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Algorithms for Radio Networks

Multicasting with Network Coding
COPE

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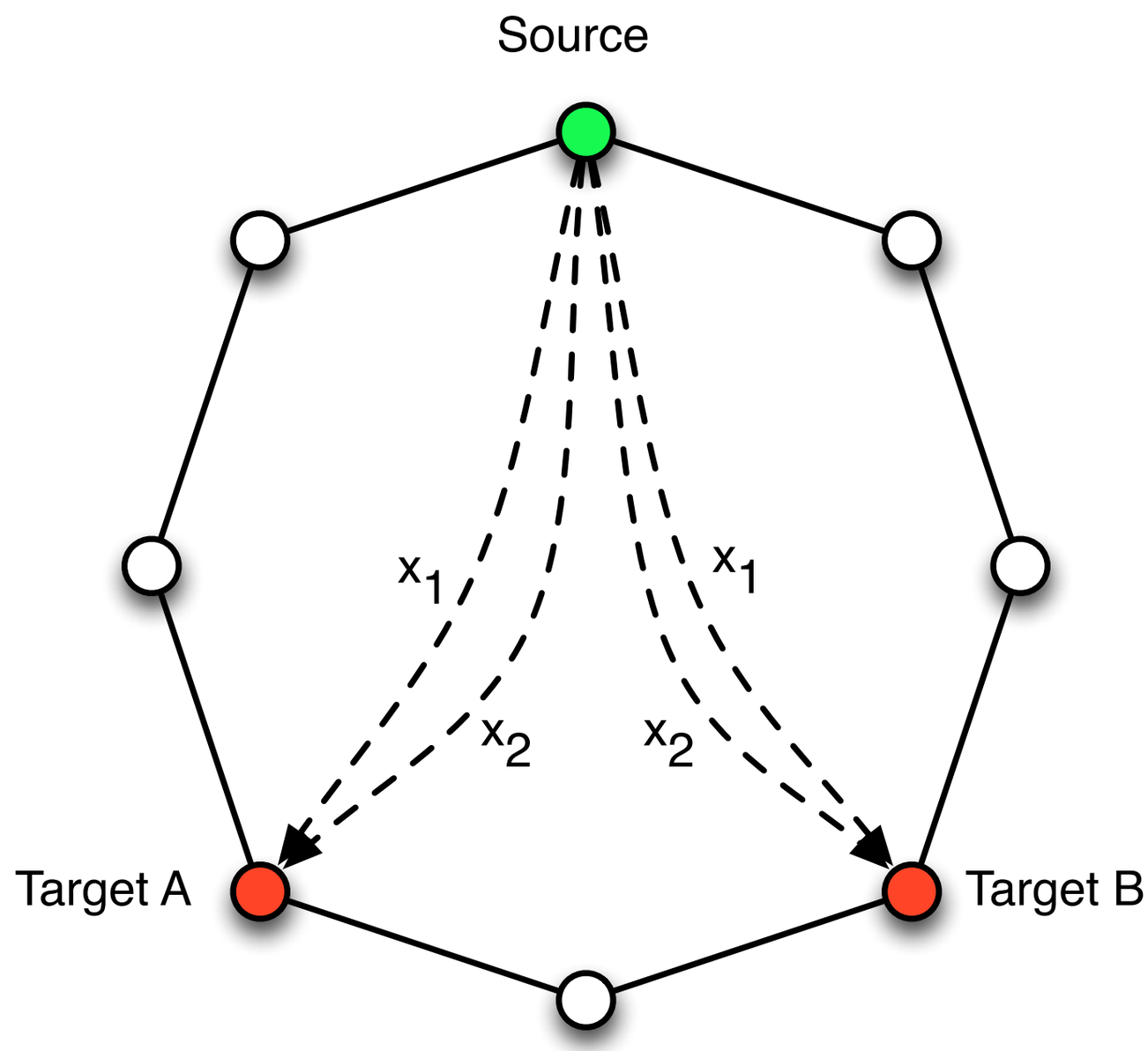
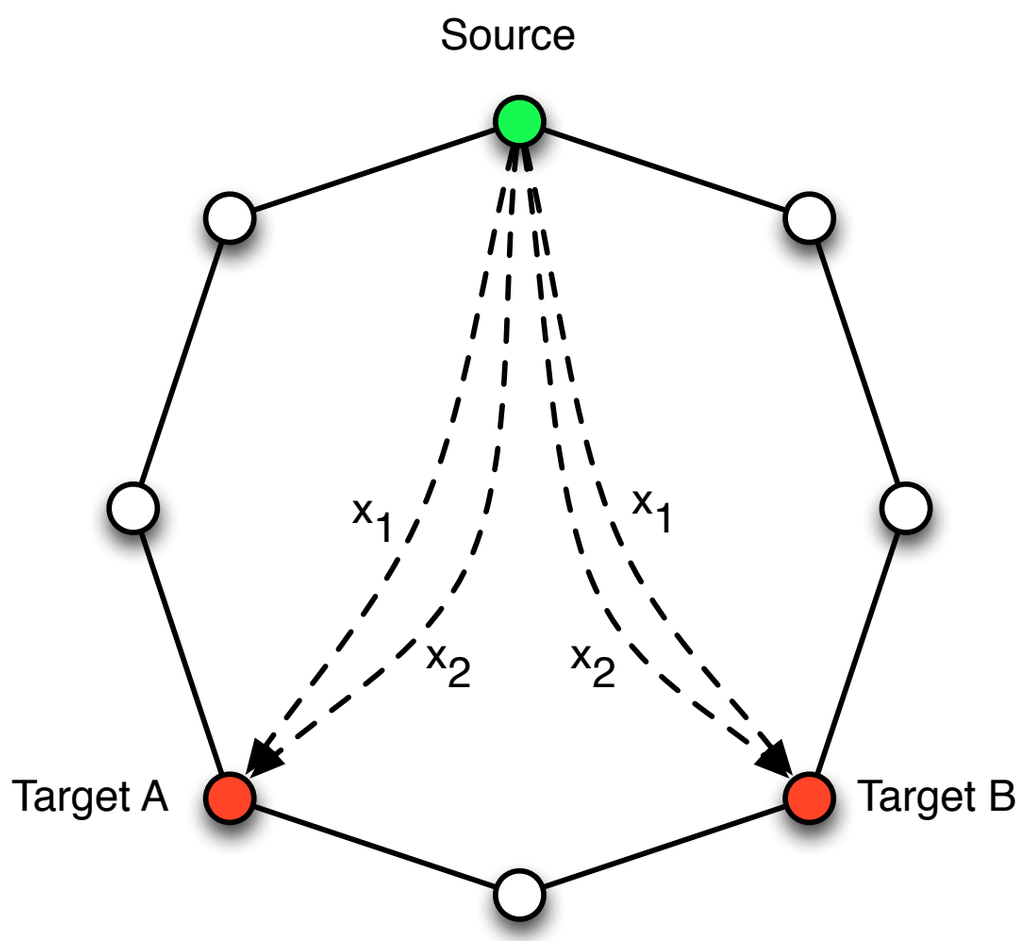
Multicasting in Ad Hoc Networks

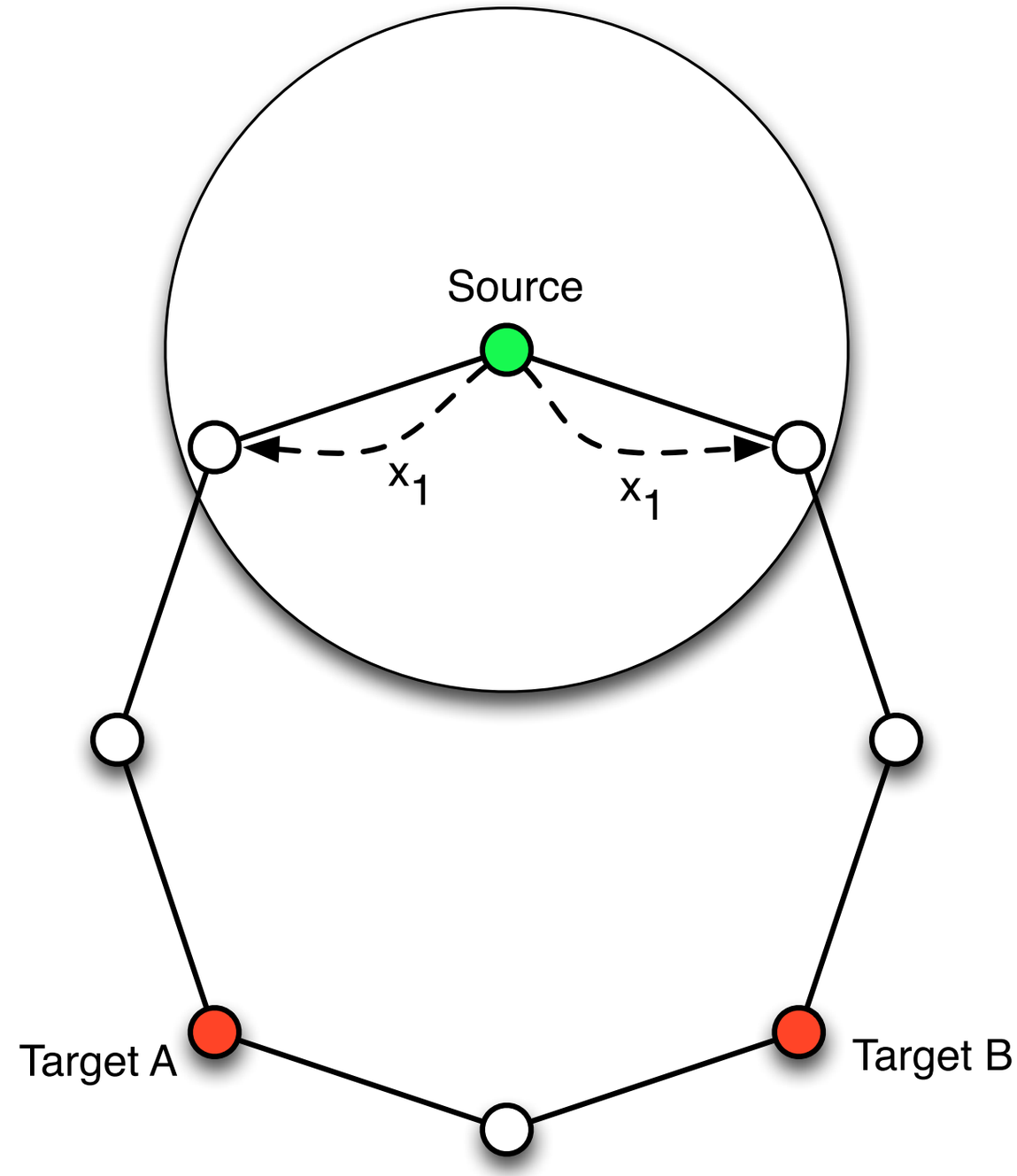
- **Wu, Chou, Sun-Yuan,**
  - Minimum-Energy Multicast in Mobile Ad hoc Networks using Network Coding, 2006
- **Multicast**
  - Distribute message from one node to a given set of nodes
- **Cost measure**
  - Each one-hop broadcast costs an energy unit



