Jarkko Paavola (Turku University of Applied Sciences – TUAS)
09.11.2012 @ FRUCT conference in Oulu

TV white space test environment

for emerging spectrum sharing opportunities

TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

Presentation outline

- Some definitions
- Motivation to use white spaces
- Challenges in using white spaces
- Current international standardization and regulation activities
- Finnish activities
- Turku TV white space testbed
- Future of spectrum sharing
- Q&A

What is white space?

- Locations where spectrum allocated for some wireless communication system is unutilized appear as white areas in system coverage maps.
- Therefore, they are referred to as *White spaces*.
  - Another names are spectral holes or spectral gaps
- TV white space (TVWS) is the unused spectrum on TV broadcasting frequencies (UHF and VHF bands) in an arbitrary location. TV White Spaces are created especially by efficient spectrum utilization of the digital broadcasting.

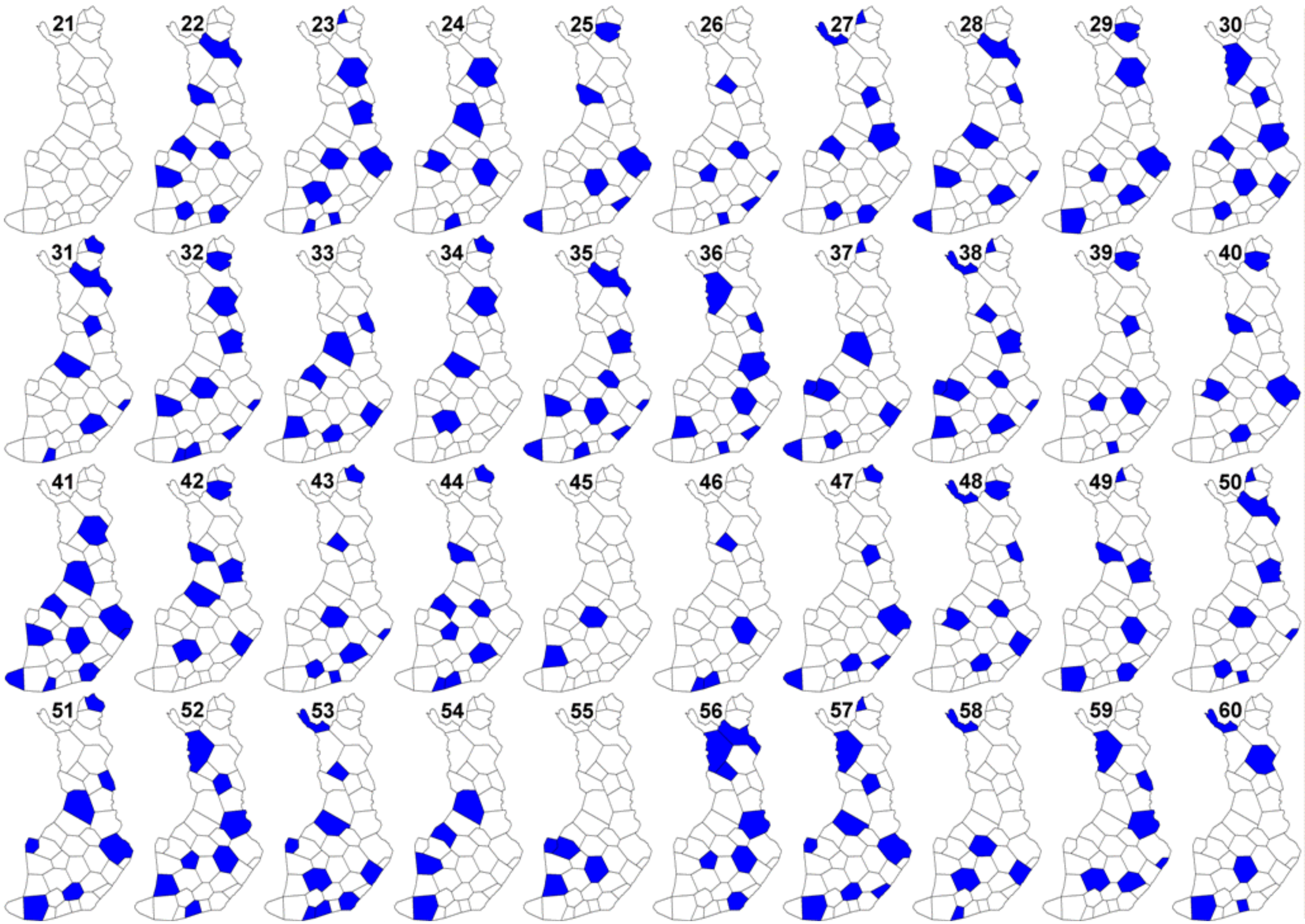
Why to use white spaces?

