Sample Project Topics for ECE 257A, Fall'20

Note: Below are some sample project topics for ECE 257A. Note that the topic descriptions are quite high-level, and you are encouraged to search for and briefly go through relevant tutorials or survey papers that can help you gain sufficient background. You are also encouraged to come up with your own ideas.

---------- Sample topics for project options 1 and 2 ----------

1. (Multi-access protocol for IoT) Designing a scalable multi-access protocol for the IoT.
   IoT will connect everything, including not only smartphones, but also smart everyday objects equipped with sensors. These IoT network nodes often do not need high bit-rate, but their density can be very high. Many communication or networking technologies have been proposed to meet the IoT connectivity demand. Examples include NB-IoT, LoRa, etc. However, it is still unclear whether these technologies can handle the data burst when thousands of such devices are connected simultaneously. This project will design a new medium access control protocol that has high efficiency, low latency, and low collision rate.

2. (Cloud VR over 5G network slices). Cloud virtual reality (VR) can potentially bring interactive VR to extremely thin hardware, without requiring high-end PC servers and headset at the user side. However, the low throughput and long latency of wireless access networks is still impeding this vision. Network slicing, a key technology in 5G, can provide dedicated virtual network for a VR application with guaranteed latency/throughput. This project leverages existing open-source 5G network slicing framework to build a cloud VR framework.
   Related publications (Google to get the pdf):
   (a) CloudVR: Cloud Accelerated Interactive Mobile Virtual Reality
   (b) Low Latency Edge Rendering Scheme for Interactive 360 Degree Virtual Reality Gaming
   (c) 5G-EmPOWER: A Software-Defined Networking Platform for 5G Radio Access Networks
   (d) Design and Experimental Validation of a Software-Defined Radio Access Network Testbed with Slicing Support
   (e) Implementation of Web AR Applications with Fog Radio Access Networks Based on Openairinterface Platform

3. (Machine learning for wireless communications)
   Pick one wireless communication problem that classical closed-form models cannot address well. Design a machine learning framework to address the problem.

Reference: https://mlc.committees.comsoc.org/research-library/

4. (Network modeling and analysis: asymptotic capacity) Can millimeter-wave networks support ubiquitous coverage and mobility?
   Millimeter-wave networking is considered as the cornerstone technology for 5G mobile broadband. However, there are still doubts regarding whether it can provision ubiquitous wireless access. This is mainly because millimeter-wave networks use highly directional, steerable radio beams for communication purposes. Such beams tend to be broken when the transmitter and receiver move, or when there are obstacles in between. Tight cooperation among densely deployed basestations may be needed to ensure seamless coverage. This project will quantitatively analyze the cost and feasibility of seamless coverage. It will answer questions such as "what is the density needed in order to ensure a certain level of coverage". This research can be conducted through either simulation or analysis (e.g., stochastic geometry models).

5. (Network architecture and applications) Design and implement a virtual reality chat application.
   Design a real-time virtual-reality chat application, which uses 360-degree cameras to capture a target scene, delivers it through the Internet to an end-user that uses VR headset (e.g., Google Cardboard) to view the 360-degree video. This application can realize a one-way VR chat, when the target scene is a person speaking.

6. (Reusing WiFi links for activity sensing) Many recent research projects demonstrated the feasibility of using WiFi to sense human activities and location. Essentially, different human activities disturb the WiFi signal phase/magnitude following different patterns. By identifying such patterns, one can detect the activities with high precision. The detection algorithms can be either closed-form signal processing, or black-box machine learning. In this project, you can explore such wireless sensing applications, by either developing your own closed-form sensing algorithm, or by collecting a large amount of WiFi signal data (magnitude/phase) and run machine-learning based sensing algorithms on top.

7. AI-driven 5G mmWave networking. Millimeter-wave (mmWave) represent a core technology for 5G broadband. mmWave links use highly directional, electronically steerable beams to achieve high link SNR and capacity. Such steerable beams can help establish dynamic mesh-like topology, on top of which intelligent network operations and management schemes can be applied. Example include energy-aware node on/off scheduling, congestion-aware dynamic routing, interference-aware beam management, etc. However, realizing such dynamic topologies at large scale entails substantial challenges. The complexity is often beyond the specification capacity of rule-based network standards (e.g., 5G NR). This project

aims to develop a software-defined, AI-driven network architecture, which learns from historical data and automates the network protocols.

8. AI-driven WiFi network management. Despite two decades of evolution, the WiFi network performance is still far from ideal. Although single link capacity can already reach Gbps, the actual throughput often drops dramatically in an unmanaged environment (e.g., an apartment with a large number of independent access points, or adversarial environment with misbehavior nodes and other coexisting devices such as ZigBee and Bluetooth), and the tail latency often escalates to tens to hundreds of milliseconds. The default WiFi protocol stack cannot address such issues since it assumes everyone follows similar protocols. This project aims to use a machine learning based framework to automate the WiFi network management, allowing WiFi to operate efficiently even in unmanaged settings.
   Reference: Open-source 5G-EMPOWER project: http://5g-empower.io

9. Blockchain for IoT. Blockchain is known to be a distributed security mechanism that can be used to track transactions on a large IoT network. However, due to the low-efficiency transaction verification mechanism, the actual implementation remains an open problem. Certain hybrid network architectures which mix conventional authentication with blockchain, may potentially the problem, likely at the cost of leaving certain vulnerability. In this project, you will propose a new IoT blockchain architecture to resolve the issue, and implement a prototype based on open-source blockchain framework.

10. Intelligent spectrum access. DARPA held a Spectrum Challenge, aiming to develop “Collaborative Intelligent Radio Network, which is a radio network capable of autonomous collaboration with other competitors’CIRNs. CIRNs reason and collaborate in order to automate the currently inefficient, labor-intensive process of spectrum management. Specifically, CIRNs figure out the best way to share congested radio frequencies between independent systems that don’t use the same radio communications standard, and dynamically adapt as the situation changes.” In this project, you will follow this high level idea to realize your own intelligent radio network. See related work here:

    https://www.spectrumcollaborationchallenge.com/about/technology/

11. Reproduce a recent well known publication in communication networks (esp. those published in ACM SIGCOMM, MobiCom and NSDI). Reinvestigate the premise and conclusions in that work, and describe your new discoveries. You can reuse the open-source code from these papers.

---------- Sample topics for project options 3 ----------

1. A survey of software defined wireless networks
2. A survey of edge computing for 5G
3. A survey of network protocols for robust millimeter-wave access
4. A survey of physical layer informed mobile applications
5. A survey of network architectures and protocols to achieve ultra-low latency in next-generation mobile networks
6. A survey of blockchains for IoT applications