Beispiel

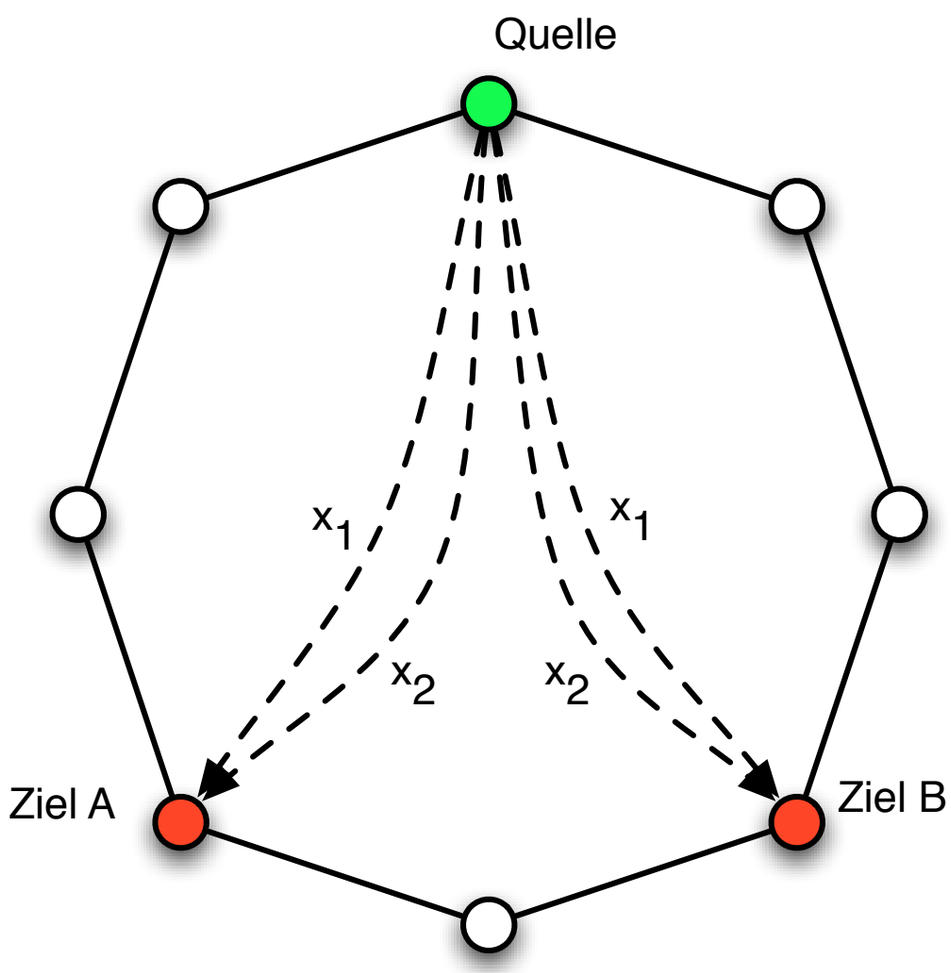
- **Traditionally,**
  - it costs 5 energy units for a multicast message

