COOPERATION IN WIRELESS COMMUNICATION NETWORKS

Weihua Zhuang and Muhammad Ismail

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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
  - → User mobility support
  - → Limited resources

Cooperation Scenarios

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

Introduction Cont.

- 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?

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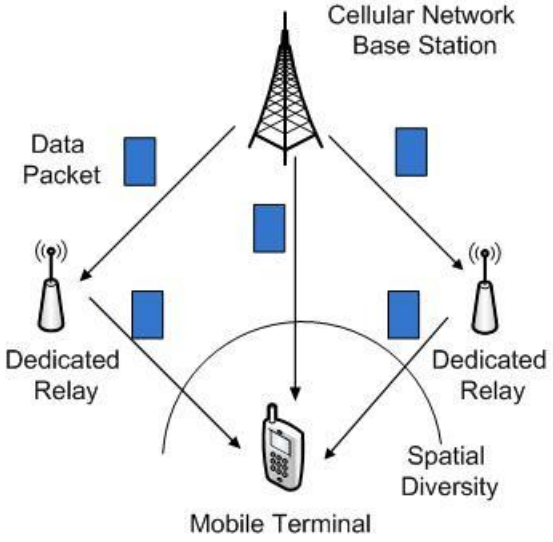
Potential Benefits

1 Improved Channel Reliability

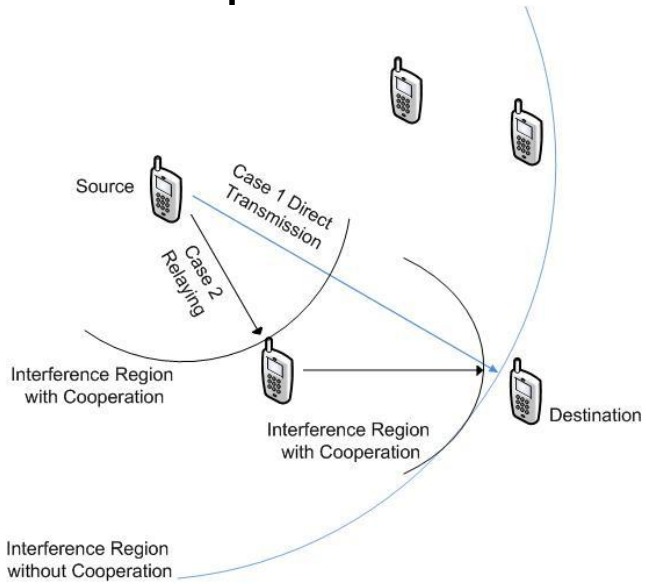
Mitigating Channel Impairments

Spatial Diversity

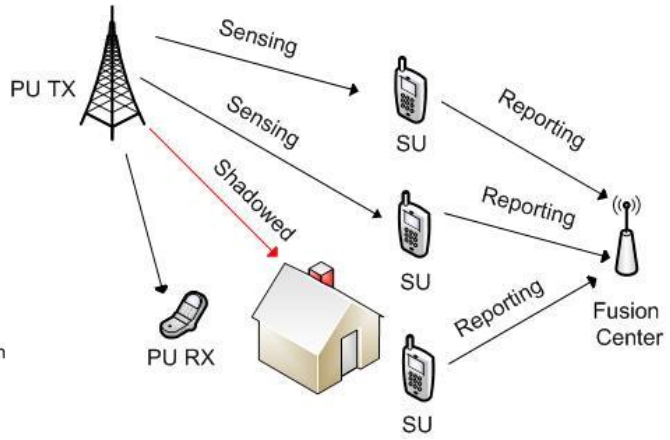


Interference Reduction

Txion power reduction



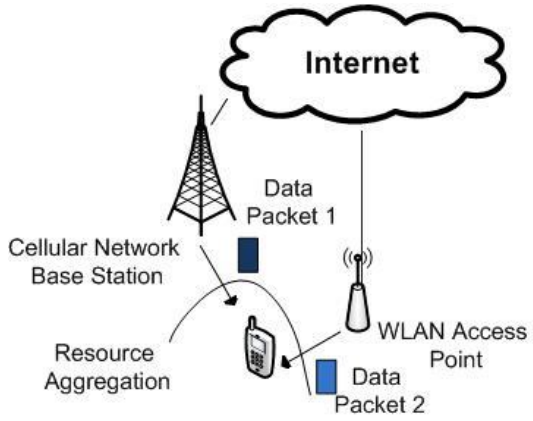
Solving hidden terminal



Potential Benefits Cont.

