Cog-TV: Business and Technical Analysis of Cognitive Radio TV Sets for Enhanced Spectrum Access (CNS 1247941/1247914)

PI (UNL): Mehmet C. Vuran (CSE, mcvuran@cse.unl.edu)
Co-PI (UNL): Demet Batur (Management, dbatur@unl.edu)
PI (OSU): Eylem Ekici (ECE, ekici@ece.osu.edu)

Motivation

- Existing argument: "*Emerging cognitive radio networks result in a technical and an economical conflict with the TV broadcast companies*"
- Our view: Conflict → Opportunity
- Is it economically and technically viable for broadcast companies to utilize TV white spaces for
  - low-cost Internet provision
  - web-enabled TV services?

Research Goals

- Business Aspects of Cog-TV: Dynamic pricing schemes to balance demand between peak and non-peak periods; infrastructure cost analysis for Cog-TV integrated network.
- Neighborhood Watch : Analysis of spectrum sensing accuracy and correlation in the spectrum sensing information; optimal sensing scheduling algorithms to minimize sensing overhead and maximize bandwidth.
- Cog-TV-initiated Spectrum Handoff: Methodologies to estimate the opportune times to initiate spectrum handoff; strategies for broadcast companies to address the self-competition challenge that results in serving two types of customers: TV viewers and cognitive Internet users.

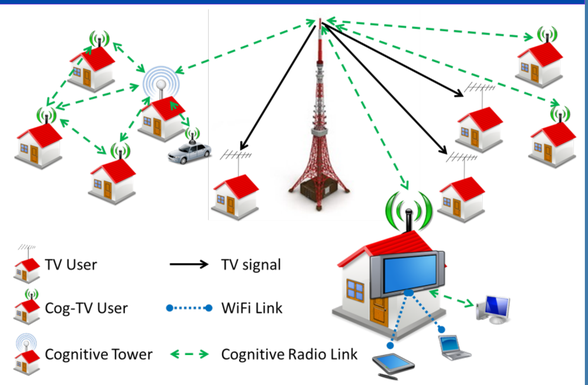
Cognitive radio-equipped TV sets (Cog-TVs)

- TV tuner, integrated CR interface, and Wi-Fi interface
- Cog-TV provides three main capabilities
  - Low-cost access to the Internet in residential and commercial spaces
  - Interference measurement of TV services for enhanced quality of user experience
  - Localized collaborative spectrum sensing for fine-grained spectrum management

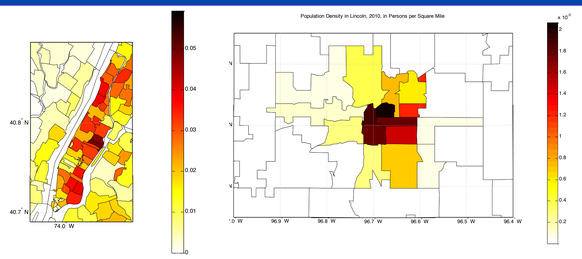
Potential Payoffs

- Enable transformative and economically viable CRN development and management approaches
- Bring affordable Internet service to a large group of American households
- Impact consumer market by creating a niche market in new TV sets

Cog-TV Network Architecture



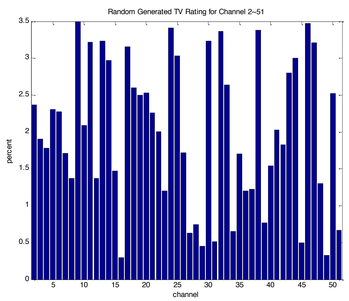
Available Channel Capacity: Cog-TV vs. FCC



Manhattan Population Density

Lincoln Population Density

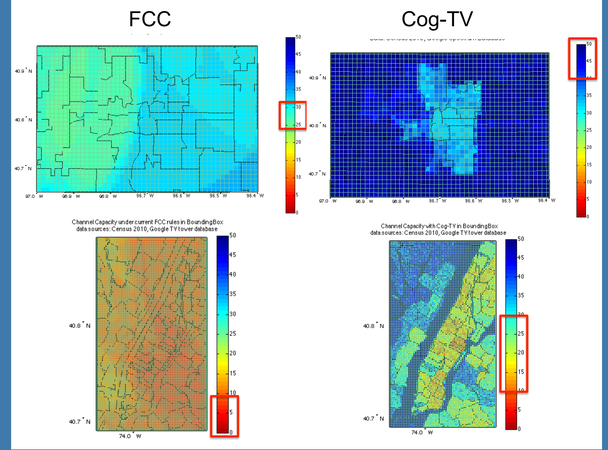
TV Ratings (Worst-Case, Static)



