

Cooperative Communications: *What, Why, and How?*

Shuguang Cui



What is Cooperative Communication?

A Definition: Any communication schemes that have *multiple* nodes contributing to the *processing* of the *same* piece of information.

- “Processing” stands for:
 - Joint transmission at the physical/MAC layers
 - Relay at the network layer
 - Information handling at the application layer



Cooperative Concept is not NEW!

- Traditional Networking Protocol

- Multi-hop routing
- Deterministic medium access control
- Certain random access schemes

} Traditional
networking
is cooperative!

- What's New?

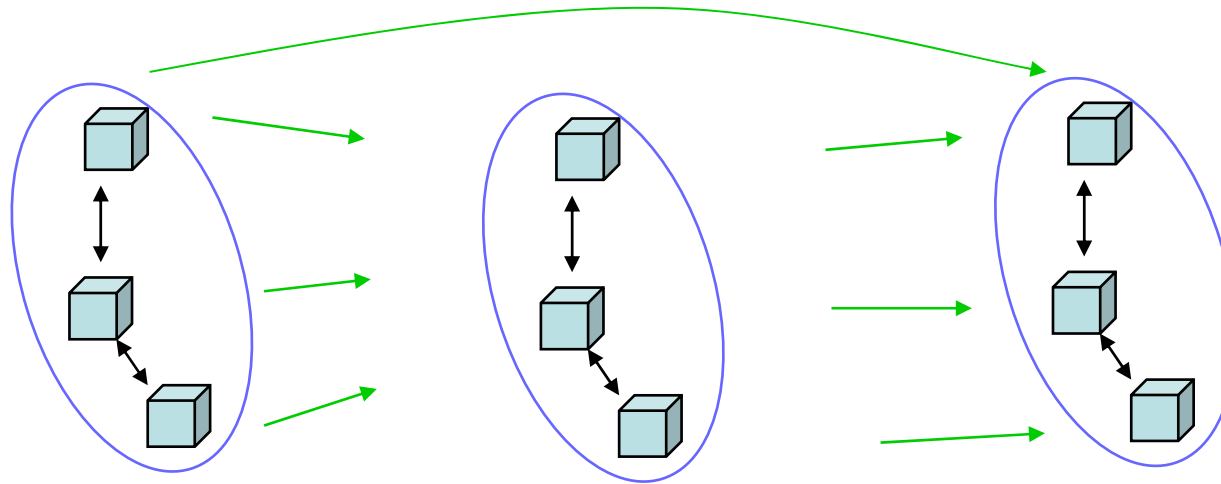
- Cooperative transmission in the link layer (motivated by MIMO results)
- Integrated design with cross-layer optimization or network coding approach
- Cooperative behavior in autonomous networks



Why to Cooperate?

- Type I: **Network-driven**
 - Designed to cooperate (such as sensor networks)
 - Maximize sum/common utility (no fairness guarantee)
- Type II: **Self-driven**
 - Designed to compete (such as cognitive radios, things in the ISM bands)
 - Cooperate because of being greedy: Only cooperate when it is more beneficial
 - Maximize individual utility (no cooperation guarantee)

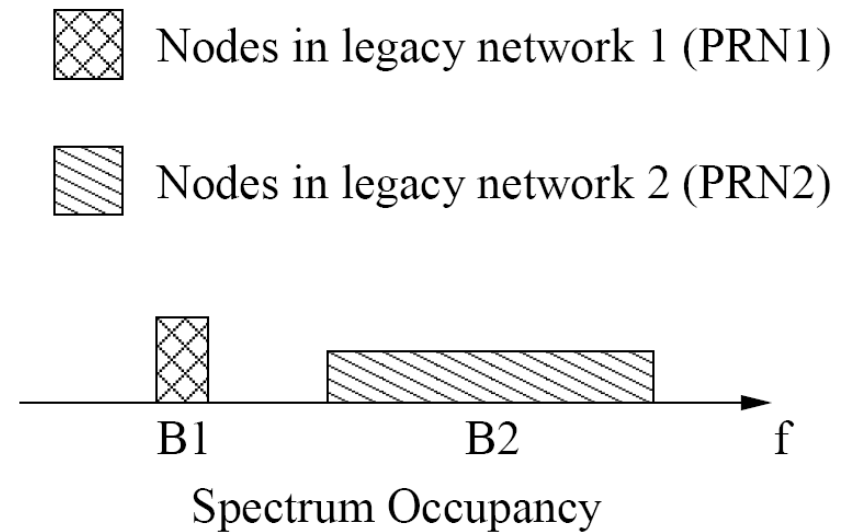
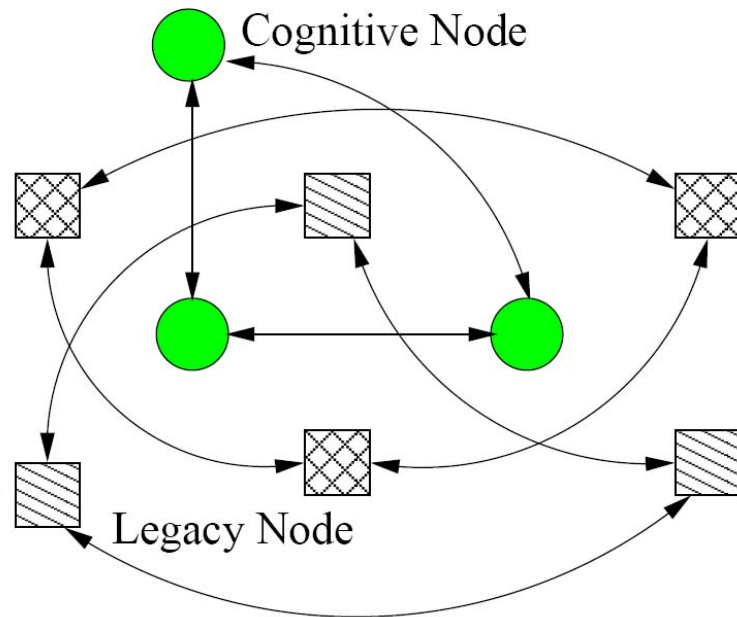
Cooperation with Cross-layer Design



- Cooperative communication is inherently a cross-layer or even layerless design problem
- Cooperative MIMO + MAC + Routing
- Suitable for network-driven applications



A Self-driven Cooperative Example



- Competition over spectrum
- Cooperation with traffic relaying



Applications of Game Theory

- Games with individual players
 - Competition with rational strategies
 - Cooperation only means less aggressiveness
 - Equilibrium solutions may not be social optimal
 - Possible distributed implementation
- Cooperative games with coalitions
 - Full cooperation within a coalition, with promised larger individual utility
 - More severe competition among coalitions
 - Compromise between centralized and pure distributed approaches



Challenges

- Lack of network-wide optimality criteria
 - Maximize rate? Minimize power? Minimize distortion? Or a unified figure of merit?
- Cross-layer design is still a myth
 - Balance between layered and layerless approaches
- Problems with cooperation at individual layers
 - Application layer: Security (authentication and encryption)
 - Networking: Route discovery in a mixed cooperative + competitive neighborhood
 - MAC: Balancing cooperation and competition in a distributed way
 - Physical Layer: Synchronization

