

An IT Infrastructure for Responding to the Unexpected

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AN IT INFRASTRUCTURE FOR RESPONDING TO THE UNEXPECTED

Executive Summary

The University of California, Irvine (UCI) and the University of California, San Diego (UCSD) received NSF Institutional Infrastructure Award 0403433 under NSF Program 2885 CISE Research Infrastructure. This award is a five year continuing grant and the following report is the Year Four Annual Report.

The NSF funds from year four (\$234,700) were split between UCI and UCSD with half going to each institution. The funds were used to expand the campus-level research information technology infrastructure known as Responsphere at the UCI campus as well as expansion of the mobile command infrastructure at UCSD. The results from year four include 67 research papers published in fulfillment of our academic mission. A number of drills were conducted either in the Responsphere infrastructure or equipped with Responsphere equipment in fulfillment of our community outreach mission. Additionally, we have made many contacts with the First Responder community and have opened our infrastructure to their input and advice. Finally, as part of our education mission, we have used the infrastructure equipment to teach or facilitate a number of graduate and undergraduate courses at UCI including:

UCI ICS 214A, UCI ICS 214B, UCI ICS 215, UCI ICS 203A, UCI ICS 278, UCI ICS 199, UCI ICS 290, UCI ICS 280, UCI ICS 299.

The following UCSD courses have either utilized Responsphere infrastructure, or in some cases, project-based courses have either contributed to infrastructure improvements or built new components for the infrastructure:

ECE 191 (6 projects), MAE 156B (1 project), CSE 294 and CSE 218. In addition, researcher BS Manoj taught ECE 158B (Advanced Data Networks, which covers challenges in communications during disasters).

In year four, we are collaborating with Vital Data Technology Incorporated (VDT), which is a company specializing in emergency medical records. They have several synergies with us including information dissemination, information privacy, and information security. Additionally, we have a PhD student interning at this company

We are planning a pilot study in collaboration with Fonevia LLC and the Redondo Beach School District. The purpose of the partnership is the study the deployment of early warning systems and customized alert technologies. These technologies were developed and deployed using the Responsphere infrastructure.

At UCSD, we collaborated with Ericsson, Inc. on CalMesh research; Ericsson is sponsoring a project on opportunistic ad-hoc routing at UCSD. We continue to explore opportunities in the public safety sector with QUALCOMM; and have been working with Talkphone on a campus-wide emergency notification network. Anritsu has worked with us in gathering and understanding wireless spectrum data using their Electromagnetic Interference Measurement Software for portable spectrum analyzers.

The Rescue Disaster Portal (www.disasterportal.org/ontario) was originally designed with one group of First Responders (The City of Ontario California Emergency Services). The portal has gained in popularity after its successful usage last year during the California wildfires. We are currently in negotiations with several First Responder agencies to deploy the Disaster Portal for their communities. This portal is housed at UCI and uses the Responsphere research infrastructure to power it.

At UCI, we are continuing our work with our local First Responder groups including the Environmental Health and Safety (EH&S) office, Irvine Police Department, UCI Police Department, as well as the Orange County Fire Authority. During year four we have participated in a number of drills and first response activities with these agencies, including a large-scale technology testing drill (August, 2007) with the City of Ontario, California Fire Department. The purpose of these drills is to test Responsphere technologies both within the testbed and outside of the testbed.

Collaboration with UCSD Campus Police and UCSD Emergency Management has continued to evolve; specifically in our participation in a campus-wide Drill (October 2007) and also in a new project: working with the UCSD police, emergency services departments and a small company to pilot a campus-wide emergency notification network.

The CalMesh infrastructure developed at UCSD was used to provide connectivity for all of the devices used in the WIISARD project. Responsphere researchers participated in and deployed CalMesh in a number of RESCUE and WIISARD project activities. On January 24, 2008 the CalMesh team, in conjunction with the WIISARD project, participated in a drill organized by the San Diego regional Metropolitan Medical Strike Team (MMST) at both the Coors Amphitheatre and Knotts Soak City Waterpark – providing an opportunity for us to test the concurrent deployment of two wireless ad-hoc mesh networks.

Both UCI and UCSD are currently preparing for large scale exercises in the near future. At UCSD, plans are to participate in another campus drill tentatively scheduled for Fall 2008. At UCI, we are planning a table-top exercise utilizing simulators as well as a Zone evacuation and working with EH&S for a campus-wide drill.

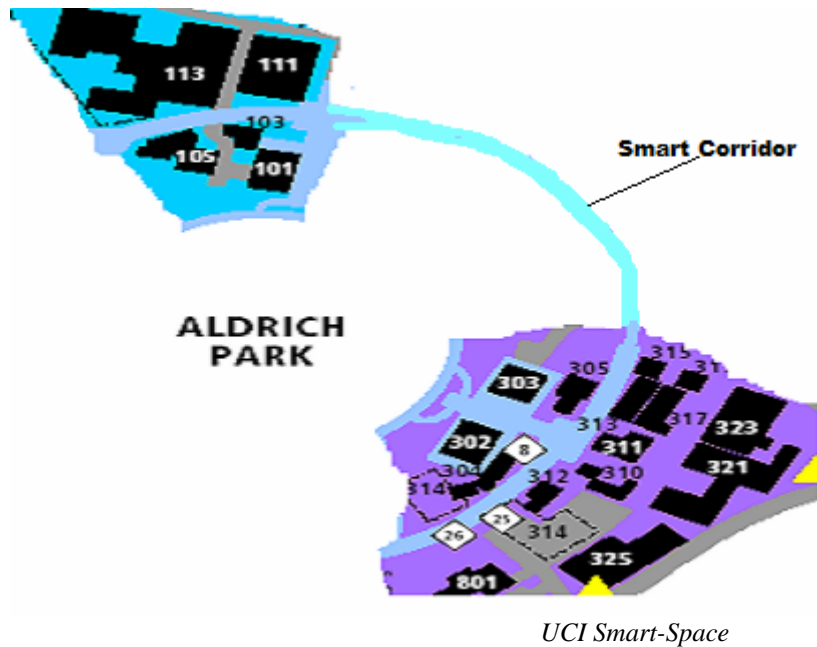
Spending Plan

Spending plans for year 4 at UCI include: personnel salary to maintain and extend the infrastructure, extend the storage capacity of the data sets repository, and adding computers and other systems as necessary. As indicated in the initial budget proposal, staff salary for designing, implementing, and maintaining the Responsphere will increase during latter years of the grant. Additionally, we will host a number of drills, exercises and evacuations in the Responsphere infrastructure.

Spending plans for year 5 at UCSD include maintaining the existing infrastructure and developing any additional infrastructure needed for drills.

Infrastructure

Responsphere is the hardware and software infrastructure for the Responding to Crisis and Unexpected Events (ResCUE) NSF-funded project. The vision for Responsphere is to instrument selected buildings and an approximate one third section of the UCI campus (see map below) with a number of sensing modalities. In addition to these sensing technologies, the researchers have instrumented this space with pervasive IEEE 802.11a/b/g Wi-Fi and IEEE 802.3 to selected sensors. They have termed this instrumented space the “UCI Smart-Space.”



The sensing modalities within the Smart-Space include audio, video, powerline networking, motion detectors, RFID, and *people counting* (ingress and egress) technologies. The video technology consists of a number of fixed Linksys WVC54G cameras (streaming audio as well as video), mobile Linksys WVC 200 tilt/pan/zoom cameras, D-Link DCS-6620G cameras, and several Canon VB-C50 tilt/pan/zoom cameras. These sensors communicate with an 8-processor (3Ghz) IBM e445 server as well as an 8-processor (4 dual-cores) AMD Opteron MP 875 server. Data from the sensors is stored on an attached IBM EXP 400 with a 4TB RAID5EE storage array. This data is utilized to provide emergency response plan calibration, perform information technology research, as well as feeding into our Evacuation and Drill Simulator (DrillSim). The data is also provided to other disaster response researchers through a Responsphere Affiliates program and web portal. Back-ups of the data are conducted over the network to Buffalo Terrastation units as well as a third generation stored off-site.

This budget cycle (2007-2008), we have worked on a middleware platform, Stream Acquisition and Transformation Ware (SATWare), for accessing the UCI Responsphere infrastructure. The middleware platform provides access to sentient spaces by virtue of semantic extraction as opposed to low-level sensor feeds. SATWare provides researchers a semantic view of the physical space whereupon they can build their research. Additionally, we have put together several mobile optical/acoustic sensing platforms for usage during drills and other disaster response activities.

Significant technical advances were made for many components of the Robust Networking Infrastructure. Notably, a new routing MAC layer protocol called MACRT was developed for the CalMesh platform; it was successfully introduced and tested during the Winter/Spring 2008. In addition, the CalMesh hardware was overhauled with a more capable Linux platform and faster WiFi cards (we now run a 500Mhz CPU and use 802.11g rates on Atheros cards). We call this updated platform CalMesh2 and it can be either hosted in the same rugged aluminum cases as the first version, or in a smaller form factor enclosure that is also designed for outdoor use.

Two new models of the Gizmo truck were developed this year, one for a private company and the other to be used by students as a building platform. GPS capabilities have been added to the Gizmo platform. Also, a new circuit board has been designed in order to integrate all of the, now quite numerous, functionalities present in Gizmo. A new CalNode was developed, CalNode-Semi-Mobile (CalNode-SM) to add functionality to the CogNet system.

UCSD has also been continuing to develop the mobile command and control vehicle for emergency response - the pickup truck we purchased in September 2006 has participated in all of our drills. The major work on the truck this year was to add a new solar power system and controllers which enable all of our wireless infrastructure components (Gizmo, Wifli Condor, CalMesh, etc.) to interface with the vehicle.

One of the primary successes this year was the tight integration among the multiple components of the networking infrastructure, which was showcased and tested for the first time in full-scale drills. The integration provided a more cohesive, interoperating infrastructure. This was successfully demonstrated when we showcased nearly a dozen of our technologies, tools and devices during the two emergency drills in which we participated this year: UCSD Campus Drill (full-scale exercise with an active-shooter scenario), October 16, 2007 and an MMST full-scale drill, dubbed Operation Silver Bullet (in South Bay, San Diego, CA, January 24, 2008 (unique scenario with dual incidents situation, the first time for the local MMST).

Portable tiled-display wall for visualization in crisis response - NUTSO (Non-uniform Tiled System Optiportal) demonstrated the ability to create a mobile platform that can serve as a mobile command center, and integrate a number of video feeds and other sources of information in a single, flexible viewing area. Multiple types of feeds were handled well, including video feeds from cameras, news coverage, online resources, internal documents, etc.

Rich Feeds worked seamlessly with NUTSO. A first cut at crosscutting concern processing for authorization/authentication/policy evaluation was integrated into the ESB. Based on user-supplied credentials, the feed list presented to the user is determined, such that a lack of credentials filters out the UCSD Police camera feed, for example.

The main infrastructure acquisition for UCSD in Year 4 was the purchase of a LIDAR sensor- Leica ScanStation2 laser scanner and Panoscan panoramic camera for high speed data capture. These devices have been used to collect environmental and structural data to be input for network simulation models. In addition, other projects have been pioneering the use of these tools for cultural heritage applications; we have collected structural data of historical buildings (Palazzo Vecchio and Palazzo Medici in Florence), and of an archaeological site in the Anza-Borrego desert in southern California.

CalMesh nodes have provided a mobile wireless ad-hoc mesh networking infrastructure to support both research and activities (training exercises and drills) for both the RESCUE and WIISARD (Wireless Internet Information Systems for Medical Response in Disasters) projects, including a UCSD campus emergency response drill in October 2007, and the San Diego Metropolitan Medical Strike Team exercise at Coors Amphitheatre/Knotts Soak City in San Diego in January 2008..

Outreach

In fulfillment of the outreach mission of the Responsphere project, one of the goals of the researchers at the project is to open this infrastructure to the first responder community, the larger academic community including K-12, and the solutions provider community. The

researchers' desire is to provide an infrastructure that can test emergency response technology and provide metrics such as evacuation time, casualty information, and behavioral models. These metrics provided by this test-bed can be utilized to provide a quantitative assessment of information technology effectiveness. Printronix, IBM, and Ether2 are examples of companies that have donated equipment in exchange for testing within the Responsphere testbed.

One of the ways that the Responsphere project has opened the infrastructure to the disaster response community is through the creation of a Web portal. On the www.responsphere.org website there is a portal for the community. This portal provides access to data sets, computational resources and storage resources for disaster response researchers, contingent upon their complying with our IRB-approved access protocols. IRB has approved our protocol under Expedited Review (minimal risk) and assigned our research the number HS# 2005-4395.

At UCI we have been active in outreach efforts with the academic community, organizing the following conferences and workshops:

1. Emergency Medical Perspectives on Information Technology, May 2008

We have also hosted a number of K-12 and other outreach events:

1. Summer 2008 – Vital Data Technology Inc. (VDT) is hosting a Rescue PhD student as an internship. This student will work on their medical records dissemination technology.

At UCSD we have been active in outreach efforts with the academic community, organizing the following conferences and workshops:

1. Ramesh Rao, Manoj Balakrishnan and Alexandra Hubenko co-chaired a special session at the 5th Conference of the International Community on Information Systems for Crisis Response and Management (ISCRAM) titled “Technology Showcase: Communication Systems and Technologies for Crisis and Disaster Response”

Other outreach activities at UCSD included demonstrating our infrastructure and research technologies for industry groups, domestic and international governmental delegations, and conferences that take place at Calit2; including Future in Review (FiRE)

Responsphere researchers and technologists from both campuses gave a number of keynote addresses and invited talks. These addresses provide the Responsphere team the opportunity to engage a number of stakeholders (Government, industry, academia, and First Responders) within the emergency response domain. We list a sample of such talks below.

B. S. Manoj attended IEEE Globecom 2007 in Washington, D.C., and presented a paper titled On Adding Link Dimensional Dynamism to CSMA/CA based MAC protocols.

Don Kimball attended ICAST 2007 in Ghana, during December 2007 and presented a paper, authored as part of this project, titled On the Viability of Wireless Mesh Networks as a Next Generation Wireless Networking.

B. S. Manoj attended IEEE CCNC 2008 in Las Vegas, NV, during January 2008 and presented a paper titled On Optimizing Non-Asymptotic Throughput of Wireless Mesh Network. This paper received the Best Paper Award at IEEE CCNC 2008.

Bheemarjuna Tamma attended IEEE WCNC 2008, during March 2008 and presented a paper titled On the Accuracy of Sampling Schemes for Wireless Network Characterization.

UCSD K-12 outreach activities included demonstrations at the 2008 Calit2 Take your Daughters and Sons to Work Day; and sponsoring a total of 12 student interns from the Preuss School during the 2007-2008 academic year, a charter school under the San Diego Unified School District whose mission is to provide an intensive college preparatory curriculum to low-income student populations and to improve educational practices in grades 6-12. These students worked on projects related to the Gizmo platform.

Responsphere Drills

- August 2, 2007 Technology testing drill with the City of Ontario, California. The Disaster Portal (www.disasterportal.org/Ontario) was debuted and tested as well as the crisis alert system.
- July 11, 2007 Active Shooter and Casualty Drill at UCI, RESCUE and Responsphere teams. Conducted with Campus EH&S, UC Irvine Police Department, Orange County Fire Authority.
- October 16, 2007: UCSD Campus Drill. UCSD's RESCUE and Responsphere projects participated in a campus drill (active shooter scenario)
- January 24, 2008; MMST Drill at Coors Amphitheatre, National City, CA. UCSD participated in a large-scale emergency response drill in conjunction with the San Diego Metropolitan Medical Strike Team (MMST) and the UC San Diego Police and Emergency Services departments on the UCSD campus on August 22, 2006. The ENS system was demonstrated and used as the backbone network for emergency response activities demonstrated during this event

Responsphere Management

The Responsphere project leverages the existing management staff of the affiliated RESCUE project which is a NSF funded Large ITR. In addition, Responsphere, given the scale of the technology acquisition and deployment has hired technologists who are responsible for purchase, deployment, and management of the infrastructure. The management staff at UCI consists of a Technology Manager (Chris Davison). At UCSD, the management staff consists of a Project Manager (Alex Hubenko) and Project Support Coordinator (Vanessa Pool). The management staff and technologists associated with Responsphere possess the necessary technical and managerial skills for both creation of the infrastructure and collaboration with the industry partners. The skill set of the team includes: Network Management, Technology Management,

VLSI design, and cellular communications. This skill set is crucial to the design, specification, purchasing, deployment, and management of the Responsphere infrastructure.

Part of the executive-level decision making involved with accessing the open infrastructure of Responsphere (discussed in the Infrastructure portion of this report) is the specification of access protocols. Responsphere management has decided on a 3-tiered approach to accessing the services provided to the first responder community as well as the disaster response and recovery researchers.

Tier 1 access to Responsphere involves a read-only access to the data sets as well as limited access to the drills, software and hardware components. To request Tier 1 access, the protocol is to submit the request, via www.responsphere.org, and await approval from the Responsphere staff as well as the IRB in the case of federally funded research. Typically, this access is for industry affiliates and government partners under the supervision of Responsphere management.

Tier 2 access to Responsphere is reserved for staff and researchers specifically assigned to the ResCUE and Responsphere grant. This access, covered by the affiliated Institution's IRB, is more general in that hardware, software, as well as storage capacity can be utilized for research. This level of access typically will have read/write access to the data sets, participation or instantiation of drills, and configuration rights to most equipment. The protocol to obtain Tier 2 access begins with a written request on behalf of the requestor. Next, approval must be granted by the Responsphere team and, if applicable, by the responsible IRB.

Tier 3 access to Responsphere is reserved for Responsphere technical management and support. This is typically "root" or "administrator" access on the hardware. Drill designers could have Tier 3 access in some cases. The Tier 3 access protocol requires that all Tier 3 personnel be UCI or UCSD employees and cleared through the local IRB.

