Transformative Cognitive Radio Applications in Healthcare and Vehicular Emergency Networks

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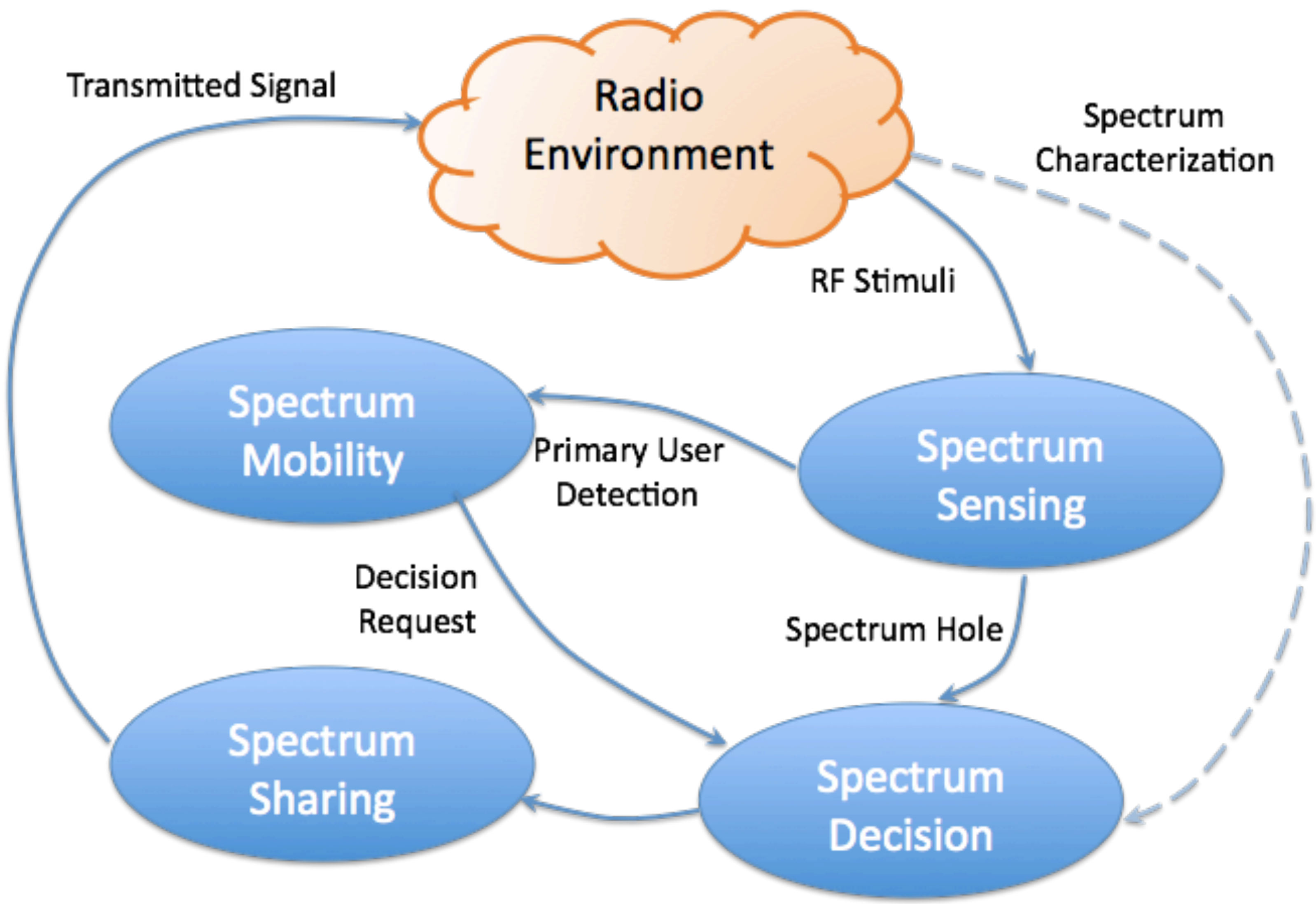
Outline: Two Different Applications

- Introduction to Cognitive Radio (CR) Networks
- CR for Wireless Medical Telemetry
- CR for Vehicular Networks

Cognitive Radio: Definition & Functions

Cognitive Radio: A radio that can adapt its transmission parameters based on interaction with the environment in which it operates

Cognitive Cycle



Wireless Medical Telemetry Service (WMTS)

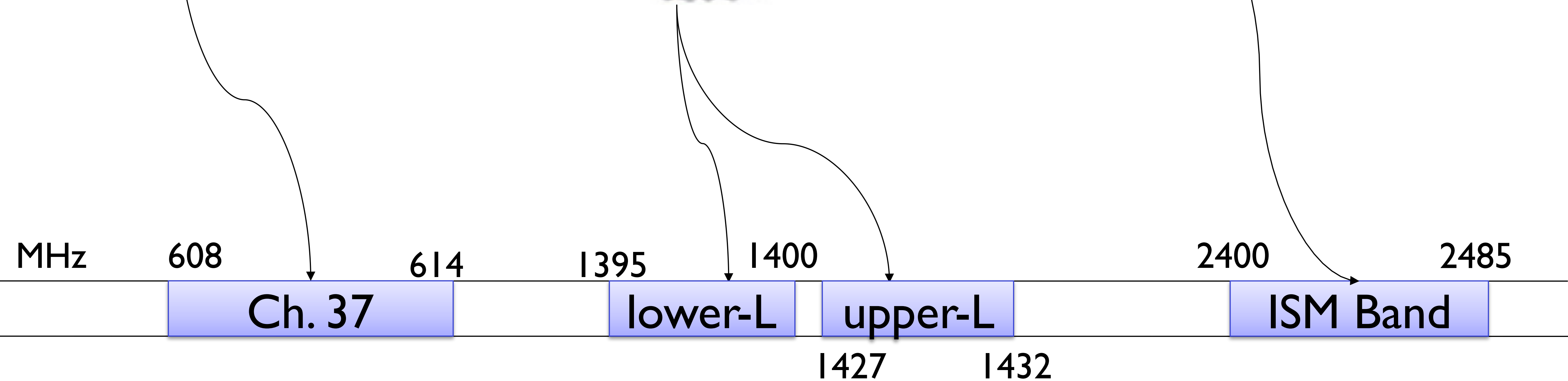
- Medical Telemetry involves transmitting patient's vital signs and signals over wireless to a monitoring station.
- In 2000, FCC has allocated 14 MHz of spectrum as Wireless Medical Telemetry Service band.
  - DTV Channel 36: 608-614 MHz
  - Lower L: 1395-1400 MHz
  - Upper L: 1427-1432 MHz