- Driving force is due to spectrum shortage.
- The huge growth of mobile data utilization has showed that current spectrum allocations for cellular or Wi-Fi networks are inadequate.
- Traditionally, frequencies are strictly regulated to guarantee that wireless communication systems do not cause interference to each other.
  - Frequency bands have been also allocated for unlicensed operation. For example, ISM band at 2.4 GHz frequency is used by WLAN and Bluetooth transmissions among other systems
- Drawback of strict regulation is that the spectrum utilization is not optimal. Depending on wireless system there can be substantial temporal and geographical differences how spectral resources are utilized.

Why to concentrate on TV white spaces?

- The transition from analog TV transmissions to digital TV frees up large amounts of frequencies in VHF and UHF bands.
- Frequencies in VHF and UHF bands are very attractive from network point-of-view.
  - Possible to cover large areas with small amount of base stations, which lowers network building costs.
- TV signal quite stable and easy to predict, which helps in interference control

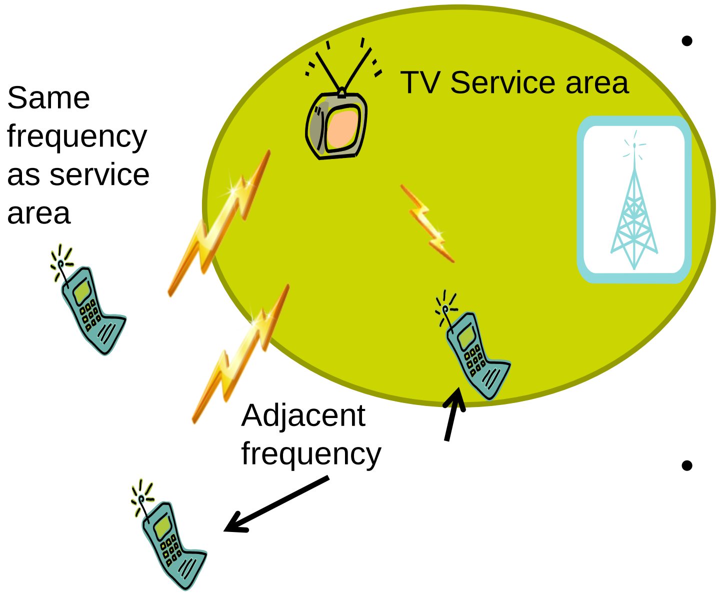
TV White spaces in Finland (470-790 MHz)



Kanava	Taajuus (MHz)
21	470–478
22	478–486
23	486–494
24	494–502
25	502–510
26	510–518
27	518–526
28	526–534
29	534–542
30	542–550
31	550–558
32	558–566
33	566–574
34	574–582
35	582–590
36	590–598
37	598–606
38	606–614
39	614–622
40	622–630
41	630–638
42	638–656
43	646–654
44	654–662
45	662–670
46	670–678
47	678–686
48	686–694
49	694–702
50	702–710
51	710–718
52	718–726
53	726–734
54	734–742
55	742–750
56	750–758
57	758–766
58	766–774
59	774–782
60	782–790

So far so good, but..

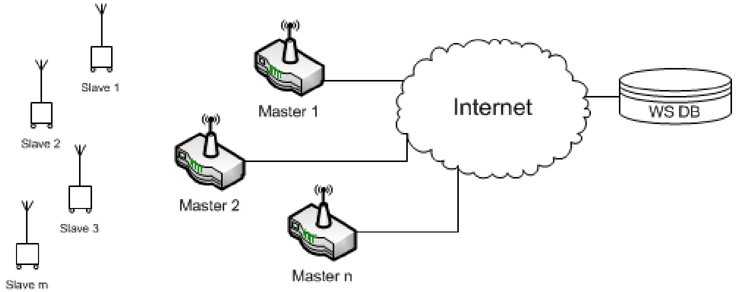
- How to provide enablers for commercial operation of wireless devices in TV white space?
- Key issue: TRUST
- Obstacles in deployment of TVWS systems
  - Regulatory bodies uncertain how to protect primary systems (TV, radio microphones)
  - Also, many operators opposing
    - Systems seen as additional interference
    - Maybe fear for losing profit with changed value networks?
- Our goal is to find out how to build trust



TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

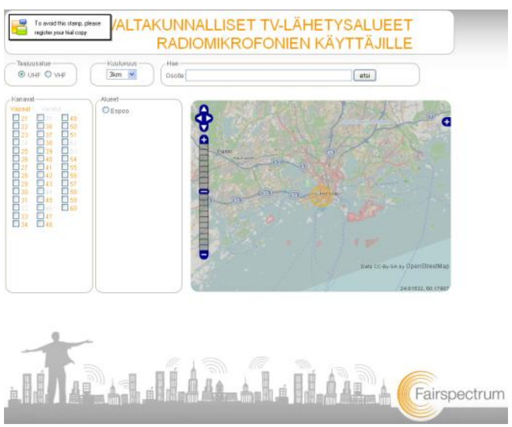
Possible methods for white space access

- Sensing
  - Difficult to perform (wide frequency range, hidden node problem, false positives …)
- Beacon signal
  - Potential extra interference, requires dedicated frequencies and infrastructure
- **Geolocation database**
  - Devices (base stations) query available frequencies from database located in Internet
  - Must guarantee negligible interference to incumbents
  - Must guarantee information security



Some white space databases

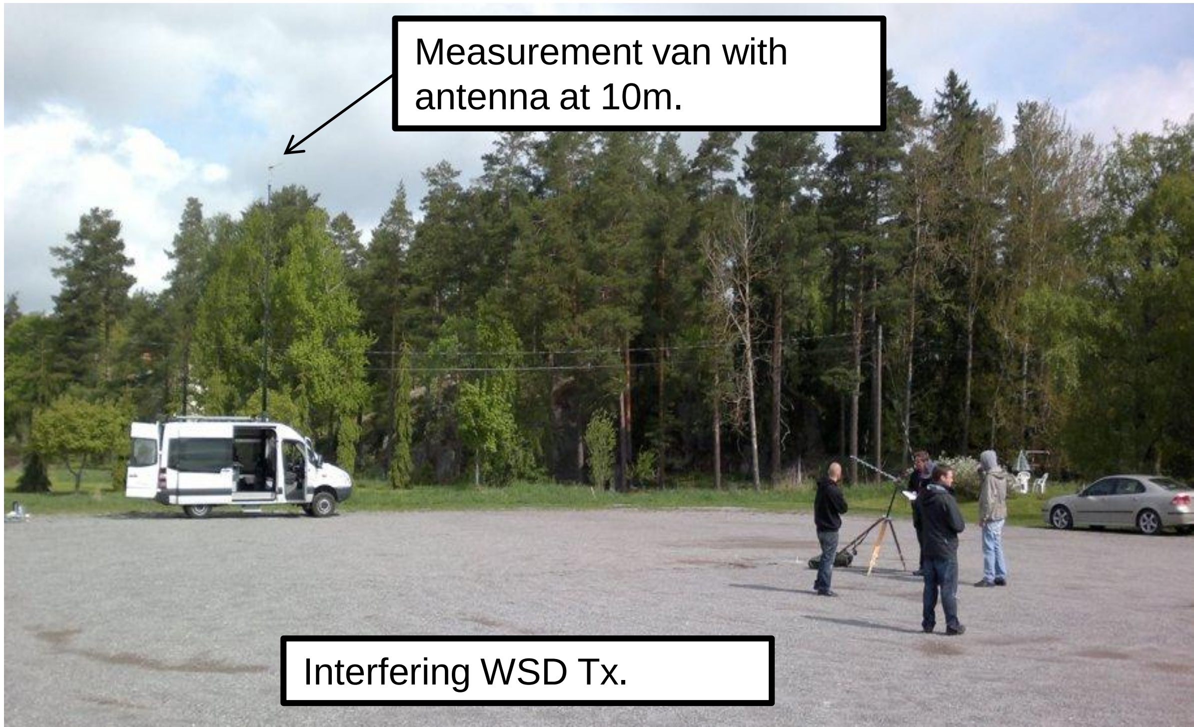
- Fairspectrum
  - http://www.fairspectrum.com
  - http://www.radiomikrofonit.fi/test/
    - Soon the be obsolete URL
- CogEU project demo system http://projectos.est.ipcb.pt/cogeu2/index.php
- Spectrumbridge – Show my white space
  - http://whitespaces.spectrumbridge.com/whitespaces/home.aspx
  - Also iPhone, iPad application available
- Microsoft Research WhiteFiService
  - http://whitespaces.msresearch.us/



Interference challenge

- How to set geographical areas and power limits for white space devices?
- A lot of efforts going on in EU, Asia, USA
- For example in Turku, Finland:

DVB-T test transmission at 610 MHz from Pääskyvuori transmitter.



