Cooperative Wireless Communications: A Cross-Layer Approach

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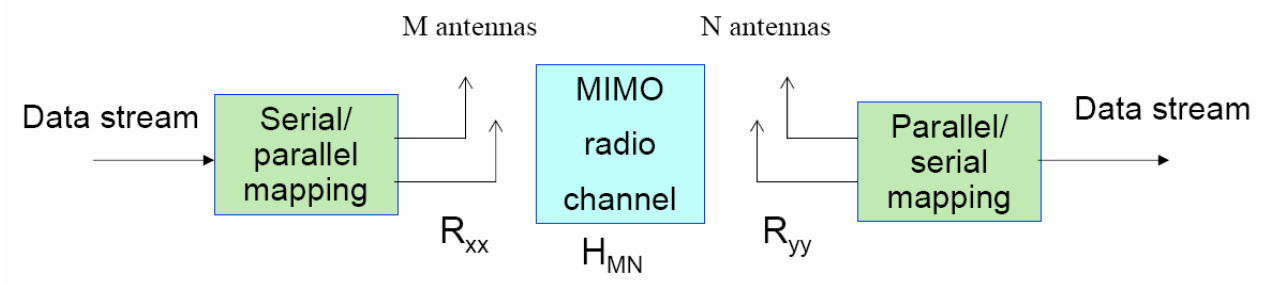
Outline

- Introduction
- Motivation for Cooperative Communication
- Benefits of Cooperative Networking
- CoopMAC: A Cooperative Medium Access Control
- Simulation
- Conclusion

Introduction

- Several technologies are developed to increase the throughput in wireless communication systems.
  - E.g. Multiple-Input Multiple-Output (MIMO)
    - At the cost of multiple RF at both transmitter and receiver
    - Limited by number of antennas that can be deployed in a mobile device
- Cooperative communication enables multiple nodes work together to form a virtual antenna array.
- Multihop networks use cooperation by enabling intermediate nodes to forward data from source to destination
- Destination node receives multiple versions of the data from source node, and one or more relay node
  - Combining these versions of signal can obtain higher rates



Motivation

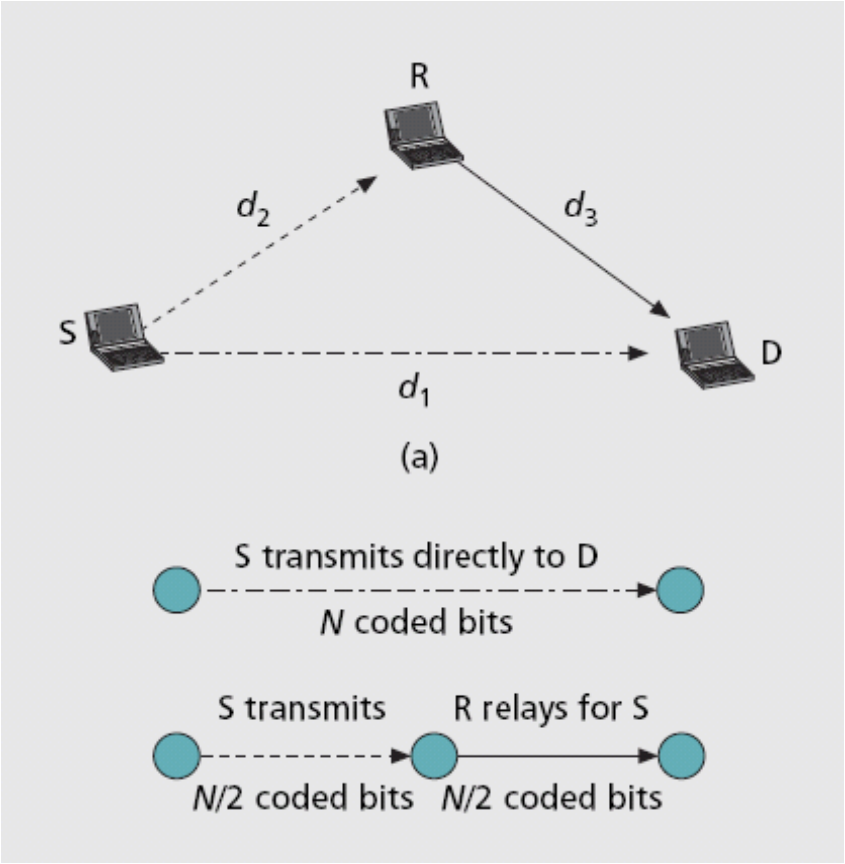
- Cooperative technique utilizes the broadcast nature of wireless signal - "Overhearing"
- Neighboring nodes can
  - Repetition of the overheard signal
  - Compressing the overheard signal
  - Involving more operations, such as forwarding

