Cooperative Multicast in Wireless Networks

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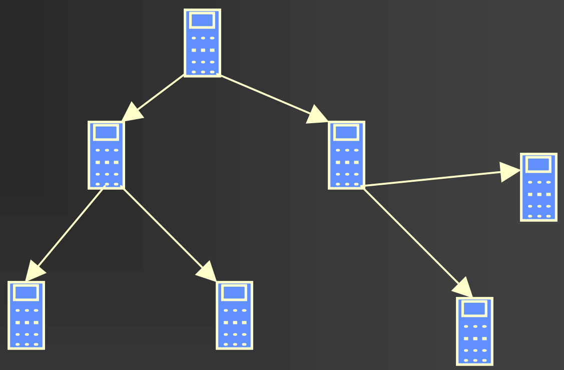
26 Jan. 2005

Outline of the Talk

- Cooperative Multicast in Wireless Networks
- Cooperative Routing in Wireless Networks

Cooperative Multicast in Wireless Networks

Why Multicast?



Multicast is an **elementary** service and many applications need it

- Info. gathering in wireless sensor networks
- Event Notification Systems
- Resource discovery, paging, etc.
- One-to-many content delivery in P2P networks, e.g., exchange name card info. at a conference
- Cellular phone-based teleconference/game among a group of people (**a possible emerging application**)
- **The bottom line: it allows efficient use of network resources (multiple users share the data on air)**

The problem

In a large and dense wireless network, how the wireless devices can efficiently communicate with each other given the resource constraints, for example the power supplies. (most of the wireless devices are equipped with limited power supplies, e.g., batteries).

We address the energy efficiency problem in wireless comm. by exploring ***cooperation*** among nodes in the network.

Philosophy: as a single node, it may NOT be able to accomplish anything, but ***collaboratively*** a number of nodes may be able to achieve a big thing (more resource savings).

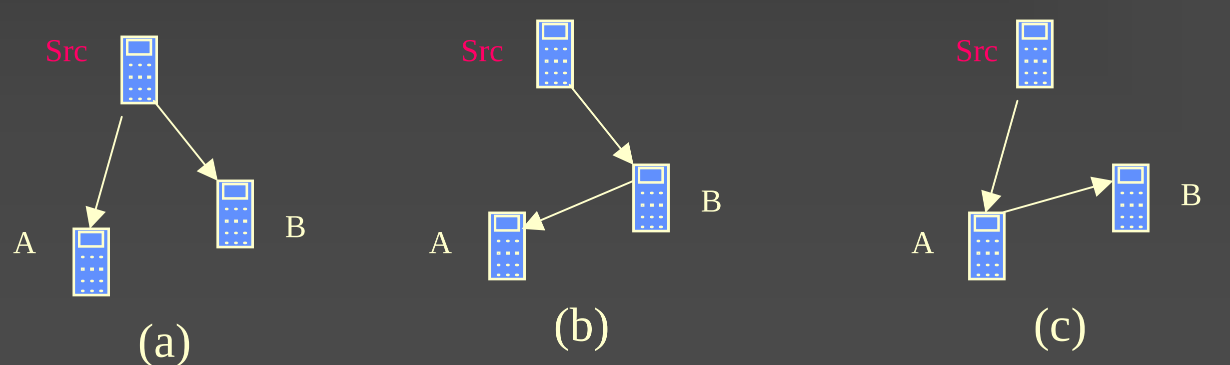
Wired vs Wireless Multicast

Wired Multicast: the total cost is simply the sum of the subcost to reach each of the destination nodes individually.

Wireless Multicast (the one-hop case): the total cost is the maximum subcost to reach each of the destination nodes individually.

Assuming that omni-directional antenna is used. This is often referred to as Wireless Multicast Advantage (**WMA**)

In our treatment of cooperative multicast in wireless networks, we assume multi-hop routes, e.g., relaying info. by intermediate nodes may save power than transmitting over a large dist.