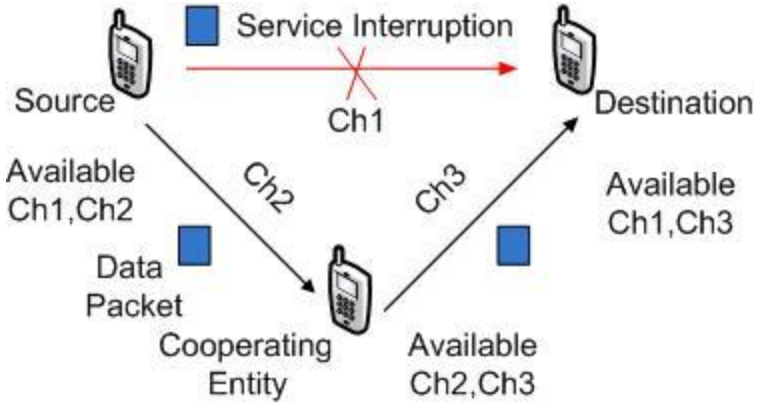
2 Improved System Throughput

Resource Aggregation



3 Seamless Service Provision

Substitute Path



4 Operation Cost Reduction

- Improved Energy Efficiency
- Network Coverage Extension

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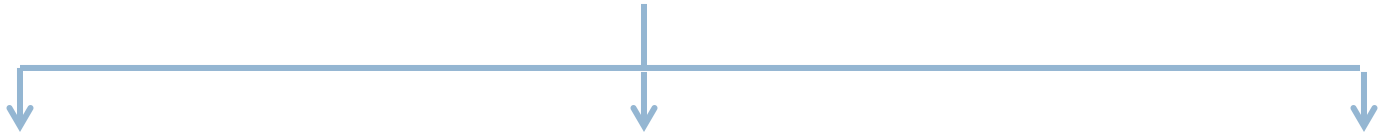
Challenging Issues

- Objective ⇨ Improve QoS

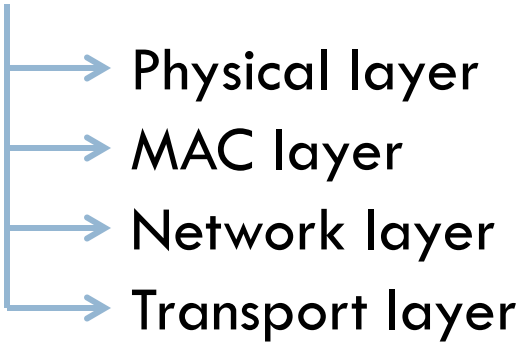


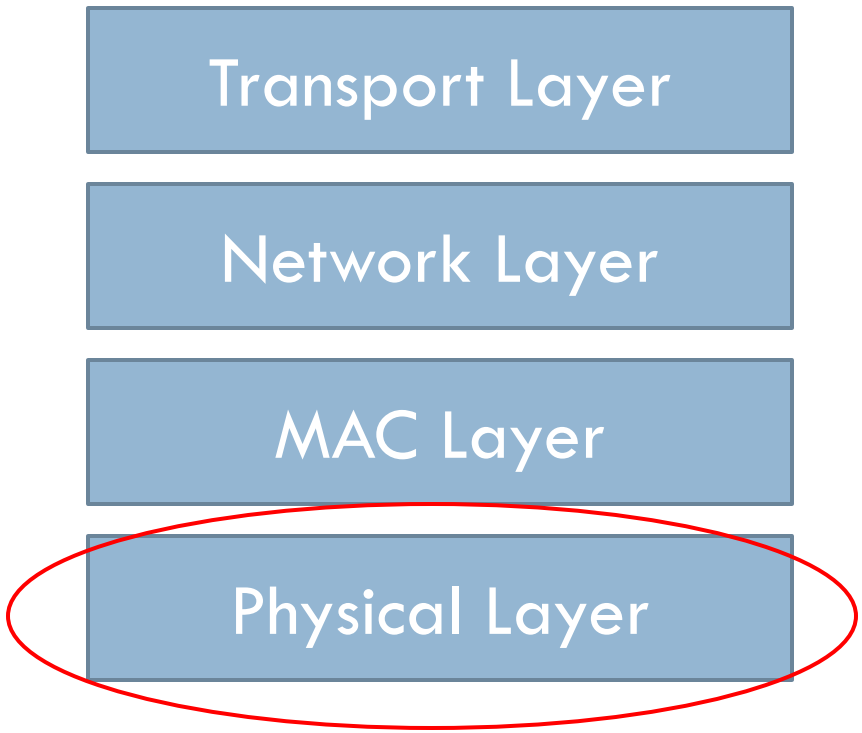
Spatial diversity to improve channel reliability

