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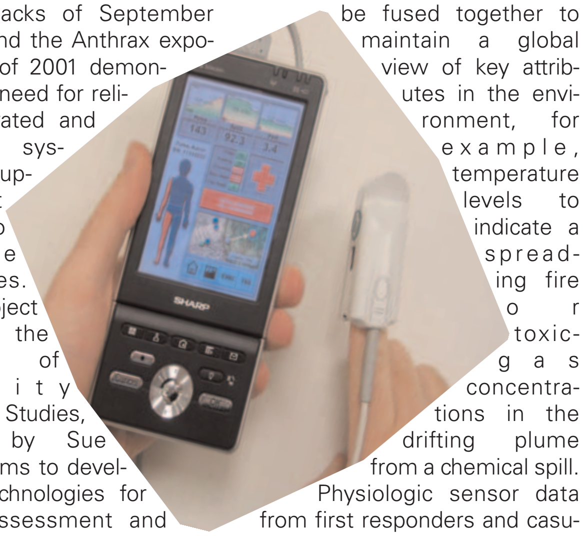
Wireless Technology for First Responders



The attacks of September 11th and the Anthrax exposures of 2001 demonstrated the need for reliable, integrated and automated systems to support response to large-scale emergencies. A new project funded by the Institute of Security Technology Studies, and led by Sue McGrath, aims to develop new technologies for situation assessment and response in the civilian domain. The team has developed a vision for an integrated approach to communication, automated information management, and sensing for emergency response scenarios. The project is focused on the development of three key components: sensing systems, communications infrastructure, and information middleware.

They are developing sensor systems that can provide environmental data and monitor the physiologic status and location of first responders and event casualties. The wireless environmental sensor network can provide responders in a particular area with critical information about their surroundings. With the addition of location sensors to each node, local sensor data can be fused together to maintain a global view of key attributes in the environment, for example, temperature levels to indicate a spreading fire or toxic-gas concentrations in the drifting plume from a chemical spill. Physiologic sensor data from first responders and casualties can be collected and analyzed by software residing on a wireless computing device located on the person being monitored. If abnormalities suggesting an injury or change in status are detected, an alert can be sent to medical personnel (paramedics, evacuation personnel, and medical teams at other locations). This data can be used to ensure the safety of first responders and assist in triage of casualties.

In a disaster scenario, sensor data and other event related information, such as situational assessments, must be moved to and from field locations, treatment sites, and command and control centers. One approach to providing communication links where traditional communication infrastructures are absent or nonfunctioning is to use ad hoc routing protocols. With ad hoc routing, each device is a network node capable of routing information from nearby nodes.

The team is developing distributed environmental and physiologic sensor platforms that can provide such an ad hoc network. Data transfer over any network is constrained by bandwidth and power available at each node. To help alleviate these problems, they are developing scheduling and polling techniques.

To address the vast informational requirements of emergency scenarios in an efficient way, they are developing middleware that will allow user applications to obtain and display information that is appropriate for each user. For instance, a high-level commander may want a global view of the incident, while an individual responder navigating a disaster scene may need detailed information about victims in her area. The middleware obtains, organizes, and distributes information to interested parties based on its content. One efficient approach is called publish and subscribe, where sensors or people publish data and other people subscribe to receive data in which they are interested. The project is extending this approach to meet the demands of emergency scenarios by incorporating features such as persistent data queries, authentication, and privacy.

Professor Denise Anthony Joins the CMC

The CMC is pleased to welcome Denise Anthony, Assistant Professor of Sociology, as a new member of its team. Professor Anthony is involved in a new project funded by McKinsey & Company to study the usage and behavior of students using the wireless networks. The team, which includes Professor David Kotz and Tristan Henderson, will monitor the wireless network activity of a collection of student volunteers, and use pagers to interrupt the students throughout the day to ask them to report on their activity. Professor Anthony also collaborates with Professor Sean Smith to understand the way people think about computer security.

New Funding

Cisco Systems

Professor Sean Smith and his PKI team received a major gift from Cisco Systems to launch "Greenpass," a joint project of the Center for Mobile Computing and the PKI Lab.

