CSci551 Syllabus—SP2019, Friday Section

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December 12, 2018

Class meets Fridays, 9am to 12:40pm, beginning January 11 and ending April 26. There is no class on March 15 (Spring Break). The date and time of the midterm is 9am March 8. The date and time of the final is Friday, May 3, 8am–10am.

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

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

2018-12-09: no changes yet

Obtaining these papers: All of these papers are available from the CSci551 Moodle site (see URL above) 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 enforce this; to get an account, go to `http://www.isi.edu/~johnh/cs551.html` and follow the instructions, or contact the professor or TA.

The *primary* source of content for the class is these papers, so you will want to download 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. Android tables work well and several PDF annotators are available (I use RepliGo PDF Reader, which is a nice annotator as well). An iPad works well, and several PDF readers and note-taking programs are available (I previously used iAnnotate). I have used a small Kindle, which worked adequately if you can tolerate only seeing half a page at a time. The large Kindle (DX) is good for reading, but my experience was that its software doesn't support note taking over PDF at all. Please let me know if you have any other suggestions.

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.)

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 SP2018. (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. (Typically project B is due the week after spring break, C is due the last week of class.)

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.

1 Reference and background

Class Week 1 (Jan. 11):

Primary: Tips for reading papers: [Hanson99a]

P1. [Hanson99a] Michael J. Hanson. Efficient reading of papers in science. Brochure of unknown origin, revised 1999 by Dylan J. McNamee, 1989.

Another viewpoint of paper reading [Jamin03a]

P2. [Jamin03a] Sugih Jamin. Paper reading and writing check lists. web page `http://irl.eecs.umich.edu/jamin/courses/eecs589/papers/checklist.html`, November 2003.

What to look for in systems papers: [Levin83a]

P3. [Levin83a] Roy Levin and David D. Redell. An evaluation of the ninth SOSP submissions, or how (and how not) to write a good systems paper. *ACM Operating Systems Review*, 17(3):35–40, July 1983.

Finding and judging new ideas: [Heilmeier92a]

P4. [Heilmeier92a] George H. Heilmeier. Some reflections on innovation and invention. *The Bridge*, 22:12–16, Winter 1992.

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

2 Design principles

Class Week 2 (Jan. 18):

Primary: The Internet architecture: [Clark88a]

P5. [Clark88a] David D. Clark. The design philosophy of the DARPA Internet protocols. In *Proceedings of the 1988 Symposium on Communications Architectures and Protocols*, pages 106–114. ACM, August 1988.

Naming: [Saltzer82a]

P6. [Saltzer82a] Jermome H. Saltzer. On the naming and binding of network destinations. In *International Symposium on Local Computer Networks*, pages 311–317, April 1982.

The end-to-end argument: [Saltzer81a]

P7. [Saltzer81a] J. H. Saltzer, D. P. Reed, and D. D. Clark. End-to-end arguments in system design. *Proceedings of the 2nd International Conference on Distributed Computing Systems*, pages 509–512, April 1981.

Supplemental:
How "tussles" affect network architecture: [Clark02a]

S1. [Clark02a] David D. Clark, John Wroclawski, Karen Sollins, and Robert Braden. Tussle in cyberspace: Defining tomorrow's internet. In *Proceedings of the ACM SIGCOMM Conference*, pages 347–356, Pittsburgh, PA, USA, August 2002. ACM.

3 Unicast Routing

Class Week 3 (Jan. 25):

Primary:

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

BGP introduction: [Caesar05a]

P8. [Caesar05a] Matthew Caesar and Jennifer Rexford. BGP routing policies in ISP networks. *IEEE Network Magazine*, 19(6):5–11, November 2005.

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

P9. [Shaikh00a] Aman Shaikh, Lampros Kalampoukas, Rohit Dube, and Anujan Varma. Routing stability in congested networks: Experimentation and analysis. In *Proceedings of the ACM SIGCOMM Conference*, pages 163–174, Stockholm, Sweeden, August 2000. ACM.

