Lahore University of Management Sciences

CS 678 – Topics in Internet Research

Spring 2016

Instructors	Dr. Ihsan Ayyub Qazi and Dr. Zartash Afzal Uzmi
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Office Hours	TBA
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Class Timings	5pm-6:15pm, Tuesday/Thursday
Class Venue	A14, Academic Block
Course URL	http://lms.lums.edu.pk

Course Basics				
Credit Hours	3 credit hours			
Lecture(s)	2 per week		Duration	75 minutes per lecture

Course Distribution	
Core	None
Elective	All
Open for Student Category	All
Close for Student Category	All

COURSE DESCRIPTION

CS678 is a graduate-level course on computer networking research. The course involves lectures, paper reading, discussions, and a semester-long research project. CS678 will focus on six key areas in networking research namely, '*Network Architectures and Principles*', '*Cloud Computing and Datacenter Networking*', '*Transports, Congestion Control, and Buffer Sizing*', '*Routers, Routing, and Censorship*', '*Wireless Networks*', and '*ICT for Developing Regions*'. For each of these areas, we will read classical research works as well as explore the state-of-the-art. Students will be required to write paper summaries and participate in class discussions. In addition, students will be expected to make presentations on assigned papers and participate in a semester-long research project.

COURSE PREREQUISITE(S)

- CS382 (Net-Centric Computing) or CS471 (Computer Networks)

COURSE OBJECTIVES

- To become familiar with the state-of-the-art in computer networking research
- To understand how to engage in networking research
- To investigate novel ideas in computer networks through a semester-long research project

Learning Outcomes

- Students will have good understanding of the principles behind state-of-the-art network protocols and architectures
- Students will have gained experience in reading research papers and critically analyzing the research of others
- Students will gain experience with carrying out an independent research project

Grading Breakup and Policy

- Quizzes: 10%
- Attendance and Class Participation: 10%
- Paper Summaries + Short Presentation(s): 10%
- Long Presentation(s): 5%
- Final Exam: 20%
- Project: 45%
  - Bi-weekly Progress Meetings: 15%
  - Project Proposal: 5%

- Mid Project Report: 5%
- Final Report/Presentation: 20%

Research Project

The semester-long research project is one of the most important components of this course. The goal is to carry out novel research in the area of computer networks that by the end of the semester would be publishable in a good quality workshop or a conference. Past research projects in this course have been quite successful. Here are some papers that started out as course projects:

- **Aqib Nisar, Aqsa Kashaf, Zartash Afzal Uzmi, Ihsan Ayyub Qazi, "*A Case for Marrying Censorship Measurements with Circumvention*" in ACM HotNets 2015, Philadelphia, USA, November 2015**
- **Hasnain Ali Pirzada, M. Raza Mahboob, Ihsan Ayyub Qazi, "*eSDN: Rethinking Datacenter Transports Using End-Host SDN Controllers*" in ACM SIGCOMM 2015, London, UK, August 2015 (poster paper)**
- **Ruwaifa Anwar, Kamran Nishat, Mohsin Ali, Zahaib Akhtar, Haseeb Niaz, and Ihsan Ayyub Qazi, "*Loss Differentiation: Moving onto High-Speed Wireless LANs*" in IEEE INFOCOM 2014, Toronto, Canada**
- **Aisha Mushtaq, Asad Khalid Ismail, Abdul Wasay, Bilal Mahmood, Ihsan Ayyub Qazi, and Zartash Afzal Uzmi, "*Rethinking Buffer Management in Data Center Networks*" in ACM SIGCOMM 2014, Chicago, USA August 2014 (poster paper)**
- **Syed Mohammad Irteza, Adnan Ahmed, Sana Farrukh, Babar Naveed Memon, and Ihsan Ayyub Qazi, "*On the Coexistence of Transport Protocols in Data Centers*" in IEEE ICC 2014, Sydney, Australia, June 2014**
- **Ali Munir, Ihsan Ayyub Qazi, Zartash Afzal Uzmi, Aisha Mushtaq, Saad Naveed Ismail, M. Safdar Iqbal, and Basma Khan "*Minimizing Flow Completion Times in Data Centers*" in IEEE INFOCOM 2013, Turin, Italy**
- **Zahaib Akhtar, Kamran Nishat, Haseeb Niaz, Ruwaifa Anwar, Mohsin Ali, and Ihsan Ayyub Qazi, "*BLMon: A Loss Differentiation Scheme for 802.11n*" in IEEE INFOCOM 2013, Turin, Italy (poster paper)**
- **Shahida Jabeen, Muhammad Bilal Zafar, Ihsan Ayyub Qazi, and Zartash Afzal Uzmi, "*SplitBuff: Improving the Interaction of Heterogeneous RTT Flows on the Internet*" in IEEE ICC 2013, Budapest, Hungary, June 2013**

