MIT Roofnet: Construction of a Production Quality Ad-Hoc Network

Daniel Aguayo AGUAYO@CSAIL.MIT.EDU
John Bicket JBICKET@CSAIL.MIT.EDU
Sanjit Biswas BISWAS@CSAIL.MIT.EDU
Douglas De Couto DECOUTO@CSAIL.MIT.EDU
MIT Computer Science and Artificial Intelligence Laboratory, 200 Technology Square, Cambridge MA, 02139 USA

Abstract

This extended abstract describes our experiences from constructing the MIT Roofnet, an experimental rooftop wireless network. The ultimate goal of Roofnet is to build an ad-hoc network infrastructure capable of providing pervasive high-speed network access. Currently, the network currently consists of more than 35 nodes spread over two square kilometers of Cambridge, MA. The network is self-configuring, robust in the face of varying link conditions, and automatically finds high throughput paths in the system. The main focus of this paper is on lessons we've learned about building and deploying this kind of system, though we will touch on some research results as well.

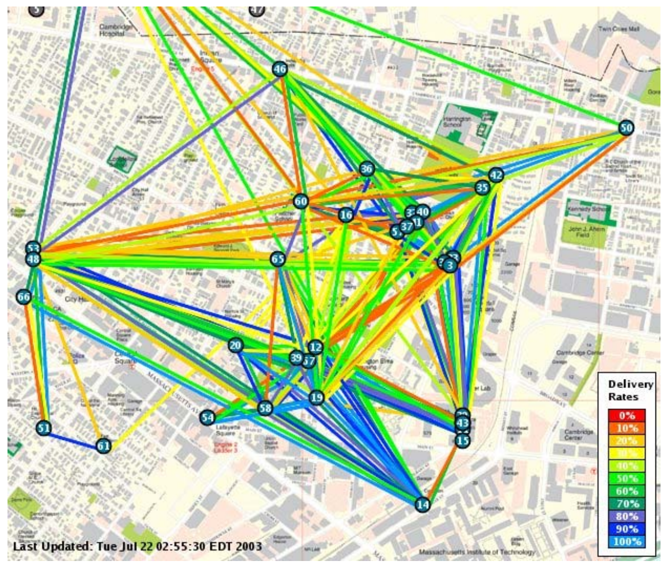

Figure 1. The Roofnet network as of July 22, 2003.

1. Motivation

This project strives to lay the foundation for a useful and pervasive Internet service network that can grow organically with only loose or non-existant control. Ideally, such a network should be built out of cheap hardware so that large deployments are feasible, and the system shold be able to compete in some dimension (if only ease of deployment) with available commercial service such as DSL or Cable.

Thus, for ideological reasons, Roofnet's design stresses self-configuration and the avoidance of central mechanisms. Building the network provides an opportunity to test research designs by exposing them to real radio propagation, a real user workload and the robustness requirements of a production network.

2. Hardware Overview

Rather than construct a planned backbone of high speed links using directional antennas, we favor a strongly connected mesh constructed using omni-directional antennas. We chose this approach for a number of reasons: First of all, node failure is not uncommon, often due to factors outside our control. Given our deployment strategy, volunteers hosting nodes are liable to relocate, inclement weather may damage or destroy equipment, and obstacles such as trees or buildings may appear over time. Furthermore, using directional links requires reconfiguration of existing nodes which makes building networks with little central organization difficult. More fundamentally, using omnidirectional antennas will create a denser mesh as the number of nodes increases, providing more routing options and thus resilience to failure. Omni-directional antennas also allow for the integration of mobile hosts in the future.

Each wireless node a standard PC using an 802.11 card; The PC hardware costs $500 and consists of a 533MHz 586-class processor with a CD-ROM drive and a wireless card, packaged in a textbook-sized case. The nodes are installed in graduate student apartments, so the form-factor was chosen for it's portability and quietness; It is small enough that a user can easily carry it home, and is low enough power so that the fans can be disconnected. The node is connected to the antenna (which is installed by the user on their roof) via a low-loss cable, which is run outside the house.

3. Software and Routing

In our earlier work (**?**) we developed a metric-based routing protocol based on DSDV (Perkins & Bhagwat, 1993), which uses a distance-vector approach to proactively disseminate routing information across the network. We use broadcast probes to detect the quality of a link and base routing decisions on the loss patterns of the links. This allows us to construct high-throughput paths by detecting and utilizing high-quality links.

Currently, our research is focusing on the characteristics of outdoor 802.11 links. We hope to gain a deeper understanding of what kind of error patterns appear and how link quality changes over time. We will develop routing protocols that use information such as transmission failures and metric changes to effectively identify when route error notification is needed.

We have implemented DSDV and other routing protocols using the Click (Kohler et al., 2000) module router. Click allows us to connect small modules called "elements" that are tied together with a particular configuration to construct more complex routing protocols. These configurations make it simple to make modifications to algorithms and allow for quick protocol protyping. Click also allows us to run multiple protocols in parallel. It also allows us to implement certain features like on demand protocols and simulation of hundreds of nodes without extensive modifications to the Linux code base.

4. Observations

Figure 1 shows the positions of all active Roofnet nodes as of late July, 2003. The area shown is about a 1.5 km on a side, in the part of Cambridge to the north of MIT. Nodes 10, 11, 14, and 30 (all at the lower right) have Yagi antennas on top of 10-story MIT buildings and act as gateways to MIT's wired campus net. The other nodes are in apartment buildings, with roof-mounted omni-directional antennas. The radios are only used to connect the nodes in a mesh; each user connects to the net through the Ethernet port of the node in his apartment.

The rest of the nodes are in the apartments of volunteers. We found these volunteers by posting flyers at MIT, by pushing them under doors in the areas of Cambridge we wanted more nodes in, and by word of mouth. Prospective users signed up on our web site, answering questions which allowed us to concentrate our efforts on the most promising locations. In particular, we required that users be affiliated with MIT; have flat roofs; and be willing to ask their landlord for permission to put an antenna on the roof.

Most of Cambridge consists of 3- and 4-story houses, so line of sight is not uncommon for long distances, however there are numerous trees and larger office buildings which obstruct the signal. The typical maximum useful radio range is about 500 meters, though the variation is enormous. Despite the nodes remaining static, the link conditions vary over time, possibly due to atmospheric interference, overall weather conditions or interference.

Building a critical mass of five to seven nodes is critical in the construction of such a wireless mesh, as new users expect an immediate connection to the network upon installation. This was less of an issue while constructing the Roofnet due to the high concentration of MIT students in the area, but it may pose problems when building network elsewhere.

References

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