"EE 555: Broadband Network Architectures"

***Catalog Description*:**

Broadband network architectures and services, technologies for high-speed access and core networks, optical infrastructure for layered network architectures, high performance switch and router architectures.
Prerequisite: EE 450 and EE 503.

***Course Description*:**

This is an advanced course focused on the principles of operation, architectures, protocol design and performance management techniques for integrated broadband computer networks designed to support multimedia transport and services. The course is basically divided into four modules namely:

- **QoS Architectural framework, concepts, analysis & modeling and algorithms** : Traffic modeling and traffic-related management strategies including call-setup procedures, congestion and flow control, admission control, traffic shaping, policing, resource allocation, scheduling and other QoS-related issues are carefully described and analyzed. This part of the course is analytical/algorithmic in nature and hence does depend on EE503 (Basic Queueing models including Priority Queueing, WFQ, WRED, Token/Leaky Buckets, etc…)
- **Switching and Routing Architectures**: Including both L2/L3 switching and L3 routing architectures, forwarding and routing protocols (Hierarchical routing, CIDR, BGP, MPLS and Multicast routing) along with "detailed" description and deployments of VLANs and VPNs.
- **Foundations of Modern Networking Technologies**: This part includes "detailed" presentations on SDN (Data and Control Planes along with the Open Flow interface), Cloud Computing (Services and Architectures) and Network Virtualization. Emphasis will be on Data Centers and Data Center Networks deployments and architectures. The course project will be based on this module
- **Optical Networks Technologies and Architectures**: Ultra-broadband Optical Networking technologies, including SONET and DWDM (Wavelength assignments and routing strategies) along with Optical Networks deployment including PON/EPON and FTTH will be discussed

❖ **Wireless Broadband Overview** (**Time permitting only**. This module belongs to EE597)

***Intended Audience*:**

This is an ambitious, exciting and very challenging course that requires both hard work and passion for the subject. The course in intended primarily for Master-Level students whose goals are to start their professional careers, in the Networking industry, immediately after graduation. If you are a Ph.D. students, I encourage you to consider EE550/EE649/EE650 instead as these courses are heavily analytical/theoretical in nature. You are of course most welcome to sit in my classes and get a wide exposure into networking technologies. There will be "minor" overlaps between EE555 and CS551/CS558, however our course will divulge, with much more details, into technical aspects of Networking.

The prerequisites for the course namely EE450 (Introduction to Computer Networks) and EE503 (Probabilistic Modeling of Computer Systems). The dependency on EE503 will be restricted to the first module only (We need to develop some appreciation for Queueing modeling. I will be scheduling "some extra sessions beyond the regular lectures" to develop some Q-models based on Markov discrete and continuous chains. No need to be scared. You should have had some exposure to these topics from EE503

Statement for students with disabilities:
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me as early in the semester as possible. DSP is located in STU 301 and is open 8:30a.m.5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on academic integrity:
USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

Course Outline **(Tentative. Subject to change)**

- ***Introduction and Overview (Quick review from EE450)***

  - Review of the Topology and Infrastructure of the Internet
  - Review of the TCP/IP Protocol Suite
  - Overview of Broadband Access Technologies (xDSL, Cable, PON, FTTH, etc..)
  - Resource sharing through multiplexing
  - Review Circuit vs. Packet switching technologies
  - Network design issues and requirements
    - Reliability
    - Scalability
    - Robustness
    - Performance Parameters: Throughput, Delay, Jitter, packet Loss, etc.
  - Traffic and service classes

- ***QoS & Traffic Management Techniques***

  - Classifications of services & Basic components of QoS models
  - Control and Data Planes functionalities
  - Traffic management techniques
    - FIFO and Priority queues
    - Fair allocation of Resources (Min-Max algorithm)
    - Scheduling: Priority, Weighted fair queuing (WFQ), GPS, etc…
    - Flow classifications, Flow control
    - Congestion control/avoidance in TCP/IP networks
    - Admission control and policing (Leaky/Token-Bucket Algorithm
    - Traffic Shaping
    - Frame Tagging
    - Multiple protocol label switching (MPLS)
  - Integrated services model
    - Classifications of integrated services
    - Guaranteed QoS, load controlled services
    - RSVP: features, soft states, path and reservation messages
  - Differentiated Service Model
    - Traffic Classification and Conditioning
    - Service Level Agreements (SLA)
    - Per-Hop Behaviors (PHBs)

- ***Switching Architectures***

  - Switch composition and basic elements
  - Input/Output Queuing models in switches
  - Approaches to carrying out switching functionalities
    - Time (shared memory) approach
    - High speed, shared bus approach
    - Space division approach
    - Combined time and space approach
  - Switching architectures
    - Crossbar switches
    - Multistage, self-routing space switches
    - Multistage Banyan, Benes, Clos, Delta and Omega networks.
  - Performance analysis of above switching architecture
    - Blocking analysis
    - Queuing Delay analysis
    - Throughput analysis
    - Complexity, reliability and scalability considerations

- ***High Speed Switched Local Area Networks (L2 switches)***

  - Evolution from shared to switched LANs
  - Technologies for building switched-LANs
  - Role of LAN switching in campus networks
  - Components of switched LANs
  - Multi-layer switching technologies
  - Cut-through vs. Store-and-forward
  - Spanning Tree Algorithm
  - Virtual LANs: Concepts, Types, deployment and configurations, Access and Trunks ports, IEEE802.1Q, etc…
  - Switching vs. routing debate
  - Case studies

- ***Routing Architectures***

  - Overview of Routers architectures
  - Hierarchical Routing in the Internet
  - New generation IP: IPv.6
  - Classless Inter-Domain Routing (CIDR)
  - Intra-Domain and Inter-Domain Routing algorithms and Protocols
  - The Border Gateway Protocol (BGP): eBGP, iBGP, attributes and policies, etc..
  - Multicast and Multicast Routing: Addressing, IGMP, Multicast Trees, Algorithms including SP, RBP, RPM, etc…), Multicast routing protocols (PIM)
  - MPLS: Multi-Protocol Label Switching, fundamentals and deployment architectures
  - Virtual Private Networks: Types, Tunneling, Deployment Architectures, etc…

- ***Modern Networking Technologies***

  - Motivation, elements, requirement and technologies
  - Software Defined Networks (SDN): Basic elements of SDN, SDN Data and Control planes, Interfaces (Open Flow), Flow Tables structure
  - Cloud Computing: Motivation, models , services (SaaS, PaaS, IaaS, NaaS), deployments (Private vs. Public Clouds)
  - Data Centers (DC) and Data Center Networks (DCN): Architectural models (Access, Aggregation and Core), Intra and Inter DC switching/routing, Load balancers, Challenges, etc…
  - Virtualization of Data Centers: Server Virtualizations and Hypervisors, Switch Virtualizations (OpenVSwitch), V-Bridging Technologies (VEB, VEPA, etc..), Network Virtualizations and Network Functions Virtualizations (NFV)

- ***Overview of Optical Networks***

  - Survey of optical components
    - Optical fiber: Single and multi-mode, Optical couplers, Light sources: LED, Lasers, Light detectors, optical amplifiers & filters, WDM, etc…
  - Optical switching/routing/Technologies & architectures
    - Wavelength & routing assignments algorithms
    - Broadcast & select optical packet networks, Multi-hop optical packet networks (capacity and delay analysis), Rearrangable optical networks
    - Passive Optical networks (PONs), Point-to-Point, DWDM-based optical networks, SONET devices, deployments, wavelength assignments, etc..