Chapter 1 Introduction

Kuang-Hao Liu

Institute of Communications Engineering
National Tsing Hua University

Outline

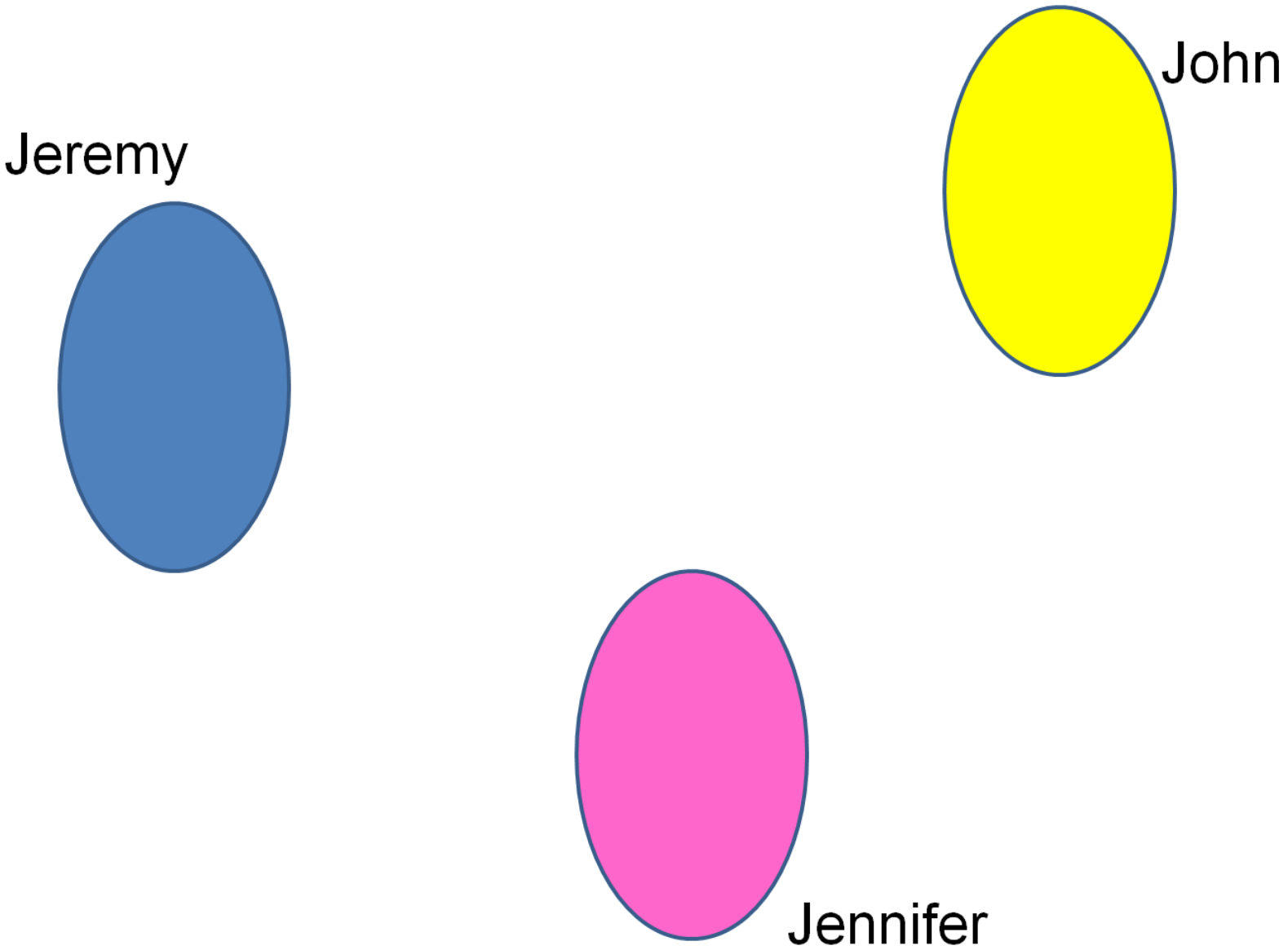
- Background
- Concept of Cooperative Relaying
- Concept of Base Station Cooperation
- Summary

Jennifer, should I choose MVC as my booster shot ?

Let me make a call.

The best choice ever!

Why Cooperation?