Resource aggregation to improve system throughput

Achieve seamless service provision for service continuity

- Challenging issues at different layers of protocol stack




Transport Layer
Network Layer
MAC Layer
Physical Layer

Challenging Issues ➔ Physical Layer

1 Challenges at Physical Layer

Spatial Diversity

- Cooperative strategies:

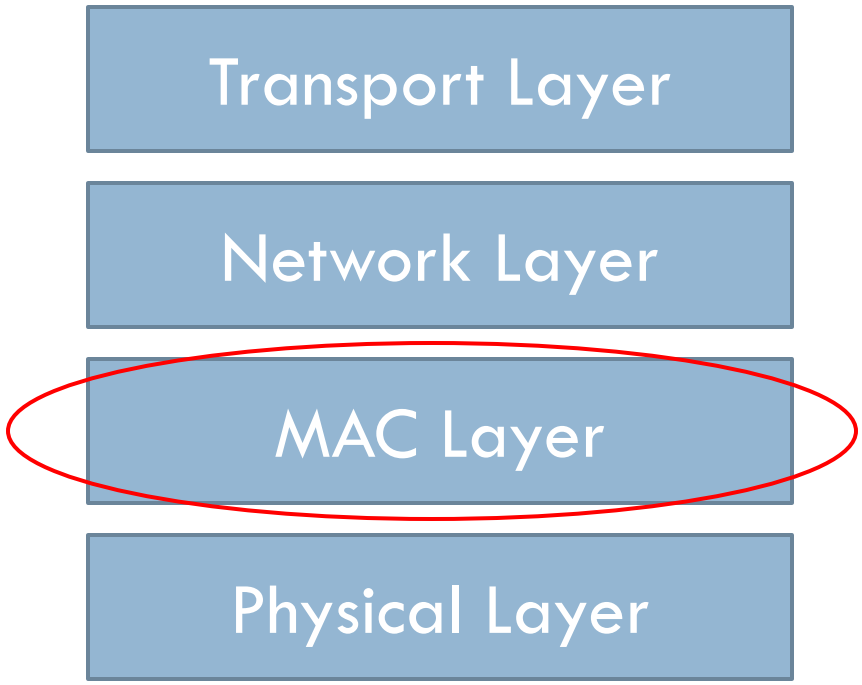
  AF, DF, and CC

- 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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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

