Modeling and Simulation of Wireless LANs – an example of Communications Research in ECE

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Ed. Casas
UBC Electrical and Computer Engineering

Why Research?

- in a university, research is usually closely associated with graduate studies
- research trains graduate students to:
  - find and evaluate previous research
  - analyze problems
  - make measurements
  - report results
- how this is done depends on the research area
- this talk is an example of how we do research in communications

Why Research (continued)?

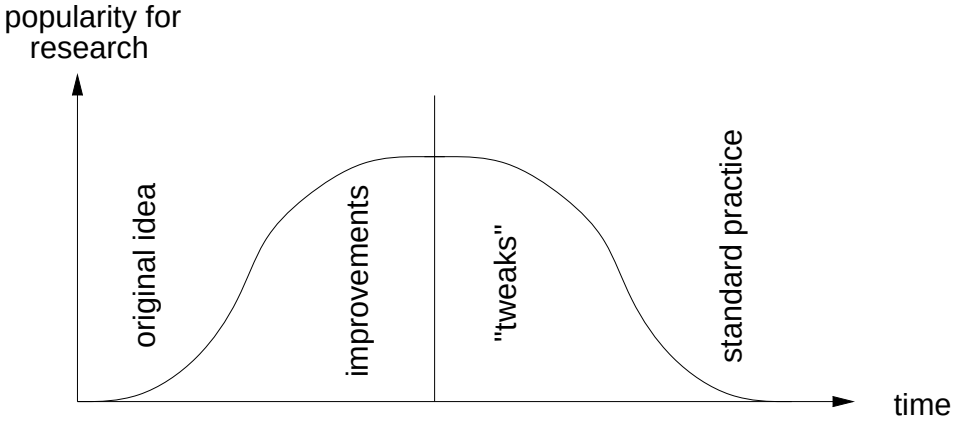
- there are many other good (?) reasons to consider graduate studies:
  - make the world a better place to live
  - help UBC raise money by licensing patents
  - delay looking for a job for a few more years
  - help local industry and create jobs
  - make more $$$ when you do get a job
  - put more letters after your name
  - help the IEEE fill up its journals
  - increase your sex appeal

Step by Step Instructions

- How to “Do Research” [in Communications at UBC]
  - Step 1 – Select a Swell(ing) Subject
  - Step 2 – It’s Mainly about Modeling
  - Step 3 – Simply Simulate Simply
  - Step 4 – Test Thoroughly
  - Step 5 – Report your Results

Step 1 - Select a Swell(ing) Subject

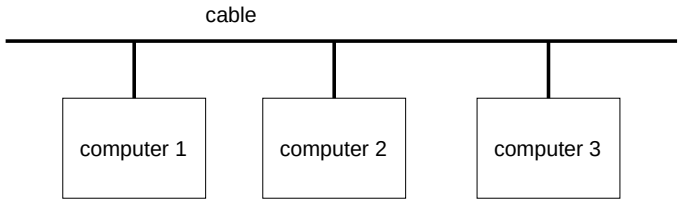
- pick an idea that hasn't been fully developed
- ideas seem to have a "Gaussian" life cycle:



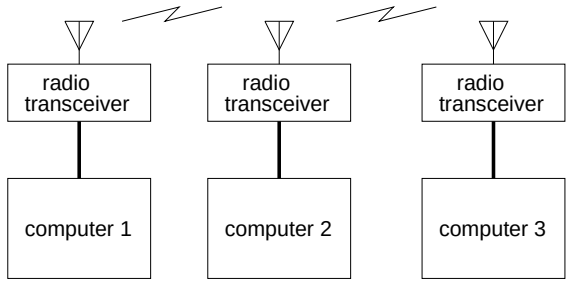
- research supervisors can usually suggest swell(ing) ideas
- let's look at a specific idea: *Wireless* Local Area Networks

Wireless Local Area Networks

- Local Area Networks (LANs) are used to transfer data between computers.
- LANs are connected with wires:



- Wireless LANs do away with the wires and use radio signals:



Pros and Cons of Wireless LANs

- Advantages:
  - no wiring costs
  - faster installation/removal
- Disadvantages:
  - more expensive (radios are more complex)
  - lower data rates (limited, shared frequencies)
  - less reliable (more interference)
  - less secure (no need to wiretap)

The IEEE P802.11 MAC Protocol

- IEEE standard P802.11 is the most widely discussed standard for WLANs
- LANs (wired and wireless) use broadcast media: this means all computers can hear (and interfere with) each other
- a protocol, the Media Access Control (MAC) protocol, is needed to decide who may use the channel at any given time
- the P802.11 MAC protocol is called Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)

The IEEE P802.11 MAC Protocol (continued)

- a simplified description of the CSMA/CA protocol is that when you need to send a packet:
  - if the channel is already free, send your packet immediately
  - otherwise initialize a count-down timer to a random value
  - decrement the count-down timer only when the channel is free
  - when the timer expires, it's your turn to use the channel!
- there are many, many more details (about 500 pages worth!)
- but the performance of CSMA/CA had not been studied for fading channels
- so our Research Problem was: what is the performance of CSMA/CA in a fading channel?

Step 2 - It's Mainly about Modeling

- modeling is probably the most important step
- a model isolates the important features of the problem and ignores everything else
- if the model is too simple (ignores important features) the results won't be useful
- if the model is too complex (includes irrelevant features) then we may not obtain widely applicable (i.e. useful) results
- the model identifies important variables and how they are related

- for example, to study the performance of CSMA/CA over fading channels our model included:
  - the details of the CSMA/CA protocol itself
  - packet length statistics
  - packet inter-arrival time statistics
  - un-faded connectivity of the network
  - fading statistics

- irrelevant details might include details about the packet headers, the use of encryption, inter-network routing, very detailed fading models, etc.

Step 3 - Simply Simulate Simply

- some models are simple enough that we can obtain our results as equations
- but for most communications problems we can't derive simple relationships
- so we use Monte-Carlo computer simulations:
  - a random number generator generates model inputs
  - a program computes results using our model
  - we measure the statistics of the results and draw conclusions
- for example, a CSMA/CA simulation requires about 3500 lines of 'C' – about 1200 to describe the CSMA/CA protocol and about 800 to model a fading channel

- for the MAC protocol study:
  - we randomly generate fading, packet sizes, inter-arrival times, and the “backoff” times in the protocol
  - we measure the time it takes for each packet to arrive at its destination and compute the delay (milliseconds) and throughput (bits/second)
  - the simulation is run for a “long” time to obtain statistically reliable results

Step 4 - Test Thoroughly

- this is the problem with simulations – how to tell if our results are correct?

- we can't, but we can apply some checks to increase our confidence:
  - bounds (upper and lower limits)
  - boundary conditions (e.g. fully connected, fully disconnected networks)
  - special case results derived through analysis
  - previous, independently obtained, results

- in the case of the CSMA/CA simulation, we can obtain results (1) using the CSMA/CA protocol *without* fading, and (2) a simpler protocol (Aloha) *with* fading – and compare these two cases to already published results

Step 5 - Report your Results

- a thesis is required ($\approx \frac{1}{2}$ lb. is a healthy weight)
- results can also be published as:
  - technical report (printed or on the Web)
  - conference poster or paper
  - journal paper

Other Research Methods

- lab or field measurements — expensive, time-consuming, best way to discover errors in modeling

- analysis — usually requires simpler models, may lead to a better understanding of problem

Summary

- research in communications at UBC usually involves:
  - pick a problem
  - model it
  - simulate it
  - check it
  - write a report

- (in the cases studied the throughput in Rayleigh fading decreased by about 50%)