Background

Envision of 6G

- Very high speed: $\uparrow$ 100 Gigabits
  3G: 2Mbps; 3.5G: 14.4Mbps; 4G: 3Gbps; 5G: 10 Gbps
- Massive connectivity: 10^7 devices/Km^2
- Extremely-high reliability: 10μ sec

Fundamental challenge: signals transmitted over wireless attenuated in various forms

Background (Cont'd)

Signal attenuation

- Path loss
- Shadowing
- Multipath propagation

Pathloss and shadowing may be mitigated by power control

Multipath propagation is tackled by diversity techniques

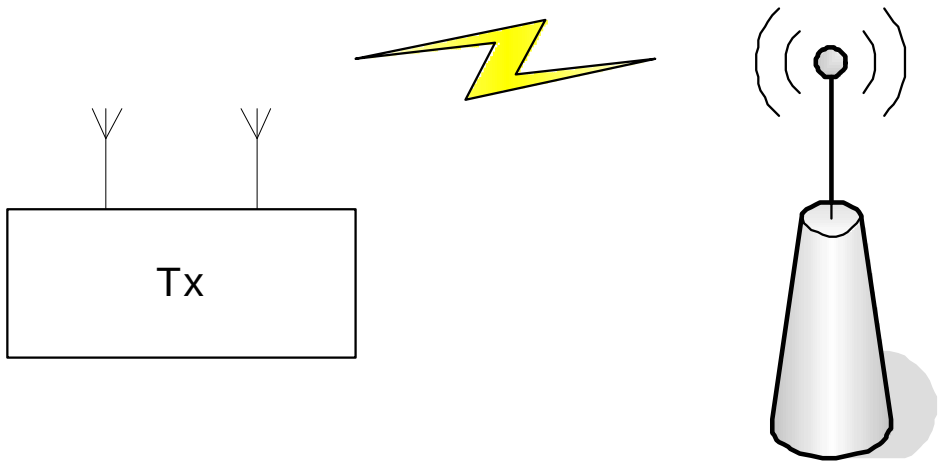
Diversity

Send the same (redundant) information over different _____.

Spatial Diversity

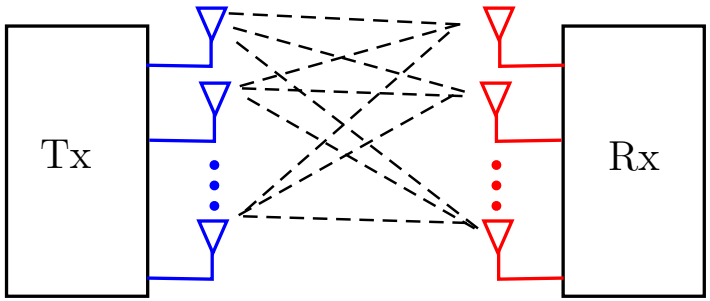
- Transmit diversity (MISO)
- Receive diversity (SIMO)
- Transmit and receive diversity (MIMO)

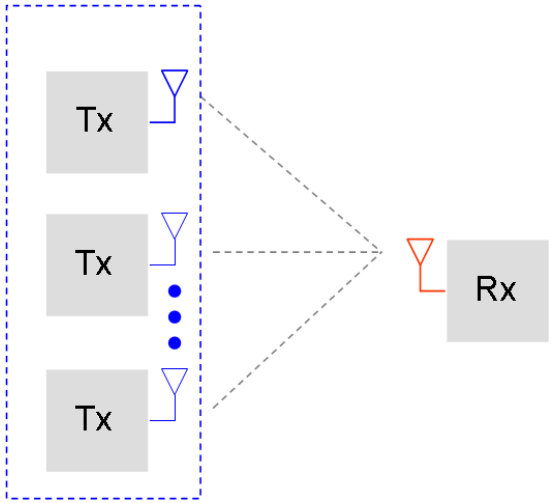
Spatial Diversity



- Antennas should be separated by the distance of a few wavelengths
- E.g., wavelength = 0.33 m for 900 MHz signal
- For small form factor of mobile (handheld) devices, large antenna array is not feasible