WMTS Devices: Examples of Current Technology

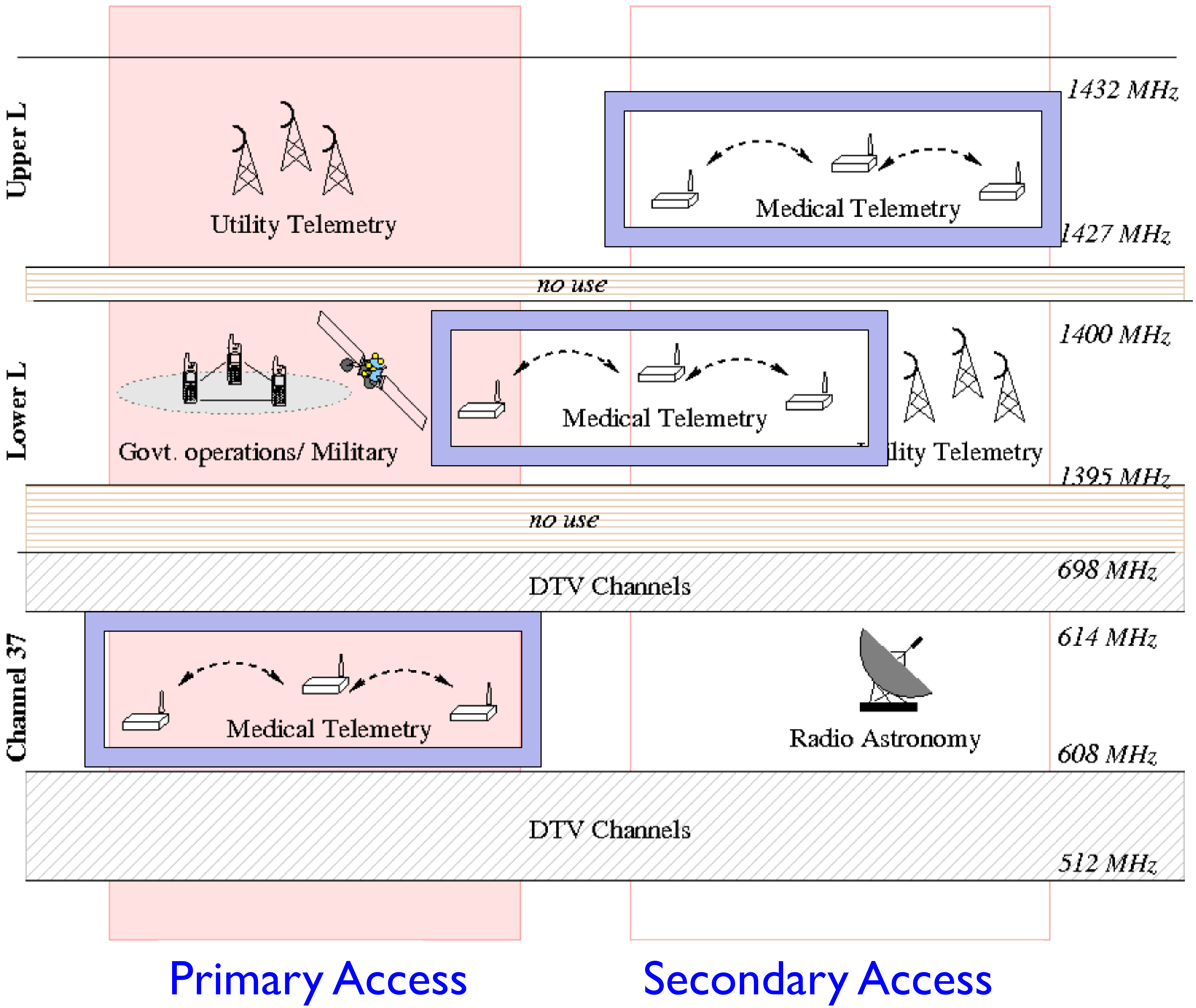
GE Appex Pro
(FM Modulation)

Philips Intellivu
(Smart-Hopping)

Welch Allyn FlexNet
(OFDM)



WMTS Bands: Complex Frequency Allocation

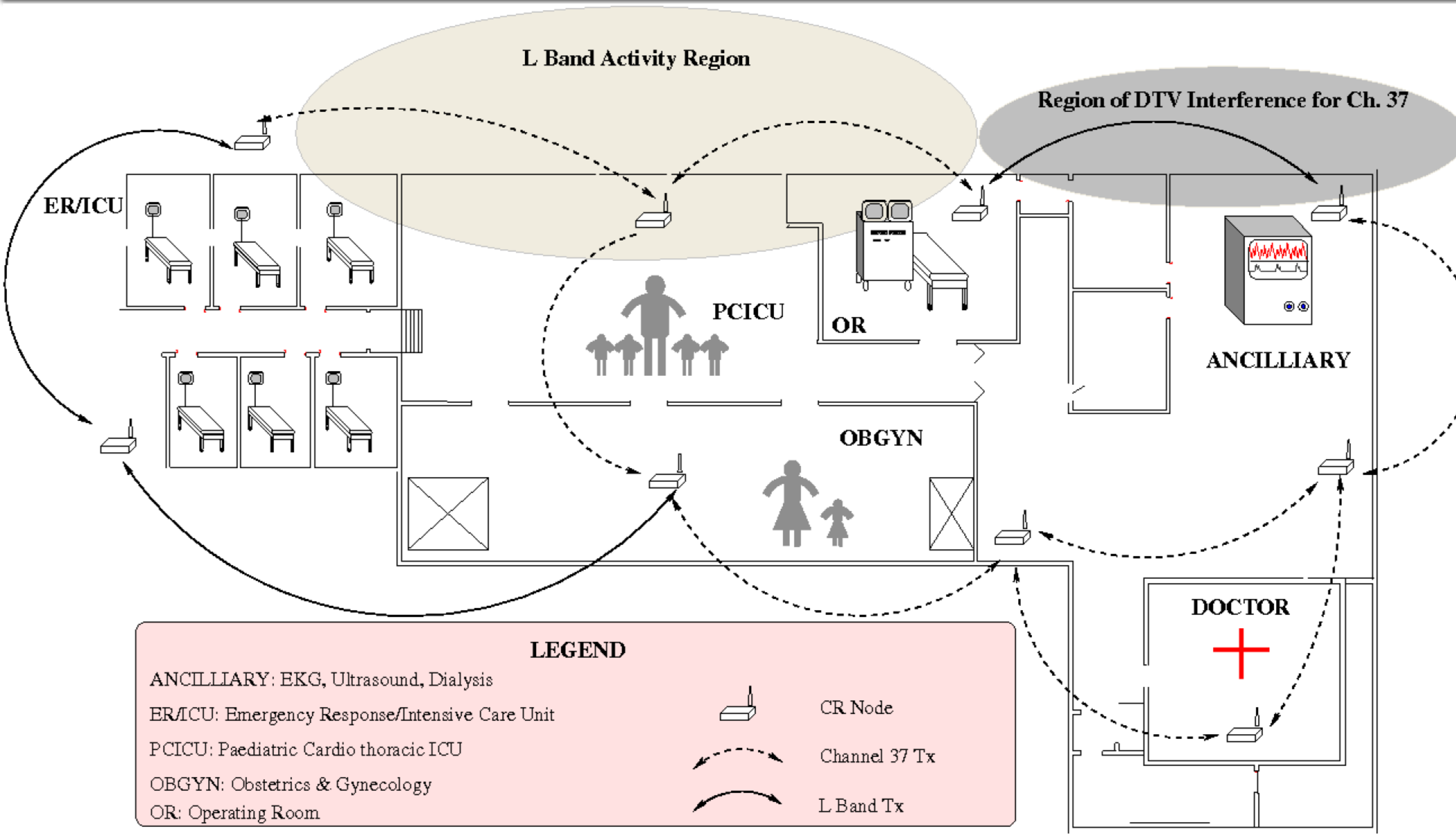


WMTS: Limitations & Drawbacks

- No streaming multimedia (video/audio) allowed in WMTS band
- Shared with utility telemetry companies and the military/governmental installations in the US on the L-band.
- UHF Channel 37 can still be potentially interfered by TV Channel 36 and 38.
- There is no channelization defined for this band and must be used as is
- No standard has been developed for sharing, interference management band and existing devices are using the band sporadically, inefficiently