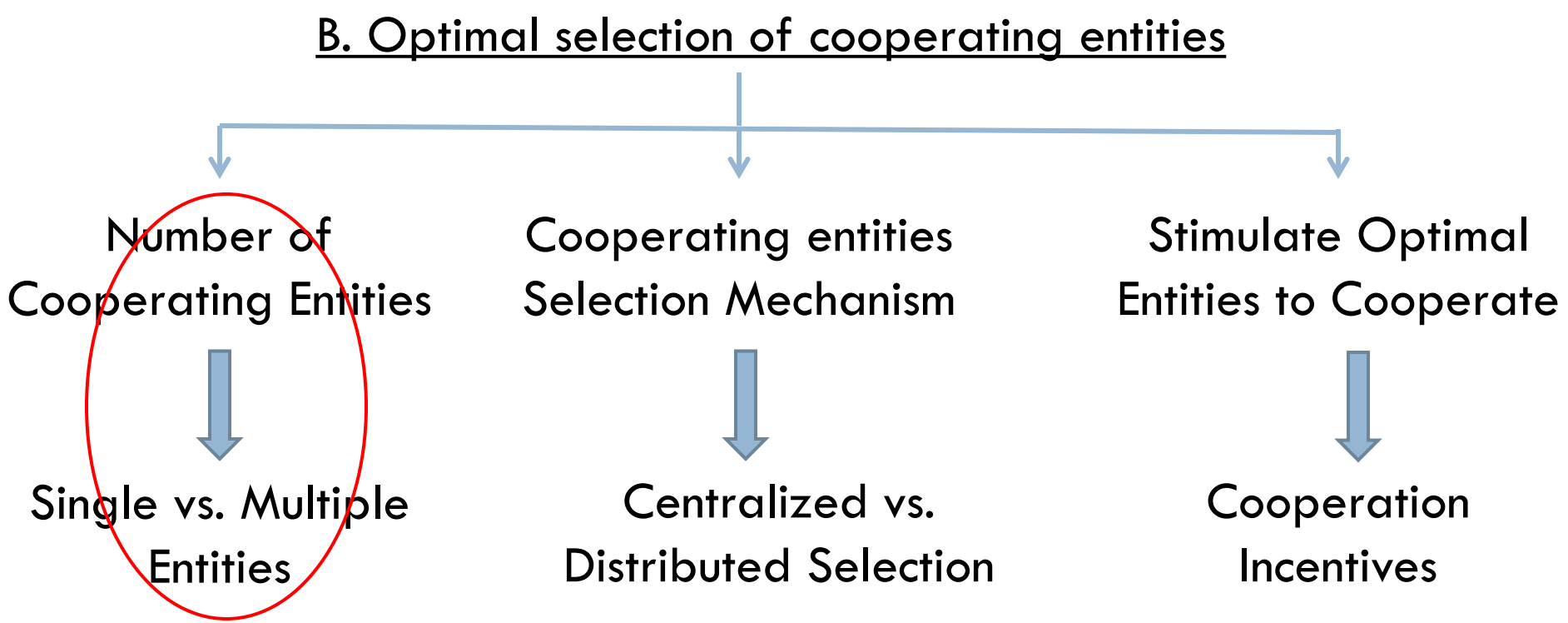
  EX: Cooperation to improve channel reliability is beneficial only when:

  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

Challenging Issues → MAC Layer Cont.



Challenging Issues ➔ MAC Layer Cont.