Project Proposal

The project proposal is due on Monday, February 8th in the form of a written document (max 2 pages). Students will also be expected to deliver a 10-min presentation on the proposal on Friday, February 12th. The proposal should have answers to the following questions:

a) What is the problem you plan to address?
b) What are the most related works? (state and cite some papers)
c) What is your proposal and how does it differ from prior work?
d) Mention a timeline and a division (if there are 2 or more members in the project) of the project tasks

Paper Summaries

A short written summary (max 1/2-page) of each assigned paper will be due by 11:59pm the day before the class. The summaries will be expected to cover the following points: *main idea (no more than 2 sentences), critique, and key assumptions made in the paper*. Students will be given bonus points for answering the following two questions: (a) *an advantage of the proposed work that was not discussed in the paper*, and (b) *a suggestion for extending or building on the paper for future work*.

All paper summaries will be expected to be submitted on LMS. We will be using piazza this semester for paper discussions. You can sign up for the class at the following URL: piazza.com/lums.edu.pk/spring2016/cs678

Bi-weekly Progress Meetings

The purpose of these meetings is to ensure that (a) the research projects are on track and (b) to strategize in case there are any bottlenecks in the project. Students will be expected to submit a list of milestones/tasks achieved (as bullet points) as well as a list of tasks to be carried out in the next two weeks (maximum 5 bullet points can be submitted). These need to be submitted on piazza as a private message to the instructors (select folders with names 'biweekly1', 'biweekly2', … , 'biweekly6').

Mid-Project Report

Students will be expected to submit a 1-page mid-project report on the milestones achieved, challenges faced and how you overcame them, and a list of future tasks to be carried out and a plan for the execution of the tasks.

Final Report

The final report should be structured as a conference/workshop paper and should include (a) description of the problem, (b) problem motivation, (c) your solution/idea, (d) discussion of related works, (e) evaluation of your solution, and (f) a conclusion. We strongly suggest that you write your final report using LaTeX. It is the de-facto tool in which most CS/EE research papers are written. While it has a small start-up cost, it is much easier to collaboratively write research papers using LaTeX than using Word. Here is a sample LaTex paper (http://www.cs.cmu.edu/~dga/15-744/S07/sample.tar.gz) and a MS Word template (sample file: http://www.acm.org/sigs/publications/pubform.doc) for ACM SIG proceedings).

Source Code Control

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You are required to use GitHub, version control platform for performing source code control for your project as well as for the paper/report you are writing. Please share a link of your public repository by the project proposal deadline.

Long Presentations
Students will be expected to deliver one or more long presentations (maximum 15mins, no more than 10 slides) in the course. We will assign papers to the students randomly. In some circumstances, two students may be assigned to make a joint presentation. It will be expected that the presenters will be prepared to answer any related questions.

Short Presentations
Students will be expected to present a short (oral) summary of the paper at the start of a class. Students will be chosen *randomly* for this purpose.

Class Participation (CP)
Students will be expected to participate actively in the class in the form of questions, critique of the paper, new ideas, etc. Grading of CP will also include attendance as a component.