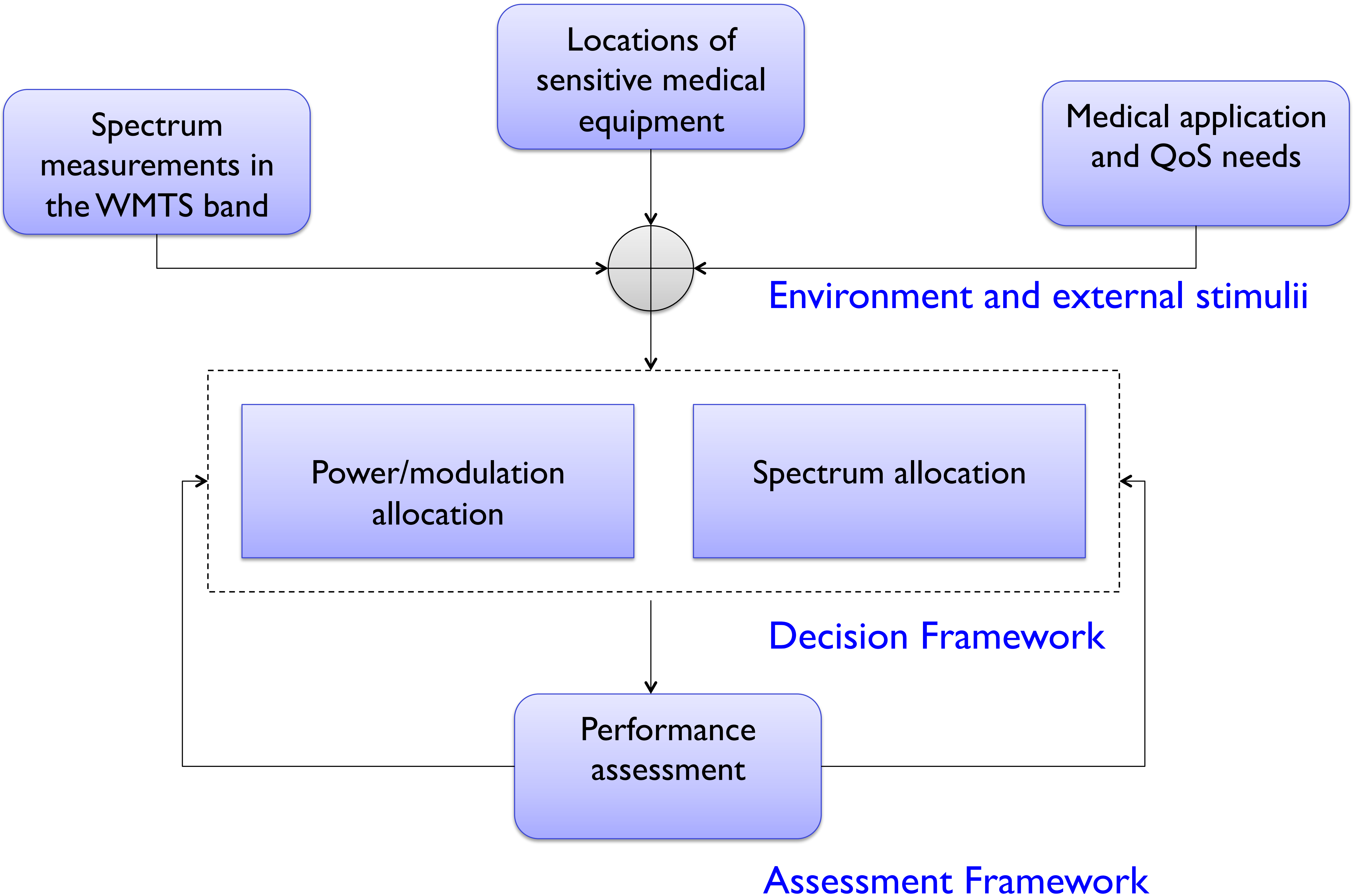
Solution - Cognitive Radio!

CR-enabled WMTS Network: Architecture

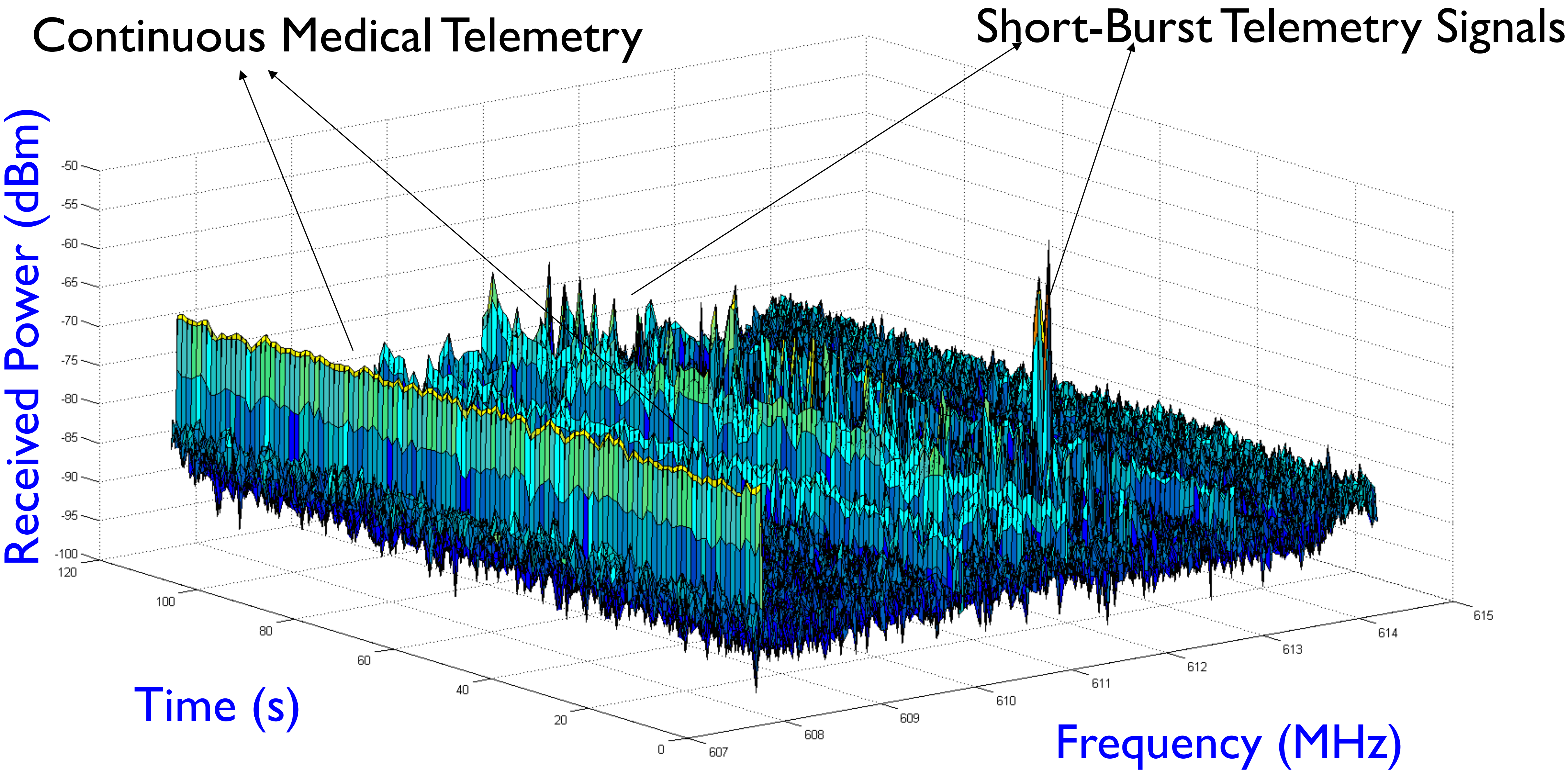


Each hop needs its own channel assignment and power allocation.