The Greenpass initiative applies PKI technology to the challenge of authenticating users of WiFi wireless networks, and specifically to make it possible to allow users to delegate limited network access to visitors. With Greenpass, we would be able to close Dartmouth's WiFi networks from the drive-by spam artists and yet easily grant full network access to a visiting colleague. For more information see the paper listed on Page 3.

intel

Professor David Kotz and postdoctoral fellow Tristan Henderson recently received a grant from Intel's University Research Council to better understand the workloads generated by high-throughput wireless applications. Henderson will collect extensive MAC-layer traces from Dartmouth's campus-wide 802.11 wireless network, then analyze the data to develop workload models that will be used to develop future wireless network MAC protocols. New high-throughput wireless applications and devices will become common at Dartmouth during the three-year period of study. (Dartmouth is replacing its traditional telephone PBX with a VoIP system, and has started to plan to move cable television onto the IP network.) This research aims to understand wireless protocols that support those applications.

CMC's Brad Noblet Named One of the Top 50 Most Powerful People in Networking

Network World Fusion magazine has named Brad as 44th on the list of most powerful and influential individuals in networking. Brad's name appears on a list which includes many illustrious CEOs and industry leaders such as Steve Ballmer, John Chambers, Bill Gates and Michael Dell. Network World Fusion had also run an article on the Dartmouth network earlier in November.

TeleSym Phone System Chosen for Campus Wide Use at Dartmouth

TeleSym, Inc. announced that its SymPhone System software for voice calling on wireless networks has been selected for campus-wide use at Dartmouth College, Hanover, NH. SymPhone adds cordless-phone capability to mobile computers. Under the Dartmouth contract, TeleSym will be supporting thousands of users on one of the world's largest wireless IP telephony installations, expected to eventually serve a community of 13,000 students, faculty and staff.

Dartmouth has been the scene of many 'firsts' in organizational computing, as the first Ivy League institution to be fully wired, then fully wireless. By year-end, it will also be the first college to fully deploy voice-over-IP (VoIP) on its wireless networks. When you call from computer to computer, the quality can be indistinguishable from wired phones and noticeably better than cell phones.

Unleashed Conference

In early October 2003, leading thinkers in wireless computing came to Hanover for "Unleashed," a three-day conference dedicated to the Wi-Fi revolution. Information technology professionals from higher education and business joined industry experts at Unleashed to discuss wireless technology and how it is used on campuses nationwide. The conference explored what it takes to implement a large wireless network, sustain it, and secure it. This conference brought together nearly 100 participants and 30 panelists to examine how wireless technology can be used effectively for teaching in the classroom and for facilitating and conducting research projects.

"Wireless technology is showing early maturity in the college and university market," says David Kotz, Professor of Computer Science and Director of the Center for Mobile Computing, and one of the organizers of the conference. "Increasingly, it is deployed pervasively in campus environments like Dartmouth, and we're studying how it's being used here in Hanover. This conference is one way to share what we've learned."

According to Larry Levine, Director of Computing Services and another conference organizer, there is a competitive imperative to offer extensive wireless computing in higher education environments.

"Wireless capability, once deployed, can be utilized across all disciplines: in all of the arts and sciences and at our three professional schools of business, engineering and medicine. It's a powerful technology," says Levine.

Unleashed began with a keynote speech by Reed Hundt, chairman of the Federal Communications Commission from 1993 to 1997 and a senior advisor to McKinsey and Co., a global management consulting firm. Unleashed presenting sponsors were Cisco Systems and Intel. Supporting sponsors were Aeroprise, Bearing Point, Newbury Networks, Microsoft Research, Telesym and Datavision. For more information see unleashed.dartmouth.edu.

Reed Hundt, Former Chairman of the FCC

Outdoor Routing Experiment

Last October 14th, commuters driving past the Garipay athletic field at Dartmouth College were treated to an unusual sight, not a soccer or rugby game, but instead forty students, staff members, and even interested parents carrying laptop computers from one end of the field to the other. Rather than witnessing a strange new sport, these commuters were seeing one of the largest ad hoc wireless routing experiments to date.

This experiment, led by Research Engineer Bob Gray, represented the culmination of nearly three years of wireless research and had two goals. The first was a comparison of the real-world performance of four ad hoc routing algorithms, AODV, ODMRP, GPSR, and STARA, while the second was an examination of the assumptions commonly made in wireless simulations. Each laptop had 802.11 cards and GPS units. While participants walked about randomly, the laptops ran each routing algorithm for fifteen minutes while continuously logging positions, signal strengths, and network traffic.

The experiment data first was used to examine common simulation assumptions, such as circular transmission areas, symmetric network links, and simple signal-strength models. Although it is perhaps intuitive that these assumptions do not hold in the real world, the magnitude of the mismatch was often surprising. The probability of a laptop receiving a beacon from a neighbor, for example, varied from 30 to 60 percent depending on the relative orientation of the 802.11 cards. Other assumptions were closer to reality. For example, although the signal strength of individual transmissions varied widely, mean observed signal strength (over distance) did fit a simple power curve.