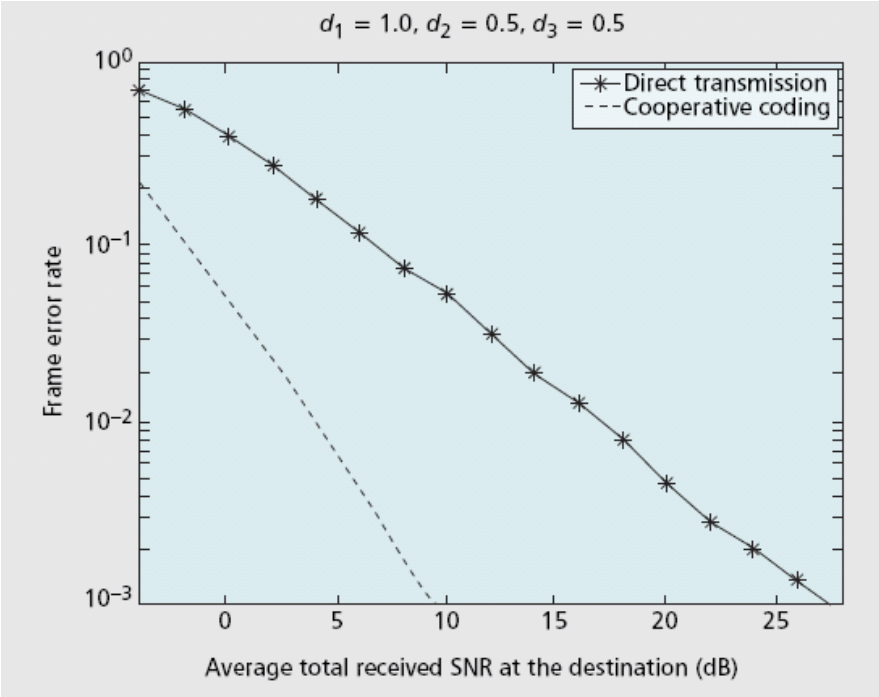
Motivation

- The main advantages of cooperative communications are:
  - Higher spatial diversity
  - Higher throughput/Lower delay
  - Reduced interference/Lower transmitted power
  - Adaptability to network conditions

- A cross-layer research is proposed to facilitate the cooperative communication in WLAN.

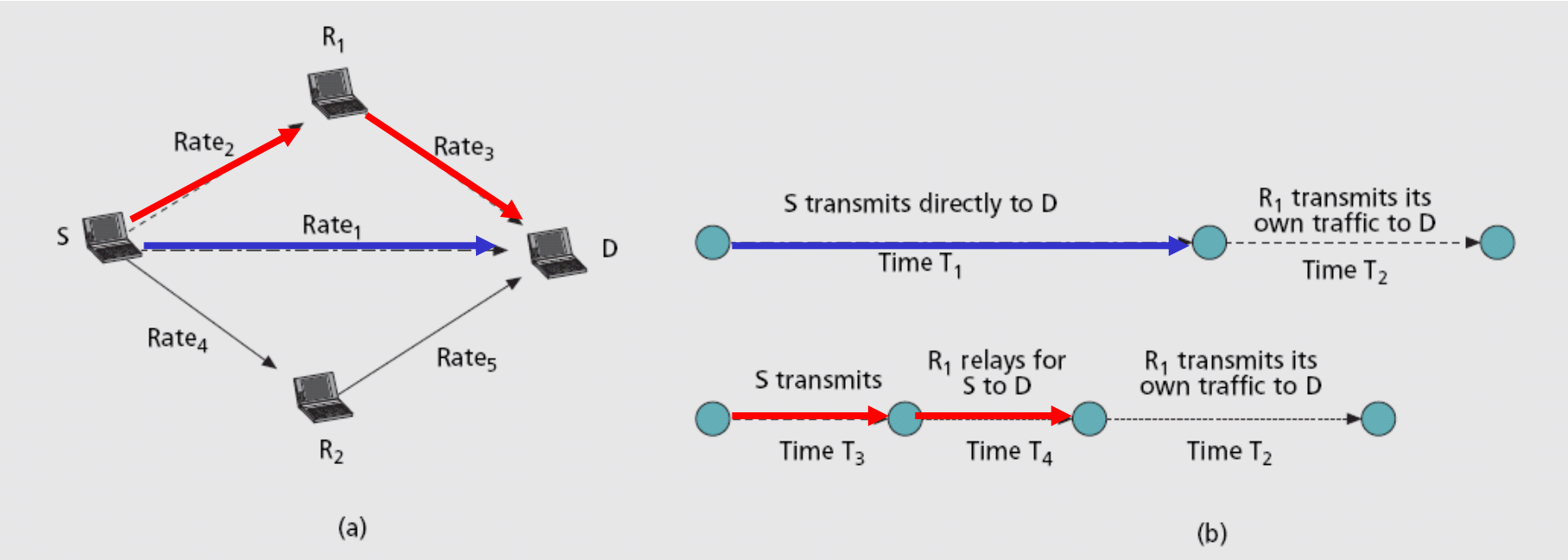
Spatial Diversity





- Cooperative relaying is different than traditional Multihop or infrastructure methods