Virtual Antenna Array



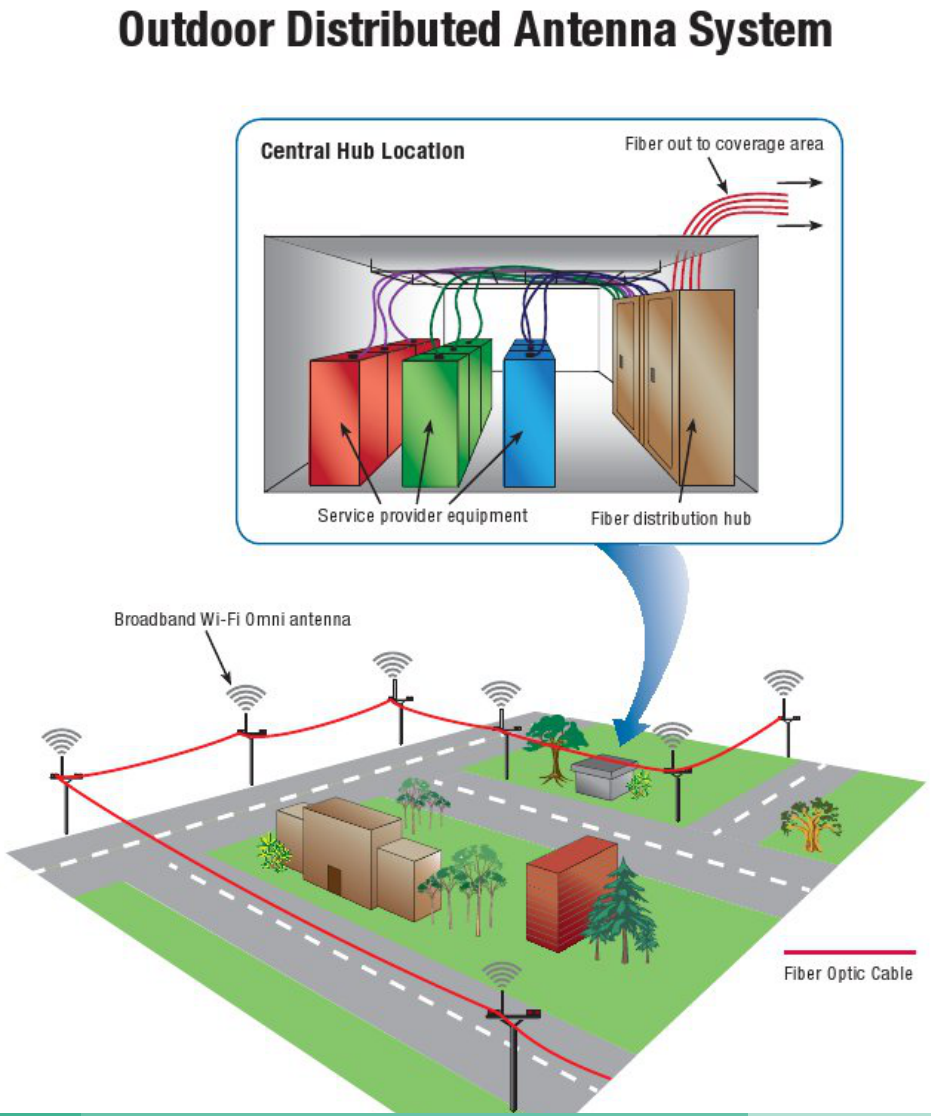


- Forming a *Virtual* antenna array (VAA) by distributing antennas in the network [*Dohler'02*]
- Promising alternative to MIMO without the need of collocated antennas