Security challenge

- Geo-location database is accessed through public Internet.
- Compromised information security could block TV transmissions in addition to white space network. Thus, at least following issues has to be considered
  - Confidentiality
  - Mutual authentication
  - Integrity of database content
  - Reliability of database i.e. service continuity
- Security is ultimately the responsibility of the database administrator.

Current standardization activities include

- IEEE 802.22
  - Wireless broadband for rural areas
  - ”Super Wi-Fi” or ”Wi-Fi on steroids”
- IEEE 802.11af
  - Wi-Fi extension to TVWS
- IEEE 802.16h
  - WiMAX extension to TVWS
- IEEE 802.15.4m
  - Extension of PAN standards to TVWS
- IEEE 802.19.1
  - Co-existence of several white space systems
- IETF PAWS (Protocol to acces white space)
  - Device - database communication protocol
- ECMA-392, IEEE 1900.4°, IEEE 1900.7

Current regulatory situation

- FCC (USA)
  - Ten database operators are selected (incl. Google and Microsoft)
  - First commercial systems are running
- Ofcom (UK)
  - Decision September 2011 to start commercial operation ”as soon as possible”
- Industry Canada
  - Decision October 2011 to start utilizing white spaces
- FICORA (Finland)
  - Full cognitive radio test license granted to Turku area
- Strong interest in Asia, Europe

Regulation and standardization in EU

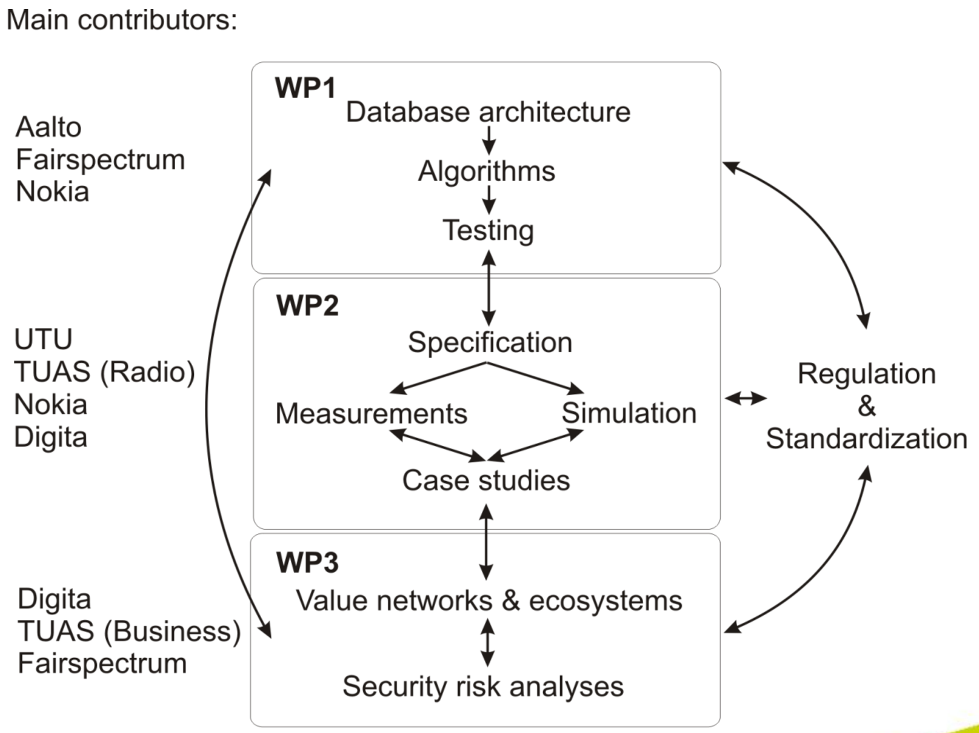
- CEPT ECC SE43 (EU)
  - Technical work on requirements for intereference control and database operation; final reports to be published soon
- ETSI BRAN (Broadband Radio Access Networks)
- ETSI RRS (Reconfigurable Radio Systems)
- CEPT Frequency Management (FM) Project Teams 52 and 53 for ASA/LSA licensing
- EU Commission Communication (September 2012): ”Promoting the shared use of radio spectrum resources in the internal market”
  - Strong indication for EU Commission support for spectrum sharing
  - TV White Spaces
  - ASA/LSA (Authorised Shared Access/Licensed Shared Access) spectrum licensing schemes