Higher Throughput /Lower Delay

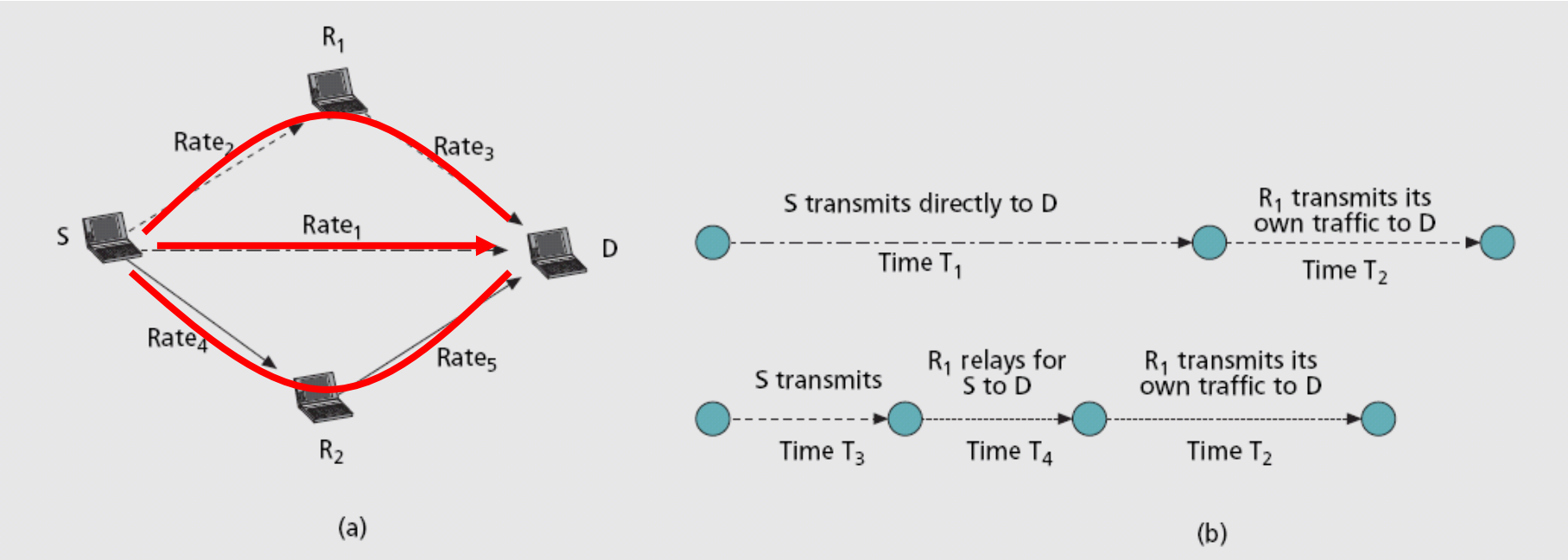


- If $Rate_2$ and $Rate_3$ are higher than $Rate_1$
  - Transmission time from S to D through R_2 can be reduced

Lower Power Consumption /Lower Interference

- Shorten the average channel access time used by MS can reduce power consumption
- Signal-to-Interference (SIR) between cells using the same channel can be reduce under the same metric
  - Error rate, throughout, etc.
- A more uniform coverage can be achieved

Adaptability to Network Conditions



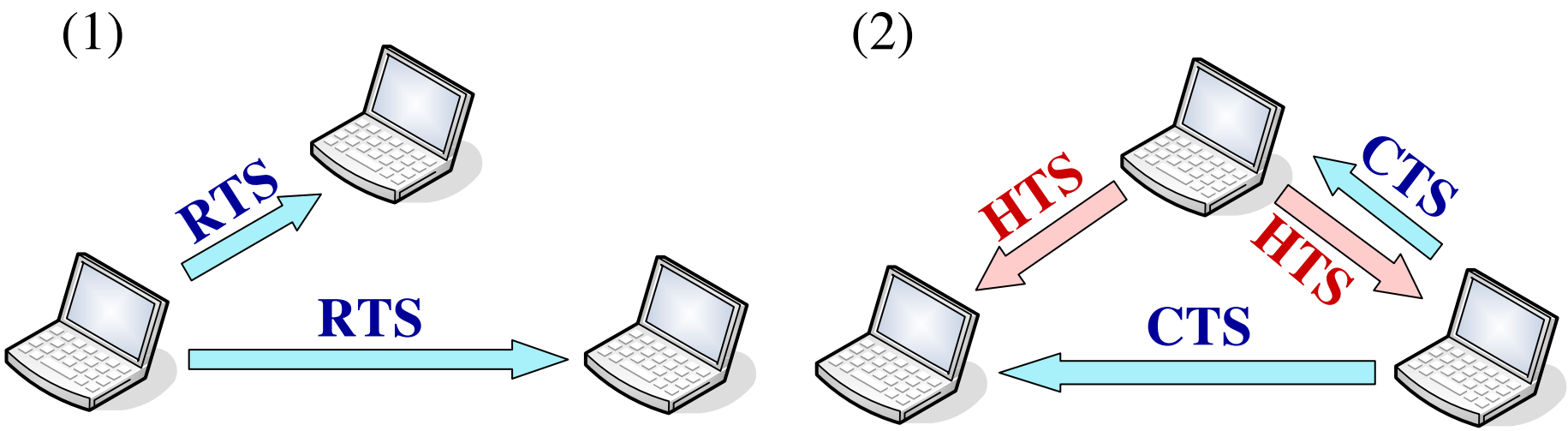
- S may transmit information to S
  - Directly, using R1 or R2 or both

