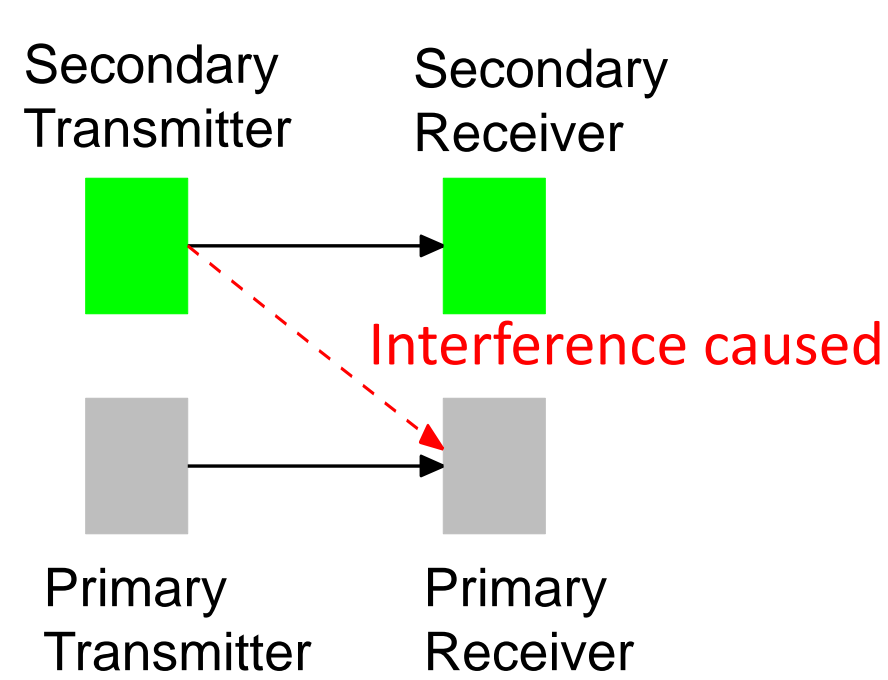


# Interference-Constrained Cooperative Relaying for Cognitive Radio

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## Cognitive Radio (CR)

- Wireless spectrum is being unutilized or partially utilized
- CR enables reuse of already allocated spectrum
  - Solves spectrum shortage issue
- **Types of users:** Primary and secondary users