Routing security:

[Goldberg14a]

P10. [Goldberg14a] Sharon Goldberg. Why is it taking so long to secure Internet routing? *Communications of the ACM*, 57(10):56–63, October 2014.

Supplemental:
Additional background about BGP: [Balakrishnan08a]

S2. [Balakrishnan08a] Hari Balakrishnan. Interdomain internet routing. web page `http://stellar.mit.edu/S/course/6/sp08/6.829/courseMaterial/topics/topic4/lectureNotes/noname/noname`, Spring 2008.

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

S3. [Floyd94b] S. Floyd and V. Jacobson. The synchronization of periodic routing messages. *ACM/IEEE Transactions on Networking*, 2(2):122–136, April 1994.

Routing hierarchy and policy: [Gao01b]

S4. [Gao01b] Lixin Gao. On inferring autonomous system relationships in the Internet. *ACM/IEEE Transactions on Networking*, 9(6):733–745, December 2001.

Classic cases where policy choices in peerings result in oscillations: [Griffin99a]

S5. [Griffin99a] Timothy G. Griffin and Gordon Wilfong. An analysis of BGP convergence properties. In *Proceedings of the ACM SIGCOMM Conference*, pages 277–288, Cambridge, MA, USA, September 1999. ACM.

Class Week 4 (Feb. 1): **Network outages in the control and data planes**

Primary:

Ethane is out of order because we will review it for the class project.) Running an enterprise network (Ethane, a parent of OpenFlow): [Casado09a]

P11. [Casado09a] Martin Casado, Michael J. Freedman, Justin Pettit, Jianying Luo, Natasha Gude, Nick McKeown, and Scott Shenker. Rethinking enterprise network control. *ACM/IEEE Transactions on Networking*, 17(4):1270–1283, August 2009.

Congestion in the network: (NEW SP2019) [Dhamdhere18a]

P12. [Dhamdhere18a] Amogh Dhamdhere, David D. Clark, Alexander Gamero-Garrido, Matthew Luckie, Ricky K. P. Mok, Gautam Akiwate, Kabir Gogia, Vaibhav Bajpai, Alex C. Snoeren, and kc claffy. Inferring persistent interdomain congestion. In *Proceedings of the ACM SIGCOMM Conference*, pages 1–15, Budapest, Hungary, August 2018. ACM.

Edge-network outages: [Quan13c]

P13. [Quan13c] Lin Quan, John Heidemann, and Yuri Pradkin. Trinocular: Understanding Internet reliability through adaptive probing. In *Proceedings of the ACM SIGCOMM Conference*, pages 255–266, Hong Kong, China, August 2013. ACM.

Network topology: [Oliveira08a]

P14. [Oliveira08a] Ricardo V. Oliveira, Dan Pei, Walter Willinger, Beichuan Zhang, and Lixia Zhang. In search of the elusive ground truth: the Internet's AS-level connectivity structure. In *Proceedings of the ACM SIGMETRICS*, pages 217–228. ACM, June 2008.

Supplemental:
Routing outages, results, and causes: [Wang06b]

S6. [Wang06b] Feng Wang, Zhuoqing Morley Mao, Jia Wang, Lixin Gao, and Randy Bush. A measurement study on the impact of routing events on end-to-end Internet path performance. In *Proceedings of the ACM SIGCOMM Conference*, pages 375–386, Pisa, Italy, August 2006. ACM.

Path inflation: [Spring03a]

S7. [Spring03a] Neil Spring, Ratul Mahajan, and Thomas Anderson. Quantifying the causes of path inflation. In *Proceedings of the ACM SIGCOMM Conference*, pages 113–124, Karlsruhe, Germany, August 2003. ACM.

SDN-like control by lieing to IGP: [Vissicchio15a]

S8. [Vissicchio15a] Stefano Vissicchio, Olivier Tilmans, Laurent Vanbever, and Jennifer Rexford. Central control over distributed routing. In *Proceedings of the ACM SIGCOMM Conference*, page to appear, London, UK, August 2015. ACM.

4 Transport protocols, Congestion Control, and Queue Management

Class Week 5 (Feb. 8):

Primary:

TCP and congestion control: [Jacobson88a]

P15. [Jacobson88a] Van Jacobson. Congestion avoidance and control. In *Proceedings of the ACM SIGCOMM Conference*, pages 314–329, Stanford, California, USA, August 1988. ACM.

Congestion control from first principles: [Ramakrishnan90a]

P16. [Ramakrishnan90a] K. K. Ramakrishnan and Raj Jain. A binary feedback scheme for congestion avoidance in computer networks. *ACM Transactions on Computer Systems*, 8(2):158–181, May 1990.

Modeling TCP: [Padhye98a]

P17. [Padhye98a] J. Padhye, V. Firoiu, D. Towsley, and J. Kurose. Modelling TCP throughput: A simple model and its empirical validation. In *Proceedings of the ACM SIGCOMM Conference*, pages 303–314, Vancouver, Canada, September 1998. ACM.

Bottleneck Bandwidth and Round-trip TCP [Cardwell17a]

P18. [Cardwell17a] Neal Cardwell, Yuchung Cheng, C. Stephen Gunn, Soheil Hassas Yeganeh, and Van Jacobson. BBR: Congestion-based congestion control. *Communications of the ACM*, 60(2):58–66, February 2017.

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

S9. [Cerf74a] Vint Cerf and Robert Kahn. A protocol for packet network interconnection. *IEEE Transactions on Communications*, COM-22(5):637–648, May 1974.

TCP extensions for a datacenter: [Alizadeh10a]

S10. [Alizadeh10a] Mohammad Alizadeh, Albert Greenberg, David A. Maltz, Jitendra Padhye, Parveen Patel, Balaji Prabhakar, Sudipta Sengupta, and Murari Sridharan. Data center TCP (DCTCP). In *Proceedings of the ACM SIGCOMM Conference*, New Delhi, India, August 2010. ACM.

Congestion control by exhaustive computer search: [Winstein13a]

S11. [Winstein13a] Keith Winstein and Hari Balakrishnan. TCP ex machina: Computer-generated congestion control. In *Proceedings of the ACM SIGCOMM Conference*, pages 123–134, Hong Kong, China, August 2013. ACM.

Class Week 6 (Feb. 15): TCP follow-up. XCP and other transport protocols. Queue management. Fair queueing.

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

P19. [Demers89a] Alan Demers, Srinivasan Keshav, and Scott Shenker. Analysis and simulation of a fair queueing algorithm. In *Proceedings of the ACM SIGCOMM Conference*, pages 1–12, Austin, Texas, September 1989. ACM.

Early drop with CoDel: [Nichols12a]

P20. [Nichols12a] Kathleen Nichols and Van Jacobson. Controlling queue delay. *Communications of the ACM*, 55(7):42–50, July 2012.

XCP and non-TCP congestion control: [Katabi02a]

P21. [Katabi02a] Dina Katabi, Mark Handley, and Charlie Rohrs. Congestion control for high bandwidth-delay product networks. In *Proceedings of the ACM SIGCOMM Conference*, pages 89–102, Pittsburgh, PA, USA, August 2002. ACM.

Supplemental:
Random early detection: [Floyd93a]

S12. [Floyd93a] Sally Floyd and Van Jacobson. Random early detection gateways for congestion avoidance. *ACM/IEEE Transactions on Networking*, 1(4):397–413, August 1993.

QUIC, an proposed replacement for TCP that can be more rapidly evolved [Langley17a]

S13. [Langley17a] Adam Langley, Alistair Riddoch, Alyssa Wilk, Antonio Vicente, Charles Krasic, Dan Zhang, Fan Yang, Fedor Kouranov, Ian Swett, Janardhan Iyengar, Jeff Bailey, Jeremy Dorfman, Jim Roskind, Joanna Kulik, Patrik Westin, Raman Tenneti, Robbie Shade, Ryan Hamilton, Victor Vasiliev, Wan-Teh Chang, and Zhongyi Shi. The QUIC transport protocol: Design and internet-scale deployment. In *Proceedings of the ACM SIGCOMM Conference*, pages 183–196, Los Angeles, CA, USA, August 2017. ACM.

5 Wireless and Mobile Networking

Class Week 7 (Feb. 22):

Primary:

MAC protocols: [Bharghavan94a]

P22. **[Bharghavan94a]** Vaduvur Bharghavan, Alan Demers, Scott Shenker, and Lixia Zhang. MACAW: A media access protocol for wireless LANs. In *Proceedings of the ACM SIGCOMM Conference*, pages 212–225, London, UK, September 1994. ACM.

Non-IP routing in sensor networks: [Intanagonwiwat00a]

P23. **[Intanagonwiwat00a]** Chalermek Intanagonwiwat, Ramesh Govindan, and Deborah Estrin. Directed diffusion: A scalable and robust communication paradigm for sensor networks. In *Proceedings of the ACM International Conference on Mobile Computing and Networking*, pages 56–67, Boston, MA, USA, August 2000. ACM.

Mobile (cellular) networks: [Huang13a]

P24. **[Huang13a]** Junxian Huang, Feng Qian, Yihua Guo, Yuanyuan Zhou, Qiang Xu, and Z. Morley Mao. An in-depth study of LTE: Effect of network protocol and application behavior on performance. In *Proceedings of the ACM SIGCOMM Conference*, pages 363–374, Hong Kong, China, Aug 2013. ACM.

Supplemental:
Wireless propagation characteristics: [Aguayo04a]

S14. **[Aguayo04a]** Daniel Aguayo, John Bicket, Sanjit Biswas, Glenn Judd, and Robert Morris. Link-level measurements from an 802.11b mesh network. In *Proceedings of the ACM SIGCOMM Conference*, pages 121–132, Portland, Oregon, USA, August 2004. ACM.

Wireless security: [Borisov01a]

S15. **[Borisov01a]** Nikita Borisov, Ian Goldberg, and David Wagner. Intercepting mobile communications: The insecurity of 802.11. In *Proceedings of the ACM International Conference on Mobile Computing and Networking*, pages 180–189, Rome, Italy, July 2001. ACM.

Polymorphic radios: (NEW SP2019) [Rostami18a]

S16. **[Rostami18a]** Mohammad Rostami, Jeremy Gummeson, Ali Kiaghadi, and Deepak Ganesan. Polymorphic radios: A new design paradigm for ultra-low power communication. In *Proceedings of the ACM SIGCOMM Conference*, pages 446–460, Budapest, Hungary, August 2018. ACM.

Wireless software radios: [Bahl09a]

S17. **[Bahl09a]** Paramvir Bahl, Ranveer Chandra, Thomas Moscibroda, Rohan Murty, and Matt Welsh. White space networking with Wi-Fi like connectivity. In *Proceedings of the ACM SIGCOMM Conference*, pages 27–39, Barcelona, Spain, August 2009. ACM.

6 Characterizing Network Traffic

Class Week 9 (Mar. 1):

Primary:

Self-similarity in LAN traffic: [Leland94a]

P25. **[Leland94a]** W.E. Leland, M.S. Taqqu, W. Willinger, and D.V. Wilson. On the self-similar nature of Ethernet traffic (extended version). *ACM/IEEE Transactions on Networking*, 2(1):1–15, February 1994.

And in WAN and web traffic: [Crovella97a]

P26. **[Crovella97a]** Mark E. Crovella and Azer Bestavros. Self-similarity in world wide web traffic: evidence and possible causes. *ACM/IEEE Transactions on Networking*, 5(6):835–846, December 1997.

Changes to the network traffic mix: [Labovitz10c]

P27. **[Labovitz10c]** Craig Labovitz, Scott Iekel-Johnson, Danny McPherson, Jon Oberheide, and Farnam Jahanian. Internet inter-domain traffic. In *Proceedings of the ACM SIGCOMM Conference*, pages 75–86, New Delhi, India, August 2010. ACM.

Supplemental:
Packet-level network dynamics: [Paxson99b]

S18. **[Paxson99b]** Vern Paxson. End-to-end Internet packet dynamics. *ACM/IEEE Transactions on Networking*, 7(3):277–292, June 1999.

xxx-consider-dropping

7 Midterm

Class Week 8 (Mar. 8):

The **midterm exam will be March 9**.

The **Midterm Exam** will be 9am to 10:30am on March 9. We *will* have lecture during the second half of class. (Sorry, but I hope neither you nor I want a four hour midterm exam. :-)

The second half of class does not have new papers scheduled, but we are usually behind a few papers at this point in the semester, so this will be a chance to catch up.

8 Spring Break: March 16

9 Cloud Computing and In the Cloud

Project B will be due noon Tuesday March 19, 2019.

Class Week 10 (Mar. 22):

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]

P28. **[Fox97a]** Armando Fox, Steven D. Gribble, Yatin Chawathe, Eric A. Brewer, and Paul Gauthier. Cluster-based scalable network services. In *Proceedings of the 16th Symposium on Operating Systems Principles*, pages 78–91, St. Malo, France, October 1997. ACM.

Data-parallel processing with map/reduce: [Dean04a]

P29. **[Dean04a]** Jeffrey Dean and Sanjay Ghemawat. MapReduce: Simplified data processing on large clusters. In *Proceedings of the USENIX Symposium on Operating Systems Design and Implementation*, pages 137–150, San Francisco, California, USA, December 2004. USENIX.

Performance out of the cloud: [Dean13a]

P30. **[Dean13a]** Jeffrey Dean and Luiz André Barroso. The tail at scale. *Communications of the ACM*, 56(2):74–80, February 2013.

Supplemental: Streaming and in-memory: [Zaharia12a]

S19. **[Zaharia12a]** Matei Zaharia, Mosharaf Chowdhury, Tathagata Das, Ankur Dave, Justin Ma, Murphy McCauley, Michael J. Franklin, Scott Shenker, and Ion Stoica. Resilient distributed datasets: A fault-tolerant abstraction for in-memory cluster computing. In *Proceedings of the USENIX Symposium on Network Systems Design and Implementation*, San Jose, CA, USA, April 2012. USENIX.

10 Data Center Networks and Software Defined Networking

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

Class Week 11 (Mar. 29):

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

[Casado09a] see above.

P4, generalzing OpenFlow: (NEW SP2019) [Bosshart14a]

P31. **[Bosshart14a]** Pat Bosshart, Dan Daly, Glen Gibb, Martin Izzard, Nick McKeown, Jennifer Rexford, Cole Schlesinger, Dan Talayco, Amin Vahdat, George Varghese, and David Walker. P4: Programming protocol-independent packet processors. *ACM Computer Communication Review*, 44(3):88–95, July 2014.

Optimizing a datacenter network: [Greenberg09a]

P32. **[Greenberg09a]** Albert Greenberg, James R. Hamilton, Navendu Jain, Srikanth Kandula, Changhoon Kim, Parantap Lahiri, David A. Maltz, and Parveen Pat. VL2: A scalable and flexible data center network. In *Proceedings of the ACM SIGCOMM Conference*, pages 51–62, Barcelona, Spain, August 2009. ACM.

Getting the data out of the datacenter: [Schlinker17a]

P33. **[Schlinker17a]** Brandon Schlinker, Hyojeong Kim, Timothy Cui, Ethan Katz-Bassett, Harsha V. Madhyastha, Italo Cunha, James Quinn, Saif Hasan, Petr Lapukhov, and Hongyi Zeng. Engineering egress with edge fabric: Steering oceans of content to the world. In *Proceedings of the ACM SIGCOMM Conference*, pages 418–431, Los Angeles, CA, USA, August 2017. ACM.

Supplemental:
A review of 10 years of Google datacenter topologies: [Singh15a]

S20. **[Singh15a]** Arjun Singh, Joon Ong, Amit Agarwal, Glen Anderson, Ashby Armistead, Roy Bannon, Seb Boving, Gaurav Desai, Bob Felderman, Paulie Germano, Anand Kanagala, Jeff Provost, Jason Simmons, Eiichi Tanda, Jim Wanderer, Urs Hoelzle, Stephen Stuart, and Amin Vahdat. Jupiter rising: A decade of Clos topologies and centralized control in google's datacenter network. In *Proceedings of the ACM SIGCOMM Conference*, page to appear, London, UK, August 2015. ACM.

Programming SDNs: [Bosshart14a]

[Bosshart14a] see above.

Programming SDNs: [Foster13a]

S21. [Foster13a] Nate Foster, Michael J. Freedman, Arjun Guha, Rob Harrison, Naga Praveen Katta, Christopher Monsanto, Joshua Reich, Mark Reitblatt, Jennifer Rexford, Cole Schlesinger, Alec Story, and David Walker. Languages for software-defined networks. *IEEE Communications Magazine*, 51(2):128–134, February 2013.

Network virtualization in datacenters: [Koponen14a]

S22. [Koponen14a] Teemu Koponen, Keith Amidon, Peter Balland, Martín Casado, Anupam Chanda, Bryan Fulton, Igor Ganichev, Jesse Gross, Natasha Gude, Paul Ingram, Ethan Jackson, Andrew Lambeth, Romain Lenglet, Shih-Hao Li, Amar Padmanabhan, Justin Pettit, Ben Pfaff, Rajiv Ramanathan, Scott Shenker, Alan Shieh, Jeremy Stribling, Pankaj Thakkar, Dan Wendlandt, Alexander Yip, and Ronghua Zhang. Network virtualization in multi-tenant datacenters. In *Proceedings of the USENIX Symposium on Network Systems Design and Implementation*, pages 203–216, Seattle, WA, USA, April 2014. USENIX.

11 Network Architecture Past and Future

Class Week 12 (Apr. 5):

Primary:

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

P34. [Jain13a] Sushant Jain, Alok Kumar, Joon Ong Subhasree Mandal, Leon Poutievski, Arjun Singh, Subbaiah Venkata, Jim Wanderer, Junlan Zhou, Jonathan Zolla Min Zhu, Urs Hölzle, Stephen Stuart, and Amin Vahdat. B4: Experience with a globally-deployed software defined WAN. In *Proceedings of the ACM SIGCOMM Conference*, pages 3–14, Hong Kong, China, August 2013. ACM.

Information-centric networking: [Jacobson12a]

P35. [Jacobson12a] Van Jacobson, Diana K. Smetters, James D. Thornton, Michael Plass, Nick Briggs, and Rebecca Braynard. Networking named content. *Communications of the ACM*, 55(1):117–124, January 2012.

Modern congestion control and streaming video: (NEW SP2019) [Akhtar18a]

P36. [Akhtar18a] Zahaib Akhtar, Yun Seong Nam, Ramesh Govindan, Sanjay Rao, Jessica Chen, Ethan Katz Bassett, Bruno Martins Ribeiro, and Hui Zhang Jibin Zhan. Oboe: Auto-tuning video ABR algorithms to network conditions. In *Proceedings of the ACM SIGCOMM Conference*, pages 44–59, Budapest, Hungary, August 2018. ACM.

Quality of service and admission control: [Shenker95a]

P37. [Shenker95a] Scott Shenker. Fundamental design issues for the future Internet. *IEEE Journal of Selected Areas in Communication*, 13(7):1176–1188, September 1995.

Supplemental:
Lighter-weight QoS: [Stoica03a]

S23. [Stoica03a] Ion Stoica, Scott Shenker, and Hui Zhang. Core-stateless fair queueing: a scalable architecture to approximate fair bandwidth allocations in high-speed networks. *ACM/IEEE Transactions on Networking*, 11(1):33–46, February 2003.

Use of QoS and differentiated services: [Davie03a]

S24. [Davie03a] Bruce Davie. Deployment experience with differentiated services. In *Proceedings of the ACM Workshop on Revisiting IP QoS*, pages 131–136, Karlsruhe, Germany, August 2003. ACM.