Policies
- All deadlines are hard
- All assigned work must be done individually (unless specified otherwise)
- Re-grading can be requested within 2 days after grade reporting

Examination Detail	
Midterm Exam	Yes/No: **No**
Final Exam	Yes/No: **Yes** Duration: **3 hours**

	Session	Author(s)	Date	Lead Instructor
1	[Introduction] Course Introduction & Overview of Networking Research "*Starting a Research Project*" "*How to Read a Paper*" "*How to build research network systems in your spare time*" in ACM SIGCOMM CCR 2010	 Wilkes et al. S. Keshav R. Mahajan	26th Jan, 2015	Zartash Afzal Uzmi Ihsan Ayyub Qazi
	Network Architectures and Principles			
2	[Internet Architecture] "*The Design Philosophy of the DARPA Internet Protocols*" in ACM SIGCOMM 1988 [Optional] "*End-to-end Arguments in System Design*" in ACM Transactions on Computer Systems [Optional] "*Forty Data Communications Research Questions*" in ACM SIGCOMM CCR 2011 (*useful for research projects*)	 Clarke et al. Saltzer et al. Craig Partridge	28th Jan, 2015	Ihsan Ayyub Qazi
3	[Control Plane Architectures] [Video] "*The future of networking and the past of protocols*", talk by Scott Shenker at the Open Networking Summit, 2011 [Slides] "*Software-defined networking*", IEEE INFOCOM 2009 Keynote talk "*OpenFlow: Enabling Innovation in Campus Networks*" in ACM SIGCOMM CCR 2008 (focus on Section 2 and onwards) [Optional] "*The Road to SDN: An intellectual history of programmable networks*" in ACM Queue 2013	 Scott Shenker Nick McKeown Mckeown et al. Feamster et al.	2nd Feb, 2015	Ihsan Ayyub Qazi

	[Optional] "*Onix: A Distributed Control Platform for Large-scale Production Networks*" in OSDI 2010	Koponen et al.		
4	[Application of SDN: Middleboxes] "*SIMPLE-fying Middlebox Policy Enforcement Using SDN*" in ACM SIGCOMM 2013. [Optional] "*BlindBox: Deep Packet Inspection over Encrypted Traffic*" in ACM SIGCOMM 2015 [Optional] "*E2: A Framework for NFV Applications*" in SOSP 2015	Zafar Ayyub Qazi et al. Sherry et al. Palkar et al.	4th Feb, 2015	
5	[Programmable Data Planes] "*Millions of Little Minions: Using Packets for Low Latency Network Programming and Visibility*" in ACM SIGCOMM 2014 [Optional] "*Programming Protocol-Independent Packet Processors*" in ACM SIGCOMM CCR 2014 [Optional] "*Network Functions Virtualization*" - White Paper, 2012 [Optional] "*Fabric: A Retrospective on Evolving SDN*" in HotSDN 2012	Jeyakumar et al. Bosshart et al. Casado et al.	9th Feb, 2015	Zartash Afzal Uzmi
Transports, Congestion Control (CC), and Buffer Sizing				
6	[Resource Sharing with TCP] "*Congestion Avoidance and Control*" in ACM SIGCOMM 1988 "*Sizing Router Buffers*" in ACM SIGCOMM 2004 [Optional] "*Analysis of the Increase and Decrease Algorithms for Congestion Avoidance in Computer Networks*", Computer Networks and ISDN Systems, 1989 [Optional] "*Rethinking Buffer Management in Data Center Networks*" in ACM SIGCOMM 2014 (poster)	Jacobson et al. Appenzeller et al. Chiu et al. Aisha Mushtaq et al.	11th Feb, 2015	Ihsan Ayyub Qazi
7	[Beyond TCP] "*Processor Sharing Flows in the Internet*" in IWQoS 2005 "*TCP ex Machina: Computer-Generated Congestion Control*" in ACM SIGCOMM 2013 (read the introduction and skim the rest) [Optional] "*Congestion Control With Multipacket Feedback*" in IEEE/ACM Transactions on Networking, 2012	Dukkipati et al. Winstein et al. Ihsan Qazi et al.	16th Feb, 2015	Zartash Afzal Uzmi
Routers, Routing, and Censorship				
8	[Routing] "*Interdomain Internet Routing*", Notes	Balakrishnan et al.	18th Feb, 2015	Zartash Afzal Uzmi
9	[Routers] "*IP Router Architectures: An Overview*" in International Journal of Communication Systems, 2001 "*Interconnections: Bridges & Routers*" Book Chapter-13 (focus on Part-I) [Optional] "*Issues and Trends in Router Design*" in IEEE Communications Magazine, 1998 [Optional] "*Tree Bitmap*" (focus on just the main idea)	James Aweya Radia Perlman S. Keshav & R. Sharma Eatherton et al.	23rd Feb, 2015	Zartash Afzal Uzmi

