

Data Communications and Networks

Spring 2024

Syllabus and Reading Assignments

Revision Date: January 15, 2024

Course Description:

This course teaches the design and implementation techniques essential for engineering robust networks. Topics include networking principles, Transmission Control Protocol/Internet Protocol, naming and addressing (Domain Name System), data encoding/decoding techniques, link layer protocols, routing protocols, transport layer services, congestion control, quality of service, network services, Software Defined Networks (SDNs), programmable routers and overlay networks, wireless and mobile networking, security in computer networks, multimedia networking, and network management.

The following sections provide the lecture topics for each class under the ***Description*** heading.

The material listed under ***Reading*** must be read PRIOR to the date of the lecture (except for the first lecture).

Prerequisites: Students must have a working knowledge of fundamental data structures and associated algorithms. For some of the practical aspects of the course, a working knowledge of an object-oriented programming language (e.g., C++, C#, Python, or preferably Java) is expected. An undergraduate course in data communication and networks is helpful but not required.

Session 1 – Introduction and Overview

Description

The session will cover administrative details for the course and will provide an overview of the topics and related assignments that will be covered during the semester. This first session will introduce some of the key elements of communications and networking to help get a “feel” for networking and understand

the terminology, and will provide an overview of the Internet from a structural and service perspective.

More in-depth details will be covered later in the course. Some of the key concepts covered in this session are as follows:

- Layered protocol model
- What *is* the Internet?
- Network edge
 - End systems, access networks, links
- Network core
 - Packet switching, circuit switching, network structure
 - Multiplexing
- Delay, loss and throughput in networks
- Protocol layers, service models
- Networks under attack: security
- History

The overview provided in this first session is very broad and will span both the first and second lectures.

Reading Session 1 Slides
Textbook: Abstract and Chapter 1

Session 2 – Application Layer

Description

The session will cover transport-layer service models, the client-server paradigm, peer-to-peer paradigm, Content Distribution Networks (CDNs). The approach followed is to learn about protocols by examining popular application-level protocols such as HTTP, FTP, SMTP / POP3 / IMAP, DNS. Creating network applications using the socket API will also be discussed.

Some of the key concepts covered in this session are as follows:

- Principles of network applications
- Web and HTTP
- FTP
- Electronic Mail
 - SMTP, POP3, IMAP
- DNS
- P2P applications
- Video streaming and content distribution networks
- Ethernet (network packet sniffer)

- Socket programming with UDP and TCP

Reading

Session 2 Slides

Textbook: Chapter 2

Session 3 – Data Encoding and Transmission

Description

The session will cover data transmission and encoding concepts for digital data transmission over digital and analog signals as well as analog data transmission over digital and analog signals. The session also covers ADTs for protocol design and related fundamental data structures used in communication protocols (e.g., Finite State Machines, Queues, Ring Buffers, etc.)

Some of the key concepts covered in this session are as follows:

- Data encoding and transmission concepts
- Digital data transmission over digital signal
 - NRZ encoding
 - Multilevel binary encodings
 - Biphasic encodings
 - Scrambling techniques
- Digital data transmission over analog signal
 - Public telephone system
 - Amplitude Shift Keying (ASK)
 - Frequency Shift Keying (FSK)
 - Phase Shift Keying (PSK)
 - Performance of digital to analog modulation schemes
 - Quadrature Amplitude Modulation (QAM)
- Analog data transmission over digital signal
 - Digitization
 - Pulse Code Modulation
 - Non-linear encoding
 - Delta modulation
- Analog data transmission over analog signal
 - Asynchronous transmission
 - Synchronous transmission
 - Ethernet link layer frame example

Reading

Session 3 Slides

Session 4 – Data Link Control

Description

The session will cover the principles behind the data link layer services and the instantiation and implementation of various link layer technologies.

Some of the key concepts covered in this session are as follows:

- Introduction and services
- Error detection and correction
- Multiple access protocols
- LANs
 - Addressing & ARP
 - Ethernet
 - Switches
 - VLANs
 - PPP
- Link virtualization
 - MPLS
- Data center networking
- Web request processing

Reading

Session 4 Slides

Textbook: Chapter 6

Session 5 – Wireless and Mobile Networks

Description

The session will cover the principles behind wireless communication and mobility.

Some of the key concepts covered in this session are as follows:

- Wireless
 - Wireless links, characteristics
 - CDMA
 - IEEE 802.11 wireless LANs (“Wi-Fi”)
 - Cellular Internet Access
 - Architecture
 - Standards (e.g., 4G, LTE, 5G)
- Mobility
 - Principles: addressing and routing to mobile users
 - Mobile IP
 - Handling mobility in cellular networks
 - Mobility and higher-layer protocols

Reading Session 5 Slides
Textbook: Chapter 7

Session 6-1 – Transport Layer (Part 1)

Description

Reliable Data Transfer (RDT) between communicating entities is one of the most important topics in communications. RDT will be defined in this session and three fundamental protocols will be examined: Stop and Wait, Go Back N, and Selective Repeat. Finite State Machines (FSMs) will be used to represent protocols throughout the discussion of this topic. This session will also conduct a thorough examination of the TCP connection management, flow control, and error detection/correction protocols, and in particular, use TCP as a practical implementation of a sliding window protocol. The material covered in these topics will make it possible for students to examine a TCP session trace and understand exactly what is happening.

