SEVENTH FRAMEWORK PROGRAMME

LOG-a-TEC testbed applications in TVWS

CREW workshop on TV white spaces

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European Commission

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 258301 (CREW project).

Outline

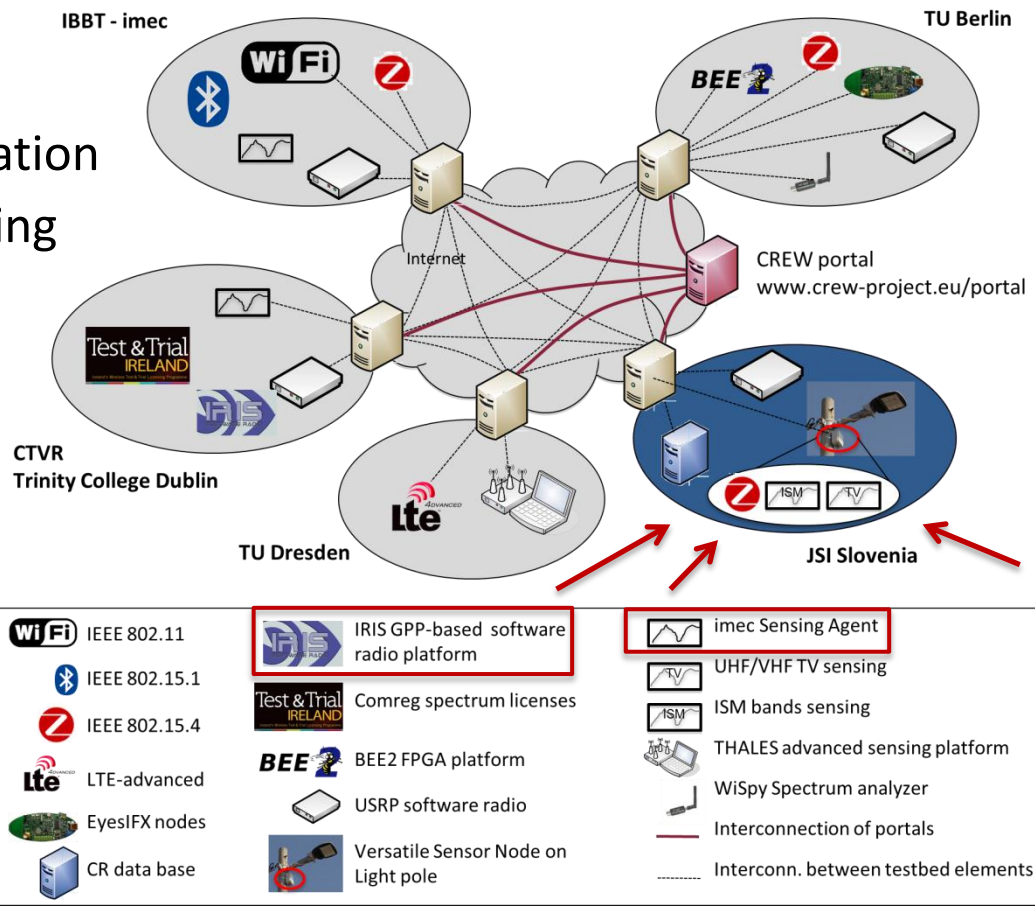
- **What is LOG-a-TEC?**
  - Setup & Building blocks
- **What can LOG-a-TEC offer to TVWS Experimenters?**
  - Testbed capabilities
- **What types of experiments can be carried out at LOG-a-TEC?**
  - Past / ongoing / planned experiments and why they are interesting for broader community including regulatory and standardisation

... overall focusing on functional capabilities of the testbed and on the example experiments

What (and where) is LOG-a-TEC?

JSI testbed as part of CREW federation

- **JSI campus, Ljubljana**
  - Combined indoor and outdoor installation
  - Used for cognitive networking experimentation
  - Used for spectrum sensing and cognitive radio experimentation (test site for LOG-a-TEC)
- **LOG-a-TEC, Logatec**
  - Outdoor installation
  - Used for spectrum sensing and cognitive radio



LOG-a-TEC testbed

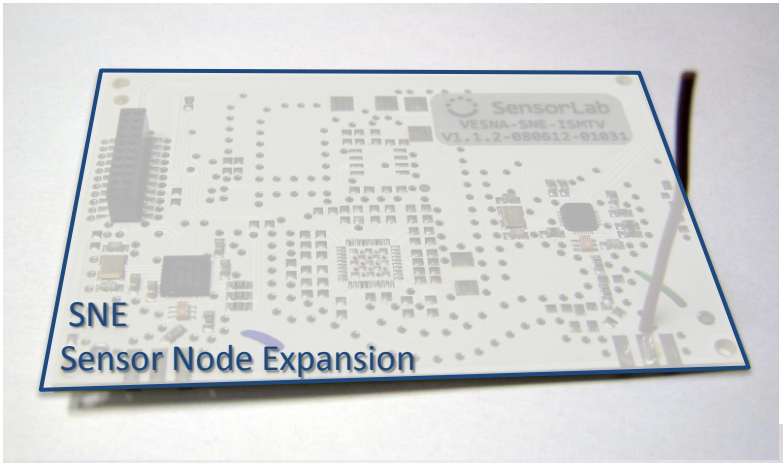
- Deployed in the city of Logatec, Slovenia

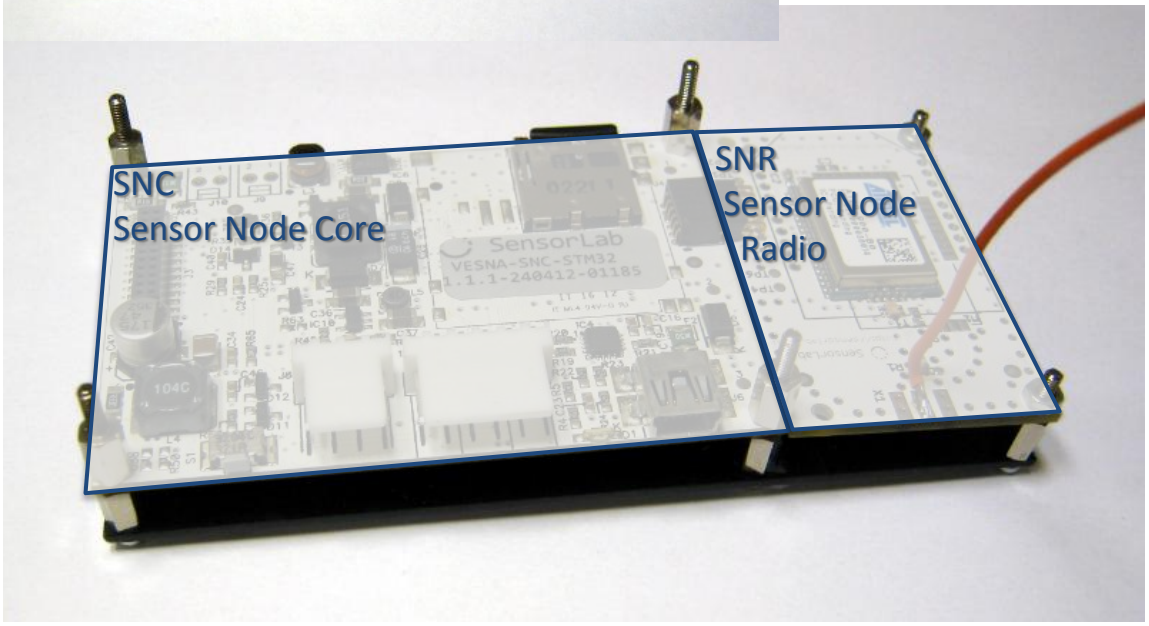
- Based on wireless sensor network
- Sensor nodes are (mostly) installed on public light poles
- Infrastructure rewiring ensures 24/7 power supply

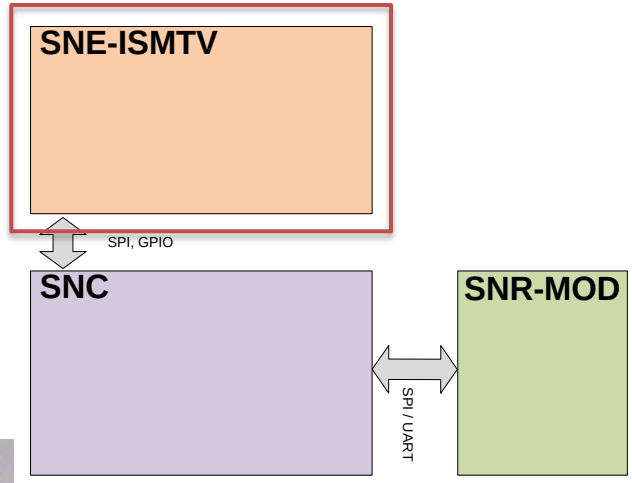
- Within CREW project used for spectrum sensing and cognitive radio experimentally-driven research

VESNA

- VESNA = VErsatile platform for Sensor Network Applications
- Modular platform for WSN (VESNA = SNC + SNR + SNE)

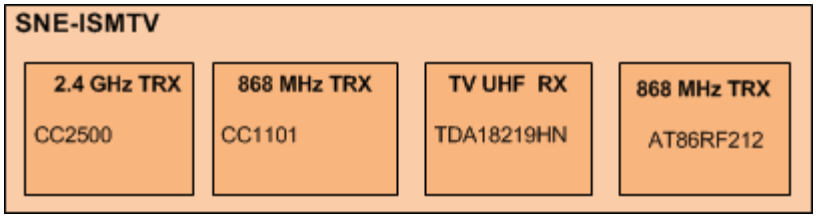






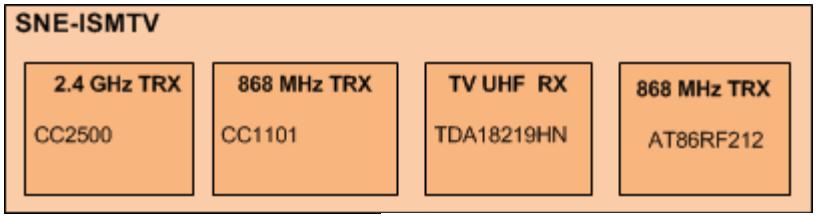
VESNA SNE-ISMTV

- **One PCB with several placement options**



- **Spectrum sensing**
  - ISM 868 MHz RF transceiver
    - Based on CC1101 (sub-GHz @ 315, 433, 783, 868, 915 MHz)
    - Receiver sensitivity of -112 dBm @ 868 Mhz
    - Programmable output power up to 12 dBm
  - ISM 2.4 GHz RF transceiver
    - Based on CC2500 (2.4 GHz)
    - Receiver sensitivity of -104 dBm
    - Programmable output power up to 1 dBm