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10	[Internet Exchange] "*SDX: A Software Defined Internet Exchange*" in ACM SIGCOMM 2014 "*iSDX: An Industrial-Scale Software Defined Internet Exchange Point*" NSDI 2016 [Optional] "*Anatomy of a large European IXP*" in ACM SIGCOMM 2012	Gupta et al. Gupta et al. Ager et al.	25th Feb, 2015	Zartash Afzal Uzmi
11	[Secure Routing] "*Why Is It Taking So Long to Secure Internet Routing*?" in ACM Queue 2014 [Optional] "*A Survey of BGP Security Issues and Solutions*" in Proceedings of the IEEE (skim through)	Goldberg et al. Butler et al.	1st March, 2015	Ihsan Ayyub Qazi
12	[Censorship] "*Characterizing Web Censorship Worldwide: Another Look at the OpenNet Initiative Data*" in Transactions on Web 2015 "*A Look at the Consequences of Internet Censorship Through an ISP Lens*" in ACM IMC 2014 [Optional] "*Tools and Technology of Internet Filtering*" [Optional] "*Tor: The Second-Generation Onion Router*" in USENIX Security Symposium 2004 [Optional] "*Pakistan hijacks YouTube*" - Dyn Research	Gill et al. Khattak et al. Murdoch et al. Dingledine et al.	3rd March, 2015	Zartash Afzal Uzmi
13	[Measuring Internet Censorship] "*Encore: Lightweight Measurement of Web Censorship with Cross-Origin Requests*" in ACM SIGCOMM 2015 "*A Case for Marrying Censorship Measurements with Circumvention*" in ACM HotNets 2015 [Optional] "*Can Censorship Measurements Be Safe(r)?*" in ACM HotNets 2015 [Optional] "*OONI: Open observatory of network interference*" in FOCI 2012 [Optional] "*Internet censorship detection: A survey*" in Computer Networks 2015.	S. Burnett et al. Aqib Nisar, Aqsa Kashaf, et al. B. Jones et al. Filasto et al. Aceto et al.	8th March, 2015	Ihsan Ayyub Qazi
14	[Censorship Resistance/Circumvention] "*Examining How the Great Firewall Discovers Hidden Circumvention Servers*" in ACM IMC 2015 [Optional] "*Blocking-resistant communication through domain fronting*" in PETS 2015 [Optional] "*Evading Censorship with Browser-Based Proxies*" in PETS 2012 [Optional] "*Do You See What I See? Differential Treatment of Anonymous Users*" in NDSS 2016	R. Ensafi et al. Fifield et al. Fifield et al. Khattak et al.	10th March, 2015	Zartash Afzal Uzmi
15	[Privacy and Advertising] "*Privad: Practical Privacy in Online Advertising*" in NSDI 2011 [Optional] "*Private-by-Design Advertising Meets the Real World*" in ACM CCS 2014 [Optional] "*Web Identity Translator*" in ACM HotNets 2015	Guha et al. Reznichenko et al. Papaodyssefs et al.	22nd March, 2015	Ihsan Ayyub Qazi

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Cloud Computing and Datacenter Networking