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

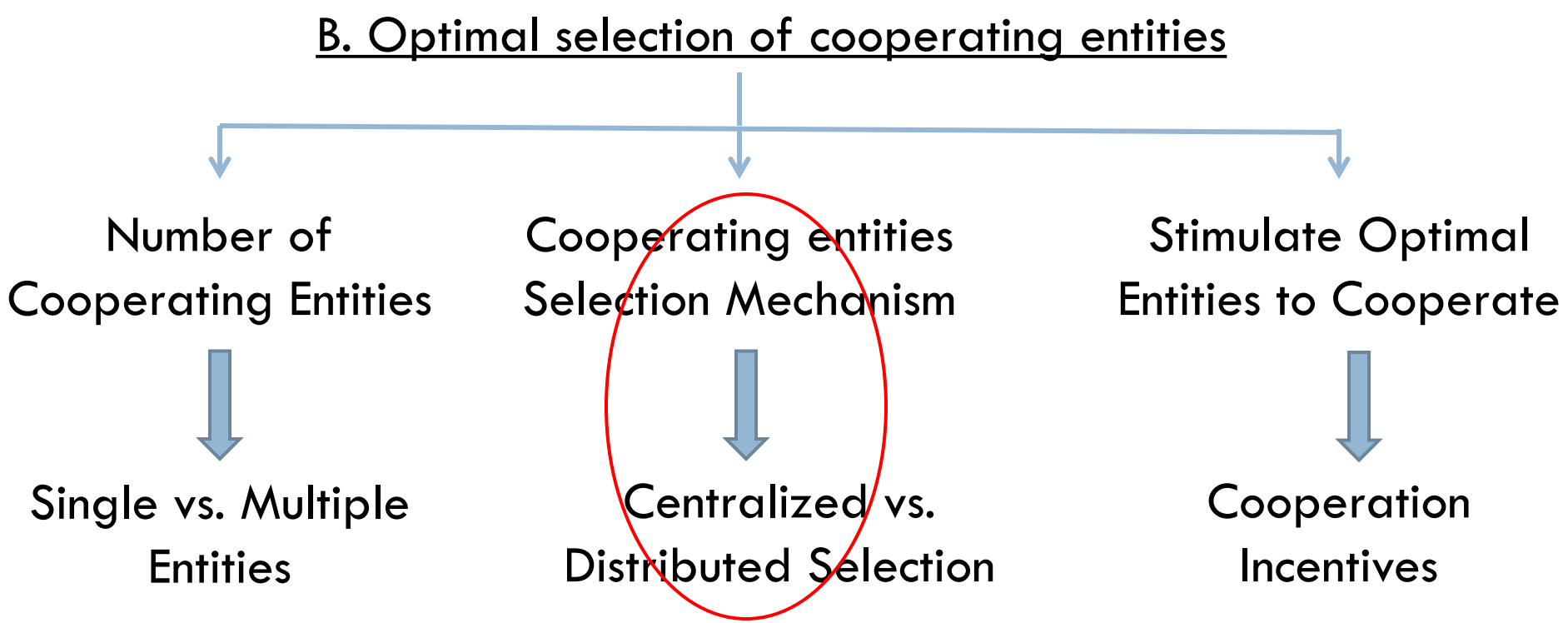
Enlarged interference

- Proportional to number
- Reduce spatial freq. reuse
- Obj.: Min. number of entities and reducing interference range while satisfying QoS

