White Space Regulation and Opportunities

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creating and sharing knowledge for telecommunications

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- Spectrum management
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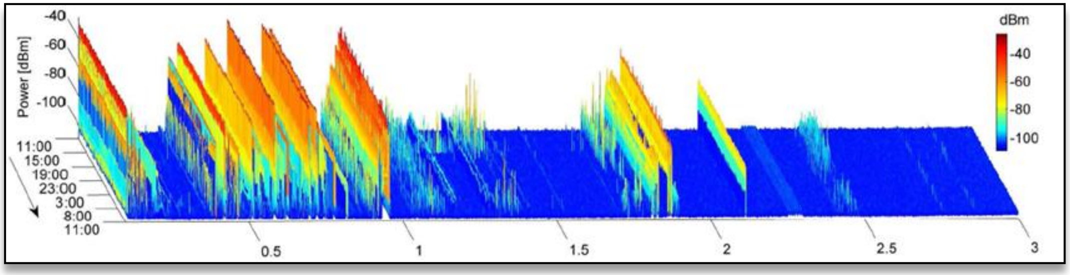
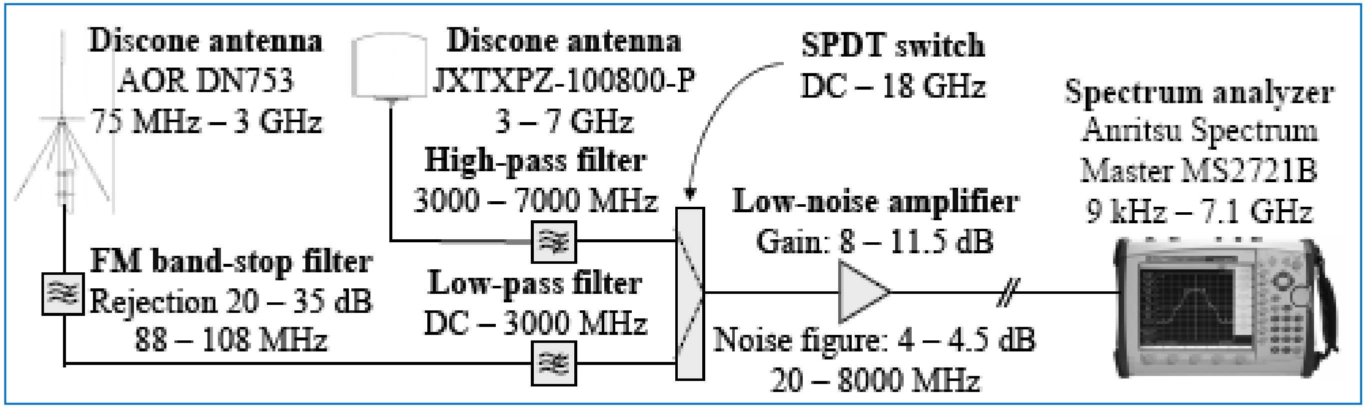


- Measurement setup
- Measurement results
- Measurement conclusions

SPECTRUM OCCUPANCY MEASUREMENTS

Measurement setup

- Building elements
  - –Antenna
    - one or several; each optimized for a given sub-band;
  - –Filters
    - remove strong in-band signals;
    - limits out-of-band interference;
  - –LNA
    - sensivity improvement;
  - – Spectrum analyzer
    - power spectral density measures;
    - store results.



Source: M. López-Benítez, F. Casadevall, “Methodological aspects of spectrum occupancy evaluation in the context of cognitive radio” in Proceedings of the 15th European Wireless Conference (EW 2009), Aalborg, Denmark, May 17-20, 2009, pp. 199-204.

Measurement setup

- Spectrum analyzer configuration
  - Frequency bins:
    - should be narrower than the bandwidth of the signals being detected;
  - Resolution bandwidth:
    - Reducing it improves capability to detect weak signals, but increases measurement time.
- Pos-processing
  - Most of the times uses energy detection method.
  - Detection threshold may be established using several criteria:
    - Maximum noise sample;
    - X-dB above noise floor (e.g. X=3, 6, 10dB)
    - Probability of false alarm (only x% of noise samples above threshold)

  - Energy detection is not suitable for detecting:
    - spread-spectrum signals;
    - wideband signals under frequency selective channels.