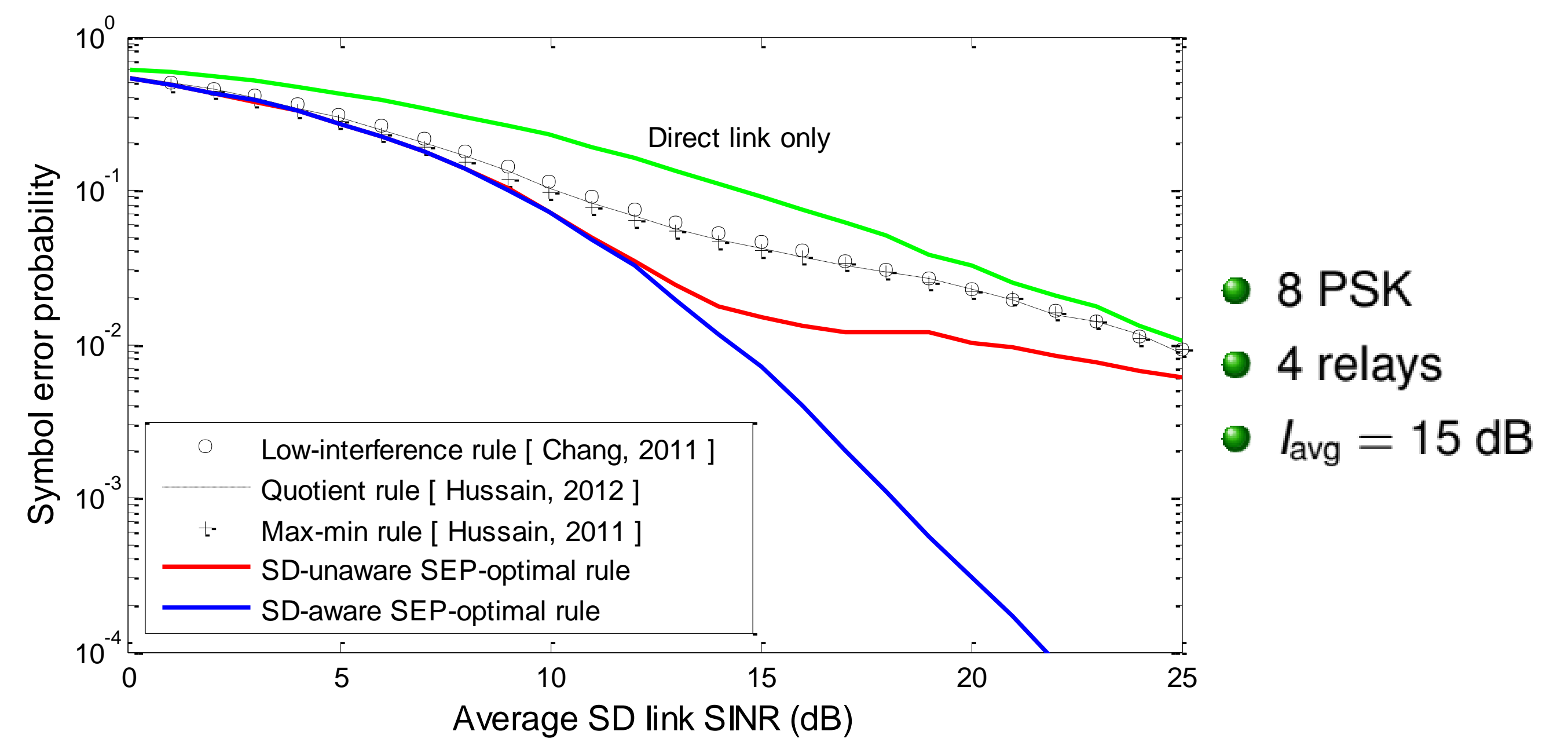


### Mode of operation: Underlay CR

- Secondary users transmits **simultaneously** with primary users