A Simple Example

Cooperative Multicast in Wireless Networks

Design Challenges:

- **Energy Efficiency**: minimize total required power
- **Adaptability**: automatically adjusts the multicast tree structure to reflect changes (channel conditions, node mobility, etc.)
- **Decentralization**: The protocol to form the multicast tree structure is fully distributed
- **Scalability**: The protocol overhead grows slowly as more nodes added in the network
- **Reliability**: robustness against node failures, node leaves/joins, etc.

Cooperative Multicast in Wireless Networks

Complexity Issues

With a source node and (N-1) intended destination nodes, the number of possible multicast trees are

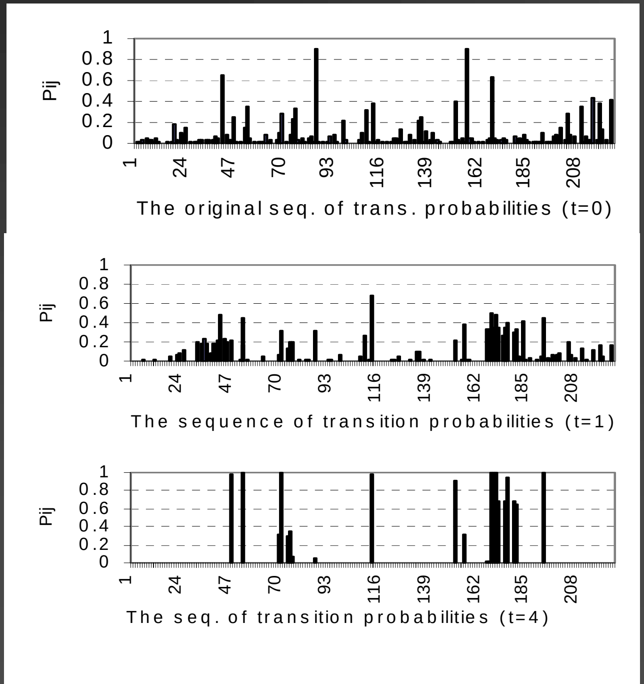
$$N^{(N-2)}$$

An NP-hard problem to find the minimum energy multicast tree.

Cooperative Multicast in Wireless Networks

A Randomized Optimization Approach (cross-entropy method)

We define the one-step transition matrix $Q = (q_{i,j})_{(N \times N)}$, where N is the number of destination nodes and q_{ij} denotes the probability that there is a transmission from node *i* to node *j*. The basic idea is that if it performs well in the previous round, it will have high transmission probability in the next round.

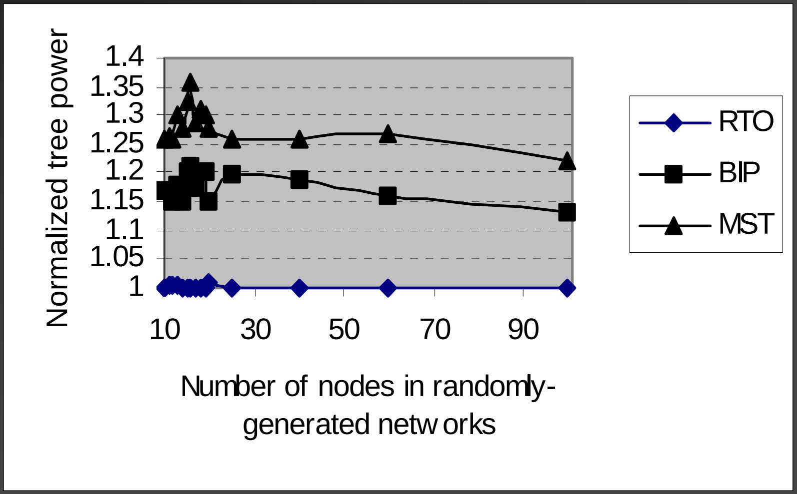


An Illustration of the evolving of the transition probability matrix

(it quickly converges after several rounds: with some Pij’s converging to 1s and others to 0s.)

Cooperative Multicast in Wireless Networks

Empirical Results



Average normalized tree power by RTO, BIP and MST over 100 random instances with varying number of nodes in the network

CM Protocol Components

Control Msg Exchanges

Control msgs are exchanged among local nodes to form an energy-efficient multicast tree structure such that every intended destination is covered and the total required energy is the least.

