An Overview of Cognitive Radio and Intelligent Transportation Systems

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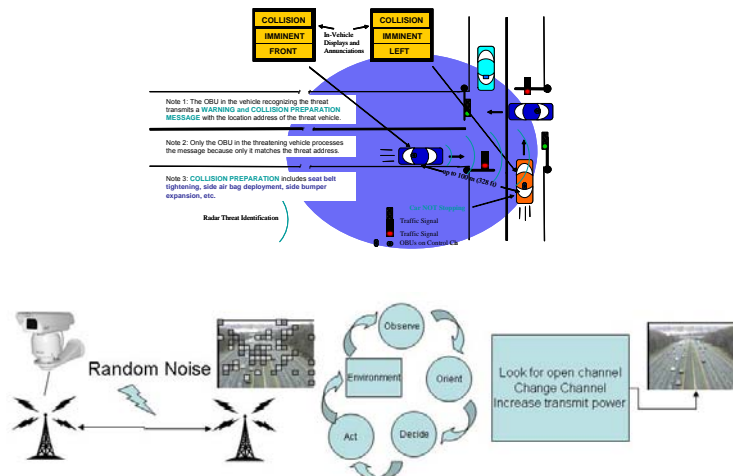AAmanna@vtti.vt.edu

Presentation Overview

- ## Cognitive Radio
  - Applications, Activities, and relationship to SDRF

	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		

COLLISION IMMINENT FRONT In-Vehicle Displays and Annunciations COLLISION IMMINENT LEFT

Note 1: The OBU in the vehicle recognizing the threat transmits a **WARNING and COLLISION PREPARATION MESSAGE** with the location address of the threat vehicle.

Note 2: Only the OBU in the threatening vehicle processes the message because only it matches the threat address.

Note 3: **COLLISION PREPARATION** includes seat belt tightening, side air bag deployment, side bumper expansion, etc.

Radar Threat Identification

Traffic Signal
Traffic Signal
OBUs on Control Ch

Random Noise

Observe, Orient, Decide, Act, Environment

Look for open channel
Change Channel
Increase transmit power

- ## Intelligent Transportations Systems and Cognitive Radio
  - Needs and potential uses for cognitive radio in ITS

What is Cognitive Radio?

- "An approach to wireless engineering wherein the radio, radio network, or wireless system is endowed with the capacities to:
  - acquire, classify, and organize information (*aware*)
  - retain information (*aware*)
  - apply logic and analysis to information (*reason*)
  - make and implement choices (*agency*) about operational aspects of the radio,
 - network, or wireless system in a manner consistent with a purposeful goal (*intelligent*)."[1]

1. Cognitive Radio Definitions and Nomenclature," SDRF-06-R-0009-V0.08
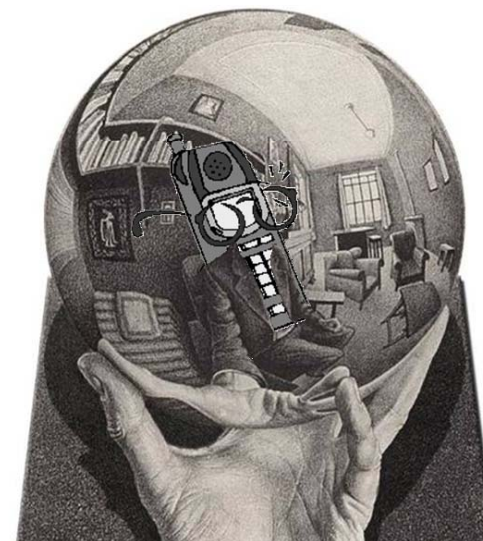
1. A design paradigm AND a device / network