  For cooperation strategy
- Additional three-way handshaking procedure and new signaling message is needed

CoopMAC:
A Cooperative Medium Access Control

- RTS/CTS + “HTS”

HTS : Helper-ready To Send



CoopMAC:
A Cooperative Medium Access Control

- Relay node sends HTS to indicate its availability after receiving RTS from the source
- Receiver
  - Issues a CTS to reserve channel time for two-hop communication after hearing HTS, or
  - Still sends out CTS, otherwise.

CoopMAC:
A Cooperative Medium Access Control

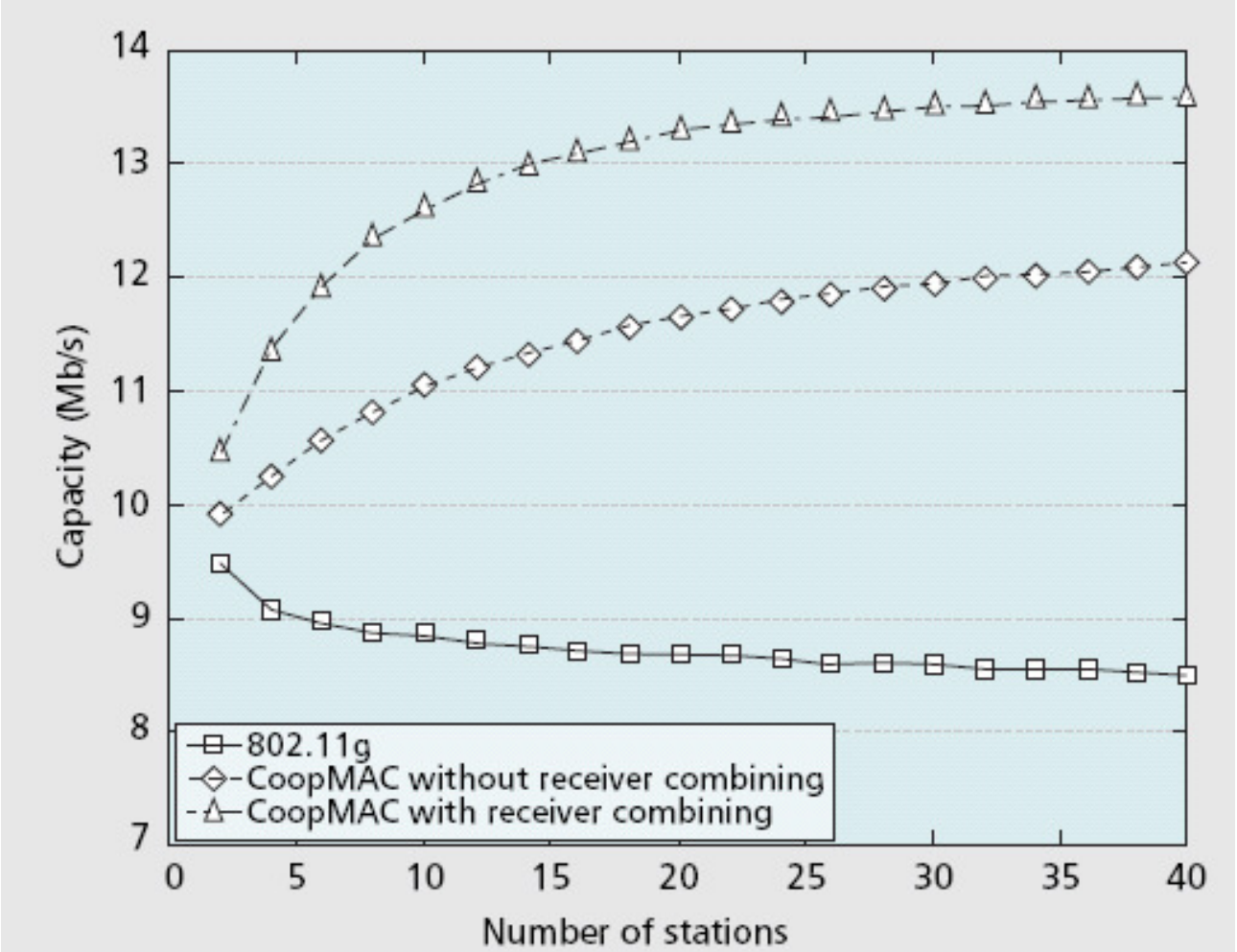
- Some cases
  - If both HTS and CTS are received by source
    - Data packet is transmitted to relay node first and then forwarded to receiver
  - If only CTS are received by source
    - Data packet is transmitted to receiver directly
- Acknowledgement
  - The same as legacy method
  - Retransmission is attempted in a cooperation fashion if necessary