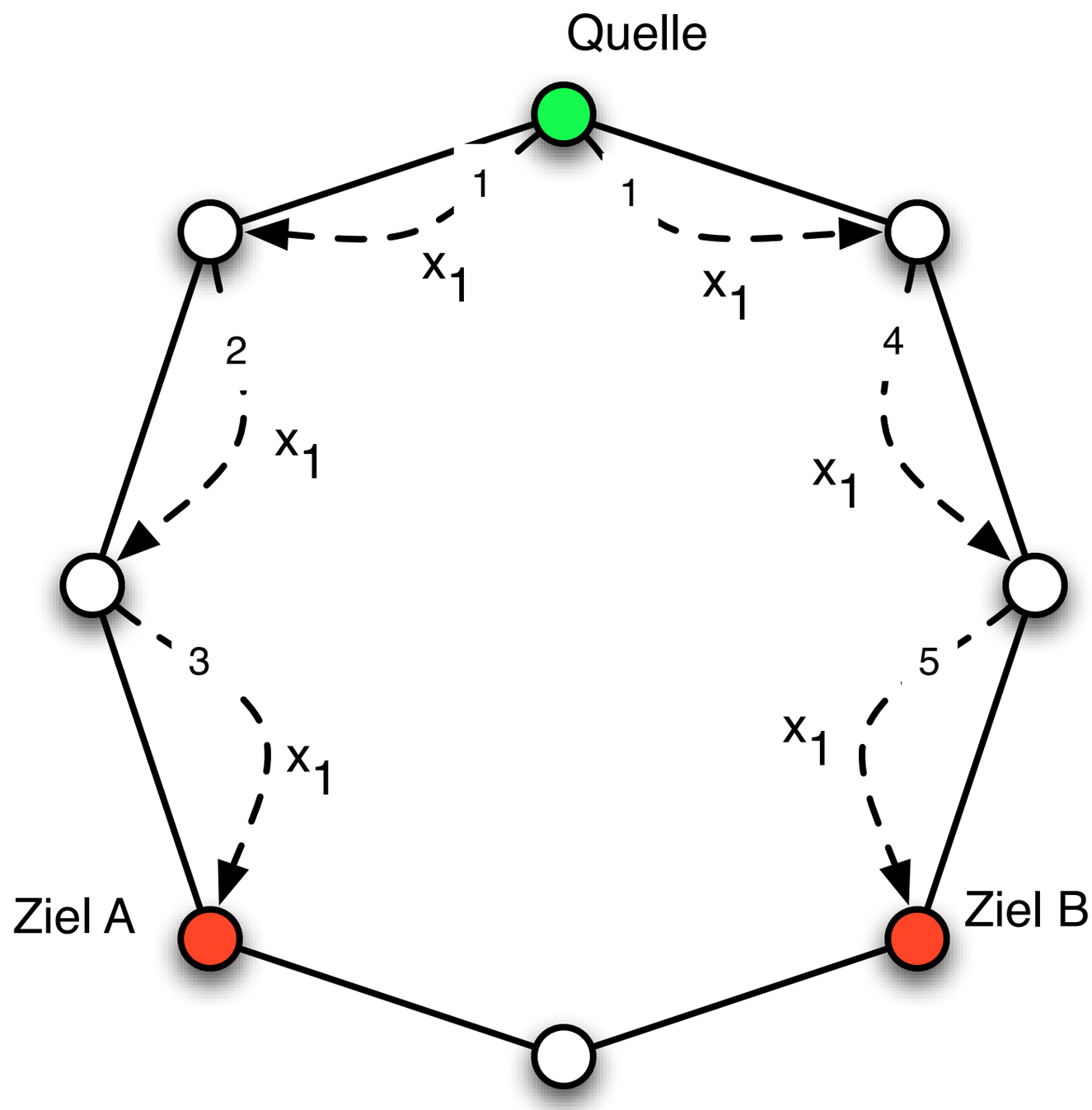




Example

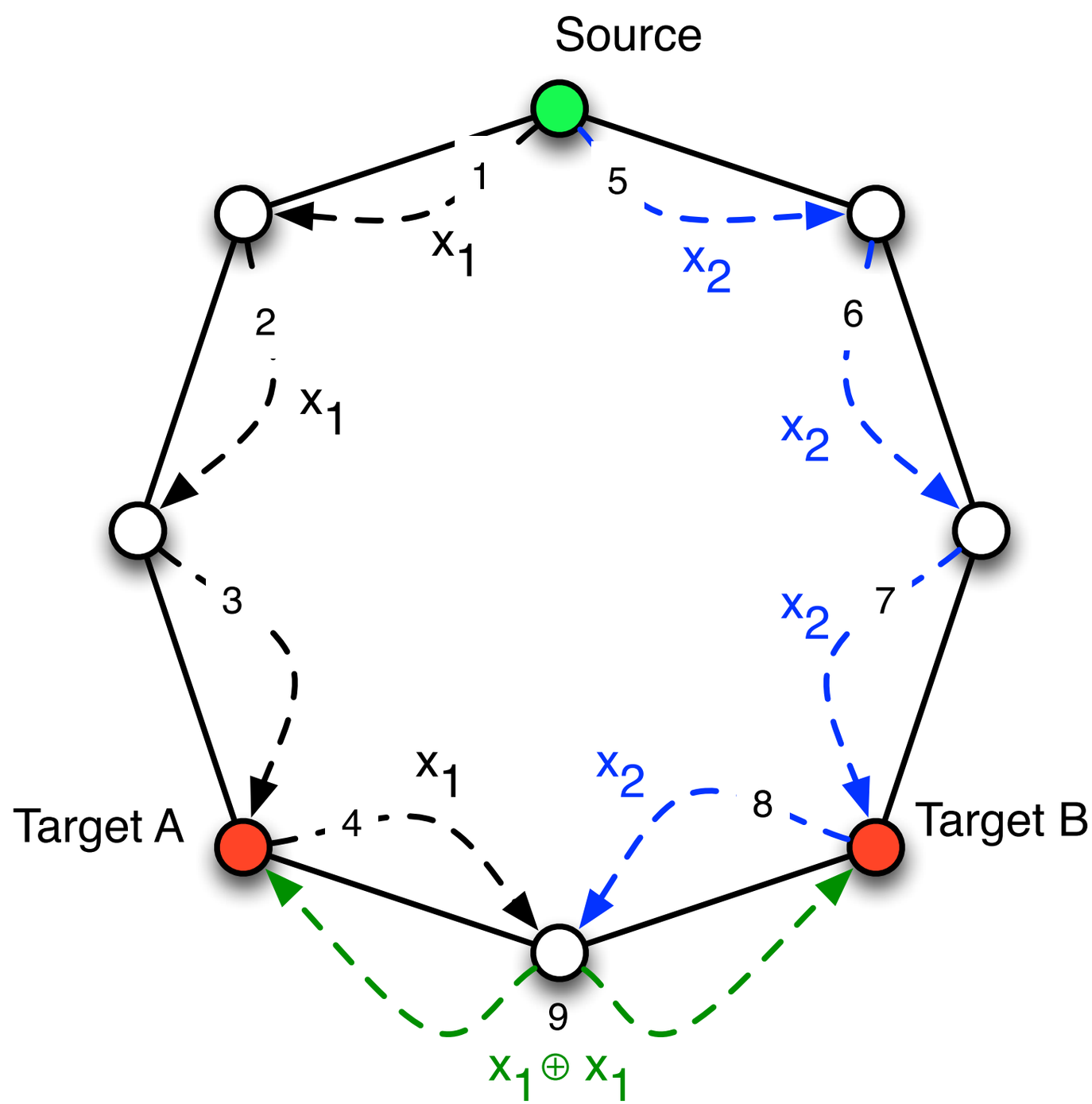
- **Traditionally,**
  - it costs 5 energy units for a multicast message





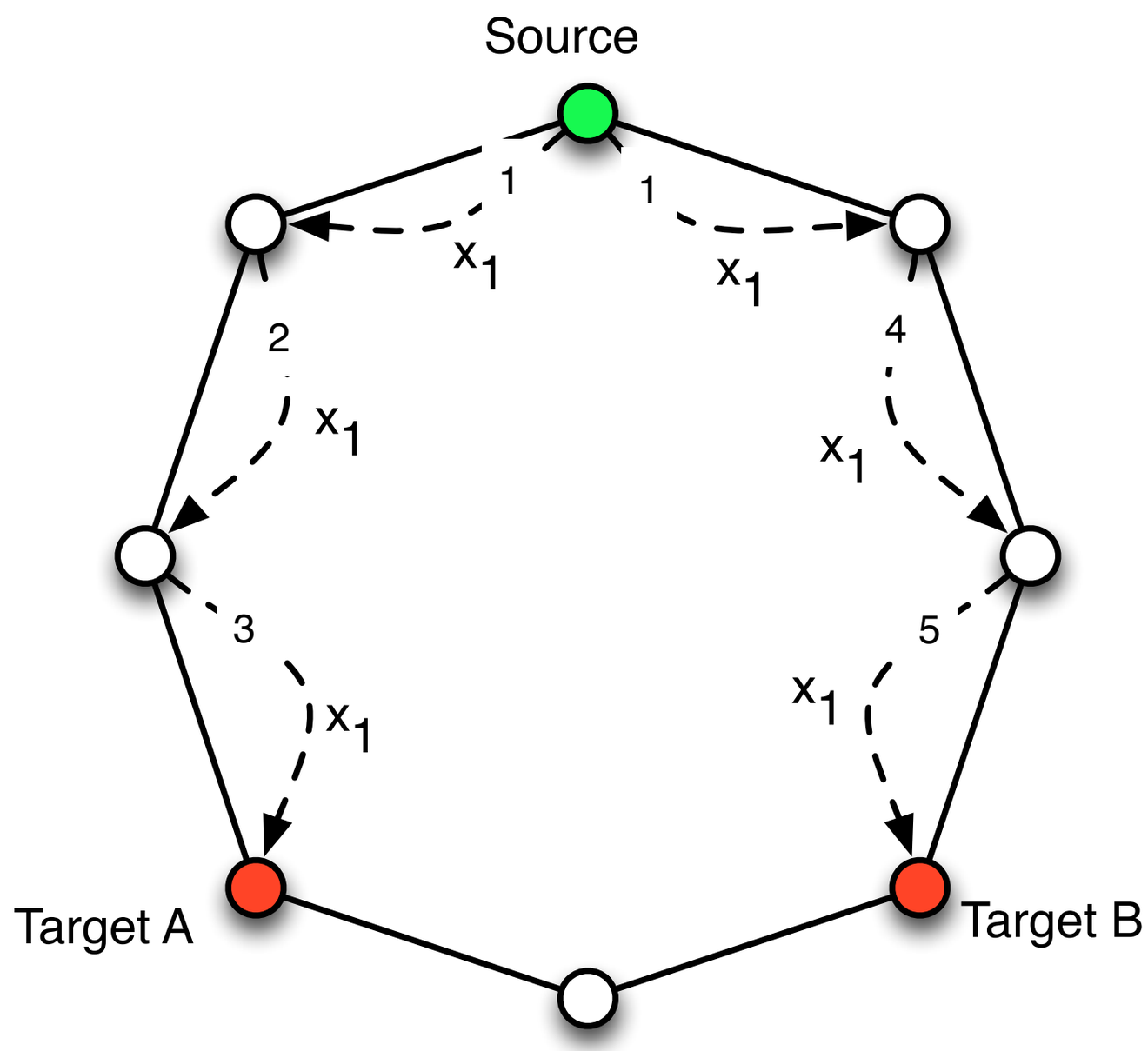
Example

- **Network coding**
  - 9 energy units for 2 messages
  - Average of 4.5
- **Without network coding**
  - 5 units for one multicast message