The data now is being used to compare the performance of the four routing algorithms, including delivery ratios, control overheads, and end-to-end latencies. A future newsletter will provide results on this second effort.

PHOTO BY DOUG HILL

New Research Papers

Complete Text at http://cmc.cs.dartmouth.edu/papers

Guanling Chen and David Kotz.
Application-Controlled Loss-Tolerant Data Dissemination. Dartmouth College Computer Science Technical Report TR2004-488, February 2004.

Reactive or proactive mobile applications require continuous monitoring of their physical and computational environment to make appropriate decisions in time. These applications need to monitor data streams produced by sensors and react to changes. When mobile sensors and applications are connected by low-bandwidth wireless networks, sensor data rates may overwhelm the capacity of network links or of the applications. In traditional networks and distributed systems, flow-control and congestion-control policies either drop data or force the sender to pause. When the data sender is sensing the physical environment, however, a pause is equivalent to dropping data. Arbitrary data drops are not necessarily acceptable to the reactive mobile applications receiving sensor data. Data distribution systems must support application-specific policies that selectively drop data objects when network or application buffers overflow.

In this paper we present a data-dissemination service, PACK, which allows applications to specify customized data-reduction policies. These policies define how to discard or summarize data flows wherever buffers overflow on the dissemination path, notably at the mobile hosts where applications often reside. The PACK service provides an overlay infrastructure to support mobile data sources and sinks, using application-specific data-reduction policies where necessary along the data path. We uniformly apply the data-stream "packing" abstraction to buffer overflow caused by network congestion, slow receivers, and the temporary disconnections caused by end-host mobility. We demonstrate the effectiveness of our approach with an application example and experimental measurements.

Qun Li, Ron Peterson, Michael DeRosa, and Daniela Rus.
Reactive Behavior in Self-reconfiguring Sensor Network (Mobicom Poster). ACM Mobile Computing and Communications Review, January 2003.

A self-reconfiguring sensor network consists of many sensors that have the ability to self-configure by turning themselves on and off. This kind of self-reconfiguration results in power savings and extends the lifetime of the network. In this paper we present a formulation for the problem of adapting a sensor network to the environment and the task. We develop distributed algorithms for self-reconfiguring sensor networks that respond to tracking a target and directing a target through a region.

Jason Liu, Yougu Yuan, David M. Nicol, Robert S. Gray, Calvin C. Newport, David Kotz, and Luiz Felipe Perrone.
Simulation Validation Using Direct Execution of Wireless Ad Hoc Routing Protocols. Proceedings of the Workshop on Parallel and Distributed Simulation (PADS), May 2004.

Computer simulation is the most common approach to studying wireless ad-hoc routing algorithms. It offers a flexible means of experimentation, in a repeatable and controllable fashion. Simulation results, however, are only as good as the models the simulation uses. One should not underestimate the importance of validation, as inaccurate models can lead to wrong conclusions. In this paper, we use direct-execution simulation to validate radio models that drive ad-hoc routing protocols, against real-world experiments. This paper documents a common testbed that supports direct execution of a set of ad-hoc routing protocol implementations in a wireless network simulator. The testbed read traces generated from real experiments, and uses them to drive direct-execution implementations of several ad-hoc routing protocols. Doing so we reproduce the same network conditions as in real experiments. By comparing routing behavior measured in real experiments with behavior computed by the simulation, we are able to validate the models of radio behavior upon which protocol behavior depends. Our experiments reveal two conclusions. One is that it is possible to have fairly accurate results using a simple radio model, but the second is that routing behavior is quite sensitive to one of this model's parameters. The implication is that one either should (i) use a more complex radio model that explicitly models point-to-point path loss, or (ii) use measurements from an environment typical of the one of interest, or (iii) study behavior over a range of environments to identify sensitivities.

Libo Song, David Kotz, Ravi Jain, and Xiaoning He.
Evaluating location predictors with extensive Wi-Fi mobility data. INFOCOM '04, March 2004. An extended version appears as Dartmouth College Computer Science Technical Report TR2004-491.