VESNA SNE-ISMTV



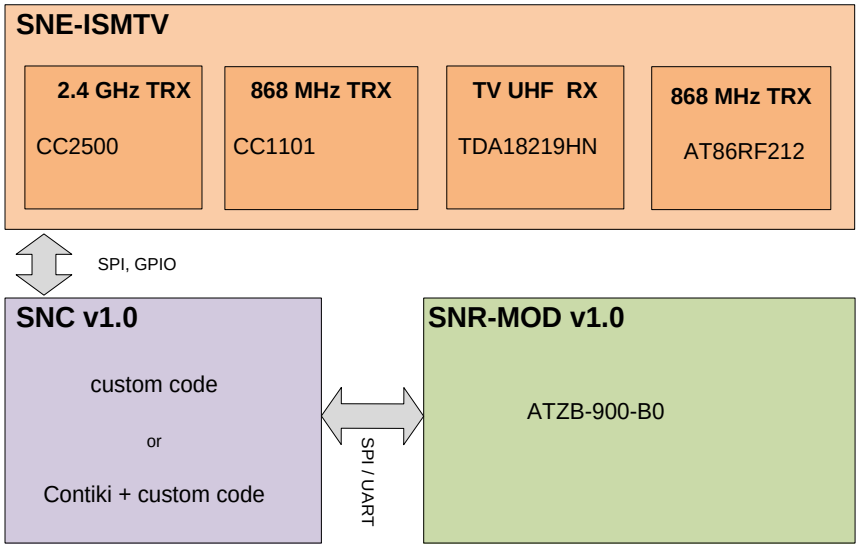
Spectrum sensing

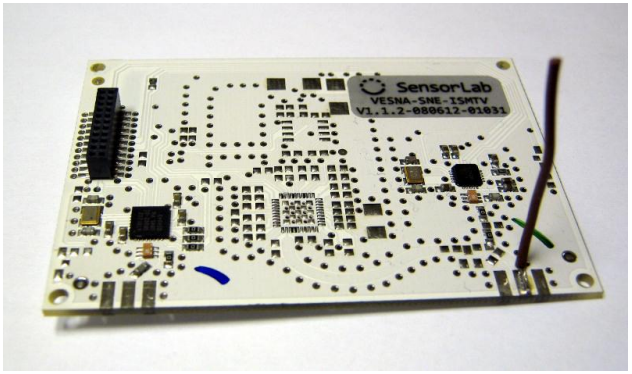
- VHF/UHF (TVWS)
  - NXP TDA18219HN silicon tuner
  - Analog devices AD8307 demodulating logarithmic amplifier
  - 42 – 870 MHz RF input
  - 1.7, 6, 7, 8, 10 MHz channel
  - ±1 dB linearity
  - 92 dB dynamic range

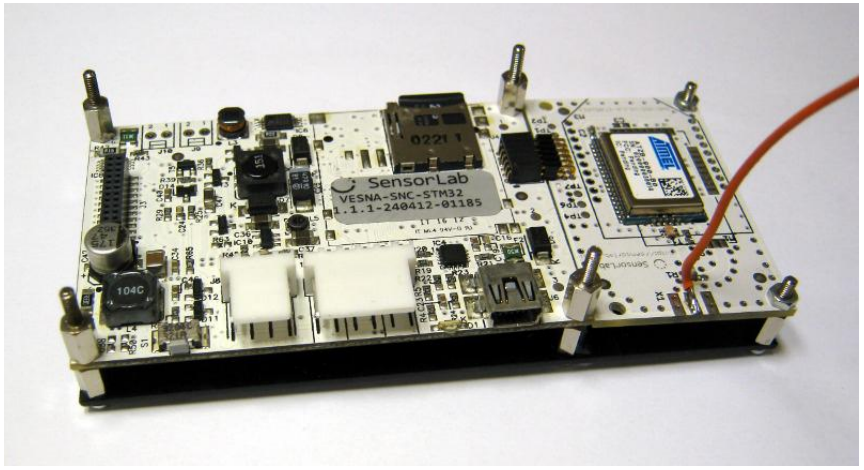
IEEE 802.15.4 transceiver

- ISM 868 MHz
  - Based on Atmel AT86RF212

VESNA assembling



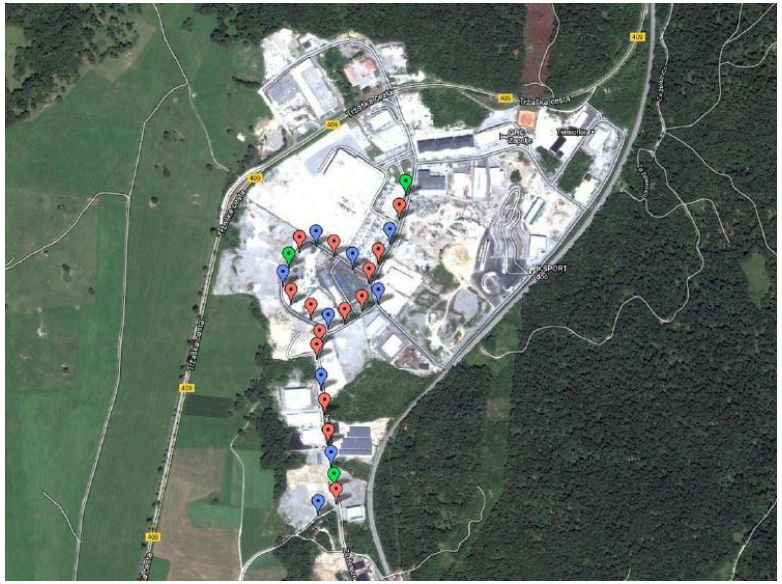




LOG-a-TEC deployment

LOG-a-TEC testbed

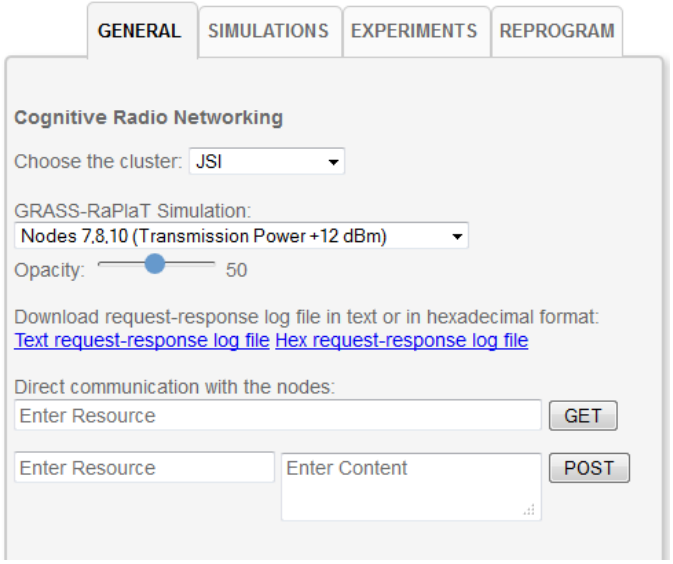
- **50 (CREW) sensor nodes are deployed in 2 clusters**
  - City center
  - Industrial zone
- **ZigBee network @ 868 MHz, Ethernet gateway**

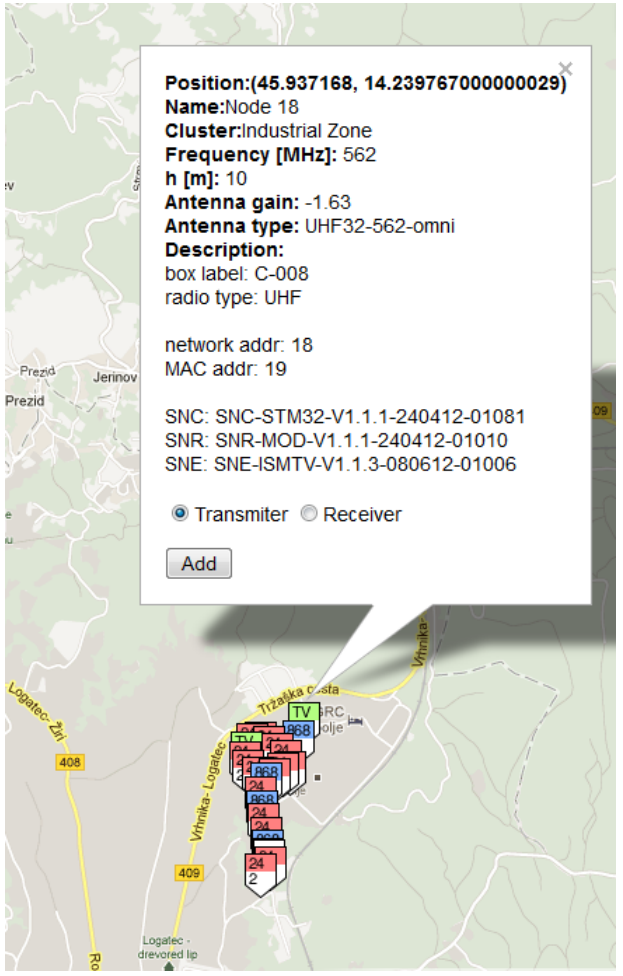


green – UHF, blue - ISM 868 MHz, red - ISM 2400 MHz, yellow - reserve locations

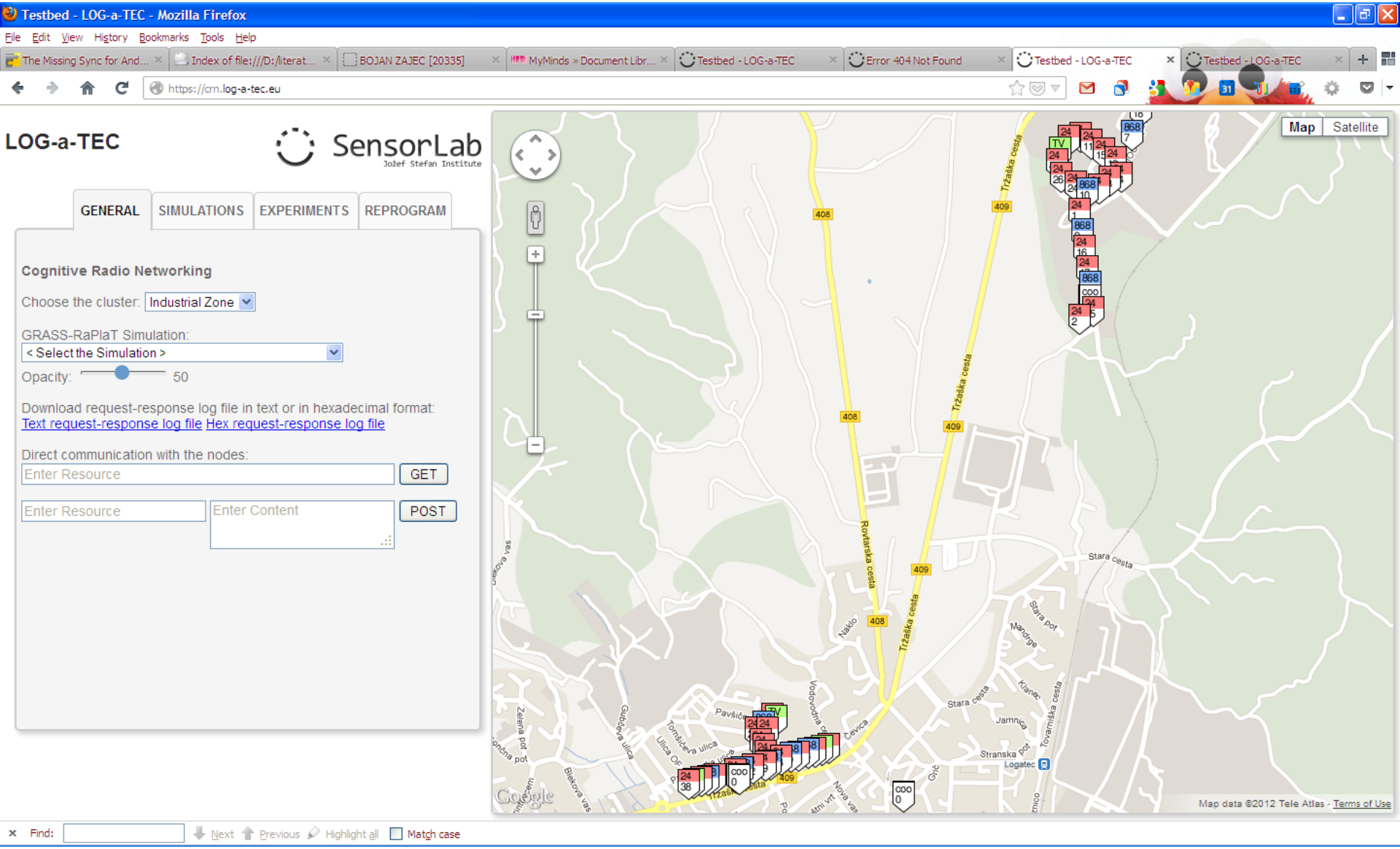
LOG-a-TEC testbed remote access portal

- **Testbed access portal at www.log-a-tec.eu allows to**
  - Show node status
  - Choose particular cluster
  - Perform an experiment
    - described as a sequence of GET and POST requests
  - Remotely (over-the-air) reprogram resources