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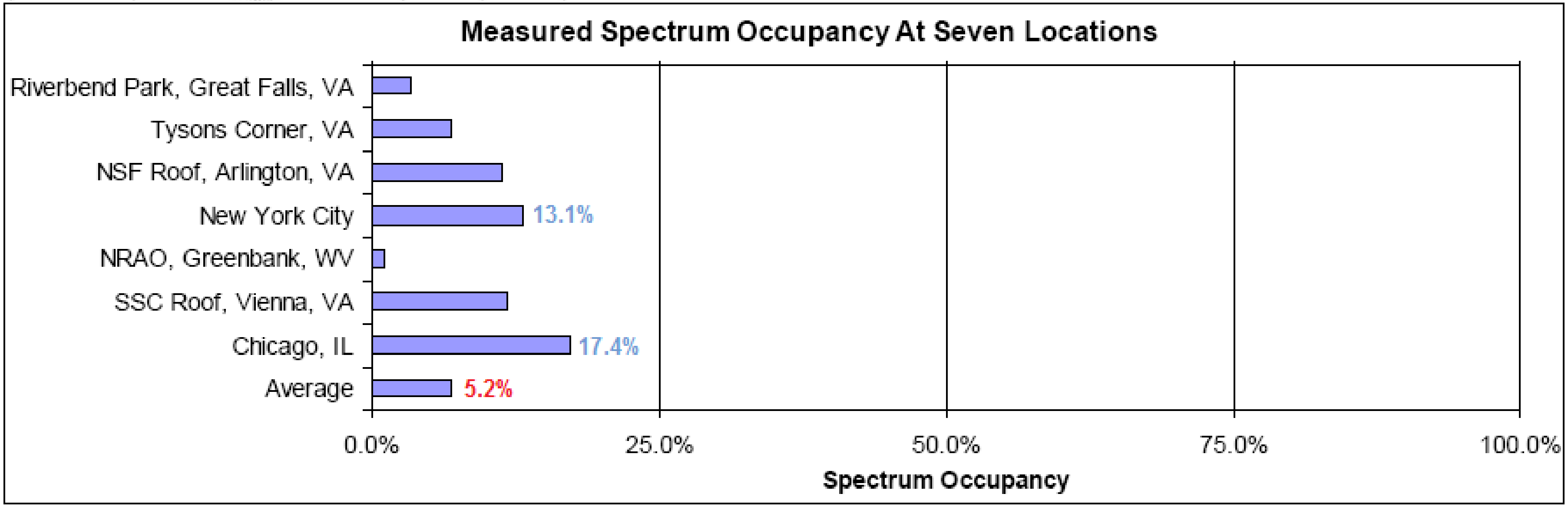
U.S.A 30MHz-3GHz Spectrum Occupancy (2004, 2005)



Source: M. A. McHenry, D. McCloskey, D. Roberson, J. T. MacDonald, “Spectrum Occupancy Measurements Chicago, Illinois”, Shared Spectrum Company and IIT Wireless Interference Lab, Dec. 2005.

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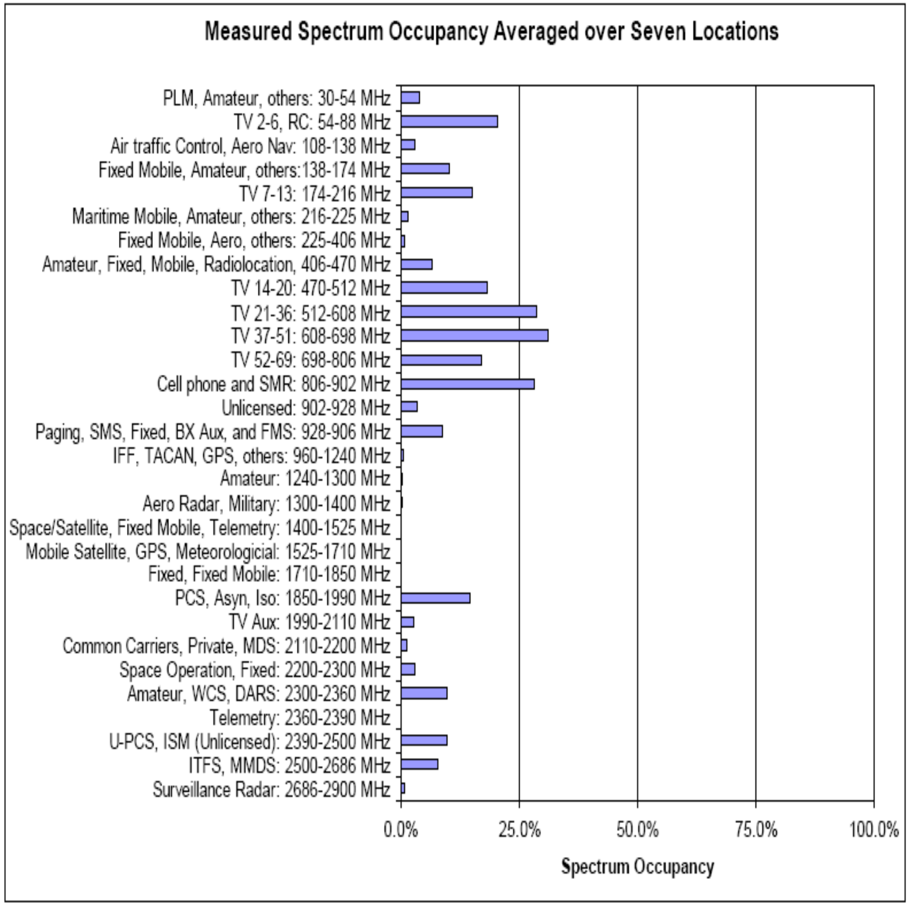