Proposed Realization: Logical block diagram

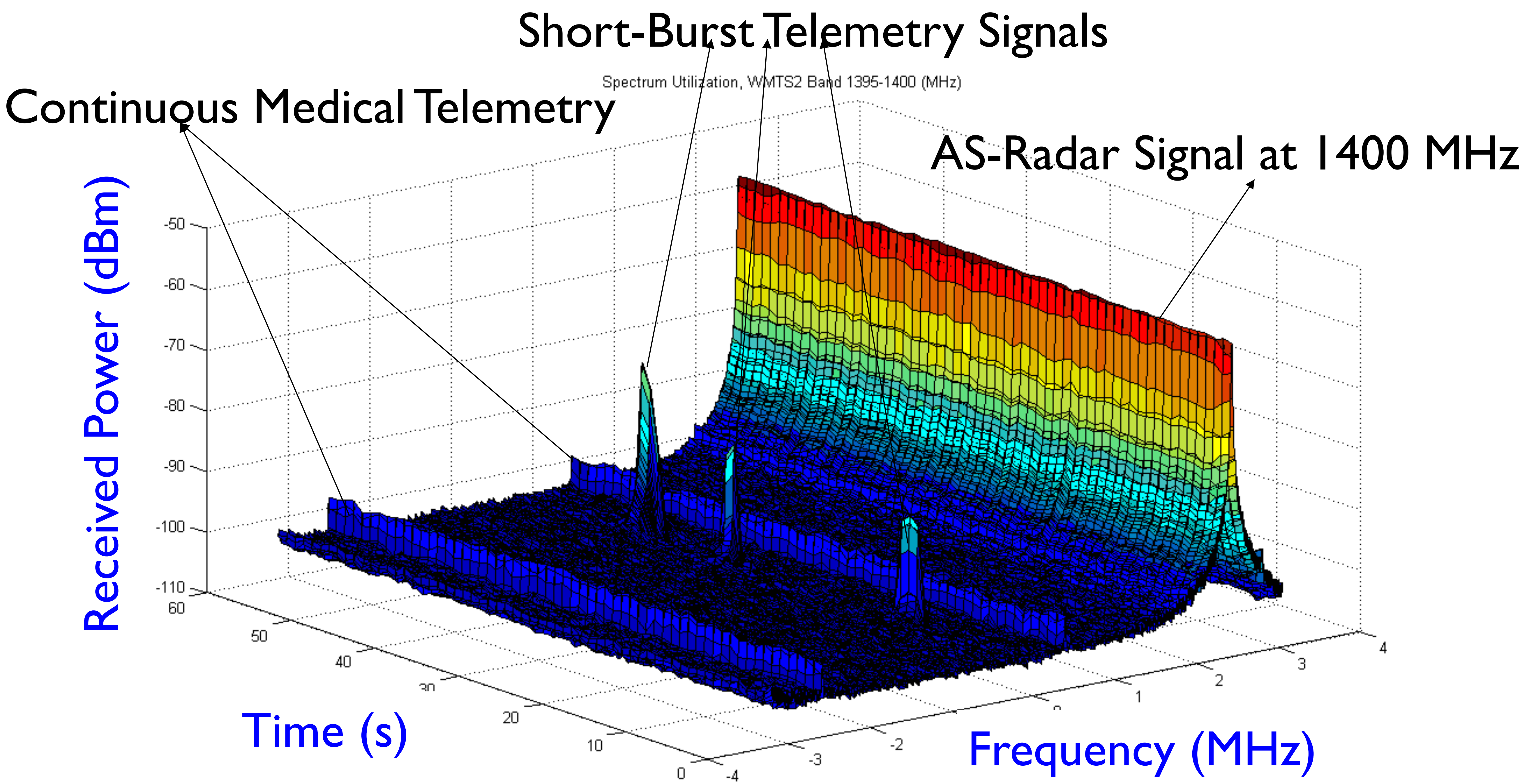


Example WMTS Measurement: Channel 37, 608-614 MHz



Measured at Boston's Longwood Medical Area

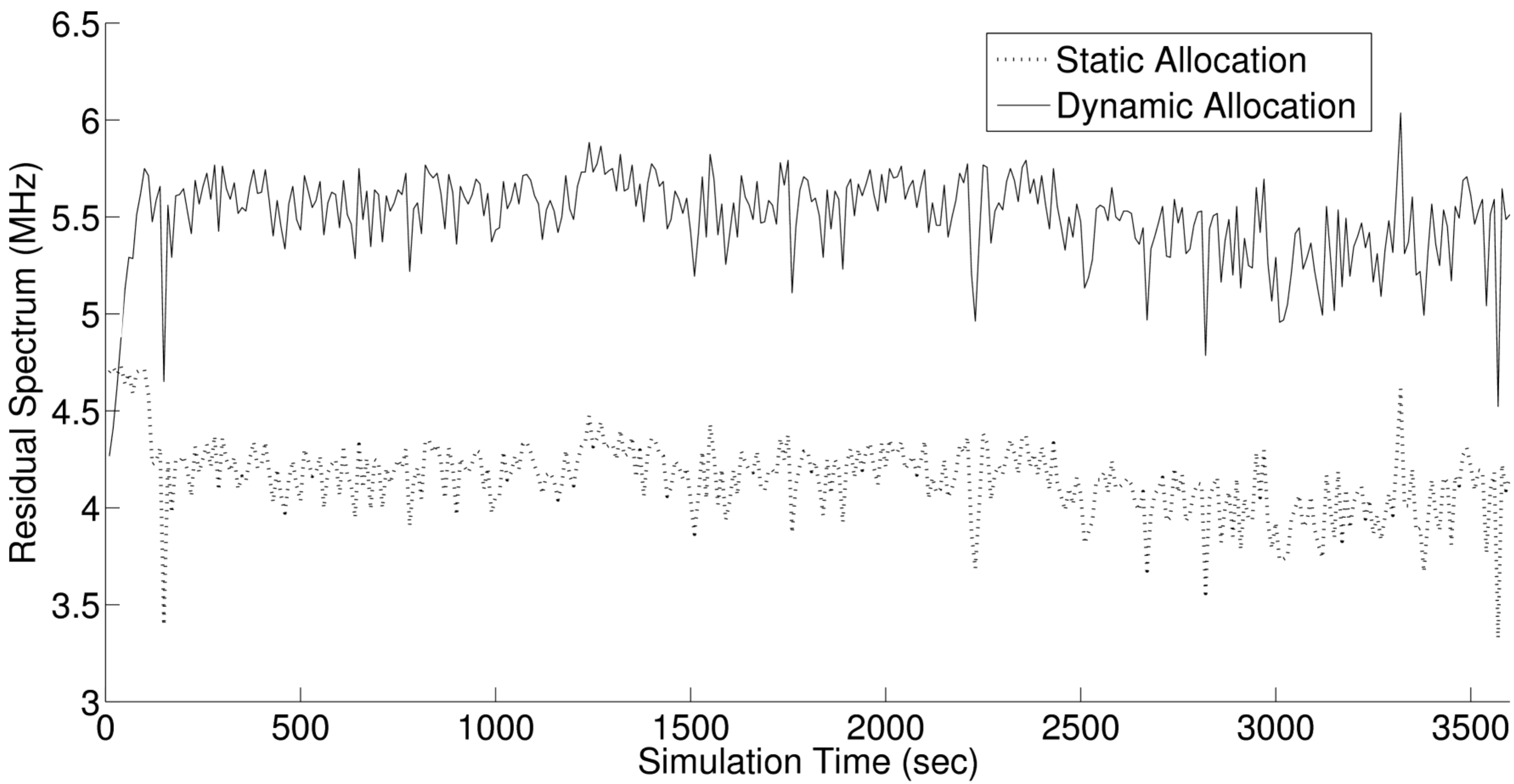
Example WMTS Measurement: Upper L, 1395-1400 MHz