- Interference caused to primary receiver must be constrained

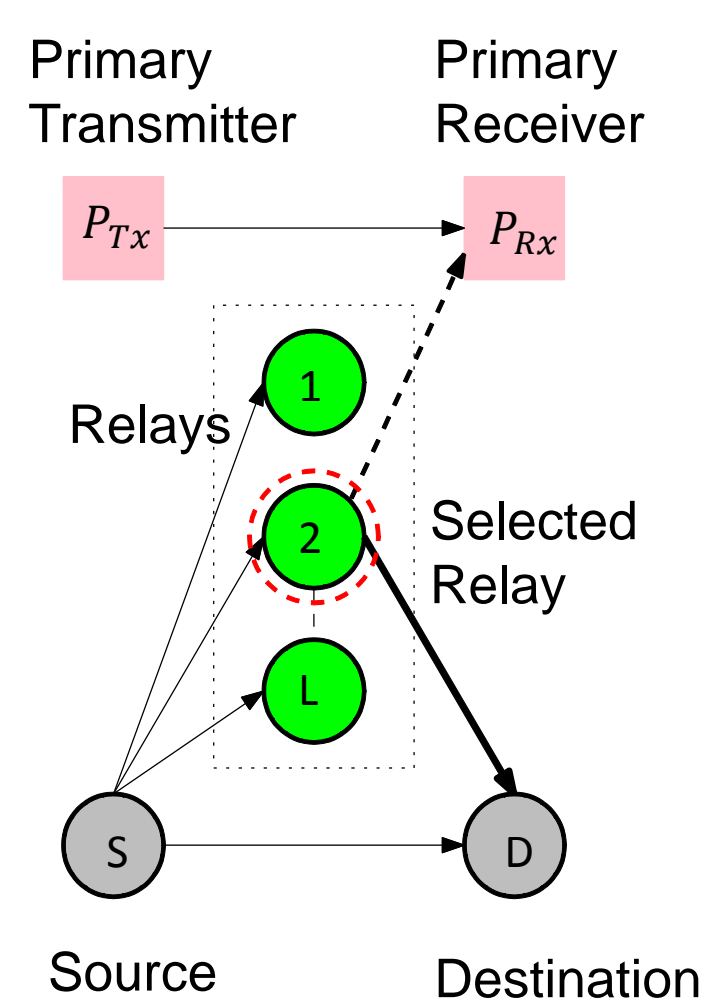
**Issue:** Interference constraint limits secondary system performance