Data packet transmission

Once the multicast tree structure is finalized, data packets are transmitted along the tree structure. Only those relaying nodes relay data packets to its child nodes. Packets are not destined to a given node will be discarded.

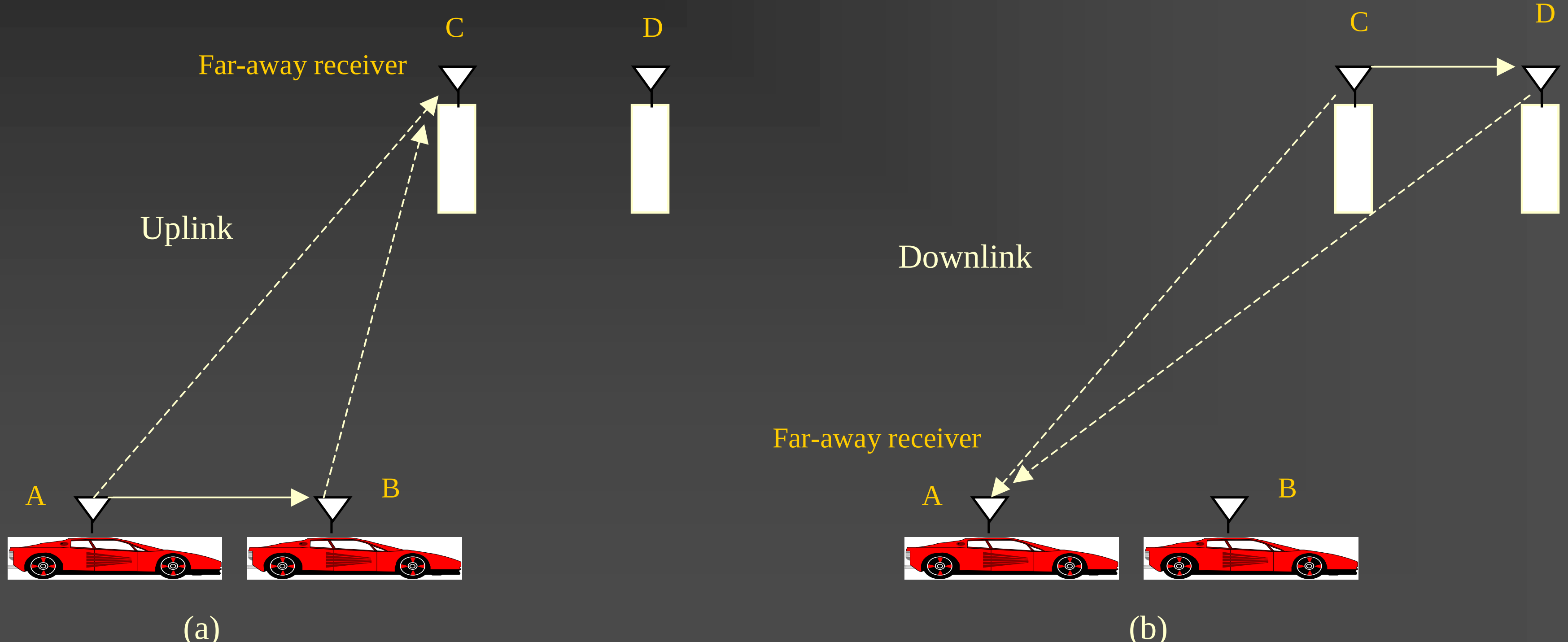
Periodic Update

Each node periodically updates the forwarding table information based on current channel conditions, network topologies, node conditions (failure due to battery low, etc.), node joins/leaves, etc. for reliability and adaptability.

