Course Project
15-496: Hands-on Introduction to Wireless Networking
Mini-4, Spring 2008

Overview

In the second part of the course, teams of student must do a course project on a topic of their choice. Experience shows that teams of two students are most effective, but different team sizes are allowed with permission from the instructor.

Deliverables and milestones

We have the following milestones and deliverables for the project:

- Friday April 4: submit project proposal through e-mail. Project proposals should be less than one page and include a project title, the names of the team members, a short motivation, a list of tasks that will be performed, and expected outcomes. You will receive feedback on your proposal by Tuesday.
- Friday April 18: status reports due through e-mail. Status reports will typically be 1-2 pages, summarizing the tasks completed so far and summarizing initial results. You will receive feedback by Tuesday.
- Last week of semester: short project presentations. Format to be determined.
- Friday May 2: Final reports due. The final report will be a slightly extended and annotated version of the slides used in the project presentations.

Pretty much any topic in the area of wireless networking can be explored in the course projects. The two criteria to consider when selecting a project are (1) are you going to learn something and (2) is the project practical. Practicality means that the project scope is well defined and limited so it can be executed in a about four weeks and the resources needed to execute the project are readily available. The wireless emulator testbed is one possible platform for experiments, but you can use other resources as appropriate.

Example projects

Below is a list of projects that you can consider. Projects with higher numbers are a bit more adventurous. The example projects are just rough ideas. Many variants are possible and it is your responsibility to work out the details, e.g. identify what specific tasks are needed, how much work is involved, etc. You can also define your own project.

Note that some (unpublished) papers are only available from CMU machines (i.e. use a VPN if you are off campus).

1. Wireless Link Characterization

We have used the wireless network emulator to do a detailed study of the wireless link behavior for 802.11 networks using PRISM wireless cards [1]. An interesting project is to build on this study. Two possible directions are:

a) Repeat some experiments in the study for Atheros wireless cards, i.e. the cards currently deployed in the emulator.

b) Perform a study on how differences between the cards, e.g. with respect to packet capture, affect interoperability and performance in hybrid networks.

2. A world model for the wireless network emulator

The wireless network emulator currently supports a very simple "free space" world model: nodes can be placed in a 3D space but there are no obstacles and all signal propagation is based on a free space model. While multi-path is supported on channels between a subset of the nodes, it must be controlled directly by the user.

The goal of this project is to develop a more interesting world model that includes walls and possibly other objects. Signals can travel through objects (with a loss in signal strength) and can be reflected by objects. The world model must automatically control the underlying signal propagation models to reflect the impact of these objects.

3. Performance studies

Projects can do a performance study, comparing different protocols or algorithms addressing a particular wireless problem. Examples include transmit rate selection and ad hoc routing, but you may be able to find other candidates. In some cases (e.g. ad hoc routing), you will have to download kernel modules available on the Internet and install them. In other cases (e.g. transmit rate selection), the Linux kernel also includes a number of solutions. There is also a CMU algorithm, called Charm [2], which is available for evaluation.

4. Framework for geographic routing protocol evaluation

Geographic routing protocols are very interesting for routing in VANETs (Vehicular Ad Hoc NETworks) [3]. However, there is currently no good experimental platform available for VANETs. Since the wireless emulator supports convenient mobile network experiments and the position of each wireless node is actually available in the control framework. It might be interesting to explore using the wireless emulator for VANETs application and protocol development and evaluation. Some examples:

- Extend the emulator control framework to tunnel the position information to the wireless nodes. (an early version of this is available).
- Port realistic VANETS mobility models, e.g. [5], to the wireless emulator.
- Implement and evaluate a popular geographic routing protocol over the wireless emulator. The authors of [4] have an outdated GPSR implementation, which might be an interesting starting point.

5. Directional and sectored antennas

A number of interesting projects using directional and sectored antennas are possible. We list two but other options are possible.

A first possibility is to use the wireless network emulator testbed. It supports emulated directional antennas. A first project is to implement a user level protocol that allows you to exploit the benefits of directional antennas in terms of reduced interference and increased throughput. The challenge is to dynamically determine in which direction transmitters or receivers or interest are located.

A second possibility is to do a study in real world environments to evaluate the benefits of directional or sectored antennas, e.g. to improve coverage in a home or apartment, etc. The focus could be on measurements to quantify benefits or on the development of a practical methodology to deploy and tune the antenna.