Overview, Cloud Abstractions, and Datacenter (DC) Topologies

16	[Overview] "*A Guided Tour through Data-center Networking*" in Communications of ACM, 2012 "*A View of Cloud Computing*" in Communications of ACM, 2010 (skim through) [Optional] "*Inside the Social Network's (Datacenter) Network*" in ACM SIGCOMM 2015 [Optional] "*Achieving Rapid Response Times in Large Online Services*" Talk by Jeff Dean, Google Fellow [Optional] "*The Tail at Scale*" in Communications of the ACM 2013 [Optional] "*Network Traffic Characteristics of Data Centers in the Wild*" in IMC 2010 (skim through)	Abts et al. Armbrust et al. Roy et al. Dean et al. Benson et al.	24th March, 2015	Ihsan Ayyub Qazi
17	[Cloud Abstractions] "*MapReduce: Simplified Data Processing on Large Clusters*" in OSDI 2004 [Optional] (Spark) "*Resilient Distributed Datasets: A Fault-Tolerant Abstraction for In-Memory Cluster Computing*" in NSDI 2012 [Optional] "*Making Sense of Performance in Data Analytics Frameworks*" in NSDI 2015	Dean et al. Zaharia et al. Ousterhout et al.	29th March, 2015	Zartash Afzal Uzmi
18	[Cloud Abstractions] "*Scaling Memcache at Facebook*" in NSDI 2013 [Blog: New Facebook DC Network] https://code.facebook.com/posts/360346274145943/introducing-data-center-fabric-the-next-generation-facebook-data-center-network/	Muralidhar et al.	31st March, 2015	Ihsan Ayyub Qazi

Datacenter Transports, Load Balancing Schemes, and Architectures

19	[DC Transports] "*Data Center TCP (DCTCP)*" in ACM SIGCOMM 2010 "*Minimizing Flow Completion Times in Data Centers*" in IEEE INFOCOM 2013 [Optional] "*It's Time for Low Latency*" in ACM HotOS 2011 [Optional] "*Low Latency via Redundancy*" in ACM CoNEXT 2013	Alizadeh et al. Munir et al. Rumble et al. Vulimiri et al.	5th April, 2015	Zartash Afzal Uzmi
20	[DC Transports] "*pFabric: Minimal Near-Optimal Datacenter Transport*" in ACM SIGCOMM 2013 "*Friends, not Foes - Synthesizing Existing Data Center Transport Strategies in PASE*" in ACM SIGCOMM 2014 [Optional] "*TIMELY: RTT-based Congestion Control for the Datacenter*" in ACM SIGCOMM 2015 [Optional] "*Fastpass: A Centralized Zero-Queue Datacenter Network*" in ACM SIGCOMM 2014 [Optional] "*Decentralized Task-Aware Scheduling for Data Center Networks*" in ACM SIGCOMM 2014 [Optional] "*Silo: Predictable Message Latency in the Cloud*"	Alizadeh et al. Munir et al. Mittal et al. Perry et al. Dogar et al. Jang et al.	7th April, 2015	Ihsan Ayyub Qazi

