Improved Bootstrapping Approach in Multichannel Cognitive Radio Ad Hoc Networks

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Motivation

• **Problem**
  – Establishment and maintenance of common control channels (CCC) in a dynamic environment

• **Research Focus**
  – Investigation of spectrally efficient distributed schemes for establishing and maintaining CCC in CRAHNs
Outline

- Related Work
- Previous Work
- New Problem
- Improvement
- Simulation Results
- Summary
Related work

Common Control Channel Design for Cognitive Radio Ad Hoc Networks

<table>
<thead>
<tr>
<th>Approach</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Dedicated</td>
<td>Design simplicity</td>
<td>Single point of failure</td>
</tr>
<tr>
<td>Ultra-Wide Band</td>
<td>Robust to PU activity</td>
<td>Transmission range</td>
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<tr>
<td>Sequence-Based</td>
<td>Bounded rendezvous time Low network overhead</td>
<td>Hopping sequences not adaptable to PU activity</td>
</tr>
<tr>
<td>Group-Based</td>
<td>Efficient broadcasting of control information</td>
<td>High network overhead</td>
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</tbody>
</table>

Design Goals!

Previous Work

Layer 2
- Wireless token-ring protocol [1]

Layer 1
- Physical layer bootstrap protocol [2]

Distributed Consensus Algorithm


Distributed Consensus Algorithm [1]

Set of spectrum opportunities

\[ M = \{1, \ldots, m\} \]

Utility Function

\[ U(m) = \frac{B_m}{|N_m|} \sum_{n \in N_m} \log_2 (1 + SINR_n) \]

Handover solution

\[ \arg \max_m U(m) \]

Distributed consensus agent

\[ O \]

\[ n^{th} \text{ ring-participant} \]

\[ n \]

Co-located interferer

\[ I \]

Received signal vector

Interference vector

Direction of token rotation

Research Idea:
Token-embedded pilot tone for SINR estimation

Token-Ring Timing Diagram

Ring-participant 1

Ring-participant n

Token Holding Time

Maximum Token Rotation Time

Simulation Results

<table>
<thead>
<tr>
<th>Simulation parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation area</td>
<td>1 km^2</td>
</tr>
<tr>
<td>Network spatial deployment</td>
<td>Random</td>
</tr>
<tr>
<td>Propagation model</td>
<td>Free space path loss</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>200 kHz</td>
</tr>
<tr>
<td>CR TX power (EIRP)</td>
<td>30 dBm</td>
</tr>
<tr>
<td>SINR threshold</td>
<td>20 dB</td>
</tr>
<tr>
<td>Receiver noise floor</td>
<td>-147 dB</td>
</tr>
<tr>
<td>Network mobility model</td>
<td>None (static network)</td>
</tr>
</tbody>
</table>

Simulation Results – Network Capacity

Simulation Results – Spectrum Occupancy

\[ \Delta = -9.0\% \quad (-1\text{ ch}) \]
\[ \Delta = -12.2\% \quad (-3\text{ ch}) \]
\[ \Delta = -14.1\% \quad (-14\text{ ch}) \]

New Problem

• Old scheme:
  – Good for bandwidth equally deployed among subnets
  – Bad otherwise

• Improvement is required
Improved Distributed Consensus Algorithm

- Takes into account number of ring-participating nodes
- Provides fairness

New Utility Function

\[ U_{new}(m) = \frac{B_m}{N_m^2} \sum_{n \in N_m} \log_2 (1 + SINR_n) \]
Simulation Results – Spectrum Efficiency

\[ \Delta = \frac{\eta_{\text{new}} - \eta_{\text{previous}}}{\eta_{\text{new}}} \] [%]
\[ \eta = \frac{C_{\text{net}}}{M \cdot B} \] [bps/Hz]

- \( C_{\text{net}} \) – total network capacity
- \( M \) – number of spectrum opportunities
- \( B \) – bandwidth of each spectrum opportunity
Demonstration Video

• Random channel hopping vs distributed consensus

• Simulation parameters
  – 200 Cognitive Radios
  – 1 km² simulation area
  – Free space path loss propagation model

1 min video
Summary

• Efficient CCC for CRAHNs
• Idea: Distributed Consensus Algorithm
• New utility function:
  – Better efficiency (4-12%)
  – Provides fairness

• Further steps:
  – SINR estimation
  – Upper bound efficiency estimation as benchmark
Questions?
Thank you for your attention!

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