## SEP Comparison and Benchmarking



- Proposed SEP-optimal rules outperform other existing schemes
- Having knowledge of direct SD link significantly improves SEP

## Cooperative Relaying with Relay Selection in CR



### Cooperative Relays

- Help to forward data
- Provide spatial diversity

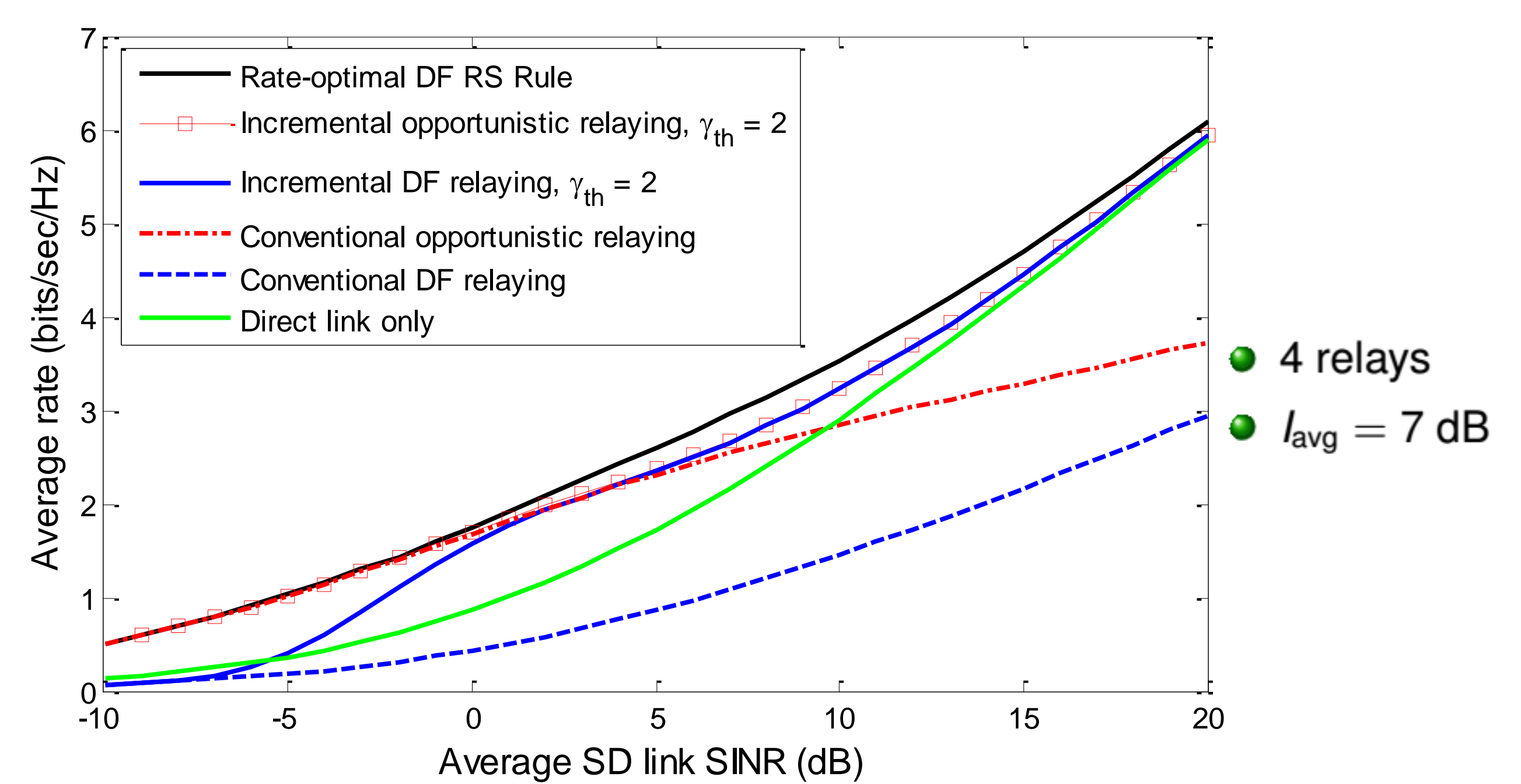
### Selecting the best relay

- Solves relay synchronization issue
- Spectrally efficient

### Focus:

- Whether to use a relay or only the direct S-to-D (SD) link.
- If a relay is selected then which relay?

## Rate Comparison and Benchmarking



- Proposed rate-optimal rule outperforms all other existing schemes

## Contributions

- Proposed **optimal relay selection rules** subject to **average interference constraint** in order to
  - Minimize average symbol error probability (SEP)
  - Maximize average data rate
- Analyzed average rate of the optimal rule
- Proposed and analyzed simpler, sub-optimal relay selection rules for minimizing SEP
- Performed asymptotic SEP and rate analysis for high and low signal-to-interference-plus-noise ratio (SINR)

## Problem Statement: Rate-Optimal Relay Selection Rule

### Find the optimal relay selection rule

- Maximize the average rate
- Average relay interference must be below a threshold,  $I_{avg}$

### Optimization Problem:

$$\begin{aligned} \max_{\phi} \quad & \mathbb{E}_{h_{SD}, \mathbf{h}} [C(\gamma_{SD}, \gamma_{SI}, \gamma_{ID})] \\ \text{s.t.} \quad & \mathbb{E}_{h_{SD}, \mathbf{h}} [P_{\beta} |h_{\beta P}|^2] \leq I_{avg} \\ & \beta = \phi(h_{SD}, \mathbf{h}) \in \{0, 1, \dots, L\} \end{aligned}$$