Personnel

University of California Irvine (UCI)

<i>Name</i>	<i>Role(s)</i>	<i>Institution</i>
Naveen Ashish	Visiting Assistant Project Scientist	UCI
Carter Butts	Assistant Professor of Sociology and the Institute for Mathematical Behavioral Sciences	UCI
Howard Chung	ImageCat	Inc.
Alessandro Ghigi	Researcher	UCI
Jay Lickfett	Researcher	UCI
Rina Dechter	Professor	UCI
Jonathan Cristoforetti	Graduate Student	UCI
Ronald Eguchi	President and CEO	ImageCat
Magda El Zarki	Professor of Computer Science	UCI
Ramaswamy Hariharan	Graduate Student	UCI
Bijit Hore	Researcher	UCI
John Hutchins	Graduate Student	UCI
Charles Huyck	Senior Vice President	ImageCat
Ramesh Jain	Bren Professor of Information and Computer Science	UCI
Dmitri Kalashnikov	Post-Doctoral Researcher	UCI

Chen Li	Assistant Professor of Information and Computer Science	UCI
Yiming Ma	Graduate Student	UCI
Gloria Mark	Associate Professor of Information and Computer Science	UCI
Daniel Massaguer	Graduate Student	UCI
Sharad Mehrotra	RESCUE Project Director, Professor of Information and Computer Science	UCI
Miruna Petrescu-Prahova	Graduate Student	UCI
Vidhya Balasubramaniam	Graduate Student	UCI
Will Recker	Professor of Civil and Environmental Engineering, Advanced Power and Energy Program	UCI
Leila Jalali	Graduate Student	UCI
Dawit Seid	Graduate Student	UCI
Masanobu Shinozuka	Chair and Distinguished Professor of Civil and Environmental Engineering	UCI
Michal Shmueli-Scheuer	Graduate Student	UCI
Padhraic Smyth	Professor of Information and Computer Science	UCI
Jeanette Sutton	Natural Hazards Research and Applications Information Center	University of Colorado at Boulder
Nalini Venkatasubramanian	Associate Professor of Information and Computer Science	UCI
Kathleen Tierney	Professor of Sociology	University of Colorado at Boulder
Jonathan Cristoforetti	Graduate Student	UCI
Charles K. Huyck	METASIM Project Leader	ImageCat
Sungbin Cho	Researcher	ImageCat
Shubharoop Ghosh	Researcher	ImageCat
Paul Amyx	Researcher	ImageCat
Zhenghui Hu	Researcher	ImageCat
Sean Araki	Researcher	ImageCat
Chris Davison	Technology Manager	UCI
Xingbo Yu	Graduate Student	UCI

University of California San Diego (UCSD)

<i>Name</i>	<i>Role(s)</i>	<i>Institution</i>
Ramesh Rao	PI; Professor, ECE; Director, Calit2 UCSD Division	Calit2, UCSD
John Miller	Senior Development Engineer	Calit2, UCSD
Ganapathy Chockalingam	Principal Development Engineer	Calit2, UCSD
Babak Jafarian	Senior Development Engineer	Calit2, UCSD
John Zhu	Senior Development Engineer	Calit2, UCSD
BS Manoj	Post-doctoral Researcher	Calit2, UCSD
Sangho Park	Post-doctoral Researcher	Calit2, UCSD
Stephen Pasco	Senior Development Engineer	Calit2, UCSD
Helena Bristow	Project Support	Calit2, UCSD
Alexandra Hubenko	Project Manager	Calit2, UCSD
Raheleh Dilmaghani	Graduate Student	ECE, UCSD

Shankar Shivappa	Graduate Student	ECE, UCSD
Wenyi Zhang	Graduate Student	ECE, UCSD
Vincent Rabaud	Graduate Student	CSE, UCSD
Salih Ergut	Graduate Student	ECE, UCSD
Javier Rodriguez Molina	Hardware development engineer	Calit2, UCSD
Stephan Steinbach	Development Engineer	Calit2, UCSD
Rajesh Hegde	Postdoctoral Researcher	Calit2, UCSD
Rajesh Mishra	Senior Development Engineer	Calit2, UCSD
Brian Braunstein	Software Development Engineer	Calit2, UCSD
Mustafa Arisoylu	Graduate student	ECE, UCSD
Tom DeFanti	Senior Research Scientist	Calit2, UCSD
Greg Dawe,	Principal Development Engineer	Calit2, UCSD
Greg Hidley	Chief Infrastructure Officer	Calit2, UCSD
Doug Palmer	Principal Development Engineer	Calit2, UCSD
Don Kimball	Principal Development Engineer	Calit2, UCSD
Leslie Lenert	Associate Director for Medical Informatics, Calit2 UCSD Division; Professor of Medicine, UCSD; PI, WIISARD project	Calit2, UCSD
Troy Trimble	Graduate Student	ECE, UCSD
Cuong Vu	Senior Research Associate	Calit2, UCSD
Boz Kamyabi	Senior Development Engineer	Calit2, UCSD
Jurgen Schulze	Postdoctoral Researcher	Calit2, UCSD
Qian Liu	Systems Integrator	Calit2, UCSD
Joe Keefe	Network Technician	Calit2, UCSD
Brian Dunne	Network Technician	Calit2, UCSD
Per Johansson	Senior Development Engineer	Calit2, UCSD
Wing Lun Fung	Undergraduate Student	ECE, UCSD
Anthony Nwokafor	Networking Engineer	Calit2, UCSD
Parul Gupta	Graduate Student	ECE, UCSD
Anders Nilsson	Graduate Student (visiting researcher)	Calit2, UCSD
Wenhua Zhao	Graduate Student (visiting researcher)	Calit2, UCSD
Daniel Johnson	Mechanical engineer	Calit2, UCSD
Ian Kaufman	Research Systems Administrator	Calit2, UCSD
Kristi Tsukida	Undergraduate student	ECE, UCSD
Eldridge Acantara	Graduate Student	ECE, UCSD
Mason Katz	Senior Software Developer	SDSC, UCSD
Greg Bruno	Senior Software Developer	SDSC, UCSD

Responsphere Research Thrusts

The Responsphere Project provides the IT infrastructure for Rescue project. The project is divided into the following six research projects: Stream Acquisition and Transformation Middleware (SATWare), Disaster Portal, Customized Dissemination in the Large, Privacy Implications of Technology, Robust Networking and Information Collection, and MetaSim. The following research and research papers (by project area) were facilitated by the Responsphere Infrastructure, or utilized the Responsphere equipment.

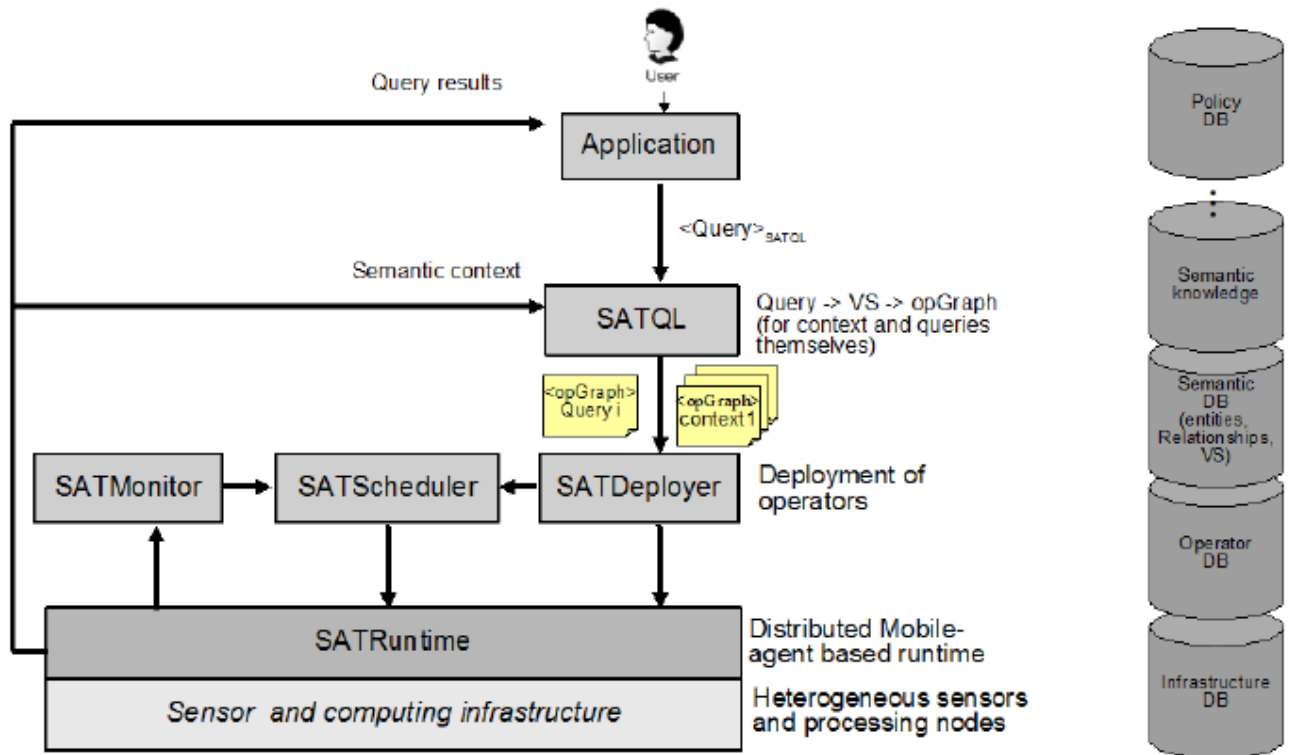
Stream Acquisition and Transformation Middleware (SATWare)

SATware is a multimodal sensor data stream querying, analysis, and transformation middleware that aims at realizing a sentient system. SATware provides applications with a semantically richer level of abstraction of the physical world compared to raw sensor streams, providing a flexible and powerful application development environment. It supports mechanisms for application builders to specify events of interest to the application, mechanisms to map such events to basic media events detectable directly over sensor streams, a powerful language to compose event streams, and a run-time for detection and transformation of events. SATware is being developed in the context of the Responsphere infrastructure at the UC Irvine campus.

In contrast with classic pervasive middleware, SATware provides application developers a semantic view of the pervasive space. This semantic layer is at the same abstraction level at which users reason. This way, application developers need to worry about the semantics of an application, and not about the details of where sensors are and how data has to be collected from them. SATware provides users with a semantic layer that abstracts sensor data streams with raw sensed data into entity based streams. The user only needs to worry about entities (for example, person X, or room Y) and events regarding those entities (for example, person X is in room Y or room Y is empty).

Activities and Findings

In the past year a new, more stable version of SATware, SATware v2.0 has been released. In the new version, extensive improvements have been made to the general architecture and several new applications have been built on top of it. The overall architecture of the current SATware system is as follows.



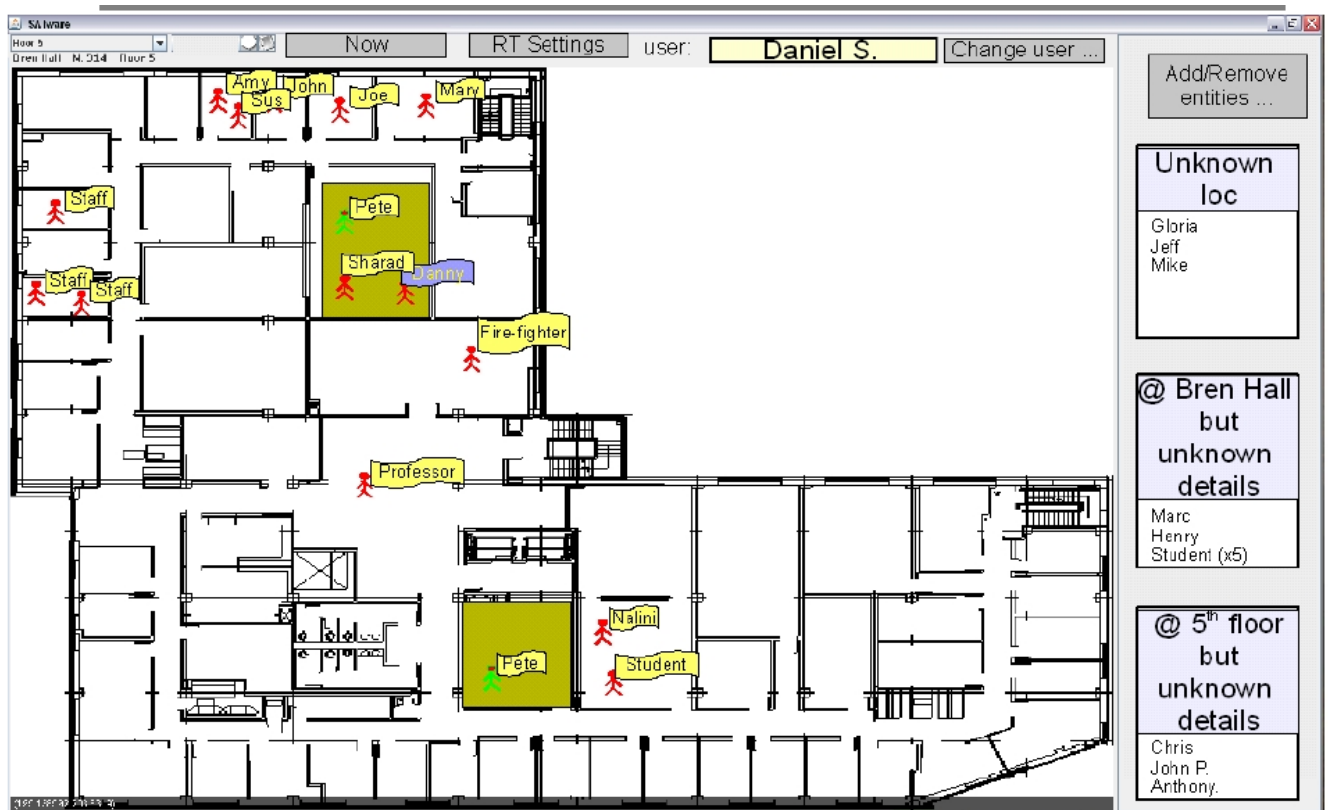
In terms of architecture, SATRuntime has been stabilized and both SATDeployer and SATQL have been implemented and deployed as centralized services running on a dedicated Responsphere server. The SATRuntime provides a distributed runtime on top of a JVM (Java virtual machine) for implementing operators. That is, each SATRuntime instance assigns threads to its operators, allows operators to send tuples to its output stream, provides support for moving operators from one SATRuntime instance to another, and for connecting a SATRuntime instance's output stream to the input stream of another SATRuntime instance.

The first stable versions of the SATDeployer and SATQL have been implemented. SATDeployer is the component responsible for deploying a virtual sensor, assigning each operator to a specific machine and creating the connections. SATQL receives context-aware queries from applications and sends to the SATDeployer a set of virtual sensors (i.e., operator graphs) that need to be deployed to answer the queries.

In addition to the SATRuntime, SATDeployer, and SATQL modules, a series of operators have been implemented. Operators can be classified into source operators, transformation operators, and user interface operators. SATware provides a wide set of source operators to deal with heterogeneous sensors such as cameras, RFID readers, people counters, and wireless sensor nodes (i.e., motes). This sensing infrastructure covers the indoors of the Calit2 and Bren Hall buildings as well as some of the outdoor space between these two buildings in UCI. The applications built on top of SATware are the following: (i) SATRecorder, which was finally completed during the past year, and (ii) the SATControlCenter and (iii) the PolicyBuilder, both designed and implemented completely in the last year. Each of these is briefly described below.

Future Plans

In addition to implementing the previous applications, we are currently working on a new application: RegionMonitor. The RegionMonitor provides a GUI (similar to that of the SATRecorder) where one can visualize the state of the different entities in Responsphere. Here, entities refer to people, appliances, and spatial locations such as rooms and buildings. The focus of this application is on designing techniques and algorithms for dynamic query processing under privacy constraints which simultaneously tries to satisfy users' privacy preferences as well as maximize the utility of the query answers given to users. Currently we are working towards formalizing the notion of utility and privacy in context of the RegionMonitor application. The subsequent work that will be done in the coming year will focus on the algorithm development and efficient implementation issues. The screenshot below displays how the RegionMonitor visualization screen might look for some user at a given moment.



Products

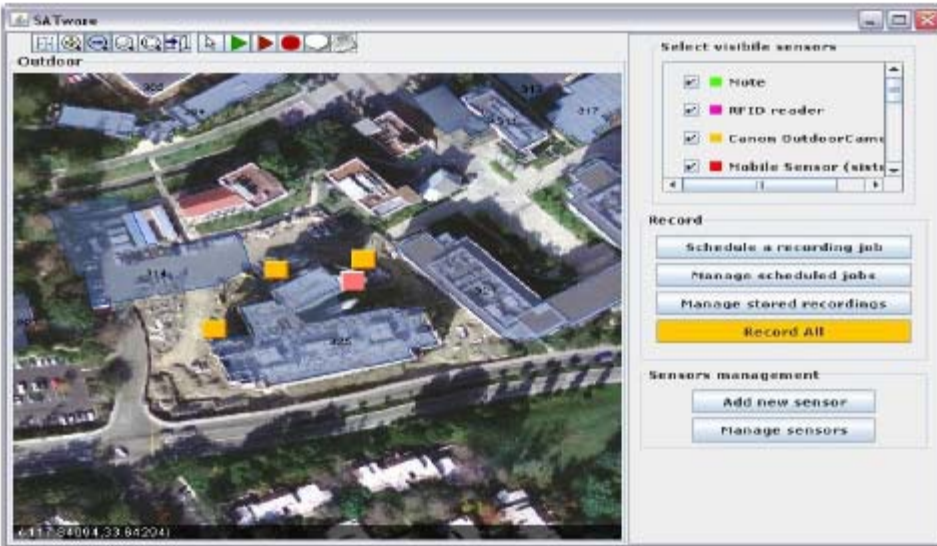
Artifact: SATWare – A middleware for sentient spaces

Website: <http://ics.uci.edu/~projects/SATware>

Contributions

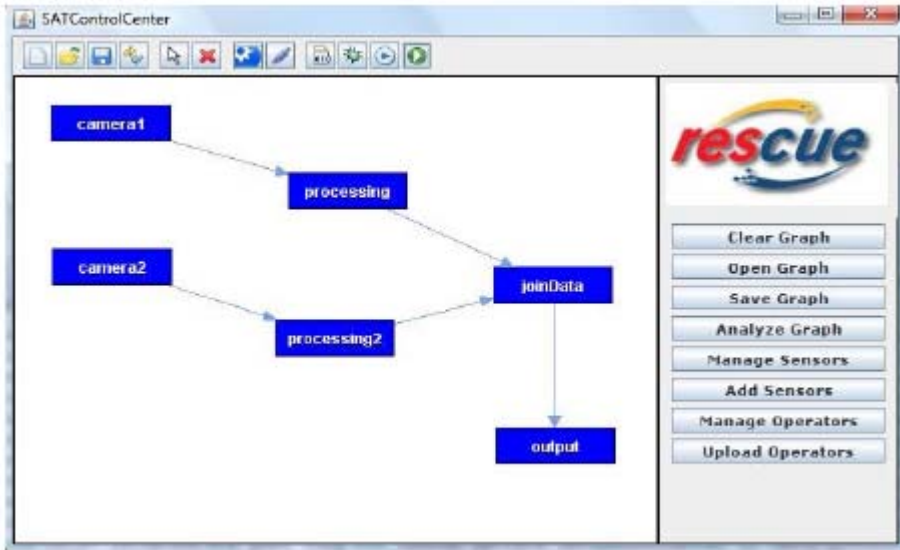
SATRecorder

The SATRecorder allows a user to browse through the UCI campus, covering both outdoor and indoor locations. The user can connect to any of the sensors within the Responsphere infrastructure and either display or record what these sensors are sensing. The user can also select to visualize events being detected by virtual sensors. In the last year the performance of SATRecorder has been improved significantly, where we focused particularly on optimizing the amount of recorded data by eliminating redundancy (e.g., not storing multiple copies of the same set of events which might have been requested by multiple users). Further efficient storage of multiple versions of the same stream of events is possible, such as the video stream with individuals masked out along with the raw stream. The figure below shows a screenshot of the user-interface for the SATRecorder application.



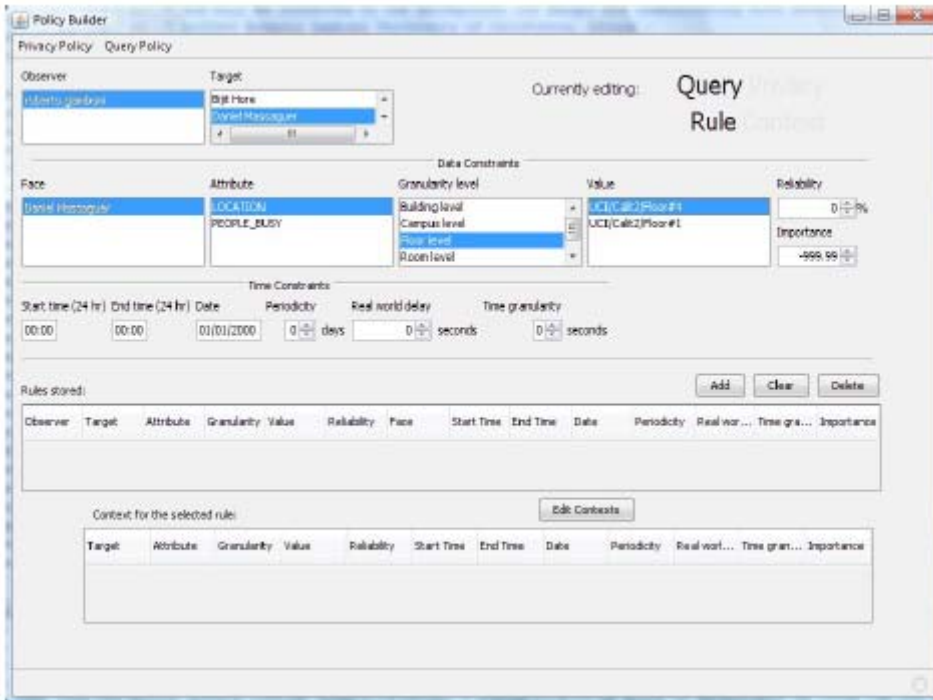
SATControlCenter

The SATControlCenter provides a simple online GUI where application builders can visually describe their application as a graph of virtual sensors and operators. The SATControlCenter will allow us to perform research on the lowest layers of SATware as well as provide a testbed (for ourselves and even other collaborators) for testing operators. In addition, the SATControlCenter allows users to upload new operators to an operator repository and select in which SATRuntimes each operator/virtual sensor will execute. The SATControlCenter is deployed as a Java Applet and available online. The interface for this component is shown below.