LOG-a-TEC testbed remote access portal



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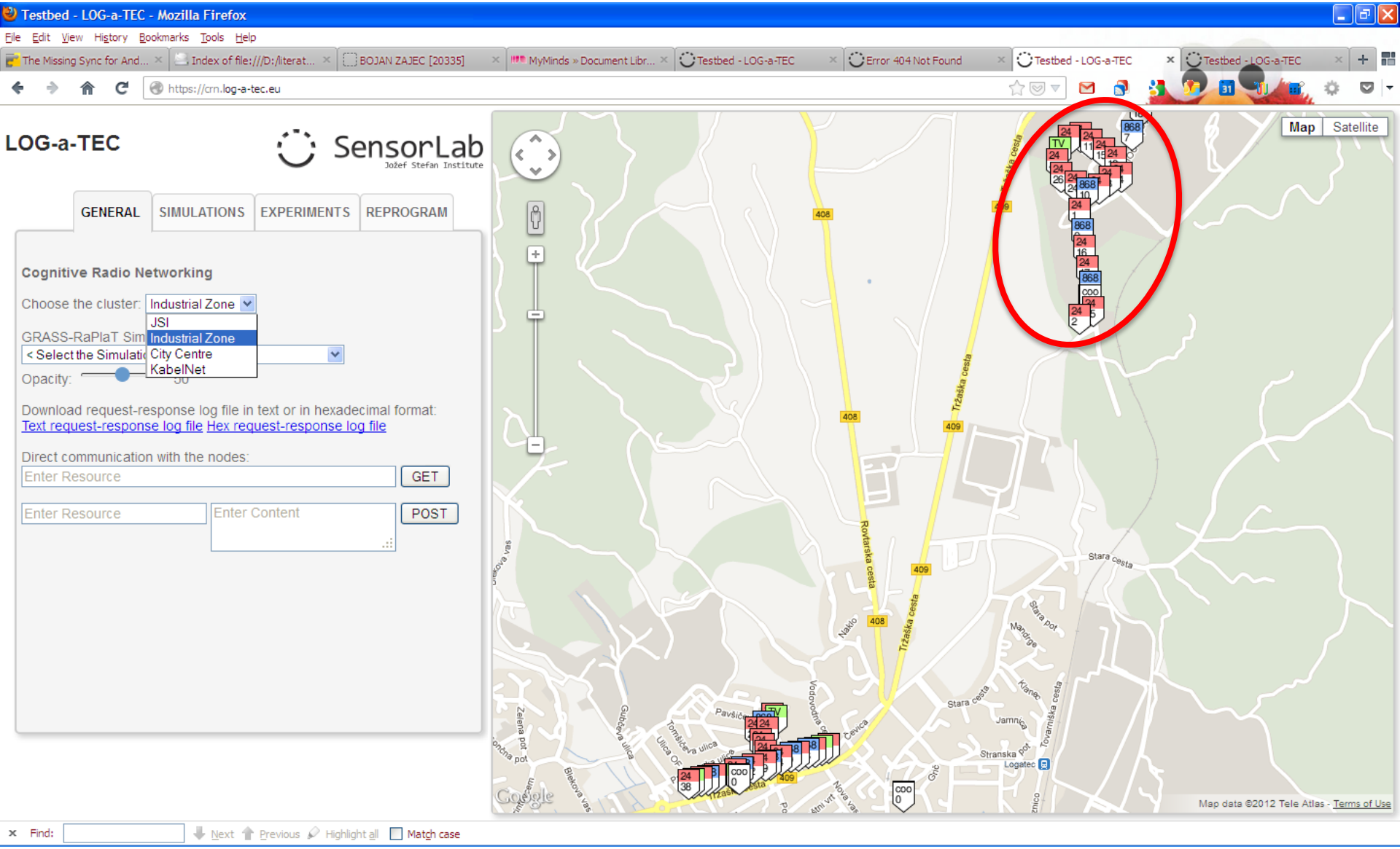
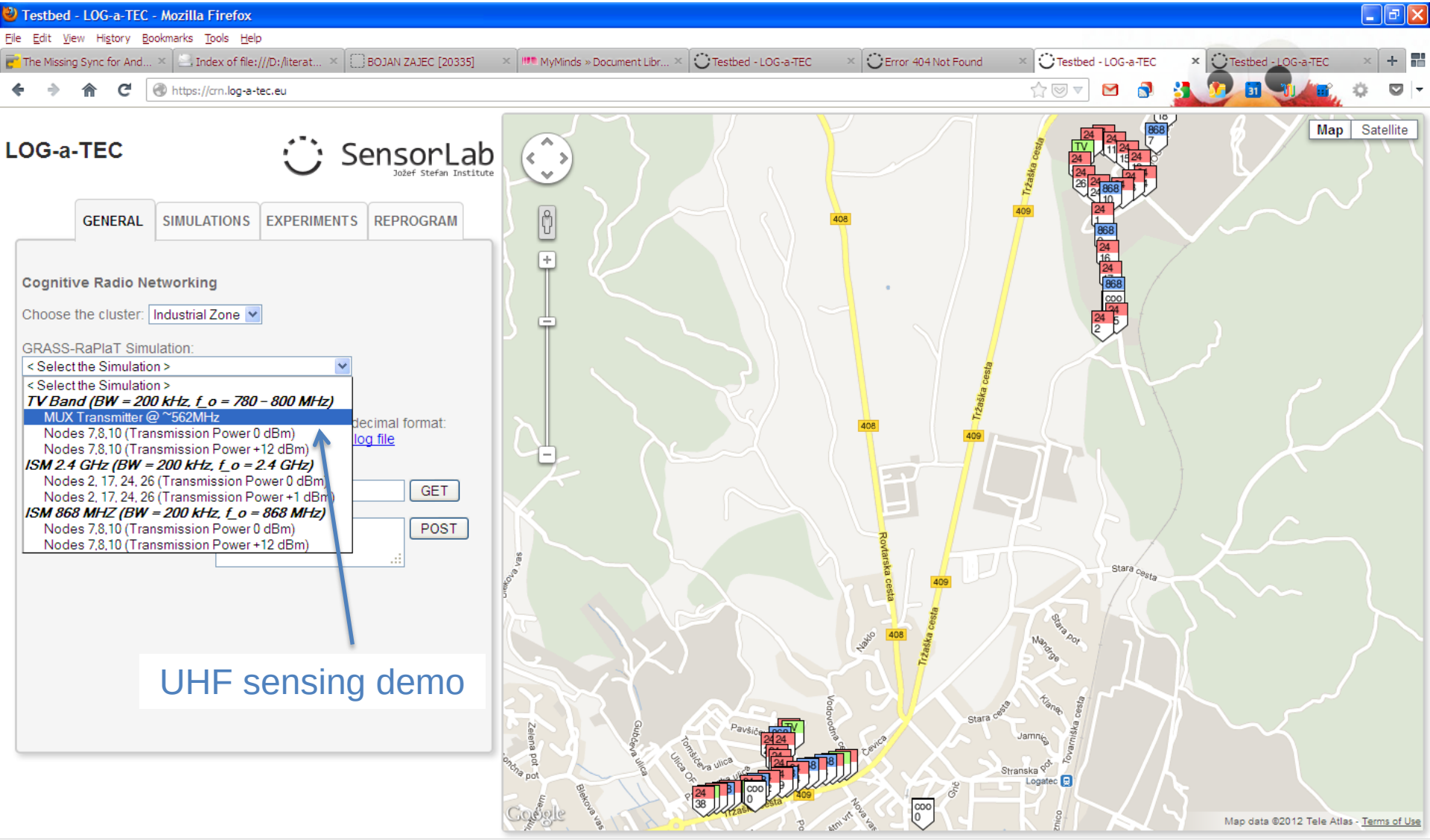
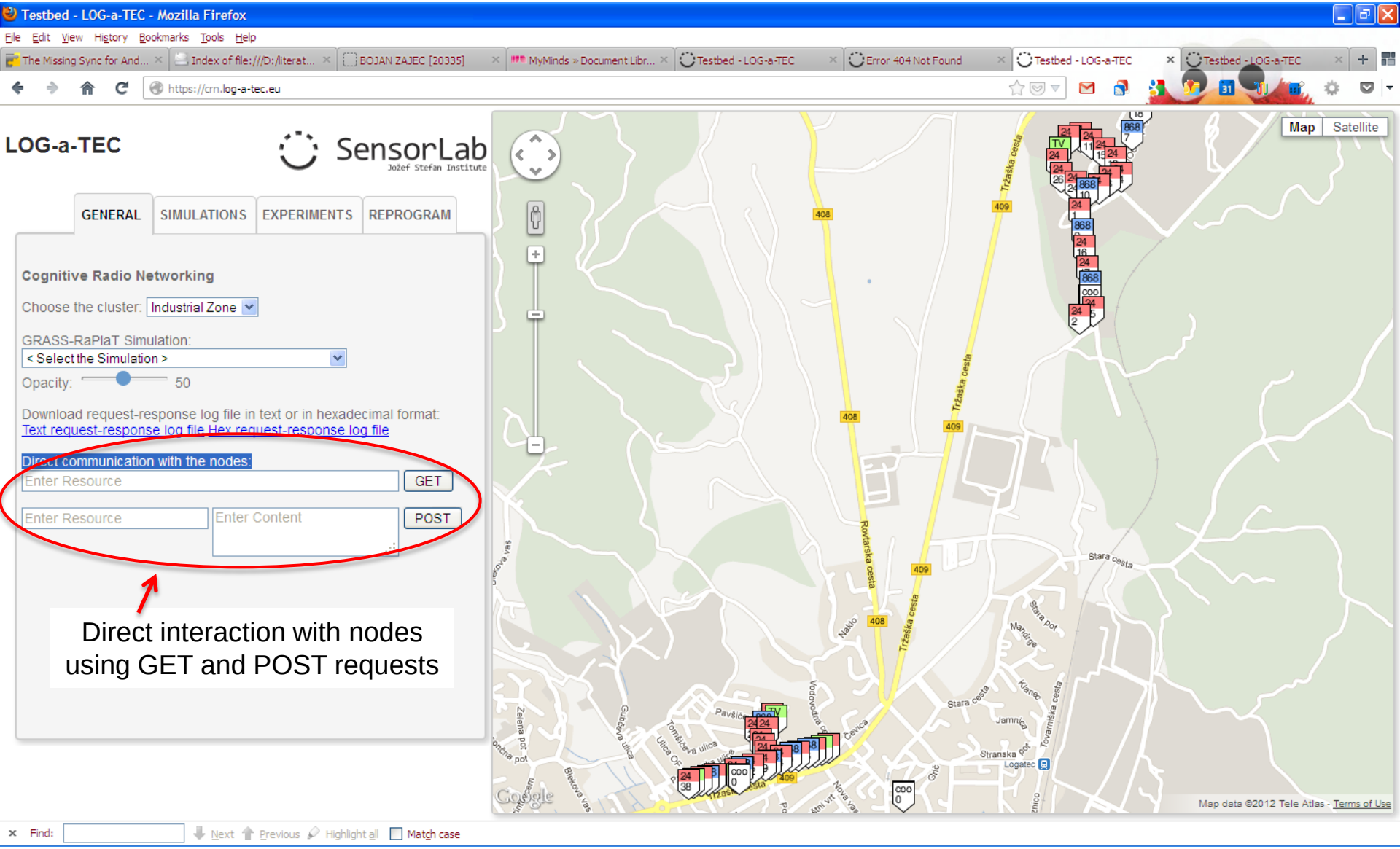


