HOCHSCHULE RUHR WEST
UNIVERSITY OF APPLIED SCIENCES

Spectrum Assignment in Narrowband Power Line Communication

Babak Nikfar, Gerd Bumiller, Han Vinck

Ruhr West University of Applied Sciences, Germany
University of Duisburg-Essen, Germany
University of Johannesburg, South Africa

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

Overview

1. Motivation and Objective

2. Problem Statement

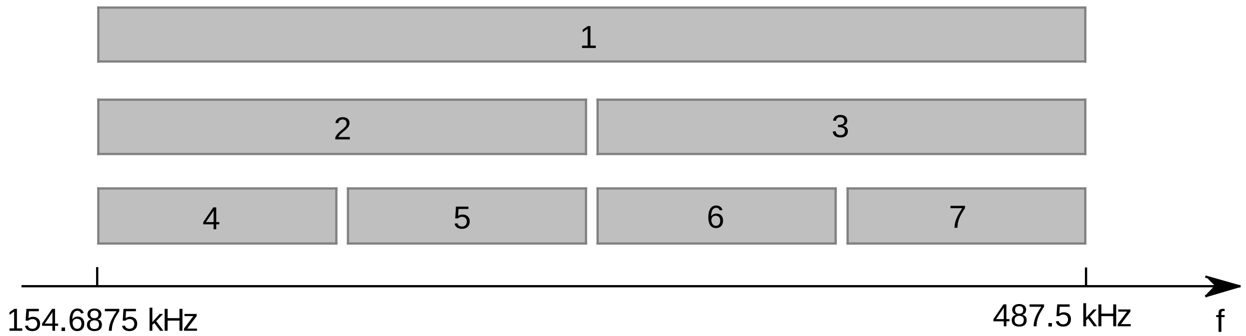
3. Probability Matching Technique

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.

Motivation and Objective

- 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- ✓ Estimation, process, and feedback delay → outdated CSI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

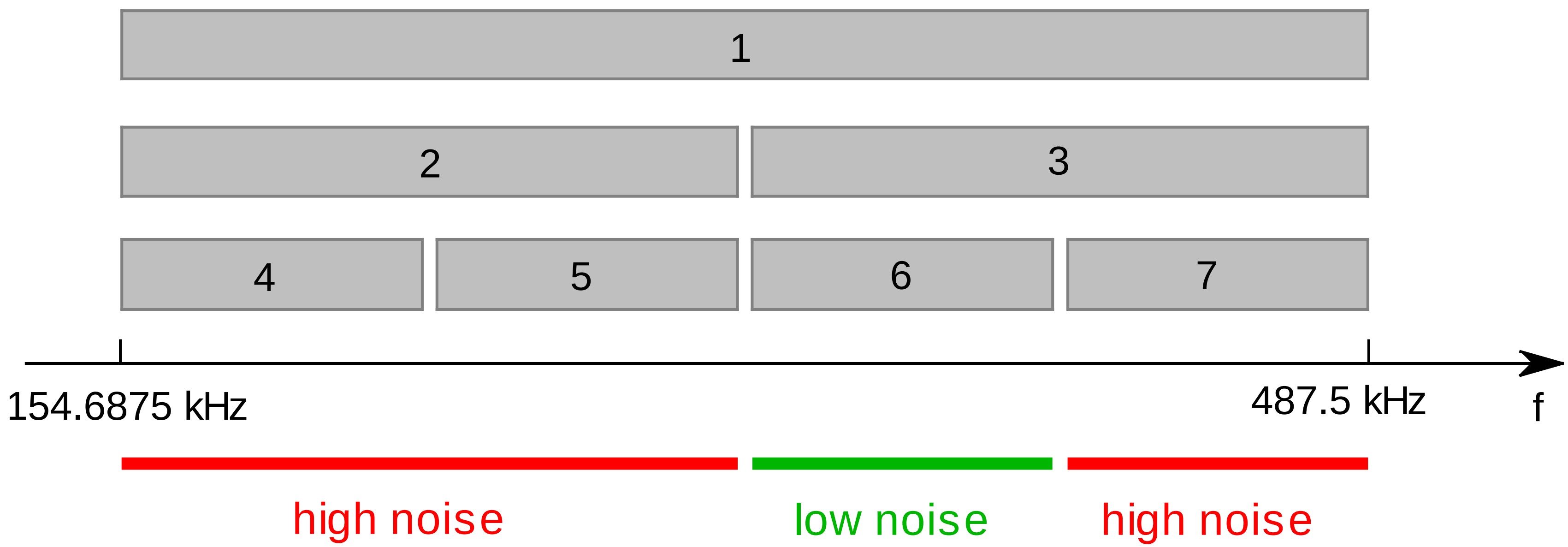
Performance Evaluation

Simulation Parameters (IEEE 1901.2)

