CarNet: A Scalable Wireless Network Infrastructure

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Robert Morris and M. Frans Kaashoek

Project Overview

Smart devices will require self-configuring wireless data networks that support mobility. Current network technologies are awkward for smart devices: for example, the Internet does not support mobility, the cellular telephone network requires expensive pre-deployed infrastructure, and existing "ad-hoc" networking proposals do not scale well. The CarNet project is designing and building a network system that avoids these restrictions.

The core of the CarNet project is the Grid ad-hoc wireless routing protocol. Ad-hoc routing allows cooperating hosts to form their own self-configuring networks, in which nodes can move and communicate without depending on pre-existing infrastructure. However, existing ad-hoc systems are not practical for more than small numbers of nodes, since in many cases they require global flooding of location queries or topology information. Grid achieves better scaling with a combination of geographic forwarding and a distributed location service; as a result, Grid should be able to support orders of magnitude more nodes.

The scope of the CarNet project includes:

- Geographic multi-hop forwarding for scalable routing;
- Scalable distributed location servers, to support mobile hosts and services;
- Integration of routing with radio power and spectrum control, to support widely varying node densities;
- Hardened routing, to minimize the effects of malicious nodes;
- Support for anonymous use, so that location tracking does not compromise users privacy;
- Geographic traffic spreading to minimize the effects of congestion hot-spots and areas devoid of forwarding nodes;
- Evaluation of the useful capacity of ad-hoc networks; and
- Location-aware and peer-to-peer applications that take good advantage of geographic information.

Progress Through June 2001

In the last six months, the project completed the following tasks.

- Published a paper, *Capacity of Ad Hoc Wireless Networks*, at the ACM MobiCom 2001 conference. The paper analyzed the reduction in capacity imposed by the need for nodes to forward each others' traffic.
- Published a paper, *Span: An Energy-Efficient Coordination Algorithm for Topology Maintenance in Ad Hoc Wireless Networks*, at the ACM MobiCom 2001 conference. This was joint work with Hari Balakrishnan. The Span protocol saves battery power by electing a temporary relay in each area to forward multi-hop traffic, letting non-relay nodes sleep.
- Continued to develop the network software in order to be able to build a production-quality network. Part of the effort has gone towards building a stable Linux environment on the Compaq iPaq hand-held computers; drivers for 802.11 wireless LAN cards have required considerable attention. Another area of focus was management and inter-connection with the wired Internet, both of which require new techniques.

Research Plan for the Next Six Months

The major focus for the next six months will be completion of a production network deployment. The specific results of this deployment will be:

- A network of stationary relay nodes deployed around the MIT AI/LCS building. Each relay will have just a wireless radio interface. The relay nodes will be placed so that they form a connected network.
- Multiple gateways to the wired Internet. There will be more than one to provide fault tolerance.
- Software for automated node configuration. The Grid/CarNet network is itself completely self-configuring. However, if nodes are to communicate with the wired Internet, they must have correct Internet IP addresses. IP addresses ordinarily tie a node to a particular place in the Internet topology. To avoid this, and to allow node mobility, we are using network address translation at the wireless/wired network boundary.
- A software distribution for the iPaq running Linux. This will include the networking software and a few network management tools; initially, the standard Linux/iPaq network applications (such as Web browsers) will be used.

In addition, we will pursue a number of longer-term research topics. The areas we have in mind:

- Position estimation using 802.11 radio signal strength. Much of our software requires that each node be able to estimate its own geographical position. In some places we can use GPS or beaconing systems such as Cricket to find locations. We plan to extend the usefulness of such infrastructure using range estimates based on signal strengths. While signal strength is not a reliable indicator of range, many of the applications for which we need positions do not require very precise estimates.
- Hardened routing. One potential objection to cooperative ad-hoc routing is that one malicious node might be able to disrupt an entire network. We will explore some ideas intended to protect networks against such attacks.