### Proposed Solution:

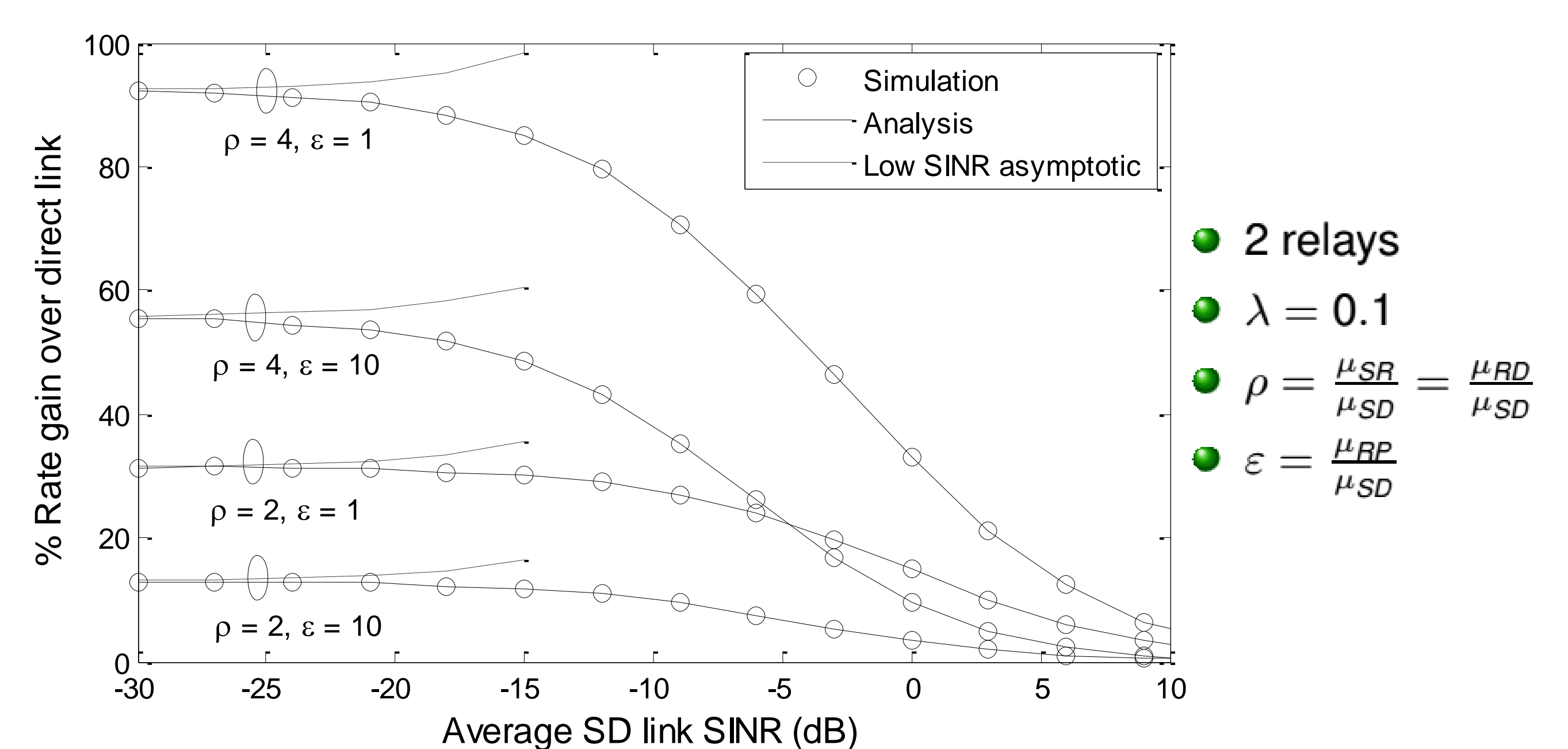
#### Theorem

Let  $I_{un}$  is average interference by relay to  $P_{Rx}$  when system is unconstrained. The rate-optimal relay  $\beta^*$  is

$$\beta^* = \begin{cases} \operatorname{argmax}_{i \in \{0, 1, \dots, L\}} \{C(\gamma_{SD}, \gamma_{SI}, \gamma_{ID})\}, & I_{un} \leq I_{avg} \\ \operatorname{argmax}_{i \in \{0, 1, \dots, L\}} \{C(\gamma_{SD}, \gamma_{SI}, \gamma_{ID}) - \lambda P_i |h_{iP}|^2\}, & I_{un} > I_{avg} \end{cases}$$

- $\lambda > 0$  is chosen s.t.  $\mathbb{E}_{h_{SD}, \mathbf{h}} [P_{\beta^*} |h_{\beta^* P_{Rx}}|^2] = I_{avg}$

## Rate Gain Achieved Over Direct Transmission



- As SINR decreases, gain increases due to cooperation by relays
- Gain increases as relay links become stronger than SD link
- Gain decreases as interference link becomes stronger than relay links

## Summary

- Proposed optimal relay selection rules outperformed benchmarking schemes for underlay CR
- Analyzed average SEP and rate of proposed rules
- Performed asymptotic analysis that helped to understand when to use direct SD link over a relay link