12 Network Security

Class Week 13 (Apr. 12):

Primary:

Spam and anti-spam: [Levchenko11a]

P38. [Levchenko11a] Kirill Levchenko, Andreas Pitsillidis, Neha Chachra, Brandon Enright, Márk Félegyházi, Chris Grier, Tristan Halvorson, Chris Kanich, Christian Kreibich, He Liu, Damon McCoy, Nicholas Weaver, Vern Paxson, Geoffrey M. Voelker, and Stefan Savage. Click trajectories: End-to-end analysis of the spam value chain. In *Proceedings of the IEEE Symposium on Security and Privacy*, pages 431–446, Oakland, CA, USA, May 2011. IEEE.

Onion routing (TOR): [Dingledine04a]

P39. [Dingledine04a] Roger Dingledine, Nick Mathewson, and Paul Syverson. Tor: The second-generation onion router. In *Proceedings of the 13th USENIX Security Symposium*, pages 303–320, San Diego, CA, USA, August 2004. USENIX.

Supplemental:
Denial of service attacks: [Hussain03b]

S25. [Hussain03b] Alefiya Hussain, John Heidemann, and Christos Papadopoulos. A framework for classifying denial of service attacks. In *Proceedings of the ACM SIGCOMM Conference*, pages 99–110, Karlsruhe, Germany, August 2003. ACM.

Worm propagation: [Staniford02a]

S26. [Staniford02a] Stuart Staniford, Vern Paxson, and Nicholas Weaver. How to 0wn the Internet in your spare time. *Proceedings of the 11th USENIX Security Symposium*, pages 149–167, August 2002.

End-to-end encryption: [Popa14a]

S27. [Popa14a] Raluca Ada Popa, Emily Stark, Jonas Helfer, Steven Valdez, Nickolai Zeldovich, M. Frans Kaashoek, and Hari Balakrishnan. Building web applications on top of encrypted data using Mylar. In *Proceedings of the 11th USENIX Symposium on Network Systems Design and Implementation*, pages 157–172, Seattle, WA, USA, April 2014. USENIX.

Multi-party TLS: [Naylor15a]

S28. [Naylor15a] David Naylor, Kyle Schomp, Matteo Varvello, Ilias Leontiadis, Jeremy Blackburn, Diego Lopez, Konstantina Papagiannaki, Pablo Rodriguez Rodriguez, and Peter Steenkiste. Multi-context TLS (mcTLS): Enabling secure in-network functionality in TLS. In *Proceedings of the ACM SIGCOMM Conference*, page to appear, London, UK, August 2015. ACM.

(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.

13 Peer-to-peer and Content Delivery Networks

Class Week 14 (Apr. 19):

Primary:

Efficient peer-to-peer storage: [Stoica00a]

P40. [Stoica00a] Ion Stoica, Robert Morris, David Karger, M. Frans Kaashoek, and Hari Balakrishnan. Chord: A scalable peer-to-peer lookup service for Internet applications. In *Proceedings of the ACM SIGCOMM Conference*, pages 149–160, Stockholm, Sweden, September 2000. ACM.

Akamai, a modern CDN: [Gillman15a]

P41. [Gillman15a] David Gillman, Yin Lin, Bruce Maggs, and Ramesh K. Sitaraman. Protecting websites from attack with secure delivery networks. *IEEE Computer*, 48(4):26–34, April 2015.

Microsoft Bing's anycast CDN: [Calder15a]

P42. [Calder15a] Matt Calder, Ashley Flavel, Ethan Katz-Bassett, Ratul Mahajan, and Jitendra Padhye. Analyzing the performance of an anycast CDN. In *Proceedings of the ACM Internet Measurement Conference*, Tokyo, Japan, October 2015. ACM.

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

S29. [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]

S30. [Isdal10a] Tomas Isdal, Michael Piatek, Arvind Krishnamurthy, and Thomas Anderson. Privacy-preserving P2P data sharing with OneSwarm. In *Proceedings of the ACM SIGCOMM Conference*, pages 111–122, New Delhi, India, August 2010. ACM.