Implementation of VAA

Two approaches to implement VAA

- VAA connected through coaxial cables or fibers



Concept of Cooperative Relaying

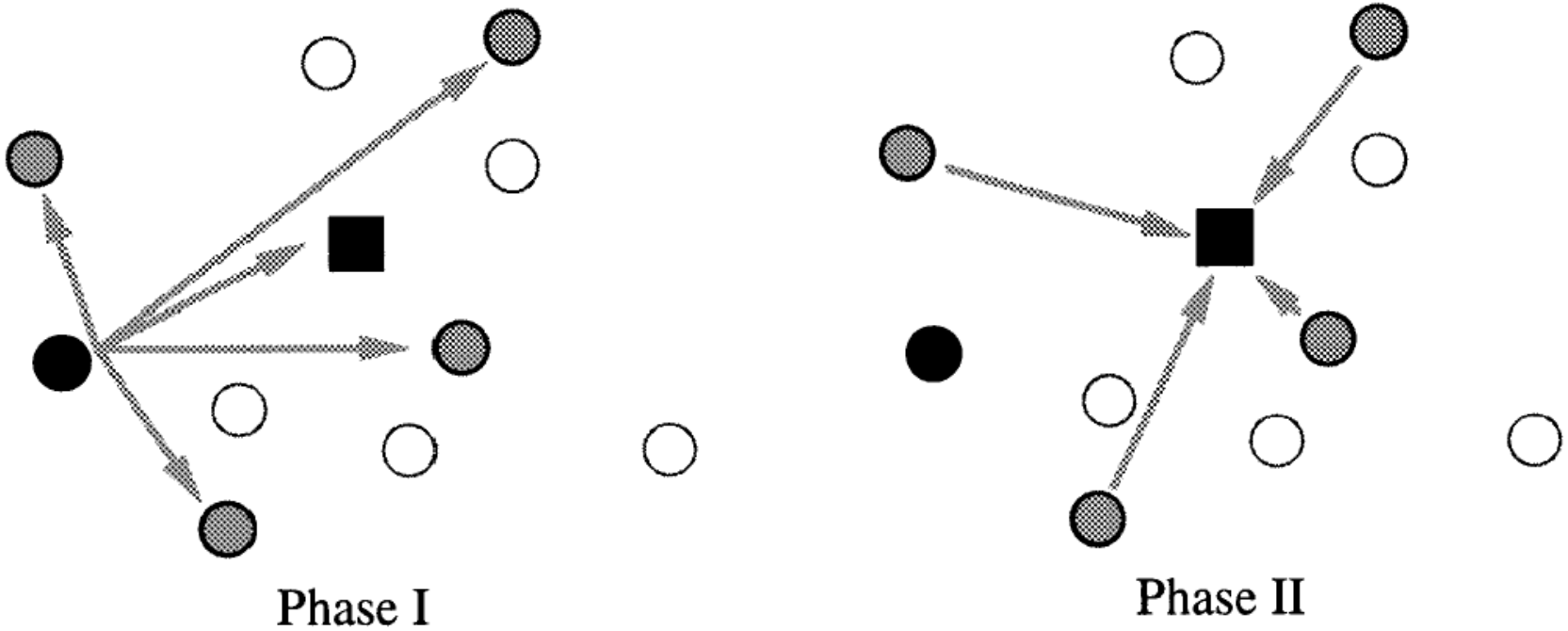
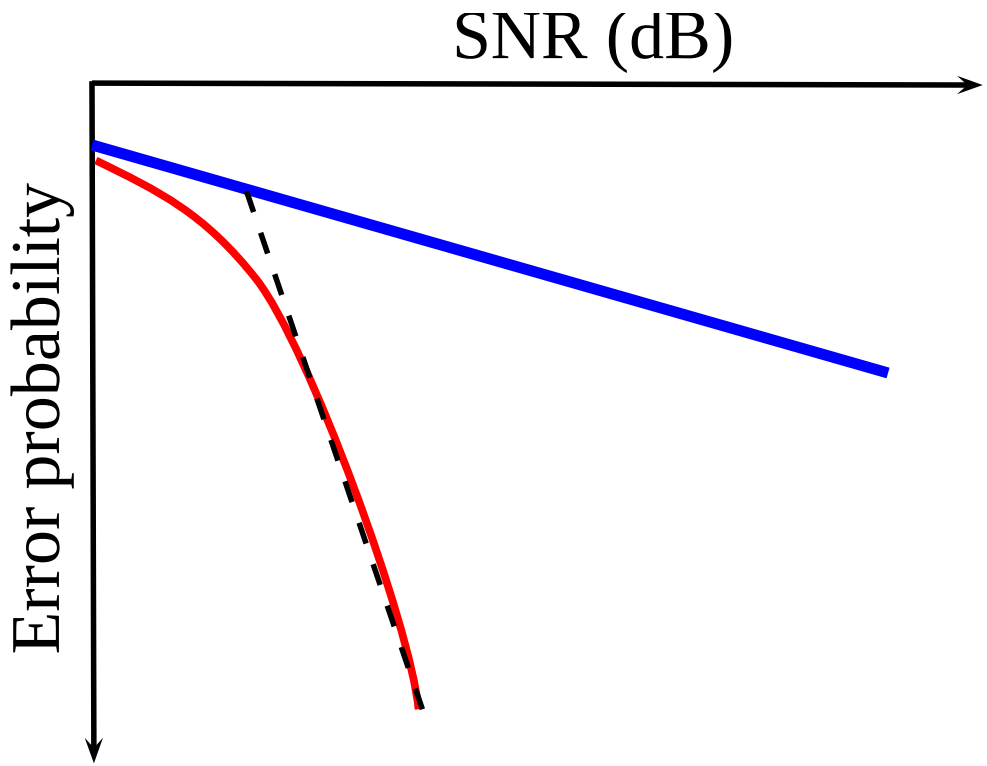