Not available publicly
Assumptions:
(1) 8% of population are watching broadcast TV **(worst-case)**
(2) Randomly generated rating data

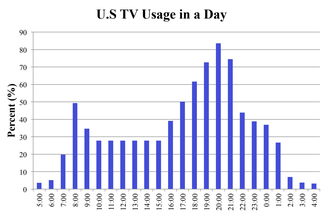
Results: Available TV Channels

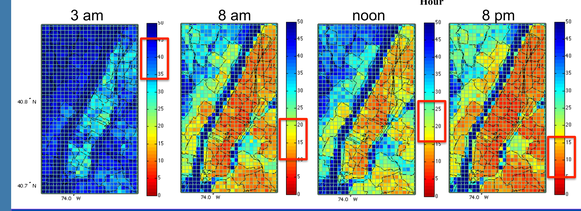
- Spatial distribution of available channels (Lincoln & Manhattan, NY)



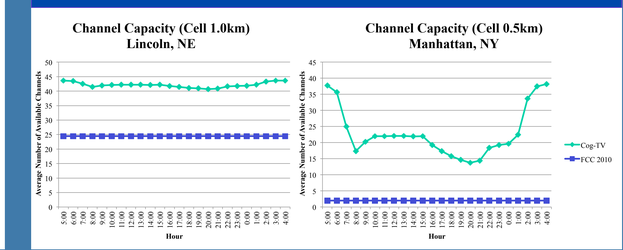
Daily Variations of TV Viewership

- Limited public data on daily variations of TV viewership [1]
- Interpolated to hourly intervals
- 3.50% - Broadcast only TVs over total TVs [1]
- Avg. 2.24 TVs per TV household [2]
- 7.84% - Broadcast only TV sets over U.S population [3]





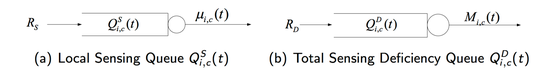
Daily Dynamics of Available Capacity



CORN²: Correlation-Based Cooperative Spectrum Sensing in CRNs [4]

- Local information essential to assess spectral availability
- Most observations are highly correlated in Space, Time, and Spectrum
- Objective:
  Leverage correlations for cooperative spectrum sensing to minimize energy consumption
  Develop (centralized and distributed) sensing scheduling algorithms

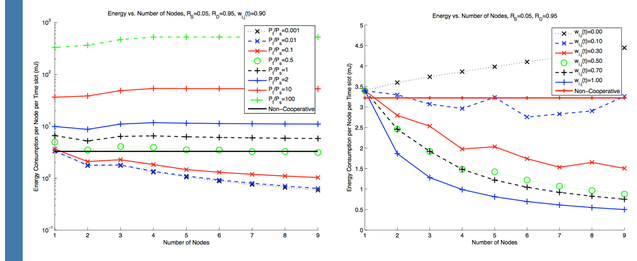
Virtual Queue Concept



(a) Local Sensing Queue $Q^S_{i,c}(t)$ (b) Total Sensing Deficiency Queue $Q^D_{i,c}(t)$

- Local Sensing Queue ensures that nodes perform sensing at a rate > R_S and do not cheat
- Sensing Deficiency Queue ensures a sensing quality > R_D by eliminating deficiency at rate $M_{ic}(t)$
- The centralized solution ensures stability of all queues while minimizing total energy consumption
- If total contribution of all neighbors is bounded, then a fully distributed algorithm exists
- Bounded contribution holds for low SNR cases and when temporal correlation is high
- The resulting algorithm can be computed locally

Results: Energy Consumption / Node



$R_S = 0.05$, $R_D = 0.95$, $P_S = 3.5$mJ, $P_{Tx} = 0.1125$mJ, $w_{ij}(t) = 0.90$

References

[1] Nielsen Npower, Season-to-date 9/19/2011 to 1/29/2012 and 9/24/2012 to 1/27/2013 (http://www.nielsen.com)
[2] http://www.csun.edu/science/health/docs/tv&health.html#tv_stats
[3] Census 2010
[4] D. Xue, E. Ekici, M. C. Vuran, ``(CORN)^2: Correlation-based Cooperative Spectrum Sensing in Cognitive Radio Networks,'' in Proc. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt'12), Paderborn, Germany, May 2012.