Activities in Finland

- Tekes technology program *Trial – Environment for Cognitive Radio and Networks 2011–2014*
  - http://www.tekes.fi/programmes/trial
- “The aim of the programme is to transform Finland into a globally attractive cluster of expertise and unique trial environment for cognitive radio and networks.”
- Tekes – *the Finnish Funding Agency for Technology and Innovation* is the main public funding organisation for research, development and innovation in Finland.
- Estimated volume of Trial program is 32 M€ from which Tekes funding is approximately 14 M€

WISE (White space test environment for broadcast frequencies) project

- Work based on Turku test network and Fairspectrum geolocation database



WISE focus

- Interference
  - Modeling / simulation
  - Lab and field tests
  - Database algorithms
- Database operational issues
  - Radio microphone registration to geolocation database
  - Database test tools
  - Information security

ReWISE (Reliability Extension to White Space Test Environment)

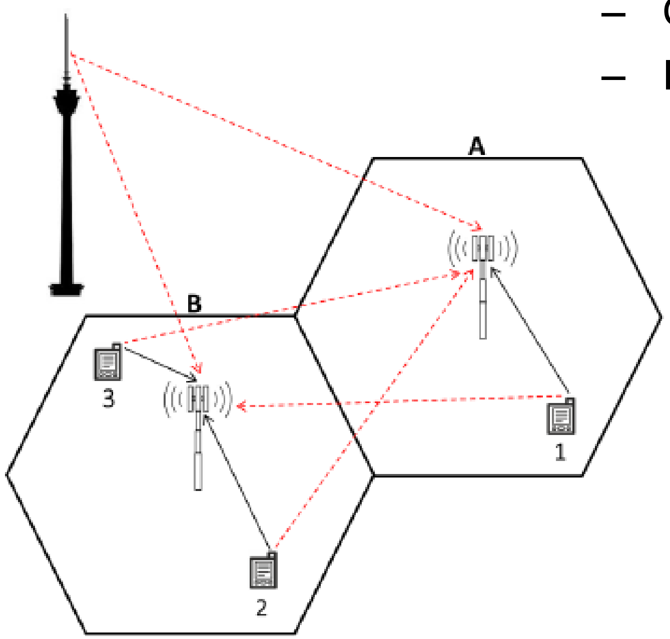
- Joint effort between
  - Turku University of Applied Sciences (TUAS)
  - The University of Ontario Institute of Technology (UOIT)
- Rapid progress in regulatory work during 2011 not anticipated in WISE resourcing
- Strict database reliability required but problems are left for database operators to solve
  - UOIT security testing facility part of Turku Trial test network
- Also, mobile device issues not considered in WISE
  - With white spaces the air interface connected to device security modules first time
  - Analysis is required for needed changes to mobile trusted module in wireless device