LOG-a-TEC testbed remote access portal

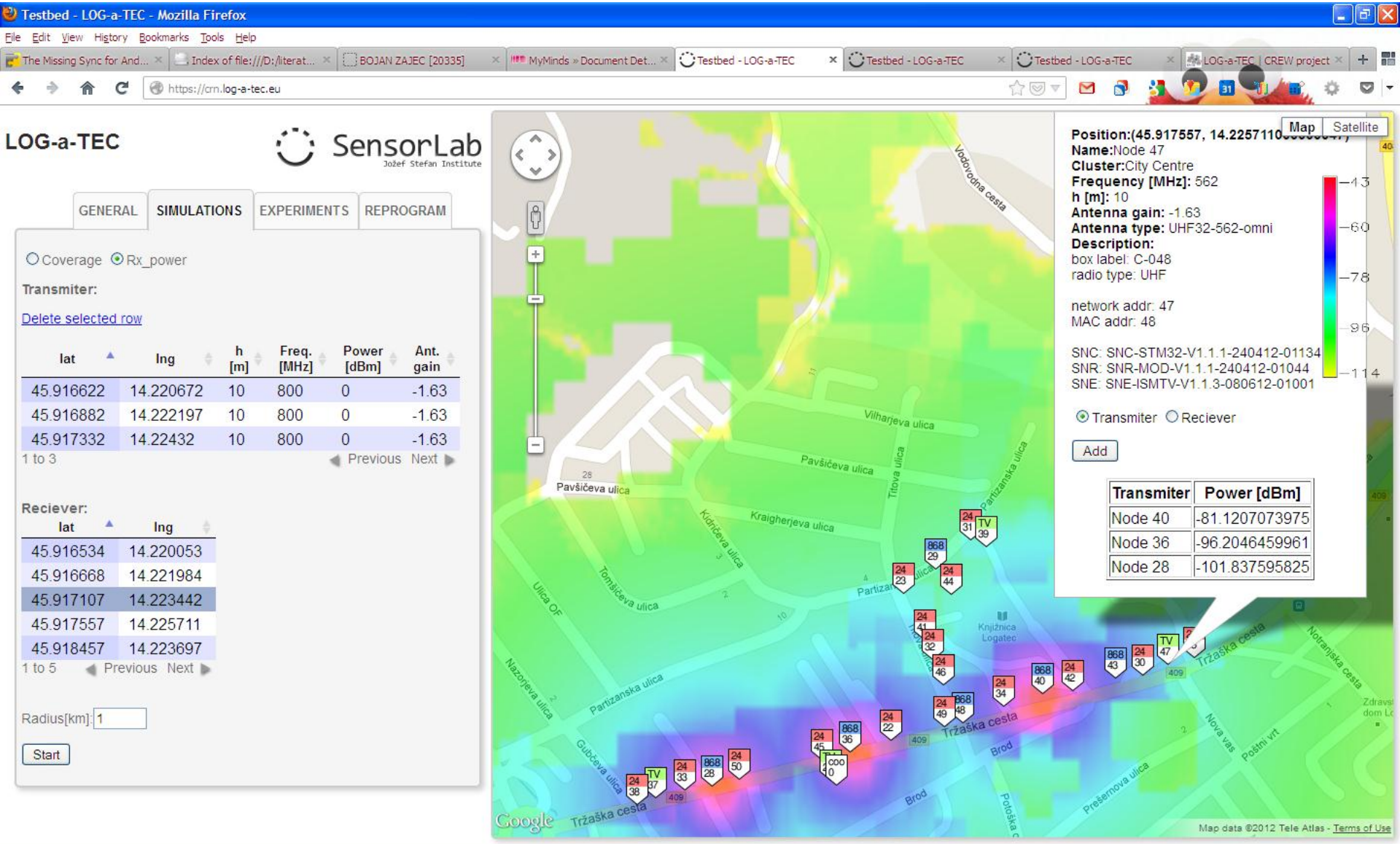


LOG-a-TEC testbed remote access portal

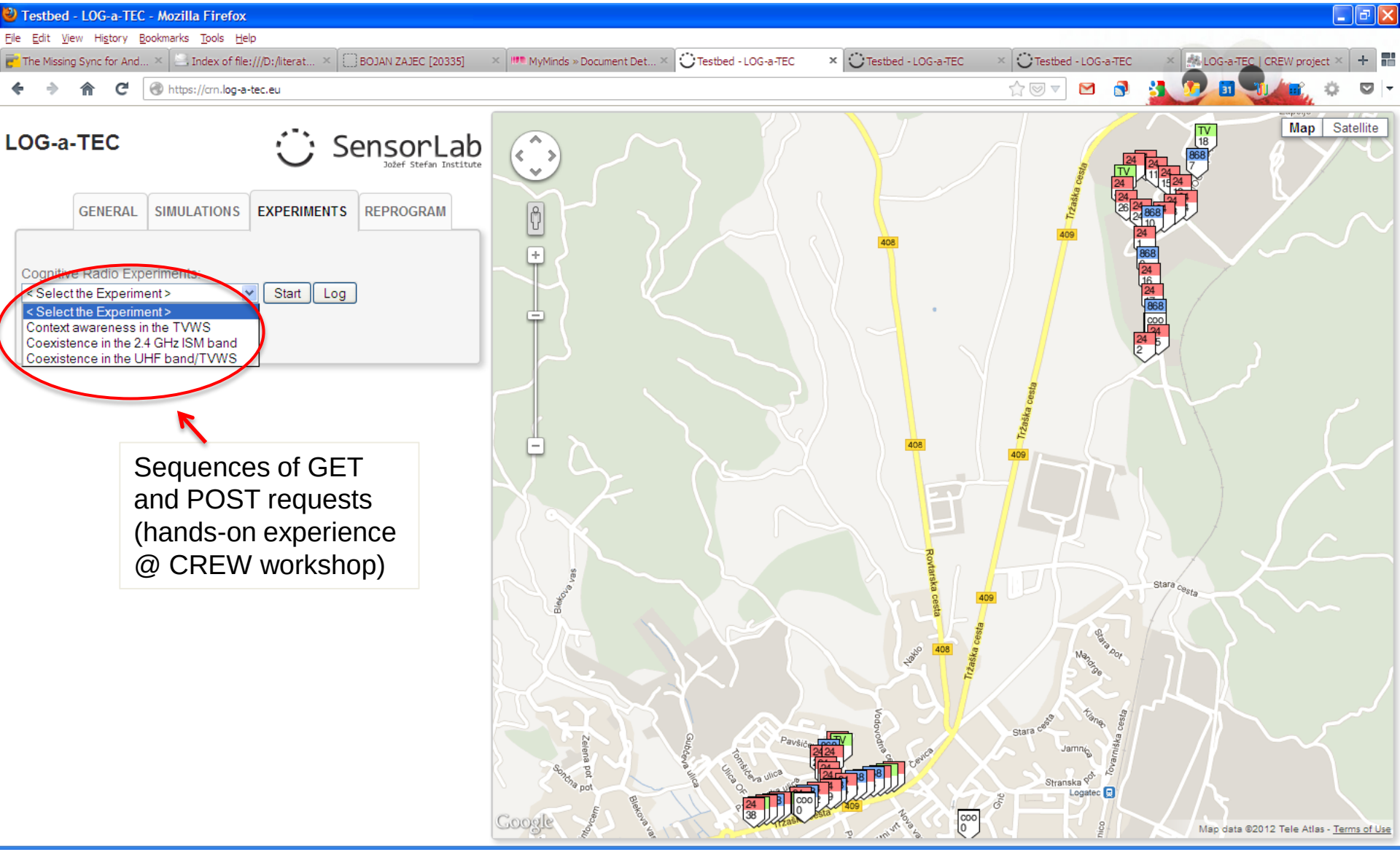


Direct interaction with nodes using GET and POST requests

LOG-a-TEC testbed remote access portal



LOG-a-TEC testbed remote access portal

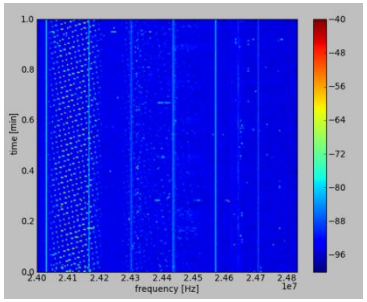


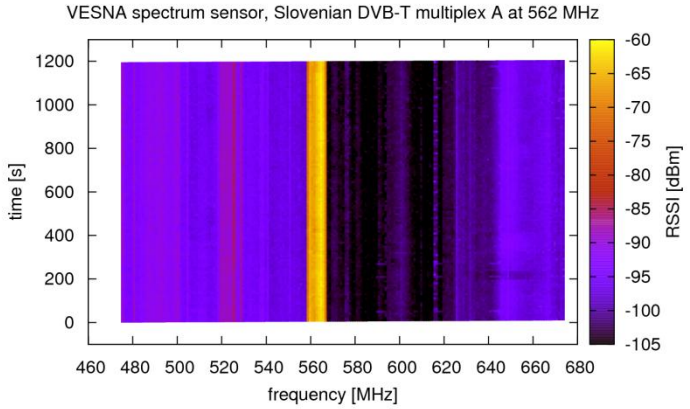
Sequences of GET and POST requests (hands-on experience @ CREW workshop)

Spectrum sensing experiment

- A batch of pre-prepared spectrum sensing profiles is available
- Once profile is selected VESNA sensor node is accordingly configured (reprogrammed)
- Experiment is run according to spectrum sensing specifications
- Results are saved locally on the SD card and sent in batches to the server

Sensing profile
- Frequency band
- Channel bandwidth
- Averaging
- …

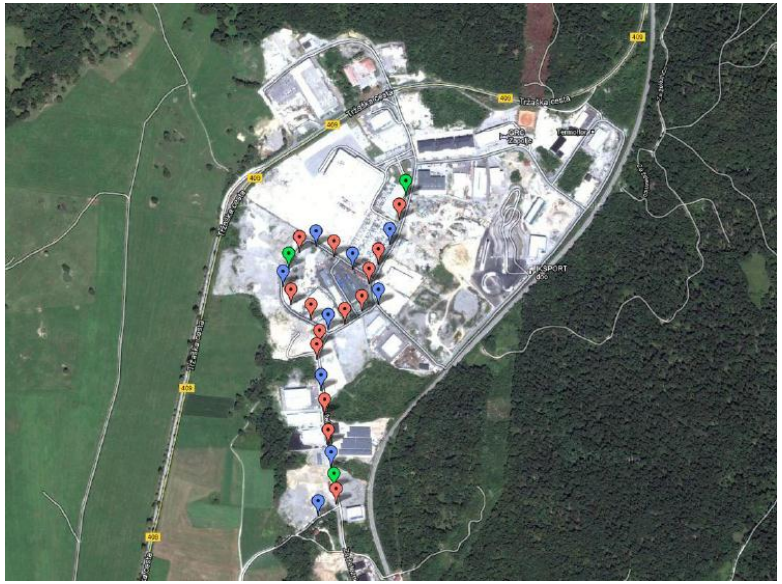




What can LOG-a-TEC offer to TVWS Experimenters?