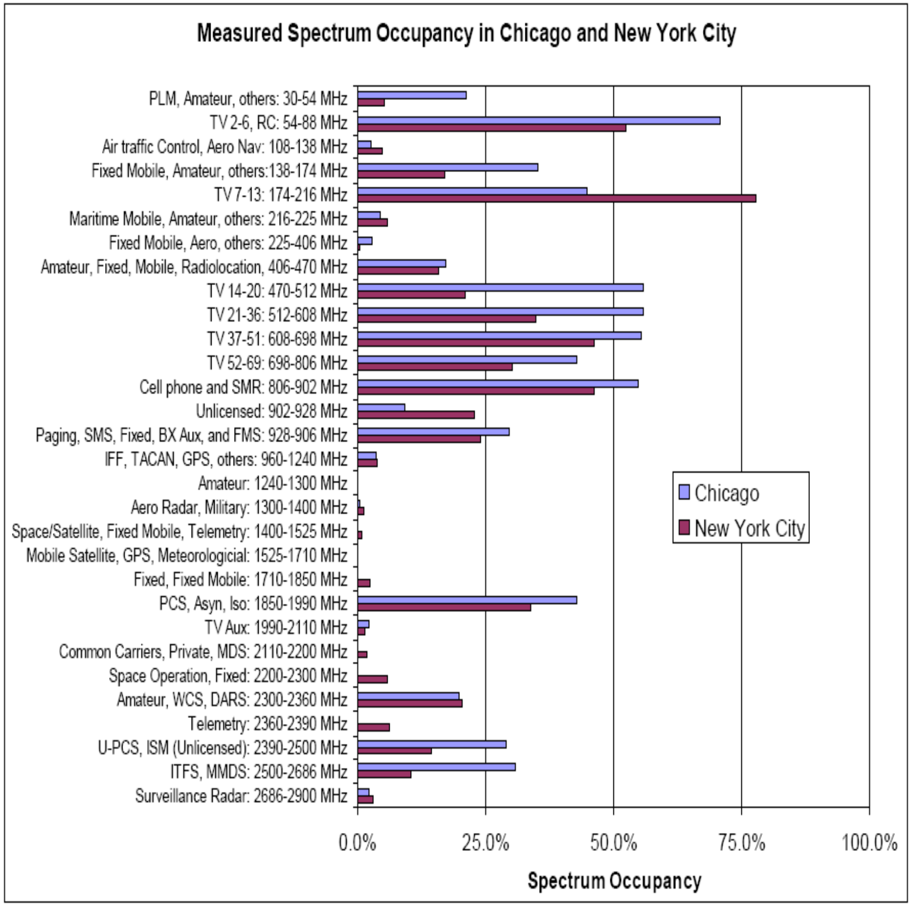

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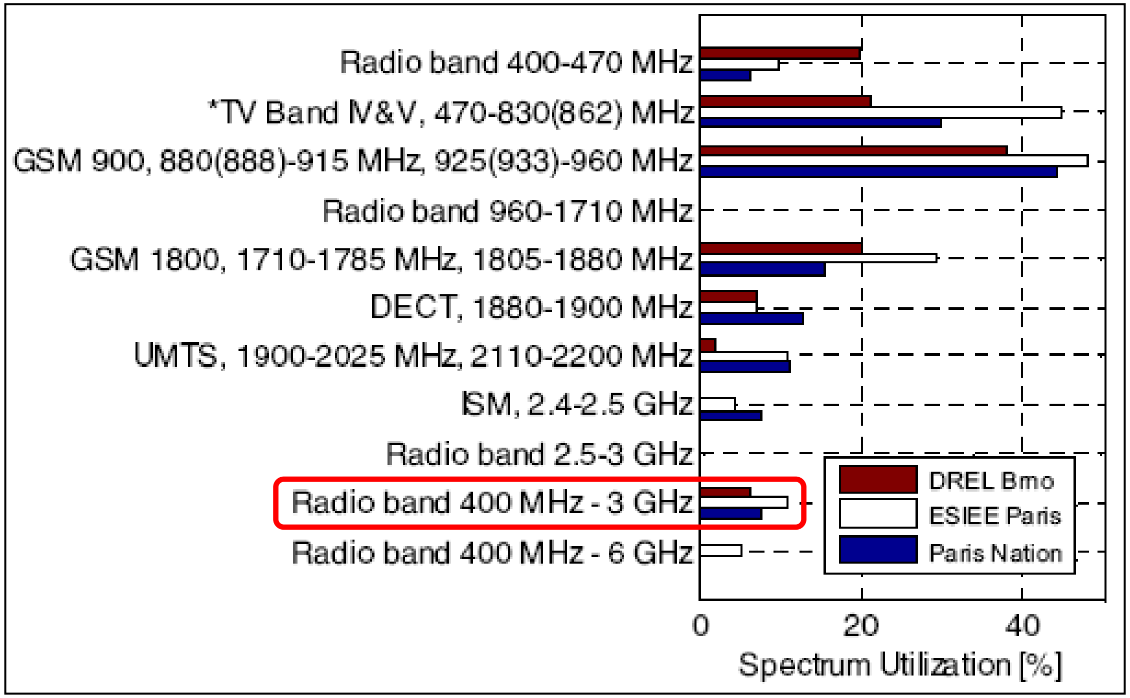
France’s 400MHz-3GHz Spectrum Occupancy



Comparison of spectrum occupancy in the band 400MHZ-3GHz

Average occupancy of the band 400MHZ-3GHz	
Brno (suburban)	6.5%
Paris (suburban)	10,7%
Paris (urban)	7,7%

•**Source:**V. Valenta, R. Marsálek, G. Baudoin, M. Villegas, M. Suarez, and F. Robert, “Survey on spectrum utilization in Europe: Measurements, analyses and observations,” in Proc. of the 5th Int. Conf. on Cognitive Radio Oriented Wireless Networks Communications (CROWNCOM), Jun. 2010, pp. 1–5.

