MIT Roofnet: Construction of a Community Wireless Network

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1. Introduction

Community wireless mesh networks are emerging as a low-cost alternative to conventional forms of wired infrastructure traditionally used for last-mile Internet access. These networks leverage cheap and widely available wireless networking hardware to construct a cooperative mesh in which individual nodes relay data to a set of gateways, making it possible to share a small number of wired Internet connections with a large community of users. The wireless nature of these networks drastically reduces physical infrastructure cost, encourages unplanned growth of the network by loosely-coordinated individuals and makes it possible to extend Internet access into areas which do not have wired networking infrastructure. As these networks increase in size and density, they can be used to provide pervasive Internet access throughout large geographic areas.

A handful of hobbyist groups such as Wireless Leiden, Seattle Wireless, Bay Area Wireless Users Group and the South Hampton Wireless Network are in the initial stages of constructing mesh networks. Due to the distances involved in connecting a group of users spread over tens or hundreds of square kilometers, the networks mentioned above rely on a set of backbone nodes linked with directional antennas. We call this the *engineered* architecture. While the engineered architecture works well for sparse networks connecting small pockets of users, it may be difficult to scale the system to a dense mesh of nodes. To increase the reach of the network a node must be a member of the backbone set, but joining the backbone presents financial and technical hurdles. A backbone node must have multiple radios and antennas. The node's owner must coordinate with other backbone members to form point-to-point links, and they must spend the time to align their directional antennas correctly. Furthermore, if community networks are to become widely adopted, they must be accessible by non-technical members of the community who may not have the expertise required for antenna aiming and maintainence.

An alternative *unplanned* architecture, geared towards denser networks, is to equip each node in the network with a single omni-directional antenna, so that there is no designated set of backbone nodes. In addition to being simpler to install and easier to maintain, omni-directional antennas promote network growth, since new nodes do not require reconfiguring the antennas on the older nodes. Reducing the number of radios and antennas from three or more to one also lightens the financial burden of installing a node, further encouraging the addition of new nodes to the network. At a more fundamental level, the unplanned architecture can take advantage of more links than the engineered approach, and may thus be more fault tolerant.

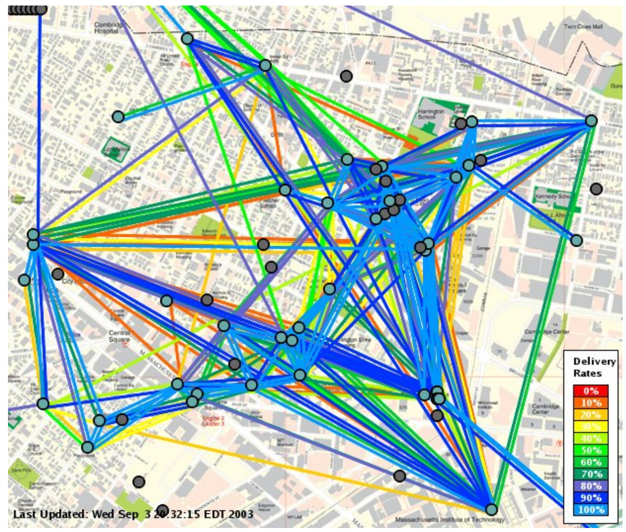

Figure 1. The Roofnet network as of September 3, 2003. The MIT Roofnet is the largest community wireless network in operation.

However, an unplanned approach using omni-directional antennas introduces some drawbacks such as shorter links and more notably the presence of marginal links which pose a problem for the routing mechanism. Despite the existence of high-quality links in the system, the marginal links are likely to cover greater distances in a single hop, appearing as shorter routes. Link fidelities are also susceptible to time-varying environmental conditions such as weather and interference, so the routing machinery must be aware of variable link conditions. Omni-directional antennas also introduce self-interference along a given route, which is difficult to predict or model.

In this paper, we present Roofnet, a practical architecture for building dense community networks which offers solutions to these challenges and preserves the advantages. All nodes in a Roofnet have a single radio and an omni-directional antenna and are self configuring. Nodes in a Roofnet network constantly measure link conditions to nearby nodes in an effort to estimate link quality; the SRCR routing protocol, a variant of the Dynamic Source Routing (DSR) (Johnson, 1994) protocol, uses these estimates to choose a set of five optimal routes. SRCR addresses self-interference by forwarding traffic over all give optimal routes and choosing a specific route based on observed performance rather than relying on predictions.

We evaluate our architecture and routing protocol on a 43-node Roofnet deployed in a five square kilometer region of Cambridge. To better understand the practical issues involved in building a community wireless network, we began with two nodes and grew the system incrementally. Volunteers enlisted over a period of three months and were given self-installation kits consisting of a router appliance based on PC hardware running the Roofnet software, an omni-directional antenna to mount on their roofs and other parts necessary for installation such as cabling, lightning arrestors, chimney mounts, etc. Performance evaluations indicate Roofnet exhibits throughput and latency similar to other residential Internet infrastructures such as DSL or cable. Comparisons with the Open Shortest Path First (OSPF) and Destination Sequence Distance Vector (DSDV) (Perkins & Bhagwat, 1993) protocols which are commonly deployed on multi-hop wireless networks suggest the SRCR protocol generally identifies and forwards traffic over higher throughput routes.

2. Hardware Overview

Each node in the Roofnet system consists of a small textbook-sized PC with a 533-MHz 586-class processor, 200mW 802.11 card, CD-ROM and 40GB hard drive. The nodes are installed in graduate student and staff apartments, so the nodes were designed to be portable and quiet; the entire self-installation kit is small enough to carry home on foot and the nodes use a fan-less processor to minimize noise. A 1.5 foot long 8dBi omni-directional antenna is installed by the user on their roof and connected to the node via a low-loss coaxial cable and lightning arrestor. Each self-installation kit also includes instructions detailing the installation procedure; even the most non-technical users were able to install their node without assistance within an hour, indicating it is feasible to construct a network where the users are not experts in wireless networking.

3. Software and Routing

Users connect their computers to the Ethernet port on their local node to gain access to the Internet. The Roofnet software, which is based on the Click Modular Router (Kohler et al., 2000), maintains state about each TCP flow and forwards traffic to the gateway node which had the optimum route when the flow was initiated. Nodes acting as wired gateways to the Internet use Network Address Translation (NAT) to mask Roofnet-internal addresses, obviating the need for routable address space.

Every node in the system periodically broadcasts probes containing its link statistics to all of it's neighbors in an effort to estimate transmission count. These statistics are generated by counting the number of probes received from nearby nodes within a sliding window, resulting in rough an estimate of link quality (DeCouto et al., 2002). When a node requests a route to another node or gateway, it floods a query throughout the network and the other nodes respond with measurements of links along the various routes to the destination node. Nodes eavesdrop on all traffic in the network and only respond to a query if they know of a better link which has not yet been advertised.

Once the source node has a list of the best routes to the destination, it forwards traffic over each of the top five routes, observing end-to-end throughput. After identifying the best route, the remainder of all packets in the given TCP flow travel along the determined route until the TCP connection is closed, a link failure is detected or performance degrades below a certain re-querying threshold. Selecting from a set of candidate routes rather than choosing the best route based on link metrics accounts for self-interference which may occur along a path and is otherwise difficult to predict.

References

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