2. Formalization of a pre-existing trend

3. One emerging example of domain-specific AI.
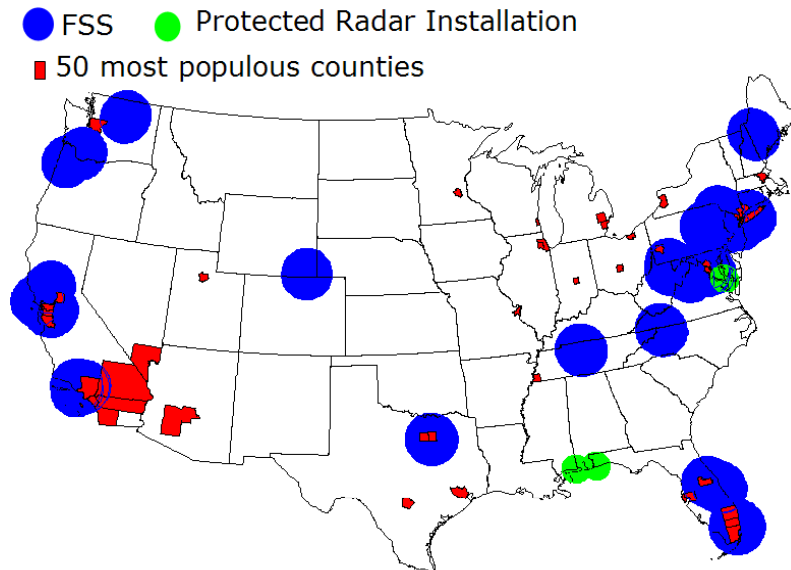
Why Cognitive Radio?

- CR paradigm enables many applications
  - Too tedious to do manually
  - Things requiring a fast response
- CR allows design decisions to be made in the field
  - Simultaneously solve fewer corner cases
  - Adapt to the use case at hand, rather than solve all use cases simultaneously
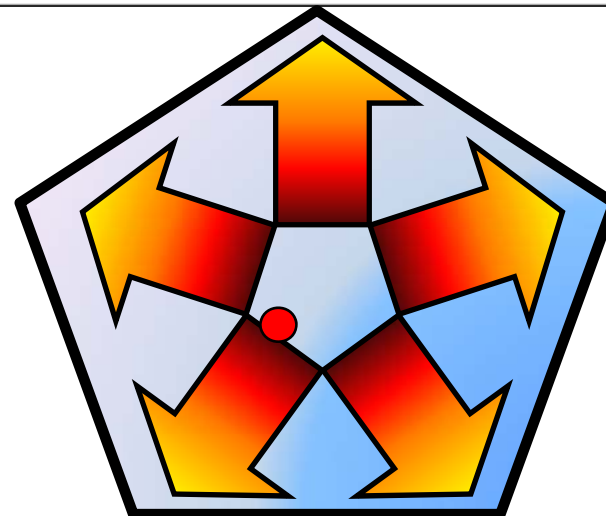
Dynamic Spectrum Access (DSA)

- **DSA enables run-time flexible access to spectrum**
  - Spectrum allocated to service A, but can be used by service B when A is not using it
- **Rules for access defined via policy (implicit or explicit)**
- **Focus is on primary-secondary coexistence**
- **Common technologies**
  - Spectrum sensing
  - Geolocation / database
  - Policy reasoning
  - Dynamic Frequency Selection
  - Transmit Power Control

Geolocation and DSA in 802.11y

🔵 FSS   🟢 Protected Radar Installation

🟥 50 most populous counties

Source: IEEE 802.11-06/0YYYr0

- **Commercial examples**
  - 802.22
  - 802.16h
  - 802.11h
  - 802.11y,
  - White Space Devices

Cognitive Radio standardization activities

- **White Space Database Group**
  - Addressing FCC requirements
- **CogNeA**
  - Publishing through ECMA (TG-48 TG1)
- **802 Executive Committee Study Group on White Spaces**
  - Assess the impact of the FCC White Space R&O on IEEE 802 activities and form initial plans
- **Next Generation Mobile Networks**
  - http://www.ngmn.org/

SCC41

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- **802**
  - 802.11h, y
  - 802.16h
  - 802.19
  - 802.22
- **E3**
- **LTE-Advanced, 802.16m**

SDR is a natural platform for CR

- Corner cases still drive hardware costs / performance
- Simply easier to implement CR processes in software

SDR forum

- CRWG
  - Definitions
  - Uses & explanation for ITU
  - Quantified results
  - Dynamic databases

- Modeling Languages for Mobility
  - Ontology for interactions and policy
- Test & Measurement
  - How to test CR functions?
- Public Safety SIG
  - Identify relevant uses
  - Study applicability of WNAN
- Satellite SIG
  - Deconflict satellite and WiMAX
- Liasions with 802, E3, ITU
- Timely workshops