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Measurement results

Location(s)	Year	Measurement frequency range	Average indoor occupancy	Average outdoor occupancy
7 locations (USA)	2004 2005	30MHz – 3GHz	---	5.2% (N. York: 13.1%, Chicago: 17.4%)
Barcelona (Spain)	2009	75MHz–7.075GHz	12.1%	17.8%
Paris (France)	2009	400MHz – 3GHz	---	10.7% (suburb) 7.7 (centre)
Aachen (Germany)	2007	20MHz – 3GHz	32%	Near 100%
Brno (Czech Republic)	2008	400MHz – 3GHz	---	6,5%
Singapore	2007	80MHz – 5.85GHz	---	4,5%
Auckland (New Zealand)	2006	806MHz – 2.75GHz (no TV bands)	5,7%	6,2%

Measurement campaign conclusions

- Most of the occupied spectrum is below 3GHz.
- In densely populated areas, less than 20% of spectrum bands below 3GHz are used during a working day.
- In rural areas the occupation is even lower.
- Spectrum occupation is higher indoors than outdoors.
- The most occupied bands are TV and cellular bands.

- Current strategies;
- Identified opportunities;
- Enabling technologies.

SPECTRUM MANAGEMENT

‘Standard’ strategies

- Command and control
  - One band ↔one service ↔ one technology ↔ one owner
  - Beauty contests
    - Wins a license who provides better service (coverage, bit-rate, latency, …) using a specific technology.
    - All contestants would pay the same.
- Spectrum market
  - One band ↔ any service ↔ one owner
  - Spectrum auctions
    - Wins a license who pays more for it.
    - Technology and service neutrality.
    - Possibility to trade spectrum rights.
- Spectrum commons
  - One band ↔ any service ↔ no owner
  - Users access the spectrum freely and under equal circumstances.
  - Deploy the service they need (e.g. WLAN, medical devices, …).

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Standard strategies' weaknesses

- Command and control
  - –Ineffective: low overall spectrum occupancy
- Spectrum market
  - –Spectrum investment for speculation purposes .
  - –Frequency bands without use.
  - –Spectrum monopoly by wealthy players.
  - –Spectrum fragmentation.
- Spectrum commons
  - –Uncoordinated operation.
  - –Higher interference levels.

Spectrum management opportunities

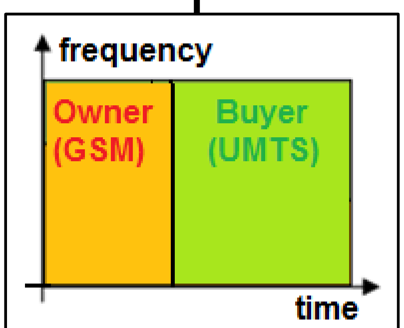
Command & control
- Static allocation
- Little sharing
- Low flexibility

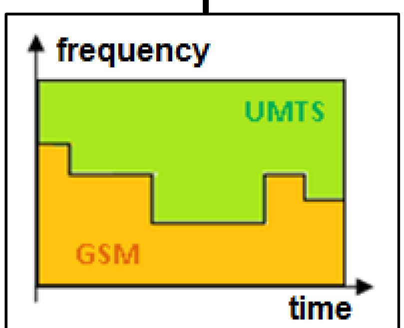
Dynamic spectrum access

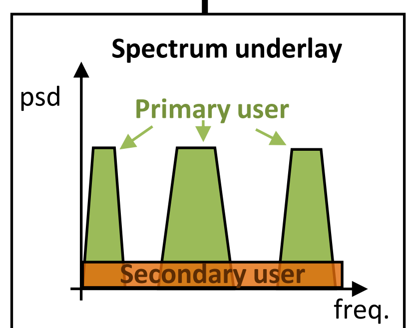
Exclusive use model
- One owner;
- Flexible allocation
- Flexible use

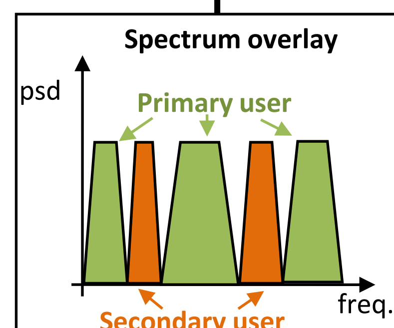
Open sharing model
- Spectrum commons
- No owners/Peer users
- e.g. ISM band

Hierarchical use model
- Primary users (licensed)
- Secondary users (unlic.)





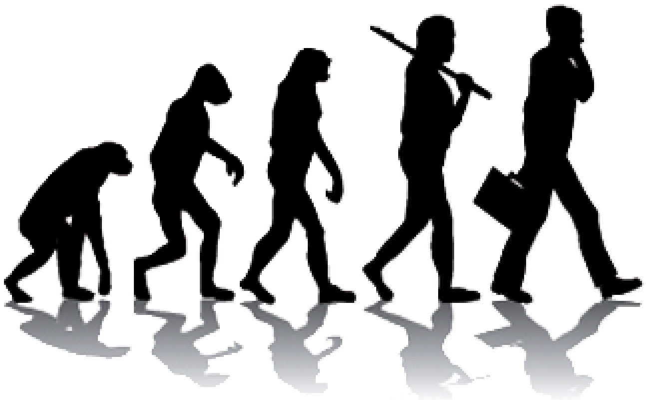




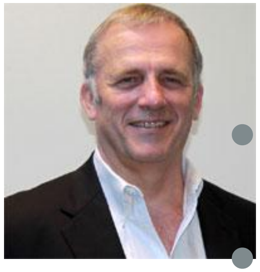
Source: Zhao, 2010

Enabling technology

- Cognitive radio
  - – observe radio environment
  - – adapt autonomously
  - – learn with previous experience



- Concept: Dr. Joseph Mitola III (1998).
- Applications: DSA & beyond
- Real life implementations: early steps



- Proof of concept: easier scenarios first !
- One such scenario: TV band.