Policy Builder

PolicyBuilder is an application for editing a user's privacy policies as well as allowing users to issue context-aware queries into the system. The same interface (and XML language) is used for both privacy policies specification and issuing queries. Namely, PolicyBuilder allows users to log into the system and change who can see what attribute values of them, when, and under what context. Analogously, a user can also ask SATware for another entities' attribute values at some given time interval and context. Along with the PolicyBuilder application, we have designed a preliminary XML-based language to express context-aware policies and queries.



Disaster Portal

The development of the Disaster Portal is based on two primary considerations. While we aim to provide practical applications and services of immediate utility to citizens and emergency managers, we also strive to significantly leverage many relevant pieces of IT research within Responsphere. The advanced technologies that are currently incorporated into the Disaster Portal include components for customizable alerting, family reunification, scalable load handling, unusual event detection and internet information monitoring..

Activities and Findings

Major achievements made by the Disaster Portal project during the last year include the incorporation of several new research elements within the application modules and deployment of the system at the City of Ontario, California, and packaging of the system for further deployments with additional cities.

Infrastructure scalability was an area of active development during the past year, and Flashback is a good example of a Responsphere technology integrated into the Disaster Portal to address that issue. During disasters, information portals such as the Disaster Portal commonly experience flash loads due to very large numbers of users attempting to access the portal simultaneously. The Flashback web server creates and utilizes a peer-to-peer infrastructure and transmits much of the flash load back to end-user browsers which are dynamically recruited to share some of the server load.

Another area of active development during the past year was in creating dynamic scalability of the existing Responsphere server infrastructure via the use of cloud-computing services such as Amazon's Elastic Computing Cloud. The capability allows for dynamic provisioning of virtual machine instances hosting the Disaster Portal system in order to load balance flash traffic as coordinated by key Responsphere servers.

In September of 2007, the Disaster Portal project's community partner City of Ontario officially debuted the system. Shortly thereafter the system saw significant use by the city during the October wildfires. During the fires the system received over 50,000 hits and was used to post more than 20 announcements with maps, emergency sheltering status information, and to notify media organizations of new updates.

Future Plans

Over the next year the Disaster Portal team will focus on establishing the use of the system at additional cities, and ensuring a path for continuity of the system beyond the completion of the Responsphere project to allow cities which have deployed the system to be able to continue to utilize it. Several options are currently under consideration including open-sourcing the system or licensing the system to a partner for commercial development.

Success of the system deployed at the City of Ontario has led to interest from a number of additional cities, and discussions are ongoing to coordinate these additional deployments. These include the Cities of Rancho Cucamonga, Aliso Viejo, Rancho Santa Margarita, and Orange; all in Southern California, and also the City of Champaign, Illinois. All deployments of the Disaster Portal are currently hosted on Responsphere servers; we anticipate packaging the Disaster Portal with documentation needed to allow cities to host their own instances of the system.

Products

Artifact: Disaster Portal – a modular, easily customized web portal and suite of component applications.

Websites:

Disaster Portal Project Website

<http://rescue-ibm.calit2.uci.edu/DisasterPortalProject/disasterportal.html>

City of Ontario, California Disaster Portal

<http://www.disasterportal.org/ontario>

Demonstration / Pre-deployment Websites:

City of Rancho Cucamonga - <http://www.disasterportal.org/cityofrc>

City of Aliso Viejo - <http://www.disasterportal.org/alisoviejo>

City of Rancho Santa Margarita - <http://www.disasterportal.org/ranchosantamargarita>

City of Orange - <http://www.disasterportal.org/orange>

Contributions

Community Disaster Alerting - The alert system automatically creates customized notification messages for a set of recipients who may be affected by a disaster or emergency situation based on administrator defined rules. These messages can be delivered via a variety of modalities including email, text messaging, and the RAPID peer-to-peer system also developed by RESCUE. The system is utilized in the Disaster Portal for broadcasting messages such as press notifications and announcements.

Family Reunification - The Disaster Portal family reunification module provides the ability to integrate crawling and/or searching of other missing person information sources on the web so that the user can effectively search many sites at once. This and related improvements will utilize results of ongoing research into issues such as crawling, information extraction, data uncertainty, data lineage, approximate query processing on text, and management of structured and unstructured data using the same infrastructure.

P2P Web Server - Flashback is an experimental web server which creates and utilizes a peer-to-peer infrastructure to address the problem of flash crowds overloading a traditional web server. Flashback is being integrated into the Disaster Portal to allow it to be deployed on typical web server hardware yet still remain effective during high-demand periods as might be expected during a disaster.

Traffic / Population Prediction - This project utilizes activity modeling in conjunction with live roadway loop sensor data from CalTrans to provide information on current traffic patterns as well as predictions of near future conditions. Current efforts are being made to extend these models to track movements of populations in a given area.

Additionally, other RESCUE research in areas such as text extraction, web information disambiguation, multi-dimensional document analysis, faceted web search, and scalable publish-subscribe techniques may be incorporated into future Disaster Portal releases. b technology (blogs, wikis, web servers) and browser toolbars for Firefox and Internet Explorer.

Customized Dissemination in the Large

This goal of this project is to generate the next generation of warning systems using which information is disseminated to the public at large specifically to encourage self-protective actions, such as evacuation from endangered areas and sheltering-in-place.

Activities and Findings

In the customized dissemination project, we are exploring 3 main research thrusts:

- (1) Understanding Dissemination Context: we have focused on information diffusion simulations to model the communication behavior of community members upon receipt of warning messages from our Crisis Alert system.
- (2) Supporting customization needs through flexible, timely, and scalable technologies
- (3) Scalable and Robust Delivery Infrastructure, both in wired and wireless networks

The key artifact of this project is the CrisisAlert System which allows fast and customized dissemination of alert messages through the Internet and incorporates some of the research findings achieved within this project.

In Year 4, there has been significant progress in all three research fronts. Significant progress was also made in the implementation, testing and deployment of the CrisisAlert System in government organizations. Working with industry partner, Nokia, we have developed fast broadcasting services on Nokia devices equipped with multiple wireless interfaces.

We are also in discussions with industry in the school-based communication domain (primarily Fonevia Inc.), through whom we expect to obtain participation of some Southern California school districts for the pilot study to be conducted in the coming year.

We are also in discussion with several agencies to test and deploy versions of the CrisisAlert system.

Research Thrust 1: Understanding Dissemination Context

In order to determine the effectiveness of the CrisisAlert system as well as the dissemination protocols that we have incorporated in it, our research team has performed a series of computer-based simulations. These simulations help us understand various aspects of how well the system and, subsequently, the population at large disseminate the messages. Using demographic data as well as research from sociological studies of communication patterns and frequencies between various types of people, the simulations model the communication behavior of the community members upon receipt of warning messages from our Crisis Alert system. The simulation method is preferred over an initial real-world study for matters of practicality and speed—the information obtained about the information dissemination behaviors of simulated human actors will be used to help inform the Crisis Alert system with far less time and money than would be needed in a real-world study of these behaviors.

As the simulation model evolves we can also factor in the geographic locations of the schools and establish various rules based on peoples' distances from various important locations (such as schools, shelters, and the like). Overall, we are able to control and test for various effects in the information dissemination process due to various factors such as sex, age, race, education level, and so forth. As we observe the various behaviors of the actors in the simulated world, we can further refine how the Crisis Alert system will be used.

Research Thrust 2: Customized information dissemination in large scale Publish/Subscribe

The customized information dissemination can be provided through a scalable Publish/Subscribe (Pub/Sub) infrastructure. A hierarchical Pub/Sub system consisting of set of content brokers can provide scalability and fault tolerance for delivering relevant information to receivers. Existing approaches provide scalable Pub/Sub by forming efficient overlay network to connect content brokers. Tree-based and DHT-based architectures are two most common architectures in forming broker overlay network in distributed Pub/Sub systems. We have proposed a fast and robust broker overlay architecture that provides fault tolerance and speeds up the content dissemination process. The proposed approach also balances the content dissemination load among brokers which results in more robust and scalable infrastructure. Our proposed approach achieves fault tolerance and scalability by organizing event brokers in clusters. Multiple inter-cluster links provide continuous availability of dissemination service in presence of broker failure without requiring subscription retransmission or reconstruction of broker overlay. Furthermore, the proposed architecture balances broker load and provides a fast event dissemination infrastructure that significantly reduces subscription and publication dissemination traffic and load on event brokers. Our experimental results show that even in the presence of high failure rate in broker network, information dissemination is not interrupted and dissemination speed and load are not affected significantly.

Efficient management of subscriptions in Pub/Sub systems is also an important challenge. We have been working on a subscription subsumption approach to reduce the cost of subscription dissemination load among brokers. The proposed technique extends the subscription covering technique to prevent unnecessary dissemination of subscriptions that are subsumed by a set of previously stored subscription. We analyze the problem for d -dimensional content space and prove that the complexity of subscription subsumption evaluation is exponential. We then propose heuristics to exploit the subscription subsumption as much as possible and evaluate our proposed techniques through extensive simulations.

All of the above Pub/Sub systems ignore the heterogeneity in the receiver desired content format and deliver the published content to all the receivers in the same format. However, in real applications users may desire to receive information in variety of formats. For instance, users that receive information on handheld devices such as PDA or cell phone desire to receive contents that are suitable for such devices. Therefore, a customized information dissemination system should not only deliver the information to relevant receivers but also it should customize the content format to in such a way that it fits the receiver's context. Existing distributed Pub/Sub systems do not provide such service and disseminate information in the same format to all receivers. We propose a DHT-based Pub/Sub architecture that not only delivers content to the relevant users, but also customize the information for each user based on their desire. The

customization is done through the content adaptation operators that accept content in one format and convert it into another format. Examples of content adaptation operators are content transcoding for multimedia information and content translation for multilingual receivers.

The important challenge in information customization in distributed Pub/Sub system is deciding about the place that the customization operations must be performed. Two straight forward options are to perform required operations in the source or in the destination of the published information. However, such decision may result in increased customization cost or increased network traffic or both. We define the customized Pub/Sub system as the problem of selecting perfect location in broker overlay for performing customization operators and show that this problem is NP-Complete (Steiner Tree Problem). We then propose heuristics for selecting locations for content adaptation and compare the proposed techniques with the approaches that perform adaptation in the source or destination brokers. Our analysis shows that the proposed approaches reduce the computation cost resulted from customization operators along with communication cost resulted from content transmission.

Research Thrust 3: Scalable and Robust Delivery Infrastructure

Scalable and Robust Information dissemination in wired networks

During this year we mainly focused on very short term information dissemination, as is the case for seismic early warning where only few seconds are available before the earthquake strikes. In this scenario, given that the information available is limited, the amount of data to disseminate to a large number of recipients is usually small. As in the case of Flash dissemination that we already explored in the previous years, information needs to be disseminated as fast as possible. Reliability is another key factor in this type of applications, although the failure model that we adopt does not include massive failures since the disaster has not strike yet and the network infrastructure should be fairly stable.

We have studied existing protocols for group communication and identified some that could apply to the early warning scenario. In particular, we considered various implementations of Application Layer Multicast and gossip protocols. We identified some major issues of those protocols and adapted some of them to our highly constrained scenario, where very low latency and high reliability are required.

We have developed a new protocol that merges both gossip and Application Layer Multicast advantages and exploits the knowledge of the group structure to minimize the overhead and the dissemination speed. We are currently testing it through simulations to show the advantages of this protocol in the early warning scenario as compared to others.

We are assuming a use case scenario where schools throughout California are the possible recipients and groups of receivers can be built based on their locations. In fact, we make the assumption that schools in the same geographic region (i.e. county or city) will need to receive the same early warning message and we exploit this knowledge to speed up the dissemination. Given this scenario, we can test the scalability of our protocol as the number of recipients increases.

In order to test our protocol in a complete and more realistic manner, we are considering a failure model that includes both independent random failures (pre-disaster) and geographically coordinated failures that can happen as the disaster strikes. We are planning to determine to which extent our protocol can be used to effectively disseminate early warning under these failure assumptions.

Finally, we will integrate this protocol in the Crisis Alert system, adding the capability to disseminate early warning or high priority messages.

Information Dissemination in Heterogeneous Wireless Environments

Wireless networks (e.g., cellular, Wi-Fi) extend wire-line networks in warning and notifying large number of people (both the public at large and first responders) in crisis situations. People with handheld devices (e.g., cell phones, PDAs) not only receive emergency alerts, but also share warnings and other related information between each other via ad hoc networks. In this work, we study reliable, fast, and efficient dissemination of application-generated data in heterogeneous wireless networks.

(1) We have addressed supporting adaptive reliability guarantee for the dissemination of application content data to a group of mobile devices that may or may not have infrastructure support but rather are connected through ad hoc connectivity. This suits the application scenario where a mobile device generates rich content information, e.g., pictures, annotated maps, etc., and has to disseminate the content to all other reachable devices in the proximity. Different applications may desire different levels of reliability guarantees. As opposed to existing work which assumes network size knowledge, topological knowledge, or receiver's pre-awareness of disseminations, in this work we make minimum assumptions. We have proposed to adopt a distinct approach, which decomposes the reliable dissemination task into two concurrent subtasks: awareness assurance and data diffusion. We have developed and implemented the RADcast (Reliable Application Data Broadcast) protocol. RADcast is able to provide reliability guarantee for the delivery of application data to all receivers regardless of whether network size knowledge is available. It is composed of an awareness diffusion sub-protocol, Peddler, and a data diffusion sub-protocol, Pryer. Peddler employs small messages called walkers which traverse the network to assure the dissemination metadata reaches the recipients. Pryer provides guaranteed delivery of the content data to those dissemination-aware receivers through concurrent push and pull. By intelligently integrating Peddler and Pryer, as well as smart exploitation of network size knowledge, RADcast supports three levels of reliability guarantee: Max Reliability, High Reliability and Medium Reliability. Timeliness and message efficiency are slightly sacrificed when a higher level of reliability guarantee is desired. Applications can select the desired reliability level when calling RADcast, and RADcast tailors its components and parameters for the desired reliability while achieving the best performance. In the coming year, we will take one step further, and study real-time broadcasting of video content in wireless ad hoc networks. This suits the application scenario wherein a mobile device captures video and disseminates the video content in real time to all other devices in the proximity.

(2) We have built a prototype system on Nokia N800 Internet Tablets, which forms Wi-Fi ad hoc networks among a group of devices in the proximity. The system enables users to see each

other's presence, do text messaging, file sharing and dissemination, video and audio streaming and talking. All those forms of communication can be one-to-one, one-to-many and one-to-all. The system is useful for special scenarios such as a group of first responders communicating at a rescue site, as well as other general scenarios where people socialize with friends and strangers in the vicinity. The system has integrated our proposed protocol, RADcast, for reliable content dissemination services. It helps us obtain better understanding of the operation of wireless networks in realistic settings. Moreover, it provides a good platform and testbed for realizing research ideas and testing the performance of new ad hoc networking protocols in the real world. We are currently conducting experiments on this platform to better understand the performance difference offered by Wi-Fi infrastructure mode and Wi-Fi ad hoc mode. This will benefit our future research work on exploiting heterogeneous wireless networks for the good of information dissemination.

CrisisAlert: An Artifact for Customized Dissemination.

The Crisis Alert system artifact has been built during last year with the goal to integrate the research in information dissemination and to respond to the issues identified in the warning literature regarding over-response and under-response in crisis situation. In fact, Crisis Alert has the ability to send emergency notifications that are customized for the needs of each recipient and contain rich information such as maps of the area, location of the open shelters closer to the recipient's location, current state of hospitals and their address and contact information and they can be automatically created by the system according to a set of rules defined during the risk-knowledge phase of deployment of a warning system.

To reach a greater part of the population and to overcome partial failure of the communication infrastructure, Crisis Alert delivers emergency notifications through different modalities. In addition, Crisis Alert takes advantage of the emergency response plan of each organization, integrating social networks in the emergency dissemination process. Each organization's emergency plan defines decision makers for each emergency. These decision makers have the responsibility to organize the organization's response to the emergency: one of the goals of the system is to target the emergency notification to them, providing enough information to organize a proper response.

The main goal of this year for the Crisis Alert system has been to test it in real scenarios and incorporate the findings due to these tests.

The Ontario drill has provided useful inputs to improve the usability of the system, regarding the case where no policies have been identified for the current emergency. In order to face this situation, the policy language has been enriched with the concept of "protective action", allowing the emergency personnel to specify policies that can be applied to different and unpredictable events. The drill has also highlighted the need for defining the concept of group of events. In fact, when a major disaster strikes, it usually generates a set of emergencies that are related to the major one but that can be of different nature and require different countermeasures. In this case, the population response could be improved if complete information is provided by the authorities through a single notification or update.

We are also trying to validate the Crisis Alert system through a series of pilot studies that involve schools and educational institutions. There are multiple purposes for these studies: to deploy the software prototype that we already have into a test scenario, to gather feedback from both the emergency personnel and the alert recipients involved, and to compare the information learned from this feedback to information obtained from actual drills. In this study we would like to take advantage of the infrastructure that has already been put into place by Fonevia, which is used on a day-to-day base for disseminating information from schools to parents during non-disaster times. In fact, if people are already familiar with the dissemination system, it is more likely to obtain a prompt reaction when a warning is issued. Furthermore, we will supplement our technology testing with a simulation framework that will help us understand the alert dissemination in the whole community. Given knowledge of the geographies, policies and protocols – we can conduct a what-if analysis of the speed at which information can be spread in the community given different technology and usage scenarios.

Finally, in the next months we are planning a workshop with representative from Southern California schools and school districts to collect information about existing warning systems, processes and procedures for emergency warnings and alerts to schools. This information will help us design the next generation of technologies and processes to help educational institutions better prepare for disasters and effectively respond in real-time to emergencies.

Products

1. Proximity chat on Nokia N800 Internet Tablets. A WiFi ad-hoc network system.
2. Crisis Alert System. A multi-modal emergency alert dissemination system.

Contributions

Crisis Alert System: This system is one of the artifacts that is being developed in the Rescue Dissemination Project. The goal of this artifact is to create an automated system to disseminate information to schools and other organization in case of crisis and disasters. The dissemination will be done by exploiting the organization's emergency plans by sending, for each event, the right information to the person that, according to the emergency plan, should received it. The existing emergency's plans are so improved by having updated, relevant and customized information easily available to the people who need them.



Privacy Implications of Technology

Privacy concerns in infusing technology into real-world processes and activities arise for a variety of reasons, including unexpected usage and/or misuse for purposes for which the technology was not originally intended. These concerns are further exacerbated by the natural ability of modern information technology to record and make persistent information about entities (individuals, organizations, groups) and their interactions with technologies – information that can be exploited in the future against the interests of those entities. Such concerns, if unaddressed, constitute barriers to technology adoption or worse, result in adopted technology being misused to the detriment of the society. Our objective is to understand privacy concerns in adopting technology from the social and cultural perspective, and design socio-technological solutions to alleviate such concerns. We focus on applications that are of interest in crisis management. For example, applications for situational awareness might involve personnel and resource tracking, data sharing between multiple individuals across several levels of hierarchy and authority, information integration across databases belonging to different organizations. While many of these applications have to integrate and work with existing systems and procedures across a variety of organizations, another ongoing effort is to build a “sentient” space from ground up where privacy concerns are addressed right from the inception, trying to adhere to the principle of “minimal data collection”.

Activities and Findings

Responsphere provides the Privacy research team with the necessary hardware, software, and drills to create privacy-aware technologies. Continuing the work on design of privacy-preservation techniques for applications using location based data; we developed algorithms for trajectory hiding and applied them to human-centric data collected in a sentient space like SATware. In particular, we address privacy issues like risk of identification and revelation of sensitive location information pertaining to individuals whose information is collected in the published data.

We designed and implemented DataProtector, a transparent security middleware for web based data services. DataProtector acts as a transparent middleman between the browser and the web server and enforces security requirements at the level of HTTP requests. DataProtector utilizes a rule based framework for determining the flow of sensitive information via HTTP requests/responses and protects the confidentiality and integrity of such information using cryptographic techniques. DataProtector utilizes the rules based frameworks to rewrite the HTTP requests ensuring that information is not leaked to the untrusted service providers and this process is done without the loss of security. DataProtector utilizes a novel bloom filter based search technique that allows the services to conduct keyword search on encrypted data. DataProtector is a generic middleware that can protect data outsourced to a wide variety of web based data services.