Measured at Boston's Longwood Medical Area

Similar measurements collected for Lower L

Performance Evaluation



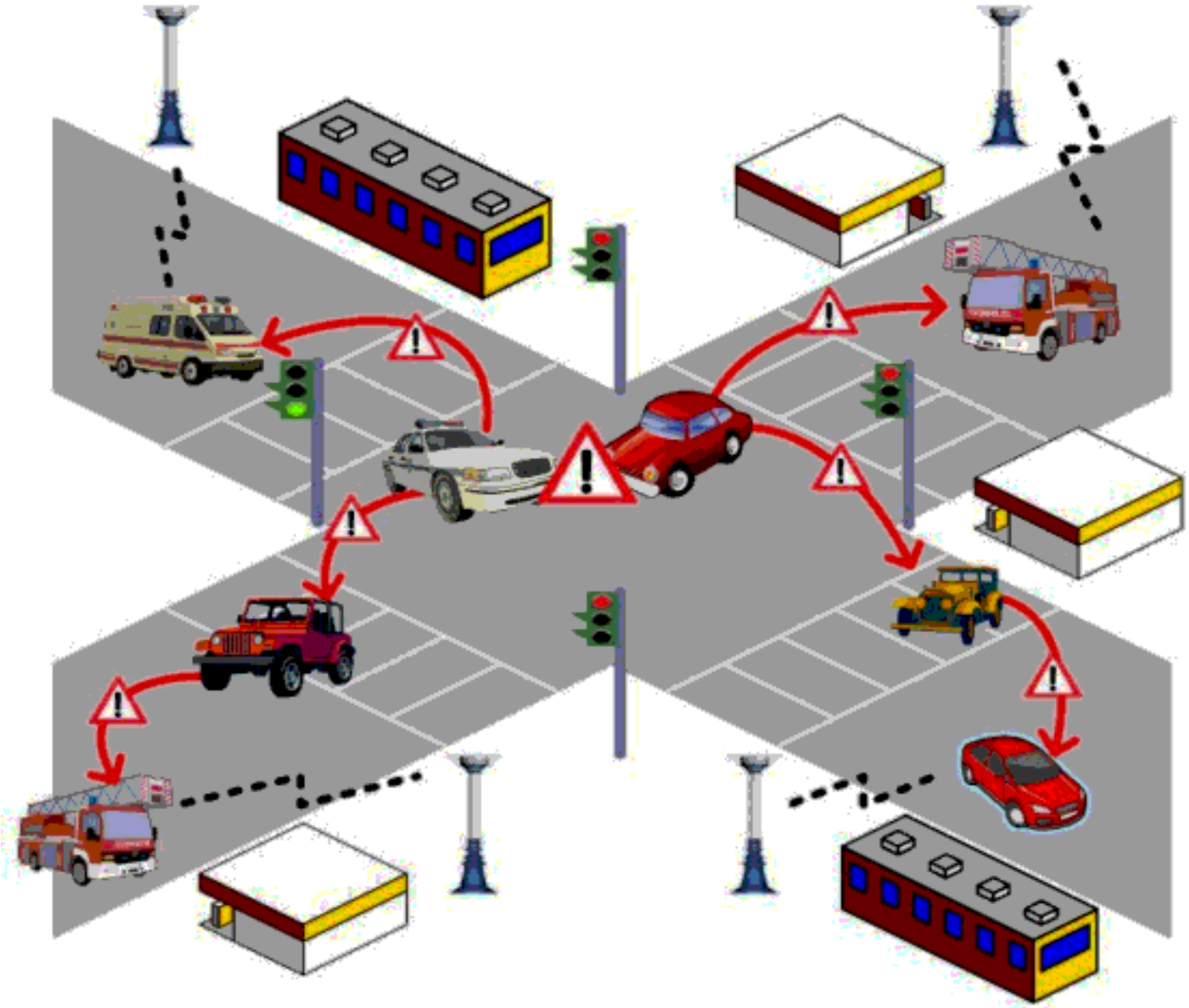
Residual capacity of WMTS band in static and dynamic spectrum allocation scenarios

Research Challenges

- Ensuring that the EMI (electromagnetic interference) at each sensitive device location is under permissible threshold- plug and play possible?
- Exploring "reliability" for multimedia medical communication in DTV bands (as WMTS rules prohibit this)
- Exploring "reliability" in higher layer protocol operation, including equation based transport protocols, TCP, etc
- Identifying the spectrum shapes of typical utility meter transmissions, distinguishing them from other WMTS signals – new feature detection