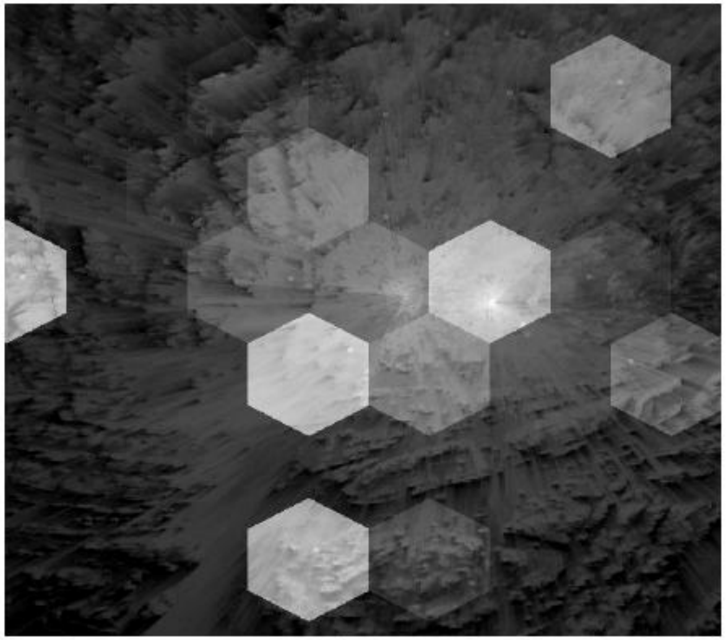
WISE project activities

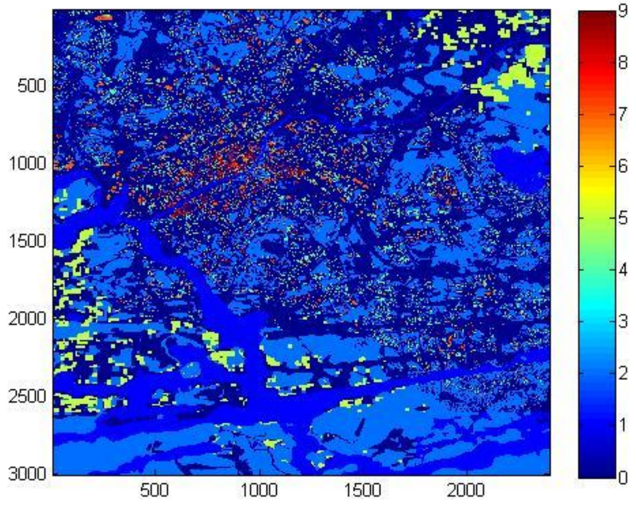
TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

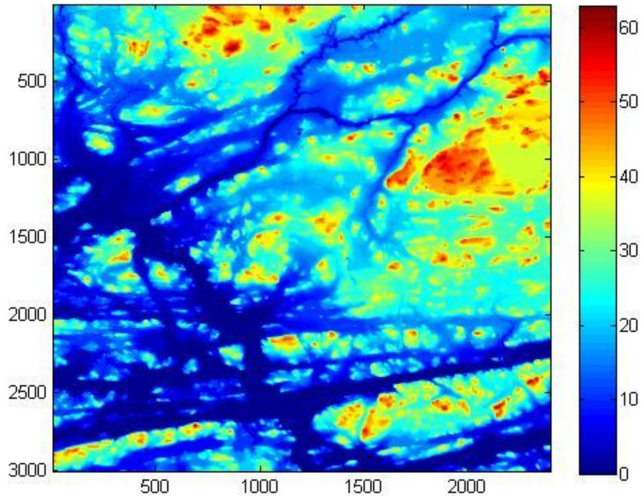
Simulation activities

- Assuming cellular structure for cognitive radio network and CEPT maximum power rules search base stations and WSDs maximizing network capacity
- Study for different methods in updating database using measurements from WSDs. Comparison of algorithms
  - Capacity
  - Interference