The DataProtector middleware run successfully in conjunction with the Google Docs and Calendar services. This empirically proves that it is possible to secure personal information and yet utilize the web services on the internet. We are currently conducting extensive analysis of the

performance of the DataProtector software to confirm its feasibility. The next step is to conduct user studies to measure the impact of DataProtector on user navigation. It is well known that users turn off security measures when confronted with performance delays. Our goal is make sure that DataProtector does not end up being a middleware that will be disabled by the users

Future Plans

- Complete the (ongoing) work on the RegionMonitor application described above. This includes several technical challenges, like clearly defining the privacy/disclosure risks involved and understanding the implications of the various privacy policies on the system architecture and communication protocols. Finally, we need to practical (efficient) implementation of the protocols using the existing Responsphere infrastructure. One new area of research we are beginning to investigate is regarding the play of trust and privacy in sensor driven pervasive spaces.
- While we are interested in understanding the implications of privacy policies and their enforcement in context of specific application such as the RegionMonitor, our bigger goal is to understand the generic principles of information disclosure control and privacy management in general in context of designing sensor-based systems. One approach that we will explore in the coming year is that of “minimal information collection” while designing data collection algorithms. The goal is to characterize what is the minimal amount of data that needs to be collected by sensors to achieve a given functionality (required by some application). We believe that adhering to the principle of minimal data collection will allow one to design more secure and privacy-aware applications in general.
- Building a secure data sharing infrastructure: We want to extend the middleware to allow users to outsource their data sharing requirements to untrusted service providers. The middleware leverages the sharing models present at the service provider and yet provides the users with security mechanisms that ensures that untrusted service providers do not learn about user.s data. Any data sharing infrastructure requires components that perform: a) authentication; b) data distribution and c) data storage. Our task would be building such components via an untrusted server ensuring the minimal loss of information in this process.
- Building applications that leverage the middleware: We want to build a suit of useful applications that leverage the security middleware. This will allow us to a) understand the strengths and limitations of the middleware; and b) understand the practical implications of the middleware.
- Co-operative Search: Our work so far concentrated on designing search techniques that allow search on encrypted data via servers that are uncooperative. In other words, we built search techniques after carefully studying the capabilities of the service providers and assuming that they will be unwilling to change their protocols to support secure data outsourcing. We will relax this assumption and explore techniques that allow search on encrypted data via service providers who are willing to change their protocols/interfaces.

Even in this case, care should be taken to ensure that information is not leaked in any fashion to the service providers.

Products

1. DataGuard. This software builds a secure network drive over the untrusted data storage offered by the Internet data storage providers (IDPs).
2. DataProtector. A transparent security middleware for web based data services.

Contributions

- <http://ics.uci.edu/~projects/SATware>
- <http://dataprotector.ics.uci.edu>
- <http://dataguard.ics.uci.edu>

Robust Networking and Information Collection

The primary goal of the Robust Networking efforts is to develop an efficient, reliable, and scalable network infrastructure to aid and support emergency response activities. Efforts to expand upon, improve and advance our emerging technologies and systems continued this past year, producing significant results.

The infrastructure is being developed to provide computing, communication, and intelligent information collection, management, and maintenance systems for on-site use at the site of emergencies and disasters. This is being done under the assumption that one or more possible environmental constraints exist, for example, lack of electric power, partial or full unavailability of fixed communication networks (either severely compromised or, in fact, never existed), and the use of heterogeneous sets of communication technologies and techniques from multiple first-responder organizations focusing on different aspects of the scene (police, fire, SWAT, bomb squad, paramedics and other medical personnel, etc.). This work on the Networking infrastructure has produced a portfolio of components.

Significant technical advances were made for several components and peripherals of the infrastructure. Notably, a new routing protocol called MACRT was developed for the CalMesh platform; it was successfully introduced and tested during the Winter/Spring 2008. In addition, the CalMesh hardware was overhauled with a more capable Linux platform and faster WiFi cards (we now run a 500Mhz CPU and use 802.11g rates on Atheros cards). We call this updated platform CalMesh2 and it can be either hosted in the same rugged aluminum cases as the first version, or in a smaller form factor enclosure that is also designed for outdoor use.

Two new models of the Gizmo truck were developed this year, one for industry and the other for use by students as a building platform. GPS capabilities have been added to the Gizmo platform. Also, a new circuit board has been designed in order to integrate all of the, now quite numerous, functionalities present in Gizmo. A new CalNode was developed, CalNode-Semi-Mobile (CalNode-SM) to add functionality to the CogNet system.

We continued to develop the mobile command and control vehicle for emergency response - the pickup truck we purchased in September 2006 has participated in all of our drills. The major work on the truck this year was to add a new solar power system and controllers which enable all of our wireless infrastructure components (Gizmo, WiFli Condor, CalMesh, etc.) to interface with the vehicle.

One of the primary successes this year was the tight integration among the multiple components of the networking infrastructure, which was showcased and tested for the first time in full-scale drills. The integration provided a more cohesive, interoperating infrastructure. This was successfully demonstrated when we showcased nearly a dozen of our technologies, tools and devices during the two emergency drills in which we participated this year: UCSD Campus Drill (full-scale exercise with an active-shooter scenario), October 16, 2007 and an MMST full-scale drill, dubbed Operation Silver Bullet (in South Bay, San Diego, CA, January 24, 2008 (unique scenario with dual incidents situation, the first time for the local MMST).

NUTSO (Non-Uniform Tiled System Optiportal) demonstrated the ability to create a mobile platform that can serve as a mobile command center, and integrate a number of video feeds and other sources of information in a single, flexible viewing area. Multiple types of feeds were handled well, including video feeds from cameras, news coverage, online resources, internal documents, etc.

Rich Feeds worked seamlessly with NUTSO. A first cut at crosscutting concern processing for authorization/authentication/policy evaluation was integrated into the ESB. Based on user-supplied credentials, the feed list presented to the user is determined, such that a lack of credentials filters out the UCSD Police camera feed, for example.

The dual incident scenario of the MMST drill was designed to test the ability to rapidly adapt and manage a multiple site attack in the greater San Diego area. It required two incident command posts and an overall area command center, each of which required information simultaneously (dual and single source). Additional load was placed on the infrastructure with new functionality being tested (accountability with bar-coded ID badges for the providers at the scene) and it rained. Both the researchers and the first-responders were very pleased with the results. "We were able to display data from both venues at Area Command, so they could truly get a bird's eye view of the entire situation," noted Colleen Buono, of WIISARD. Buono is an assistant clinical professor of emergency medicine at UCSD's School of Medicine and medical director at Palomar Paramedic College.

Details of all networking infrastructure advancements made during the year and results of drill-related experiments conducted, as well as data analysis and measurements made during the two drills are detailed below.

Activities and Findings

MMST Drill: Operation Silver Bullet, Chula Vista, January 24, 2008

Background

On January 24, 2008, the San Diego Metropolitan Medical Strike Team (MMST) held a large scale drill (called Operation Silver Bullet) at the Coor's Amphitheater and Knott's Soak City in Chula Vista, CA. In this drill, the first responders were tasked to deal with a simulated dual site large scale terror attack at these two locations (inspired by the 7/7 bombings in London, 2005).

The key objective for the drill was to test the ability to rapidly adapt and manage a multiple site attack in the greater San Diego area. The scenario was a coordinated dual location attack taking place about 30 minutes apart at two geographically separated locations. However, for practical reason the two simulated incidents were located only 200-300m apart; first attack took place at Coors Amphitheater and the second at Knott's Soak City theme park. Since focus was set on inter-agency communication and agility to adapt resources to a new situation, the exercise still tested the intended functions within each agency.



Figure 1. CalMesh WiFi mesh node (left) and Gizmo (right)

We participated in the drill with several technologies developed within the Responsphere program to support first responders in mass casualty disasters. The CalMesh ad-hoc wireless network infrastructure and Gizmo were among them. A video equipped remote controlled rover using the CalMesh infrastructure was used during the drill (Figure 1). CalMesh continues to be the key, central role for communications and all the applications demonstrated at these drills. MMST is a team of local, state, and federal responders who work together to develop and implement response plans for major urban crises and disasters.

CalMesh, Mesh Networking Platform

CalMesh is an ad-hoc network of small, lightweight, and easily reconfigurable nodes that quickly self-organize to form a reliable wireless mesh network. CalMesh is designed to be rapidly deployed at the site of a crisis to restore the communication fabric crucial to emergency response, and has been used in conjunction with previous drills with the MMST. It is the cornerstone of the infrastructure.

The CalMesh nodes use IEEE 802.11b-based WiFi technology for users to easily set up communication during emergencies. The intelligent gateway nodes communicate with each other using an advanced wireless multi-hop relaying process. CalMesh nodes can use any of a variety of wired and wireless backhauls to allow users to seamlessly roam across and aggregate multiple network infrastructures to maintain connection to the Internet.

During 2007 the CalMesh project developed a new mesh network routing protocol to replace the spanning tree based routing currently used in the CalMesh network. Latency in route reconfiguration in the event of failing links and nodes was the main drawback of the spanning tree protocol.

Moreover, the CalMesh hardware got an overhaul to get a more capable Linux platform and faster WiFi cards (we now run a 500Mhz CPU and use 802.11g rates on Atheros cards). We call this updated platform CalMesh2 and it can be either hosted in the same aluminum cases as the first version, or in a smaller form factor enclosure that is also designed for outdoor use.

The routing protocol, denoted MACRT as in MAC Routing, was first developed in our ICEMAN (Inter-layer Communication Enhanced Mobile Ad hoc Networks) architecture, which offers an easy user space testing and prototype development environment for low-level network programming in Linux, e.g., cross-layer routing protocols. The MACRT ICEMAN prototype was used to test and verify functionality of the protocol. After the prototyping phase, the per-packet intense operation of the protocol was moved into the Linux Kernel space in order to achieve desired performance in terms of throughput and latency.

MACRT is a layer 2 (MAC) ad hoc on-demand routing protocol and was inspired by the popular layer 3 (IP) AODV protocol. However, as the name suggests, it operates on layer 2 of the OSI stack, which means that the mesh nodes uses MAC addresses to "route" between source and destination mesh nodes. Similar to AODV, every new packet flow is preceded by a short "Route Request" message flooded in the mesh network, which will invoke a "Route Reply" from the source node once it is received. The nodes along the "best" path will form the route for the new packet flow in the following way: the flooded "Route Request" packets all set up a reverse route in all the nodes it passes on its way from source to destination node. The destination sends the "Route Reply" message back along the route from which the "best" "Route Request" was received (it carries a link cost aggregated along the route.)

MACRT also incorporates several improvements and new functions:

First, for the client management, the new protocol intercepts the 802.11 client management messages and uses these messages to help clients roam between Access Points (AP).

Secondly, the ETX (Expected Transmission Count) is used as a link metric in the routing algorithm in order to give established routes better throughput of the network compared to a pure hop metric.

Thirdly, existing ad hoc on demand protocols (such as AODV) only process the first received route request, which results in suboptimal routes. MACRT deploys an algorithm which introduces very short delays before "Route Requests" are forwarded. In addition it allows route updates to be sent out during an ongoing route discovery procedure to discover the best route.

Fourthly, the link quality between two wireless nodes normally fluctuates widely, which makes it a challenge to maintain route stability for a self healing routing algorithm such as MACRT. To counter this, MACRT has a neighbor subsystem that maintains the connections to its adjacent nodes by using a bounded random walk model of the RSSI (Received Signal Strength Indication) values; in effect, the subsystem filters out unstable neighbors. In addition, the neighbor subsystem also deploys an adaptive link break detection algorithm based on the 802.11 transmission failure messages.

CalMesh Infrastructure Deployment for MMST Drill

The CalMesh network was tasked to support the first responders with WiFi connectivity at both locations and was configured into two interconnected IP sub-networks. Figure 2 depicts the network set-up at both sites, where the larger Coors site deployed 6 CalMesh nodes one EVR (EV-DO Router; a CalMesh node with EV-DO Internet access) and the smaller Knott's site required 4 CalMesh nodes. The two sub-networks were interconnected via an IEEE 802.11g link using directional antennas due to the relative long distance (approximately 200m). Internet connectivity to the entire network was provided with 3 separate CDMA2000 EV-DO devices integrated with 3 CalMesh gateway nodes. A subset of the CalMesh nodes had GPS devices, which offers a location service to applications that require geolocation (e.g., situational awareness systems, maps etc.) Most of the CalMesh nodes were mounted on tripods in order to achieve a better coverage than located directly on the ground. Two of the Coors nodes were however placed on higher vantage points: node 21 was tied to a light pole about 10 feet off the ground to avoid shadowing from large vehicles and node 13 mounted on a tripod located on the roof of the Wireless Communications Mobile Command and Control Vehicle (aka the ResponSphere Truck).

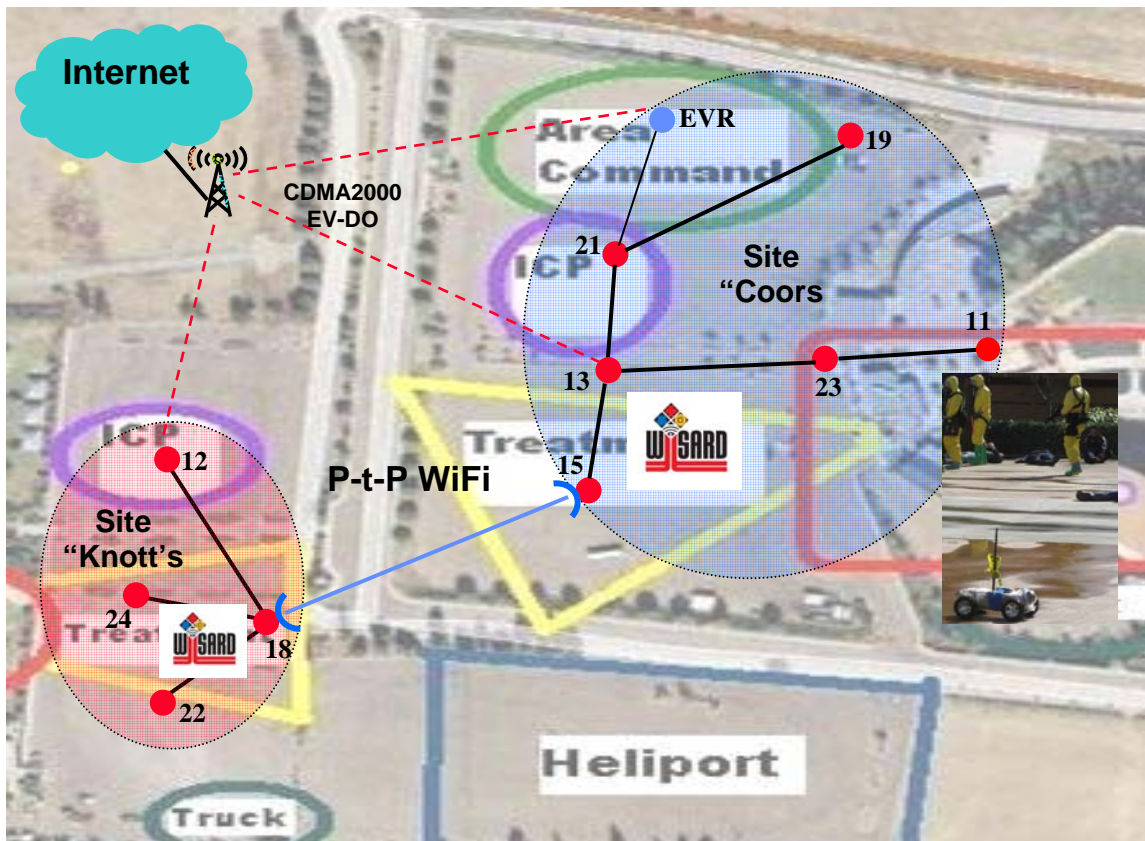


Figure 2. Dual site deployment configuration for CalMesh during Operation Silver Bullet.

Deployed Applications

A number of applications used the network infrastructure provided by the CalMesh deployment.

WIISARD:

WIISARD (Wireless Internet Information System for Medical Response in Disasters) is an integrated application that brings wireless Internet technologies from the hospital to the field treatment station. It has components that enhance the situational awareness of first responders, facilitate recording of medical data, aid in the monitoring of severely ill patients, and facilitate communication of medical data to hospitals. A mix of tablet PCs, PDAs, sensor devices (e.g., pulse oximeters developed at Calit2) is used in the WIISARD application, all running on top of the CalMesh WiFi infrastructure that allows for a seamless connectivity. During the Silver Bullet exercise, WIISARD's ability to operate and coordinate multiple incidents simultaneously was tested successfully. Figure 2 shows the two treatment areas and Incident Command Posts (ICPs) where the WIISARD system was deployed by the MMST. Moreover, the Coors site also had an overall Area Command, overseeing the entire operation where a Command and Control tool, part of the WIISARD suite, was deployed to provide situational awareness for the incident commanders. The Command and Control tool made use of the GPS data reported by the CalMesh nodes to geolocate the devices involved in the incidents (laptops, PDAs, patient sensor devices) and helped the commanders to account for both providers and patients. (The WIISARD project is a NLM funded project, jointly led between UCSD School of Medicine, UCSD Jacobs School of Engineering, and Calit2)

Gizmo, Mobile Mesh Networking Platform

Gizmo is a remote-controlled model truck built from regular RC model parts found in any hobby store, but hosting an array of technologies that makes it a compelling tool in a first responder setting - at a very affordable cost. It carries an onboard embedded Linux computer that provides the computational power necessary for communication, control, GPS information, and video streaming. Gizmo connects to the CalMesh network and can seamlessly roam around within the coverage provided by the network. Signals to control the direction and speed of the truck are sent from a regular USB game controller connected to a PC (laptop) computer within the CalMesh network (or off-site over the Internet). The video stream from the webcam on the truck is also fed to the computer to aid the control of the truck. The same video feed can be observed at several locations in the CalMesh network through a regular web browser. During Operation Silver Bullet (MMST drill), Gizmo was sent into the disaster Hot Zone and provided video feed back to the Incident Command and Area Command. (See Figure 3)



Figure 3. Gizmo providing live video feed inside the Coors Hot Zone during Operation Silver Bullet. (clips of this video has been archived into four clips)

Over the year much progress was made on Gizmo:

Two new models of the Gizmo truck have been developed this year. We built four of the first model (three of them have since gone to Intellisys). Of the second model, we have built two prototypes. One is used by the Preuss High school students as a test platform.

A new circuit board has been designed in order to integrate all the components present in Gizmo (16 servos, one gas sensor, 4 serial ports, +12V and +5V inputs/outputs, Bluetooth, 15 ADC, I2C, ISP, Spread spectrum receiver, 900Mhz radio, and override circuitry. New software has been developed which allows two-way audio and video. New cellphone programs have been created which enables control of Gizmo using a phone.

The GIZMO is a mesh network node on top of a remote-controlled truck for outdoor autonomous deployment using GPS. It's an extension of CalMesh. Once the CalMesh nodes have been deployed, users can check the homogeneity and stability of the network throughout the area of coverage in order to fix possible gaps (spots with no coverage). GIZMO is equipped with an open-source signal strength detector developed by UCSD undergraduate students, which can detect SSIDS, IP addresses, MAC addresses, type of connectivity, and signal strength. GIZMO also has a GPS module, so it can record the location-specific measurements over time as it is driven around an area. The data is sent over the CalMesh network and stored remotely. Gizmo's audio and video outputs let users get situational awareness of a remote location, while corresponding inputs can be used to guide the truck's path. Integrated environmental sensors will allow the truck to collect gas sensor data (e.g., from a carbon monoxide sensor) and send

measurements via SMS to a designated cell phone. The node also remains fully operational while the remote-controlled vehicle is in motion.

The Gizmo project is growing faster and faster in multiple directions. Cell phone technology is advancing rapidly integrating many features as Wi-Fi capabilities. We are developing code which will allow full two-way audio/video with control using a cellphone. At the moment we are using an N95 which has accelerometers which are using to control the Gizmo robot just tilting the phone. From a radio point of view, we have integrated a spread spectrum receiver at 2.4GHz for controls, a 900MHz radio for long distance order wire and we are working on the Zigbee and 700MHz communication.

A distance/collision system has been designed and integrated into the system. An obstacle avoidance algorithm is under development right now and should be ready by July.

GPS capabilities have been added to the Gizmo platform. A new algorithm which will allow gizmo to travel from one point to the other is being develop this quarter and should be ready by July.

Gizmo captured the attention of the popular media this year, with print and video features appearing on multiple TV news reports and in articles in newspapers (local, national and international) and on the web.

Mesh Network Antenna Caddies

The Mesh Network Antenna Caddies were deployed from our Wireless Communications Command and Control Vehicle. One Antenna Caddy is equipped with a remote control pan-tilt antenna pointing mechanism for point to point 1km maximum distance mesh network hops. A total of 3 antenna caddies have been constructed.