Concept

Applications

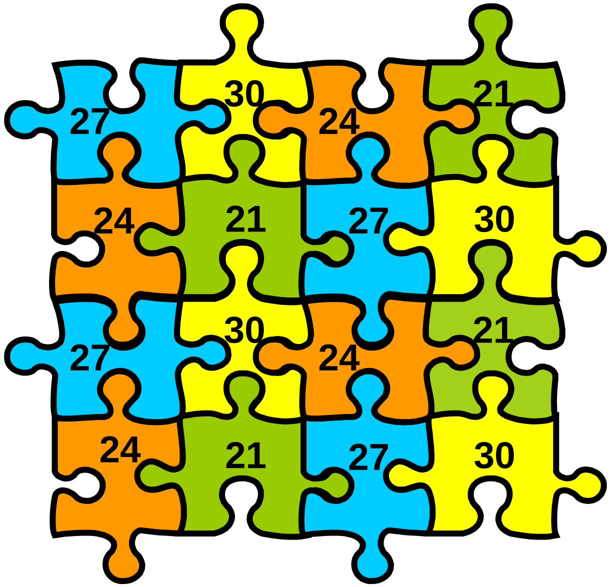
Current regulation

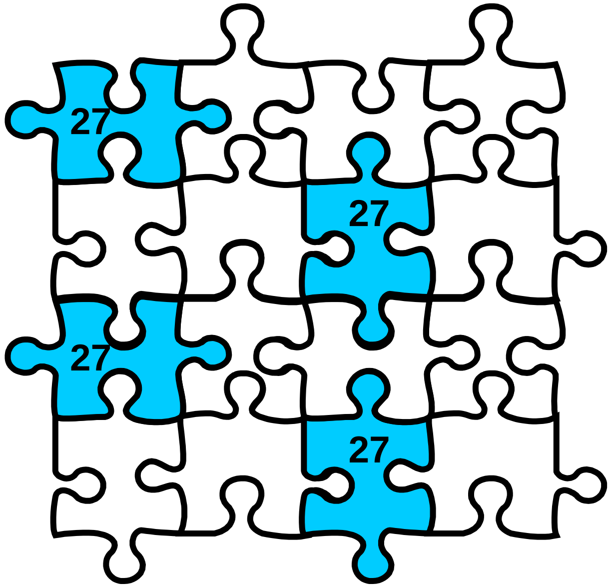
Standards

TV WHITE SPACES

TV White Spaces

- Digital TV coverage planning considers some gaps (“TV white spaces”) to avoid interference (MFN networks).
- As DTV transmitters are not moving, white spaces are easier to identify.
- TV white spaces could be used by other services as long they do not interfere with TV broadcasting.





TV White Spaces advantages:

Digital switch-over frees significant UHF spectrum.

Digital TV channels with desirable bandwidth (8MHz) for many systems currently using other crowded bands or for innovative services;

In TV bands, licensed and unlicensed coexistence is easier;

TV bands provide better coverage (on average 3 times higher than ISM band);

Use of TV bands have potentially no cost (if unlicensed use allowed).

Many key players such as Google, Dell, Intel and Microsoft anticipate significant innovation in this TV band.

How to identify TV White Spaces ?

- Primary users protection using Cognitive Radio
  - **Spectrum sensing**
    - Monitors spectrum and deduces it's free if it senses no activity.
    - Problem: hidden-terminal; false positives on adjacent channels.
  - **Device geo-localization and database enquiry**
    - Device capable of geolocate itself and connect to a database to know what channels are free in a given region.
    - Expected better interference avoidance capability than sensing alone
    - Adds spectrum management and 'turn off cognitive' capabilities.
  - **Cognitive Pilot Channel / Beacon reception**
    - Base station transmits a radio signal with information on available channels/technologies in that location. Costly!!
    - Do not transmit if beacon not detected (may be shadowed)
    - Problem: Frequency harmonization, beacon overlap.
  - **Data fusion**
    - A mixture of the methods above.

