Spring'19

Thu5sday 6:00 pm - 8:50 pm

6516 Sennott Square

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Course Objectives

The focus of this course is on the fundamental concepts and basic principles that underlie the design and deployment of large-scale internets. The first of the course examines the main design issues and tradeoffs that emerge in the design of protocols for large-scale wide-area networks. The main topics covered in this part of the course include naming and addressing, flow control, routing and congestion control.

The second component of the course provides an in-depth discussion of how the design principles and approaches, covered in the first part, are used in the design and implementation of the Internet architecture and protocols. The discussion will focus on basic principles underlying the design of the TCP/IP protocol stack, and a brief overview of the main protocols that support the basic Internet functionality.

The third component of the course explores the network design mechanisms and protocols to support quality-of-service (QoS) requirements of multimedia applications. QoS characterizes the ability of the Internet to differentiate between communications traffic in order to provide different levels of service to end users. The focus will be on recent advances in resource and traffic management to meet QoS requirements in multiservice networks. Protocols for QoS support in the Internet, including resource management and traffic scheduling, and IP and multiprotocol label switching.

The last of the course discusses emerging networking architecture and functionality, focusing on Software Defined Networks (SDN) and Network

Function Virtualization. (NFV). SDN is an emerging computer networking paradigm to manage network services through abstraction of lower-level functionality. Network function virtualization provides a flexible way to accelerate service deployment, at scale, by significantly reducing dependency on dedicated and specialized hardware. The OpenFlow standard that regiments the interaction between the control and data plane will be discussed.

Course Topics

The following list of topics will be discussed:

- **Network Architectures and Protocols - Introduction**
  - Networks and Network Classification
  - Layered Network Architectures
  - Protocols and Interfaces
  - Internet Architecture Design and Protocol
  - End-to-End Argument in Network Design
- **Traffic Control and Network Resource Management**
  - Routing Algorithms and Protocols
    - Optimality Principle
    - Shortest Path Routing
      - Distance Vector Protocols
      - Link State Protocols
  - Congestion Control
    - Effects of Congestion
    - Backpressure
    - Implicit Congestion Signaling: Delay and Packet Dropping
    - Explicit Congestion Signaling
      - Binary, Credit-based and Rate-based Schemes
    - Preventive and Reactive Control
    - Closed and Open Loop Control
- **Multiservice Networks Design**
  - Design Requirements for Multi-service Architecture
    - Characteristics and Performance Requirements
    - QoS Support and Service Guarantees
  - Traffic Control and Management
    - Traffic Models and Classes
    - Admission Control
    - Traffic Descriptors
    - Traffic Shaping and Policing
      - Leak-Bucket
    - Traffic Discard
      - Tail Dropping, Selective Packet Dropping

    - Queuing Discipline
        - Fair Queuing
        - Processor Sharing
        - Bit-round Fair Queuing
        - General Processor Sharing
        - Weighted Fair Queuing
- **Internet Architecture and Protocols**
    - Internet Design Principles
        - Best-Effort Service
    - IP addressing
        - Prefixing and NAT
    - Internet Protocol
        - Datagram Service
    - Internet Directory Service
        - DNS architecture, service and protocols
    - IP Router Architecture
        - Data and Control Planes
        - Basic IP Router Functionalities
        - Packet Classification and Matching
        - Packet Processing and Forwarding
    - Border Gateway Protocol
        - Design, Stability and Security
    - Internet Transport Protocols
        - UDP and TCP Overview
        - TCP Traffic and Congestion Control
    - Internet Traffic Management
        - IP Switching
        - Multi-Protocol Label Switching (MPLS)
- **Software Defined Networking**
    - Background and Motivation
    - Data and Control Plane Separation
    - SDN Architecture and Components
        - Data Plane and Control Plane
        - SDN Protocols
    - OpenFlow
    - SDN in Data Centers and in the Cloud
    - SDN in Wide Area Network
- **Network Function Virtualization**
    - Background and Motivation
    - Virtualization Concepts
        - Virtual Machines, Hypervisors and Dockers
    - NFV Architecture
        - Virtualization of Network Functions

