

CS594 Special Topics: Emerging Trends in Large-Scale Computer Systems

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September 6, 2025

1 Course Goals

Large-scale computer systems play a pivotal role in both high-performance computing and cloud computing. This class is designed to enable students to keep up with the latest developments in modern computing platforms, with hardware and software working in concert to deliver good levels of performance and efficiency. The lectures cover a broad array of topics including heterogeneous architecture, networking, storage, power management, availability and reliability, resource management, and emerging topics such as machine learning for systems. These concepts are reinforced with research paper readings and hands-on projects that involve computer system design and analysis. By the end of this course, students will:

- Gain a deep understanding of the core principles and technologies behind large-scale computer systems that power high-performance computing and cloud computing.
- Develop practical skills in concerted hardware and software development for massive computing.
- Dive into emerging areas of interest such as energy efficiency and AI for system optimization.
- Apply the knowledge to solve real-world problems through hands-on projects and case studies.

2 Course Materials

A recommended textbook is “Datacenter as a Computer: An Introduction to the Design of Warehouse-scale Machines” by L. Barroso, Jimmy Clidaras, U. Hoelzle (BCH), 3rd edition, Morgan & Claypool Publishers, 2019.

A number of research papers taken from premier cloud computing conferences (e.g., USENIX conferences) and high-performance computing conferences

(e.g., SC, HPDC, IPDPS, Cluster) will be used for class reading. All the reading material will be provided to students as either PDF files or pointers to online resources.

3 Course Outline (Tentative)

Week	Topic	Readings
Core concepts		
Week 1	Software infrastructure	BCH ch. 1,2
Week 2	Hardware architectures	BCH ch. 3,6
Week 3	Power management	BCH ch. 4,5
Week 4	Availability and reliability	BCH ch. 7
Week 5	Resource management	Research papers
Week 6	Networking	Research papers
Week 7	Storage and file systems	Research papers
Emerging topics		
Week 8	Emerging architectures	Research papers
Week 9-10	Energy efficiency	Research papers
Week 11-12	ML for systems	Research papers
Week 13-14	LLMs for science	Research papers
Week 15	Digital twins	Research papers

4 Course Work

We expect students to have a basic understanding of computer systems CS361 or CS461, high-performance computing CS455, and machine learning knowledge. The course is a combination of lectures and paper reading, including reading, presenting, and a semester-long research project.

5 Summary

This course focuses exclusively on the **emerging hardware and software trends in large-scale computer systems** deployed for cloud and high-performance computing. Upon completion, students will be well-prepared to tackle the challenges and opportunities presented by modern systems in these domains.