6. Reliable communication in multi-hop wireless networks

Achieving reliable communication over multi-hop wireless networks is a challenging problem. Many research groups have developed solutions, but these have typically only been evaluated using simulation.

A number of interesting projects can be defined exploring whether the solutions (or variants) work on real hardware. Note these projects will typically require modifications to the device driver.

A first option is to conduct experiments to study the interaction between TCP and routing protocols in multihop wireless networks.

- Simulation results show that over multihop paths, TCP often runs into congestion collapse with the on-demand routing protocols [6], e.g., AODV and DSR. It might be interesting to confirm those observations over emulator.
- Impact of various routing protocols, e.g., link-state protocol (OLSR) vs. on-demand protocol (AODV and DSR), on the TCP performance.

A second option is to study various approaches, e.g., cwnd clamping, small router buffers, to alleviate the problem. The main idea is to reduce interference in the network by limiting how many packets are traveling in the network [7].

Another option is to implement hop by hop flow control, e.g. as suggested in [8]. Variants are possible in terms of buffer sizes and management of the buffers.

7. Building a CSMA MAC on the USRP software radio

Imagine that you are given a physical layer that provides you nothing more than raw bits. Your goal is to develop a MAC protocol on top of a software-defined radio that uses the given physical layer to successfully transfer a file in the presence of channel conditions that can create packet corruption and loss. It is up to you to design the MAC frame to contain the fields needed to detect a frame, that the frame is destined for your host, as well as additional fields. Given that you must recover from loss in the network, it is likely you will need to implement some sort of ACK'ing and error detection scheme. The loss could completely clobber a whole frame, or only certain bits.
This project will use the USRP software radio and will build on an existing MAC framework for the USRP. Possible milestones include

1. Attempt to design your frame and all of the fields needed. You can start with something simple, and can look to 802.11 for guidance.
2. Transmission and detection of raw frames: code the MAC to simply transmit empty frames (no payload) and get _any_ receiver to detect them (i.e., detect framing bits only).
3. Add an addressing scheme to your frame and now get only a specific receiver to decode the frames.
4. Begin to stuff your frames with a fixed number of bytes and get your receiver to decode them properly using coax (increase SNR, eliminate chance of loss).
5. Migrate to a variable length frame size and ensure that your receiver decodes the specific number of bytes.
6. Introduce an CRC field for your receiver to check that the frame was decoded properly. Using coax, all frames should pass a CRC check successfully.
7. Introduce an ACK'ing scheme so that the transmitter knows when to transmit the next the frame.
8. Finally, introduce a re-transmission scheme such that when loss occurs, the sender can detect it and re-transmit the frame.

Citations

[1] Understanding Link-level 802.11 Behavior: Replacing Convention with Measurement, Glenn Judd and Peter Steenkiste, Wireless Internet Conference 2007 (WiCon07), October 2007, Austin, Texas.

[2] “Efficient Channel-aware Rate Adaptation in Dynamic Environments”, Glenn Judd, Xiaohui Wang, and Peter Steenkiste, The Sixth International Conference on Mobile Systems, Applications, and Services (MobiSys’08), Denver, June 2008. Draft: http://www.cs.cmu.edu/~prs/cmu-only/RateSelection.pdf

[3] K.Nahm, et al., TCP over Multihop 802.11 Networks: Issues and Performance Enhancement, MOBIHOC 2005

[4] Y.J.Kim et al., Geographic Routing Made Practical, NSDI 2005.

[5] V.Naumov, R.Baumann and T.Gross, Online Optimisations Driven by Hardware Performance Monitoring, MOBIHOC 2006

[6] V.Naumov and T.Gross, Connectivity-Aware Routing (CAR) in Vehicular Ad Hoc Networks, INFOCOM 2007

[7] C. Lim, H.Y. Luo and C.H. Choi, RAIN; A Reliable Wireless Network Architecture, ICNP 2006.

[8] Yang Su, Peter Steenkiste, and Thomas Gross, Performance of TCP in Multi-Hop Wireless Networks, accepted for presentation at IWQoS 2008. Draft: http://www.cs.cmu.edu/~prs/cmu-only/TCP-wireless-draft.pdf

[9] George Nychis, Thibaud Hottelier, Zhuocheng Yang, Srinivasan Seshan, Peter Steenkiste, Enabling MAC Protocol Implementations on Software-defined Radios, in preparation. Draft: http://www.cs.cmu.edu/~prs/cmu-only/sdr-mac.pdf