White Space Regulation and Opportunities

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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**
    - sensitivity improvement;
  - **Spectrum analyzer**
    - power spectral density measures;
    - store results.

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.

• Post-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.

Measured Spectrum Occupancy Averaged over Seven Locations

- PLM, Amateur, others: 30-54 MHz
- TV 2-6, RC: 54-88 MHz
- Air traffic Control, Aero Nav: 106-136 MHz
- Fixed Mobile, Amateur, others: 138-174 MHz
- TV 7-13: 174-216 MHz
- Maritime Mobile, Amateur, others: 216-225 MHz
- Fixed Mobile, Aero, others: 225-406 MHz
- Amateur, Fixed, Mobile, Radiolocation: 406-470 MHz
- TV 14-20: 470-512 MHz
- TV 21-36: 512-608 MHz
- TV 37-51: 608-696 MHz
- TV 52-68: 696-806 MHz
- Cell phone and SMR: 896-902 MHz
- Unlicensed: 902-906 MHz
- Paging, SMS, Fixed, DX Aux, and FMS: 926-956 MHz
- IFF, TACAN, GPS, others: 960-1240 MHz
- Amateur: 1240-1300 MHz
- Aero Radar, Military: 1300-1440 MHz
- Space/Satellite, Fixed Mobile, Telemetry: 1400-1625 MHz
- Mobile Satellite, GPS, Meteorological: 1525-1710 MHz
- Fixed, Fixed Mobile: 1710-1860 MHz
- PCS, Asym, Isc: 1850-1990 MHz
- TV Aux: 1990-2110 MHz
- Common Carriers, Private, MDS: 2110-2200 MHz
- Space Operation, Fixed: 2200-2300 MHz
- Amateur, WCS, DARS: 2300-2360 MHz
- Telemetry: 2360-2390 MHz
- U-PCS, ISM (Unlicensed): 2390-2500 MHz
- ITFS, MMDS: 2500-2586 MHz
- Surveillance Radar: 2686-2900 MHz

France’s 400MHz-3GHz Spectrum Occupancy

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

Average occupancy of the band 400MHz-3GHz

<table>
<thead>
<tr>
<th>Location</th>
<th>Occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brno (suburban)</td>
<td>6.5%</td>
</tr>
<tr>
<td>Paris (suburban)</td>
<td>10.7%</td>
</tr>
<tr>
<td>Paris (urban)</td>
<td>7.7%</td>
</tr>
</tbody>
</table>

## Measurement results

<table>
<thead>
<tr>
<th>Location(s)</th>
<th>Year</th>
<th>Measurement frequency range</th>
<th>Average indoor occupancy</th>
<th>Average outdoor occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 locations (USA)</td>
<td>2004</td>
<td>30MHz – 3GHz</td>
<td>---</td>
<td>5.2% (N. York: 13.1%, Chicago: 17.4%)</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barcelona (Spain)</td>
<td>2009</td>
<td>75MHz–7.075GHz</td>
<td>12.1%</td>
<td>17.8%</td>
</tr>
<tr>
<td>Paris (France)</td>
<td>2009</td>
<td>400MHz – 3GHz</td>
<td>---</td>
<td>10.7% (suburb) 7.7 (centre)</td>
</tr>
<tr>
<td>Aachen (Germany)</td>
<td>2007</td>
<td>20MHz – 3GHz</td>
<td>32%</td>
<td>Near 100%</td>
</tr>
<tr>
<td>Brno (Czech Republic)</td>
<td>2008</td>
<td>400MHz – 3GHz</td>
<td>---</td>
<td>6.5%</td>
</tr>
<tr>
<td>Singapore</td>
<td>2007</td>
<td>80MHz – 5.85GHz</td>
<td>---</td>
<td>4.5%</td>
</tr>
<tr>
<td>Auckland (New Zealand)</td>
<td>2006</td>
<td>806MHz – 2.75GHz (no TV bands)</td>
<td>5.7%</td>
<td>6.2%</td>
</tr>
</tbody>
</table>
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, …)
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.
White Space Access Methods Comparison

- Sensing
  - Desirable solution.
  - Insufficient reliability (with current technology; autonomous operation)

- Geolocation
  - Can provide good reliability & efficiency
  - Need practical coordination

- Beacons
  - Difficult to use by different unlicensed wireless devices, using broad range of frequencies and technologies.
  - Costly infrastructure.
  - No operational advantages over other methods.
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, ...)

Maintenance, Billing
TV White Spaces Applications - Examples

- Automotive applications
- Manufacturer maintenance services
- Manufacturer software download or upgrade
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
  – Radio Spectrum Committee (RSC) → Technical advising
    - 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.
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
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
  – 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.
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