Figure from J. N. Laneman *et al.* '03

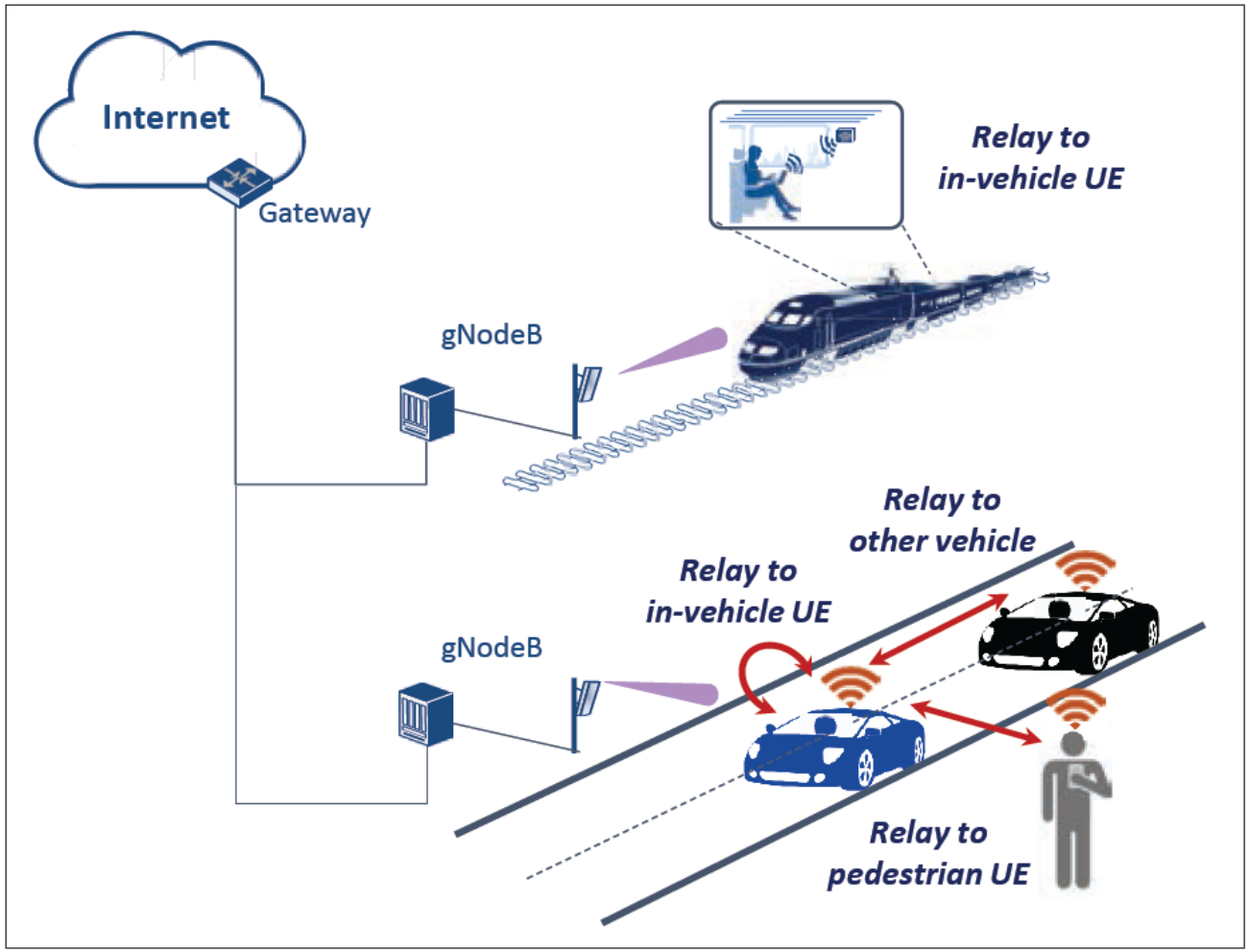
Benefit of Cooperative Relaying

Diversity gain: a metric to evaluate the increase in the error rate slope as a function of SNR



Standardization Activity

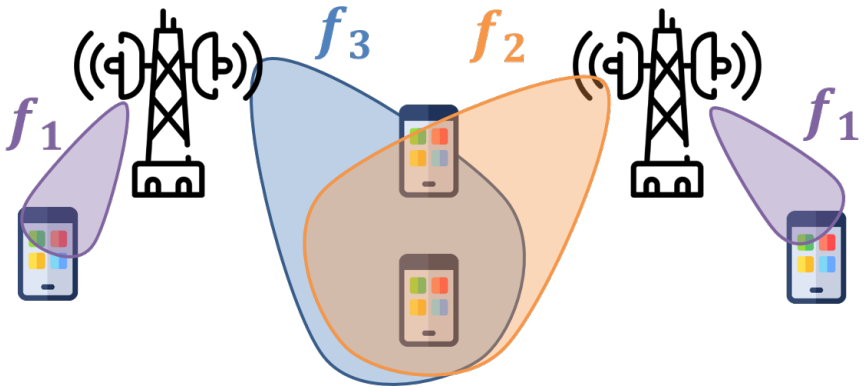
- Included feature of IEEE 802.16j
- Mobile relays discussed in 3GPP



