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Distributed Spectrum Detection Algorithms for Cognitive Radio

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Thursday 18th September 2008
Background and Introduction

• For Cognitive Radio networks
  – There is a need to identify the White Space in the spectrum
  – The capabilities of the terminals could allow them to perform spectrum sensing to achieve this
  – The sensing task could be implemented more accurately/efficiently by teaming of terminals

• This technique introduced in this work
  – Decides whether a single channel is occupied
  – Shares results between CR nodes to improve performance
Background and Introduction

Spectrum Occupancy and White Space
Spectrum Sensing Challenges

- Maintaining an up to date picture of spectrum occupancy is difficult
  - Transmitters may be agile
  - Path loss may suffer temporal changes between transmitter and sensor
  - Transmitter may be temporarily hidden due to shadowing

- Getting it wrong
  - False detection: lost re-use opportunity
  - Missed transmission: potential interference
Distributed Sensing
Distributed Sensing

\[ Q = [X_1 \ldots X_N] \begin{bmatrix} D_1 \\ \vdots \\ D_N \end{bmatrix} + [Y_1 \ldots Y_M] \begin{bmatrix} T_1 \\ \vdots \\ T_M \end{bmatrix} + S \times Z \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M )</td>
<td>Number of previous results/time-steps included</td>
</tr>
<tr>
<td>( N )</td>
<td>Number of neighbouring nodes included</td>
</tr>
<tr>
<td>( X_n )</td>
<td>Sensing result from neighbouring node ( n ) [+1,-1]</td>
</tr>
<tr>
<td>( D_n )</td>
<td>Weighting factor according to distance applied to neighbouring node ( n )</td>
</tr>
<tr>
<td>( Y_m )</td>
<td>Result from ( m ) time-steps previously</td>
</tr>
<tr>
<td>( T_m )</td>
<td>Weighting applied to previous result ( m )</td>
</tr>
<tr>
<td>( S )</td>
<td>Weighting applied to the node’s own result</td>
</tr>
<tr>
<td>( Z )</td>
<td>Node’s own result [+1,-1]</td>
</tr>
<tr>
<td>( Q )</td>
<td>Final result [positive, negative]</td>
</tr>
</tbody>
</table>
Weighted Algorithm

• Various Trade-offs exist
  – How many neighbour nodes to include?
  – How to weight the importance of neighbour nodes’ decisions?
  – How to weight the importance of the own node’s decision
  – How to weight historic results

• Factors
  – Extra control traffic required
  – Accuracy of results and false-positives
Simulations

• MATLAB simulations to test algorithm performance
  – Sensor nodes deployed randomly
  – Aim is to test the probability of detecting a transmission
  – Compare single node vs distributed algorithm

• 5 Different transmitter types to detect
  – Distinguished by transmitter power

• 3 scenarios
  – Simulation area
  – Path loss exponent
  – Shadowing variance
Simulations
Performance – Single Node Sensing

Probability of detection

Rural
Urban
Dense Urban

Primary system type

TV
UMTS Microcell
UMTS Macrocell
TV Broadcast
DVB-T 27dBW

TV Broadcast 50dBW
UMTS Microcell 17dBW
UMTS Macrocell 32dBW
TV Broadcast 47dBW
DVB-T 27dBW
Performance – With Distributed Detection

- **TV Broadcast**: 50dBW
- **UMTS Microcell**: 17dBW
- **UMTS Macrocell**: 32dBW
- **TV Broadcast**: 47dBW
- **DVB-T**: 27dBW

The diagram shows the probability of detection for different primary system types in various urban settings: Rural, Urban, and Dense Urban. The y-axis represents the probability of detection, ranging from 0% to 100%. The x-axis lists the primary system types.
Sensitivity – Node Density

- Dense Urban Scenario – 1km²

Probability of Detection vs. No. of Receivers per sq. km
Sensitivity – Number of Neighbours

Primary System Type

- TV Broadcast 50dBW
- UMTS Microcell 17dBW
- UMTS Macrocell 32dBW
- TV Broadcast 47dBW
- DVB-T 27dBW

Probability of Detection

No Sharing
5 Neighbouring Nodes
10 Neighbouring Nodes
15 Neighbouring Nodes
Conclusions

• Sharing of single channel sensing information
  – Can greatly improve detection accuracy
  – >99% accuracy has been shown in these simulations
  – Not so good for lower power transmissions in highly shadowed propagation environments

• Applications and further work
  – Allocation of sensing task for multiple channels
  – WiMAX bandsharing with swept radar
  – Real-time updating
  – Spectrum Access
• Thank you for your attention