Topics covered:

Advanced topics in networking research: Overview and vision of the future Internet and wireless ad hoc networks, IP mobility support and efficient handoff schemes, multicast in ad hoc networks, systematic testing of multicast routing and ad hoc MAC protocols using the stress methodology.

Fundamentals of performance analysis and measurements, congestion and flow control concepts, network simulation and emulation (and the difference between implementation and simulation). Also covered are basics of traffic characterization, topology mapping, and switching algorithms. In addition, students learn basics of setting up testbeds, how to create meaningful interpretations of collected/measured data and simulation results.

These concepts will be applied at different layers of the protocol stack (from the data-link/MAC layer up to the application layers). Protocols studied include Transmission Control Protocol (TCP), unicast routing (RIP), multicast routing (DVMRP/PIM)/Mbone, network simulation (NS) and animation (NAM), protocol stress testing, diagnostic tools for routing (traceroute, mtrace), delays (ping), tcp and packet/frame level tracing (tcpdump), MAC layer (802.11 wireless LANs) and Mobile IP.

There will be lecture sessions and lab sessions. The lecture sessions will be covered for the first few class meetings by the Professor and will include advanced research topics and thrusts mainly in the fields of ad hoc networks, protocol design and testing and IP mobility. Later lecture sessions will include prepared presentations by student teams/groups to cover topics related to their own interest and semester projects.

The lab sessions will include a set of lab experiments covering topics in wireless networking, congestion control, network measurement and monitoring, and measurement analyses. A list of the experiments is given below.

Contact Information:

- Instructor: Prof. Ahmed Helmy
  Office Hours: Friday 10-12 (extended until 12:30 as needed) in EEB 232 (or EEB 351 lab)
  Email: helmy@ceng.usc.edu, web: http://ceng.usc.edu/~helmy

- Lab Assistants:
  Jaben Faruque
  Office Hours: TBD
  Email: faruque@usc.edu

  Sandeep Mudgal
  Office Hours: TBD
  Email: mudgal@usc.edu

- Class Website: Current/temp website: http://ceng.usc.edu/~helmy/ee499
- Future website: http://protocoltesting.usc.edu/ee499 or nile.usc.edu/ee499
• Lecture/Lab times:

Regular class meeting and lecture sessions: Friday 2:00 - 4:50pm, Room: GFS 101.

Tentative Lab session Hours: Session1: Monday (9:30-12:30), Session 2: Friday (8:00-11:00) (you must sign up for a session with your group) [The lab holds about 5 groups at a time (i.e., 15 students in groups of 3)]. Room/lab: EEB 351.

• Student responsibilities:
  • Attendance (lecture and lab sessions), class discussions, weekly reviews, paper readings
  • Lecture presentation, project proposal, high quality final project report, demo
  • Team work, lab preparation, in-lab experiments/evaluation, assignments

• Pre-requisites:

In general, very good knowledge of fundamentals of computer networks is required. In addition, very good programming skills are an absolute requirement, along with knowledge of operating systems (especially Unix/Linux). Knowledge of network simulation, tcl/tk or a scripting language is a plus.

More specifically, the pre-requisite courses that must be taken before this course include:

- EE/CS 450 Introduction to Computer Networks (with grade “A”), or EE 555 (with “A- or better”), or CS 551 (with “A- or better”), and
- CS402 Introduction to Operating Systems (with grade “A”), or CS 455 Programming in C and C++ (with grade “A”), or CS 555 (with “A- or better”), and
- Background in basic probability theory and statistics (EE 465 or EE 464 with “A-” or better, if taken).

The capacity of this course will be a maximum of ‘30’ (thirty) students, chosen mainly based on academic merit, and background preparation.

• Format:

A major part of this class is conducting a semester-long group research project. Each group of ‘3’ students presents an initial project proposal (approx. 2 pages) to the Prof. around the 5th week of class. Based on feedback, a final project proposal (approx. 3 pages) is required around the 8th week of the semester. An initial draft of the project report (approx. 8 pages) will be due around the 11th week of class. Then the final project report (approx. 12 pages) will be due on the last lecture. In addition, each group is required to prepare and present a lecture presentation on a research topic (usually closely related to the project). A demo session will be held at the end of class to illustrate results of the research project (as applicable). The tasks of each individual student within a project must be stated very clearly. In addition to the overall project and teamwork, contribution of each individual will be evaluated separately (to deal with effort mismatches).

Otherwise, the course will be centered around lab experiments and projects accompanied by lectures on theory and concepts (offered by the Prof. and the students). The experiments (around 7 main experiments total) are carried out in groups of ‘3’ with combined reports. Each individual should understand and be able to perform the experiments on his/her own (there may be random pop quiz to test this ability). Students will also be required to design a new lab experiments. The students will
also be asked to write reviews for papers that will be presented in class (around 10 reviews total).

Students are expected to participate actively in various aspects of this course (such as, suggesting new experiments, carrying discussions on the class newsgroup, even suggest exam questions!, among others).

Instructions for the project proposal and report will be posted on the web in as much detail as possible. Similarly, instructions for performing lab experiments and samples of reviews will be posted.

- **Grading:**

  Attendance, class participation, paper reviews (10 papers to review) (15%)

  Experiments and assignments (approximately 7 lab experiments) (28%)

  Project(s) (proposal, presentation/demo and final report) (40%)

  Final (17%) [format to be decided!]. An alternative is to put weight of the final towards the project.

- **List of lecture topics:** (To be included shortly. To be updated throughout the semester.)