The Needs of Transportation

Wireless Communications
- Remote sensors
- Wireless CCTV
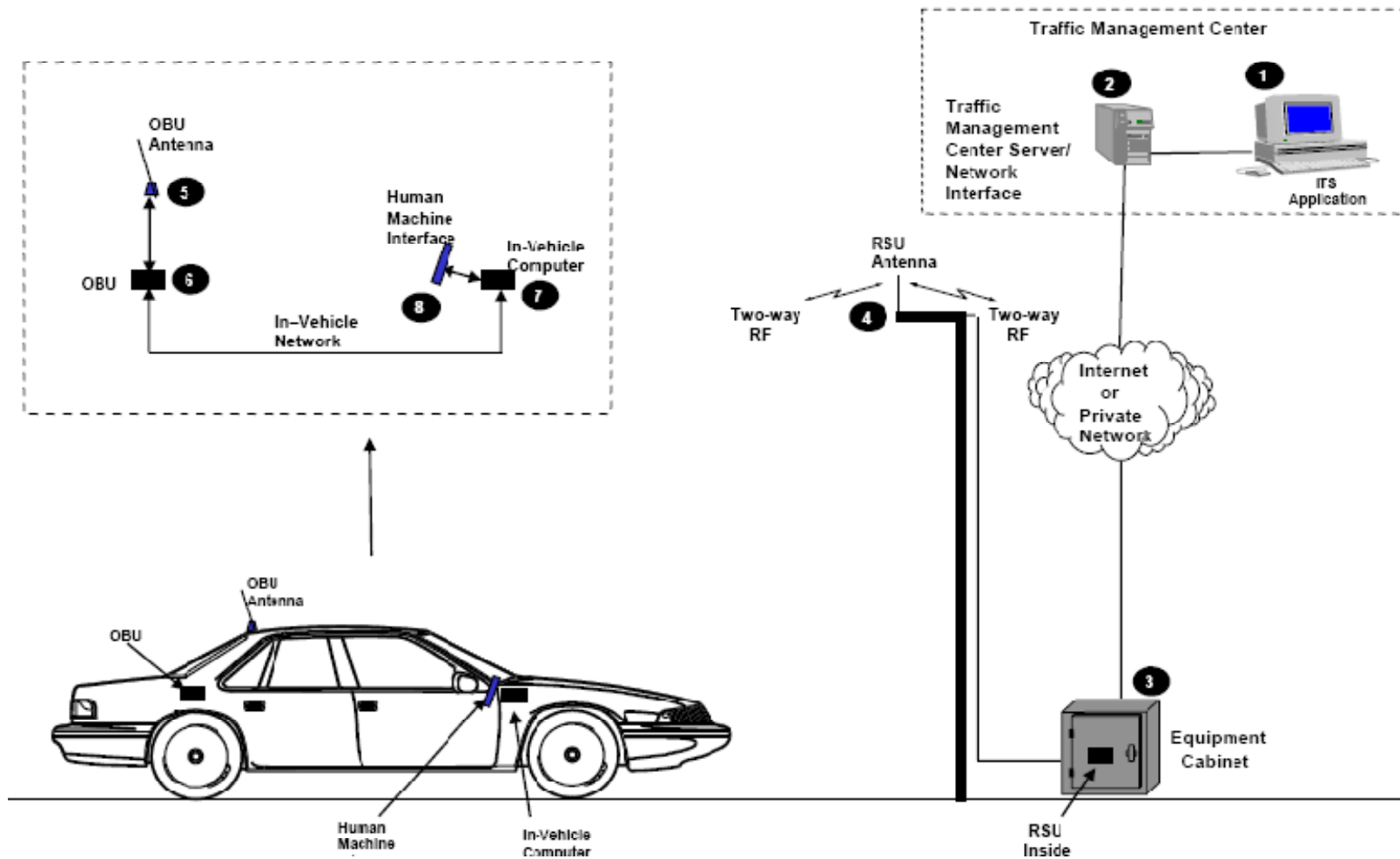- V2I communications
- V2V Communications

802.11p DSRC

- DSRC designed to adapt 802.11a to vehicle environment
- 5.850-5.925Ghz
- Modified 802.11a MAC
- Low latency, Speeds up to 120mph
- Prioritization scheme
- Seven 10MHz channels, 1 control channel, 6 data channels

IntelliDrive (V2V, V2I)

