**EL 6323 Introduction to Wireless Networking**  
**Professor:** Sundeep Rangan

**Overview:** An introduction to wireless communications with a focus on implications at the MAC, networking and application layers. Topics includes channel and rate modeling, ARQ, buffer management, QoS, random access, scheduling, mobility and wireless security with overviews and examples from state-of-the-art cellular and wireless LAN systems. Time permitting, the course may also cover HTTP and multimedia streaming over wireless. The course is designed for students both intending to specialize in wireless communications as well as students who are interested in the consequences of wireless communication in other areas including multimedia delivery, networking or mobile applications.

**Prerequisites:** Undergrad probability and EL5363 (Principles of Communication Networks) or equivalent. No wireless or digital communications classes are required.

**Text:** Stallings, “Wireless Communications and Networks”, 2nd edition [Suggested]

**Grading:** Weekly in class quizzes (20%), midterm (30%) and final (50%).

**Project:** Students may opt for a project instead of the final. But, the project must involve significant development / simulation work or analytic work worthy of a conference paper. Projects must be approved by the instructor.

**Syllabus:** 12 lectures of 2.5 hours each.

1. **Overview**  
   - The wireless revolution  
   - History  
   - Challenges for wireless communications  
   - Course admin details  
   - Requirements for communication: delay, error rates, mobility,  
   - Challenges for wireless communications: Key differences to wireline communications

2. **Basics of wireless channels and communication**  
   - Components of a wireless transmitter and receiver  
   - Bandwidth, duplexing, licensed and unlicensed bands  
   - Power, rate and SNR  
   - Shannon’s capacity, bandwidth and power-limited regimes, modeling of practical receivers  
   - Distance-based path loss and shadowing

3. **Rate variability at the link layer**  
   - Challenges for reliable transmission with rate variability  
   - Open loop techniques: Outage probability, fade margin  
   - Problems with fade margin compensation  
   - Basic ARQ mechanisms: stop-and-wait, go back N, selective ACK
- Rate selection with ARQ
- Channel quality feedback
- Adaptive rate selection
- Example 1: 802.11 rate selection (trial & error system for low mobility)
- Example 2: HSDPA rate selection (CQI based with high mobility)

4. End-to-end effects of rate variability
   - Basics of buffering
   - Buffer size, delay and fading duration
   - Basics of flow control
   - TCP flow control
   - Review of TCP congestion control mechanism
   - TCP over wireless
   - HTTP over wireless

5. Random access systems and WiFi
   - Types of multiplexing: Fixed assignment vs. statistical multiplexing
   - Aloha, slotted Aloha
   - Review of Poisson process and analysis of Aloha
   - CSMA with collision avoidance and collision detection
   - WiFi: History and motivation
   - Architecture
   - DCF mode, RTS-CTS, hidden and exposed terminal problem
   - 802.11n enhancements

6. Circuit-switched cellular systems (GSM and UMTS rel. 99)
   - What is interference? SINR calculations.
   - Cellular concept and spatial reuse
   - Interference-limited and coverage-limited systems
   - Frequency reuse
   - Cellular vs. WiFi. The exposed terminal problem revisited
   - Example 1: GSM including discussion of architecture, voice support
   - Example 2: UMTS release 99, basics of CDMA, architecture and key channels
   - Partial vs. universal frequency reuse

7. Packet-switched cellular systems (HSPA and LTE)
   - Packet-switched vs. circuit-switched communication
   - HSDPA (High Speed Dowlink Packet Access)
   - HSUPA (High Speed Uplink Packet Access)
   - Introduction to LTE: history, architecture
   - OFDM
   - UL and DL communication in LTE

8. Quality of service and scheduling
   - What is quality of service?
   - Requirements of typical applications.
   - Traffic flow concept
o Queues, head-of-line blocking.
o Multi-user scheduling in LTE and the bearer concept
o QoS in 802.11e

9. Segmentation and reassembly
   o Why fragment? MAC vs. IP-layer packet sizes
   o Example 1: Fragmentation in 802.11
     ▪ Basic fragmentation
     ▪ Block transmissions in 802.11n
   o Example 2: The radio link control (RLC) layer in 3GPP
     ▪ Logical channels, MAC transport blocks
     ▪ RLC layer with fixed MAC packet sizes (pre-release 7)
     ▪ RLC layer with variable MAC packet sizes (release 7)
o A preview of mutliflow concepts

10. Mobility
   o Principles of handovers: switching conditions, hysteresis, detection.
o Mobility at different layers. Application vs. network-layer mobility.
o Mobility in cellular systems
     ▪ The gateway concept, measurement reports, bearer management, mobility procedures
     ▪ Cellular backhaul technologies in use today.
o Mobile IP
     ▪ Basic components, tunneling
     ▪ Route optimization
     ▪ Enhancements for Mobile IPv6
   o Vertical handovers
     ▪ Handovers in the EPC and PMIPv6

11. Intermittent Communication and Power Management
   o Power consumption on smartphones
   o Power consumption for typical background communication.
o Intermittent communication in cellular
     ▪ Slotted paging, tracking areas, location updates
     ▪ Idle mode handover and cell selection/ reselection
     ▪ Discontinuous transmission and reception (DTX and DRX)
o Wireless personal area networks (PANs)
     ▪ Bluetooth 802.15.1
     ▪ Zigbee 802.15.4

12. Other lectures
   o Midterm and final exams
   o Review sessions
   o Project presentations
   o Special topics