CS 678: Project Ideas

Video/Cellular

On-demand video streaming (e.g., Netflix, YouTube), live video conferencing (e.g., zoom), and video gaming traffic makes up a large fraction of traffic on the Internet today. Increasingly, users access such services from their smartphones. Projects under this theme will explore mobile video performance and figure out ways to make the ecosystem more performant and usable.

1. **Measure and evaluate performance of zoom**: Unquestionably, zoom has become a major goto tool for live video conferencing. However, there is little work on understanding how well it performs over mobile devices across different clients. As part of this project, you will measure zoom performance over different types of mobile devices and the cellular control plane messages it generates across different network conditions.

References:

- *http://www.mobileinsight.net/*
- *https://support.zoom.us/hc/en-us/articles/202920719-Meeting-and-phone-statistics*

2. **Evaluate performance of 360 videos (AR 180) on entry-level phones**: Different types of videos are becoming common on video platforms like YouTube e.g., 360^{o} videos, VR180. In this project, you will measure the performance of such videos over different types of mobile devices (e.g., low-end vs. high-end). For such videos, ABR algorithms must optimize the *portion* of the scene that they fetch, in addition to the quality. There are different approaches to solve this problem: Facebook encodes the entire scene into each chunk, but others have proposed a tiling solution, where each chunk has only a part of the scene. Compare both solutions. Can you come up with a more (bandwidth) efficient approach? What if you have an estimate of where the viewer is expected to look on the screen?

References:

- *Shahryar Afzal, Jiasi Chen, and K. K. Ramakrishnan. 2017. Characterization of 360-degree Videos. In Proceedings of the Workshop on Virtual Reality and Augmented Reality Network (VR/AR Network '17), 1–6. DOI:https://doi.org/10.1145/3097895.3097896*
- *Firefly: Untethered Multi-user VR for Commodity Mobile Devices, 2020 USENIX Annual Technical Conference*
- *https://en.wikipedia.org/wiki/360-degree_video*

3. **Evaluate games performance over entry-level smartphones**: Mobile video games are increasing in popularity. However, there are many challenges in making them work on entry-level smartphones, which are prevalent in developing countries. In particular, a major bottleneck is the device memory. This project will measure the performance of different mobile games on smartphones and will suggest ways to better manage device resources (e.g., memory, CPU cores) to optimize performance.

References:

- *Android memory and games (Google I/O'19).* *https://www.youtube.com/watch?v=D070YWwOXTk*
- *https://developer.android.com/games*
- *https://developer.android.com/games/optimize/memory-allocation*

4. **Fast Failure detectors for 5G edge applications:** 5G and future cellular networks are aiming to support emerging latency-sensitive and safety-critical applications, such as immersive augmented and virtual reality, self-driving cars, remote surgery, critical industrial IoTs, and multiplayer online gaming. To enable these applications cellular networks must provide low latency (in the order of a few milliseconds). To reduce end-end delays, 5G networks are building support for Edge Computing; a paradigm whereby applications are hosted closer to the users, on cell towers, and closeby micro-datacenters. Many cellular providers are working with major cloud providers for deploying edge applications inside the cellular infrastructure. A key challenge in this regard is to provide ultra-low latency despite failures in edge deployments to fully support such applications. As part of this project, you will design a fast failure detector for detecting failures in edge deployments.
    a. *Pre-reqs: This project requires a good background in Distributed Systems. To pursue this project, you should have preferably taken CS 582: Distributed Systems.*

References:

- *Mukhtiar Ahmad, Syed Usman Jafri, Azam Ikram, Wasiq Noor Ahmad Qasmi, Muhammad Ali Nawazish, Zartash Afzal Uzmi, and Zafar Ayyub Qazi. 2020. A Low Latency and Consistent Cellular Control Plane. In Proceedings of the Annual conference of the ACM Special Interest Group on Data Communication on the applications, technologies, architectures, and protocols for computer communication (SIGCOMM '20), 648–661. DOI:https://doi.org/10.1145/3387514.3406218*
- *Abhinandan Das, Indranil Gupta, and Ashish Motivala. 2002. SWIM: Scalable Weakly-consistent Infection-style Process Group Membership Protocol. In Proceedings of the 2002 International Conference on Dependable Systems and Networks (DSN '02). IEEE Computer Society, USA, 303–312. DOI: https://dl.acm.org/doi/10.5555/647883.738420*
- *Tushar Deepak Chandra and Sam Toueg. 1996. Unreliable failure detectors for reliable distributed systems. J. ACM 43, 2 (March 1996), 225–267. DOI:https://doi.org/10.1145/226643.226647*

Mobile Web

Today, the majority of users access the Web through their smartphones. However, the Web wasn't designed while keeping the constraints of smartphones in mind. As a result, we see a substantial gap in user-perceived performance of the Web when pages are loaded on smartphones compared to laptops or desktop machines. The projects under this theme are given below.

5. **Measure Web using audits of Google's Lighthouse**: The Web is a highly complex ecosystem comprising Web pages with diverse objects (e.g., iframes, videos, images, CSS, JavaScript). However, it is unclear how pages could be optimized for mobile devices. As part of this project, you will conduct a detailed audit analysis of Alexa top 10,000 Web pages using Google's Lighthouse tool. The goals are to (a) highlight the key opportunities for improvement in page load performance and (b) experimentally evaluating the benefit of improving pages on the Web.

References:

- *Ihsan Ayyub Qazi, Zafar Ayyub Qazi, Theophilus A. Benson, Ghulam Murtaza, Ehsan Latif, Abdul Manan, and Abrar Tariq. 2020. Mobile web browsing under memory pressure. SIGCOMM Comput. Commun. Rev. 50, 4 (October 2020), 35–48. DOI: https://doi.org/10.1145/3431832.3431837*
- *https://web.dev/learn/#lighthouse*

6. **When to do server-side rendering? And when not?** One challenge with loading entire Web pages on low-end smartphones is that it can take a long time. One possible way to address this challenge is to (partially or completely) render the Web page on the server side (e.g., fetch 3rd party content, run JavaScript at the server end) and send the resulting page to the client. However, doing so can inflate the base HTML page. In this project, you will experimentally evaluate when to do server-side rendering and when not to? You will be using the WebPageTest framework to carry out your tests.

References:

- *Ammar Tahir, Muhammad Tahir Munir, Shaiq Munir Malik, Zafar Ayyub Qazi, and Ihsan Ayyub Qazi. 2020. Deconstructing Google's Web Light Service. In Proceedings of The Web Conference 2020 (WWW '20), 884–893. DOI: https://doi.org/10.1145/3366423.3380168*
- *Ihsan Ayyub Qazi, Zafar Ayyub Qazi, Theophilus A. Benson, Ghulam Murtaza, Ehsan Latif, Abdul Manan, and Abrar Tariq. 2020. Mobile web browsing under memory pressure. SIGCOMM Comput. Commun. Rev. 50, 4 (October 2020), 35–48. DOI: https://doi.org/10.1145/3431832.3431837*
- *https://www.webpagetest.org*

7. **Device-aware usability metrics**: There are a wide variety of metrics for measuring user-perceived performance of page loads (e.g., largest contentful paint, speed index, onload, cumulative layout shift). However, there is little consensus on which metrics are ideal for which scenarios. In this project, you will explore little explored metrics for Web page loads that depend on the device characteristics (e.g., frames per second) as well as new ways to measure Web page accessibility (e.g., for persons with color blindness, low vision).

References:

- *https://web.dev/vitals/*
- *https://chrome.google.com/webstore/category/ext/22-accessibility*
- *https://www.google.com/accessibility/products-features/*

8. **How good are page loads in Pakistan?** Pakistan is a large developing country with ~91 million 3G/4G subscribers. However, it is unclear what is the user-perceived performance of mobile subscribers in Pakistan given the heterogenous network connectivity in the country. In this project, you will measure the performance of different Web pages across different cellular providers and urban-vs-rural areas in Pakistan. You will be using the WebPageTest framework to carry out your tests.