Cooperative Routing in Wireless Networks

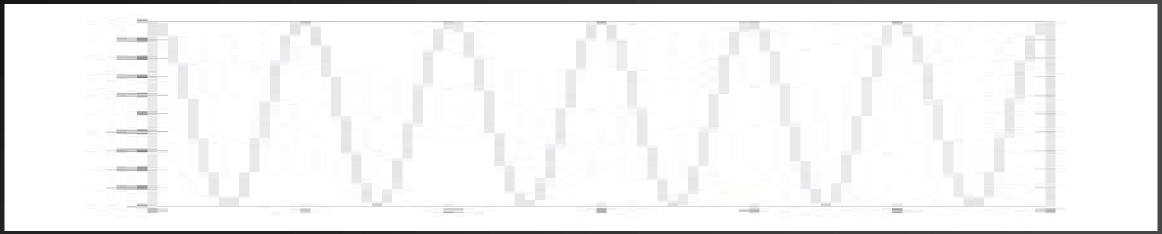
Power Combining Notation

• Signals from multiple transmitters are combined either *coherently* (in phase) or *incoherently* (out of phase using Rake receiver) at the receiver in order to achieve a desired signal-to-noise (SNR) ratio, e.g., get a decent signal.

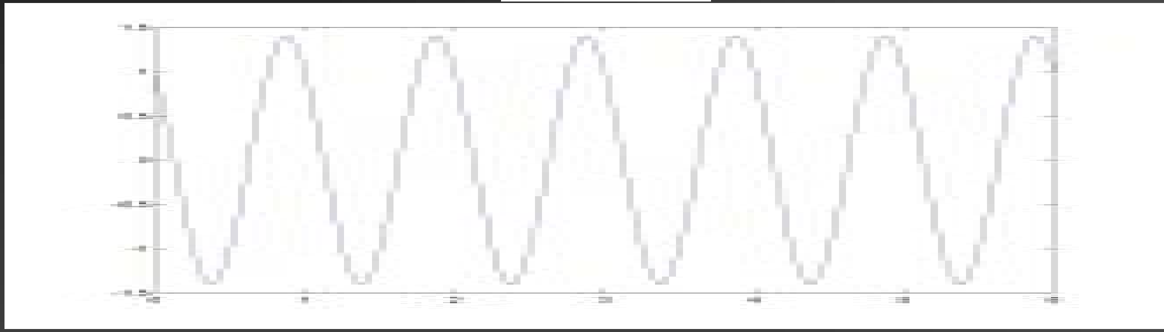


A Case for Power Combining (cars in between cities on highway, the cell tower is unsupportable)

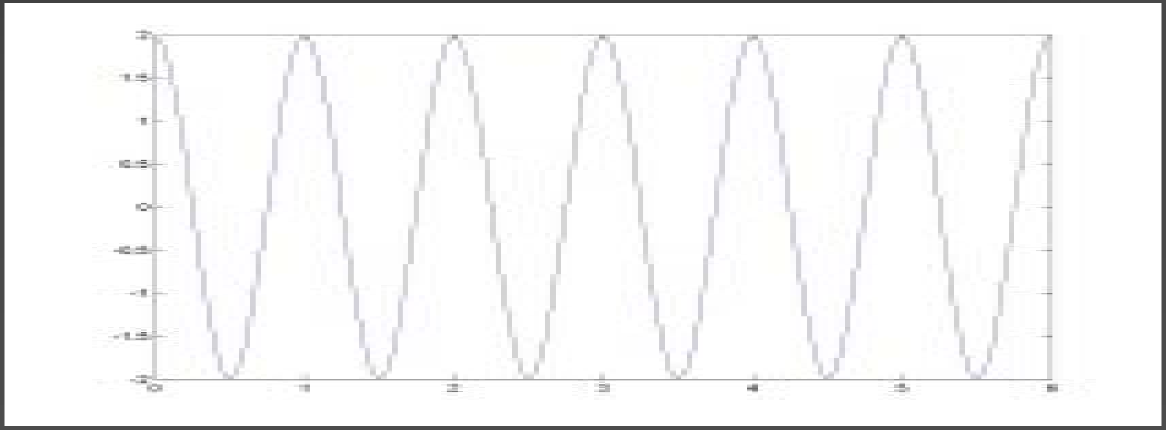
The Power Combining



(a) The shape of the signal $x_1(t) = \cos(2\pi t)$



(b) The aggregated signal of $x_1(t)$ and $x_2(t)$, where $x_2(t) = \cos(2\pi t + \frac{\pi}{2})$

