Spectrum Assignment in Narrowband Power Line Communication

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10th Workshop on Power Line Communications, Paris, France – October 11, 2016
Overview

1. Motivation and Objective
2. Problem Statement
3. Probability Matching Technique
4. Performance Evaluation
5. Conclusion
Motivation and Objective

- **Narrowband power line communication**: frequencies below 500 kHz
- **FCC-above-CENELEC** spectrum consists of seven transmission bands (IEEE 1901.2, G3-PLC, PRIME)

The transmitter selects one of these bands before sending each data packet and the receiver can receiver in all bands.
Why transmit only in a part of the entire spectrum?

- Frequency-selective fading
- Unpredictable impulsive noise
- Interference of other signals
- To avoid frequency notches

Transmission in a partial spectrum may result in a higher spectral efficiency & increased performance.

Main Question

How to select the transmission spectrum, which results in the best performance in terms of bit error rate?
Problem Statement

- Channel state information (CSI) is needed at transmitter in order to select the best band.
- CSI is estimated at the receiver by means of pilot signals and is fed back to the transmitter.

Great! Now what’s the problem with that?

- Frequency selectivity → CSI for all subcarriers (overhead)
- Time-variation → CSI at all times (overhead)
- Several nodes and links → CSI for all links (overhead)
- Estimation, process, and feedback delay → outdated CSI
Problem Statement

Problem

- Obtaining full CSI at transmitter is not realistic and implementable.
- How to select the best transmission band without CSI?

Proposed Solution

- Reinforcement Learning
  - A selecting agent in an environment of incomplete information
  - The goal is to maximize some notion of cumulative reward
Probability Matching Technique

- A decision strategy based on reinforcement learning.
- Tries to select the best action while completing its info.
- Basic idea:
  - A selecting agent faces a few actions to choose from
  - A probability is assigned to each action
  - At each repetition one action is selected
  - A reward is observed as a result of selected action
  - The probabilities will be updated based on the observed reward
  - Exploitation-exploration trade-off
Probability Matching Technique

- How does it apply to our problem?
  1. Assign equal probabilities to each transmission band
  2. Select a band ($b_i$) based on the assigned probabilities
  3. Receiver calculates the reward based on corrected errors ($r_i$)
  4. Acknowledgment (ACK) packet sends back the reward
  5. Transmitter calculates action value estimation based on reward

\[ Q(b_i) = Q_{old}(b_i) + \beta [r_i - Q_{old}(b_i)] \]

6. Update probabilities based on action value estimates

→ Repeat 2 - 6
## Performance Evaluation

Simulation Parameters (IEEE 1901.2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start frequency</td>
<td>154.6875 kHz</td>
</tr>
<tr>
<td>End frequency</td>
<td>487.5 kHz</td>
</tr>
<tr>
<td>Total number of subcarriers</td>
<td>256</td>
</tr>
<tr>
<td>Total number of used subcarriers</td>
<td>72, 36, 18</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>4.6875 kHz</td>
</tr>
<tr>
<td>Sampling Frequency</td>
<td>1.2 MHz</td>
</tr>
</tbody>
</table>
Performance Evaluation

- Total of 200 episodes (data packets, reward, ACK, selection)
- Frequencies between 323.4375 kHz – 403.125 kHz encounter noise with lower variance:

![Frequency spectrum diagram](image)

- High noise: 154.6875 kHz – 235.46875 kHz
- Low noise: 235.46875 kHz – 487.5 kHz
- High noise: 487.5 kHz – 403.125 kHz

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Performance Evaluation

![Graph showing frequency bands and number of episodes](image-url)

- **First 200 Episodes**
- **First 100 Episodes**

**Frequency Bands**

1. 2. 3. 4. 5. 6. 7.
Performance Evaluation

- **entire spectrum**
- **random selection**
- **probability matching technique**

The chart illustrates the accumulated reward over episodes for different spectrum assignment techniques. The x-axis represents the episode number, while the y-axis shows the accumulated reward.

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Conclusion

- Partial spectrum usage can increase spectral efficiency and performance of transmission.
- CSI is needed at transmitter in order to make an informed decision, however it is nearly impossible to obtain CSI at transmitter.
- Machine learning can help the transmitter to perform decisions without CSI.
- Probability matching technique is a reliable reinforcement learning approach for this problem.

- Future work:
  - Static vs. dynamic spectrum assignment
  - Greedy learning algorithms
Thank You for Your Attention!