We have also constructed a flexible deployment system for our ViaSat LinkStar satellite data link. The current mounting scheme allows for deployment from or on top of a truck, or on the ground. In this way, the satellite link can be decoupled from the vehicle, and left in a better location with a view of the southern sky. In some cases, the vehicle may need to park in a location without a southern sky view. We have found this to be true in urban canyon environments. The dish diameter of 1.8m is sized for antenna gain so that only a 2W RF amplifier is required for a 512kb/s uplink. This low power RF amplifier with a high gain parabolic dish increase usable time in battery powered applications.

NUTSO (Non-Uniform Tiled System Optiportal)

The UCSD Non-Uniform Tile System OptIPortal (NUTSO) display was set-up in the Area Command. NUTSO is a command-and-control display wall. NUTSO displayed real-time video and data feeds from Gizmo from inside the Coors Hot Zone. A CalMesh node inside the Area Command area was configured to offer a dedicated Internet access over a CDMA2000 EV-DO USB device since NUTSO required a relatively large amount of external access.

Hypothesis: Deployment of NUTSO at the EOC during the drill. We measured the time required to set up the entire system, as well as general utility/functionality of the system and its integration of various video feeds.

Design: NUTSO consists of three small PCs, one 19 inch LCD monitor, two high definition LCD monitors, and twelve convertible tablets. One PC is designated as a head node which controls the display of the remaining two PCs and the twelve tablets using a private gigabit network connected via a switch. The resulting configuration creates a tiled display consisting of the two high definition LCD displays and the twelve tablets. Each can display images/video/webpages independently, or can be used in conjunction with any adjacent displays. For portability, the case in which all of the components are packaged/shipped doubles as the platform to mount the equipment on. A portable generator was brought along as well in the event that external power was not available.

Outcome: NUTSO was up at the MMST drill site just prior to the actual event's launch. It took approximately 40 minutes for two people to unpack the system and connect everything together. NUTSO was up and running during the drill, and was able to display the Rich Feeds web page, as well as the Calit2 Traffic website. It also was able to display the feeds from both Gizmo cameras. Finally, it was able to connect to the WIISARD Command and Control system, and display the relevant data as required. Early into the drill, the external power feed was interrupted and proved unstable. The portable generator was used for the duration of the drill (nearly four hours) without issue. NUTSO handled the power outage as expected, with the tablets continuing to run on battery power, while the head node and two PCs driving the high definition LCD displays power cycled. One PC automatically rebuilt, and while this operation was going on, the entire system was able to be reconfigured so that the twelve tablets were able to function properly. NUTSO was connected directly to a MESH node that had a direct EVDO connection to the Internet, so that NUTSO was able to communicate to both the MESH network and the Internet seamlessly.

Observations: Set up of NUTSO proved to go smoothly. A tent was used to partially protect the equipment from the elements, which proved to be necessary when a light rain began to fall. The feeds from Gizmo were a little rough at times due to issues regarding its power source as well as Gizmo's extended run deep into the event site where the number of hops between MESH nodes caused significant packet drops and bandwidth issues. Gizmo was reconfigured to use a different codec for its video feed, one that was more network friendly. Unfortunately, NUTSO's system was not compatible with this format. The experienced power outage highlighted a configuration parameter that was left out - automated rebuilding of a node is the default in such an event, however, it is probably best to not rebuild every time as it leads to downtime and potential data loss. Issues with the MMST Command and Control interface, as well as some logistical planning errors, prevented NUTSO from displaying the interface until the end of the drill.

Analysis: NUTSO again performed as well as expected. There was significant interest shown in NUTSO as well as its underlying architecture from both drill participants and observers. The inability to display some of the video feeds from Gizmo due to codec incompatibilities is something that needs addressing. Future upgrades to the underlying architecture will facilitate a better and more flexible network configuration toolset, and experimentation with improved content management/display software may allow for multiple users to push data up onto the display, allowing for more collaboration and quicker response to requests for information. It may

be necessary to redesign the overall set up, discarding the "non uniform" aspect of the design in favor of an easier to manage form factor with uniform display properties.

Conclusion: NUTSO demonstrated the ability to create a mobile platform that can serve as a mobile command center, and integrate a number of video feeds and other sources of information in a single, flexible viewing area. During the occurrence of a disaster or some sort of incident where multiple Emergency responders need to work in tandem with each other, and need access to any available sources of information that may be relevant to the situation (such as video feeds from cameras, news coverage, online resources), a system similar to NUTSO can be dropped in place, integrated into any local or ad-hoc network, or even create a network of its own with the correct components, and be used to retrieve, organize, and share the desired information.

Future Plans: The issue of incompatible codecs from the Gizmo and other camera feeds may be addressed through the use of machine virtualization. The latest ROCKS distribution makes use of the Xen virtualization software that is packaged with Red Hat Enterprise Linux/CentOS distributions. (ROCKS is the core system software package used to deploy NUTSO as a cohesive unit.) It may be possible to install a Windows OS virtual machine which may then be displayed on the wall, allowing NUTSO to utilize the Windows proprietary formats that some of the cameras use.

Rich Feeds

Rich Feeds is a sub-project of the RESCUE project. It is a work in progress that demonstrates how unconventional data feeds (including RESCUE research feeds) and emergent data feeds can be captured, preserved, integrated, and exposed in either real time or after the fact. Rich Feeds promotes situational awareness during a disaster by integrating and displaying these feeds on a Google map in real time.

To meet these challenges, Rich Feeds' design is based on a Service Oriented Architecture (SOA) pattern called Rich Services, which delivers the benefits of SOA in a system-of-systems framework using an agile development process. Rich Feeds is a hierarchically decomposed system that integrates data producers, data consumers, and a data storage and streaming facility into a structure that services crosscutting concerns such as authorization, authentication, and governance flexibly and reliably. Rich Feeds' service oriented architecture allows the addition of new data producers and consumers quickly and with low risk to existing functionality while providing clear paths to high scalability.

As a result, Rich Feeds provides users with the opportunity to integrate research and emergent feeds to create novel presentations and gain novel insights both in emergency and research settings.

Hypothesis: According to the premise of the San Diego MMST (Metropolitan Medical Strike Team) drill, bombs will be exploded at two different sites within minutes of each other. The sites would be the Coors Amphitheater and the Knotts Soak City, both in Chula Vista, Ca. The objective of the drill was to demonstrate MMST activities spanning two venues simultaneously. In both venues, the bombs would cause a number of casualties of unknown nature.

In order to manage and resolve the event, the county sheriff and first responders from a number of jurisdictions must contribute their talents under an incident commander (IC) operating under the standard Incident Command System (ICS). The IC develops situational awareness using a number of sources, including police and television reports. Based on this information, the IC can determine strategies and resource deployments.

Our hypothesis for this drill was that the Rich Feeds data feed visualization could supplement traditional information sources, thereby improving the IC's understanding of the situation and its confidence in managing it.

Experiment Design: The experiment involved displaying two data feeds relevant to the MMST scenario, and verifying the availability and fidelity of the feeds throughout the drill.

The Calit2 Traffic Reporting System and the Calit2 Tracked Objects System provide data feeds that enumerate peer-reported traffic anomalies on local freeways and track the locations of instrumented objects. Integrating them on the Rich Feeds map improves situational awareness by allowing a user to see the spatial relationships amongst numerous objects. Additionally, the user can drill into any traffic anomaly or tracked object on the map so as to display anomaly and object details.

Two of the tracked objects were Calit2 Gizmo robots outfitted with live video cameras; drilling into these objects allowed a user to see the live video transmitted by a Gizmo as it traversed the disaster scene, especially the victim field. Therefore, the information presented to an IC would include the position and video feed derived from each Gizmo robot. An IC could choose whether the map showed a street layout, an archived satellite picture, or both.

By observing the consistency and correctness of the data presented, we hoped to demonstrate that the data feeds would be reliable and informative enough to place before an IC so as to improve situational awareness and influence strategy and decision making.

Outcome: The feed presented by the Calit2 Traffic Reporting System operated through the five hour drill. The feed generated by the Calit2 Tracked Objects System operated for three hours until the batteries on the tracked object positioning sensors wore down. Regardless of the state of the position sensor batteries, the Gizmo cameras operated for the duration of the drill.

Acquiring the Calit2 position feeds relied on Internet access to the Calit2 servers, while acquiring the Gizmo camera feed relied on access to the disaster venue mesh network. The Internet and mesh access provided by Calit2 at the venue were sufficient to support the position feeds and the Gizmo cameras. Consequently, Rich Feeds was able to show the two position feeds, and show the camera feed whenever the camera was broadcasting.

(Note that the Gizmo camera was capable of generating a video feed using both the Motion JPEG (MJPEG) format and the Microsoft ASF format. The Gizmo investigators chose to exercise one feed or another during various phases of the drill. Because the Rich Feeds display

system can receive only MJPEG feeds, Rich Feeds was able to show Gizmo video feeds for only part of the drill.)

During the drill, we noticed that Rich Feeds periodically lost track of the Calit2 Tracked Objects positions, and it erased them from the display. This occurred because of an overly conservative rule concerning a filter that governed which subset of positions to display. When Rich Feeds noticed that the filter was out of date (because new position data had arrived), it notified the user by clearing the display and showing a warning message. Once we modified the display program to allow the filter to track the incoming position data, and the Rich Feeds display kept proper and constant track of objects, including the Gizmo robots.

Observations: Once the filtering issue was corrected, the Rich Feeds display showed traffic anomalies and asset positions consistently and correctly. Additionally, it showed Gizmo camera feeds reliably and with sufficient fidelity that we spent much time simply watching Gizmo's travels.

Analysis: By observing the location of the Gizmo robot assets on the Rich Feeds map, and by watching the Gizmo camera images, it was clear that Rich Feeds could make a credible contribution to the situational awareness of an IC.

Anecdotally, the SWAT team took great interest in the Gizmo robot operations and camera feeds produced at the Gizmo investigator station. While the Gizmo feed was available to them, the Gizmo position was not. Had the SWAT team had access to the Rich Feeds integration, they might have been even more interested in Gizmo.

Based on the comments of the Gizmo investigators, it seems clear that additional opportunities for Gizmo-based situational awareness exist: outfitting Gizmo with a rear camera and outfitting Gizmo with a microphone. Should this come to pass, adding these perspectives to the Rich Feeds display would be desirable.

Conclusion and Broader Impact: Based on the positive experience of Rich Feeds at the MMST drill, it seems plausible that Rich Feeds could improve situational awareness both for the IC and for the SWAT team. Furthermore, since the traffic and asset positions are global and not limited to a single venue, Rich Feeds offers the opportunity for situational awareness across all venues.

For the next drill, we should identify a number of constituencies that could benefit from Rich Feeds' integration, and then offer to deploy it accordingly. Assuming proper authentication, authorization, and policy management, such constituencies could include IC, SWAT, medical teams, and the public at large.

Over the year much progress was made on Rich Feeds:

- We have created and developed case studies of the Rich Services architecture pattern. Our activities have generated field experience pertaining to the elicitation, development, and deployment issues of a rich data acquisition, integration, and visualization system focused on information collected and disseminated during both disaster and non-disaster events.

- By working with our collaborators, we have defined the types of data they generate and the way in which they generate them. We have created a Rich Service-based architecture which incorporates data acquisition services tailored to the collaborators' instruments and feeds.
- The central data store is a service within a Rich Service-based architecture. It stores data from each of the collaborator sources, and is structured so that new collaborators and feeds can be added with minimal effort.
- The data store is exposed to queries for the purpose of visualization and data analysis through both a Rich Service connector and through internal Rich Services. The external interface is Javascript/AJAX-based. The internal interface is SQL-based. In either case, because the data store is exposed in a Rich Service context, data flow and storage can easily be subject to policies such as governance, encryption, validation, and transformation yet to be chosen.
- The power demonstrated by the Rich Service implementation is its flexibility in accepting data from new collaborators and dispensing data to new integrators, analyzers, and visualizers. The flexibility is further demonstrated by allowing crosscutting concerns to be addressed without impacting either the producer or consumer applications.
- In addition, we have created a documentation framework that readily accepts data source definitions and promotes data usage by potential integrators, analyzers, and visualizers, thereby encouraging the use of this data by investigators other than the original researchers.
- We have exposed data in various demonstration visualizations that integrate multiple feeds in novel ways, including filtering data based on values profiled from the existing database. We have also created an animation mode that creates a compressed-time rendering of data arriving into the system in a user-specified time bound.
- We integrated live camera feeds either as data embedded within a mobile asset (as with the GIZMO robot), and as primary data elements (as with the CalIT2 and UCSD Police cameras).
- We integrated a first cut at crosscutting concern processing for authorization/authentication/policy evaluation. Based on user-supplied credentials, the feed list presented to the user is determined - lack of credentials filters out the UCSD Police camera feed.
- We leveraged the visualization and collateral integration support to recruit a new data stream using Rajesh Hedge's Situation Aware feed, which included text and pictures from mobile stations.

Cell Phone Based Location Tracking and Vehicle Telematics System

Location tracking technologies are applied during the drill. Two separated system are used: One is based on cell phone based AGPS and the other is based on the Telematics unit installed inside a vehicle with GPS unit. The Telematics unit allows us to control and vehicle and monitors the

location and vehicle status. The phone based AGPS supported by Verizon wireless includes network mode, local mode, and hybrid mode. In the network mode, latitude and longitude is calculated at network. In the local mode, the location is calculated at cell phone, and hybrid is the combination of network and local mode. Software is implementation with different modes to compare location-fix performance.

Hypothesis: Performance of different AGPS mode will be compared. And current implementation of cell phone based AGPS is supporting Verizon wireless network with BREW platform only. We will start looking into the GPS support of carriers like Sprint PCS and AT&T wireless. Those two carriers support Java (J2ME) mobile platform. We are planning to test the accuracy of AGPS's location tracking at network mode, local mode, and hybrid mode. We are also planning to test the stability and reliability of Telematics unit when vehicle is in motion.

Experiment design: As shown in Figure 4, the overall Tracking/Telematics system consists of the following subsystems:

- Mobile Phone (with AGPS) – Provides mobile tracking, vehicle command console and vehicle status report.
- Tracking Devices (with GPS and GSM Module) – Provide tracking and alert.
- Vehicle Telematics Control Unit (TCU) – This is an embedded GSM module with GPS. It's installed inside vehicle. It provides GPS tracking, geo fencing, panic button, lock/unlock vehicle doors, play vehicle Horn, turn on/off vehicle flash lights, and disable vehicle by cutting of power supply.
- WEB based Tracking Console for Consumer/Enterprise – It provides customer management console for Account, User, Vehicle, and Mobile. It is the user interface for Vehicle and Mobile control and monitoring console. It offers map display of latest vehicle or mobile position, the trace of vehicle or mobile.
- Interactive Tracking Console – It offers real-time location tracking and supports tracking playback. It is a good user interface for operation center.
- Service Platform – This is the core of the whole system. It is responsible for mapping, customer management, tracking service, and the integration with 3rd party services.

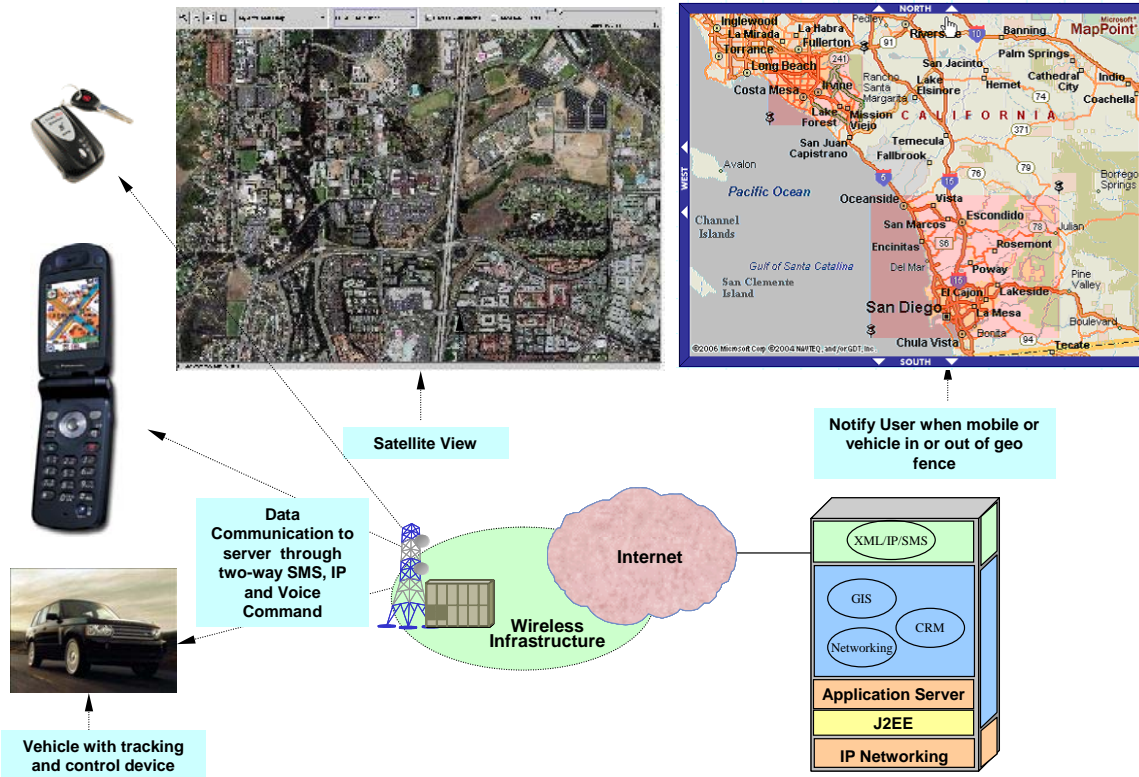


Figure 4

Outcome, Observations, Analysis: The result of AGPS based location tracking is as good as expected:

- Network Mode – Allows us to perform location tracking even the phone is inside building. But it takes longer to calculate the location since it relies network for the calculation. It takes 5 to 20 seconds.
- Local Mode – The response is much faster, 2 to 5 seconds. The indoor location fixing is difficult.
- Hybrid Mode – Since this mode is the combination of network and local. It is also the compromise of the two.

The result of vehicle Telematics:

- Location tracking – It offers accurate location tracking including location, speed of travel.
- Vehicle control – The network connectivity to vehicle is stable which allows us to control vehicle anytime, anywhere including play the horn, close/open door, turn on lights, disable vehicle, etc. We can perform vehicle location tracking and control via WEB and cell phone.

During the year, we began a licensing agreement of our mobile-based tracking technologies with a startup in the Bay Area to build traffic sensor networks in US and India. We will provide both BREW based AGPS mobile tracking software and J2ME with Bluetooth GPS-based mobile tracking software.

Wireless Communications Command and Control Vehicle

The emergency response and communication deployment vehicle project platform is a Chevy 2006 Silverado 3500HD. In addition to hauling the emergency communication devices to drills, it provides a robust home base-station during emergencies and drills. A New dual solar system was developed for the truck this year.

The vehicle has been equipped with

- In-dash touch screen running on a Mac Mini platform
- Urban Mesh node mounted to cargo roof rack
- Double lid crossover pickup toolbox equipped with dual solar panels
- Tracking/Telematics system (see below for more information)
- Front and rear power distribution boxes for communication technologies
- The power feeds into the distribution box behind the rear seat.
- Components that are installed next to the rear power block include: power amplifiers for interior truck audio and exterior loud speaker accessories, telematics system, and a DC to AC power inverter.

The Telematics system allows privileged users to track and control various aspects of the truck. Users can perform a GPS Fix, set geo fencing, alert for speed limit, start/stop vehicle tracking, display latest position, display the trace, turn on lights, sound the horn, voice wiretap, activate/deactivate vehicle ignition.

The overall Tracking/Telematics system consists of the following subsystems:

- Mobile Phone (with AGPS) - Provides mobile tracking, vehicle command console and vehicle status report.
- Tracking Devices (with GPS and GSM Module) - Provide tracking and alert.
- Vehicle Telematics Control Unit (TCU) - This is an embedded GSM module with GPS. It's installed inside vehicle. It provides GPS tracking, geo fencing, panic button, lock/unlock vehicle doors, play vehicle Horn, turn on/off vehicle flash lights, and disable vehicle by cutting of power supply.
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- Service Platform - This is the core of the whole system. It is responsible for mapping, customer management, tracking service, and the integration with 3rd party services.