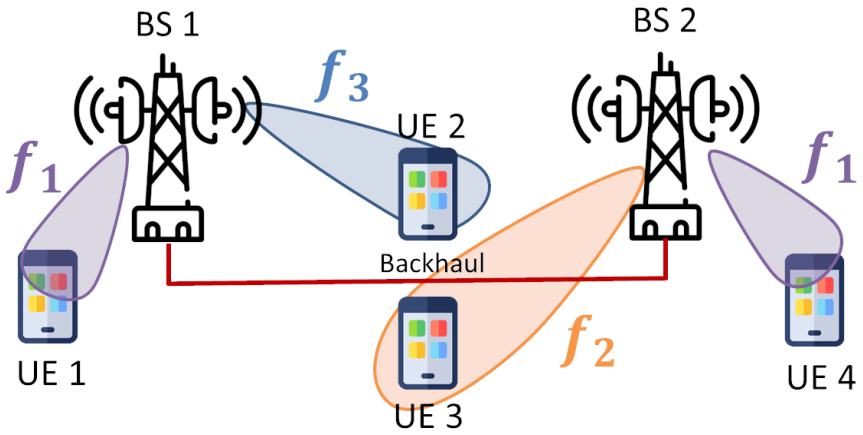
G. Noh, H. Chung, and I. Kim, "Mobile relay technology for 5G," IEEE Wireless Commun., 2020.

Base Station Cooperation

Coordinated scheduling



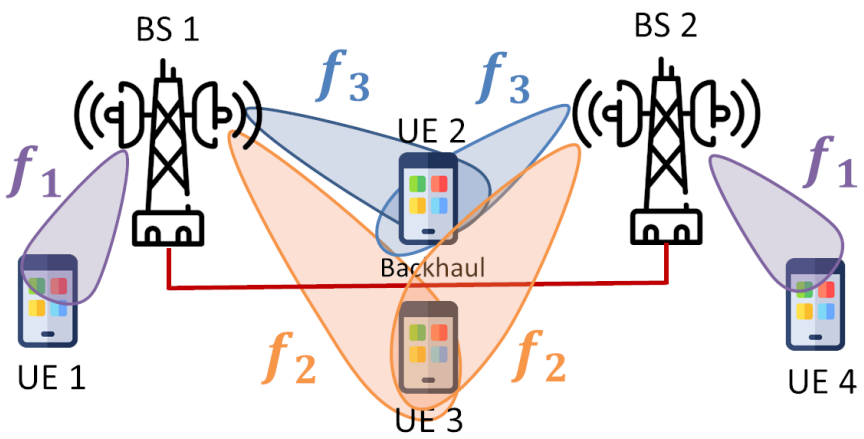
Coordinated beamforming



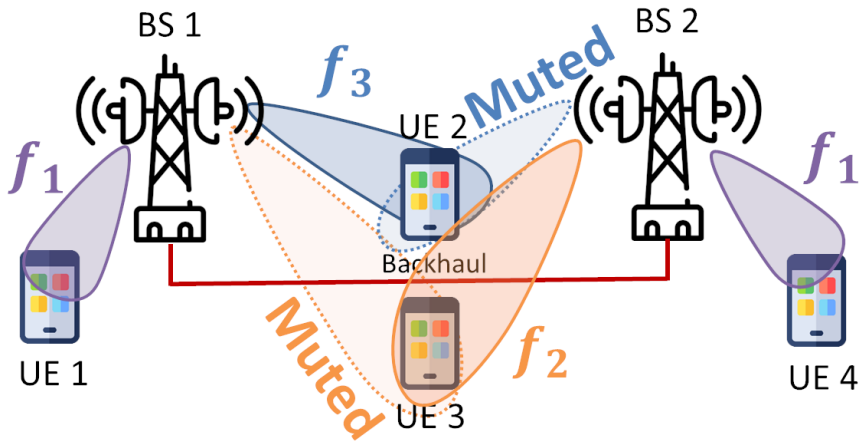
- Avoid interference by coordination between BSs.

Base Station Cooperation (cont'd)