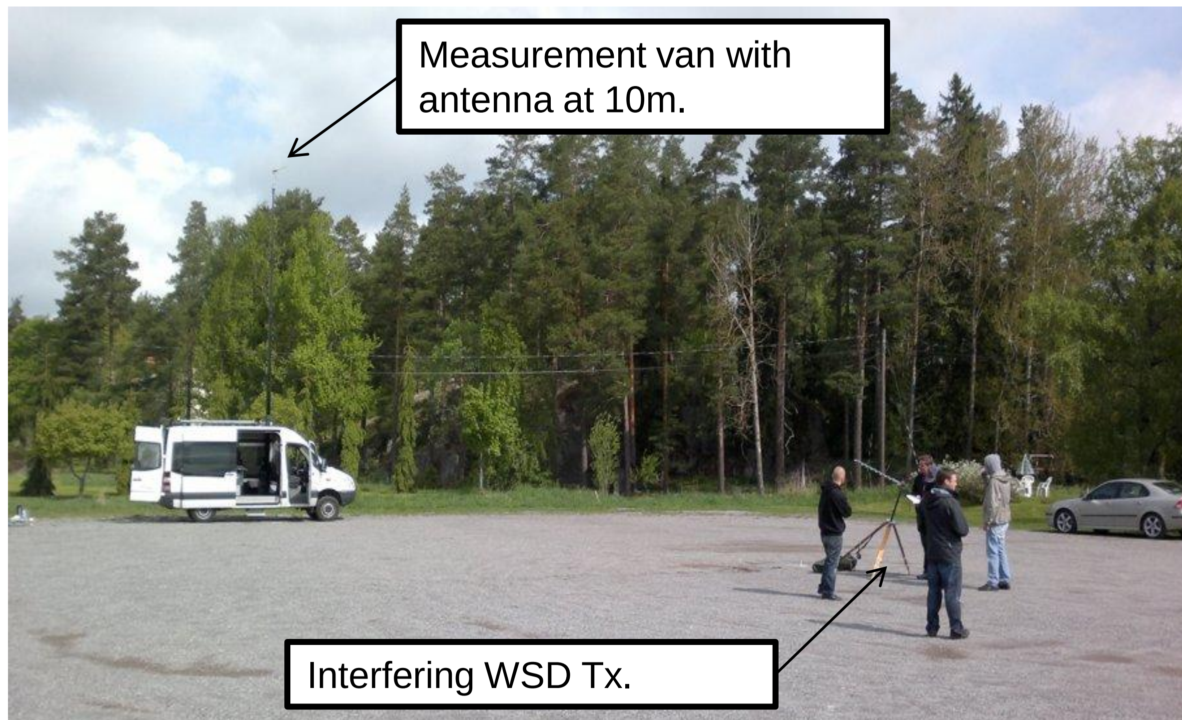
Hybrid propagation models

- Propagation models for simulations and geolocation database implementation
- Attenuation parameters for different terrain types – propagation path divided
- Modeling method applied in Turku test network
  - Available data includes 10 different terrain types and height information

White Space Device (WSD) Maximum Power Measurements

- Receive DTV with roof top antenna (10m) at noise limited +3 dB case and some higher power levels like +13 dB, +23 dB.
- Interfering WSD at 22m away
- Increase the WSD power until picture failure for co-channel and adjacent channel at N-1, N-2, N-3 and N-4.
- Compare true WSD interference power levels to calculated power levels.

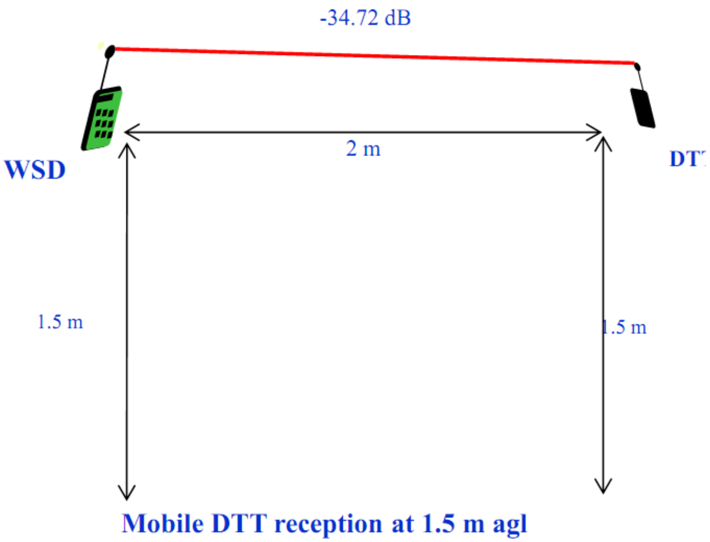
DVB-T test transmission at 610 MHz from Pääskyvuori transmitter.



TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

WSD maximum Power Indoor Measurements in Turku Test Network

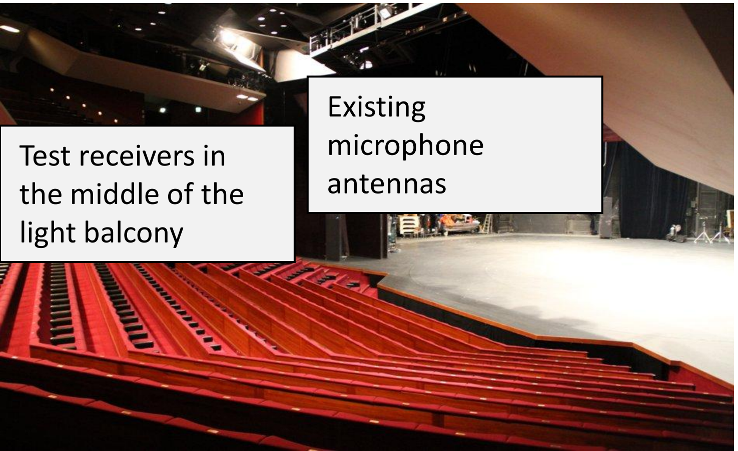
- Similar work as outdoor measurements but with the following reference geometry:



TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

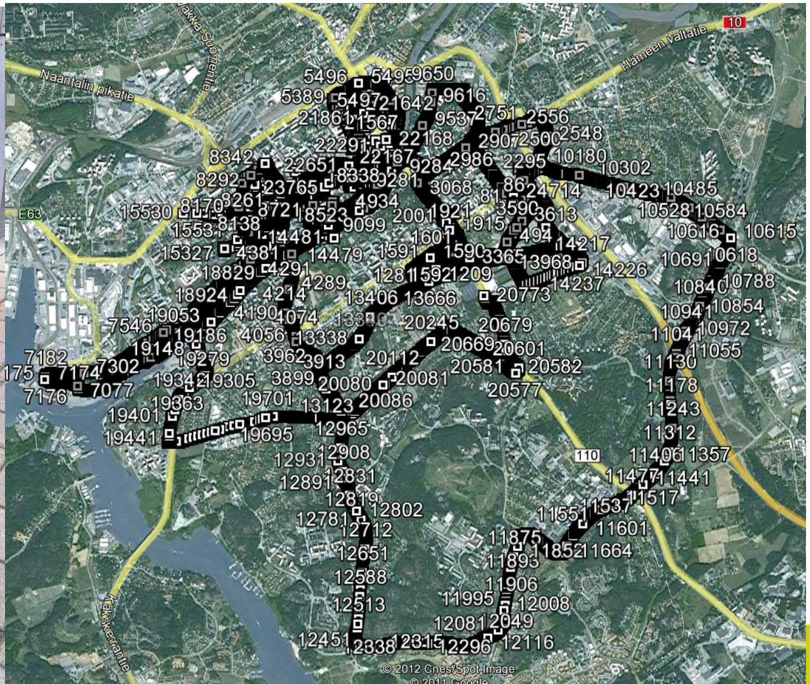
PMSE protection measurements in Helsinki City Theatre

- The tested microphones were installed and used like the operational microphones in theatres
- The microphone receivers were interfered with a simulated WSD-signal until interference was observed. This was repeated in several locations with both co- and adjacent channels.
- It was found that there is a major effect on how the microphones are used.
- Outside the theatre building, at a distance of 560 m it was not possible to cause interference anymore with the available WSD-power.



Pedestrian and mobile measurements in Turku test network

- Used equipment: modified Nokia N900 with OFDM signal sensing capability
- Power levels in test network
- Data stored and can made available for Trial projects
- Utilized e.g. in simulator environment development



WISE achievements so far

- Original goal of WISE testbed was build trust towards regulators and industry to utilize TV white space
- Testbed is up and running
  - Full cognitive radio license in Turku for frequencies 470 – 790 MHz granted by FICORA
- Interference measurements and contributions to regulation in CEPT SE 43
- Tools for geolocation database testing and wireless microphone registration
- Service pilots: rural broadband, electronic news gathering
- WISE international workshop will be organized 10.12.2012 in Helsinki
  - Register: http://wise2012.eventbrite.com/

TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

Planned WISE testbed utilization 2013-2014

- Additional service pilots
  - ITS, Smart grid, Video surveillance, etc.
- Geolocation database development towards ASA/LSA spectrum sharing model
- Radio Environment Mapping
- Network capacity analysis
- WISE testbed is looking for
  - Services / use cases utilizing white space communications
  - Equipment (SDR radios) to test

Future of spectrum sharing

- Spectrum sharing will happen
- ASA/LSA between operators?
- TV White spaces, but which applications..
  - Rural broadband in e.g. USA, Canada having large geographical area?
  - M2M communications?
- In the USA, The report "Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth" (July 2012) from the President's Council of Advisors on Science and Technology (PCAST) says the "traditional practice of clearing and reallocating portions of the spectrum used by Federal agencies is not a sustainable model." Instead, spectrum should be shared.
  - Plans are for allocating 1000 MHz

Contact: Jarkko Paavola (jarkko.paavola@turkuamk.fi)

More information:
http://www.tekes.fi/programmes/trial
http://wise.turkuamk.fi/

THANK YOU!

TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES