Class meets Monday and Wednesday, 10am to 11:50pm, beginning Monday August 26 and ending Wednesday December 4, with a final exam on Monday December 16 at 8am. There will be no class on September 2 (Labor day) nor on November 27 (Thanksgiving recess). We will have two short midterms at 10am September 23 and 10am October 28. The date and time of the final is Monday, 2024-12-16, 8am–10am.

All students are expected to confirm they can make both the midterm and final exams—we do not offer alternative dates.

All classes will be hybrid in-person and online via DEN’s web videoconferencing. DEN prefers Cisco WebEx as the platform and we will use that. I have an interactive lecture style and will do my best to adapt it to online class—I strongly encourage students to attend class synchronously and be prepared to comment during class to get the most out of class.

Changes: This syllabus may be updated over the semester. The most recent version can always be found at the class Moodle site.

2024-07-05: no changes yet
2024-08-08: moved [Demers89a] forward one week.
2024-08-12: moved the TCP papers forward to week 3.

Obtaining class papers: All class papers are available from the CSci551/651 Moodle site (described below) in PDF format. Because they are copyrighted they are available only for classroom use. The Moodle site is only available to students with class-specific accounts.

To get a Moodle account, go to http://www.isi.edu/~johnh/cs651.html and follow the instructions, or e-mail the professor or TA.

The primary source of content for the class is these papers, so you will want to download the papers from the website and read them. Downloaded they take up about 95MB storage.

A good option for handling the paper is to get some kind of an e-reader. Several class members and the professor did that last year. You need something that can display 8.5 × 11 inch PDF files comfortably. Tables work well for this—the iPad is common (I previously used the iAnnotate PDF reader and note-taker), and Android tablets also work well (I currently use the Xodo PDF Reader and annotator). The reMarkable e-ink tablet is beautiful and light, although I’m not as fond of their proprietary annotations. In 2024 there are some new fast-update e-ink readers that look promising—if you try one, please let me know what you think. In 2024 the Kindle script might be worth trying, but some reports are that it’s PDF management and annotations mechanisms are limited.

Printing out the papers is also tried and true, and note taking with pencils works well. If you print the papers out, I strongly encouraged you to use a double-sided printer. You will need a 3-inch binder if you keep them that way. (If you have to pay for printing, you may find it cheaper to get together with other students to print one copy and photocopy additional ones. Please do so safely during the pandemic.)

Some of the papers were scanned. These tend to have large (2–5MB) PDF files, and may look slightly fuzzy when printed. Some of the papers may not display well in Acrobat on the screen, but they all should
look reasonable when printed.

In SP2005 we tried making hardcopies of the papers available to students. Unfortunately, USC requires that we charge for these (to recover the duplication costs), and the copyright owners (ACM, IEEE, etc.) insist that if there is any charge, then they must get a copyright fee. The total fee for the entire paper set was well over $250, and it was still more than $100 even if the optional papers were eliminated. For this reason I do not plan to make hardcopies available.

In this syllabus, “new” indicates papers that are new since my section of CSci651 or CSci551 from FA2022. (There will be other variations between my section and sections taught by other professors.)

Class Pace: We will usually go over three or four papers or so per week, and occasionally more. The syllabus is designed to be slightly front-loaded, with the intent that we will run a paper or two (or sometimes a full class) behind for part of the semester.

Primary and Supplemental Papers: There are two groups of papers. We will discuss primary papers in class. The concepts and details from primary papers is fair game in exams. On the other hand, supplemental will not be discussed in class, and you are not required to know details from those papers for exams (although the concepts might, since they are networking papers). You are encouraged to read the supplemental papers if you’re interested in an area. (Supplemental papers will also appear on homework 1.)

I am happy to take questions about either primary or supplemental papers in class or office hours.

Other class activities: This syllabus lists exams and papers. You should also expect a class project, typically in three parts (A, B and C), and several homework assignments (often 4, but at least 3 and no more than 6). Dates for these will be given as the semester progresses.

Please note that the class dates are when you are expected to have read the papers. At times during the semester we will probably be behind a couple of papers, but you are encouraged to stay with this syllabus for reading.

# Reference and background

Class Week 1 (Aug. 26 and Aug. 28):

**Project A assigned August 25, due September 10.**

Primary: Tips for reading papers: [Hanson99a]


Another viewpoint of paper reading [Jamin03a]


What to look for in systems papers: [Levin83a]


Finding and judging new ideas: [Heilmeier92a]

No paper, but we will review and discuss: General networking, network addressing, data marshalling, packet formats and encoding.

2 Design principles

Class Week 2 (Sep. 2 and Sep. 4):

No class Sept. 2 due to Labor Day, a USC holiday.

Primary: The Internet architecture: [Clark88a]


Naming: [Saltzer82a]


The end-to-end argument: [Saltzer81a]


Supplemental:

How “tussles” affect network architecture: [Clark02a]


3 Transport protocols, Congestion Control

(Usually we do transport protocols later in the semester, but they relate to the class project so we’re doing them earlier this time.)

Class Week 3 (Sep. 9 and Sep. 11):

Project B assigned Sep. 9, due October 15.

Primary:

TCP and congestion control: [Jacobson88a]

Congestion control from first principles: [Ramakrishnan90a]


Bottleneck Bandwidth and Round-trip TCP [Cardwell17a]


Supplemental:
An early academic paper on TCP, prompting the 2004 Turning Award for its authors: [Cerf74a]


Modeling TCP: [Padhye98a]


TCP extensions for a datacenter: [Alizadeh10a]


4 Routing and Topology

Class Week 4 (Sep. 16: and Sep. 18):

Primary:

Review of unicast and distance vector routing. (Will use class notes, plus please review your EE450 work.)

BGP introduction: [Caesar05a]


Routing stability and oscillation (plus a taste of queueing theory): [Shaikh00a]


Routing security:

[Goldberg14a]

Supplemental:
Additional background about BGP: [Balakrishnan08a]


Synchronization problems in routing (but also applies much wider): [Floyd94b]


Routing hierarchy and policy: [Gao01b]


NEW: Google’s peering approach (Espresso) [Yap17a]


Class Week 5 (Sep. 23 and Sep. 25):

Short Midterm 1 will be the first 35 minutes of September 23.

Network measurement: topology

Primary:

Network topology: [Oliveira08a]


Class Week 6 (Sep. 30 and Oct. 2):

Network measurement: outages and traffic

Edge-network outages: [Quan13c]


This is your network on Covid: [Boettger20a]


Supplemental:
Congestion in the network: [Dhandhere18a]
5 Active Queue Management and a Return to Transport Protocols


Primary: Active queue management, such as fair queueing: [Demers89a]


Early drop with CoDel: [Nichols12a]


XCP and non-TCP congestion control: [Katabi02a]


Supplemental:
QUIC, an replacement for TCP that avoids head-of-line blocking [Langley17a]


Congestion control by exhaustive computer search: [Winstein13a]

6 Wireless and Mobile Networking

Class Week 8 (Oct. 14 and Oct. 16):


Primary:
Non-IP routing in sensor networks: [Intanagonwiwat00a]


Mobile (cellular) networks: 4G LTE performance: [Huang13a]


5G mobile networks: [Narayanan21a]


Supplemental:

MAC protocols: [Bharghavan94a]


Wireless propagation characteristics: [Aguayo04a]


More about 5G performance: [Hassan22a]


Polymorphic radios: [Rostami18a]

7 Characterizing Network Traffic

Class Week 9 (Oct. 21 and Oct. 23):

Primary:

Self-similarity in LAN traffic: [Leland94a]


And in WAN and web traffic: [Crovella97a]


Changes to the network topology: [Labovitz10c]


Supplemental:

Packet-level network dynamics: [Paxson99b]


Economics and availability of broadband: [Paul23a]


8 Cloud Computing and In the Cloud

Class Week 10 (Oct. 28 and Oct. 30):

Short Midterm 2 will be the first 35 minutes of October 28.