  
  - Building a small topology map using the above tools and/or other tools (e.g., Tkined)
  
  - Measurements and statistics of delays, throughput, and packet behavior
      - Statistics on path characteristics: ping, pathchar
      - TCP and packet trace tools: tcpdump, etherfind, packet filters (e.g., bpf) (other packet sniffers), tcplib
      - Real-audio vs. tcp-based traffic (ftp vs telnet vs http)
  
  - Traffic characterization: collect traffic samples, use existing samples and traces from known web sites (e.g., CAIDA ‘www.caida.org, moat.nlanr.net’), show characteristics (heavy tail distributions, self similarity, etc.). Compare to Poisson processes or on/off models, also compare to simulated traffic.
  
  - Setting up test beds, topology configuration, tunnels, virtual/logical topologies (overlays, xbone (www.isi.edu/xbone)), creating topology failures for testing/experimentation [using emulation (e.g., ns) to introduce extended delays, packet loss patterns]
  
  - Multicast: Fundamentals of sparse/dense mode multicast (DVMRP, PIM-DM, PIM-SM). Installing/setting up multicast, using/experimenting with the MBone tools (sdr, vic, vat, wb) and other conferencing tools.
  
  - Congestion and rate control: Simulating/emulating ATM rate-based adaptation for ABR. Application level TCP slow start/congestion avoidance. Performance
measurement.

- Scheduling and queuing disciplines: FIFO, fair queuing, RED and other scheduling disciplines, switching techniques, table lookup performance measurement
- TCP performance: with and without RED
- Wireless medium access control: MAC layer 802.11: CSMA/CA, RTS/CTS mode
- TCP performance over wireless
- TCP performance with mobility and handoff
- IP mobility: Mobile IP basics: Home Agent/Foreign Agent setup. Mobility, using DHCP, handoff measurements
- Multicast-based Mobility
- Simple Ad hoc/sensor Networks

Possible Projects:

- Mobility Modeling for wireless/ad hoc mobile networks: Collect traces and statistics describing possible movement patterns of mobile devices over a relatively long period of time (say 3 weeks). Identify main characteristics of such patterns as function of the movement mode (pedestrian, vehicular, public transportation,… etc), time of day (daytime vs night time… etc), and day (weekend vs working day.. etc). Develop a simplistic model to capture such characteristics. Also use the model and traces to simulate and evaluate two ad hoc routing protocols (say DSR and AODV). Based on your evaluation metrics, compare your results to previously obtained/published results using the standard random way-point mobility model. Does the mobility model matter?

- Create a complete, new lab experiment (one that you have not seen exactly in this course). Explain the theory behind it, the experiment setup and its goals, the tools to be used, the procedures (step by step) of conducting the experiment, and the results with adequate explanation and analysis.

- Evaluation of ad hoc networks architectures
  - Example target architectures: self-organization, hierarchical ad hoc nets, multicast in large-scale ad hoc networks
  - details and sub-topics (to be included shortly)
- Evaluation of efficient handoff mechanisms using various protocols:
  - Example protocols: MIPv6, hierarchical MIP, multicast based mobility
  - more details and sub-topics (to be included shortly)

List of references/useful links and resources:

- Lab web page: ‘protocoltesting.usc.edu’ or ‘nile.usc.edu’
- Network simulation (NS-2): the VINT project ‘www.isi.edu/nsnam/vint’
Systematic protocol testing: the STRESS project ‘catarina.usc.edu/stress’
Multicast routing: the PIM project ‘catarina.usc.edu/pim’
Internet traffic and topology measurements: www.caida.org, moat.nlanr.net, www.isi.edu/scan

Readings/books:

There is no required textbook for this class. An updated list of readings (of conference papers and journal articles) will be posted on the web (provided by the Prof. initially, then updated by the student presenters). This will cover the lecture sessions, projects and weekly reviews.

List of readings: (to be included shortly. For initial look check the website for EE-599 fall’00 on Internet protocol design, testing and simulation at ceng.usc.edu/~helmy/ee599).

Description of the networking laboratory (EEB 351):

Current equipment includes 25 PCs (for simulations and testbed), 20 laptops, handhelds (HP-Jornada) and pocket PCs (iPAQ), 3 wireless base stations and 14 wireless Orinoco/WaveLan cards, 10 wireless sensors (smart dust motes) among others. [Note: this is a joint research/instruction laboratory, so not all equipment are available for EE 499 students. Equipment will be available as necessary for the experiments.].

Goals of the course:

For students to acquire hands-on experience and familiarize themselves with a networking laboratory setup. To experiment with state-of-the-art networking technologies and tools that enable students to diagnose and perform measurements on a network.

To get involved in research projects on advanced topics in computer networks, and be able to present and write high quality technical reports on protocol design, analysis and simulation. To be part of a team and to tackle challenging research problems in a semester project. To suggest solutions to these problems and to be able to demonstrate the feasibility and performance of the solution. To learn how to review publications in the networking field from selected journal articles and conference proceedings.

All the skills acquired in this class should emphasize and supplement deep understanding of actual protocol and network behavior. Students should test their understanding of the basic elements of a network, the behavior of the fundamental and evolving network protocols (such as transport and congestion control of TCP, unicast and multicast routing protocols, media access control (MAC) protocol of wireless networks, among others). Aside from this basic understanding, students should realize that network behavior is a collective behavior of all such protocols (and others), their interaction among themselves, and with the ‘faulty’ and (sometimes highly) dynamic network environment. By integrating network failures, such as packet losses, link failures and crashes, and through diagnostic and measurement tools, students should be able to study the effects of various network conditions on the overall behavior of the network.

Such deep understanding and practicality, along with acquiring the above skills, are essential tools for future networking research and industry, that would greatly help in understanding today’s networks, and designing networks of the future.

Note: This course relies very heavily on students’ own effort and experimentation. It is a hands-on course where most assignments are conducted in a laboratory setting by the students. The students
will also be involved in giving lecture presentations and working in teams on a semester project.