ECE463/ECE514 Course Presentation and Project Topic Selection

1. General

The goal of the project is to give you an opportunity to investigate part of the course material (or a closely related topic) in greater depth, by reading, digesting and presenting (in poster only for ECE463 students, and in both poster and project report for ECE514 students) one or more original research papers, and you may substitute for this some creative work on an existing problem mentioned in Section 6 or a problem of your own choosing. Projects can be done either individually or in a team up-to three students. A list of suggested papers can be found in Section 5. Choosing a topic does not necessarily entail digesting all related references in detail, but usually one of them with the others as background if necessary.

2. Choosing a topic

You should choose a topic and have it approved by me (email cai@ece.uvic.ca, with "Course project topic proposal" in the Subject line) no later than **November 10**. If you want to choose a project from the list, you should email your choice to me together with at least one, and preferably two alternatives in decreasing order of preference. First choices will be allocated on a first-come, first-served basis. It is also fine if you want to propose a creative project, or any other project not on the list.

3. Poster preparation

You can refer to the following document which provides the general suggestions on how to prepare the poster presentation. http://www.ece.uvic.ca/~cai/poster-preparation.pdf

4. More on reading projects

The idea here is that you should read, understand and fully digest a few papers on a topic related to those discussed in class. You should understand the work well enough to give an intuitive explanation of it, answer questions about it, assess its strengths and limitations, and have something intelligent to say about its potential for further development.

5. Possible project topics

Below is a list of papers for reading projects.

<u>Using discrete-time Markov chain for network performance analysis</u>

- Bianchi, G., "Performance analysis of the IEEE 802.11 distributed coordination function," in *Selected Areas in Communications, IEEE Journal on* , vol.18, no.3, pp.535-547, March 2000. doi: 10.1109/49.840210
- Haitao Wu; Yong Peng; Keping Long; Shiduan Cheng; Jian Ma, "Performance of reliable transport protocol over IEEE 802.11 wireless LAN: analysis and enhancement," in *INFOCOM 2002. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE* , vol.2, no., pp.599-607 vol.2, 2002 doi: 10.1109/INFCOM.2002.1019305
- Pei Liu; Zhifeng Tao; Narayanan, S.; Korakis, T.; Panwar, S.S., "CoopMAC: A Cooperative MAC for Wireless LANs," in *Selected Areas in Communications, IEEE Journal on* , vol.25, no.2, pp.340-354, February 2007, doi: 10.1109/JSAC.2007.070210

- Qing Xu, Tony Mak, Jeff Ko, and Raja Sengupta. 2004. Vehicle-to-vehicle safety messaging in DSRC. In *Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks* (VANET '04). ACM, New York, NY, USA, 19-28. DOI=10.1145/1023875.1023879
- Malone, D.; Duffy, K.; Leith, D., "Modeling the 802.11 Distributed Coordination Function in Nonsaturated Heterogeneous Conditions," in *Networking, IEEE/ACM Transactions on* , vol.15, no.1, pp.159-172, Feb. 2007 doi: 10.1109/TNET.2006.890136
- Robinson, J.W.; Randhawa, T.S., "Saturation throughput analysis of IEEE 802.11e enhanced distributed coordination function," in *Selected Areas in Communications, IEEE Journal on* , vol.22, no.5, pp.917-928, June 2004, doi: 10.1109/JSAC.2004.826929
- Hao Zhu; Guohong Cao, "rDCF: A Relay-Enabled Medium Access Control Protocol for Wireless Ad Hoc Networks," in *Mobile Computing, IEEE Transactions on* , vol.5, no.9, pp.1201-1214, Sept. 2006, doi: 10.1109/TMC.2006.137
- Zhenhuan Gong; Xiaohui Gu; Wilkes, J., "PRESS: PRedictive Elastic ReSource Scaling for cloud systems," in *Network and Service Management (CNSM), 2010 International Conference on* , vol., no., pp.9-16, 25-29 Oct. 2010, doi: 10.1109/CNSM.2010.5691343
- Almudena Konrad, Ben Y. Zhao, Anthony D. Joseph, and Reiner Ludwig. 2001. A Markov-based channel model algorithm for wireless networks. In *Proceedings of the 4th ACM international workshop on Modeling, analysis and simulation of wireless and mobile systems* (MSWIM '01), Michela Meo, Teresa A. Dahlberg, and Lorenzo Donatiello (Eds.). ACM, New York, NY, USA, 28-36. DOI=10.1145/381591.381602 http://doi.acm.org/10.1145/381591.381602
- L. X. Cai, X. Shen, Jon W. Mark, L. Cai, Y. Xiao, "Voice capacity analysis of WLAN with unbalanced traffic," in Vehicular Technology, IEEE Transactions on , vol.55, no.3, pp.752-761, May 2006, doi: 10.1109/TVT.2006.874145
- Nadoushan, Mozhgan Ahmadi, Alireza Soffianian, and Alireza Alebrahim. "Modeling land use/cover changes by the combination of Markov chain and cellular automata Markov (CA-Markov) models." Journal of Earth, Environment and Health Sciences 1.1 (2015): 16.
- Khujamatov, Khalim, et al. "Markov chain based modeling bandwith states of the wireless sensor networks of monitoring system." International Journal of Advanced Science and Technology 29.4 (2020): 4889-4903.
- X. Gu *et al*., "Performance Analysis and Optimization for Semi-Persistent Scheduling in C-V2X," in *IEEE Transactions on Vehicular Technology*, vol. 72, no. 4, pp. 4628-4642, April 2023, doi: 10.1109/TVT.2022.3223414.