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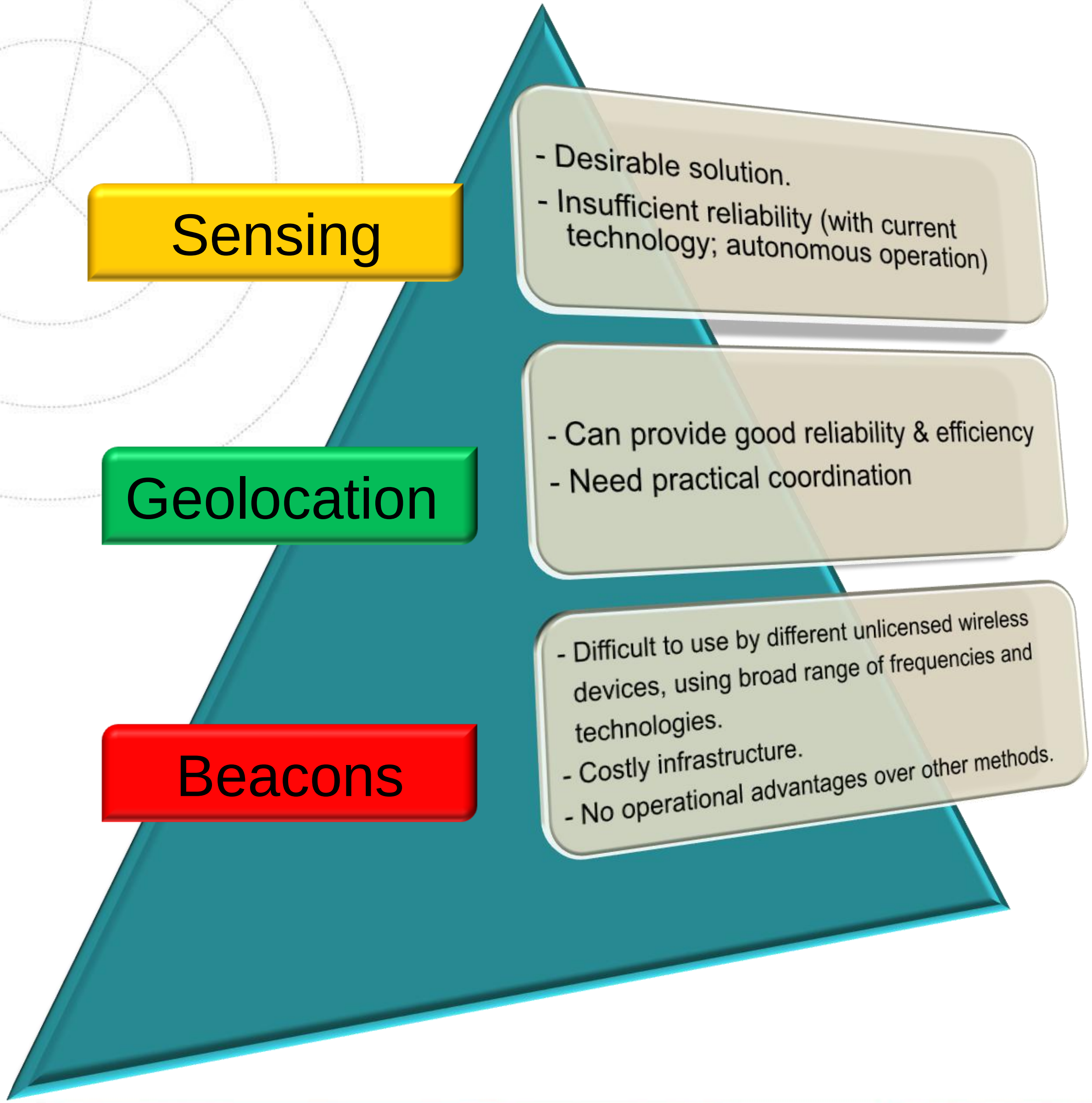
White Space Access Methods Comparison



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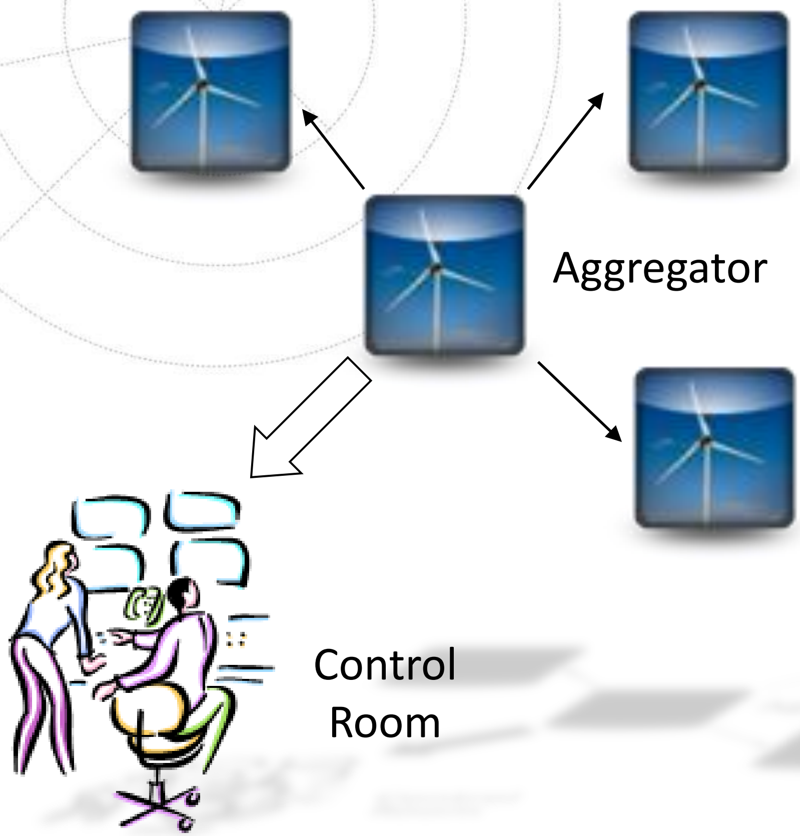
TV White Spaces Applications - Examples

- Several application categories are possible:
  - Smart Transport,
  - Energy efficiency,
  - Connected car,
  - Consumer Home Electronics,
  - Smart Cities
  - Smart Industry.

Some examples….