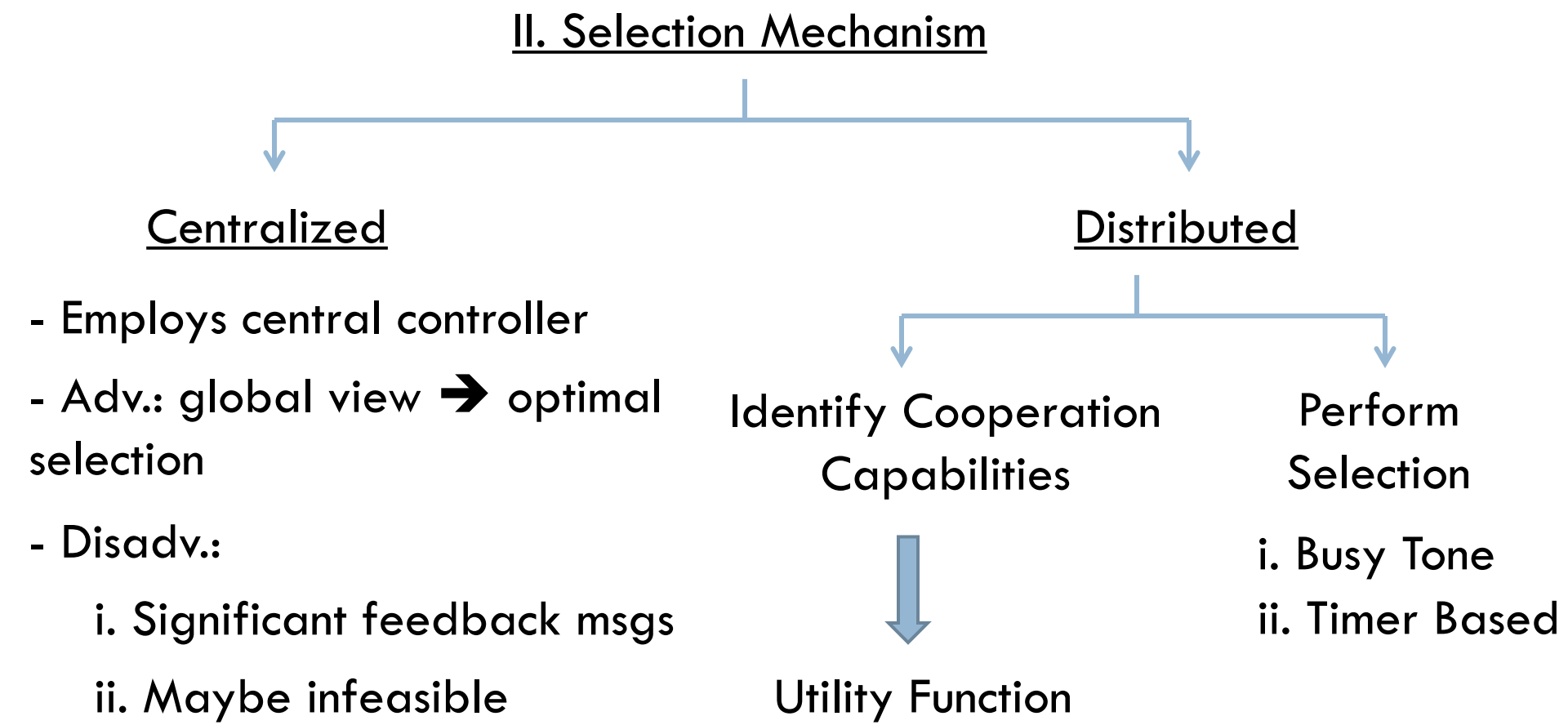
More ctrl signaling overhead

- Maybe addressed through clustering

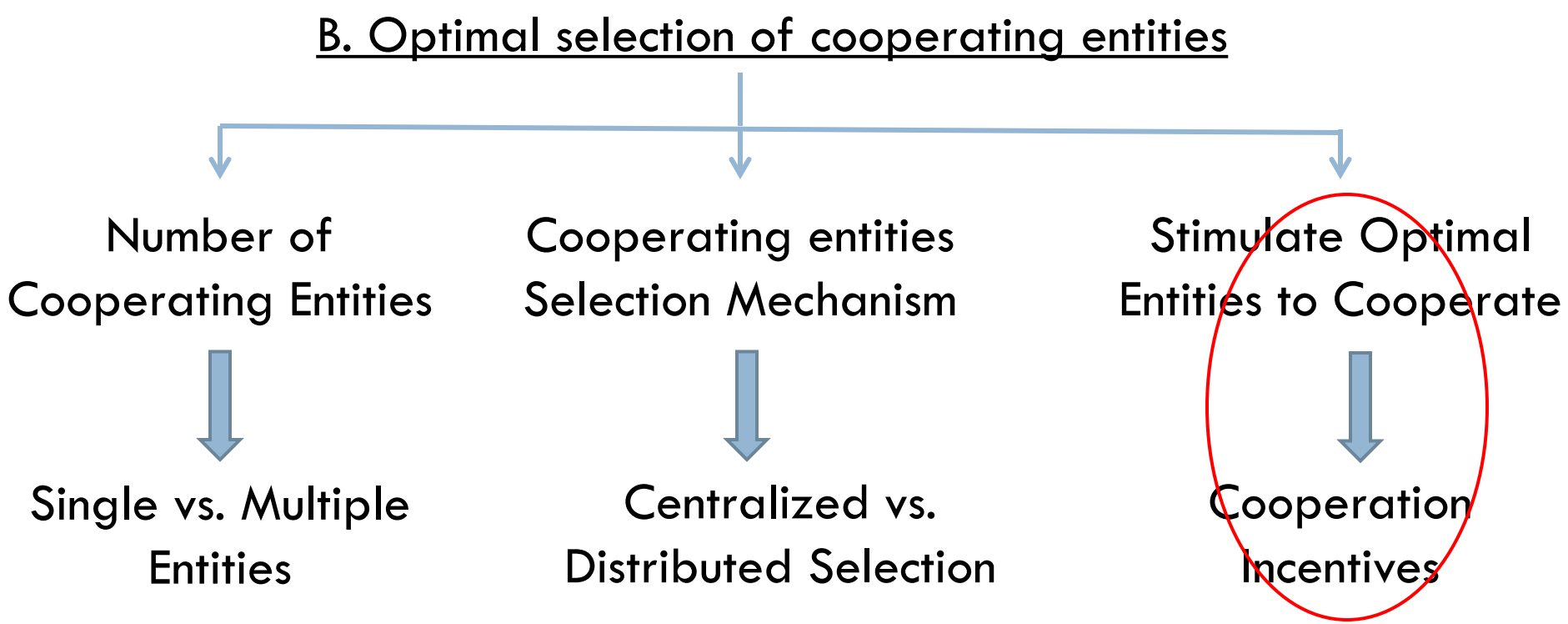
Challenging Issues ➔ MAC Layer Cont.



Challenging Issues ➔ MAC Layer Cont.