What LOG-a-TEC offers to TVWS experimenters

- **Placing experiments in realistic outdoor environments**
  - sub-urban industrial zone, city center



What LOG-a-TEC offers to TVWS experimenters

Signal transmitting equipment

- 11 remotely reprogrammable nodes on street lights
  - narrow-band TX in the upper part of UHF band (780-800 MHz)
  - emulation of wireless microphones
- R&S SMBV100A vector signal generator
- USRP N210 with IRIS or GNU Radio
- (local DVB-T multiplex transmitter, not under testbed control)

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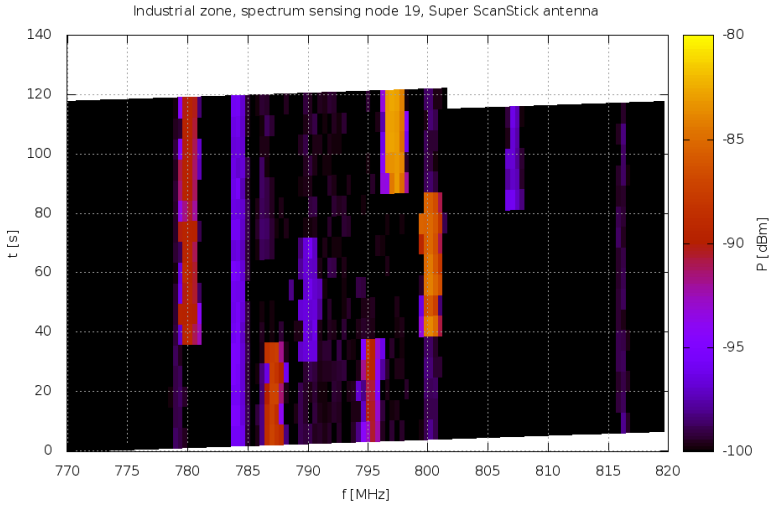
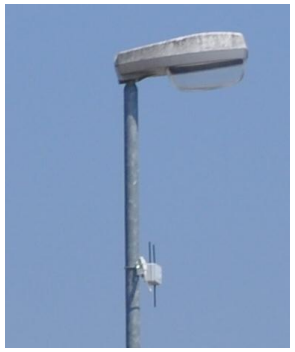


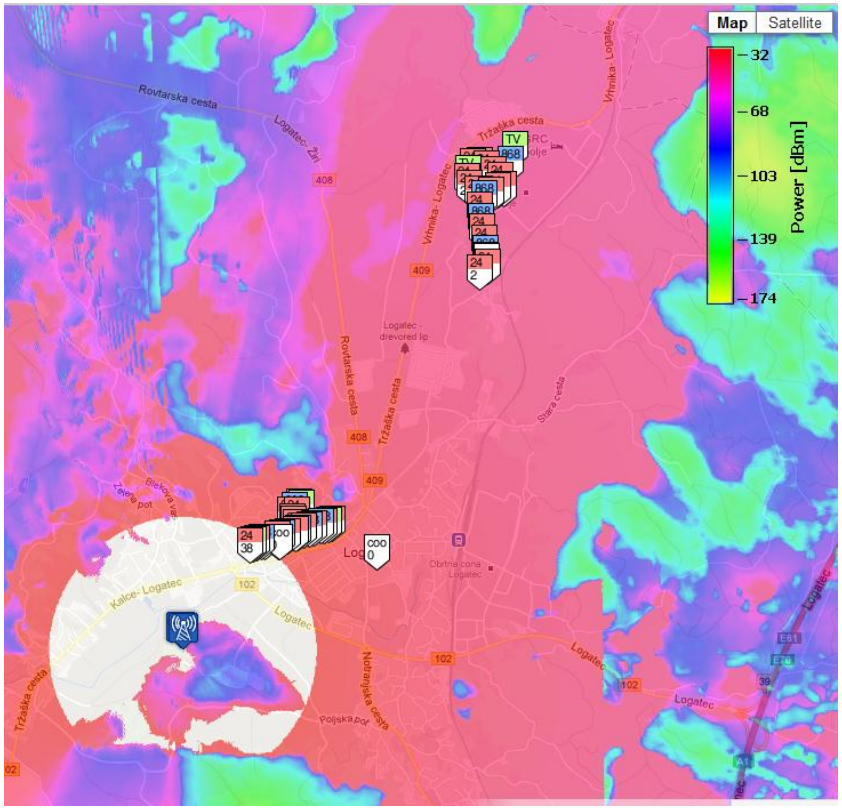
What LOG-a-TEC offers to TVWS experimenters

- **Spectrum sensing equipment**
  - 19 remotely reprogrammable nodes on street lights
    - 8 wide-band energy detectors
    - 11 narrow-band receivers
  - R&S FSV spectrum analyzer
  - USRP N210 with IRIS or GNU Radio



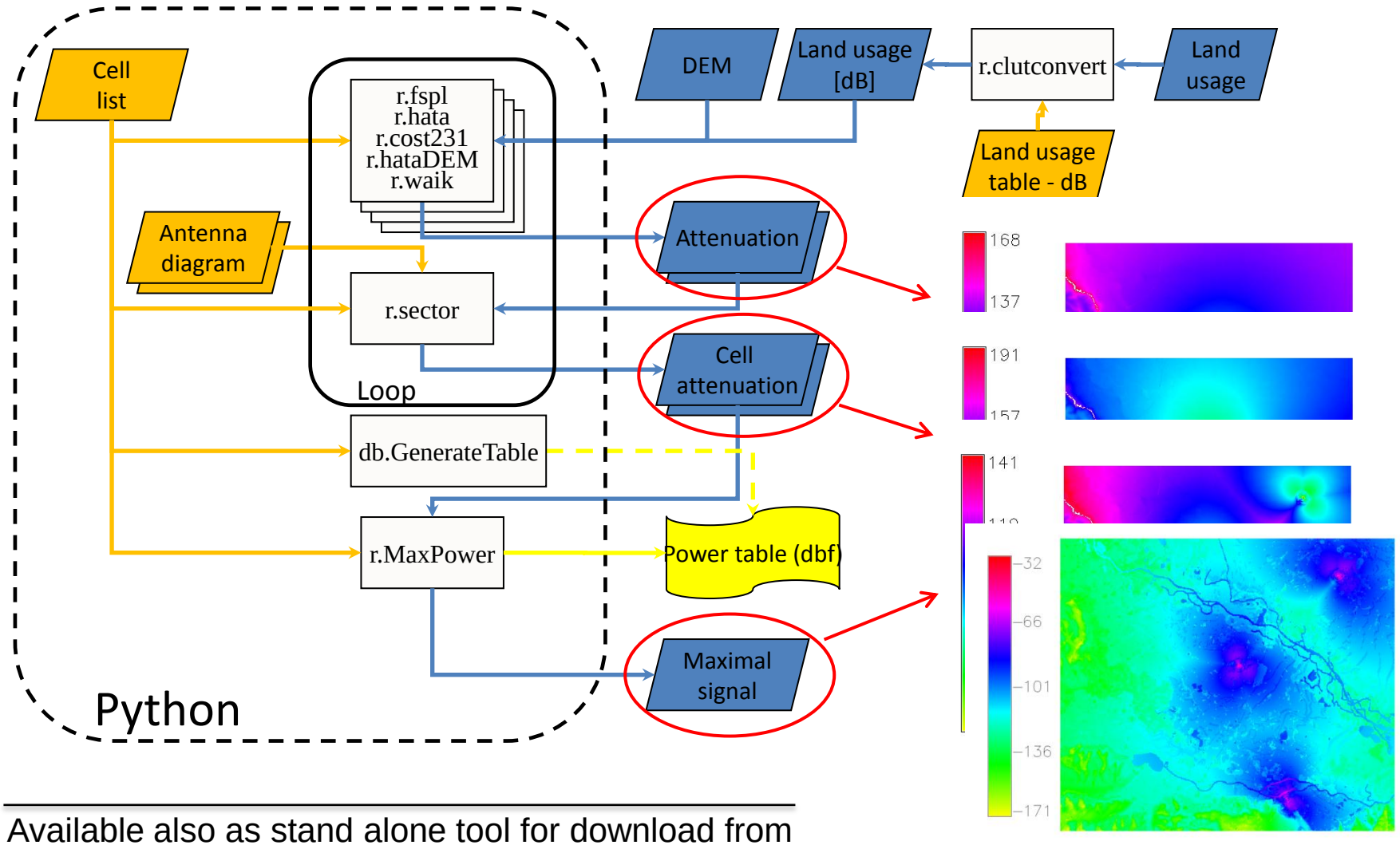
What LOG-a-TEC offers to TVWS experimenters

- **Integrated Radio Planning Tool (RaPlaT) based on open-source GIS system GRASS**
  - Experiment planning
  - Tx radio coverage calculation
  - Visualisation
  - Supporting REM estimation
- **Incorporating**
  - Digital Elevation Model
  - Clutter file
  - Six path loss prediction models
  - Ray-tracing approach for rural and urban environments



Available also as stand alone tool for download from
http://www-e6.ijs.si/en/software/grass-raplat

GRASS-RaPlaT concept



Available also as stand alone tool for download from
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What types of TVWS experiments can be carried out at LOG-a-TEC?

LOG-a-TEC testbed applications in TVWS

1. **Experiments related to geolocation databases for TVWS access**
   - Determining location of transmitters
   - Verification of propagation models
   - Monitoring and verification of occupancy databases
   - Adding dynamic content