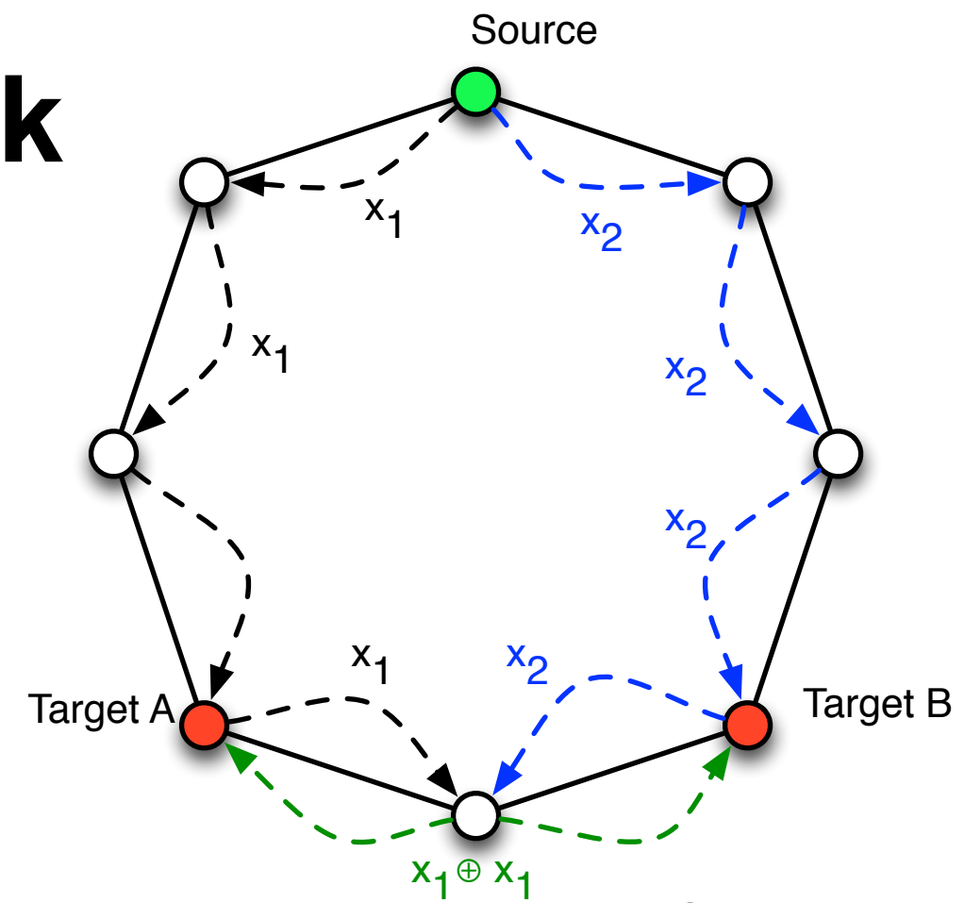
Multicasting in Ad Hoc Networks

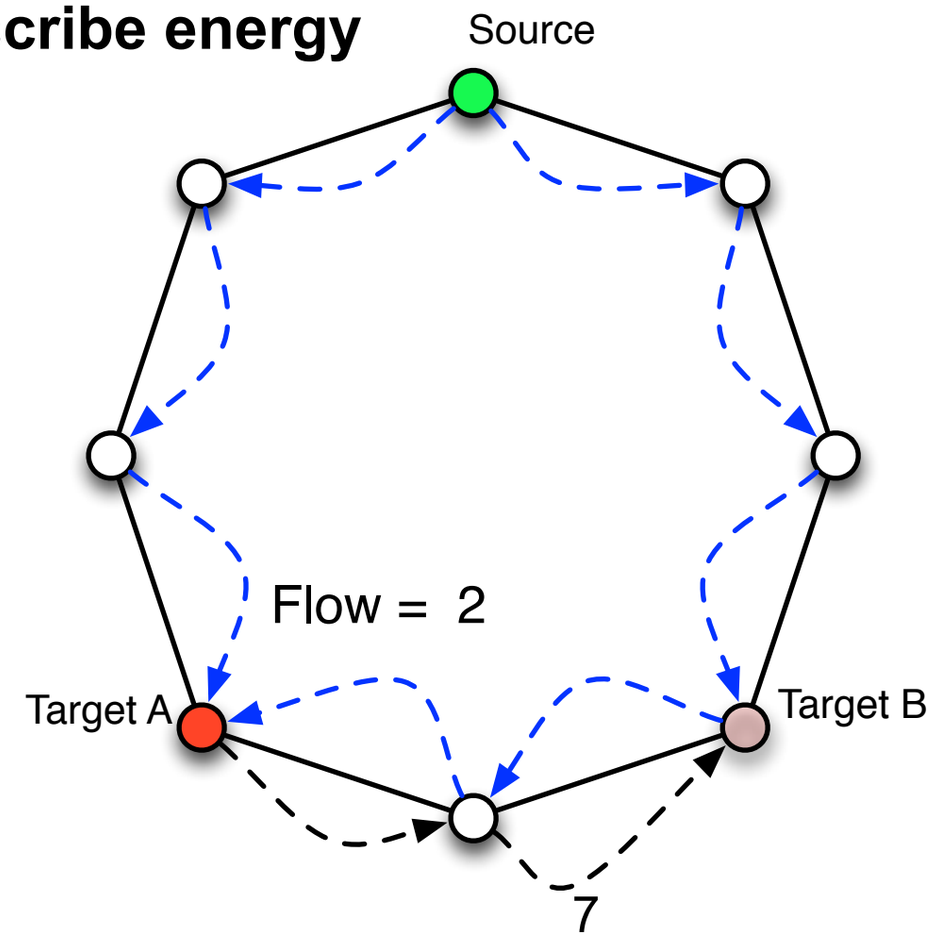
- **Solution of the minimal energy multicasting problem without network coding is NP-hard**
  - Less than constant factor approximation is NP-hard
  - Requires calculation of the discrete Steiner tree

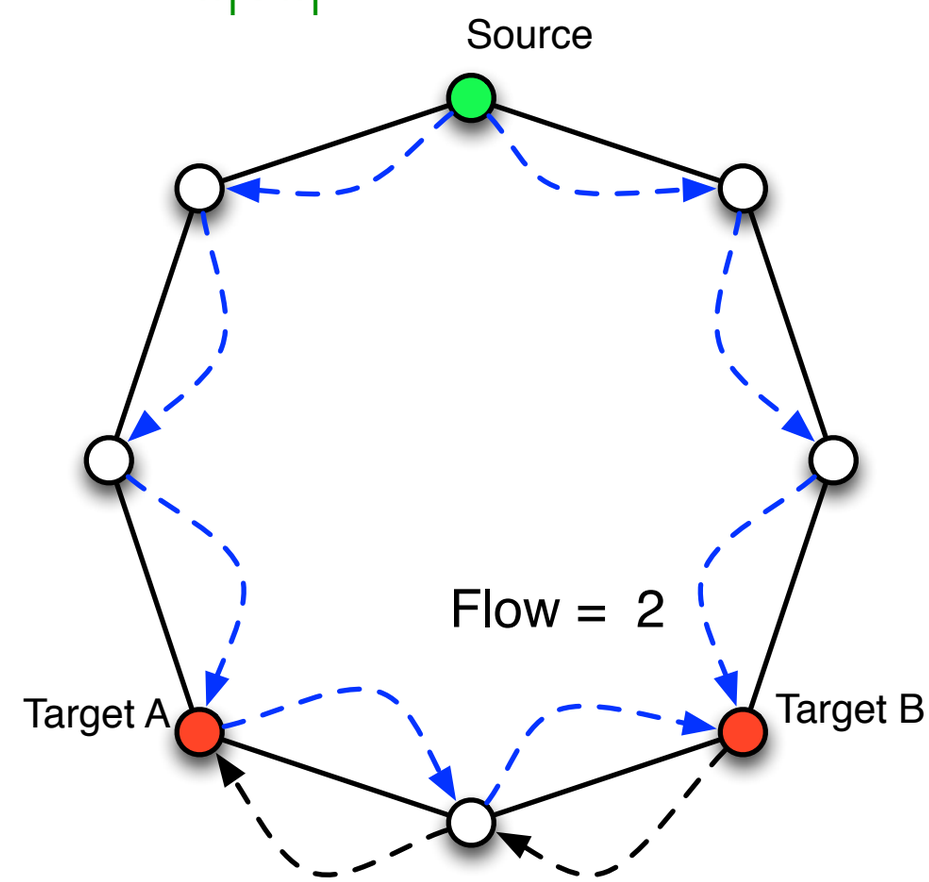


Condition for Network Coding

- **Messages allow flow of the size of the desired number of messages**
  - from the sources to each individual sink
- **If such flows are guaranteed, network coding can be applied**
- **Size of the flows describe energy consumption**