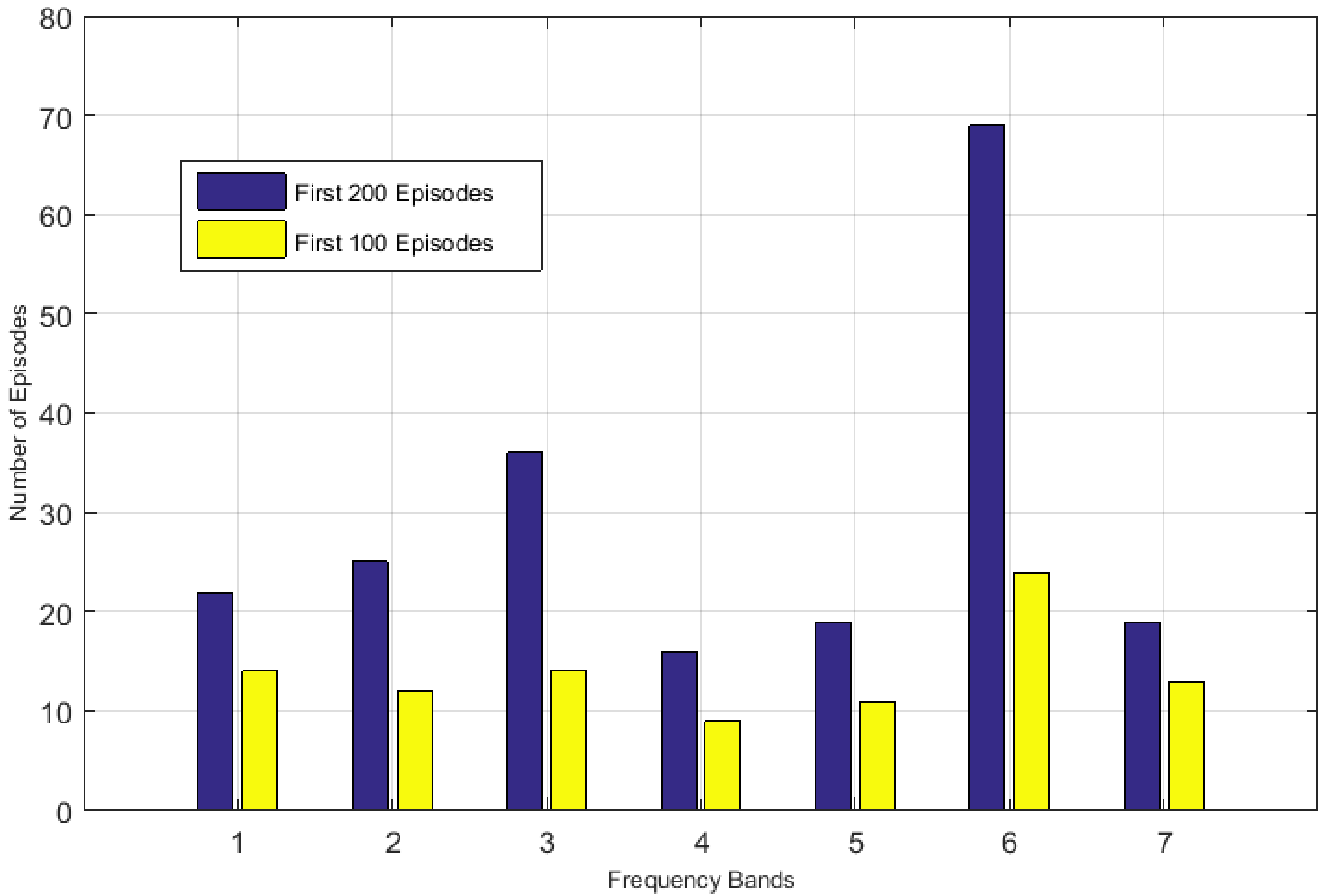
Parameter	Value
Start frequency	154.6875 kHz
End frequency	487.5 kHz
Total number of subcarriers	256
Total number of used subcarriers	72, 36, 18
Subcarrier spacing	4.6875 kHz
Sampling Frequency	1.2 MHz