Vehicular Ad-Hoc Networks: Overview

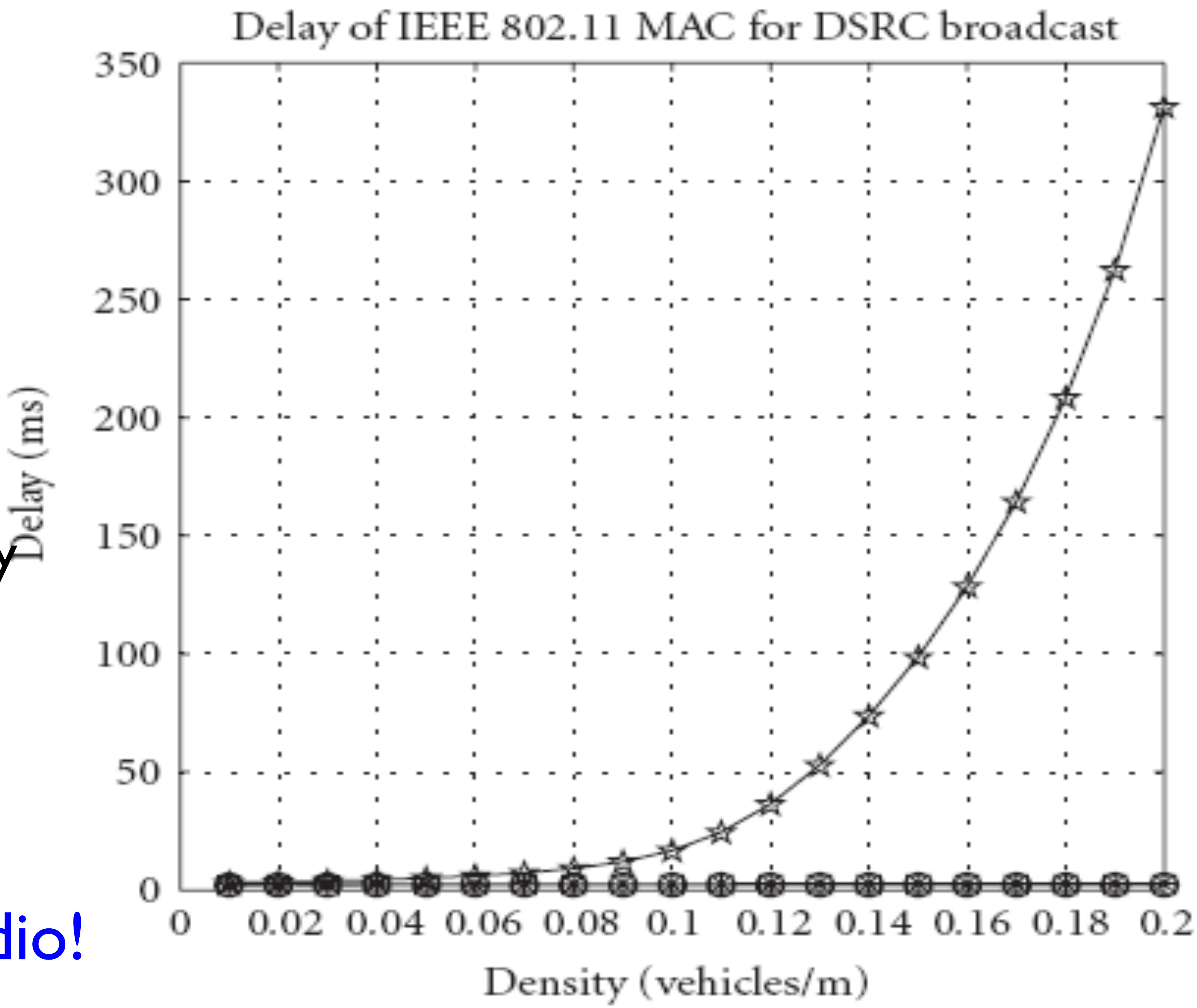
- Vehicular Ad-hoc Networks (VANETs) are composed of vehicles and road-side infrastructure.



- FCC has allocated 75 MHz of spectrum at 5.9 GHz for Dedicated Short-Range Communications (DSRC).
- IEEE 802.11p and IEEE 1609.4 has been developed for regulating vehicular communications.

VANET Concerns: Motivation to Use CR

- DSRC may not be enough to support
  - e-safety applications, peak hours of traffic,
  - high bandwidth entertainment, public safety
  - vehicular to vehicular in terms of national crises

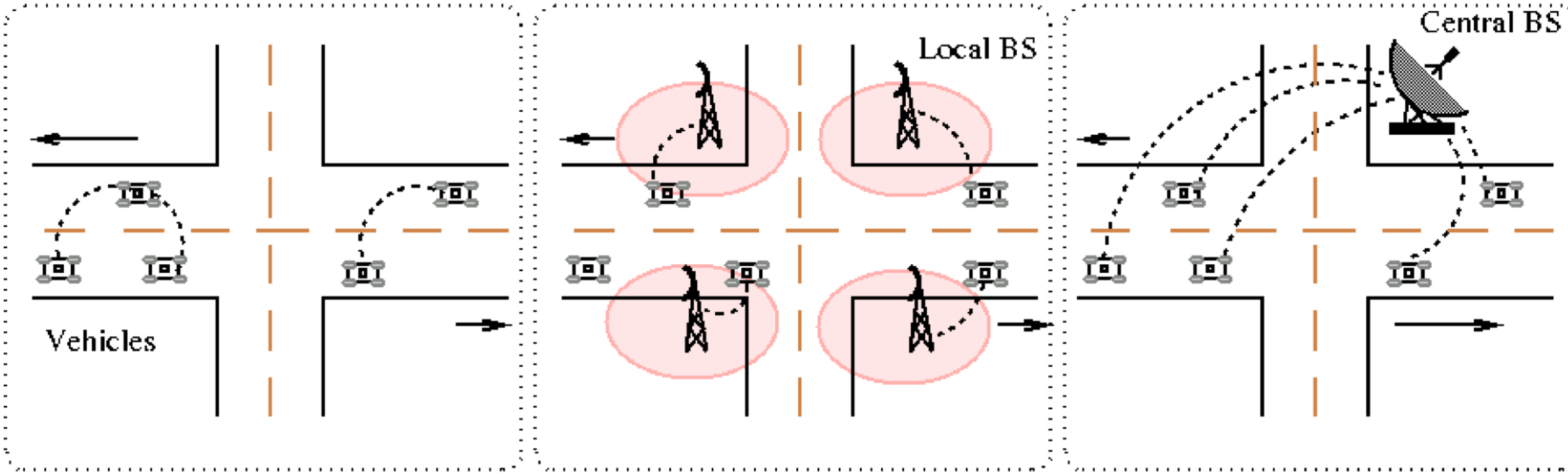


Solution - Cognitive Radio!

Xiaomin Ma, Xianbo Chen, Hazem H. Refai, Performance and Reliability of DSRC Vehicular Safety Communication: A Formal Analysis, EURASIP Journal on Wireless Communications and Networking. Vol. 2009

