Cleveland State University

Department of Electrical Engineering and Computer Science

EEC 693: Emerging techniques for wireless communications and networking

Description: The focus of this course is emerging techniques for future generation wireless networks that are expected to meet stringent requirements for capacity, energy efficiency, quality-of-service, mobility, and connectivity. The course covers in depth the theory behind **multi-user multiple-input multiple-output (MIMO)** and **orthogonal-division multiple access (OFDMA)** techniques, and their implementation in current cellular and wireless LAN networks. Moreover, the course introduces concepts and models of **cooperation, cognition, and opportunism** in communication networks, and demonstrates their potentiality for meeting the above-mentioned requirements, in particular, the need to reliably support high data rate transmissions.

This course requires some knowledge of digital and mobile communications, probability and statistics, linear algebra, and programming in MATLAB.

Course Objectives: The course is designed to enable students to

1) understand the basic and advanced theoretical concepts behind modern digital and wireless communications,
2) mathematically characterize and analyze key stages of information transmission chains from sources to destinations,
3) have in depth knowledge of multiple-antenna systems and their implementation in practice,
4) understand models and concepts behind emerging techniques that aim to significantly improve the current wireless systems.

Schedule: Fall 2015, MW 6:00-7:50 PM, FH 314.

Instructor: Dr. Batu K. Chalise
Electrical Engineering and Computer Science Department
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Tentative Course Outline:

1. Introduction (1-week)
   - Digital and Wireless Communications
   - History of Wireless and Cellular Networks
   - Math preliminaries (linear algebra and probability theory)

2. MIMO Communications (2-weeks)

- Introduction
- Instantaneous and ergodic channel capacities
- Channel state information at transmitter (CSIT) or no CSIT
- Degrees of freedom, multiplexing gain
- Water-filling Algorithm
- Diversity gain
- Effect of spatial correlations

3. MIMO Receiver design (2 weeks)
   Linear Receivers: Maximum ratio combining, Zero-Forcing, MMSE
   Non-linear receivers: Maximum Likelihood (ML), successive-interference cancellation

4. MIMO Transmitter Design (1 week)
   Beamforming
   Precoding
   Space-time block codes

5. MIMO-OFDM (2 weeks)
   Multi-carrier transmission
   OFDM modulation (basic principles)
   OFDM demodulation
   OFDM implementation using IFFT/FFT
   OFDM parameters and selection
   Time and frequency synchronization in OFDM
   Peak-to-average power ratio (PAPR)

6. MIMO OFDM for Long Term Evolution (LTE) Communication Systems (2 weeks)
   LTE-core network
   Radio access network
   Time-frequency resource plane
   Duplex schemes
   Downlink reference signals
   Multi-antenna transmission in LTE

New trends in communications

7. Cooperative Communications (2 weeks)
   Relaying
   Amplify-and-forward, Decode-and-forward, Detect-and-forward relays
   MRC receiver

Diversity gain
MIMO relays
Multiple-access and broadcast transmissions with relays

8. Opportunism in Communications (1 week)
   Time and frequency selection
   Antenna selection
   Direct and relay paths selection
   Relay selection

9. Cognitive radios (1-week)
   Introduction
   Spectrum Sharing
   Sensing-based Spectrum Sharing- detection algorithms
   Power control

10. Miscellaneous (1-week)
    Full-duplex communications: Introduction and concepts
    Large-scale multi-antenna systems: Motivation and models
    Review

Textbook: Instructor's slides

Suggested References:

[1} F. Xiong, *Digital Modulation Techniques*, Artech House, 2000

[2] E. Dahlman, S. Parkvall, and J. Skold, *4G LTE/LTE-Advanced for Mobile Broadband,* Academic Press, 2011

[3] Y. S. Cho, J. Kim, W. Y. Yang, C. G. Kang, *MIMO-OFDM wireless communications with MATLAB*, John Wiley and Sons, 2010.

[4] K. Petersen and M. Pedersen, *The Matrix Cookbook,* available online: http://www.math.uwaterloo.ca/~hwolkowi/matrixcookbook.pdf

[5] G. J. Foschini and M. J. Gans, ``On limits of wireless communications in a fading environment when using multiple antennas", *Wireless Personal Communications,* no. 6, pp. 311-335, 1998.

[6] E. Telatar, ``Capacity of multi-antenna Gaussian channels,'' *European Transactions on Telecommunications*, vol. 10, pp. 585–595, Nov./Dec. 1999 .

[7] L. Zheng and D. N. C. Tse, ``Diversity and Multiplexing: A fundamental tradeoff in multiple-antenna channels,'' *IEEE Transactions on Information Theory*, vol. 49, no. 5, pp. 1073-1096, May 2003.

[8] J. Mitola, G. Q. Maguire, Jr., ``Cognitive radio: making software radios more personal," *IEEE Personal Communications*, vol. 6, no. 4, pp. 13-18, Aug. 1999.

[9] A. Nosratinia, T. E. Hunter, and A. Hedayat, ``Cooperative communications in wireless networks,'' *IEEE Communications Magazine*, pp. 74-80, Oct. 2004.

Grading Policy:

Midterm:	25%
Homework:	15%
Final:	40%
Project:	20%

Project:

Each student or a group of maximum two students can decide a topic for the project. The topic should cover new techniques in the areas of wireless communications and networking. Each student is asked to do literature survey on existing techniques, describe his/her proposed method, demonstrate results with MATLAB simulations, and make a final presentation of the work among faculty and other students.

Homework:
There will be weekly homework. MATLAB simulations will be part of the homework.
Although students are encouraged to work together on the homework, each student must submit his or her original work.