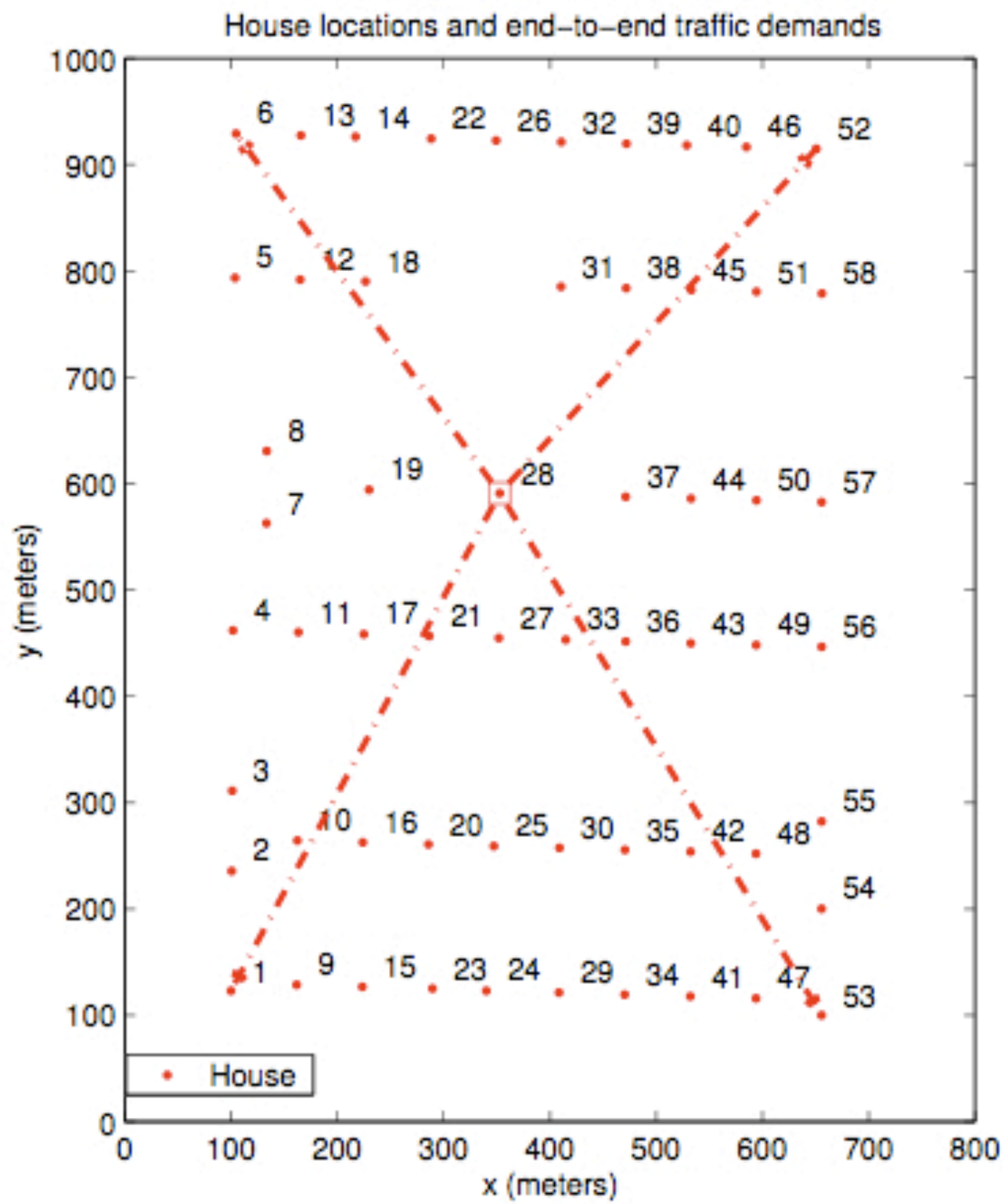




Computational Complexity

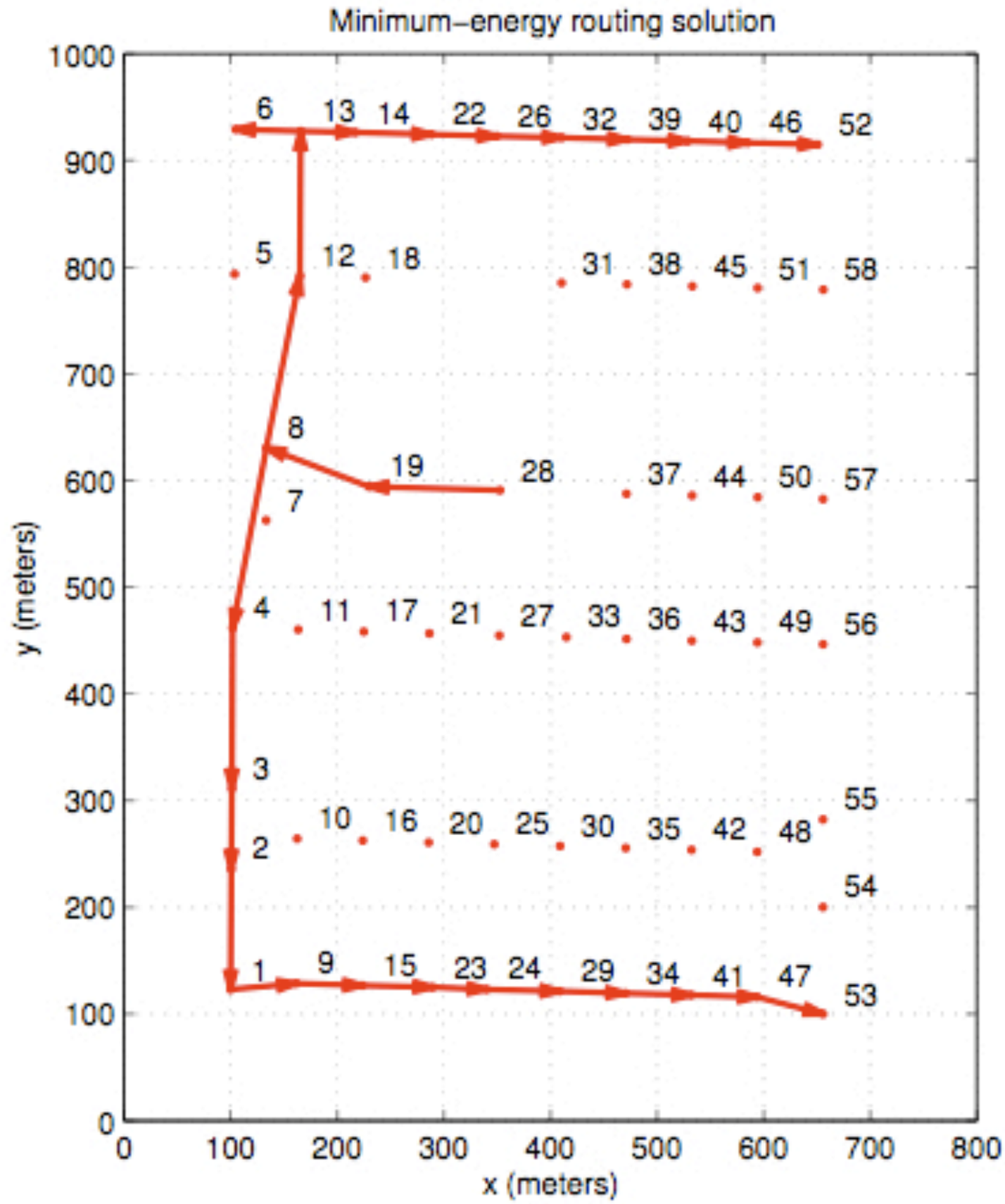
- **Algorithm**
  - Collect all available link information
  - Formulate as linear program
  - Approximation of the solution
- **With the help of network coding, the maximum throughput can be approximated arbitrarily well in polynomial time**

Example Demand



Wu, Chou, Sun-Yuan,
Minimum-Energy Multicast in Mobile Ad hoc Networks using Network Coding, 2006

Example Multicasting with minimal Energy



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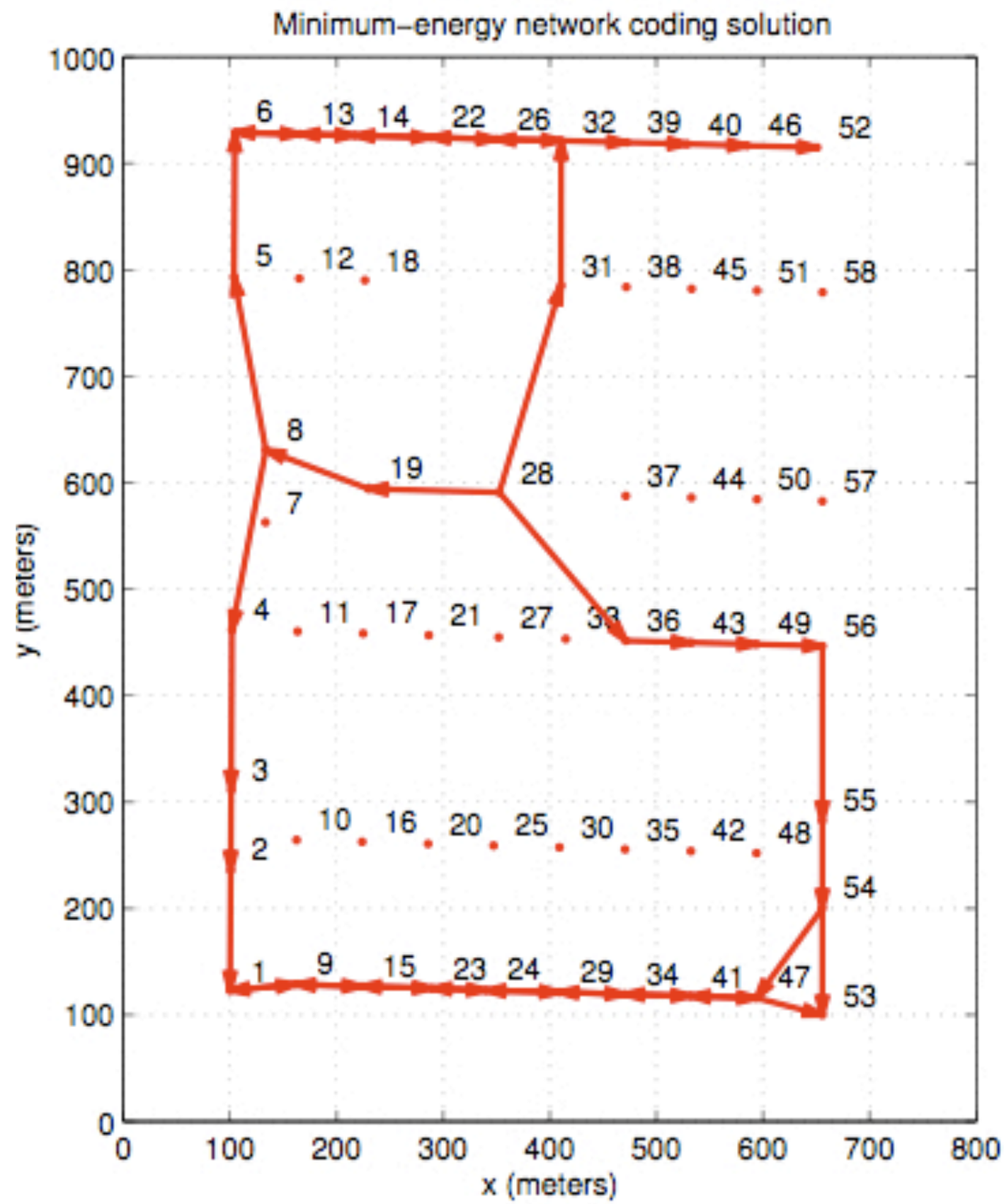
Multicasting with Network Coding