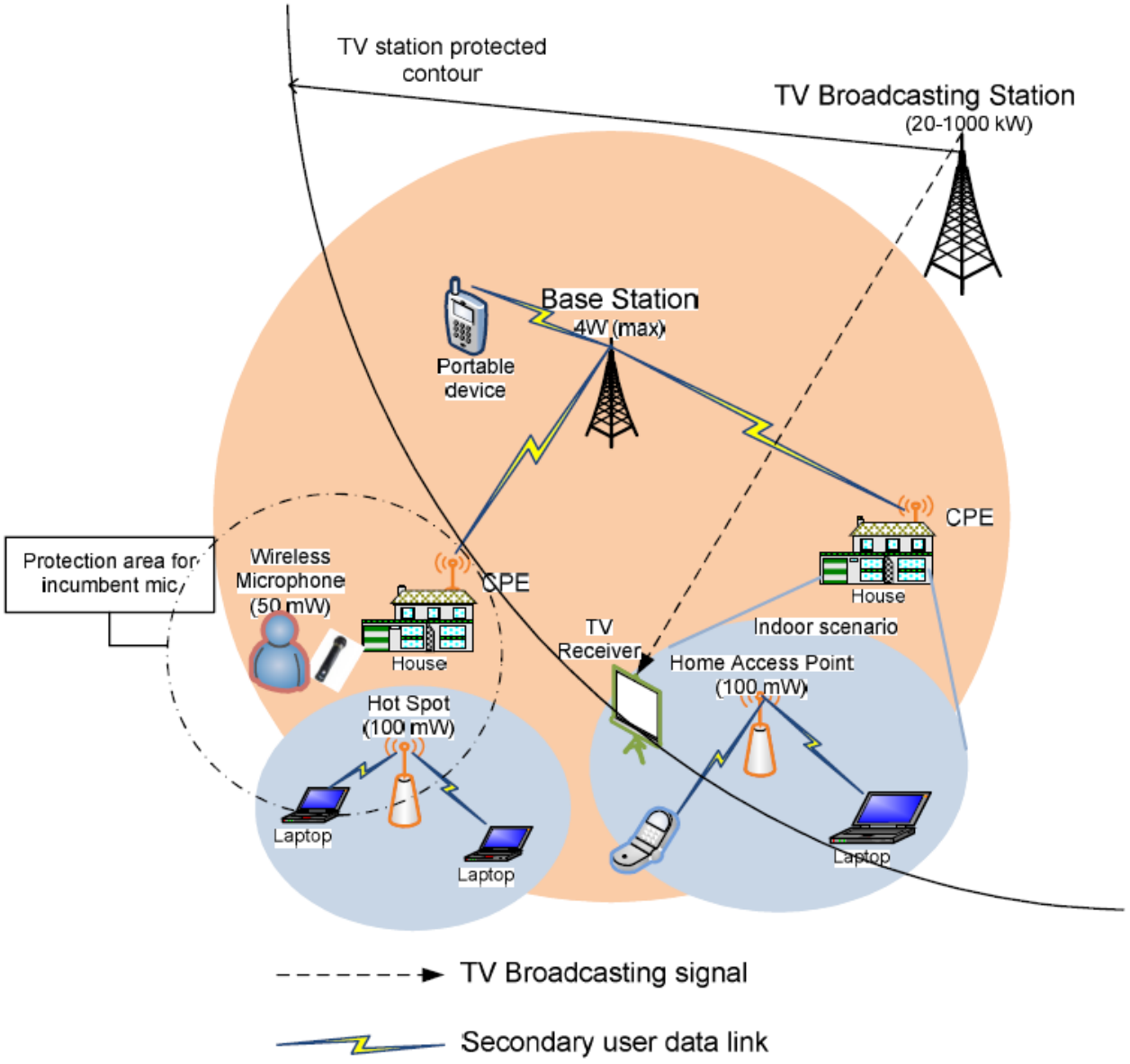
2. **Long-term statistical data gathering**

3. **Implementing spectrum sensing on low-cost devices**

Determining location of transmitters

- **Determining the location of mobile transmitters**
  - Primary (wireless microphones) and or secondary users
  - Calculated using triangulation from detected signal strength from multiple receivers in the testbed
  - Experiment planned for later this year
  - Knowing transmitter location appropriate exclusion zone can be added to the geolocation database

Typical heterogeneous coexistence scenario

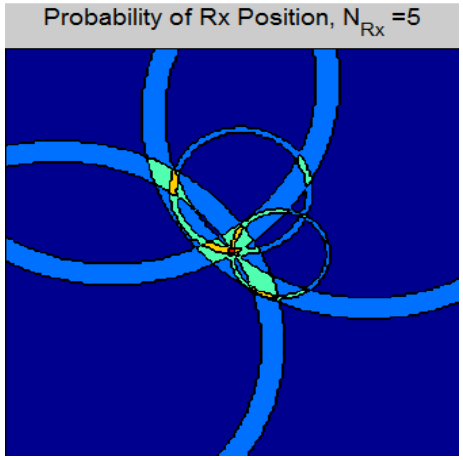


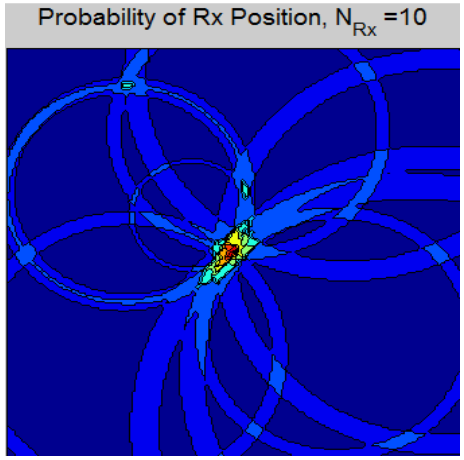
Triangulation from detected signal strength

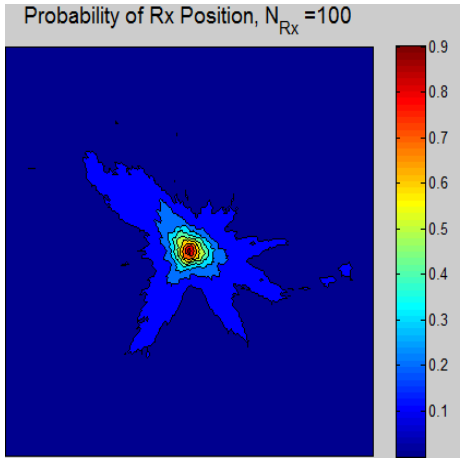
Questions addressed

- How accurately can the location be determined?
- How does the location uncertainty depend on the number and location of sensing nodes?
- What kind of infrastructure is needed for sufficient detection?

Estimation of Tx location



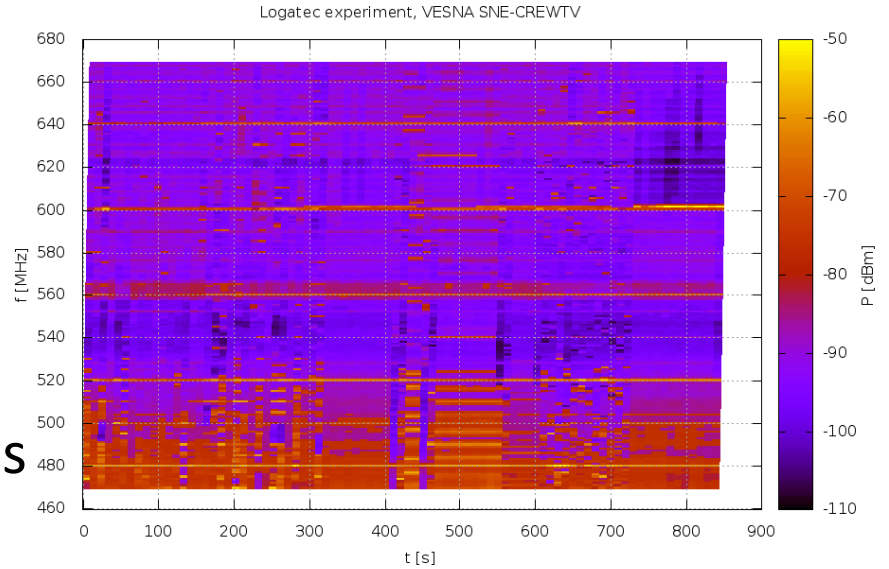




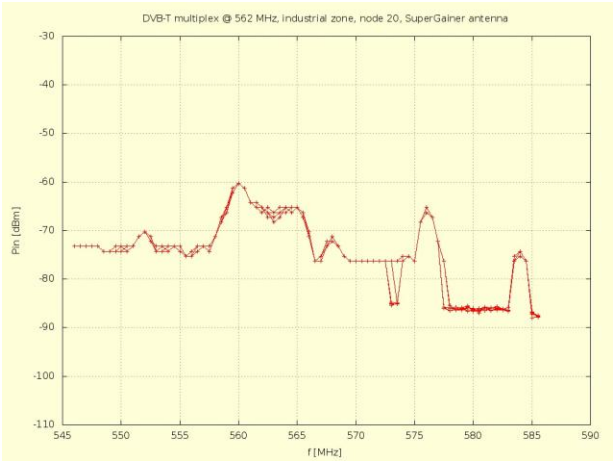
- Assuming free space loss and omnidirectional antenna
- Exclusion zone can be calculated and added to geol. database

Distributed spectrum sensing in UHF

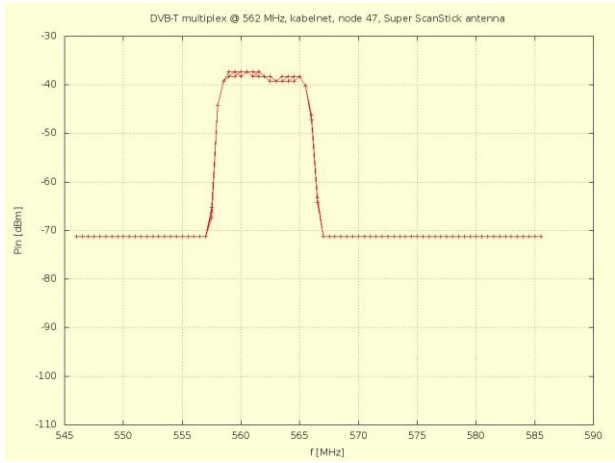
- Using multiple VESNA sensing nodes in Log-a-tec outdoor testbed to build a **radio environment map**
- Avoiding the **hidden node problem**, minimizing primary user interference
- **Context-awareness** experiments in licensed bands



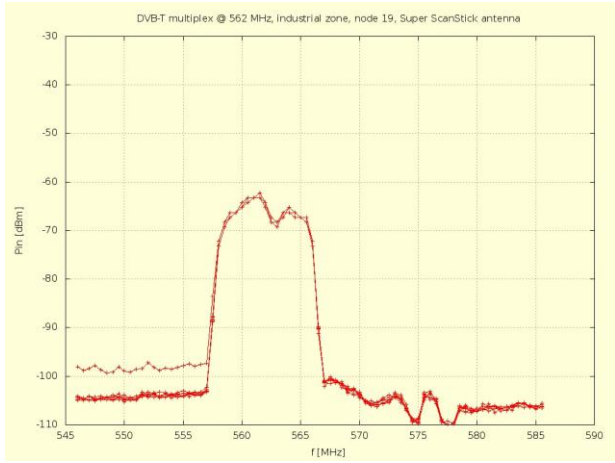
Node 20 – SuperGainer antenna



Node 47 – Super ScanStick Antenna



Node 19 – Super ScanStick Antenna



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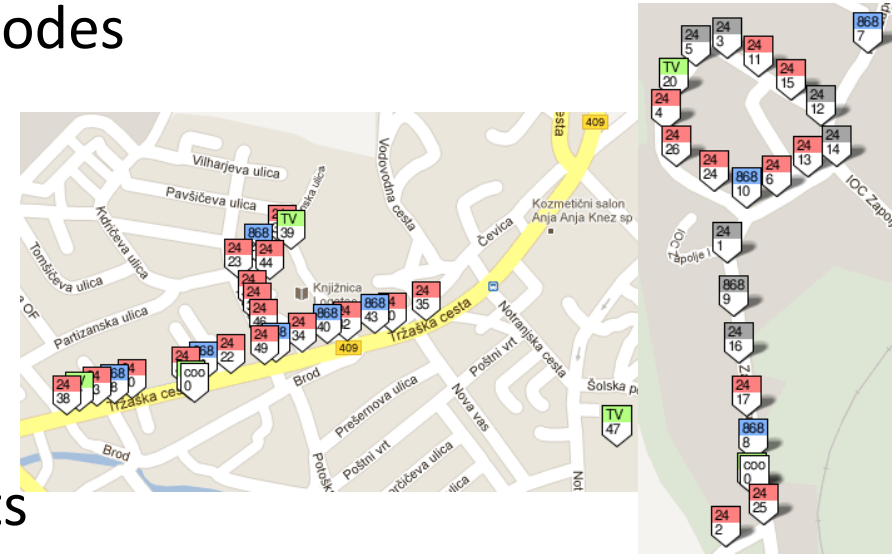