14 Privacy and Ethics

Class Week 15 (Apr. 26):

Ethics and network research: [Dittrich11a]

P43. [Dittrich11a] David Dittrich and Erin Kenneally (editors). The Menlo report: Ethical principles guiding information and communication technology research. Technical report, United States Department of Homeland Security, September 2011.

Supplemental:
Network data collection and differential privacy: [McSherry10a]

S31. [McSherry10a] Frank McSherry and Ratul Mahajan. Differentially-private network trace analysis. In *Proceedings of the ACM SIGCOMM Conference*, pages 123–134, New Delhi, India, August 2010. ACM.

15 Network Diagnosis

Failures in Google's networks: [Govindan16a]

P44. [Govindan16a] Ramesh Govindan, Ina Minei, Mahesh Kallahalla, Bikash Koley, and Amin Vahdat. Evolve or die: High-availability design principles drawn from google's network infrastructure. In *Proceedings of the ACM SIGCOMM Conference*, pages 58–72, Florianopolois, Brazil, August 2016. ACM.

Supplemental:

16 Multicast Routing, Transport, and Applications

Multicast was a major push in networking in the 1990s, and it is standardized, deployed, and used in some niches. However a glut of bandwidth and technical challenges dealing with state (most protocols required per-multicast-group state in routers) means that wide-area IP mutlicast does not seem to have prospered. The techniques developed in multicast are interesting, worth understanding, and used by some. But as of FA2014, they are all supplemental.

Supplemental:
Multicast routing (flood-and-prune, rendezvous): (*for [Deering88b], please read only sections 1–4, pages 85–103*): [Deering88b]

S32. [Deering88b] Stephen E. Deering. Multicast routing in internetworks and extended LANs. In *Proceedings of the ACM SIGCOMM Conference*, pages 55–64, Stanford, CA, August 1988. ACM.

Reliable multicast and SRM: (*for [Floyd97c], please read only through section 7.1, page 15)*) [Floyd97c]

S33. [Floyd97c] Sally Floyd, Van Jacobson, Ching-Gung Liu, Steven McCanne, and Lixia Zhang. A reliable multicast framework for light-weight sessions and application level framing. *ACM/IEEE Transactions on Networking*, 5(6):784–803, December 1997.

File distribution and coding: [Byers98a]

S34. [Byers98a] John W. Byers, Michael Luby, Michael Mitzenmacher, and Ashutosh Rege. A digital fountain approach to reliable distribution of bulk data. In *Proceedings of the ACM SIGCOMM Conference*, pages 56–67, Vancouver, Canada, September 1998. ACM.

Multimedia: [Bolot94a]

S35. [Bolot94a] Jean-Chrysostome Bolot, Thierry Turlettil, and Ian Wakeman. Scalable feedback control for multicast video distribution in the Internet. In *Proceedings of the ACM SIGCOMM Conference*, pages 58–67, London, United Kingdom, September 1994. ACM.

17 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]

S36. [Miao17a] Rui Miao, Hongyi Zeng, Changhoon Kim, Jeongkeun Lee, and Minlan Yu. Silkroad: Making stateful layer-4 load balancing fast and cheap using switching ASICs. In *Proceedings of the ACM SIGCOMM Conference*, pages 15–28, Los Angeles, CA, USA, August 2017. ACM.

Router software (Click): [Kohler00a]

S37. [Kohler00a] Eddie Kohler, Robert Morris, Benjie Chen, John Jannotti, and M. Frans Kaashoek. The Click modular router. *ACM Transactions on Computer Systems*, 18(3):263–297, August 2000.

RFID-inspired energy harvesting networks: [Liu13a]

S38. [Liu13a] Vincent Liu, Aaron Parks, Vamsi Talla, Shyamnath Gollakota, David Wetherall, and Joshua R. Smith. Ambient backscatter: Wireless communication out of thin air. In *Proceedings of the ACM SIGCOMM Conference*, pages 39–50, Hong Kong, China, August 2013. ACM.

18 Final Exam

The final exam is **Friday, May 3, 8am–10am** (sorry, it's the University's choice of start time).