CoopMAC:
A Cooperative Medium Access Control

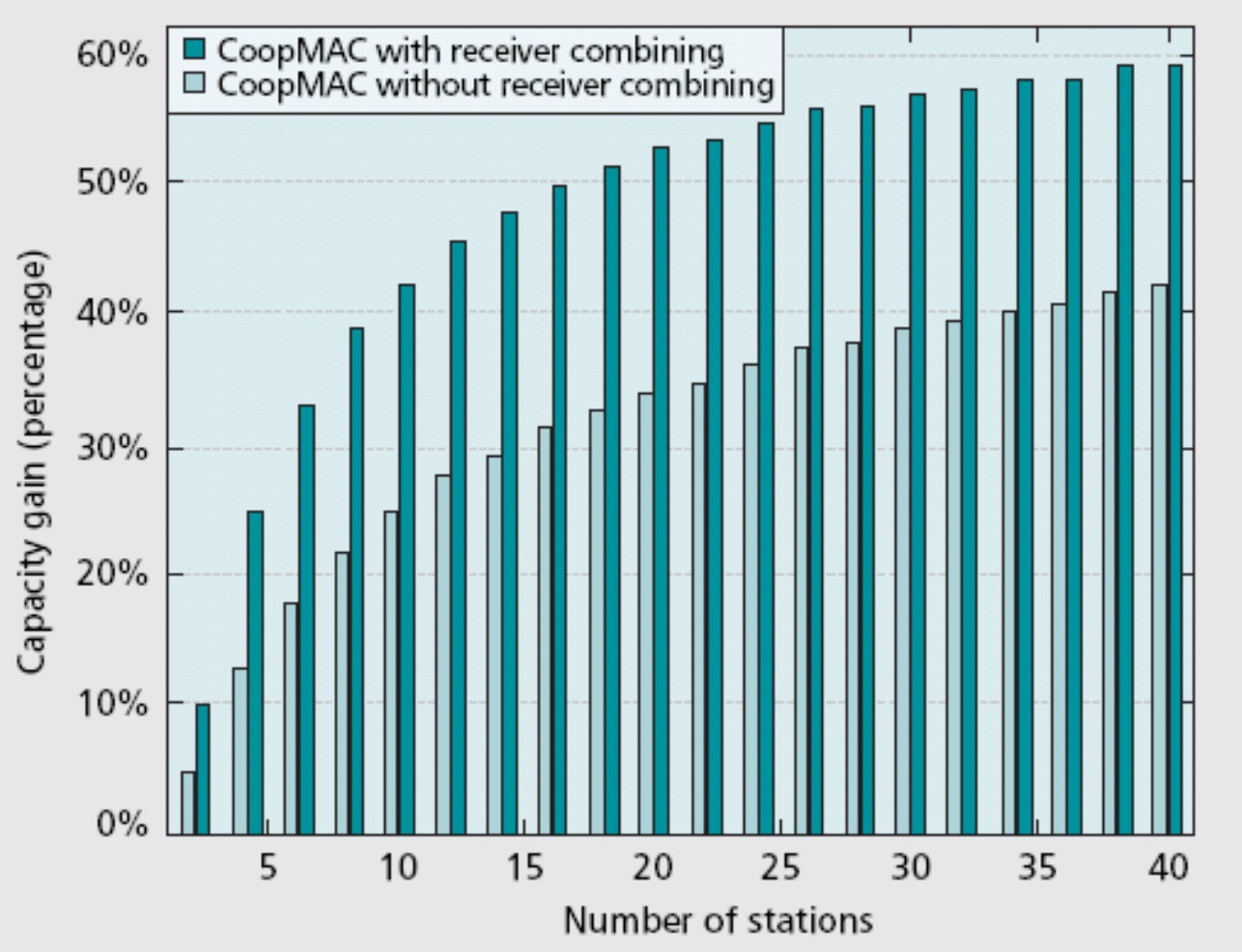
- A CoopTable corresponding to potential relay is maintained in each node
  - ID, date rate, etc.
  - Updated in a timer manner

- If destination is capable of combining two copies of signals, cooperative diversity can be fully leveraged
  - Spatial diversity gain
  - Coding gain

