University of Southern California
EE450: Introduction to Computer Networks

Course Description

This course provides an introduction to fundamental concepts in the design and implementation of computer networks, their protocols, and applications. Topics to be covered include: overview of network architectures, network applications, network programming interfaces (e.g., sockets), transport (TCP, UDP), flow control, congestion control, IP, routing, data link protocols, error-detection, multiple access, LAN, Ethernet, wireless networks, and network security. Emphasis throughout the course will be on the Public Internet. Over the course of the semester, students program in C/C++ on UNIX/LINUX systems to build web clients and servers, implement algorithms, perform Protocol Analysis and conduct Network Simulations.

Course Prerequisites

C/C++ Programming, Junior Standing

Course Materials

Required textbook: Computer Networking: A Top-Down Approach Featuring the Internet, Seventh Edition, James Kurose and Keith Ross, Addison Wesley, 2017.

Set of Lecture and Discussion Charts will be posted regularly on our course website. A list of reference texts will also be posted on the same site

Catalog Description

Network architectures; Layered protocols, Network service interface; Local Networks; long-haul Networks; Internal Protocols; Link protocols; Addressing; Routing; Flow and Congestion Control; Applications Protocols, Network Security

Course Workload

1. There will be 1 midterm and 1 final (35% and 40% respectively)
2. There will be 4~5 labs (Virtual) on Protocol Analysis (Wireshark) and Network Simulations. These Labs will count as "Extra Credit" (a maximum of 20 points) to be added to the midterm score.
3. A Network Socket Programming Project (15%~20%). The project is an individual one assigned at the end of the first month of the semester and will be due a week before the end of the semester
4. There will be 5 Homeworks (~10%), one assigned every other week

General Topics Covered

1. Basic concepts of Networking. Network Classifications and Topologies. The concept of layered architecture modeling including OSI and the TCP/IP protocol suite. Client-server communications using Sockets
2. Physical layer functionalities including signaling, modulation, multiplexing, line coding and synchronization. Transmission media. Network performance measures including throughput, delays are presented. Data vs. signaling rates, channel bandwidth and capacity.
3. Link layer functionalities including frame synchronization, error detection and control including ARQ, flow control mechanisms including sliding windows.
4. Wide area network technologies. Circuit and packet switching. Virtual circuit switching. Introduction to Software Defined Networks (SDN) and open flow. Introduction to Cloud Computing and Data Centers.
5. Local area network technologies including ETHERNET and Wireless (Wi-Fi). Multiple-access schemes such as CSMA/CD, CSMA/CA are discussed. MAC addressing. Switched vs. shared ETHERNETs. Performance evaluation, including throughputs and delays of LAN technologies
6. Interworking devices including repeaters, bridges, switches, routers and gateways. Network layer protocols, including IP, ARP and ICMP. IP addressing schemes (Classful and Classless), Subnetting and Subnet Masking
7. Internet routing including protocols used in the Internet such as RIP, OSPF and BGP. Algorithms such as Bellman-ford and Dijkstra are discussed
8. Transport layer protocols including UDP and TCP. Ports and sockets. TCP connection establishment. Error, flow and congestion control in TCP.
9. Applications layer protocols such as HTTP, FTP, DNS, SMTP, etc…
10. Basics of Network Security measures such as encryption, digital signatures, authentication, firewalls, Virtual Private Networking, etc…

Course Outline (Tentative)

- **Fundamentals of Computer Networking (Overview)**
  - What is a Network? Why do we need Networking?
  - Network Classifications: Switched vs. Broadcast
  - Network Classifications based on Coverage
  - Network Topologies: Bus, Ring, Hub, Mesh, fully connected, etc..
  - Network Components; Hardware/Software
  - Transmission Media: Guided vs. Unguided
  - Process to Process Communications models: Client Server, Peer to Peer, Cloud Computing models. Cloud-based services
  - Network Infrastructures; Access, Distribution and Core Networks
  - The Internet: Topology and Infrastructure of the Internet
  - Service Models: Reliable vs. Unreliable, Best effort vs. QoS models
  - Network Performance Measures: Latency/ Throughput, BWxDelay product
  - Switching Technologies: Circuit, Packet and Virtual Circuits

- **Networking Protocols and the Layered Architecture**
  - **The concept of Layered Architecture, OSI & TCP/IP Protocol Suite**
  - Protocol Layering
  - Functionalities of the various layers of TCP/IP Data Transfer using the layered architecture
  - **Addressing Hierarchy**
  - MAC, IP and Port addresses
  - Communications between hosts on the same network Communications between hosts on different networks
  - **Introduction to Sockets and Socket programming**
  - Classifications of Sockets: Stream Sockets vs. Datagram Sockets. Socket Address Structure
  - Socket Programming with TCP and UDP
  - Creation and binding of sockets. Reading and writing into sockets, Concurrent vs. Iterative servers

❖ **Putting the Pieces of the Puzzle together**

- **How does a host obtain an IP address?**
- DHCP: Dynamic Host Configuration Protocol
- Discover, Offer, Request & Acknowledge phases of DHCP, DHCP relay
- **How do we map a host name into an IP address**
- DNS: Domain Name Servers
- Name space and DNS in the Internet
- Types of DNS servers: Local, Root, TLD and authoritative Name Servers, Iterative vs. Recursive DNS
- DNS caching and records
- **How do we map an IP address to a MAC address?**
- ARP requests & responses
- ARP Proxies
- **How do we distinguish between Applications running in same/different machines?**
- Port numbers: Well known and ephemerals ports.