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Discussion

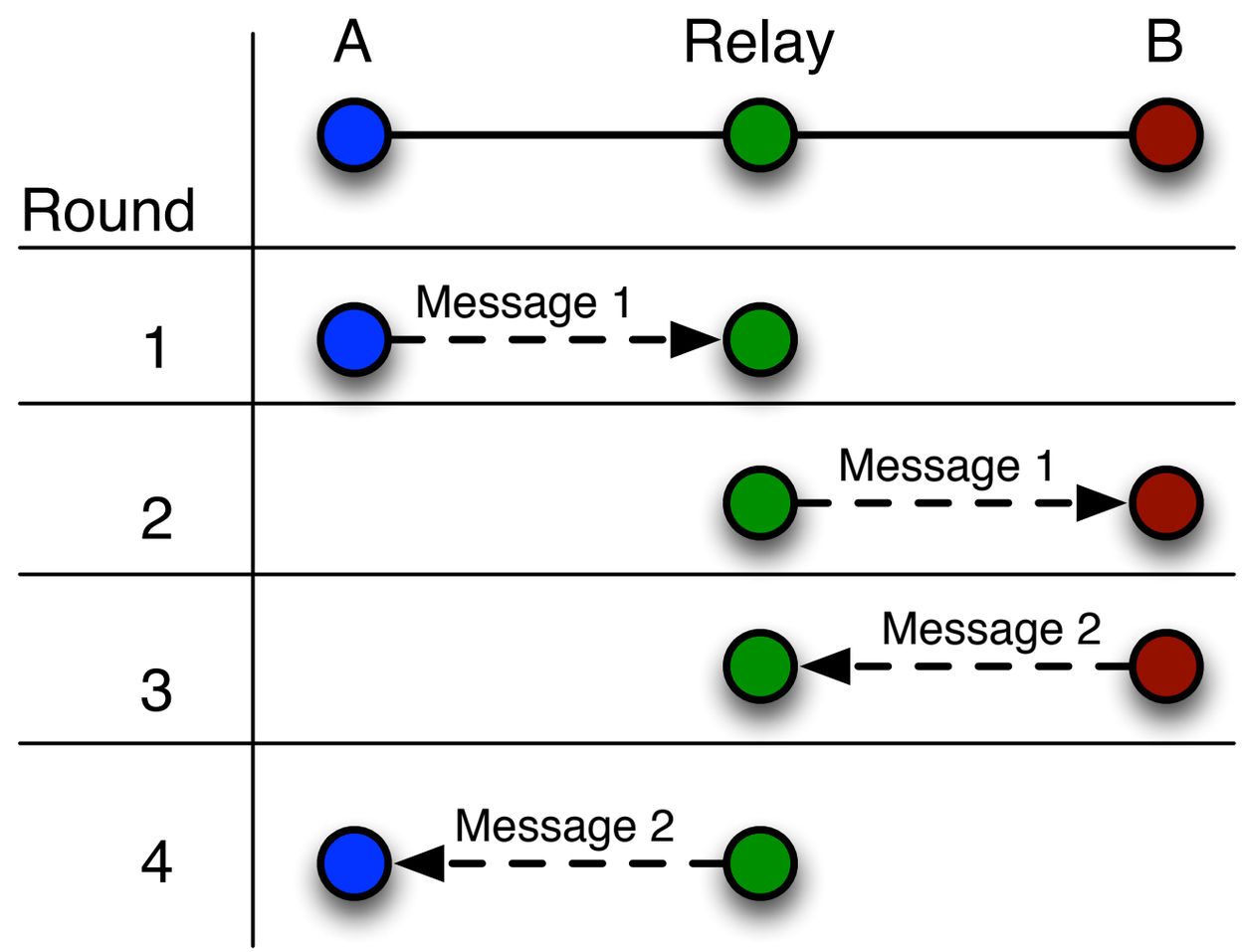
- **Options**
  - Energy model can customized
- **Limitations**
  - Network coding is not described
  - Central algorithm
  - Any change in the communication requires recalculation

Xors in the Air

- **Katti, Hu, Katabi, Médard, Crowcroft**
  - XORs in the Air: Practical Wireless Network Coding
- **Problem**
  - Maximize throughput in ad-hoc network
  - Multihop messages cause interference
- **Solution**
  - Uses only XORs of multiple messages
  - Local, opportunistic algorithm

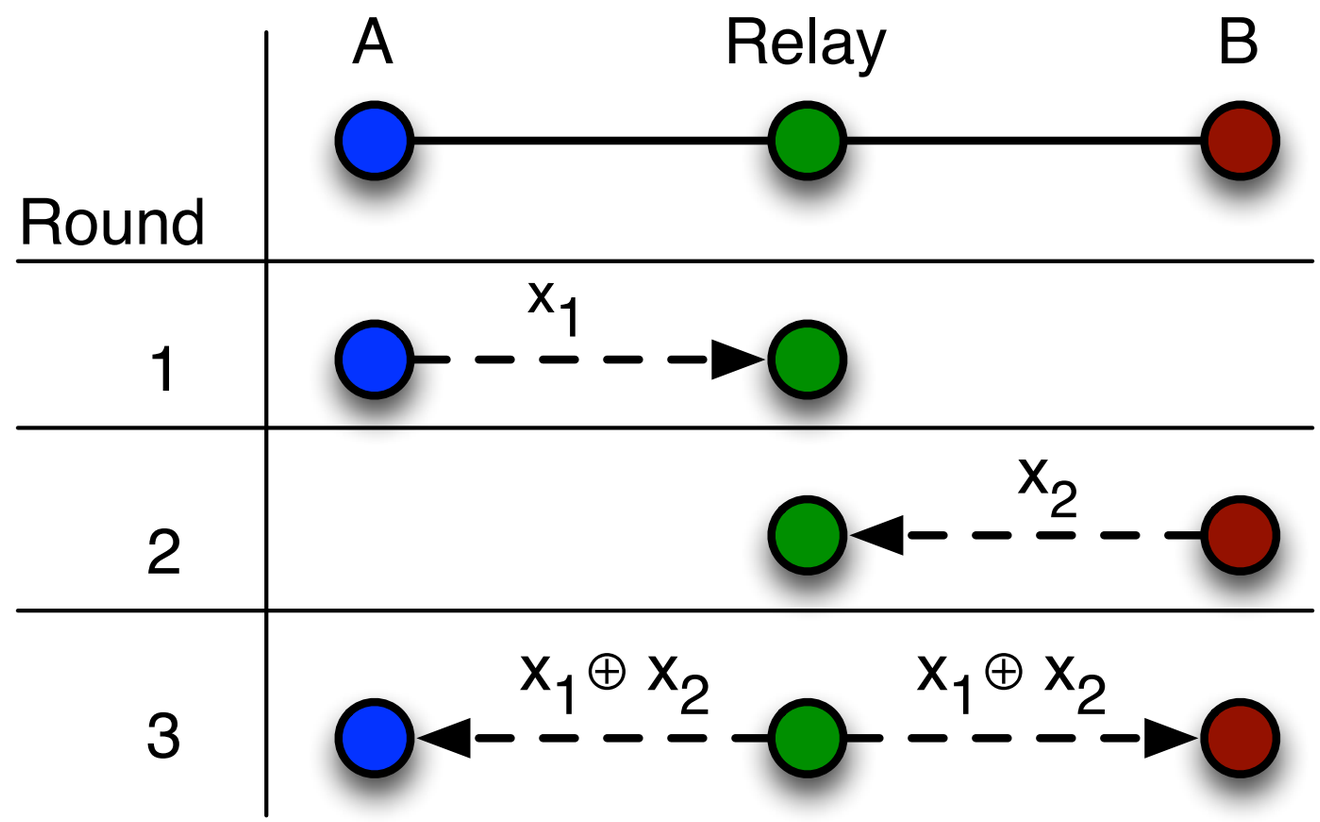
Xors in the Air

- **Problem**
  - Multihop messages cause interferences
- **Example**
  - Traditional: 4 messages to send
    - a message from A to B
    - and a message from B to A



Xors in the Air

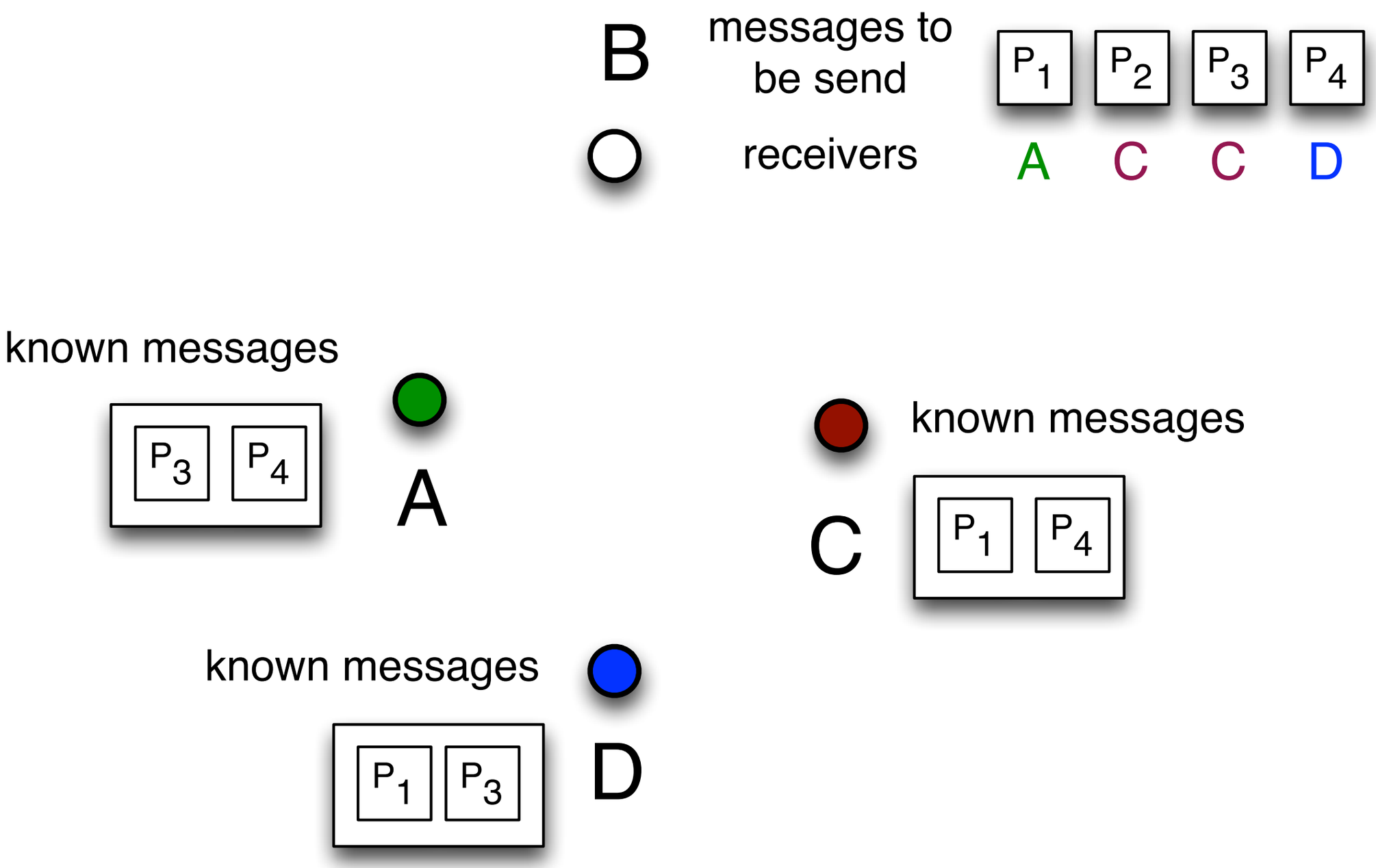
- **Problem**
  - Multihop messages cause interferences
- **Example**
  - Traditional: 4 messages to send
    - a message from A to B
    - and a message from B to A
  - Network Coding
    - 3 messages suffice



