White Spaces potentially available in Italian scenarios based on the geo-location database approach

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Fondazione Ugo Bordoni

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- FUB activities include medium and long-term research, European and National projects and technological innovation processes.

- FUB is engaged in elaborating development strategies in partnership with national and international competent bodies; supporting public administrations in technical, economical, financial, managerial, legal, and regulatory issues; acting as neutral entity for users safeguard as well as for market development; cooperating with Universities and other research bodies; supporting education and training.
Activities on spectrum issues

- FUB gives its support to the Italian Administration to develop and promote strategies for the flexible and efficient use of radio spectrum.
- FUB participates to several international bodies, including ITU and CEPT, in support to the Italian Administration.
- The area of activities includes:
  - Technical studies
  - Innovative regulatory strategies
  - Analysis of techno-economic scenarios
- In this framework, cognitive radio and white spaces are investigated with the major intent to assess the potential for improvement of flexibility and efficiency of spectrum use, in consideration of characteristics and needs of the Italian context.
Aim of this work

- Identification of WS potentially available in the TV band in different real Italian scenarios based on different geo-location database approaches:
  - Threshold based approach
  - Location Probability based approach
  - Combination of geo-location with sensing techniques

- Estimation of the maximum permitted WSD emission power based on different methodologies:
  - Acceptable degradation of DTT Location Probability
  - Fixed DTT Signal threshold model
  - Maximum acceptable degradation of DTT quality \( \frac{C}{I+N} \)
Background (1)

SINCE JULY 2012
TV IS ONLY DIGITAL

- **FUB** provides technical support to Italian administration on ICT
- **FUB** has actively worked on the digital switch-over process in Italy
- **FUB** participates to ECC project team SE43 on behalf of the Italian Administration

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Background (2)

- **WHITE SPACES**: term coined by FCC (Federal Communication Commission) to refer to frequencies allocated to broadcasting services but not used locally

- The estimation of the amount of spectrum potentially available as WS depends on:
  - WSD characteristics
  - Topology of the area
  - National rules governing the use of spectrum
  - Applications and services using the adjacent band
Background (3)

<table>
<thead>
<tr>
<th>Pixel</th>
<th>Pixel Coordinates</th>
<th>WSD EIRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>421700 200200</td>
<td>---</td>
</tr>
<tr>
<td>2</td>
<td>421800 200200</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>421900 200200</td>
<td>---</td>
</tr>
</tbody>
</table>

GEO-LOCATION DATABASE APPROACH

SPECTRUM SENSING APPROACH

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Background (4)

Select DTT channel

Select DTT transmitters operating on the channel

Propagation analysis on the national territory

Identification of potentially available pixels according to the chosen DTT protection criteria

Determination of the maximum allowed EIRP for the WSD on the pixel under investigation

Look-up table update

GEO-LOCATION DATABASE

End of DTT channels?

End of loop

Yes

No
Methodology (1)

Threshold-based approach for the population of the geo-location database

1. Compute the power received on a given channel and in a given pixel by a receiving antenna assumed at a specific height above ground level.

2. Compare the received power against a specific threshold.

3. If the received power is below the threshold, the channel is considered as vacant.

4. Iterate steps 1-3 for all the channels from 21 to 60 and for all the pixels of the considered area.
Methodology (2)

Location Probability approach for the population of the geo-location database

1. For each pixel and for each channel, the field strength level $E_{RX}$ (dBµV/m) considering all possible DTT transmitters is evaluated with a suitable propagation model.

2. The calculated field strength level $E_{RX}$ is compared with the selected planning configuration threshold $F_{k,min}$.

<table>
<thead>
<tr>
<th>Location Probability</th>
<th>$F_{k,min}$ dBµV/m at 10 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>99 %</td>
<td>60</td>
</tr>
<tr>
<td>95 %</td>
<td>56</td>
</tr>
<tr>
<td>50 %</td>
<td>48</td>
</tr>
<tr>
<td>1 %</td>
<td>34</td>
</tr>
</tbody>
</table>

3. If $E_{RX}$ is $> F_{k,min}$ the pixel is within the protected service contour, hence the channel is occupied; if $E_{RX}$ is $< F_{k,min}$ the pixel is outside the protected service contour, hence the channel is vacant.
Methodology (3)

## Combined Geo-location and sensing approach

1. Apply the geo-location approach to identify potentially available white spaces (over pixels and frequencies)

2. Perform field strength measurements in different pixels and channels and compare the results with a proper sensing threshold to identify occupied and un-occupied channels

3. Only when “un-occupied channel” is obtained from both steps 1 & 2 the pixel and frequency are considered available for WSD
**Results (1)**

Geo-location: Threshold-based approach (West Piedmont)

**Input Data**
- DTT transmitter position
- DTT Transmitter ERP
- Receiving antenna height (1.5 m - 10 m)

**Output Data**
- Power received:
  → each channel
  → each position

**ITU-R P.1546**

**Threshold:**
- - 114 dBm
- - 120 dBm

% of pixels where there is at least 1 available channel:
47.19 %

\[ h_{RX} = 1.5 \text{ m} \]
\[ \text{Th} = -120 \text{ dBm} \]