References:

- *Sohaib Ahmad, Abdul Lateef Haamid, Zafar Ayyub Qazi, Zhenyu Zhou, Theophilus Benson, and Ihsan Ayyub Qazi. 2016. A View from the Other Side: Understanding Mobile Phone Characteristics*

in the Developing World. In Proceedings of the 2016 Internet Measurement Conference (IMC '16), 319–325. DOI: https://doi.org/10.1145/2987443.2987470
- https://www.pta.gov.pk/en/telecom-indicators
- https://www.webpagetest.org/

Federated Learning and Privacy

Many machine learning (ML) tasks rely on private data to derive their usefulness. However, rising privacy concerns have made it difficult to train over such data. Privacy-preserving ML allows training over distributed data while preserving privacy. Projects in this domain will explore federated learning (FL) – a type of privacy-preserving machine learning – across various scenarios.

9. **FL over heterogeneous network conditions**: FL over heterogeneous clients is a major challenge as it can lead to exclusion of slow clients as well as lead to biased models. In this project, you will evaluate the performance FL over realistic network conditions found in developing countries. You will be investigating fairness properties of FL under different conditions as well as impact on convergence when there are heterogeneous clients involved in learning. You will be using the LEAF benchmark in this project.

References:
- *Federated Learning: Strategies for Improving Communication Efficiency. Jakub Konečný, H. Brendan McMahan, Felix X. Yu, Peter Richtárik, Ananda Theertha Suresh, Dave Bacon.* https://arxiv.org/abs/1610.05492
- https://www.tensorflow.org/federated
- https://leaf.cmu.edu/

10. **Understanding latency performance of FL**: Latency is a key consideration for real-time applications. Yet, there is little research in the latency properties of FL. In this project, you will measure and quantify the convergence properties of state-of-the-art FL algorithms and explore ways to improve convergence. In particular, the goal will be to optimize convergence towards a given target accuracy. You will measure and evaluate FL performance over different datasets and ML models using the LEAF benchmark.

References:
- *Federated Learning with Communication Delay in Edge Networks.* https://arxiv.org/abs/2008.09323
- *Federated Learning for Ultra-Reliable Low-Latency V2V Communications.* https://arxiv.org/abs/1805.09253
- https://leaf.cmu.edu/

11. **Thin ML models for low-end devices**: When clients have unique data, models can be personalized, which can lead to high quality updates. In this project, you will explore ways to customize models for individual clients. This project will first find ways to learn if the underlying data is IID or non-IID. In case of non-IID data, the framework will then proceed to customize the models. You will be using the LEAF benchmark for evaluating your results across different ML models and datasets.

References:

- Expanding the Reach of Federated Learning by Reducing Client Resource Requirements. https://arxiv.org/abs/1812.07210
- https://leaf.cmu.edu/

Blockchain

12. Blockchains like Bitcoin have seen significant adoption in the past few years. They enable new types of computer programs such as *smart contracts* that can be published on a blockchain to execute in a trustless manner (and anyone can verify their outputs) and *decentralized applications* that are user-owned and avoid centralized servers. Blockstack is a framework that has developed a consensus algorithm between two blockchains, called Proof of Transfer (PoX), that connects the Bitcoin and the Stacks blockchains and extends the functionality of Bitcoin. Leader election happens on the base Bitcoin chain, and new blocks are written on the connected Stacks chain. In this project, you will measure the performance characteristics of BlockStack (e.g., transaction capacity, latency).

References:

- https://www.stacks.co/
- [Whitepaper] https://gaia.blockstack.org/hub/1AxyPunHHAHiEffXWESKfbvmBpGQv138Fp/stacks.pdf

Additional areas to work on blockchain related projects are available here (https://www.dropbox.com/s/q1ui05556zcfmr6/cs678_blockchain_projects_basit_naveed.pdf?dl=0).