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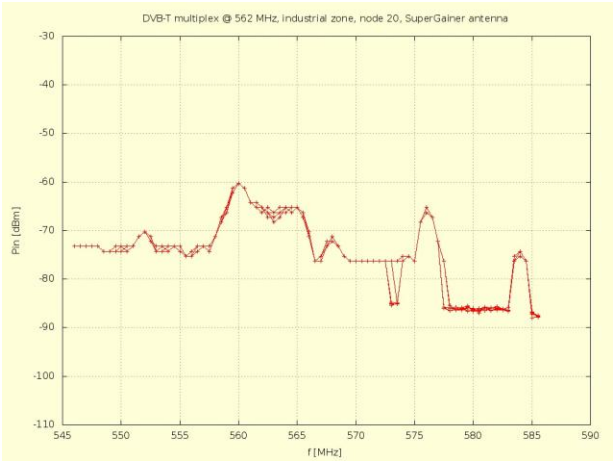

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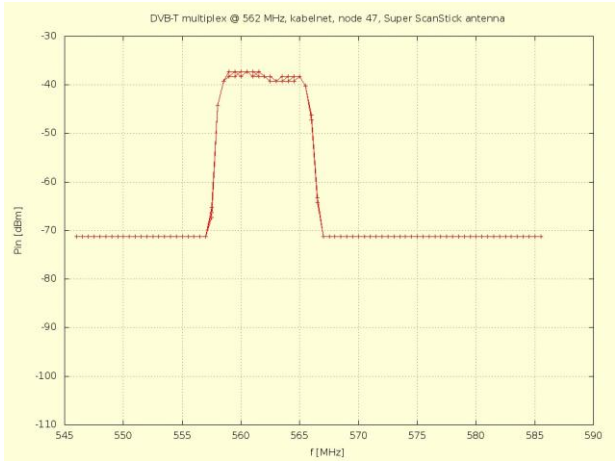

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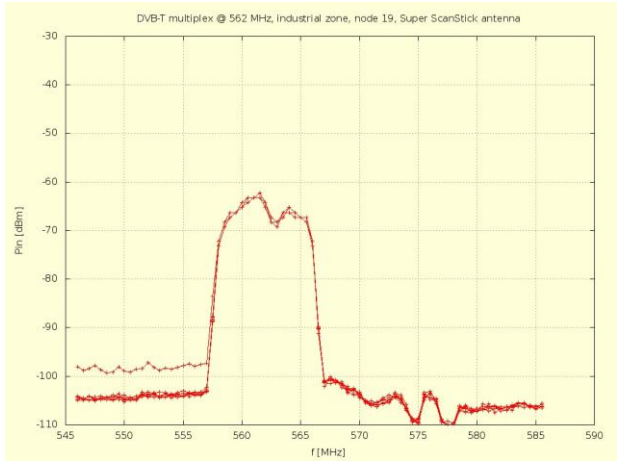
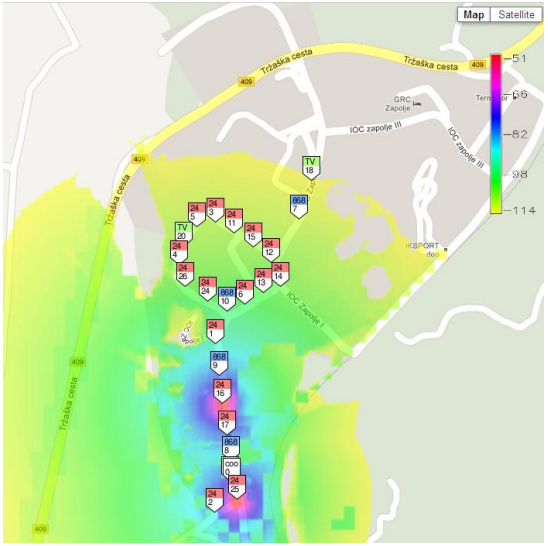
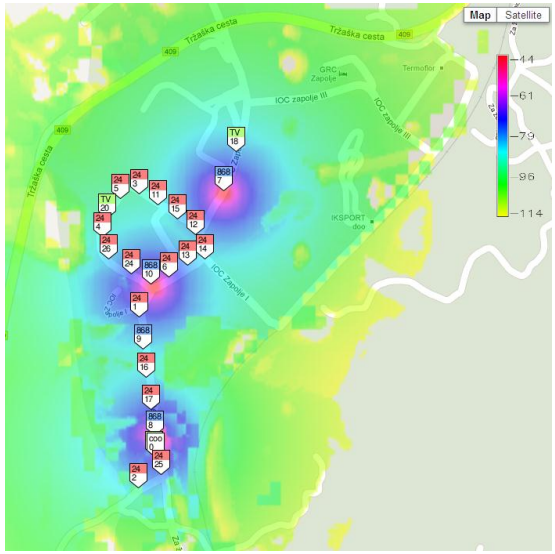
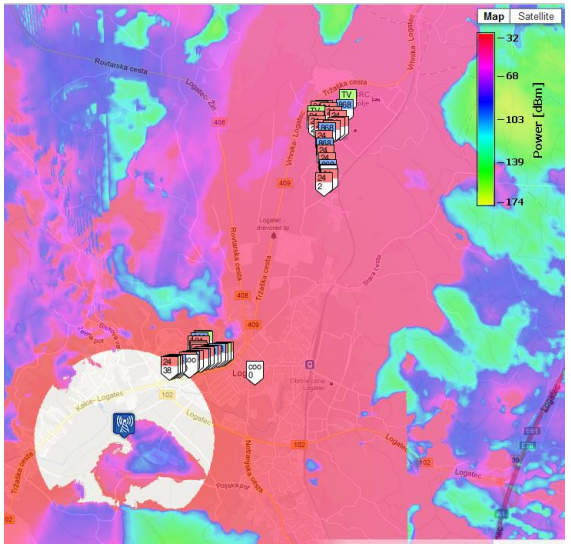


Verification of propagation models

- **Models are used to populate geolocation databases**
  - For stationary transmitters coverage can be calculated from location, power and terrain data



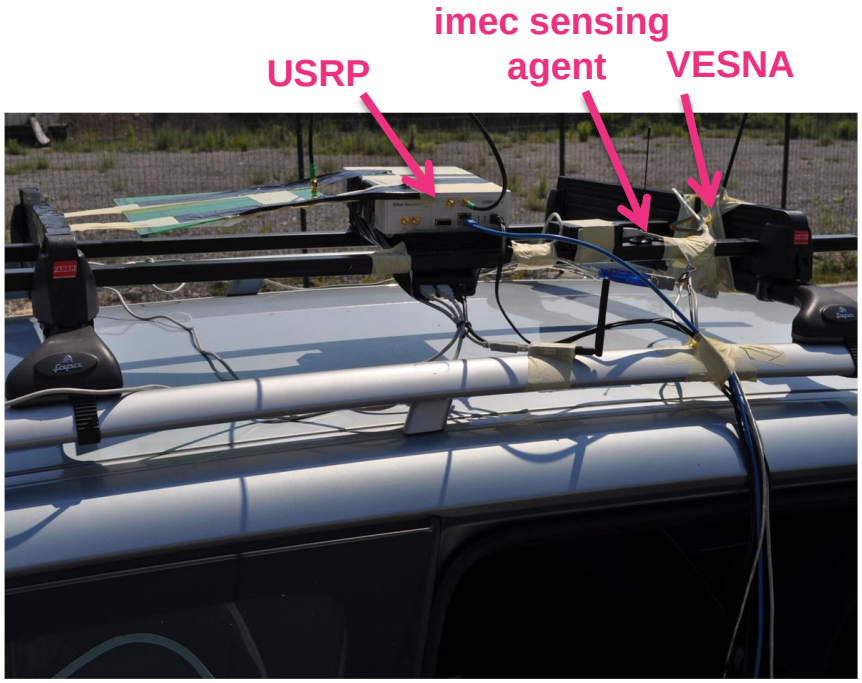


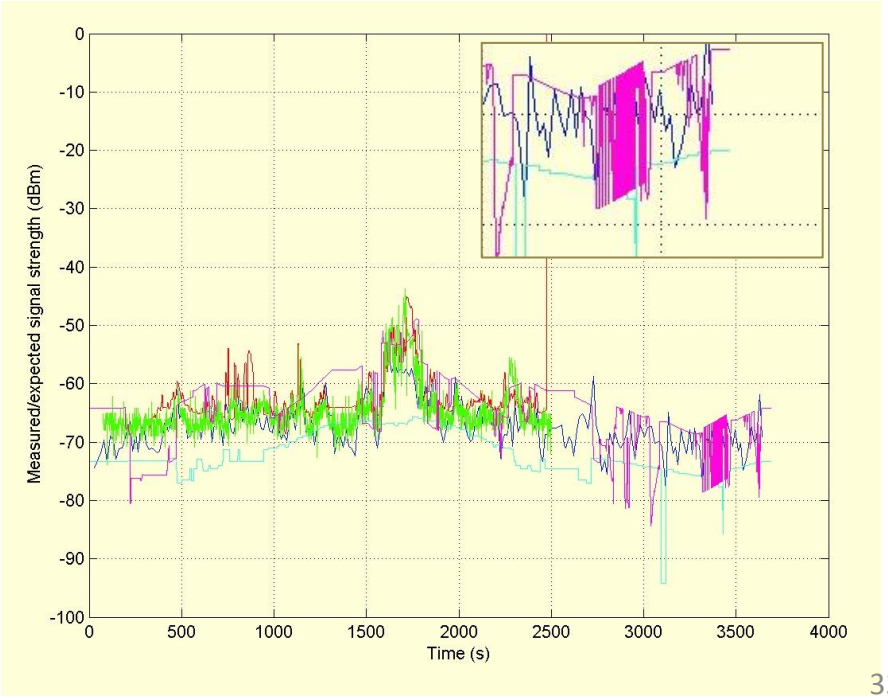


- **LOG-a-TEC testbed can be used to validate models**
  - known environment
  - compare measurements to predictions
  - experiment performed at CREW meeting in June 2012