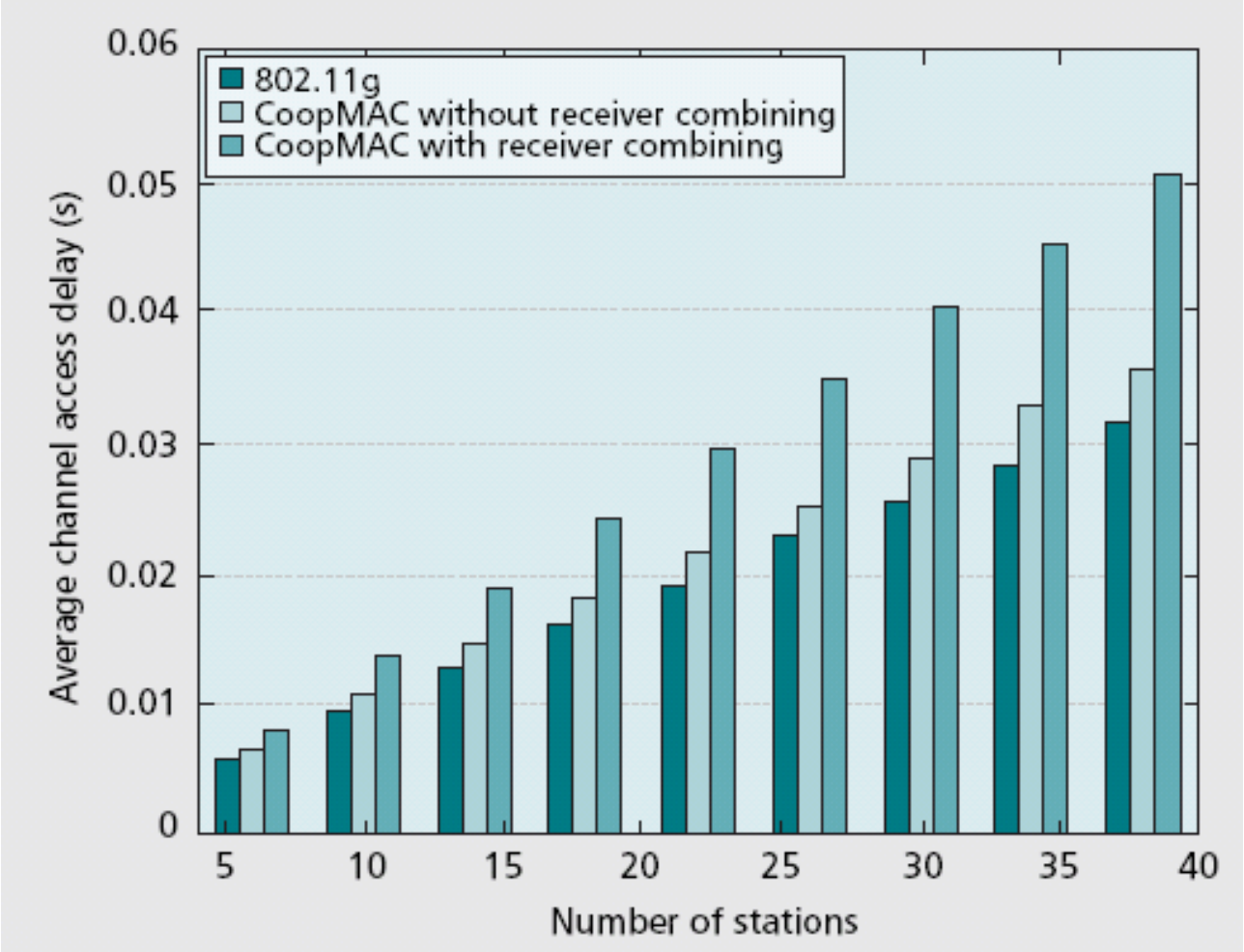
Simulation – Saturation Capacity



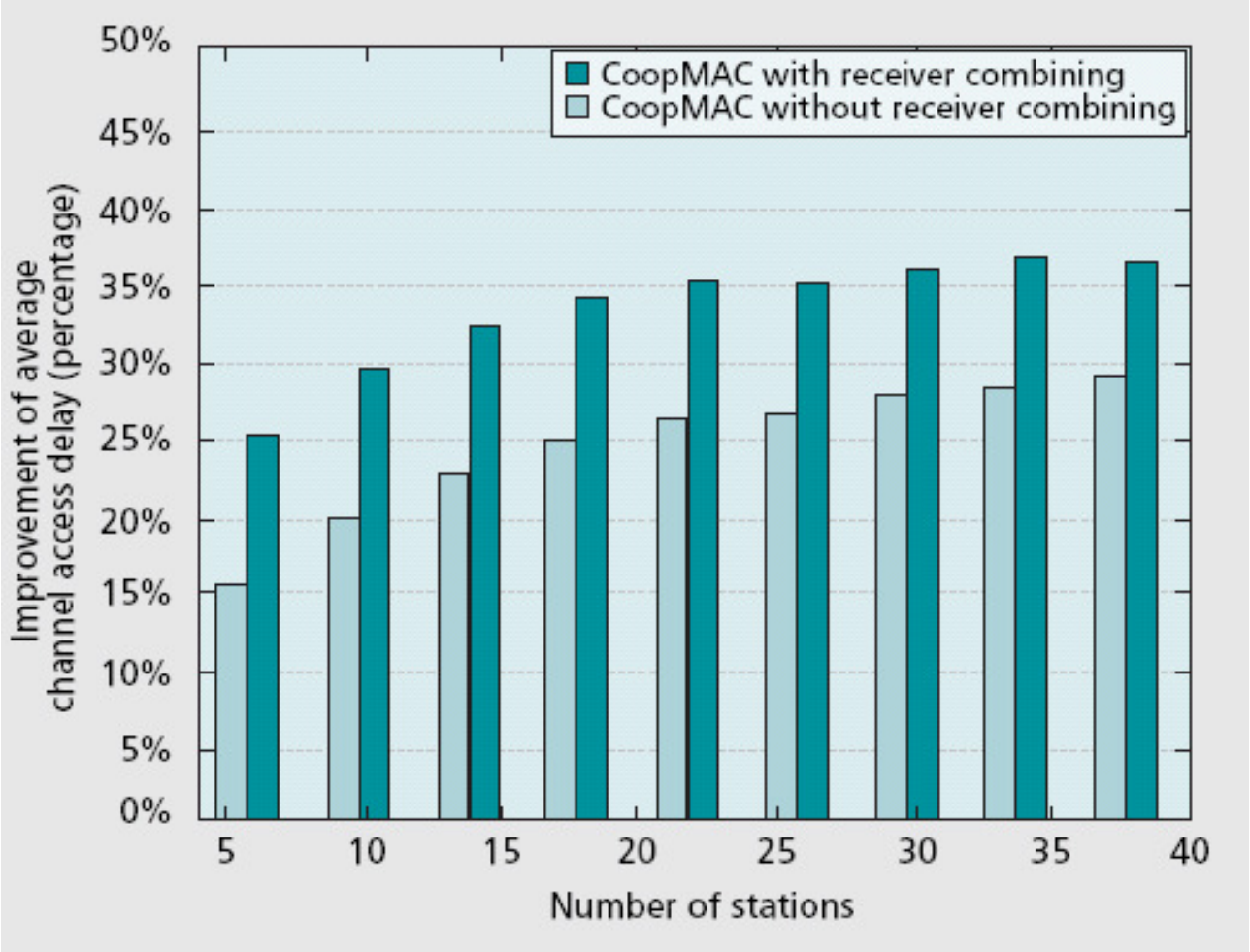
Simulation – Network Capacity



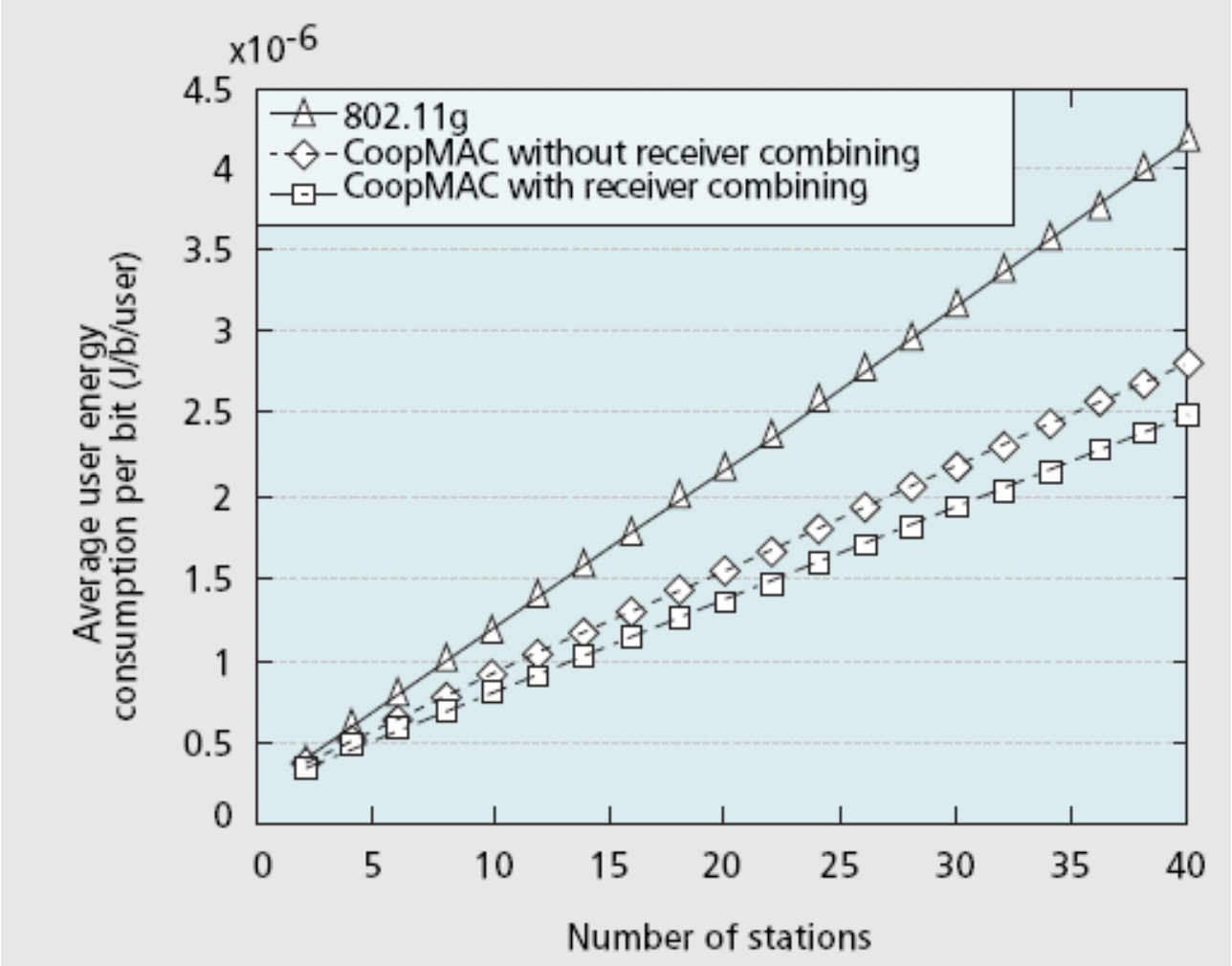
Simulation – Mean Channel Access Delay



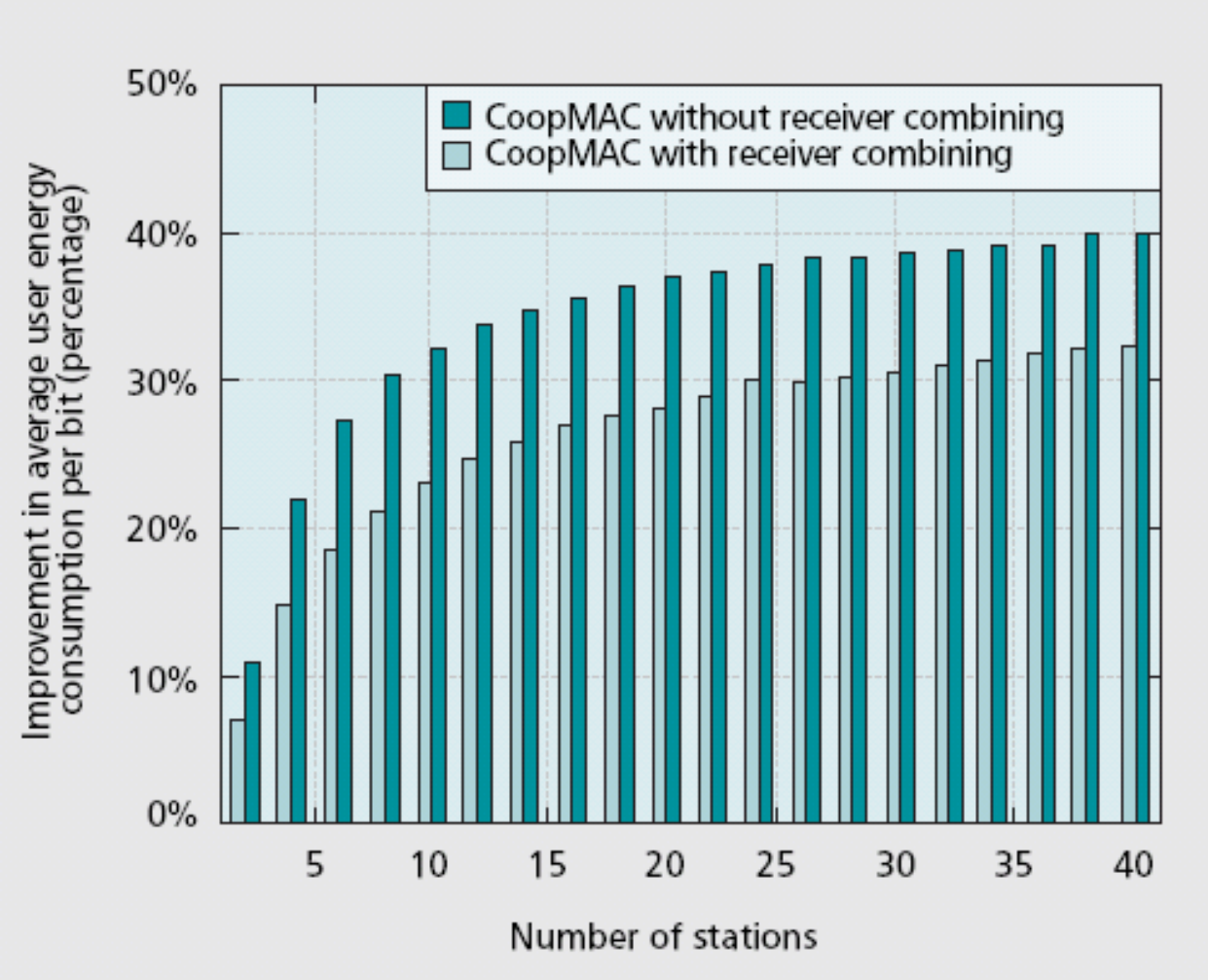
Simulation – Improvement of Mean Channel Access Delay with respect to 802.11g



Simulation – Average Energy Consumption



Simulation – Average User Energy efficiency gain with respect to 802.11g



Conclusion

- This study overviews and introduces the cooperative communication
- CoopMAC is also developed in this study to enables tremendous improvements in
  - Robustness
  - Throughput
  - Delay
  - A significant reduction in interference
  - An extension of coverage

- Question
  - Will the receiver wait for HTS before sending CTS?
    - If yes, there will be issues of utilization and delay
    - If not, there should be collision problem for sending HTS and CTS