        - Network Virtualization Infrastructure
        - NFV Management and Orchestration
    - NFV for routing, security and mobility
    - NFV in the Cloud
    - NFV and SDN

Course References

- **James Kurose** and **Keith Ross**, ***Computer Networking, A Top Down Approach***, Addison Wesley
- **William Stallings**, *High Speed Networks and Internets: Performance and Quality of Service*, 2nd Edition, 2002, Prentice Hall
- **Larry L. Peterson and Bruce S. Davie**, ***Computer Networks: A Systems Approach***, 3rd Edition (or later), Morgan Kaufmann Publishers.
- **Douglas E. Comer**, **David L. Stevens**: ***Internetworking with TCP/IP***, Prentice Hall
- **Dimitri Bertsekas and Robert Gallager**, ***Data Networks***, 2nd Edition, Prentice Hall, 1992.

Network Programming References

- **W. Richard Stevens**, ***TCP/IP Illustrated, Volume 1: The Protocols***
- **W. Richard Stevens, Bill Fenner** and **Andrew Rudoff, *Unix Network Programming, Volume 1: The Sockets Networking API*** *(3rd Edition)*,
- Online Resources
    - Material related to Linux Programming will be posted on the website of the course.

Journal Papers

Many problems related to next generation networks are under active debate and are not covered in the textbooks. Papers from current literature will be assigned.

Instructor Office Hours

- Monday: 3:00 p.m. - 4:30 p.m.
- Additional hours by appointment

TA Office Hours

- Tuesday and Thursday: 2:00 p.m. - 3:30 p.m.
- Additional hours by appointment

Important Dates

- Exam I: Tuesday February 28th, 2019.
- Exam II: Tuesday, April 25th, 2019.

Course Evaluation

- Homework: 10%
- Project: 30%
- Exam I: 30%
- Exam II:30%
- Class Participation (Round up or down)

Course Policies

The lecture notes are complemented by a reading list of important papers related to the topics covered in class. The list includes seminal research papers where the origins of the problems and techniques are discussed, and recent research papers which focus on the current state of the art. Students will be required to read and provide a short review of a selected set of papers as part of the homework assignment.

Students are expected to check the course webpage regularly for announcements, class schedules, lecture notes, homework assignment solutions, reading assignments, and other related course material, at the following website . Please, note that **all** material posted on the course webpage is subject to copyright and is only provided for personal use. It is, therefore, strictly prohibited to share any part of this material with others in any form or through any content sharing venues.

Homework assignments are expected to be turned in at the start of class period on the due date. Typically, homework is due one week after it is assigned unless otherwise mentioned. Students who are unable to attend the class may leave their homework in the instructor's mailbox at Sennott Square or at the front desk of the Computer Science Department prior to the scheduled class time. Unless a valid reason is provided, late homework will not be accepted. No homework will be accepted after the solution is posted.

Grades can be appealed up to two weeks after the solution is posted. The student must first seek resolution with the teaching assistant. If the issue is not satisfactorily resolved, the student should discuss the matter with the instructor of the course. Students are expected and strongly encouraged to actively participate in class discussions.

Academic Integrity

Students are expected to read, understand and abide by the Academic Integrity Code for the School of Arts and Sciences. Except for project assignments, all work in this course is to be done independently. Discussions among students about homework assignments should be limited to the general understanding of the problems and high-level exploration of possible approaches to the solution. Any other form of collaboration, including the use of all or part of the work of another student, will be considered cheating and will result in a failing grade for all involved parties and a report to the appropriate University authority.

Make-up Policy and Religious Observances

Students are expected to be present for all exams and quizzes. Make-up exams will only be granted in the event of an emergency, and only if the instructor is informed **in advance**. Failure to notify the instructor prior to missing an exam will result in a zero for the exam. If any of the scheduled class activities conflicts with observance of religious holidays, students are required to inform the instructor within the first two weeks of the term. An arrangement will be worked out to accommodate religious obligations.

Disability Resources and Services

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact the instructor and Disability Resources and Services, 216 William Pitt Union, 412-648-7890 or 412-383-7355 (TTY), as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course. More info at: www.drs.pitt.edu.

For a pdf version of the syllabus click on this link