Raising the detection th to - 114 dBm:
56.99 %
Geo-location: Threshold-based approach (West Piedmont)
Geo-location: Location Probability – based approach

- Predictions have been carried out using a proprietary prediction tool where the propagation model follows the ITU-R P.526

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DTT coverage area for LP 95% for the same channel used by different operators
Geo-location: Location Probability – based approach

Percentage of population living in potential white space areas for three different channels in several Italian Regions
Geo-location and sensing - based approach: province of Bologna

- Predictions have been carried out using a proprietary prediction tool where the propagation model follows the ITU-R P.526 over square pixel (400 m x 400 m)
- Measurements have been performed in six places

Field (dBμV/m)

- 30 - 48
- 48 - 56
- 56 - 60
- > 60
Simulation Results (6)

WS potentially available from Geo-Location DB

<table>
<thead>
<tr>
<th>Threshold (dBμV/m)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 34</td>
<td>20.08</td>
</tr>
<tr>
<td>≤ 48</td>
<td>38.89</td>
</tr>
<tr>
<td>≤ 56</td>
<td>46.15</td>
</tr>
<tr>
<td>≤ 60</td>
<td>50.43</td>
</tr>
</tbody>
</table>
Simulation Results (8)

- Measurements for spectrum sensing have been realised using a Narda SRM 300 spectrum analyser with two different antennas in “channel power” mode.

Receiver Antenna height = 1.5 m
Simulation Results (7)

Availability of contiguous spectrum

Geo - location

Sensing technique

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**Simulation Results (9)**

**Combined geo-location and sensing results**

<table>
<thead>
<tr>
<th>Different field strength levels for DVB-T reference planning configurations (fixed reception (DVBμV/m))</th>
<th>Different instrument threshold (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 34</td>
<td>-80</td>
</tr>
<tr>
<td>≤ 48</td>
<td>-80</td>
</tr>
<tr>
<td>≤ 56</td>
<td>-80</td>
</tr>
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<td>≤ 60</td>
<td>-80</td>
</tr>
</tbody>
</table>
Investigation of the impact of the sensing thresholds on the estimation of channel availability

The 2 order polynomial function obtained by the interpolation of log periodic antenna measurements reaches the minimum value 0% of available channels before the WSD sensitivity limit of -121 dBm.

Log periodic higher percentage of available channels with respect to omni antenna are due to stronger selectivity of DTT signals.

For omni antenna no available channels below the sensitivity threshold -80 dBm.
Estimation of the maximum permitted WSD power: Location Probability method

- DTT location probability, $q$:
  \[ q = \Pr\left\{ P_S \geq P_{S,\text{min}} + \sum_{k=1}^{K} r_k P_k \right\} \]

- DTT location probability $q'$ (presence of WSD):
  \[ q' = \Pr\left\{ P_S \geq P_{S,\text{min}} + \sum_{k=1}^{K} r_k P_k + r(\Delta f, P_S) \ G \ P_{IB} \right\} \]

WSD maximum permitted power: acceptable degradation of Location Probability $\Delta q_T$

\[ \Delta q_T = q - q' \]

This method has been investigated within a collaboration with Ofcom

Two cases has been evaluated:
1. fixed value of acceptable degradation $\Delta q_T$
2. Variable acceptable degradation $\Delta q_T$ as a function of the Location Probability
Estimation of the maximum permitted WSD power: fixed threshold method

- Defined in ECC Report 159 for autonomous operation
- e.i.r.p. limits in case of autonomous operation
- The maximum permitted in-block e.i.r.p. of a single WSD to ensure a specific level of protection of the co- and adjacent channel BS reception is evaluated from the minimum BS power
Results: comparison of LP method and fixed threshold method

The two methods coincide only in correspondence of the minimum of the LP function method.

The fixed threshold method provides precautionary transmitted power levels for the WSD to account for the worse case condition (DTT receiver at cell edge).

In order to take into account the realistic distributions of DTT signal levels more suitable methods are investigated.
Estimation of the maximum permitted WSD power: Carrier to Interference ratio method

$$\Delta q(dB) = \frac{C_{DTT}}{I_{DTT}+N} - \frac{C_{DTT}}{I_{DTT}+N+I_{WSD}}$$

\(\Delta q\) (acceptable C/I degradation) has been assumed as a function of SINR considering different curves

Acceptable degradation depends on DTT quality before the introduction of the WSD in the scenario

Minimum acceptable degradation at 21 dB C/I DTT threshold
Conclusions

- Different methodologies based on the geo-location database approach for identifying WSs potentially available in the 470-790 MHz band have been investigated and compared in real Italian scenarios.

- Results of a combined geo-location and sensing approach show that higher protection to incumbent services can be achieved provided that a proper detection threshold is applied allowing to relax the sensing threshold with respect to the case of sensing alone.

- The impact of the sensing thresholds on the estimation of channel availability has been investigated by means of interpolation of different measurements.

- Different approaches for the evaluation of the WSD maximum allowable power levels to be used with the geo-location database has been presented.
FUB contact details

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  - www.fub.it

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Thank you for the attention!