Card shuffles:

- Detailed analysis of card shuffles. [Bayer & Diaconis, Annals of Applied Probability, 1992; Diaconis, Fill & Pitman, Combinatorics, Probability & Computing, 1992.]
- David Aldous, Suffling cards and stopping times. http://statweb.stanford.edu/~cgates/PERSI/papers/aldous86.pdf
- Harald Hammarstrom, Card-Shuffling Analysis with Markov Chains, 2005 http://www.math.chalmers.se/~olleh/Markov_Hammarstrom.pdf
- Brad Mann, HOW MANY TIMES SHOULD YOU SHUFFLE A DECK OF CARDS? https://www.dartmouth.edu/~chance/teaching_aids/Mann.pdf

Kruskal count and kangaroo method (The most efficient means of breaking certain codes and digital signature schemes).

- The Kruskal Count and Wild Kangaroos. [Lagarias, Rains and Vanderbei, 2009; Montenegro and Tetali, ACM STOC, 2009.]
- How long does it take to catch a wild kangaroo?
  R. Montenegro and P. Tetali.

Proc. of 41st ACM Symposium on Theory of Computing (STOC 2009).

- The Kruskal Count.
  Jeffrey C. Lagarias, Eric Rains, and Robert J. Vanderbei.
  The Mathematics of Preference, Choice and Order (2009), pp. 371--391..

Others

- Truncated cubes and the knapsack problem. [Morris & Sinclair, SIAM Journal on Computing, 2004.]
- Application of Evolving Sets to clustering. [Anderson & Peres, ACM STOC, 2009.]

Another alternative bound on mixing times: the log-Sobolev inequality. [Diaconis & Saloff-Coste, Annals of Applied Prob., 1996; Frieze & Kannan, Annals of Applied Prob., 1999.]

- Yet another alternative bound: Nash inequalities. [Diaconis & Saloff-Coste, Journal of Theoretical Probability, 1996.]
- State of the art on volume computation. [Lovasz & Vempala, IEEE FOCS, 2003.]
- Sampling problems associated with matroids. [Feder & Mihail, ACM STOC, 1992; Azar,
- Simulated tempering: a twist on simulated annealing. [Geyer & Thompson, Journal of the American Statistical Association, 1995; Madras & Piccioni,Annals of Applied Probability, 1999.]
- The Dobrushin uniqueness condition: a "rapid mixing" condition from statistical physics. [Weitz, Random Structures & Algorithms, 2005; Hayes, IEEE FOCS, 2006.]
- Slow mixing in Markov chains. [Gore & Jerrum, ACM STOC, 1997; Borgs et al., IEEE FOCS, 1999.]
- A lower bound for Glauber dynamics. [Hayes & Sinclair, IEEE FOCS, 2005.]
- Computing the surface area of a convex body. [Belkin, Narayanan & Niyogi, IEEE FOCS, 2006.]
- An optimal scheme for approximate counting and computing partition functions [Stefankovic, Vempala and Vigoda, IEEE FOCS, 2007.]

6. Possible problems for creative projects:

A. Sensor network reliability analysis:
We deploy a number of sensor nodes to monitor an area. To save energy, each sensor will be in sleep or active mode with random durations (assuming that the sensor will be turned on/off or remain its current state in each time slot with certain probabilities).

1) Given the average sleep/active durations, how many live sensor nodes are needed to ensure that the probability of no sensor is active is below 0.001?
2) A sensor node has an initial energy E, and the energy will be reduced by E_0 for each active slot. Given that there are N new sensor nodes being deployed in the area, on average how long it take till all sensor nodes are dead?

B. RED queue analysis:
A router may implement Random Early Discard (RED) queue management solution: when the queue length exceeds a threshold, it will drop incoming packets at a probability related to the current queue length; when the buffer is full, it will drop all incoming packets. Analyze the average dropping probability of the queue when the packet arrival rate is 0.9 per slot, and the average service time is 1 slot, assuming:

1) the dropping probability increases linearly w.r.t. the queue length
2) the dropping probability increases exponentially w.r.t. the queue length

C. How many roommates can share an Internet subscription using an IEEE802.11a/b/g/n router?

Given the upstream and downstream capacity limit and the wireless router's capacity, estimate how many roommates can share an Internet subscription such that each roommate can still enjoy a decent Internet access experience.