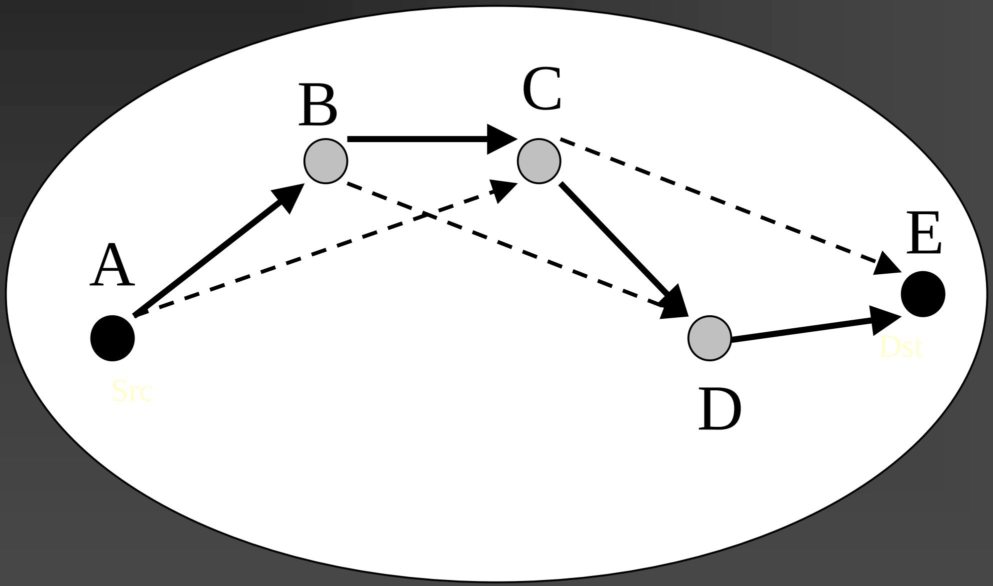


(c) The aggregated signal of $x_1(t)$ and $x_2(t)$, where $x_2(t) = \cos(2\pi t + 2\pi)$

Cooperative Routing in Wireless Networks

Cooperative Routing Notation

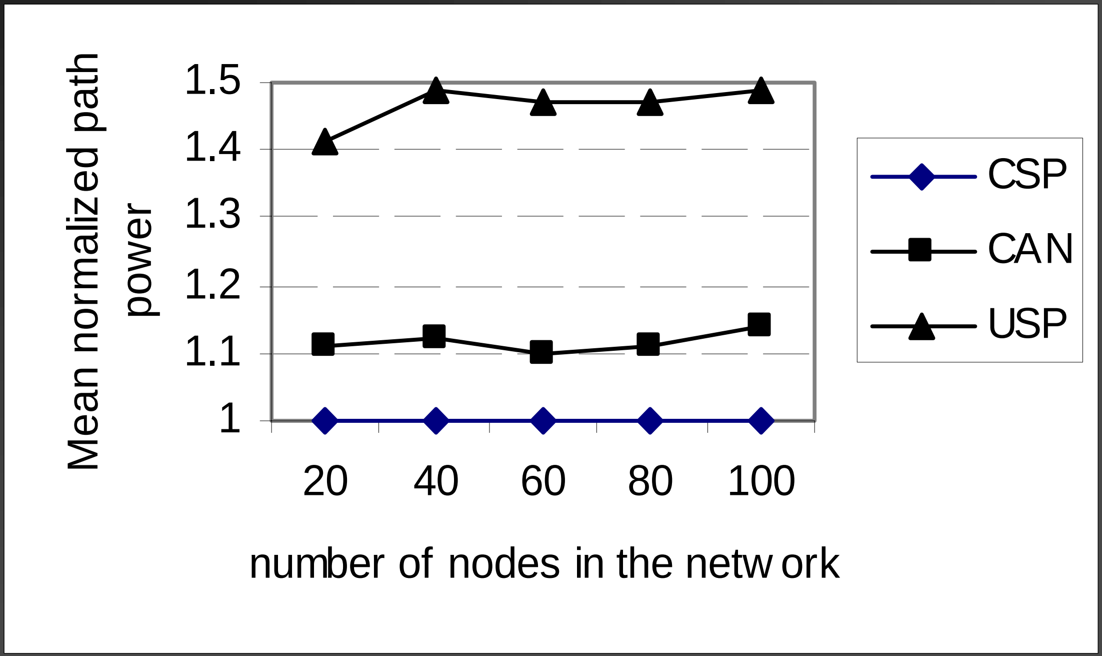
- It combines ***route selection*** and ***transmit diversity***



