COOPERATION IN WIRELESS COMMUNICATION NETWORKS

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Outline

Introduction

Potential Benefits

Challenging Issues at Different Protocol Layers

Future Directions

Conclusion
Introduction

Cooperation:
- The process of working together
- Social science & Economics → Wireless communications

Cooperation Scenarios

- Improve channel reliability through spatial diversity
- Improve throughput through resource aggregation
- Achieve seamless service provision

User mobility support
Limited resources
- Modifications to the networking protocol

- Questions:
  
  What are potential benefits of cooperation in wireless communication networks?

  What are challenging issues that arise at different layers of the protocol stack to support cooperation and how can we handle them?

  What are open research issues?
Outline

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Potential Benefits

1. Improved Channel Reliability

Mitigating Channel Impairments

Spatial Diversity

Interference Reduction

Txion power reduction

Solving hidden terminal
Potential Benefits Cont.

2. **Improved System Throughput**
   - Resource Aggregation

3. **Seamless Service Provision**
   - Substitute Path

4. **Operation Cost Reduction**
   - Improved Energy Efficiency
   - Network Coverage Extension
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Challenging Issues

- **Objective**
  
  Improve QoS

  - Spatial diversity to improve channel reliability
  - Resource aggregation to improve system throughput
  - Achieve seamless service provision for service continuity

- Challenging issues at different layers of protocol stack
  - Physical layer
  - MAC layer
  - Network layer
  - Transport layer
Transport Layer
Network Layer
MAC Layer
Physical Layer
Challenging Issues ➔ Physical Layer

1. Challenges at Physical Layer

Spatial Diversity
- Cooperative strategies: AF, DF, and CC

Channel information
- Exchange
- Update

Hardware complexity
- Sample buffer
- Combiner

Resource Aggregation & Seamless Service Provision
- TX and RX on multiple channels simultaneously

Multiple radio interfaces
- Parallel physical layers

Single radio interface
- D-OFDM
Challenging Issues ➔ MAC Layer

2 Challenges at MAC Layer

A. When to use cooperation?
   - Cooperation not always beneficial
     - Cooperation gain too small to compensate for its cost

Adaptive MAC Protocol

- Improve channel reliability
- Resource aggregation
- Seamless service provision

- Transmission accuracy
- Insufficient resources to satisfy QoS
- Unable to communicate through direct link
Challenging Issues ➔ MAC Layer Cont.

- Consider cooperation overhead in making cooperation decision

  → Signaling overhead required to select cooperating entities

  **EX:** Cooperation to improve channel reliability is beneficial only when:

  Payload length is sufficiently large compared to signaling overhead

- Decision is based on instantaneous measurements of channel gain and achieved throughput

  → Cross-layer design between MAC & physical layers
B. Optimal selection of cooperating entities

Number of Cooperating Entities
- Single vs. Multiple Entities

Cooperating entities Selection Mechanism
- Centralized vs. Distributed Selection

Stimulate Optimal Entities to Cooperate
- Cooperation Incentives
I. Number of Cooperating Entities

Single Entity Selection
- Only best cooperating entity is selected
- Adv.: simplicity of selection operation
- Disadv.: may fail to meet the required QoS

Multiple Entity Selection
- Enlarged interference
  - Proportional to number
  - Reduce spatial freq. reuse
  - Obj.: Min. number of entities and reducing interference range while satisfying QoS
- More ctrl signaling overhead
  - Maybe addressed through clustering
Challenging Issues ➔ MAC Layer Cont.

B. Optimal selection of cooperating entities

Number of Cooperating Entities
- Single vs. Multiple Entities

Cooperating entities Selection Mechanism
- Centralized vs. Distributed Selection

Stimulate Optimal Entities to Cooperate
- Cooperation Incentives
II. Selection Mechanism

Centralized
- Employs central controller
- Adv.: global view $\Rightarrow$ optimal selection
- Disadv.
  1. Significant feedback msgs
  2. Maybe infeasible

Distributed
- Identify Cooperation Capabilities
- Perform Selection
  1. Busy Tone
  2. Timer Based
B. Optimal selection of cooperating entities

- Number of Cooperating Entities
  - Single vs. Multiple Entities
- Cooperating entities Selection Mechanism
  - Centralized vs. Distributed Selection
- Stimulate Optimal Entities to Cooperate
  - Cooperation Incentives
III. Cooperation Incentives

- Cooperation is a two-way decision
- Different entities can choose not to cooperate
- Optimal selection design must guarantee win-win situation
- Incentive schemes
  a. Reputation based
  b. Remuneration based
  c. Game theory
Challenging Issues ➔ Network Layer

3 Challenges at Network Layer

A. Cooperation through Spatial Diversity

- New Link Definition
- Optimality vs. Complexity
- Multi-flow Throughput

Reinvestigate routing protocols

- Can be computational intractable

Heuristic Techniques

Contention graph
B. Cooperation through Resource Aggregation & Seamless Service Provision

- Multi-path Routing

Cost of Route Establishment and Maintenance
- Heuristic algorithms for route establishment
- N path route discovery

Delay Differences
- Differential delay problem
- Reordering buffer limited size

Multi-path Interference
- Mutually independent paths
- Path coupling metric

Heuristic Algorithms

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Transport Layer
Network Layer
MAC Layer
Physical Layer
Challenging Issues ➔ Transport Layer

4 Challenges at Transport Layer

A. Cooperation through Resource Aggregation

Multi-homing Capabilities
- Multiple paths
  - Several IPs
  - Fails
- Multiple TCP sockets
- Multi-homing feature
  - SCTP

Simultaneous Transmissions
- Path Assignment
  - Which path for which packet?
  - Reassignment of packets
- Packet Reordering
  - Unnecessary SACKs
  - NW load
  - Retransmission
  - Reduce Congestion window
Challenging Issues ➔ Transport Layer

B. Seamless Service Provision

Handoff from original path to alternative cooperative path ➔ TCP

- Low to High Delay Path ➔ Spurious RTO
- High to Low Delay Path ➔ Packet Reordering
- High to Low BDP Path ➔ Congestion (Packet loss)
- Low to High BDP Path ➔ Inefficient Utilization
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Open Research Issues

Cooperation Overhead
- Appropriate modeling
- Reduction techniques

Mobility
- Impact of node mobility on framework

Cross-layer Design
- Network & MAC
- Network & Transport
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THANK YOU!