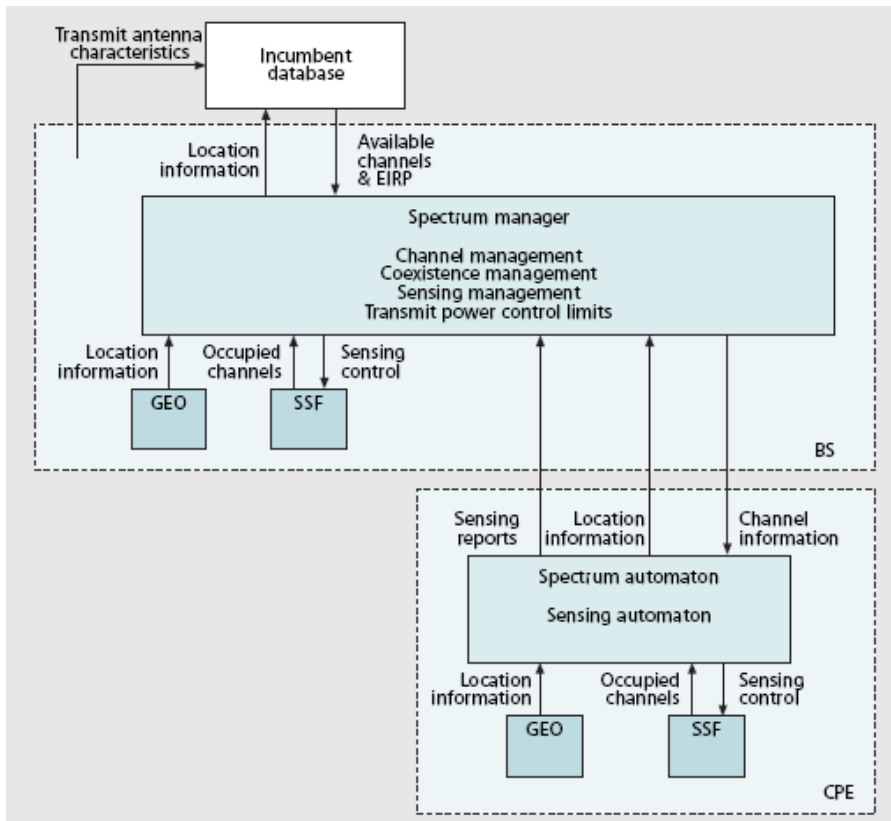
On-demand Frame Contention Protocol

- WRAN cells exchange contention messages, containing random contention numbers, to determine their rights of **Co-Channel Data Frames Access**