D. HR planning:
A company have a number of jobs, and given the transition probabilities between any two jobs or the probability of exit per year, predict the number of employees in each job after one, two, three years. How many new employees should be recruited for each job to ensure that the number of employees for each job grows at a given rate in the following three years? (https://www.youtube.com/watch?v=YCdUmlOsP8w)

E. Student number forecasting:
Students entering UVic in 2016 may transfer to other Faculty or exit at the end of an academic year. Forecast the number of graduating students in each Faculty. Note: the probability that a student in a Faculty may transfer to another department or exit may change each year. E.g., more students will transfer after their first year study.

F. Checkout queue design for grocery stores (or banks, Customs, hotels, etc.):
Given the average time to serve a customer to finish the checkout procedure, how many checkout counters should be open to minimize the cost while ensure the average queueing delay for each customer. How to arrange the queues?

G. Store recommendation system:
Among all the products sold in Target, how to narrow down the list of items that can be used to predict that the customer who purchased them is likely pregnant? We need to ensure that the false positive is below a certain threshold (to avoid the "Angry Dad" situation).
Related news: https://www.linkedin.com/pulse/20140616204813-2554671-lessons-from-target-s-pregnancy-prediction-pr-fiasco

H. Fast food and video:
A fast food company uses cameras on drive-through lanes to determine what to display on its digital menu board. When the lines are longer, the menu features products that can be served up quickly; when the lines are shorter, the menu features higher-margin items that take longer to prepare. Given a list of products, their average preparing time, and the profit of each item, how to ensure that the average queue length is below certain threshold while the profit is maximized?

I. Predictive policing:
Given the historic data of when/where violent crimes occurred, can you devise an algorithm to allocate the polices to the predicted area to reduce crimes? Assume that the presence of a police will reduce the chance of crime occur within the street block of size X by Y (where Y is a function of X). Also, polices have a constant moving speed along the streets if there is no crime.
Background information:
Related news: The Los Angeles and Santa Cruz police departments, a team of educators and a company called PredPol have taken an algorithm used to predict earthquakes, tweaked it and started feeding it crime data. The software can predict where crimes are likely to occur down to 500 square feet. In LA, there's been a 33% reduction in burglaries and 21% reduction in violent crimes in areas where the software is being used.
https://www.theguardian.com/cities/2014/jun/25/predicting-crime-lapd-los-angeles-police-data-analysis-algorithm-minority-report

J. Investment strategy:
There is a stock, whose price will either be doubled or halved after a period of time (to make it

simple, we assume that the period is fixed, T). The chance of being doubled (or halved) is 0.5. If you have 100 dollars to invest on this stock, can you make money in the long term? If so, what's the best strategy to maximize the expected return at time kT, where k>>1? If the chance of being doubled is increased to 0.55, what's the best strategy to maximize the expected return? If after T, the stock price change is uniformly distributed in [X, Y], what's the best strategy? If there are two stocks whose prices have the same changing pattern as mentioned above, and their price changes are independent to each other, what's the best strategy? If these two stocks' prices are positively correlated, what's the best strategy? If their prices are negatively correlated, what's the best strategy?
Hint: **Kelly Criterion**
http://compoundingmyinterests.com/compounding-the-blog/2012/10/12/how-did-ed-thorp-win-in-blackjack-and-the-stock-market.html

K. How to use V2V/V2I communications to replace traffic light.
All vehicles have the OBU, and have the fixed route; V2V/V2I communications have no delay, no packet loss; RSU broadcasts messages periodically, while the vehicles transmit beacon messages periodically without any loss. All roads have three lanes for left, right, or go-through traffic. Vehicles do lane change only if necessary. Any vehicles in the lane that another vehicle tries to move in and behind that lane-changing vehicle will yield road by no acceleration. Vehicles and RSUs can transmit and receive simultaneously without error. Vehicles using the received message from RSU to decide actions. In the simple example, RSU just uses round-robin for traffic light control (Green-Yellow-Red), which is a dummy solution as a starting point. Can RSU do a better job?

1. Assuming all vehicles have the OBU, and have the fixed route; V2V/V2I communications have no delay, no packet loss; RSU broadcasts messages periodically;
2. Assuming all vehicles have the OBU, and have the fixed route; V2V/V2I communications have no delay, but with a fixed packet loss rate;
3. Assuming all vehicles have the OBU, and have the fixed route; V2V/V2I communications have a fixed delay, packet loss due to collision event.

Any vehicle collisions result in the fail of the solution. If without any vehicle collision, the minimum latency in reaching the destination per vehicle is desirable. Given a map, we have a number of entrance points. Vehicles will be generated randomly at these points with a minimum inter-vehicle delay. All vehicles at the entrance have a fixed velocity and a given destination, as well as the path to the destination.

L. How to rank research papers?
We can take the idea of *PageRank* to develop an algorithm of *PaperRank*.

M. Model the Starlink network performance.
We have a Starlink testbed which has captured a large amount of network traces, which can be leveraged to build models to describe the dynamic behavior of the LEO satellite networks.