Wireless Network/Coverage Simulation -- Intelligent RF Deployment

A new Cellular RF Modeling methodology was tested for a rapid wireless network design in the case of emergency, based on the use the 3-D scanners and feed the results into standard RF

simulator. The EDX RF simulation tool was also tested based on additional, different, practical examples, following the drill.

Hypothesis: One of the main initiatives for RESCUE project is real wireless network simulation in a dynamic way. Because of randomness and unpredictability of wireless channels, it will be difficult to set up a temporary wireless network (CalMesh) and expect to have the best coverage/capacity. While cellular networks are deployed based on an extensive design process, in an emergency scenarios it is impossible to have a long design/performance analysis phase before the rapid deployment. The main idea for this experiment is to define and create a process to used a 3D laser scanner and quickly scan the deployment environment, input it into the wireless simulation tool and find the optimize location for temporary deployment of CalMesh nodes.

Experiment design: The main objective during this drill was to use Lidar 3D scanner a day before drill, input the data into EDX Wireless simulation tool and find out the optimum locations for CalMesh nodes to maximize coverage and capacity for wireless network during the drill. During the experiment inter-operability between LIDAR (see discussion below on additional uses) scanner (formats) and EDX tool needs to be tested. Also, real signal strength and operability of the network during drill must be observed to validate accuracy of design.

Outcome: The main parking area scanned successfully and relevant data collected. The size of data was less than 40 Mb and the format was XYZ. The data successfully fed to EDX tool and simulation conducted to make sure decided CalMesh location in the parking lot will provide acceptable coverage during drill. The set of 3D maps for the area would be generated and fed to the tool to create a 3D coverage map of the area. This will assure networking people that by deploying Calmesh nodes in the designated area; an acceptable coverage area will be provided during the drill.

Observations and Analysis: As it is shown in Figure 5, most of the area had a good signal strength (>-50 dBm) and at the middle there was and area with moderate signal strength (<-50 dBm). Based on this simulation results, we were confident that CalMesh locations are optimum locations to provide the best coverage. Also, the output format of 3D scanner easily input to EDX simulation tool. Since color information are not important in wireless analysis, 3D scanner just provide geometric input (XYZ format) and not color information. This caused a huge reduction in scanning time; two points of scanning and each about 30 minutes and smaller file size; tens of mega versus hundred of mega bytes.

EDX was able to consider interference effect of the nodes on each other during simulation. However, the traffic effect was not analysis during the simulation. Further studies need to find out if this capability is available for EDX.



Figure 5. Parking lot coverage map

Conclusion: The value of a two-steps design and deployment for wireless networks in emergency cases was shown during the drill. Although after any disaster or unexpected events there is no time for a systematic wireless deployment, but a real-time simulation/deployment approach can be useful to maximize the coverage and reliability in these types of deployments. Although we did not use a real-time scan/simulation/deployment approach in this drill, but different components tested separately and their interoperability tested in a non real-time scenario.

It is highly desirable to create a platform for:

- After any natural or man-made disaster, using a 3-D scanner immediately scan the area, create the 3D map
- The data feed into wireless simulation platform in a seamless manner to simulate and locate the optimum deployment locations
- Deployed nodes report the performance back to the tool for further analysis live to have a dynamic optimization.

Performance Data Analysis and Measurements – MMST Drill

Network Performance Measurements and Analysis (CalMesh)

Coors:

The 6 node network at Coors remained stable for almost the full length of the exercise, partly thanks to the planned network configuration: a star topology which reduced the maximum number of hops each data packet would have to travel from one to node to another and thus

improved the overall network bandwidth. Occasional performance degradation occurred when fire engines and ambulances began to arrive at the site. These degradations were only temporary since the network was able to reconfigure itself to a stable point. Although the maximum number of hops increased and available bandwidth decreased after such a reconfiguration, the network still performed well. See Table 1 for the throughput data between nodes in the CalMesh network at Coors.

The San Diego Hazmat team deployed sensor devices in and around the Coors Hot Zone, which were equipped with WiFi radios (we were not able to get any detailed technical data about these sensors). We expected minor service disruptions in the CalMesh network due to radio interference with these sensors but we did not detect any interference problems.

Table 1. Throughput, Coors (Mbps, direction: Row -> Column)

CalMesh node #	13	15	19	21	23
13	---	1.54	0.84	1.93	2.15
15	1.46	---	2.04	4.09	2.01
19	1.54	2.25	---	2.19	4.54
21	4.32	2.16	2.15	---	4.35
23	2.19	4.12	2.04	3.63	---

Knott's:

Four nodes were deployed at the Knott's site. Similar to issues as those seen at the Coors site was experienced at this site: Large fire engines shadowed the communication path between two of the CalMesh nodes. A repositioning of the nodes quickly solved the problem and the network recovered quickly. See Table 2 for the throughput data between nodes in the CalMesh network at Knott's.

Table 2. Throughput data Knott's (Mbps, direction: Row -> Column)

CalMesh node	12	18	22	24
12	-	3.64	3.61	
18	3.70	-	1.70	
22	3.57	1.63	-	
24				-

Network Performance Conclusions

The CalMesh network provided a stable communication infrastructure for all the applications that relied on its offered wireless connectivity. The issues that arose were immediately addressed

and resolved thanks mostly to the built in self healing ability. The Gizmo truck performed well and we were able to provide mobile video surveillance to the first responders from inside the Hot Zone. The WIISARD application operated with only minor flaws throughout the exercise and the dual incident scenario was handled very well by the application. Our EVR node at the Area Command worked flawlessly and provided necessary Internet connectivity as well as connectivity to the CalMesh network for NUTSO. The bandwidth between nodes at both sides and we found that the Coors network had a minimum bandwidth of 840 Kbits/sec (between the farthest nodes) and a maximum of 4.54 Mbits/sec (between the closest nodes). At the Knott's network we had a minimum bandwidth of 1.63 Mbits/sec (between the farthest nodes) and a maximum of 3.70 Mbits/sec (between the closest nodes).

The feedback from the first responder's community was overall very positive and the fact that they were able to see the potential use of the systems of this sort in a realistic incident setting made an even more compelling case compared to a demo in a university lab. The CalMesh infrastructure played a key, central role for all the applications and will serve as a platform for future applications (voice over IP communication within the site, audio recording and announcements on the Gizmo etc.).

Wireless Mesh Network Electromagnetic Interference Measurement and Analysis –for both the MMST and the UCSD campus drills

The UCSD Calit2 Response Sphere team has deployed dozens of wireless mesh network nodes at various emergency response drills in California. Detailed measurements of electromagnetic wireless spectrum were performed during these drills. Packet losses from 3% to 33% were usually caused by wireless electromagnetic interference. Packet losses of greater than 33% are usually caused by defective mesh network node hardware (e.g., broken antenna), while packet losses of 0.3% to 3% are usually due to mesh network traffic congestion.

This activity included on site measurements around emergency response vehicles and interviews with the personnel who use and deploy these vehicles. Most of these vehicles are operated by state and county police and firefighter units, with the remainder provided by Army Reserve and National Guard units. Most of the vehicles utilize VHF and UHF communications, and exclusively utilize voice communications with 3 to 4 25 kHz bandwidth channels in simultaneous use. These narrowband communications systems interfere with our mesh network node within a distance of 3m by virtue of their high transmit power (2-10W FM) that overloads our low noise amplifiers in our receivers due to common mode noise susceptibility limits. Surprisingly, the most significant communication degradation is the channel fading caused by the fire trucks that drive by or part within 10m of ground based mesh network nodes. The solution is to mount mesh network node antennas at height of 5m to 10m so that they remain above the 3m height of the fire trucks. The exceptions are vehicles with satellite backhauls and microwave point-to-point backhauls. These vehicles or trailers provide 6 to 12 voice lines and 2 to 4 56kbaud to 128kbaud data lines, and are used by teams 6-8 personal with 3 to 4 lines in constant use. These vehicles deploy highly directional antennas that are directed well away from our mesh network nodes near the ground. However, our wide area coverage nodes with our 10 meter tall antenna caddy can be unintentionally placed in the path of a point-to-point microwave link. Vehicles with the most broad band communications available are TV news crew vans. The

vehicles may be equipped with Ethernet routers with 1Gb/s total capacity, but local on-site outbound communication is limited to a 6MHz bandwidth channel. The TV news crew vans can become a significant source of short term source of electromagnetic interference to our mesh network nodes, so we have learned to route around these vans.

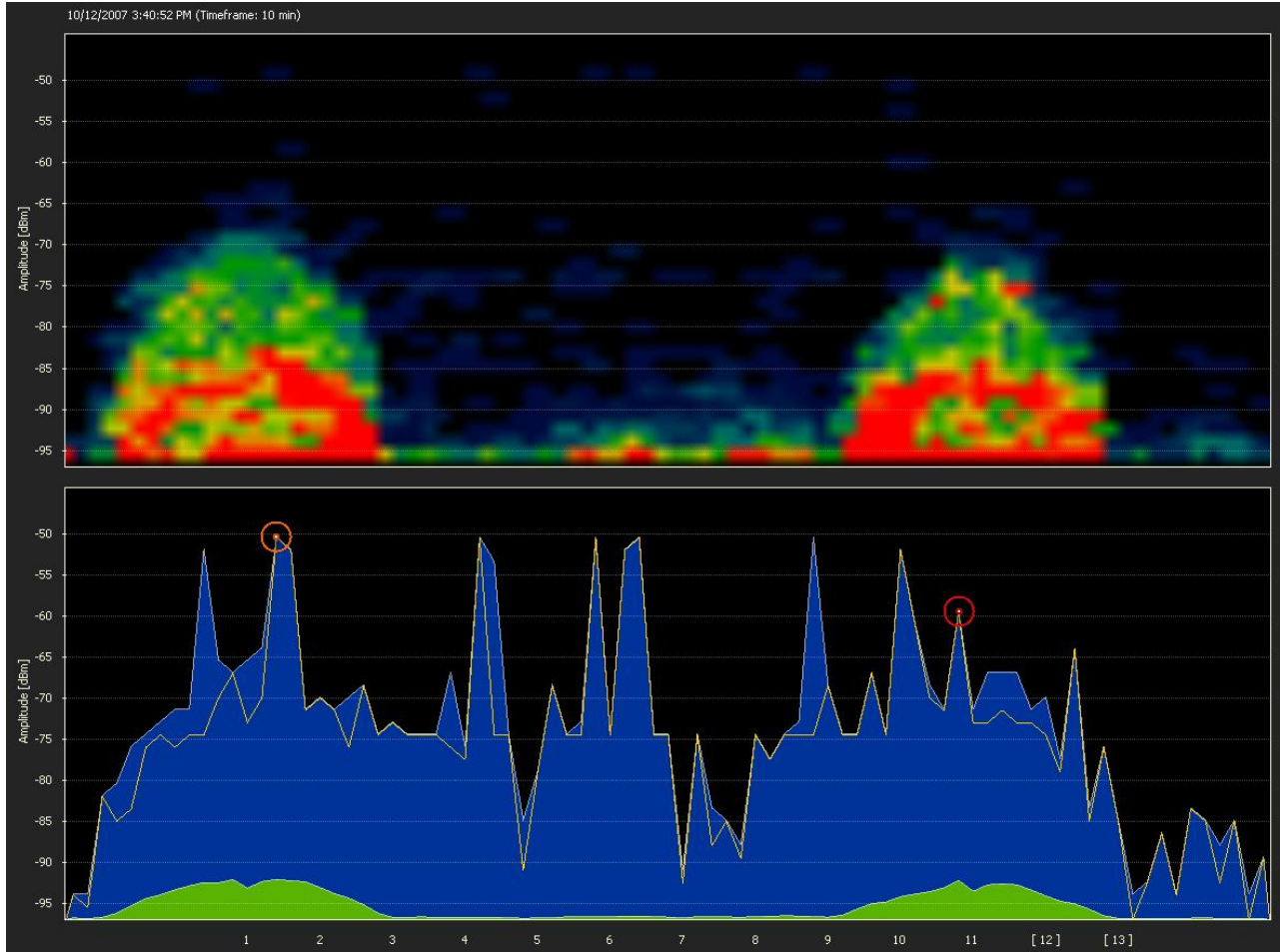


Figure 6: Leichtag Drill OCT-2007
Top WiFi Averaged Spectrum, Bottom WiFi Peak Spectrum

Most of the WiFi nodes present during the emergency response drill at UCSD near the Leichtag building were under our control or jurisdiction. We had complete control over our own wireless mesh network nodes (Cal_Mesh_Demo), and we had the cooperation of our information technology department for the UCSD WiFi access points. In this way, we could supplement the connectivity of our mesh network nodes with the standing UCSD WiFi infrastructure. At previous drills, nearby WiFi access points presented a significant source of interference since they would consume air-time capacity without sharing their frequency spectrum. Figure 6 shows the average spectrum and peak spectrum. The average spectrum show that WiFi channels 1 and 11 are in frequent use at greater than 50% duty cycle. The peak spectrum shows intermittent BlueTooth users on top WiFi users. The BlueTooth users were walking with 1m to 3m of the spectrum analyzer, so their field strength was 20dB greater than the WiFi access points and WiFi

users that were 10m to 100m away. (Not shown here are the 800MHz band cellular spectrum and the 1900MHz band PCS spectrum.) Many times our mesh network nodes will use 1xEV-DO backhauls in the PCS band or 1xRTT backhauls in the cellular band. During drills, many participants are using cell phones, but 1xEV-DO uses dedicated channels separate from voice channels, so that throughput is unaffected. Note, 1xRTT shares the same spectrum and time space with voice users, so that throughput is often degraded by 50% or more. In addition, we were able to use the campus WiFi infrastructure during the drill, so that consistent 11Mb/s or 54Mb/s throughput was achieved with greater than 90% availability.

In the next set of data we will discuss the emergency response drills conducted at the Coors Amphitheatre and Knots Soak City in Jan-2008. In this case, almost all the WiFi access points available in the hot zone region that simulated a noxious gas bomb were part of our mesh network (WISSARD and WISSARD_Link). In fact, only 1 non-emergency access point FanTM was active during the drill, resulting in no measurable electromagnetic interference. Our volunteer concert fan victims were too busy pretending to evacuate or pretending to be injured to have time to surf the net during the drill in the hot zone. In some previous drills, our wireless mesh network nodes were surrounded by high rise office buildings or high rise apartment buildings that filled much of the available WiFi channels in both frequency and time. Of course, some may argue that those locations would be subject to evacuation or loss of electricity during many real emergencies (e.g., Earthquake, Chemical Fire, etc.) Figure 7 shows WiFi average and peak spectrums. With 2 WiFi channels available with sufficient spacing, we were able to set up the most efficient wireless mesh network topology consisting of using Channel 1 for local clients and Channel 11 for node to node hops in the mesh.

This allowed for the full use of our mobile robotic mesh network node and sensor platform (GIZMO) to roam throughout the mesh during the entire drill. GIZMO is described elsewhere in the annual report in great detail, and is based on a 1:12th scale 4-wheel drive truck. In order to fully utilize the 1xEV-DO maximum data rate of 1.2288Mb/s, we equipped our mesh network nodes with 12dB gain antennas elevated at 3m above the ground. In this way, we were able to achieve sufficient signal strength from the base station 3km to 5km from our location. In fact, our mesh network cellular band reception was better than the cell phone users at the drill.

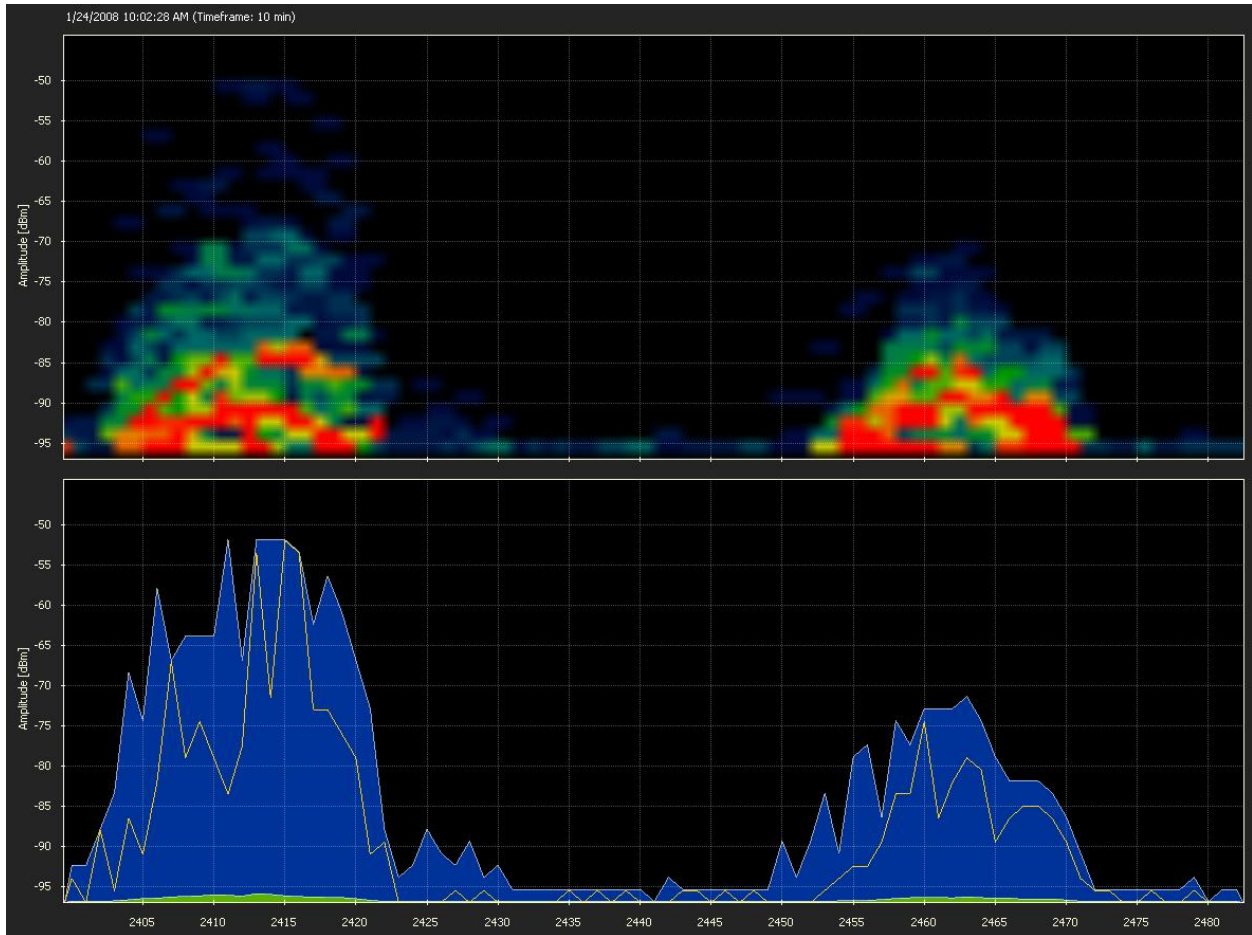


Figure 7: Coors Amphitheatre Drill JAN-2008, Hot Zone
 Top WiFi Averaged Spectrum, Bottom WiFi Peak Spectrum

Future Plans

The proliferation of Wireless Mesh Networks (WMNs) greatly depends upon regulatory, economic and social factors. These are discussed elsewhere; please contact us for additional information. The limitations caused by these factors need to be overcome.

Consequently, we have developed new approaches that will lead to success at this time. Our wireless infrastructure relies on getting both the communication into an IP network as soon as possible. This includes both human users and wireless sensors. Consequently, even traditional Push-to-Talk voice communication will be adapted to VoIP. The use of mesh networks allows for seamless relays in the event of spotty wireless coverage. The firefighter for police officer does even need to be aware that relaying is taking place. The network layer autonomously decides to relay based on Always Best Connected (ABC) protocols developed at UCSD. Using VoIP also provides the user with Call to Collaborate features developed at UCSD that can create teams without each user having to program their radio in great detail.

We will be continuing electromagnetic compatibility measurements of our wireless mesh networks. We are excited about the potential for long distance ZigBee to function as an Order-

Wire for network organization. In addition, WiMAX promises to make a seamless transition from unlicensed WLAN bands to licensed WiMAX bands at similar data rates.