Joint transmission



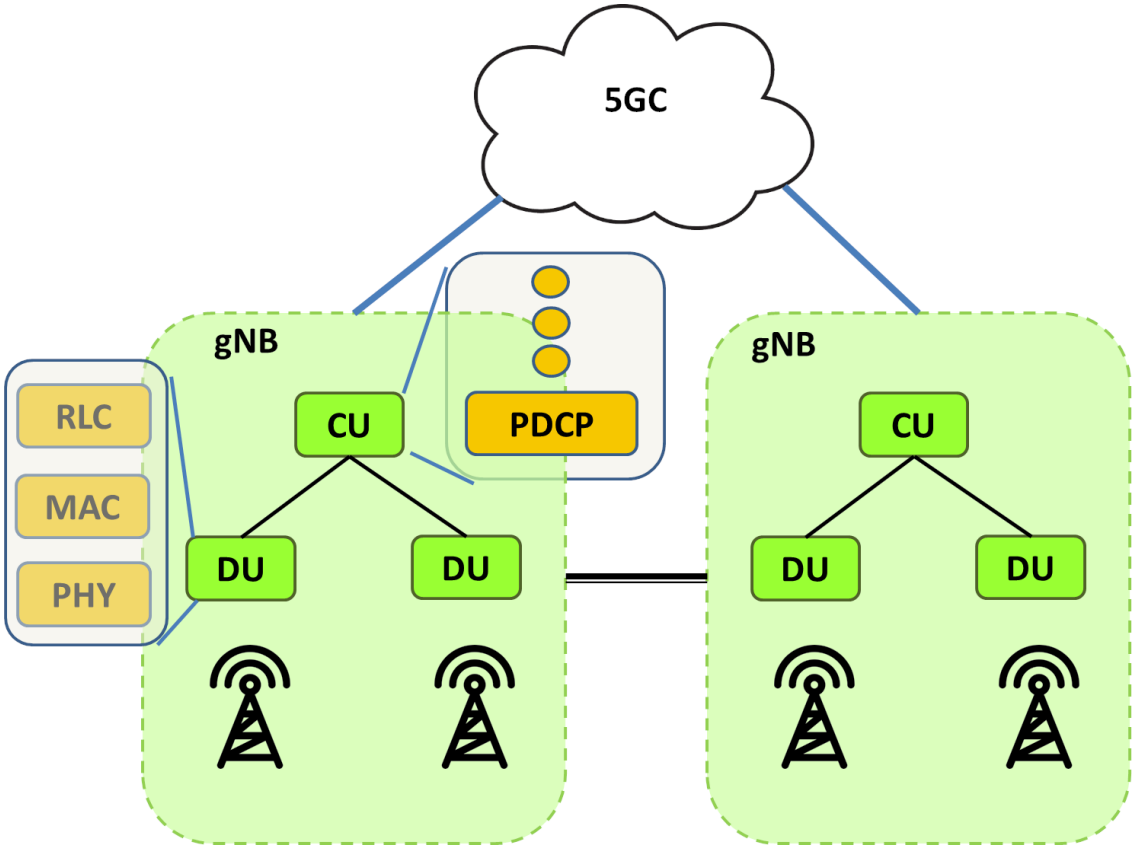
Dynamic point selection



- Enhance signal strength by coordination between BSs.
- Compared with JT, DPS introduces less interference.

Support of BS Cooperation in 5G

To support flexible coordination between BSs, 5G NR splits a physical BS into functional blocks.



Summary

- The notion of node (relay, base station) cooperation offers an alternative to overcome channel impairments
- Cooperative relaying exploits the broadcast nature of wireless transmissions to achieve spatial diversity
- Base station cooperation facilitates signal enhancement/interference cancellation provided with backhaul links