Assumption: Only Channel A is available



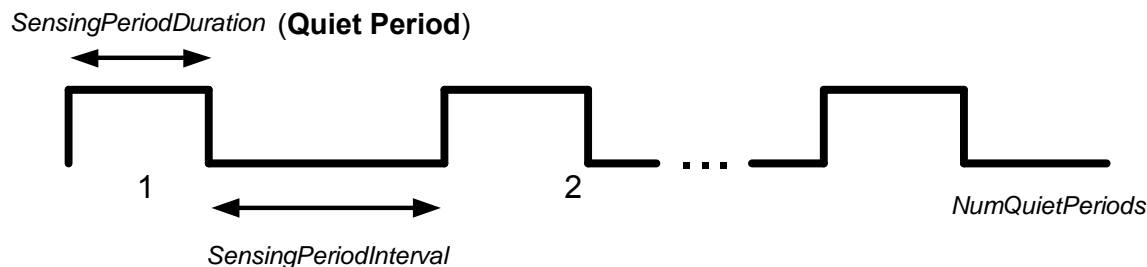
Cognitive Capabilities



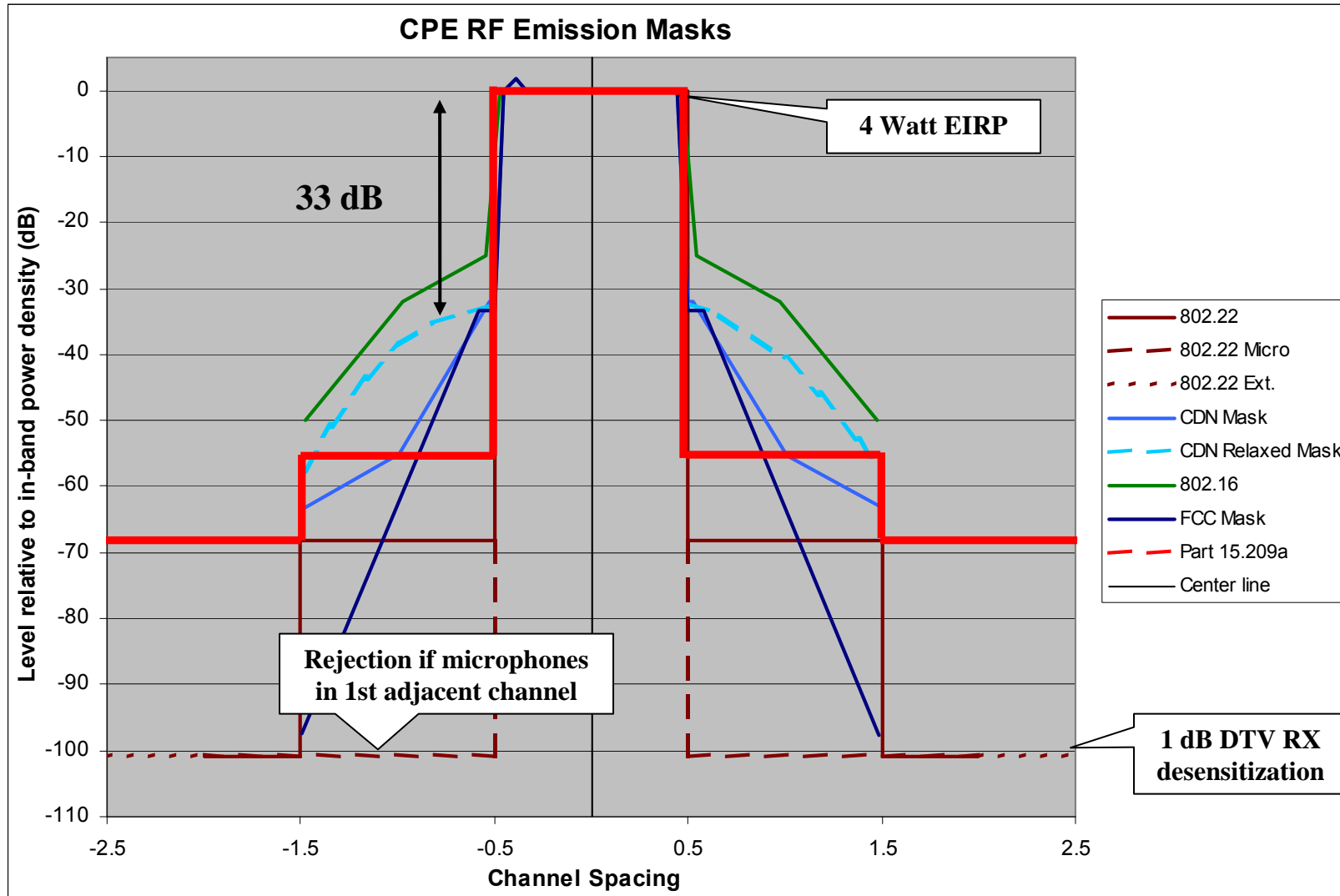
- Decision-making Policy Engines:
 - Spectrum Manager
 - Spectrum Automaton
- Identifying Available TV channels:
 - Geo-location and Access to Incumbent Database
 - Spectrum Sensing
- Protecting Incumbents:
 - Dynamic Frequency Selection (DFS)
 - Transmit Power Control (TPC)