❖ **Physical Layer**

- Functions of the Physical Layer, Data vs. Signals
- Concept of Signal Bandwidth, Channel Bandwidth, Channel Capacity, Shannon Theorem, etc…
- Modulation: Why modulate?, Classifications of Modems: Binary vs. Multilevel, Data Rates (bps) vs. Signaling rates (Baud), etc…
- A/D and D/A conversion: Sampling, Quantization and Encoding. Nyquist Theorem
- Resource Sharing/Multiplexing: Frequency Division Multiplexing, Synchronous Time Division Multiplexing, Statistical Time Division Multiplexing, Wave length Division Multiplexing
- T1 and the Digital Carrier System in the US.
- Access Technologies: ADSL and Cable Access architectures

❖ **Data Link Control Protocols: Part 1: Point-to-Point Links**

- Functions of the DLC layer. Typical "frame" format
- Error Detection: Single and two dimensional parity, Frame Check Sequence, generation of FCS bits, Error detection algorithm
- Error/Flow Control Mechanisms
- Stop and Wait ARQ
- Go-Back-N ARQ
- Selective Repeat ARQ
- Sliding Windows
- Evaluation of Link utilization and throughput of the above mechanisms

❖ **Media Access Control Protocols: Part 2: Multipoint (Shared) Links**

Taxonomy of MAC Protocols

- Channel Partitioning, FDMA/TDMA/CDMA
- Random Access: ALOHA, Slotted ALOHA, CSMA/CD and CSMA/CA
- Controlled Access; Token Passing, Polling/Selecting and Reservations

Shared ETHERNETS

- Carrier Sense Multiple Access/Collision Detection (IEEE802.3)
- Classifications of Shared ETHERNETS
- Shared vs. Switched ETHERNETS

Wireless LANs (Wi-Fi)

- Classifications of Wireless LANs: Infrastructure vs. Ad-hoc
- Problems with wireless channels
- Carrier Sense Multiple Access/Collision Avoidance schemes (IEEE802.11)
- Frame Addressing in Wi-Fi
- Brief introduction to Bluetooth

❖ **Internetworking Devices**

- Classifications of Internetworking Devices
- Shared Hubs
- Layer 2 Switches/Bridges. Spanning Tree Algorithm
- Routers: Architecture, Configuration, etc…

❖ Network Layer Protocols

The Internet Protocol (IP)

- IPv.4 Packet Format
- Fragmentation of Packets
- IP addressing: Classful and Classless (CIDR)
- Subnetting and Subnet Masking
- Private IP addressing, Network/Port Address Translations
- Introduction to IPv.6

Routing Protocols

- Routing Architecture in the Internet: Intra and Inter-Domain Routing
- Distance Vector Routing Protocol, Dijkstra Algorithm
- Open Shortest Path First, Bellman-Ford Algorithm
- Path Vector. Introduction to Border Gateway Protocol
- Hierarchical Routing in the Internet

Software Defined Networks:

- Introduction to Control & Data Plane functionalities. Concept of SDN. Open Flow and Flow Tables with examples

❖ Transport Layer Protocols

The Transmission Control Protocol (TCP)

- TCP Segment Format
- TCP Connection Set-up and tear down
- Reliable Service using TCP: Error and Flow Control
- Congestion Control in TCP: Slow Start, Congestion Avoidance, AIMD, Congestion window, Tahoe/Reno implementations

The User Datagram Protocol (UDP)

- Datagram Format
- Unreliable Service: Error detection, Multiplexing

❖ **Application Layer Protocols (This section is handled by TAs during a couple of discussion sessions early in the semester dedicated to these topics)**

Hypertext Transfer Protocol (HTTP)

- Non-Persistent, Non-Persistent with parallel connections, Persistent, Persistent with Pipelining
- HTTP messages
- Client/Server interactions
- Web Caching

Simple Mail Transfer Protocol (SMTP)

- Mail message Format
- Mail access protocols

Peer-to-Peer applications

❖ **Introduction to Network Security**

Components of Network Security

- Data Privacy via Symmetric/Public Key encryption
- Authentication procedures
- Data Integrity via Digital Signature
- Access control: Firewalls (Packet/Application Firewalls
- Security Threats: Viruses, Worms, Denial of Service, IP spoofing/Sniffing
- Security Protocols (Time permitting): PGP, SSL, IPSec, etc
- Introduction to Virtual Private Networks (VPN)