Experiments with TVWS Access

Access Delay and Energy Consumption

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TUDelft

Outline

Motivation

"spectrum sensing is expensive—in cost, energy consumption and complexity of the circuitry."

X. Ying, J. Zhang, L. Yan, G. Zhang, M. Chen, R. Chandra, **Exploring indoor white spaces in metropolises**, in Proc. ACM MobiCom, Miami, FL, USA, Sep. 30–Oct. 4, 2013

But is it really so?

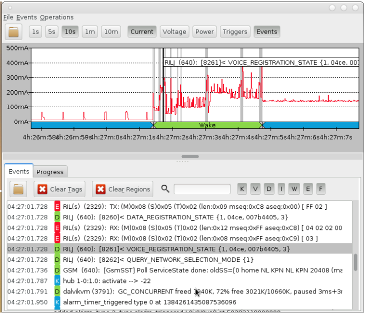
The Idea

1. Connect to WSDB through Android-based smartphone and collect data on
   - Access delay (query $\rightarrow$ response)
   - Energy consumed (per RAT, per smartphone)
2. Perform local spectrum sensing with Android-powered SDR platform and collect data on
   - Access delay (time until whole sensing is done)
   - Energy consumed (per dongle)
3. Analyze data, model results, suggest sensing strategies for embedded devices

Measuring Energy Consumption

Neat Power Measurement Toolkit

- Custom-build power measurement platform [“Embedded Monsoon”]
- Correlates system events with energy use
- Andriod-based, 2 kHz sampling, SD Card storage, external battery



N. Brouwers, M. Zuniga, K. Langendoen, **Neat: Power Measurement Platform**, submitted, 2014

WSDB Connection

- Open API allows for DB connection simulations (with randomized locations)
- Record response time (trace) and energy consumption (*Neat*)

Available WSDBs

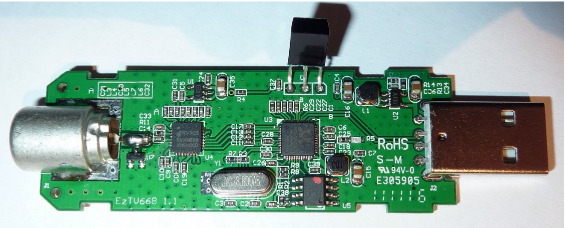
- https://www.google.com/get/spectrumdatabase
- http://specobs.ee.washington.edu
- http://whitespaces.cloudapp.net/WSFinder.aspx
- http://observatory.microsoftspectrum.com

DTV Sensing Hardware: RLT-SDR

'RTL-SDR'

- Website: http://www.rtl-sdr.com
- DVB-T TV tuner dongle based on the RTL2832U chipset
- Raw I/Q samples (debug mode), 2.4MS/s, 8 bit resolution

- 3 different RTL dongles in the lab available for experiments
- Connection to Android through USB on-the-go cable



Source: http://sdr.osmocom.org/trac/wiki/rtl-sdr

DTV Sensing Software: Osmocom

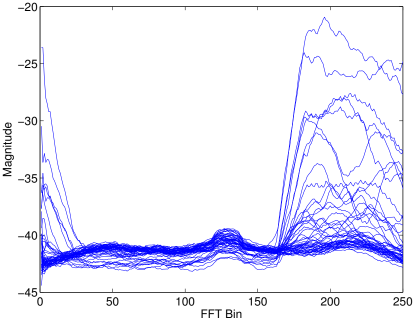
- Software: http://sdr.osmocom.org/trac/wiki/rtl-sdr
- Spectrum sensing by use of `rtl_power` file directly

Sensing procedure

- Store channel begin and end frequencies [lookup table, location specific]
- Scan for 20 ms, 4 kHz bin size, left/(right) edge of of TV spectrum (0.5 MHz) [256 FFT]
- Scan for digital TV only [no wireless mics, wireless video links, etc.]
  - Channel by channel hopping [36 channels in US, 47 channels in NL], full sweep in approx. 2 sec
  - Trigger of sensing process: user based, no algorithm for sensing scheduling [presently]