Topics to be covered next week

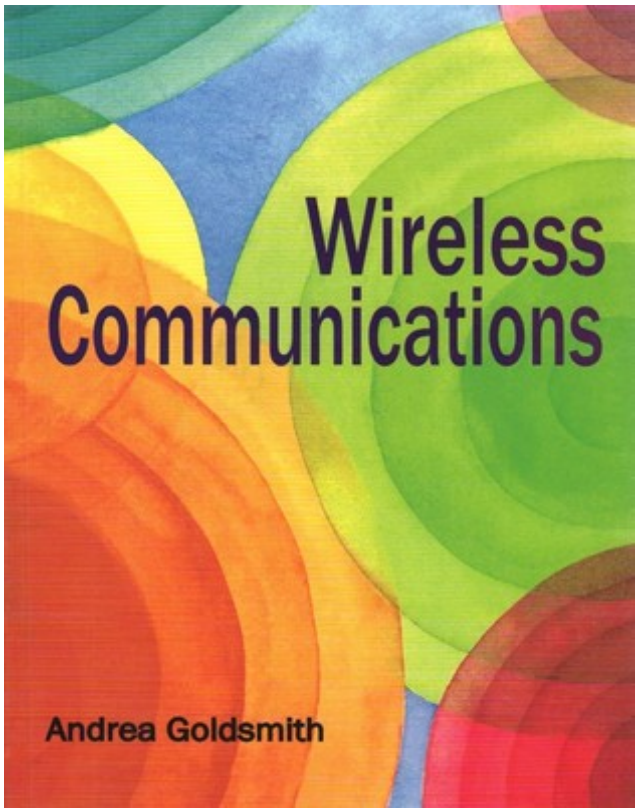
Characterization of Wireless Channels

Topics

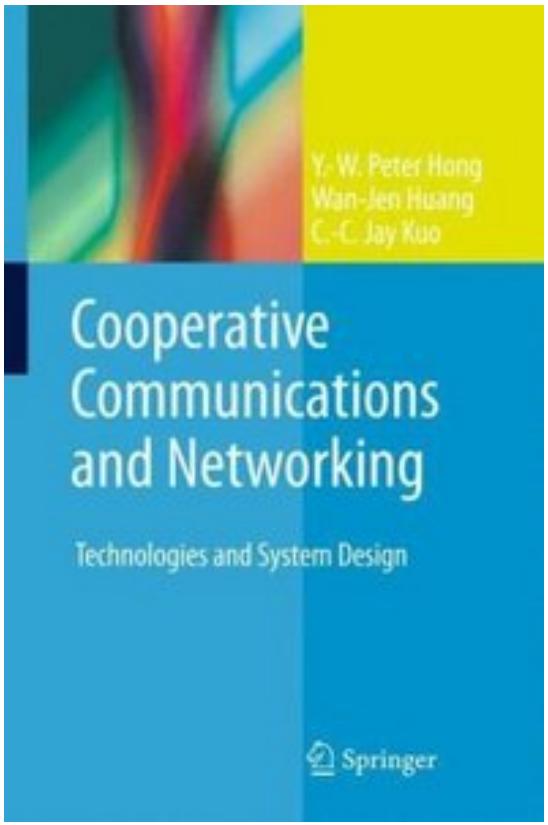
- Basic principles of wireless communications
- Simulation techniques
- Insights from theoretical analysis

Textbooks

Wireless Communications by A. Goldsmith



Cooperative Communications and Networking by Y.-W. Hong



Topics

Ch01 Introduction

Ch02 Characterization of Wireless Channels (Assignment # 1)

Ch03 Diversity Techniques for Fading Channels (Assignment # 2)

Ch04 Cooperative Communications with Single Relay (Assignment # 3)

Ch05 Cooperative Communications with Multiple Relays (Assignment # 4)

Ch06 Cooperative Communications with Multiple Sources

Ch07 Medium Access Control in Cooperative Networks

Ch08 Energy-Harvesting Relays

Ch09 Base Station Cooperation (Assignment # 5)

Ch10 Selected Applications (if time permits)

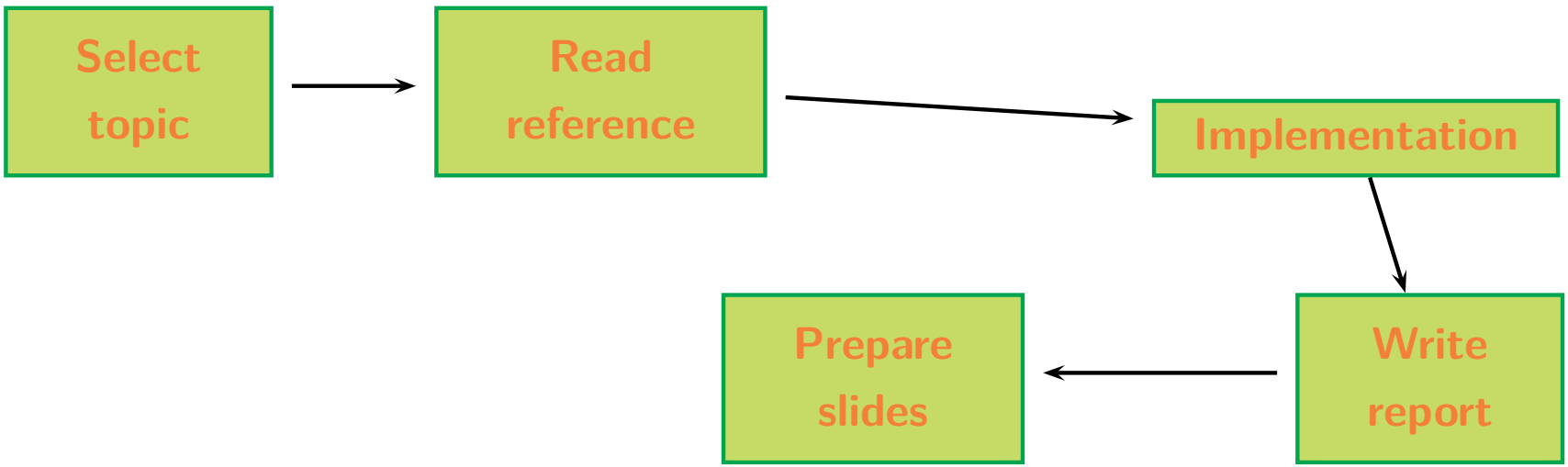
Grading Policy

- Midterm: 20% (Tentative date: April 13th)
- Project: 40%
- Assignment: 30%
  - Numerical questions
  - Simulation: Python sample code will be provided
  - Hand-in: prepared in English (will not be evaluated otherwise)

Past class performance: 87/100, 43% graded over 90

Course Project

- Purpose: Exercise basic skills of doing research.
- "New design" or "Redo" for selected topics in two months.



The END