Spectrum Sensing

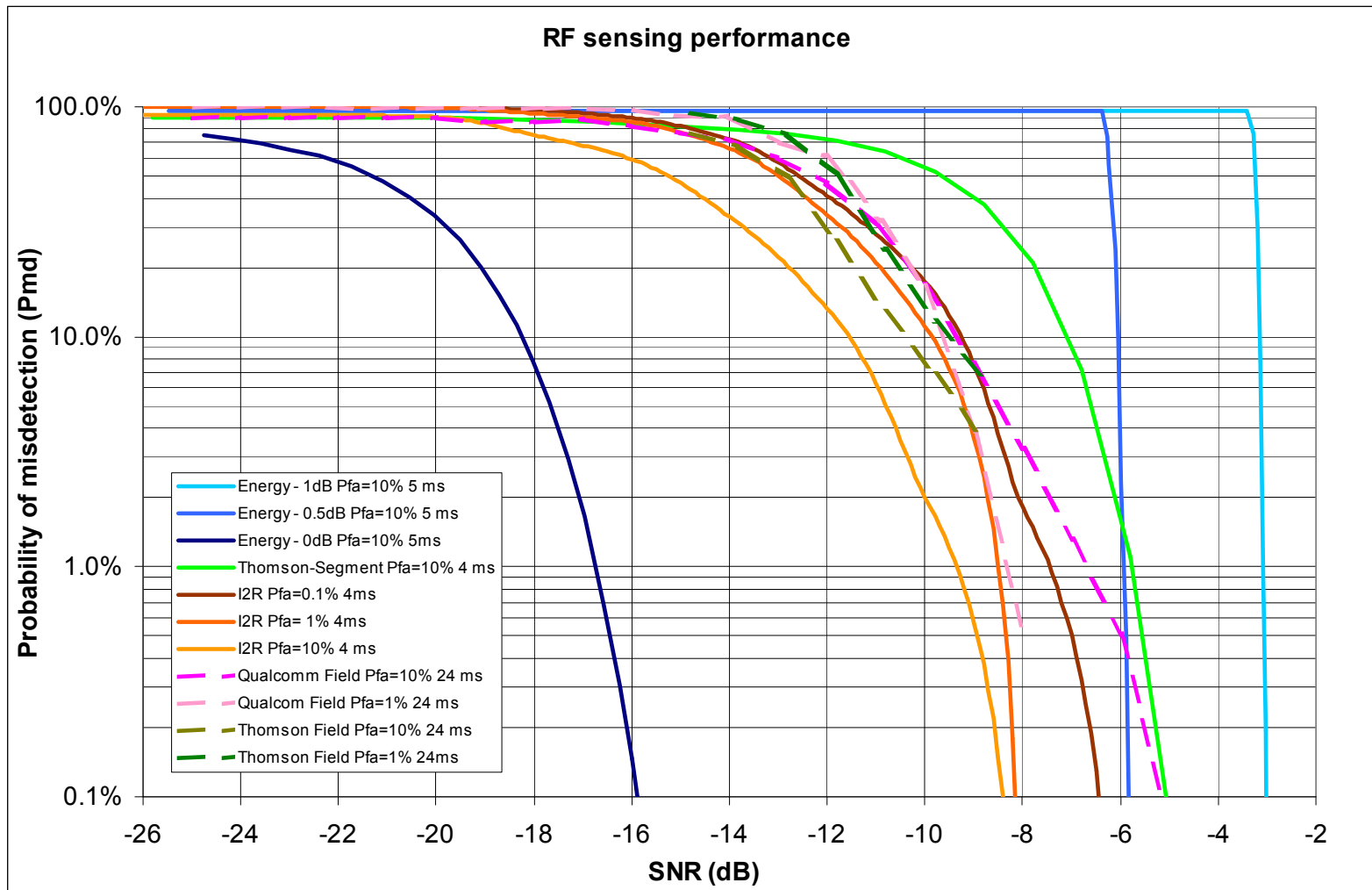
- Observing the radio frequency spectrum (during **Quiet Periods**) and processing the observations to determine if a channel is occupied by a licensed transmission.
- Sensing Thresholds:
 - Digital TV: -116 dBm
 - Analog TV: -94 dBm
 - Wireless Microphones: -107 dBm
- Channel Detection Time:
 - 2 seconds for all signal types
- Probability of Detection:
 - 90% for all signal types
- Probability of False Alarm:
 - 10% for all signal types



Further Observation 1: 802.22 RF Mask



Further Observation 2: DTV Broadcast Incumbent Sensing



Other Projects within IEEE802.22 Family

■ IEEE 802.22.1

- Standard to enhance harmful interference protection for low power licensed devices operating in TV Broadcast Bands

■ IEEE 802.22.2

- Recommended Practice for the Installation and Deployment of IEEE 802.22 Systems

Q & A

Thank you!

References

1. FCC Report and Order 08-260
 - http://hraunfoss.fcc.gov/edocs_public/attachmatch/FC-C-08-260A1.pdf
2. Industry Canada, Radio Systems Policy RP-06, "Where Initially TV channels 25, 34, 35, and 43 are Open for Licensing for Remote Rural Broadband Systems (RRBS)," June 2006.
 - Interim Guideline: <http://www.ic.gc.ca/epic/site/smt-gst.nsf/en/sf08739e.html>
3. OfCom consultations:
 - <http://www.ofcom.org.uk/consult/condocs/cognitive/>
 - <http://www.ofcom.org.uk/consult/condocs/800mhz>