Research Question #1: Local Sensing/database Access

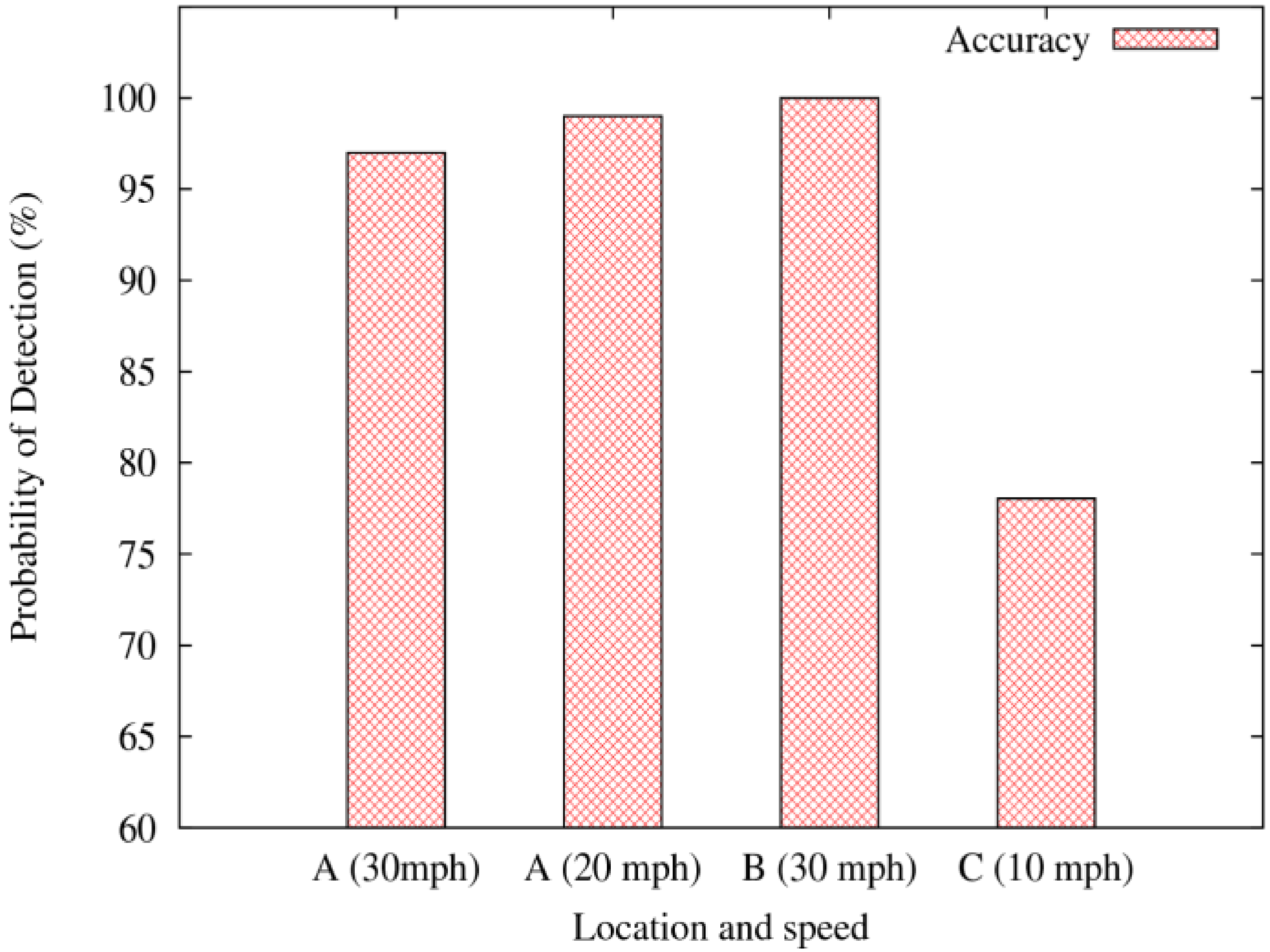
Vehicle to Vehicle   Vehicle to Roadside BS   Vehicle to Central BS



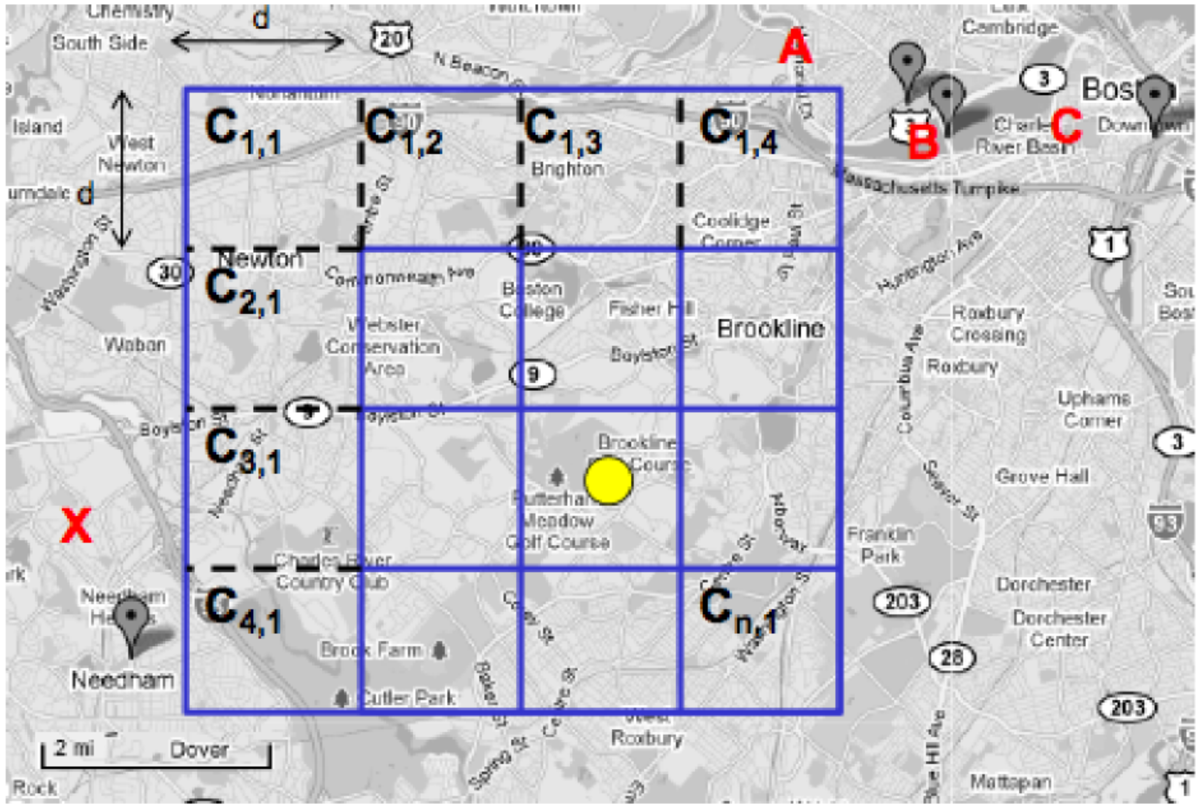
(a)   (b)   (c)

- Recent FCC rulings lay down spectrum database access rules
- The permissible access intervals and vehicular speed limit decide location/ density of external database accessible nodes (Mode II devices)

Research Question #2: Impact of Mobility



- Vehicular mobility impacts sensing accuracy for local sensing

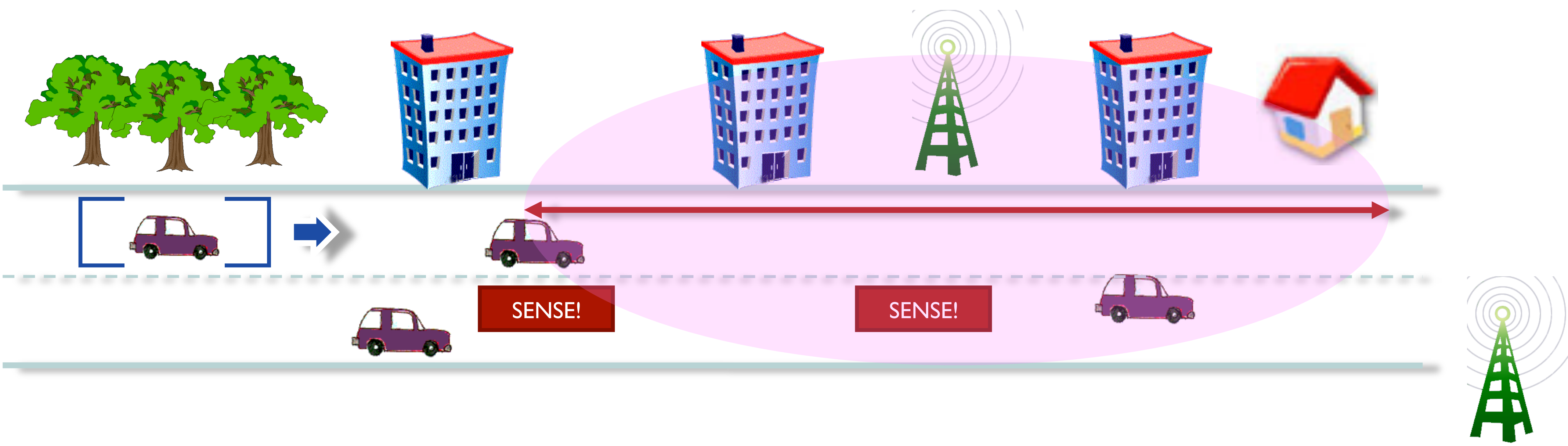


A: Vassar St. (20 and 30 mph) C: High St. (10 mph)
B: Harvard Bridge (30 mph) X: Location of PU