Heterogeneous spectrum sensing in UHF band

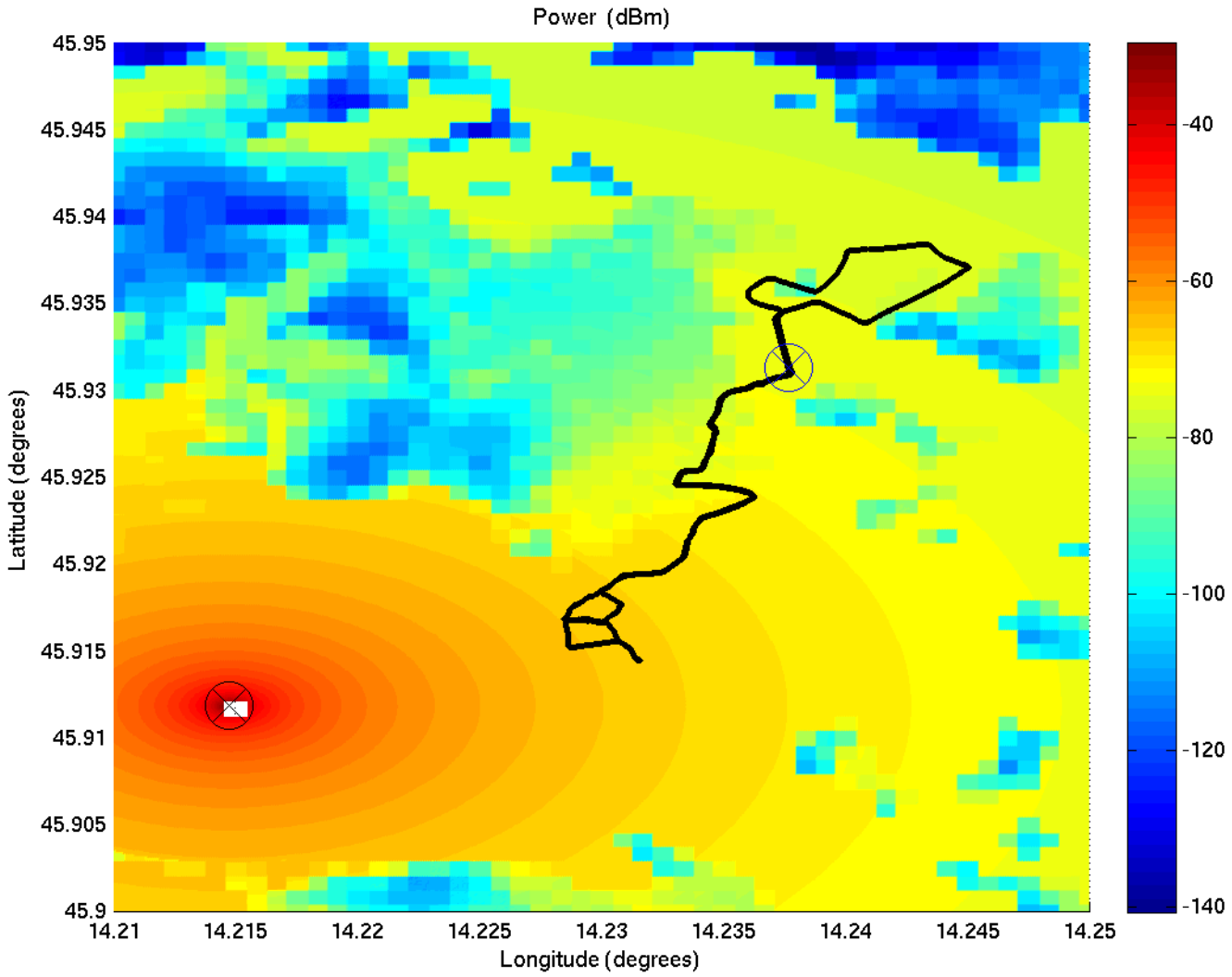
- Outdoor experiment with **relocation** of equipment
- Using **common data format** for easy processing and reporting
- Estimation of signal strength using **Longley-Rice channel model** and **GRASS-RaPlaT radio planning** tool
- **Comparison** of sensing devices to estimations from channel models



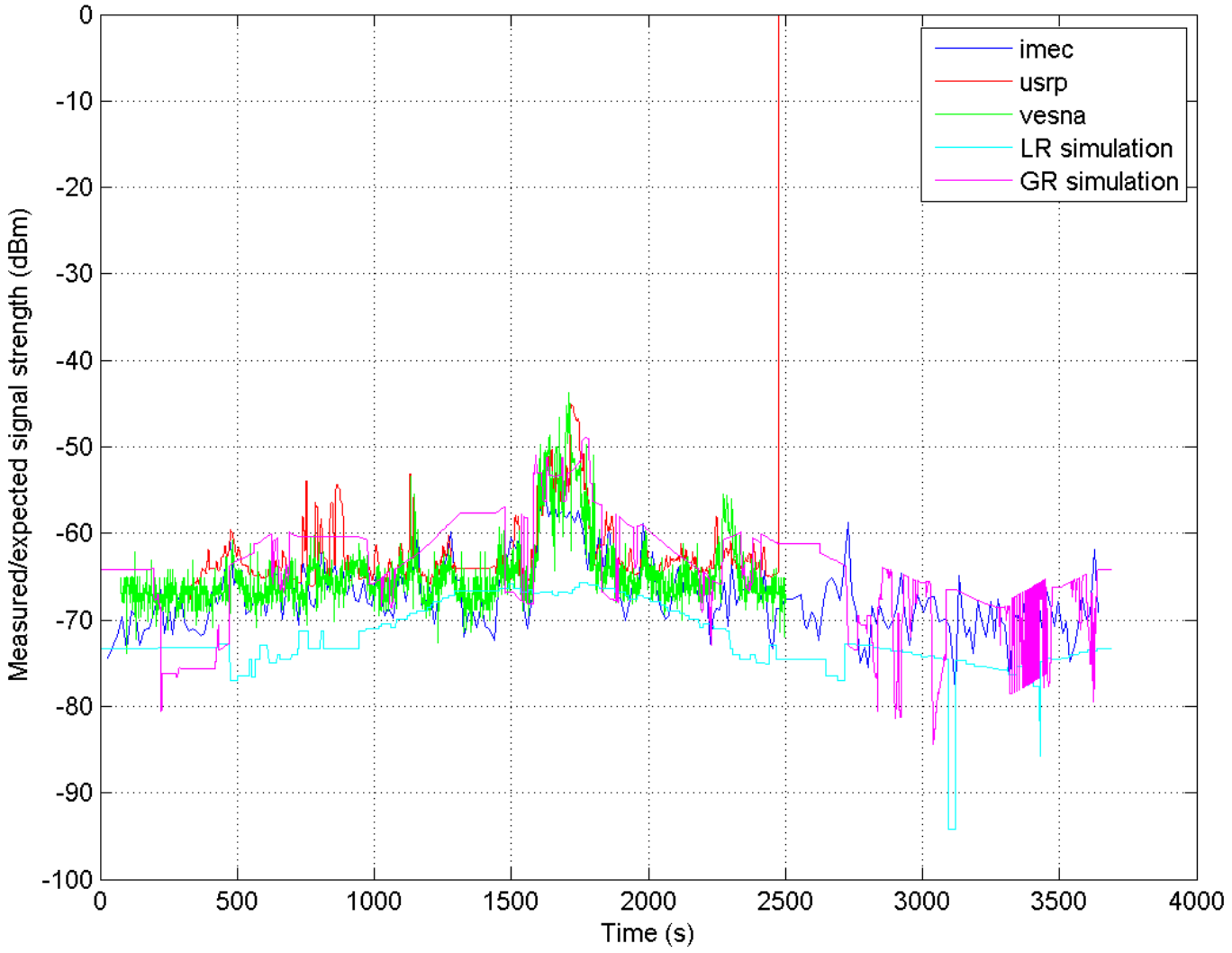


Measurement route

Route and LR-calculated power levels



Measured vs. calculated signal strength

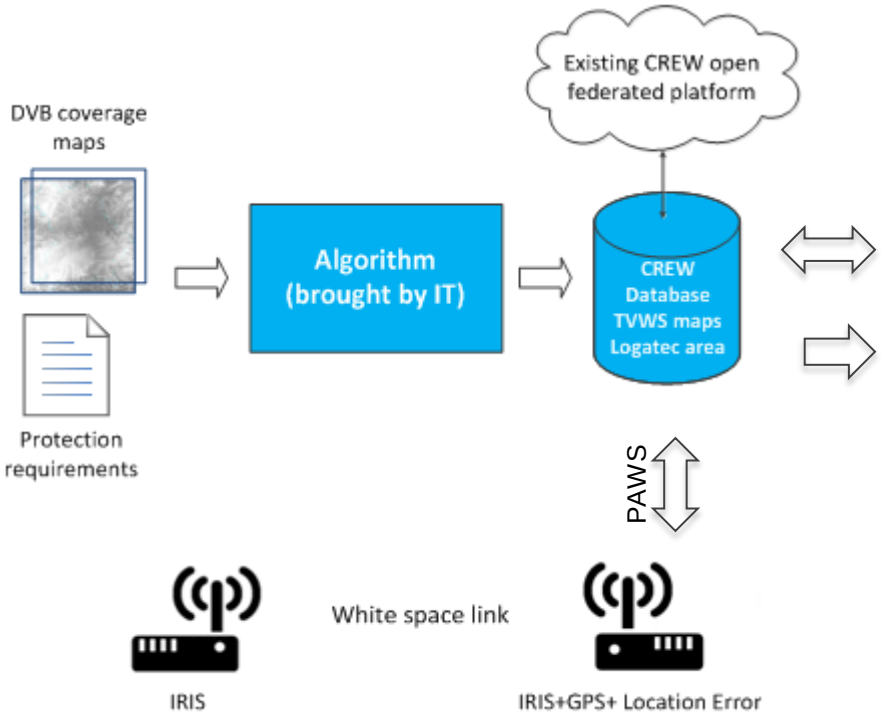


Monitoring of occupancy databases

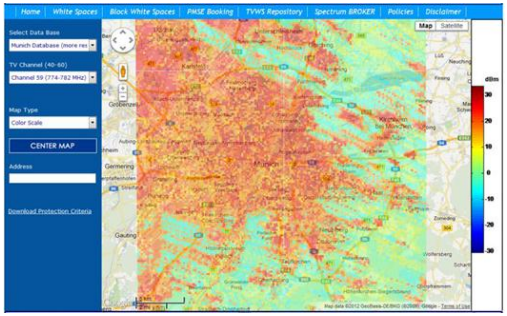
- **Geolocation databases need to be continuously monitored for accuracy**
  - Errors can come from incomplete input data
    - input data may be needed from entities under different administration
  - Distributed spectrum sensing experiments can be performed and algorithms can be investigated for comparison between the geolocation database and measurements

Adding dynamic content

- **Experiment by Instituto de Telecomunicações and CMSF-Sistemas de Informação (CREW Open Call 2)**
  - geolocation database assisted by a low-cost densely deployed spectrum monitoring network
  - to protect dynamic incumbent systems, such as wireless microphones that are not registered in the database



LOG-a-TEC testbed



Logatec TVWS maps

Long-term spectrum measurements

- **Few long-term spectrum occupancy studies**
  - what are seasonal variations in band utilization?
  - long-term trends in spectrum usage?
  - effects of weather on spectrum sensing accuracy
- **Larger data sets would also help research into**
  - channel opportunity prediction algorithms
  - can serve as a training set for machine learning
  - participatory sensing algorithms
- **LOG-a-TEC enables collection of such data**
  - spectrum sensing devices deployed in two sub-urban environments
  - (some long-term data on 2.4 GHz already being collected)
  - low-cost TVWS sensing devices developed for LOG-a-TEC can be deployed in other environments

Spectrum sensing on low-cost devices

- **Two approaches to avoiding interference in TVWS**
  - consulting geolocation database
  - detection of primary users through spectrum sensing
- **Setting requirements for secondary users**
  - Implementers faced considerable challenges meeting FCC requirements for spectrum sensing for secondary users
  - Current focus is on geolocation-based secondary use
- **Important to set realistic detection threshold**
  - Low enough probability of interference with licensed users
  - but must still be possible to economically implement on consumer devices (supporting participatory sensing)
- **LOG-a-TEC enables research into low-cost devices**
  - Wireless sensor network of low-cost sensing nodes
  - Sensors based on off-the-shelf DVB-T tuner hardware

Summary

Summary

LOG-a-TEC as part of CREW federation of testbeds

- supports experimenting in TVWS in real outdoor environment
- to support combined white spaces geolocation based and distributed spectrum sensing operation
- has capabilities for controlled transmission in UHF band and for long-term infrastructure-based spectrum sensing
- can incorporate external Tx/Rx equipment and sensing agents based on different standards
- supports investigation of using low-cost sensing devices

CREW

SEVENTH FRAMEWORK PROGRAMME

Thanks for attention!

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