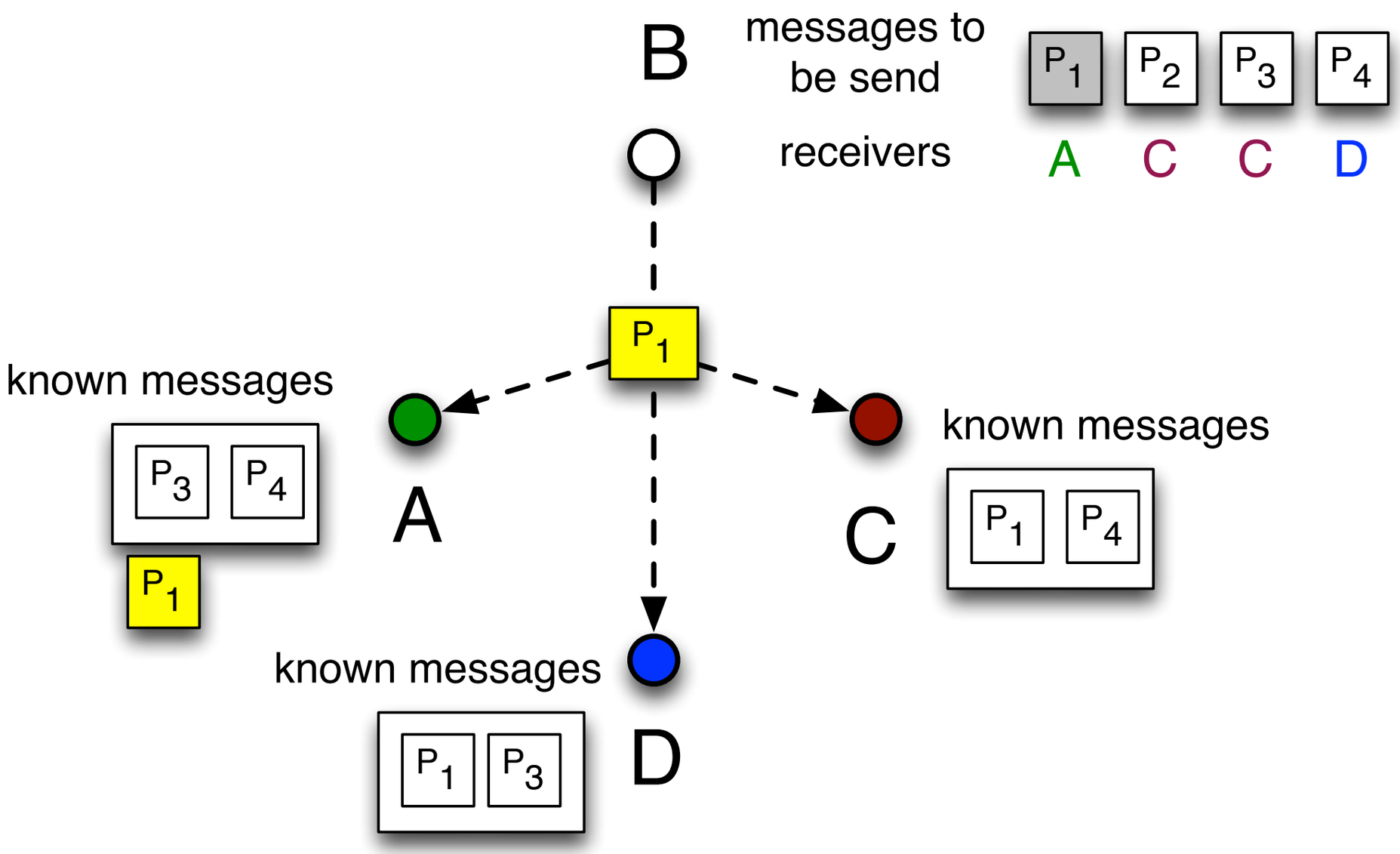
Coding Opportunistically COPE

- **Consider of multiple communication paths**
  - Opportunistic coding of messages by Xor
- **Utilization of the broadcast medium**
  - listening to the channel
  - all (even foreign) messages are buffered
  - buffered messages are used for decoding
- **Context messages**
  - announcement of level of knowledge
  - neighbors can generate code adapted to the receiver‘s knowledge
- **Guess the level of knowledge of neighbors**