An Illustration of Cooperative Routing

Cooperative Routing Cont'd

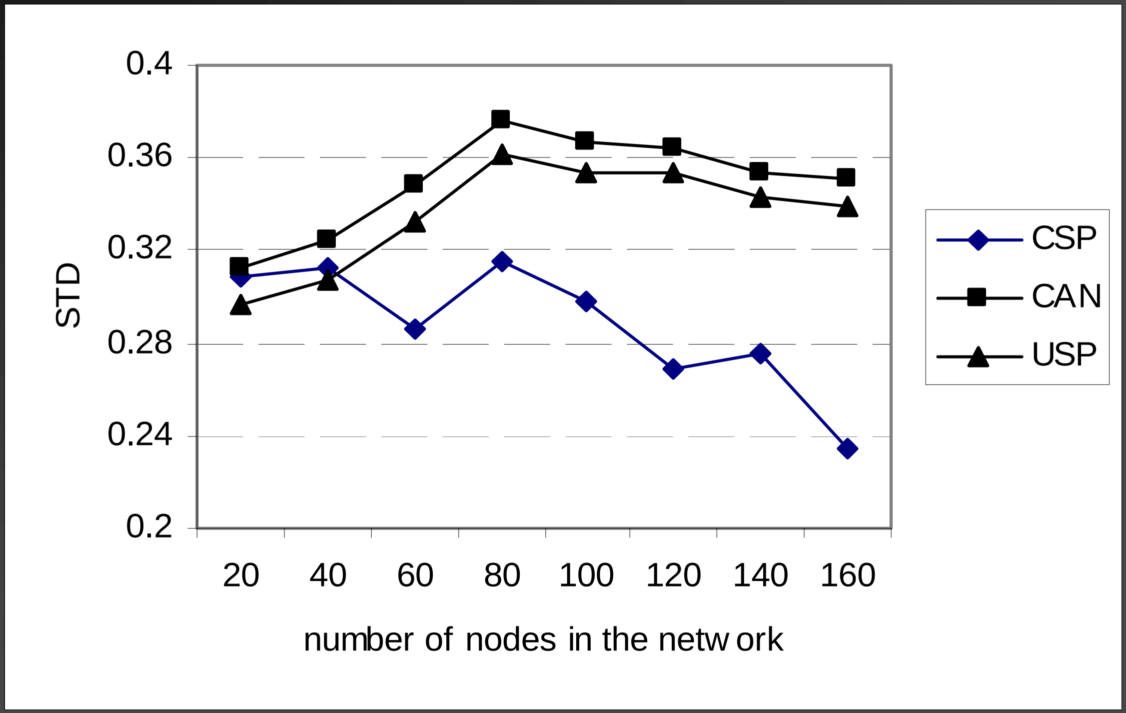
Empirical Results



Observation: As more nodes added in the network, more power savings can be achieved for the cooperative approach compared with non-cooperative approaches

Cooperative Routing Cont'd

Empirical Results



Observation: as more nodes added in the network, the presented approach achieves more fairness/load balance

Conclusion

We address ***cooperative multicast*** and ***cooperative routing*** in wireless networks.

- Emerging applications need efficient implementation of multicast and power combining in next generation wireless networks

- Our study suggests that the presented approaches tend to make the network more efficient and more scalable from both energy conservation and fairness/load balance standpoints in wireless networks

Snapshots of the network prototype

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Thank you!