Vehicle Location

- How current are the sensing results? – speed/sensing coupling

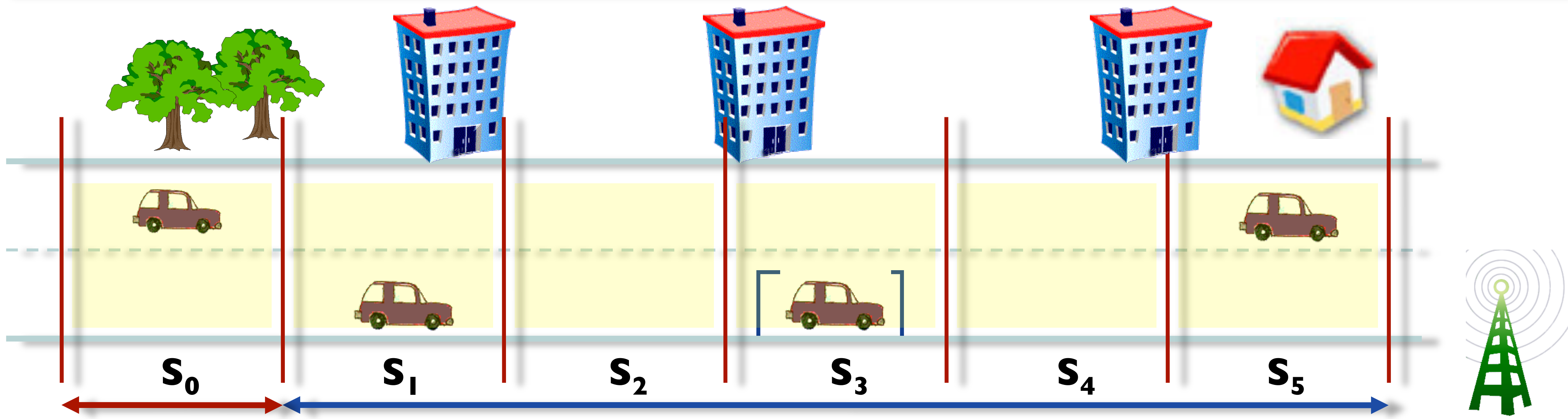
Research Question #3: Impact of Fading and Urban Topology



- Multiple observation points for sensing to beat multipath/shadowing effects from tall buildings
- How to decide which set of observations (or vehicles) to select of cooperation that avoids correlation errors but increases accuracy?

Proposed Realization: "Cog-V2V"

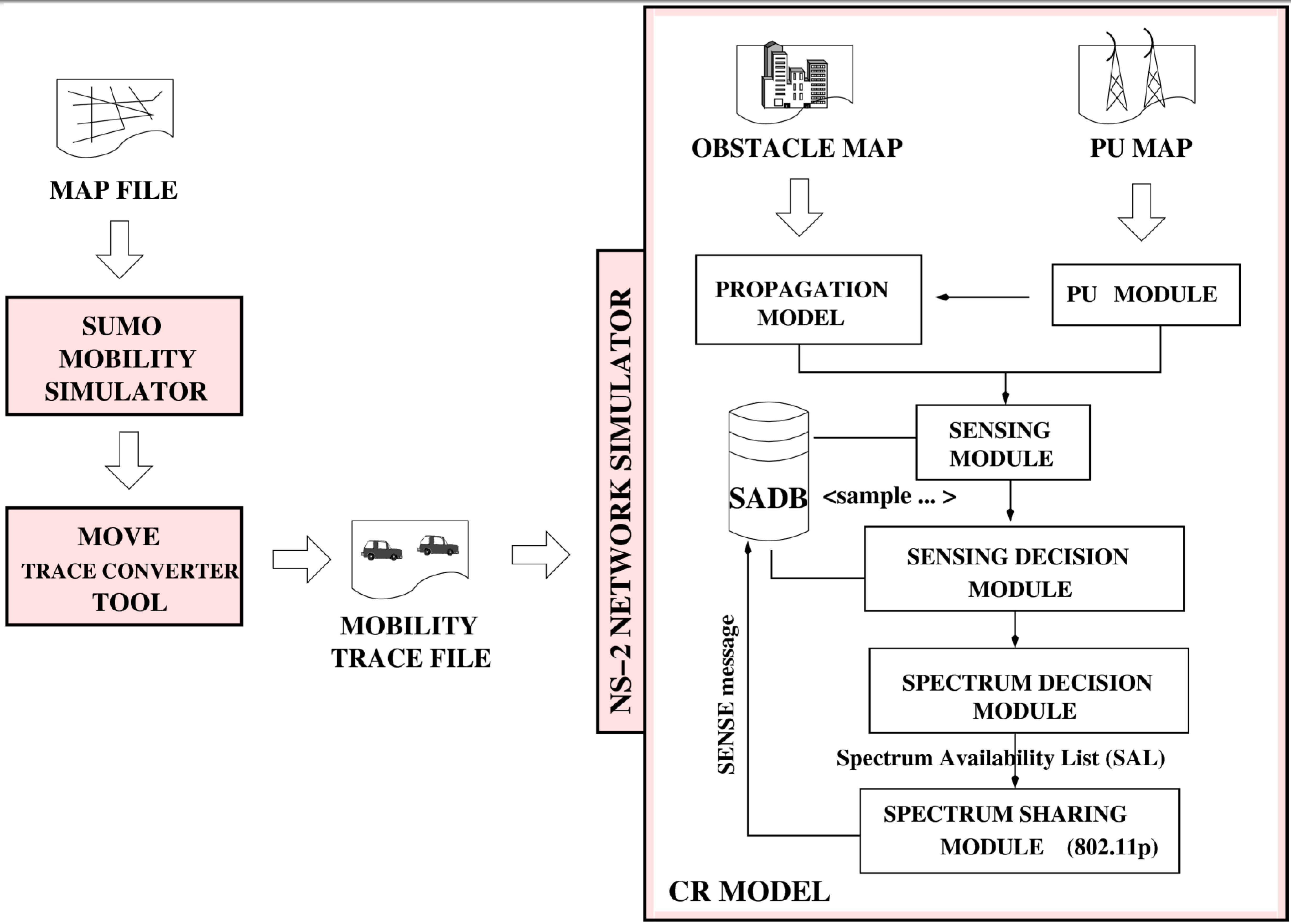
Cog-V2V: *Cross-layer Architecture for Cognitive Inter-Vehicular systems.*



SPECTRUM **HORIZON** (H)

- Cooperative spectrum sensing: Leveraging inter-vehicular distance, past history, number of samples, in a soft (recd. power-based) combination
- Channel Allocation scheme: Channel selection in advance over future locations of the vehicle to create "spectrum directions"

Evaluation of Cog-V2V: New Integrated Simulator Tool



Thank You