Primary:

While most of the class focuses on protocols that connect things, this class focuses on how one builds data services that can sit at one end of the connection, often the “inside” of the cloud. For more work in this direction, see CSci555 (graduate operating systems) and distributed computing.

Building large-scale services [Fox97a]


Data-parallel processing with map/reduce: [Dean04a]
9 Data Center Networks and Software Defined Networking

What’s the right network to run the apps from the last class?

Class Week 11 (Nov. 4 and Nov. 6):

Running an enterprise network (Ethane, a parent of OpenFlow): [Casado09a]


P4, generalizing OpenFlow: [Bosshart14a]


Optimizing a datacenter network: [Greenberg09a]


Getting the data out of the datacenter: [Schlinker17a]

10 Network Architecture Past and Future

Class Week 12 (Nov. 11 and Nov. 13):

Primary:

Google’s use of Software Defined Networking for traffic engineering: [Jain13a]


Information-centric networking: [Jacobson12a]


Quality of service and admission control: [Shenker95a]


Supplemental:

Modern congestion control and streaming video: [Akhtar18a]

Traffic engineering: [Hong13a]

**S29.** [Hong13a] Chi-Yao Hong, Srikanth Kandula, Ratul Mahajan, Ming Zhang, Vijay Gill, Mohan Nanduri, and Roger Wattenhofer. Achieving high utilization with software-driven WAN. In *Proceedings of the ACM SIGCOMM Conference*, pages 15–26, Hong Kong, China, August 2013. ACM.

## 11 Network Security

**Class Week 13** (Nov. 18 and Nov. 20):

Primary:

Spam and anti-spam: [Levchenko11a]


TLS interception: [Raman20a]


Onion routing (TOR): [Dingledine04a]


*Supplemental:*

Denial of service attacks: [Hussain03b]


Worm propagation: [Staniford02a]


Multi-party TLS: [Naylor15a]

(Note that, in this class, we intentionally do not do the cryptographic side of network security. There is coverage of that material in CSci555, Graduate Operating Systems, and most of CSci530, Security Systems, is about that.) Unfortunately there is not time to talk about security and network protocols in CSci551. CSci555 provides a good coverage of security from an operating systems perspective; see the papers by Voydock and Kent and Needham and Schroder there.

12 Peer-to-peer and Content Delivery Networks

Class Week 14 (Nov. 25 and Nov. 27):

Primary:
Efficient peer-to-peer storage: [Stoica00a]


Microsoft Bing’s anycast CDN: [Calder15a]


Latency in and out of the cloud: [Jin19a]


Supplemental:
Akamai, a modern CDN: [Schomp20a]


Freenet and anonymous peer-to-peer file sharing: [Clarke02a]

S34. [Clarke02a] Ian Clarke, Theodore W. Hong, Scott G. Miller, Oskar Sandberg, and Brandon Wiley. Protecting free expression online with Freenet. IEEE Internet Computing, 6(1):40–49, February 2002.

Privacy built over BitTorrent in OneSwarm: [Isdal10a]


12
13 Privacy and Ethics

Class Week 15 (Dec. 2)

No class Nov. 24 due to the Thanksgiving holiday.

**Poster Session:** we will have a poster session for all people doing research projects on Nov. 25 in the second half of class. The poster session is **required attendance for CSci651 students.**

Ethics and network research: [Dittrich11a]


*Supplemental:*

Network data collection and differential privacy: [McSherry10a]


14 Network Diagnosis and Alternative Architectures

Failures in Google’s networks: [Govindan16a]


NEW-FA2024: A completely different type of cloud networking (balloons): [Uyeda22a]


15 Other Topics: Hardware and Software in Routers and Devices

These are topics we cannot cover but that are considered in some similar network courses. All these materials are supplemental.

*Supplemental:*

Router design: [Miao17a]


Router software (Click): [Kohler00a]

RFID-inspired energy harvesting networks: [Liu13a]


### 16 Final Exam

The final exam is **Monday, December 16, 8am–10am** (sorry, it’s the University’s choice of start time).