Phone/Dongle Connection

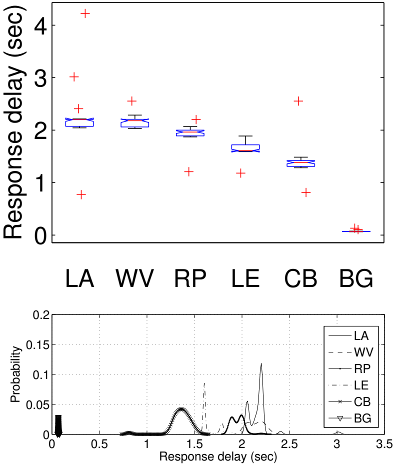
RTL-SDR Sensing: Example Trace



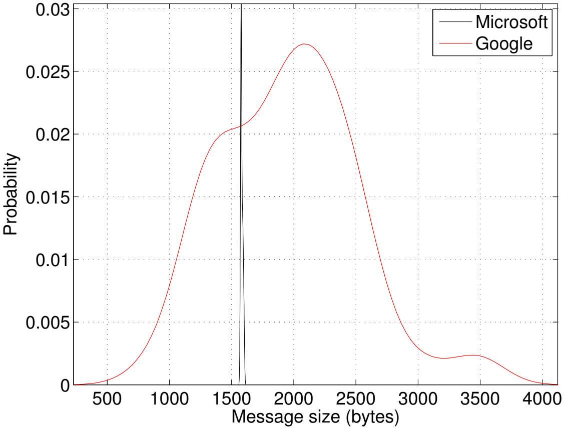
Measurement setup

- Channel 21
- 10 consecutive measurements
- TU Delft, 9th floor EWI Department

Results: Access Delay

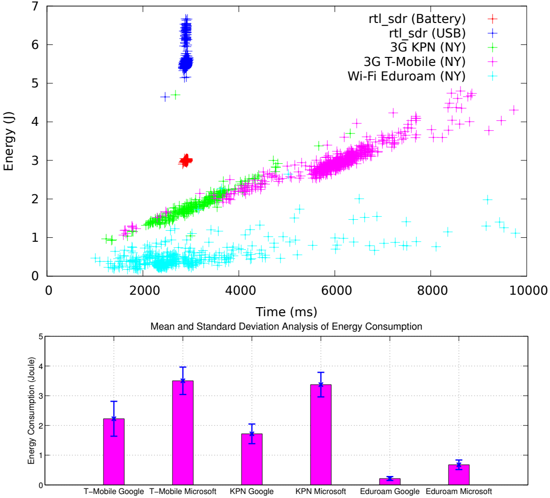


Results: Response Size



TU Delft

Results: Phone Energy Consumption



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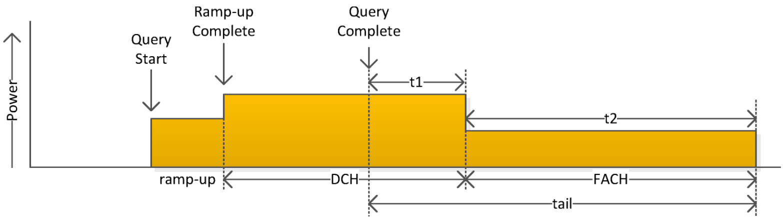
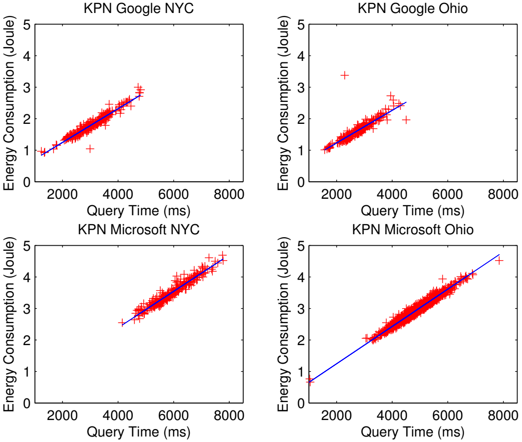
Energy Consumption Model

- **Observation I**: Energy scales linearly with no. channels sensed (RTL-SDR)
- **Observation II**: Energy scales time taken for sensing reply (WSDB)
  - $\mathbb{E}[E] = a\mathbb{E}[t] + c,\ t \in [t_{\text{min}}, t_{\text{max}}]$
    - ★ a: energy ratio (per network/per device)
    - ★ c: ramp-up



Results: Energy/Delay



Ideas from the Experiments

Sensing selection algorithm

- **What is better**: latency-prone measurement with high accuracy (WSDB) depending on network access, or localized "crappy" spectrum measurements (RTL-SDR)?

Theory of optimal channel selection

- **Lower bound for the interference probability** (both PU/SU) considering channel information accuracy and energy spent on sensing