Location is an important feature for many applications, and wireless networks can better serve their clients by anticipating client mobility. As a result, many location predictors have been proposed in the literature, though few have been evaluated with empirical evidence. This paper reports on the results of the first extensive empirical evaluation of location predictors, using a two-year trace of the mobility patterns of over 6,000 users on Dartmouth's campus-wide Wi-Fi wireless network. We implemented and compared the prediction accuracy of several location predictors drawn from four major families of domain-independent predictors, namely Markov-based, compression-based, PPM, and SPM predictors. We found that low-order Markov predictors performed as well or better than the more complex and more space-consuming compression-based predictors. Predictors of both families fail to make a prediction when the recent context has not been previously seen. To overcome this drawback, we added a simple fallback feature to each predictor and found that it significantly enhanced its accuracy in exchange for modest effort. Thus the Order-2 Markov predictor with fallback was the best predictor we studied, obtaining a median accuracy of about 72% for users with long trace lengths. We also investigated a simplification of the Markov predictors, where the prediction is based not on the most frequently seen context in the past, but the most recent, resulting in significant space and computational savings. We found that Markov predictors with this recency semantics can rival the accuracy of standard Markov predictors in some cases. Finally, we considered several seemingly obvious enhancements, such as smarter tie-breaking and aging of context information, and discovered that they had little effect on accuracy. The paper ends with a discussion and suggestions for further work.

Nicholas C. Goffee, Sung Hoon Kim, Sean Smith, Punch Taylor, Meiyuan Zhao, John Marchesini.
Greenpass: Decentralized, PKI-based Authorization for Wireless LANs. Third Annual PKI R&D Workshop, April 2004.

Wireless networks break the implicit assumptions that supported authorization in wired networks (that is: if one could connect, then one must be authorized). However, ensuring that only authorized users can access a campus-wide wireless network creates many challenges: we must permit authorized guests to access the same network resources that internal users do; we must accommodate the de-centralized way that authority flows in real universities; we also must work within standards, and accommodate the laptops and systems that users already have, without requiring additional software or plug-ins.

This paper describes our ongoing project to address this problem, using SPKI/SDSI delegation on top of X.509 keypairs within EAP-TLS. Within the "living laboratory" of Dartmouth's wireless network, this project lets us solve real problem with wireless networking, while also experimenting with trust flows and testing the limits of current tools.

Sean W. Smith.
Outbound Authentication for Programmable Secure Coprocessors. International Journal of Information Security. To appear, 2004.

A programmable secure coprocessor platform can help solve many security problems in distributed computing, particularly if coprocessor applications can participate as full-fledged parties in distributed cryptographic protocols. Thus, a generic platform must not only provide programmability, maintenance, and configuration in the hostile field—it must also provide outbound authentication for the entities that result. This paper offers our experiences in solving this problem for a high-end secure coprocessor product. This work required synthesis of a number of techniques, so that parties with different and dynamic views of trust can draw sound and complete conclusions about remote coprocessor applications.

About the CMC

The goal of the Center for Mobile Computing at Dartmouth College is to realize the potential for ubiquitous mobile devices and wireless communications to improve the way we live, the way we work, and the way we learn.

We have the opportunity to leverage Dartmouth's campus-wide wireless network, its group of experienced researchers, its residential campus with an innovative and creative student culture, its long tradition of pervasive deployment of cutting-edge technology and of technology in the classroom, and its local institutes for Security Technology (ISTS) and Information Infrastructure Protection (I3P). This combination makes Dartmouth College a unique environment for understanding the future, in which mobile computing becomes ubiquitous on university campuses, corporate campuses, and the consumer world.

The CMC is comprised of researchers from the Departments of Computer Science and Sociology and from the Thayer School of Engineering, including faculty, postdoctoral researchers, M.E. and Ph.D. students, and undergraduate students, and of staff from Dartmouth's Computing Services department. Participating faculty members have extensive experience in wireless networks, sensor networks, mobile agents, parallel and distributed computing, operating systems, information retrieval, robotics, signal processing, and sociology.

The Center's projects receive funding from the CMC industrial Partners, and federal funding from the Department of Homeland Security (through ISTS), the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research, and the National Science Foundation.

Center research facilities include campus-wide wired and wireless networks as well as a heterogeneous collection of computing systems. In effect, Dartmouth College is an extensive testbed with several thousand networked computers and active users.

Partnership

We invite corporations to become Partners of the CMC. There are clear benefits for partnerships with Dartmouth's Center for Mobile Computing. Partners have early access to advanced research that can lead to next-generation products and services. At the same time, the CMC benefits from a better understanding of the needs and direction of industry, helping to keep research relevant and driven by application needs.

Contact us if you are interested in being a partner at cmc@cs.dartmouth.edu

Benefits:

- Access to CMC students, making connections that may lead to future employment
- Access to wireless trace data
- Access to CMC faculty as consultants
- Early access to prototype systems
- Access to CMC labs and facilities, when appropriate.

Ultimately, each partnership leads to a host of benefits and to a relationship that can be customized to the needs and interests of the partner.

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