Performance Evaluation

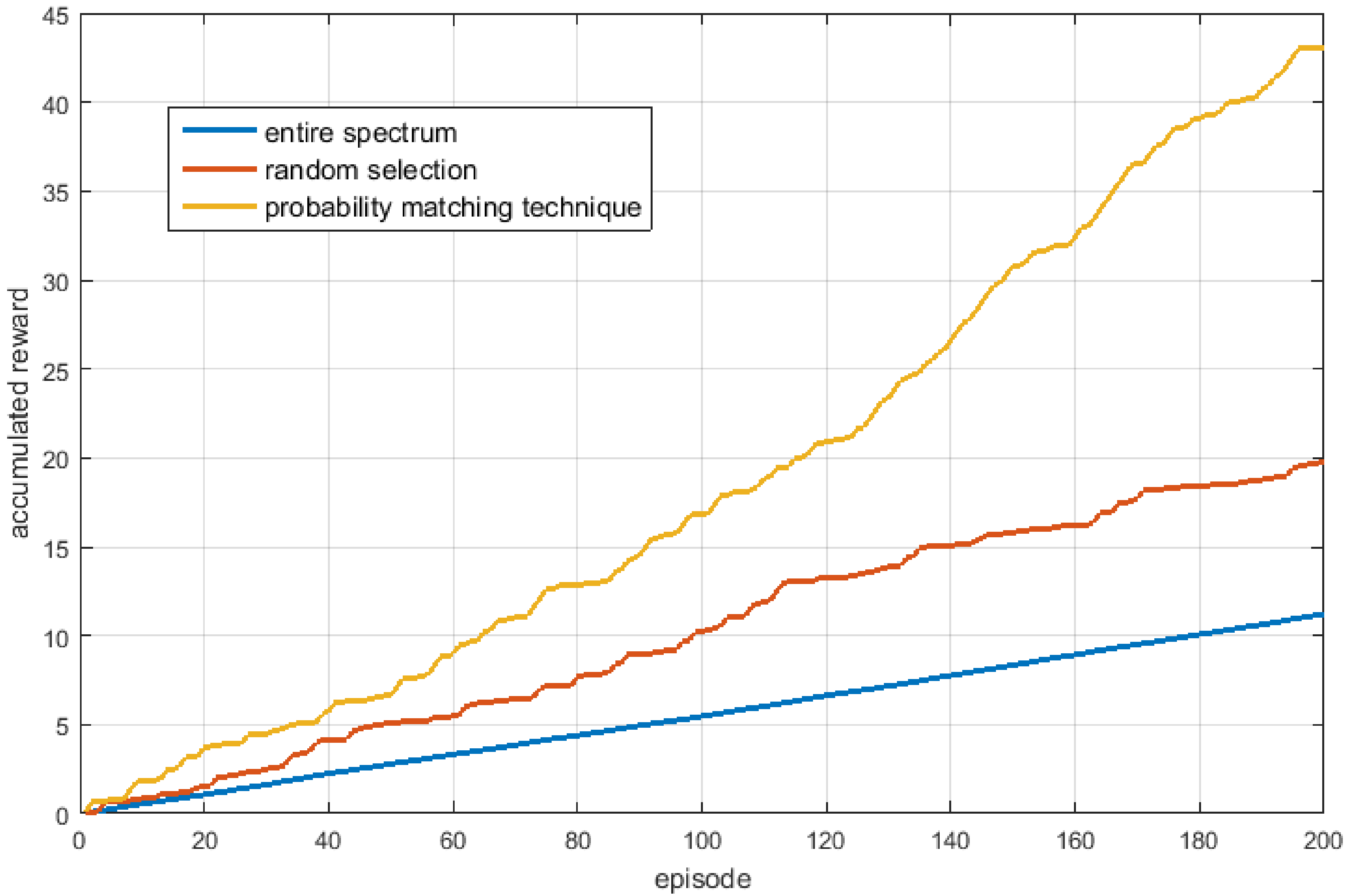
- Total of 200 episodes (= data packets, reward, ACK, selection)
- Frequencies between 323.4375 kHz – 403.125 kHz encounter noise with lower variance:



Performance Evaluation



Performance Evaluation



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!

Q&A