Besides communication equipment, we will measure the electromagnetic interference from our collapsible outdoor multi-monitor LCD display array (NUTSO). This display will be used to display large scale tables, figures, maps, and graphs that can be changed to suit the needs of the team.

UCSD Active Shooter Drill: UCSD campus, October 16, 2007

Background

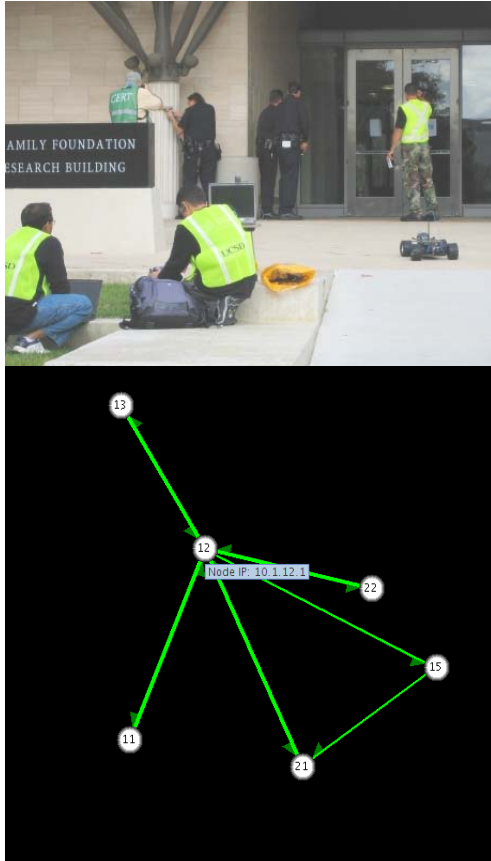
The Calit2 mesh network system, CalMesh was deployed October 16, 2007 to support part of an Active Shooter drill on the UCSD campus together with UCSD Police, San Diego City Police and Fire Department. The main part of the drill took place at the Leichtag building, located on south campus (School of Medicine), where the CalMesh network was deployed in the courtyard outside the building and surrounding grassy area, covering an approximate 100-by-200 yard area with the help of four CalMesh radio boxes.

Mesh Networking at UCSD Active Shooter Drill (CalMesh)

The CalMesh network supported 3 web camera feeds placed in the area of the incident. One of the cameras was mounted on Gizmo, which is an off-the-shelf remote-controlled scale-model truck, adapted to be a mobile platform to deploy multiple technologies. Gizmo was in operation close to the areas of activity and, in addition to the video, also provided a GPS feed to track its location on a map application. Both feeds were backhauled over the UCSD campus WiFi network, via a CalMesh network gateway, and displayed at the incident Emergency Operations Center, EOC, located in the UCSD campus Police office across the UCSD campus.

The CalMesh network was deployed in a heavily radio interfered environment due to the dense UCSD campus WiFi network AP's at the location. Despite the interference, the system managed to deliver the camera feeds to the EOC with an acceptable quality.

Tight integration among the multiple technologies was showcased and tested for the first time in a full-scale drill. The Rich Feeds system simultaneously captures numerous data feeds for dissemination and archiving, either in real time or after the fact from the CalMesh network. Multiple streams of information from the scene were sent to the Rich Feeds system and successfully displayed in the emergency operations. A Non-Uniform Tile System OptIPortal (NUTSO) display was set-up in the EOC and was connected via a secure VPN connection to the CalMesh network carried over the UCSD WiFi network. NUTSO is a command-and-control display wall of twelve tiled standard-size laptop monitors and two large television displays; each monitor can be used independently or in concert with any number of the others. NUTSO displayed real-time video and data feeds from Gizmo, two other cameras and several research applications deployed at the scene of the simulated incident. (Figure 8)



Gizmo (right foreground) captures drill action and sends video feed back to the EOC. Situational awareness researchers (left foreground) take multiple sensor measurements of the scene.

CalMesh network topology, UCSD campus drill.

Figure 8. UCSD Active Shooter Drill

NUTSO (Non-Uniform Tiled System Optiportal)

Hypothesis and Design: These parameters were the same as for the MMST drill discussed earlier in this report, except that NUTSO did not require a portable generator, as external power was readily available.

Outcome: NUTSO was up at the EOC a couple of days before. It took approximately one hour for one person to unpack the system and connect everything together. NUTSO was up and running during the drill, and was used to pull up maps and floor plans of the Leichtag building as well as wanted to pull up feeds from the two IP based cameras connected to the mesh at the drill site, as well as gizmo's camera, and captured as much footage as possible. Also, several of the installed campus security camera feeds were visible. NUTSO also displayed the rich feed content which showed various GPS locations (two phones and Gizmo) as well as Gizmo's video feed, Manoj's network analysis, Ganz's traffic page, and Rajesh's tracking system. NUTSO was configured to VPN into the mesh network to facilitate communications with devices on the mesh network as well as resources connected to the Internet.

Observations: NUTSO could have probably been set up the day of the drill, but it was decided that it would be easier to get it done prior, especially considering how small the EOC was, the number of obstacles needed to get around, and last minute networking configuration issues. Also, there was a fair number of third party observers that made the EOC even more cramped. Since

NUTSO was not supposed to be an integral part of the drill itself, it was better to not interfere. We were surprised somewhat that the chief and others actually made use of NUTSO to pull of maps and floor plans of the Leichtag building, as well as wanted to pull up feeds from the campus security camera in the drill area. Unfortunately, we received incorrect IP address information and were not able to pull up that camera's feed. Afterwards, given the correct information, NUTSO displayed the feed without issue. Limited bandwidth as well as network issues caused the feeds from Gizmo and the two IP based camera connected to the MESH network to drop off occasionally.

Analysis: NUTSO performed as well as expected and anticipated. The feeds from the campus security cameras were clear, and the feeds from Gizmo and the two IP based cameras on the MESH network were acceptable when visible. The fact that the campus Police Chief wanted to make use of NUTSO's capabilities to pull up the Leichtag floor plans as well as display the feed from the campus security camera in the area demonstrates that this kind of technology is both desirable and useful in this kind of situation. Had the correct network information been given beforehand, the set up of NUTSO would have gone much smoother, and the display of the desired camera's feeds would have been accessible. Future iterations of NUTSO and its underlying architecture should allow for more flexibility and utility. Network configuration management will be improved upon in an upcoming update to the architecture. The ability to have a number of persons using laptops to push content up instead of relying upon a single operator is also a desired feature, one that will hopefully implemented at a later date.

Conclusion: Previously discussed in this report; please see the earlier discussion of NUTSO in the MMST drill section.

Rich Feeds

Hypothesis: According to the premise of the Active Shooter drill, an unknown number of shooters begin at the Warren College and traverse the UC San Diego campus to the Leichtag building at the medical school, where they shoot at people in public spaces.

In order to manage and resolve the event, campus administration develops situational awareness using a number of sources, including police and television reports. Based on this information, decision makers determine strategies and resource deployments.

Experiment Design: Similar to the MMST drill, but from UC San Diego's Emergency Operations Center (EOC).

Outcome: The feeds presented by the Calit2 Traffic Reporting System, the Calit2 Tracked Objects System, and the Gizmo camera operated throughout the drill. The Rich Feeds display successfully showed the traffic anomaly and tracked object positions on a campus map during the first hour of the drill, and it also showed the Gizmo camera feed. Acquiring the two position feeds relied on Internet access to the Calit2 servers, while acquiring the Gizmo camera feed relied on access through the Internet to a mesh network deployed at the Leichtag building. The Internet connection was reliable, while the mesh network was partially reliable. Consequently,

Rich Feeds was able to show the two position feeds, and the camera feed was sporadically available.

In the second hour of the drill, the Rich Feeds visualization froze for reasons unknown at the time. Consequently, no additions were made to the traffic anomaly and tracked object display, and the Gizmo camera feed could not be displayed.

Observations: During the first hour of the drill, information was provided to the EOC via television, personal radio, cell phone, tactical police radio, police surveillance cameras, and the Rich Feeds display. Administrators took note of the Rich Feeds display and its contents, then turned their attention to more the traditional information sources. Their main focus was on exercising the role-based scripts predeployed for the drill.

As the drill wore on, the administrators settled into their roles and started asking for more and different kinds of information, including the Leichtag building floor plan and the surveillance cameras. Since the Rich Feeds display was relatively static, the administrators did not derive additional situational awareness from it. (The Gizmo camera feed was also available on a screen separate from Rich Feeds, and the administrators did watch it for a short time.)

Analysis: Both positional feeds were captured in the Rich Feeds database as planned. In replaying the drill using the Rich Feeds' display, we discovered that the display program was overwhelmed by the volume of data provided by the Tracked Objects feed, and so it froze in the middle of the drill. The administrators' interest in the police surveillance cameras was based on the location of the cameras and the timeliness of the information presented.

Conclusion and Broader Impact: Based on our observations and analysis, we drew two conclusions:

- The Rich Feeds display must be improved to handle higher volumes of position data
- Rich Feeds can be more attractive as a source of situational awareness by integrating more feeds, especially the police surveillance cameras, positional information of law enforcement assets, and building floor plans

The UCSD Police Department indicated a willingness to provide the surveillance camera feeds on a limited basis. Additionally, the Calit2 Situation Aware project can supply position, picture, handwriting, and speech information on law enforcement assets.

We concluded that both types of work should be prioritized for the next drill. Based on increased data capacity and the integration of more feeds, we believe the Rich Feeds display can be upgraded to come closer to a one-stop situational awareness kiosk for decision makers in the EOC.

Additionally, we conclude that these improvements have the potential of providing situational awareness to the public at large, subject to filtering feed information based on its sensitivity to police operations and privacy concerns. Such filtering requires that authentication and authorization protocols be built into Rich Feeds; such protocols should also be prioritized for the next drill.

Performance Data Analysis and Measurements – UCSD Campus Drill

CalMesh Network Performance Measurements and Analysis

Performance testing of the CalMesh network set-up used during the drill was carried out to test the network (throughput) capacity. The results are given in Table 3 below and the relatively low numbers are due to the radio interference at the drill site. The six node network topology is depicted in Figure 8, which is a screenshot of the network monitoring tool developed in conjunction with the CalMesh network. This tool offers real-time information about the network health during actual deployments - a key component in maintaining and trouble-shooting an operational network.

Table 3. Throughput figures measured during the drill CalMesh set-up (Mbps).

Node #	11	12	13	15	22
11	---	1.68	1.64	1.22	1.56
12	1.57	---	2.12		2.70
13	1.41	2.51	---		
15	0.98			---	2.05
22	2.95	2.39		2.54	---

Network Behavior Measurements, Analysis and Observations

This network data analysis was conducted on 10/16/2008 during the UCSD Active Shooter Drill in the Leichtag building, UCSD campus. We conducted an extensive data collection exercise in order to observe the network behavior as well as other research observations. The most important observation that we made during this observation was the network traffic anomaly resultant from the physical world simulated disaster. The network traffic was significantly reduced during the drill when compared to the rest of the week, as well as several days in previous weeks.

Network traffic measurement setup

We conducted four measurement campaigns. These are (i) wired network measurement on the traffic to-and-from the Leichtag building, (ii) Wireless LAN traffic measurement for inside and outside the Leichtag building, (iii) wireless mesh network traffic monitoring for the deployed CalMesh network, and (iv) cellular CDMA network measurement. This document mainly focuses on the first three measurement campaigns.

Wired Network Measurements

With the help of the ACT, UCSD, we obtained the traffic measurement on the wired network in Leichtag building. The UCSD edge router and the Leichtag building core IP router were the two measurement points used for wired traffic measurement. We mainly depended on the historical

traffic between IP routers in Leichtag Building and any host in that building for the former measurement. The IP routers used were 132.239.160.0/24, 132.239.162.0/24, and 132.239.163.0/24. Table 4 shows the wired network measurement statistics.

Table 4. Wired Network Measurement Statistics.

Day	Total data (9AM-12PM)	Packets/Sec (9AM-12Noon)	Total packets (9AM-12noon)
Tuesday, Sep 18, 2007	6.1 GB	848 Pkts/sec	9.15 Mi Packets
Tuesday, Oct 2, 2007	4.9 GB	618 Pkts/sec	6.3 Mi Packets
Tuesday, Oct 9, 2007	6.3 GB	769 Pkts/sec	8.3 Mi Packets
Tuesday, Oct 16, 2007	2.3 GB	352 Pkts/sec	3.7 Mi Packets

We conducted two comparison studies with wired network measurements. First is the comparison of Tuesday's traffic. The campus drill was held on October 16th, 2007 which is a Tuesday and therefore, we compared the traffic on that day with past Tuesdays. Some of the observations made from the wired network experiments are briefed here.

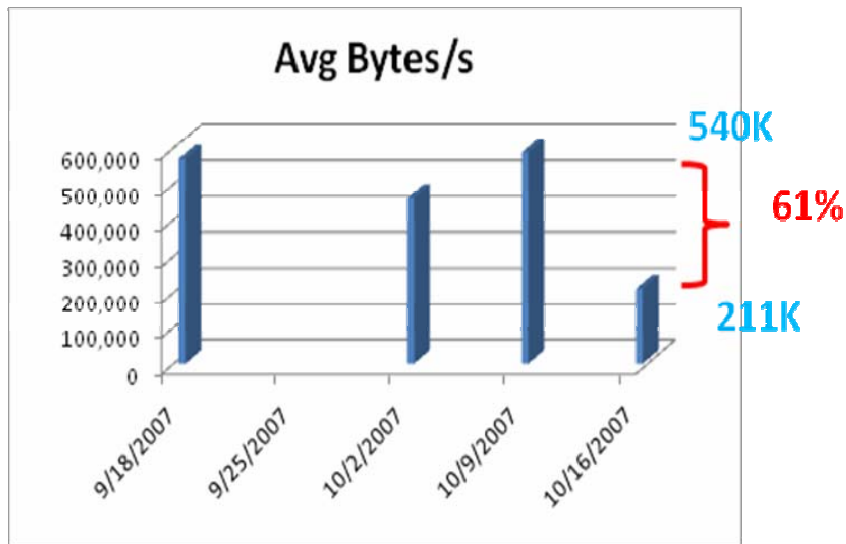


Figure 9. Average Bytes/s traffic observed on Tuesdays.

Figure 9 shows the average wired network traffic in bytes/seconds observed in Leichtag building. Due to the impact of the simulated active shooter incident on 10/16/2008, the traffic observed a 61% decrease compared to the three previous Tuesdays as observed from Figure 9. Similar difference is observed for the total traffic in terms of bytes observed on Tuesdays. Though the number of bytes, in Mega Bytes, differs on each Tuesday, the average traffic reduction due to the simulated incident on 10/16/2007 remained approximately at 61%.

Figure 10 below shows the average traffic in terms of packets/sec observed on Tuesdays. The average packets/sec that we observed for several Tuesdays prior to 10/16/2008 remains lower

than the traffic in terms of bytes/sec. Even then, the decrease in the traffic on 10/16/2008 due to the simulated drill is significant with an average reduction of 53%. Similar difference is noticed for the total packets that we observed during the 9am-12noon time slot on Tuesdays. The traffic reduction on the day of simulated incident remains approximately at 53% compared to the rest of the past Tuesdays.

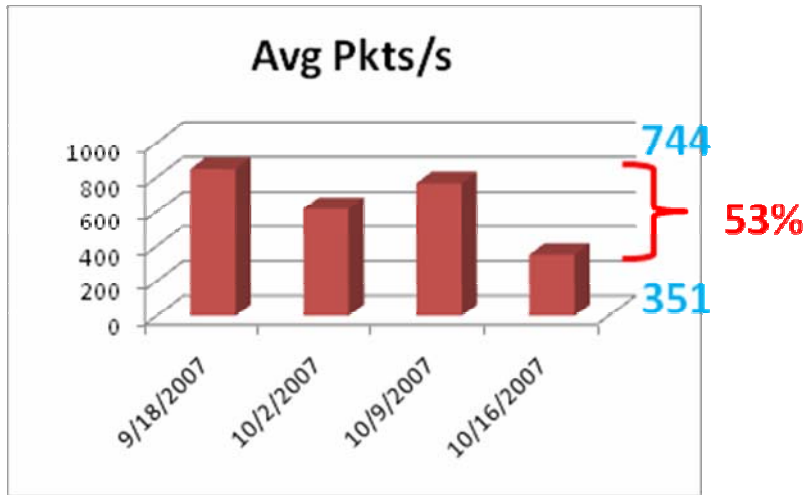


Figure 10. Average Packets/s traffic observed on Tuesdays.

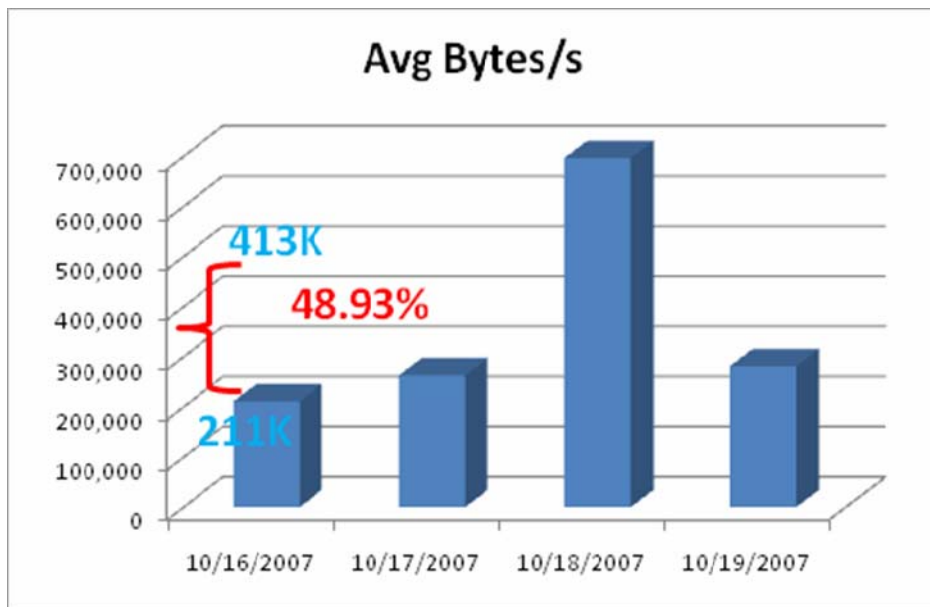


Figure 11. Wired traffic measurements for the rest of the week.

In addition to the comparison of traffic on Tuesdays, we also collected wired network traffic for the rest of the weekdays on the third week of October 2007. The measurements made on the rest of the week days are compared with the measured traffic on 10/16/2007. The observed traffic on 10/16/2007 remained at 211K Bytes/sec whereas the rest of the week averaged traffic of

approximately about 413Kbytes/sec. This amounted to a difference of 48.93% decrease in traffic, as shown in Figure 11 above, which is mainly due to the simulated disaster incident.

Figure 12 shows the total bytes transferred over the wired network during the week of drill. According to this, the total traffic showed a decrease of approximately 48% on 10/16/2007 compared to the rest of the days of the week. We also noticed high variation on the total traffic during the rest of the week's measurements. Even with high variance, all subsequent days had higher traffic in comparison to the traffic on 10/16/2007.

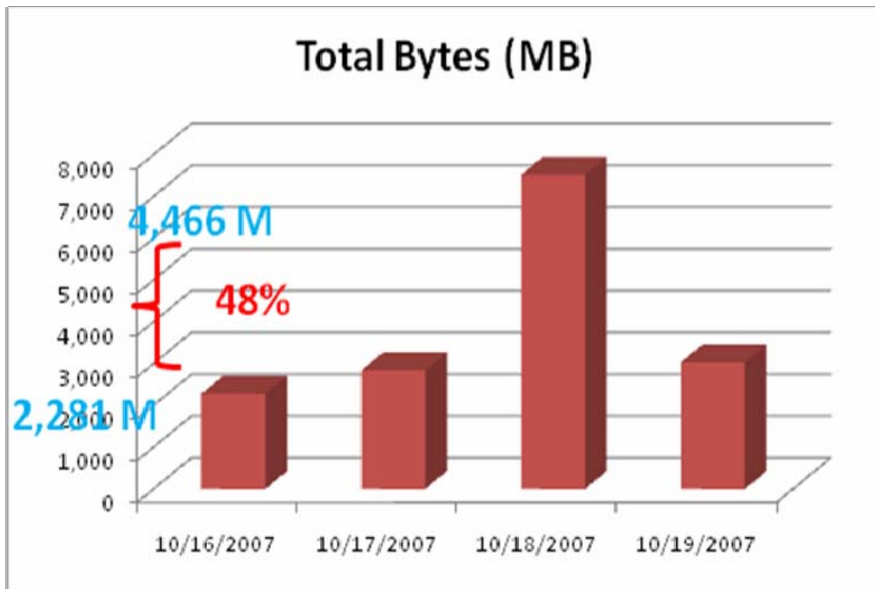


Figure 12. Total bytes transferred in Leichtag building during the week of the drill.