Source: B. Cash, 2004, *WAVE Background Information*

Numerous Applications

- Emergency warning system for vehicles
- Cooperative Adaptive Cruise Control
- Cooperative Forward Collision Warning
- Intersection collision avoidance
- Approaching emergency vehicle warning (Blue Waves)
- Vehicle safety inspection
- Transit or emergency vehicle signal priority
- Electronic parking payments
- Commercial vehicle clearance and safety inspections
- In-vehicle signing
- Rollover warning
- Probe data collection
- Highway-rail intersection warning
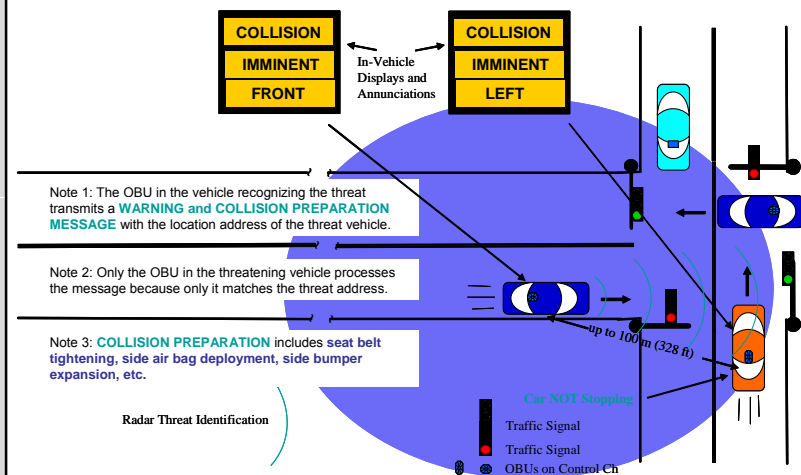
From: IEEE 802.11- 04/ 0121r0
Available:
http://www.npstc.org/meetings/Cash%20WAVE%20Information%20for%205.9%20GHz%20061404.pdf

Issues

- Limited spectrum, many users
  - Channel assignments
- Many! different use cases to satisfy
- System Integrator Deployment Costs
- Government Procurement Timelines
- Dynamic wireless environment leads to constant system tweaking
- How to encourage commercial partnership while prioritizing safety applications

CR Applications

- Adapt to changing spectrum conditions
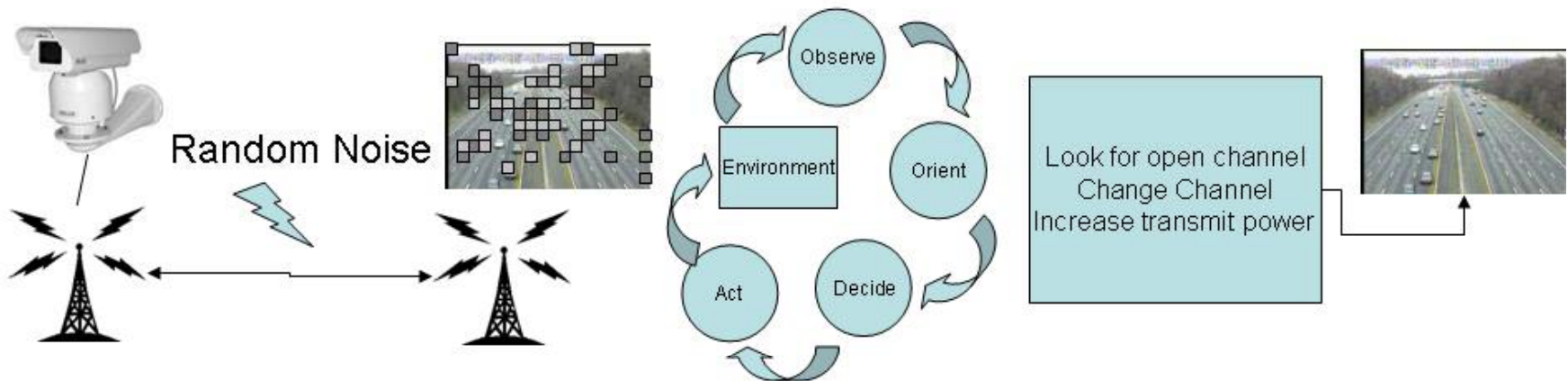
- Optimize limited medium amongst greedy agents
- Allow CR to tune communications design to changing "mission" of transportation network

CR Applications

- Optimize handoffs between roadside units
- Can DSA enable both commercial and safety application on the same spectrum?
- Can CR enable Self Organizing Network deployment
  - Self initialization, self management, adaptation
  - Save on deployment and management costs
- Can an SDR platform break the typical procurement cycle?
  - 'Future-proof' devices that can adapt

Presentation Take-Aways

- Cognitive radio is emerging as an critical technology to wireless networks
  - Most focus on spectrum access / management
  - Also allows network design to be tuned to changing uses
- ITS / 802.11p has numerous challenges
  - Cognitive radio can solve some of these
    - Spectrum access, optimizing for different apps.
  - Others may remain elusive for the moment
    - Business model