Some of the key concepts covered in this session are as follows:

- Transport-layer services
- Multiplexing and demultiplexing
- Connectionless transport: UDP
- Principles of reliable data transfer

Reading Session 6 Slides
Textbook: Chapter 3 (sections 3.1-3.5)
RFC 793 (intro, sections 1 and 2)

Session 6-2 – Transport Layer (Part 2)

Description

This session is a continuation of the previous session and completes the coverage of TCP topics with a focus on congestion control. Congestion control is a top issue in network design. This session will examine the causes, effects, and approaches to congestion control. This session will discuss TCP congestion control presently in use (AIMD) and will try to determine if this "self-policing" approach leads to fair use of the Internet.

Some of the key concepts covered in this session are as follows:

- Connection-oriented transport: TCP
 - Segment structure
 - Reliable data transfer

- Flow control
- Connection management
- Principles of congestion control
- TCP congestion control
- UDP

Reading Session 6 Slides
 Textbook: Chapter 3 (sections 3.6, 3.7)
 IETF RFC 2581

Session 7 – Network Layer – The Data Plane

Description

This session covers the principles behind network layer services including network layer service models, forwarding versus routing, and the innerworkings of a router. The session also covers instantiation of the data plane and its implementation in the Internet.

Some of the key concepts covered in this session are as follows:

- Overview of Network layer
 - Data plane
 - Control plane
- What's inside a router
- IP: Internet Protocol
 - Datagram format
 - Fragmentation
 - IPv4 addressing
 - Network address translation
 - IPv6
- Generalized Forward and SDN
 - Match
 - Action
 - OpenFlow examples of match-plus-action in action

Reading Session 7 Slides
 Textbook: Chapter 4

Session 8 – Network Layer – The Control Plane

Description

This session will cover the principles behind network control plane including traditional routing algorithms (path selection) and, in particular, dealing with scale and related advanced topics such as IPv6 and mobility. The session will delve into

the details of SDN controllers, the Internet Control Message Protocol (ICMP), network management, and routing protocols instantiation as well as their implementation in the Internet touching upon OSPF, BGP, OpenFlow, ODL and ONOS controllers, ICMP, and SNMP.

Some of the key concepts covered in this session are as follows:

- Routing protocols
 - Link state
 - Distance vector
 - Hierarchical routing
- Intra-AS routing in the Internet: RIP, OSPF
- Routing among the ISPs: BGP
- The SDN control plane
- ICMP: The Internet Control Message Protocol
- Network management and SNMP
- Broadcast and multicast routing

Reading Session 8 Slides
Textbook: Chapter 5

Session 9 – IP Multicast

Description

IP multicast allows a sender to broadcast a message to a group of interested parties anywhere on the Internet, but like IP unicast, it is unreliable. The problems one faces when designing a reliable multicast protocol are very different than for a point-to-point protocol. This session will look at IP Multicast, including a Java example, it will then look at two approaches to reliable IP multicast: PGM (Pragmatic General Multicast,) and if time permits, a very neat approach based on token passing. The session will also cover performance in queuing systems as it relates to networking. Performance of client server systems is typically a function of load (frequency of requests). This session will take a look at how queuing theory can be helpful in understanding client/server behavior under load.

This session will also allow time for questions about the final project.

Reading Session 9 Slides
Performance in Queuing Systems
IP Multicast Backgrounder
RFC 1022 (IP Multicast Extensions) (optional)
RFC 3208 (PGM) (optional)

Session 10 – Multimedia Networking

Description

This session will focus on multimedia networking applications. Some of the key concepts covered in this session are as follows:

- Streaming stored audio and video
- Making the best out of best effort service
- Protocols for real-time interactive applications RTP, RTCP, SIP
- Providing multiple classes of service
- Providing QoS guarantees

Reading Session 10 Slides
Textbook: Chapter 9

Session 11 – Security in Computer Networks

Description

This session will focus on security in computer networks. Some of the key concepts covered in this session are as follows:

- What is network security?
- Principles of cryptography
- Message integrity
- Securing e-mail
- Securing TCP connections: SSL
- Network layer security: IPsec
- Securing wireless LANs
- Operational security: firewalls and IDS

Reading Session 11 Slides
Textbook: Chapter 8

Session 12 – Network Management

Description

This session will focus on network management. Some of the key concepts covered in this session are as follows:

- Introduction to network management
 - Motivation
 - Major components
- Internet network management framework

- MIB: management information base
- SMI: data definition language
- SNMP: protocol for network management
- Security and administration
- Presentation services: ASN.1

Reading

Session 12 Slides