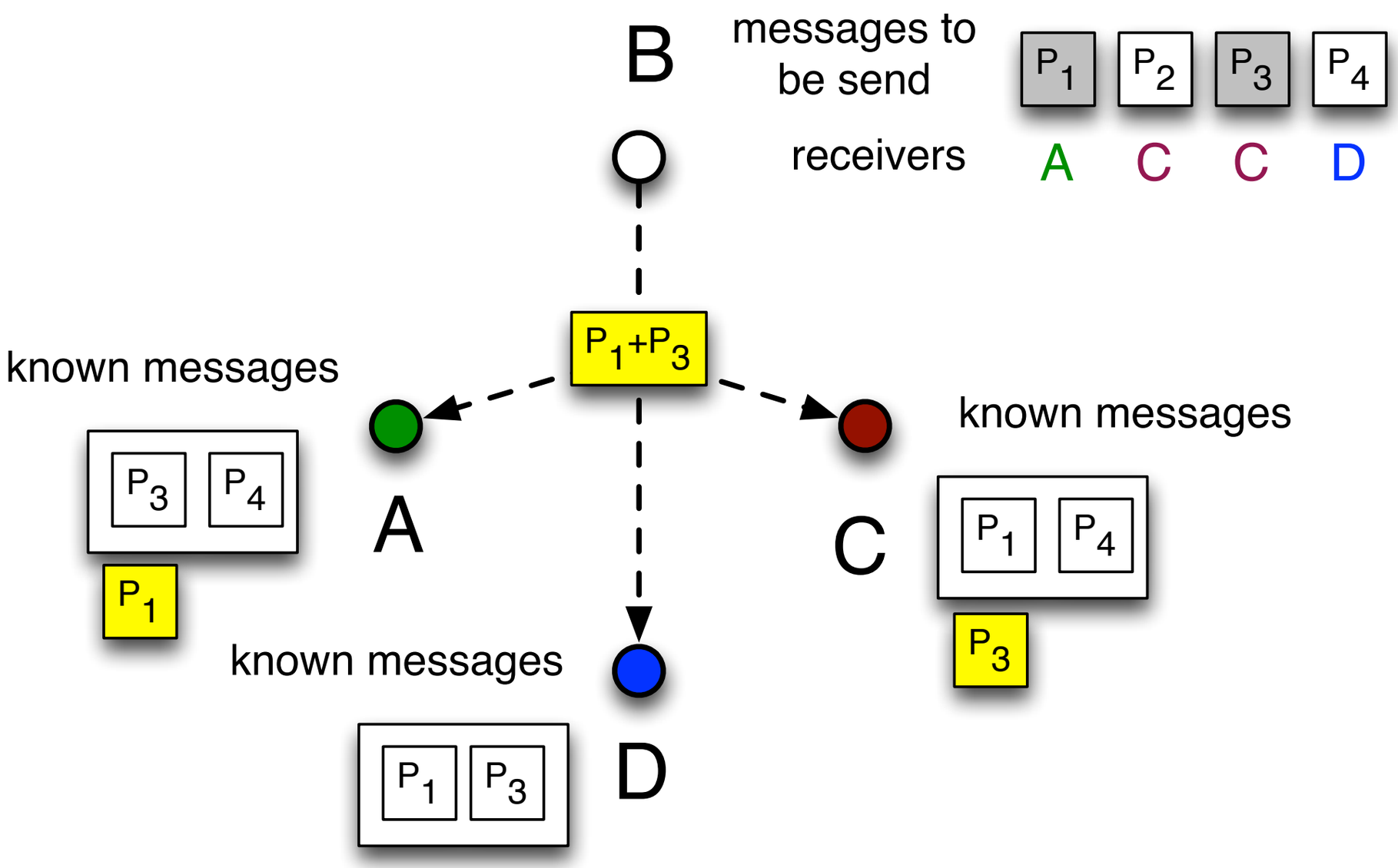
Opportunistic Coding



Opportunistic Coding



Opportunistic Coding



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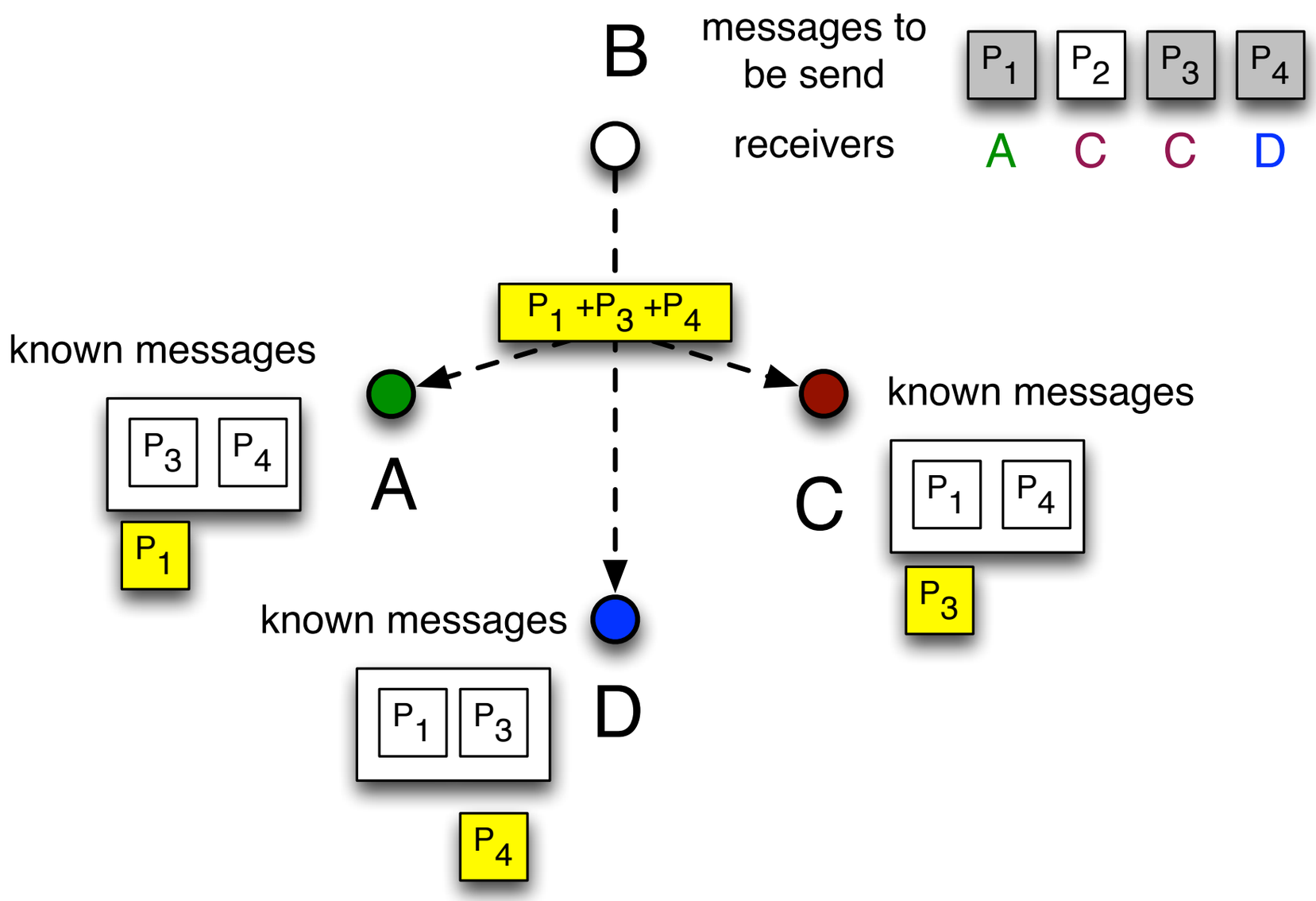
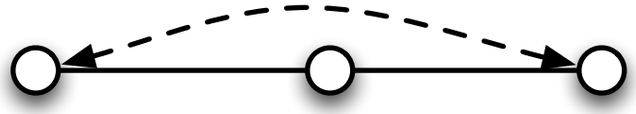
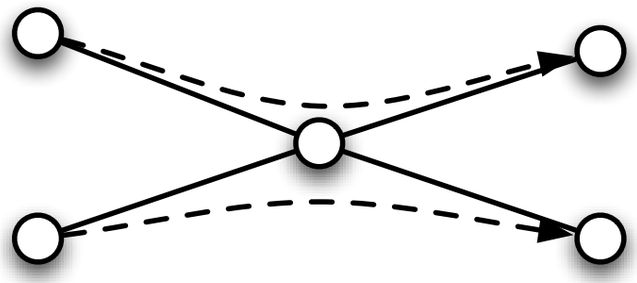


Coding Gain

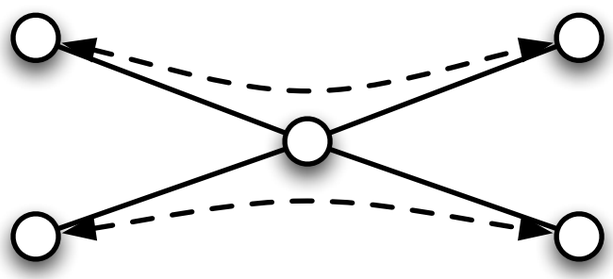
3-chain



X

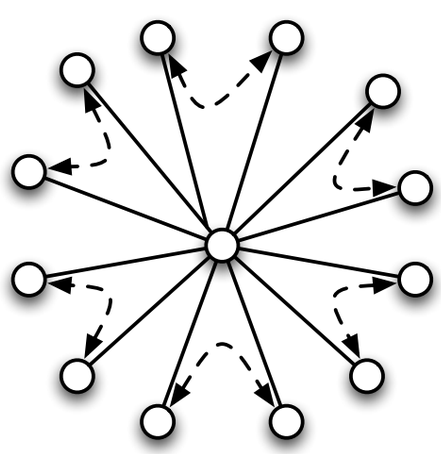


Cross



Infinite Chain

Infinite Wheel



Topology	Coding Gain
3-chain	1,333...
X	1,333...
Cross	1,666...
Infinite Chain	2
Infinite Wheel	2

Summary Network Coding

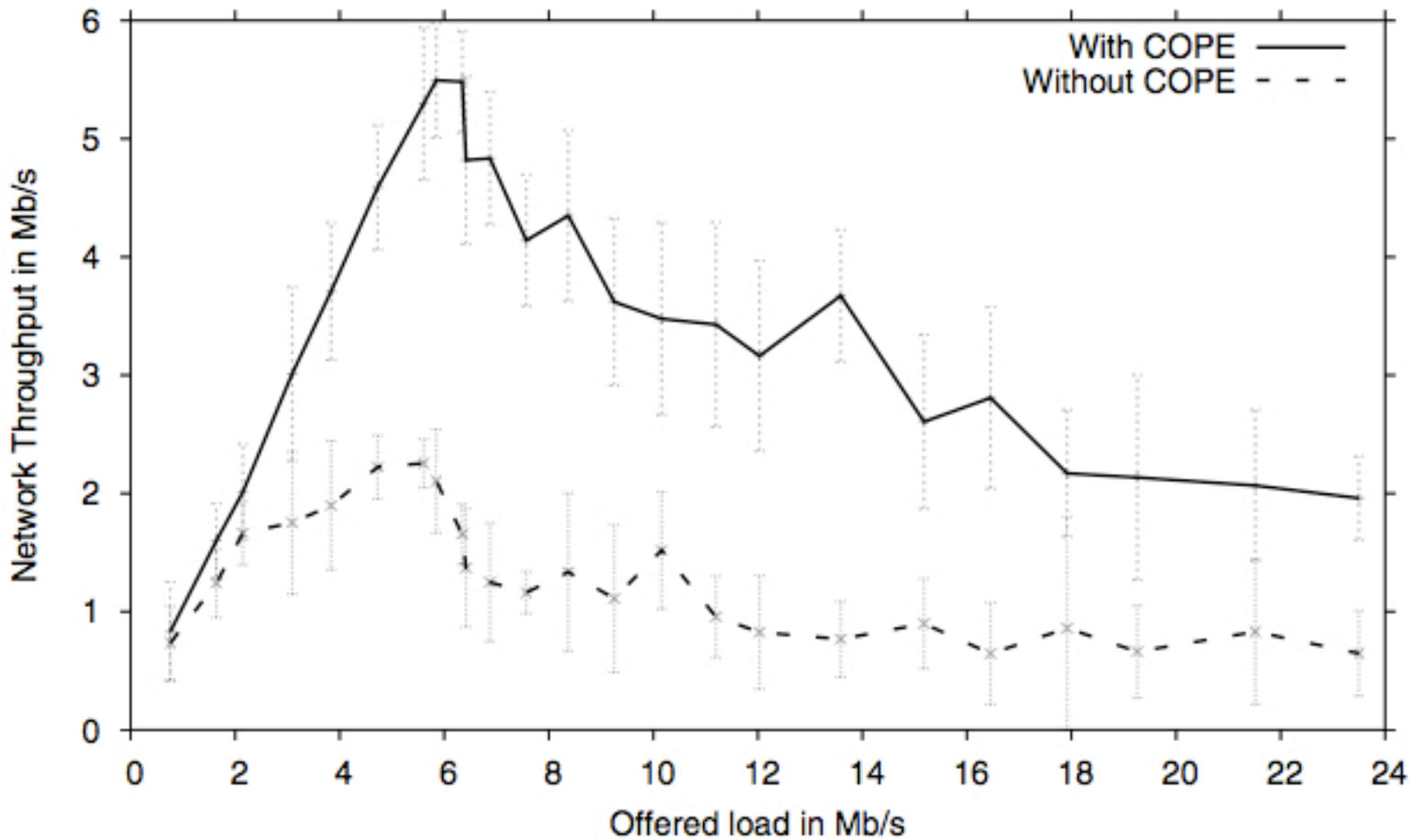


Figure 12—COPE can provide a several-fold (*3-4x*) increase in the throughput of wireless Ad hoc networks. Results are for UDP flows with randomly picked source-destination pairs, Poisson arrivals, and heavy-tail size distribution.

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Network Coding

- **Benefit**
  - Network throughput can be increased
    - COPE
  - Reduction of energy consumption
  - Higher robustness, small error rate
  - Applications in peer-to-peer networks, wireless sensor networks
- **Problems**
  - complex encoding
  - sometimes high computational cost
  - difficult organization

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