	in ACM SIGCOMM 2015			
21	[DC Routing/Load Balancing] "*CONGA: Distributed Congestion-Aware Load Balancing for Datacenters*" in ACM SIGCOMM 2014 "*Micro Load Balancing in Data Centers with DRILL*" in ACM HotNets 2015 [Optional] "*Hedera: Dynamic Flow Scheduling for Data Center Networks*" in NSDI 2010 [Optional] "*Presto: Edge-based Load Balancing for Fast Datacenter Networks*" in ACM SIGCOMM 2015 [Optional] "*FlowBender: Flow-level Adaptive Routing for Improved Latency and Throughput in Datacenter Networks*" in ACM CoNEXT 2014 [Optional] "*Improving Datacenter Performance and Robustness with Multipath TCP*" in ACM SIGCOMM 2011 [Optional] "*F10: A Fault-Tolerant Engineered Network*" in NSDI 2013 [Optional] "*Understanding Network Failures in Data Centers: Measurement, Analysis, Implications*" in ACM SIGCOMM 2011	Alizadeh et al. Soudeh et al. Al-Fares et al. He et al. Kabbani et al. Raiciu et al. Vincent et al. Gill et al.	12th April, 2015	Zartash Afzal Uzmi
22	[DC Architectures] "*PortLand: A Scalable Fault-Tolerant Layer 2 Data Center Network Fabric*" in ACM SIGCOMM 2009 [Optional] "*FireFly: A Reconfigurable Wireless Datacenter Fabric using Free-Space Optics*" in ACM SIGCOMM 2014 [Optional] "*Jellyfish: Networking Data Centers Randomly*" in NSDI 2012 [Optional] "*VL2: A Scalable and Flexible Data Center Network*" in ACM SIGCOMM 2009 [Optional] "*Enabling End-Host Network Functions*" in ACM SIGCOMM 2015 [Optional] "*Jupiter Rising: A Decade of Clos Topologies and Centralized Control in Google's Datacenter Network*" in ACM SIGCOMM 2015	Mysore et al. Hamedazimi, Zafar Qazi et al. Singla et al. Greenberg et al. Ballani et al. Singh et al.	14th April, 2015	Ihsan Ayyub Qazi
Wireless Networking				
23	[MAC Protocols for WLANs] "*Wireless Channel Access Protocols*" Notes "*Introduction to Link Layer and IEEE 802.11*" (WiFi Tutorial) [Optional] "*WiFi-NC: WiFi Over Narrow Channels*" in NSDI 2012 [Optional] "*WiFi-Nano: Reclaiming WiFi Efficiency through 800ns Slots*" in ACM MOBICOM 2011	Balabrishnan et al. Qiu et al. Chintalapudi et al. Magistretti et al.	19th April, 2015	Ihsan Ayyub Qazi
24	[Rate Adaptation & Loss Differentiation] "*Cross-Layer Wireless Bit Rate Adaptation*" in ACM SIGCOMM 2009 "*Loss Differentiation: Moving onto High-Speed Wireless LANs*" in IEEE INFOCOM 2014 [Optional] "*CSpy: Finding the Best Quality Channel without Probing*" in ACM MOBICOM 2013	Vutukuru et al. Ruwaifa Anwar et al. Sen et al.	21st April, 2015	Zartash Afzal Uzmi
25	[Context-Aware WiFi & Room-Area Networks] "*Improving Wireless Network Performance Using Sensor*	Ravindranath et al.	26th April, 2015	Ihsan Ayyub Qazi

	Hints" in NSDI 2011 "*Room-Area Networks*" in ACM HotNets 2015	 Iannucci et al.		 Zartash Afzal Uzmi
26	[Cellular Networks – 3G/4G/5G] "*KLEIN: A Minimally Disruptive Design for an Elastic Cellular Core*" in ACM SOSR 2016 [Optional] "*Wireless Software-defined Networks (W-SDNs) and Network Function Virtualization (NFV) for 5G Cellular Systems: An Overview and Qualitative Evaluation*" in Computer Network (Elsevier) Journal [Optional] "*Adaptive Congestion Control for Unpredictable Cellular Networks*" in ACM SIGCOMM 2015 [Optional] "*SoftRAN: Software Defined Radio Access Network*" in HotSDN 2013	Zafar Ayyub Qazi Akyildiz et al. Zaki et al. Gudipati et al.	28th April, 2015	Ihsan Ayyub Qazi
ICT for Developing Regions				
27	[Low Cost Data Channels] "*Hermes: Data Transmission over Unknown Voice Channels*" in ACM MobiCom 2010 "*SMS-based Web Search on Low-end Mobile Devices*" in ACM MobiCom 2010	Dhananjay et al. Chen et al.	3rd May, 2015	Ihsan Ayyub Qazi Zartash Afzal Uzmi
28	[Web Latency in Developing Regions & Long Distance WiFi] "*Dissecting Web Latency in Ghana*" in ACM IMC 2014 "*WiLDNet: Design and Implementation of High Performance WiFi Based Long Distance Networks*" in NSDI 2007 [Optional] "*On the Effectiveness of High-Speed WLAN Standards for Long Distance Communication*" in IEEE INFOCOM 2014 (poster) [Optional] "*Experiences in using WiFi for rural Internet in India*" in IEEE Comm. Mag., Special Issue on New Directions in Networking Technologies In Emerging Economies, 2007.	Zaki et al. Rabin Patra et al. Nishat et al. Raman et al.	5th May, 2015	Ihsan Ayyub Qazi Zartash Afzal Uzmi

Textbook(s)/Supplementary Readings