TV White Spaces Applications - Examples

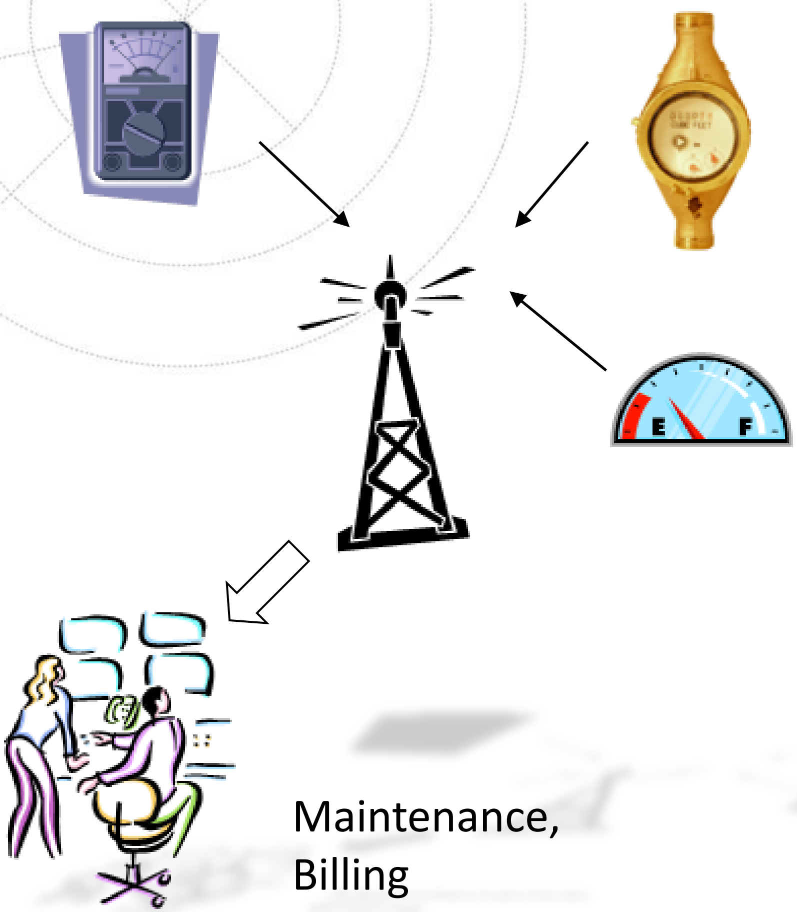


- **Energy infrastructure control, and maintenance (e.g. wind farms)**

TV White Spaces Applications - Examples

- **Urban transportation (e.g. waiting times at bus/train stops)**

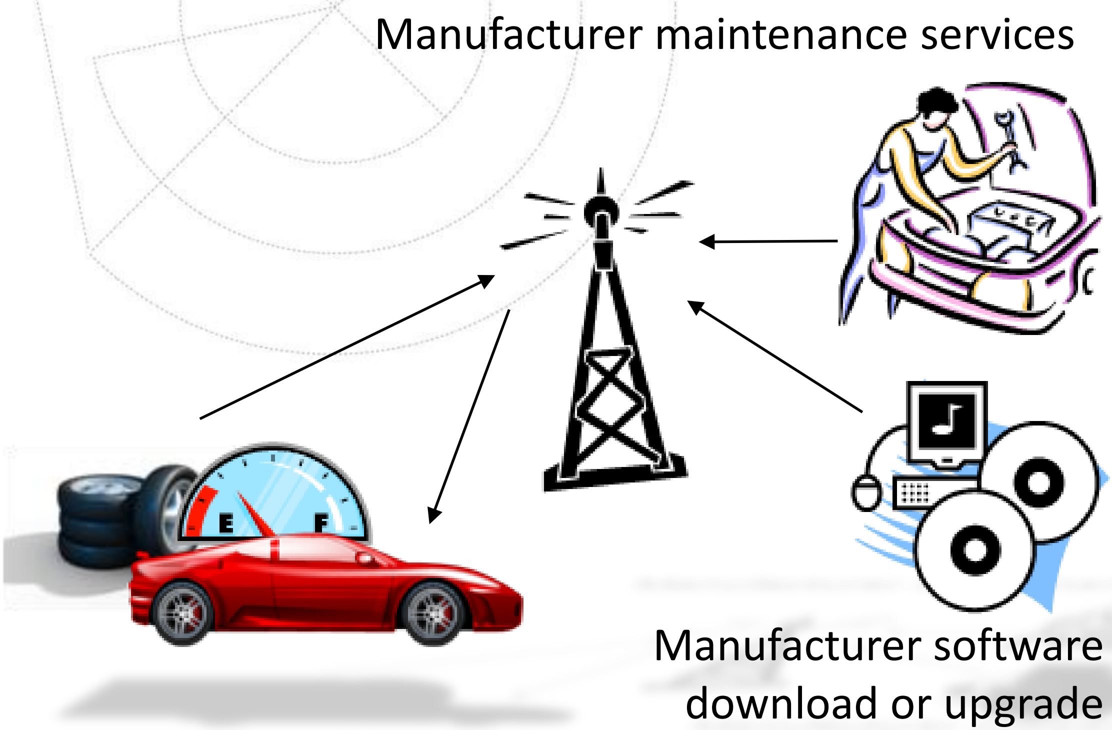
TV White Spaces Applications - Examples



- **Remote metering**

  (e.g. electricity, water, gas, …, temperature, wind speed, …)

TV White Spaces Applications - Examples



- **Automotive applications**

TV White Spaces Applications - Examples

- Extended wireless broadband coverage in open areas

… and many others ….