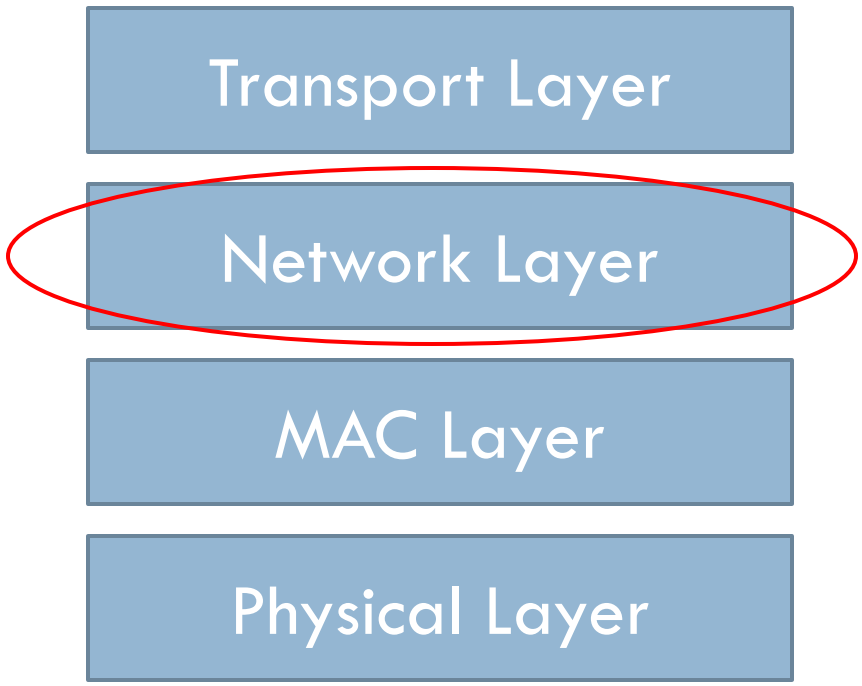
Challenging Issues ➔ MAC Layer Cont.



Challenging Issues → MAC Layer Cont.

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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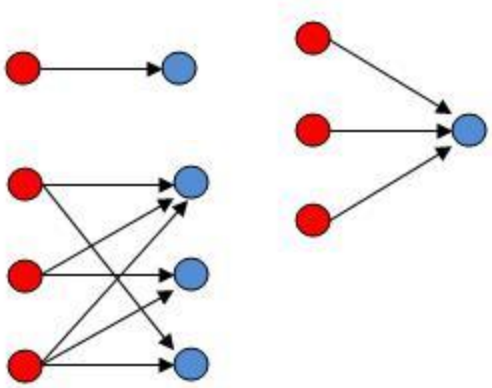
MAC Layer
Physical Layer

Challenging Issues ➔ Network Layer

3 Challenges at Network Layer

A. Cooperation through Spatial Diversity

New Link Definition



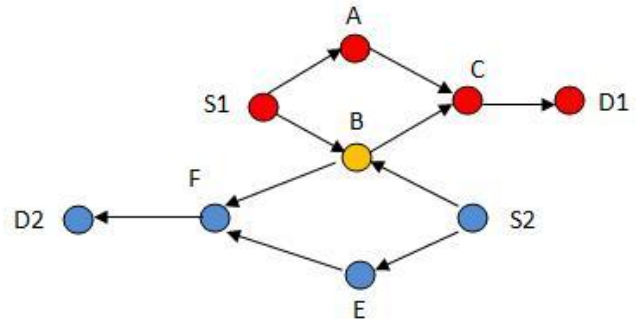
Reinvestigate routing protocols

Optimality vs. Complexity

- Can be computational intractable

Heuristic Techniques

Multi-flow Throughput

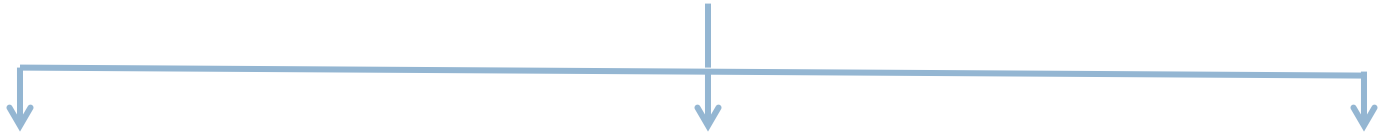


Contention graph

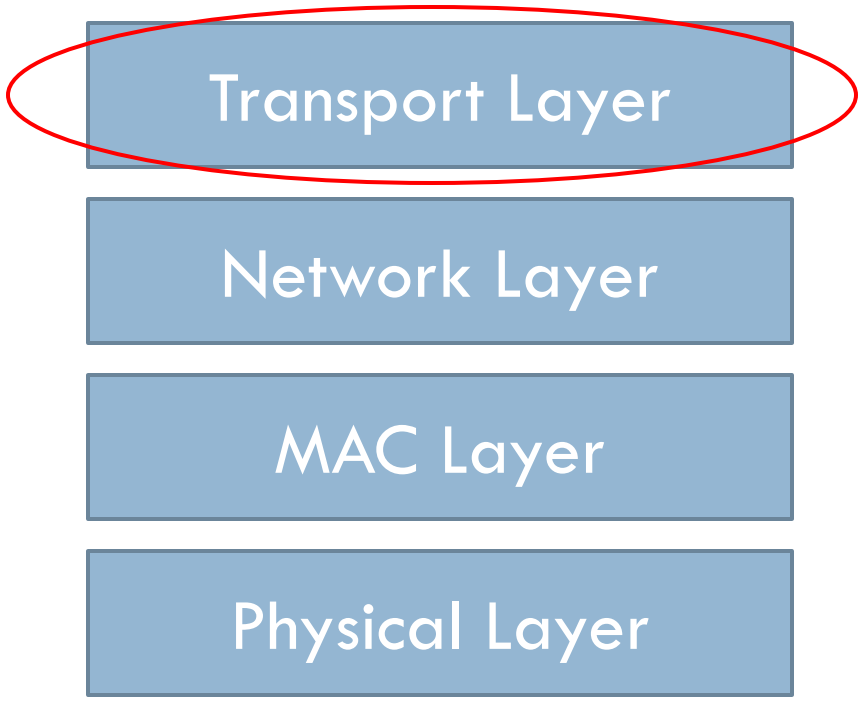
Challenging Issues ➔ NW Layer Cont.

B. Cooperation through Resource Aggregation & Seamless Service Provision

Multi-path Routing



Cost of Route Establishment and Maintenance	Delay Differences	Multi-path Interference
- Heuristic algorithms for route establishment	- Differential delay problem	- Mutually independent paths
- *N* path route discovery	- Reordering buffer limited size	- Path coupling metric Heuristic Algorithms


Transport Layer
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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
- Multiple TCP sockets
  - ⇨ Fails
- 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	High to Low Delay Path	High to Low BDP Path	Low to High BDP Path
Spurious RTO	Packet Reordering	Congestion → Packet loss	Inefficient Utilization

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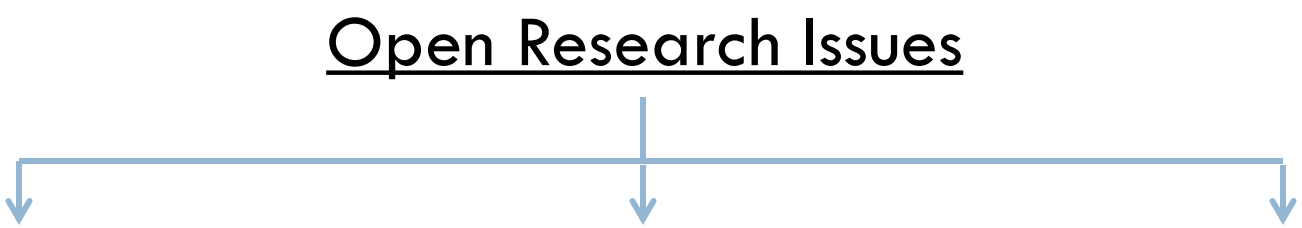

Cooperation Overhead

- Appropriate modeling
- Reduction techniques

Mobility

- Impact of node mobility on framework

Cross-layer Design

- Network & MAC
- Network & Transport

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THANK YOU !

For more information please refer to: W.Zhuang and M.Ismail, "Cooperation in wireless communication networks," IEEE Wireless Communications, vol. 19, no. 2, April 2012.