White space regulatory initiatives (Europe)

- European Union
  - Radio Spectrum Policy Group (RSPG) → Policy advising
    - Opinion on TV white spaces – Feb.2010, Feb. 2011, Jun. 2011
  - Radio Spectrum Committee (RSC) → Technical advising
    - Mandates to CEPT on the 'Digital Dividend' – Jan.2007, Apr.2008
    - **CEPT** produced **Report 24** as an answer (July 2008):
      - Technical feasibility of 'white spaces' exploitation
      - Preliminary operational parameters
  - Harmonization at pan-European level continued within CEPT in two newly formed working groups:
    - SE42: studies on DTT resilience against interference.
    - SE 43: cognitive devices access to UHF (470-790MHz) white spaces
      - **ECC Report 159 (Jan.2011)**
      - **Final 'white space' operational specifications in 2012.**

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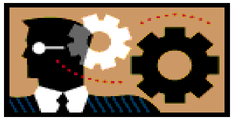
White space regulatory initiatives (Europe)

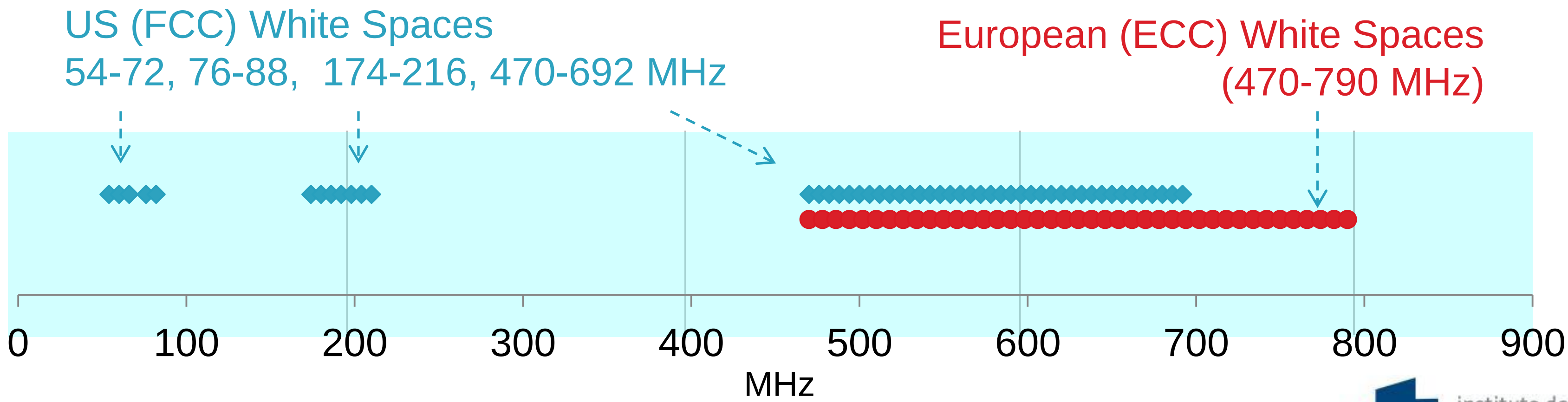
- ECC Report 159 (Jan. 2011) main conclusions on TV white spaces:
  - Type of Devices: **Personal (portable); Home Office (fixed); Base Station (fixed)**
  - Max. Output Power: **10-50 mW** (personal, home office); **1-10 W** (base station)
  - Transceivers: **UHF/OFDM + any other band/technology**
  - Network 'architecture': **Infrastructure** type or **ad-hoc** links
  - White space identification method:
    - **Autonomous sensing:**
      - **unreliable channel identification & output power calculation**
    - **Geolocation & Database:**
      - WSD communicates its location to the database **not using white-spaces**.
      - Database respond with **free channels** and **maximum E.I.R.P.** allowed.
      - Database store /compute:
        - DTT signal level in every 100x100m region with 95% confidence interval
        - Metric to identify a free channel: maximum reduction on DTT coverage 'quality' imposed by WSD.
        - Algorithms to calculate WSD power

Complexity?



White space regulatory initiatives (USA)

- FCC
  - Consultation on ‘white spaces’ exploitation (NPRM) - May 2004
  - Authorization of unlicensed use of TV band – Nov. 2008
  - Rules for “Unlicensed Operation in the TV Broadcast Bands” – Feb. 2009
  - Final rules on the technical parameters to use white spaces – Sept. 2010
  - 10 database providers appointed – Jan./Apr. 2011



Source: www.octoscope.com

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White space standardization

- ECMA-392
  - Published Dec. 2009.
  - Short range home electronics applications.
- IEEE 802.22
  - Broadband for rural areas.
- IEEE 802.16h
  - Unlicensed WiMax operation (e.g. using TV band).
- IEEE 802.11af
  - Draft phase. Expected to be concluded in 2012.
  - WiFi in the TV white spaces.
- DySPAN 1900.7
  - Early phase. Official activities started a couple of months ago.
- ETSI RRS
  - Reconfigurable heterogeneous mobile networks, with optional TV white space support.

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Conclusions

- With current spectrum management methods, many white spaces exist.
- Opportunistic spectrum access can make efficient use of white spaces without interfering with legacy systems.
- Cognitive radio is the enabling technology.
- Innovative services can be deployed in white spaces.
- Regulatory and standardization activities are being developed, despite some initial reluctance from legacy users.

Thank you for your attention

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