Similar to the traffic in terms of bytes/sec, we also noticed significant decrease in traffic in terms of average packets/sec. The rest of the week averaged a traffic approximately 629 packets/sec in comparison to 351 packets/sec on 10/16/2007, leading to a decrease of 44.16%. This is observed in Figure 13 below. The total number of packets transferred in Leichtag building also showed a decrease at 44.1% during the 9AM-12noon time window during which the drill was conducted. The total number of packets that we observed during the above mentioned time window was averaged to 6.78million packets whereas due to the drill, only 3.78 million packets were transferred.

The wired network measurements showed a significant impact of the physical world disaster, though in this case is a simulated incident, on the virtual world network traffic. In conclusion, the impact that we observed on the network traffic can potentially be used for remotely detecting physical world troubles using network measurement.

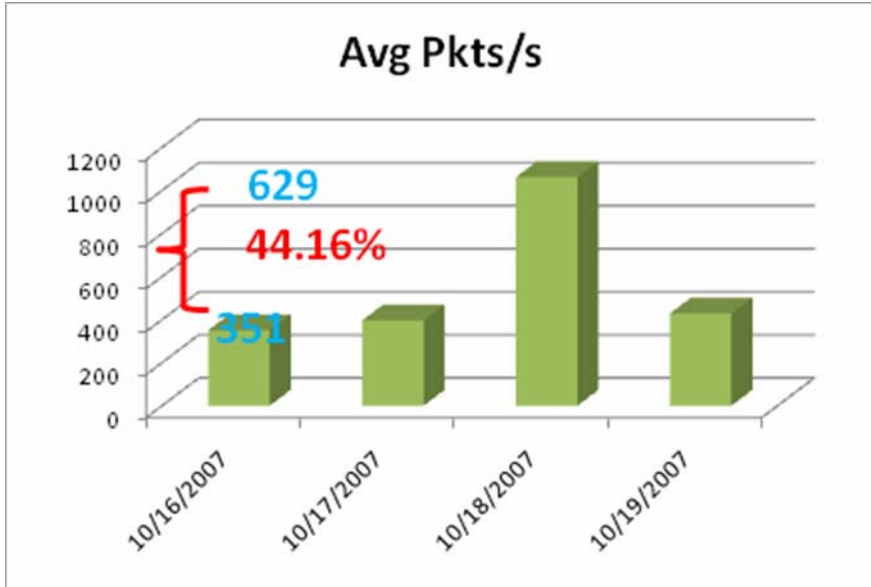


Figure 13. Average packets/s observed on wired network during the week of the drill.

Wireless Network measurements

We used 12 wireless network interfaces to conduct the wireless network traffic measurement. More than 10 million packets were captured and analyzed as part of this drill.

The first set of studies that we conducted on the wireless channel is to measure the in-building traffic observed during the drill. We, therefore, measured the traffic on all channels at both the 4th floor and the 2nd floor of the Leichtag building. Figure 14 shows the traffic variation on the 4th floor which showed a low traffic on most channels with 802.11b Channels 1, 6, and 11 showing moderate 600 Kbps traffic during the drill. The 802.11a channels are found to be completely unused in the building. However, the 2nd floor wireless traffic seemed to be even lower than the 4th floor traffic. As shown in Figure 15, the 2nd floor wireless traffic on Leichtag building showed traffic only on two 802.11b channels, 6 and 11, found to be having an average traffic of 275 kbps and 75 kbps traffic, respectively.

We followed our measurements on wireless traffic on the subsequent days of the drill. However, we noticed no significant difference on the wireless traffic in the building. Our interactions with the researchers in the building proved that the wireless channel usage in that building is minimal and many researchers depend on the wired network for their communications. This fact was underscored by our earlier discussed anomaly in wired traffic.

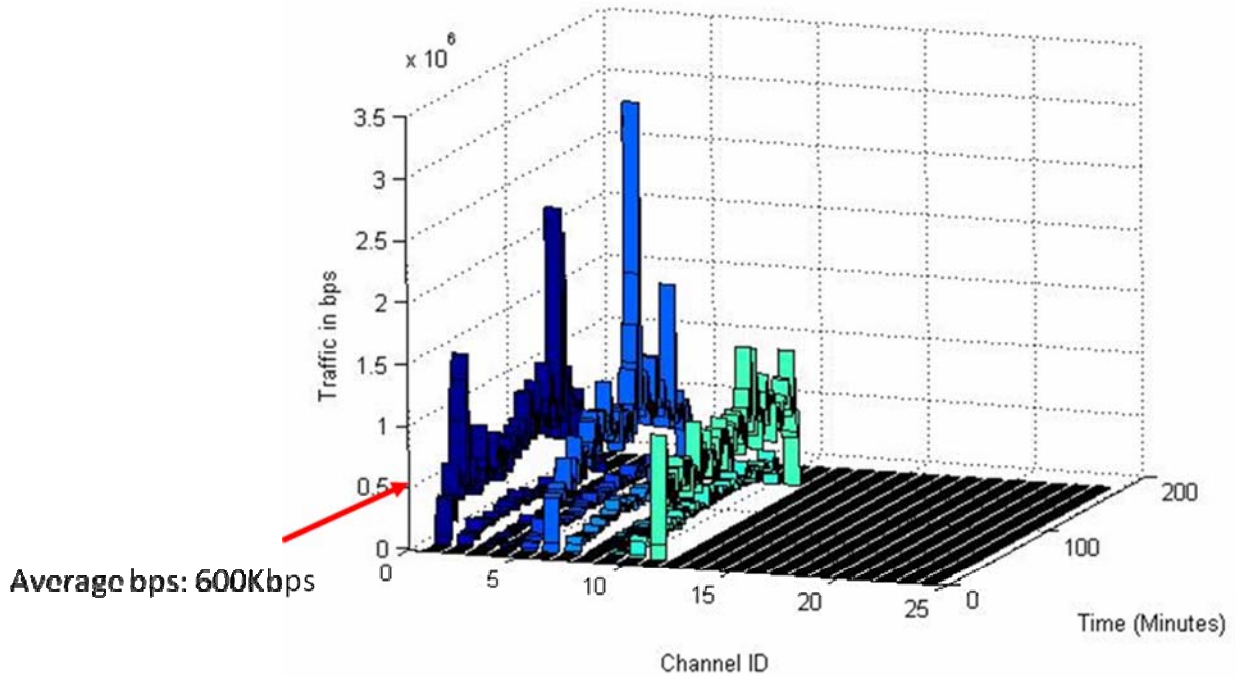


Figure 14. Wireless traffic on the 4th floor of Leichtag building.

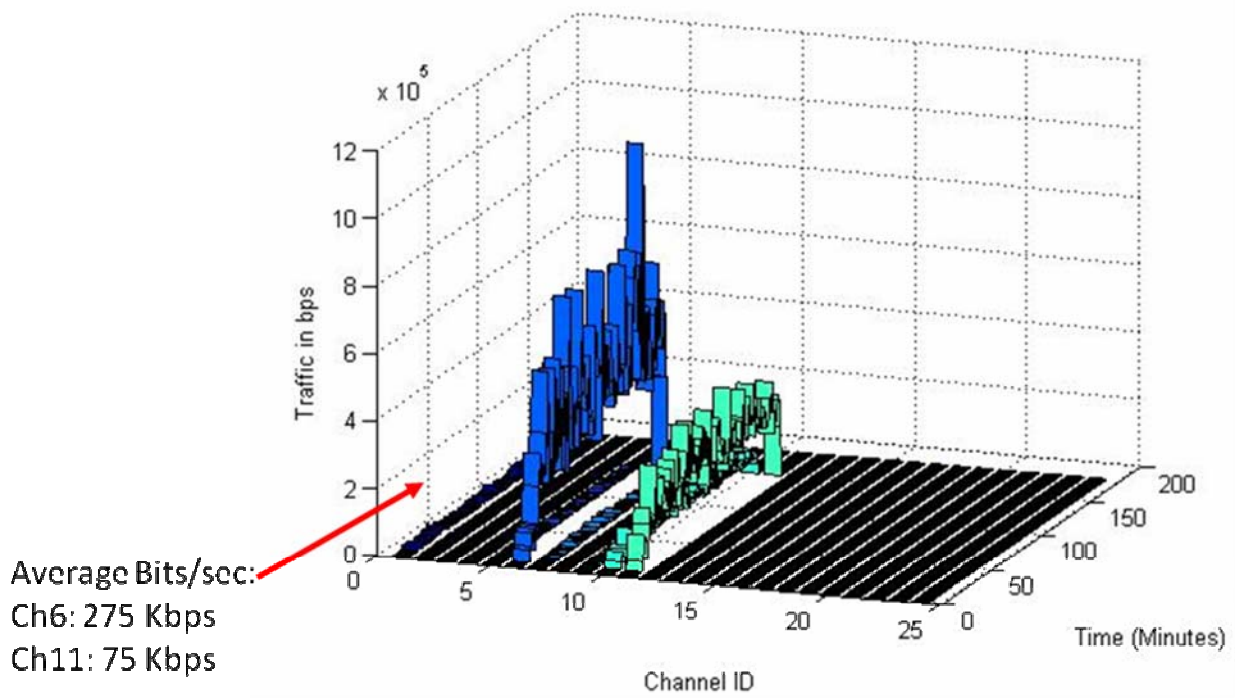


Figure 15. Wireless traffic from Leichtag building 2nd floor.

Wireless Mesh Network Measurements

The third type of measurement campaign that we conducted was aimed at observing the traffic from the Extreme Network System (ENS) setup as part of the RESCUE's CalMesh platform. Figure 16 shows the approximate locations of the nodes belong to the ENS. The ENS setup during this drill contained only three CalMesh nodes and a Gizmo - robotic video sensor-for capturing and transferring video traffic. The CalMesh nodes are labeled Mesh-FRED, Mesh-backhaul, and Mesh-antenna caddy as observed from Figure 16. The relative locations, not to the scale, are also shown in Figure 16.

The link level traffic that we observed on ENS was relatively low except for the duration 10AM-10.40AM during which the video transmissions were undertaken. We found that only two links had moderate traffic. These two links include the Gizmo-FRED link as well as the FRED-Backhaul link. This showed us that the path undertaken by the video traffic originated by Gizmo was Gizmo-FRED-Backhaul for most of the drill duration. The spikes that we observed during the end of the drill were contributed by throughput measurement tests conducted by the ENS deployment team. The maximum traffic that we observed during the drill was about 2Mbps which appeared on the link FRED-Backhaul.



Figure 16. ENS deployment during the campus exercise.

Next we looked at the data rates of the transmissions on each of the links in the ENS deployment. Figure 17 shows the results on the observations. The two links that we noticed for the low data rates are Gizmo-wireless backhaul and Gizmo-antenna caddy. On all the links, the average data rates seem to be close to being 11 Mbps. This is primarily due to the relatively short distance between the ENS nodes. The two links that operate at low data rate are due to the Gizmo's low-height antenna which did not have sufficient gain to work at higher data rates.

In addition to the traffic and the data rates, we also looked at the packet length behavior on each of the links. The data packets transferred are typically longer than the control and management packets. The packet length behavior provided another form of traffic behavior on these links. The two links that had almost only constant sized packets, mainly contributed by control and broadcast packets, are the links formed between Gizmo and antenna caddy and the link between Gizmo and wireless backhaul. In addition, the link between wireless backhaul and antenna caddy also showed an average lower packet length except for a short duration around 10.57AM. The remaining links showed variations on packet length as could be observed on any wireless link with data traffic.

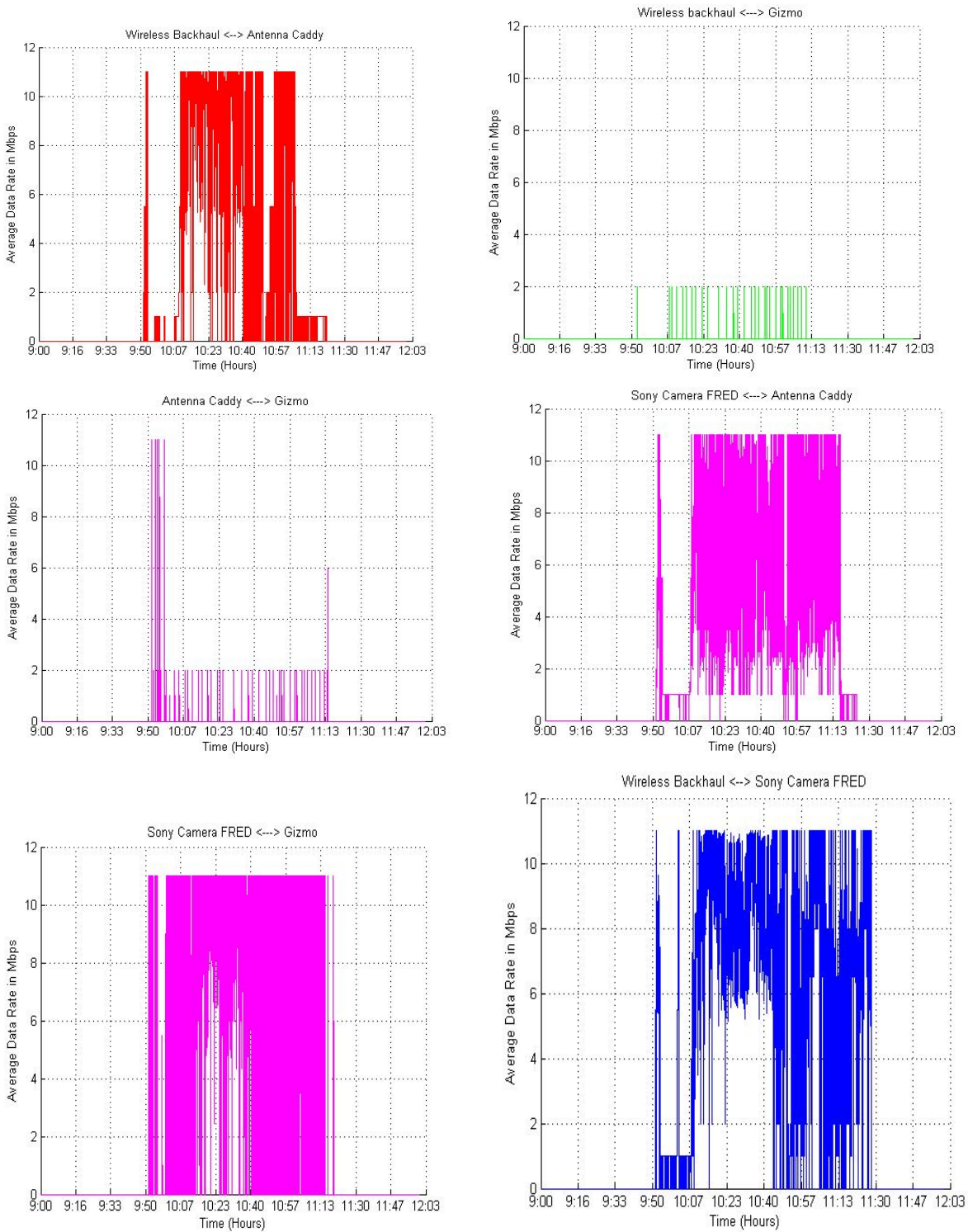


Figure 17. Average data rate observed on the links: (a) link between wireless backhaul and antenna caddy, (b) link between wireless backhaul and gizmo, (c) link between antenna caddy and gizmo, (d) link between FRED and antenna caddy, (e) link between FRED and Gizmo, and (f) link between wireless backhaul and FRED.

In addition to the link level traffic behavior observed from the above results, we also collected node level traffic. The mean, maximum, and standard deviation of the node level traffic in terms of packets per second that we observed from the network are given in the Table 5. From this, we noticed that the highest average traffic is almost the same between mesh backhaul and FRED. Figure 18 illustrates the results from the node level traffic analysis and the temporal behavior of the traffic.

Table 5. Node level mean, max, and std traffic in the ENS.

	Gizmo	Mesh-FRED	Mesh-backhaul	Mesh-antenna caddy
Mean	4.77 pps	25 pps	25.96 pps	10.7 pps
Max	160 pps	295 pps	388 pps	272 pps
Std	13.18 pps	38 pps	52.94 pps	16.56 pps

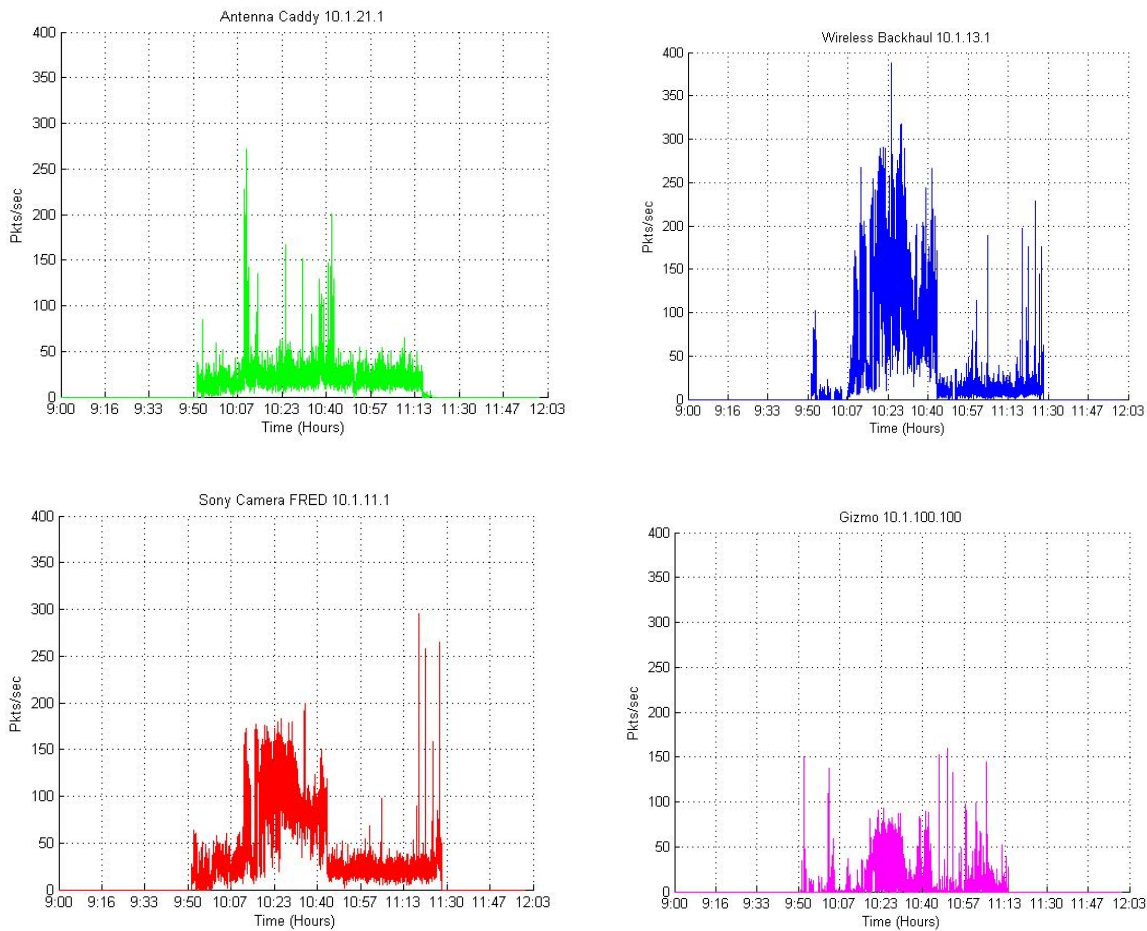


Figure 18. Node level traffic observations on ENS: (a) antenna caddy, (b) wireless backhaul, (c) FRED, and (d) Gizmo.

In addition to the network measurements, Network traffic visualization was created and exported to the UCSD police station where the command and control station was located. However, due to the errors at the network-side configurations at UCSD police station, the network connectivity from the drill site to the police station was affected. This impact was also detected by our network measurements. Figure 19 below shows the GUI for the network topology and communication visualization.

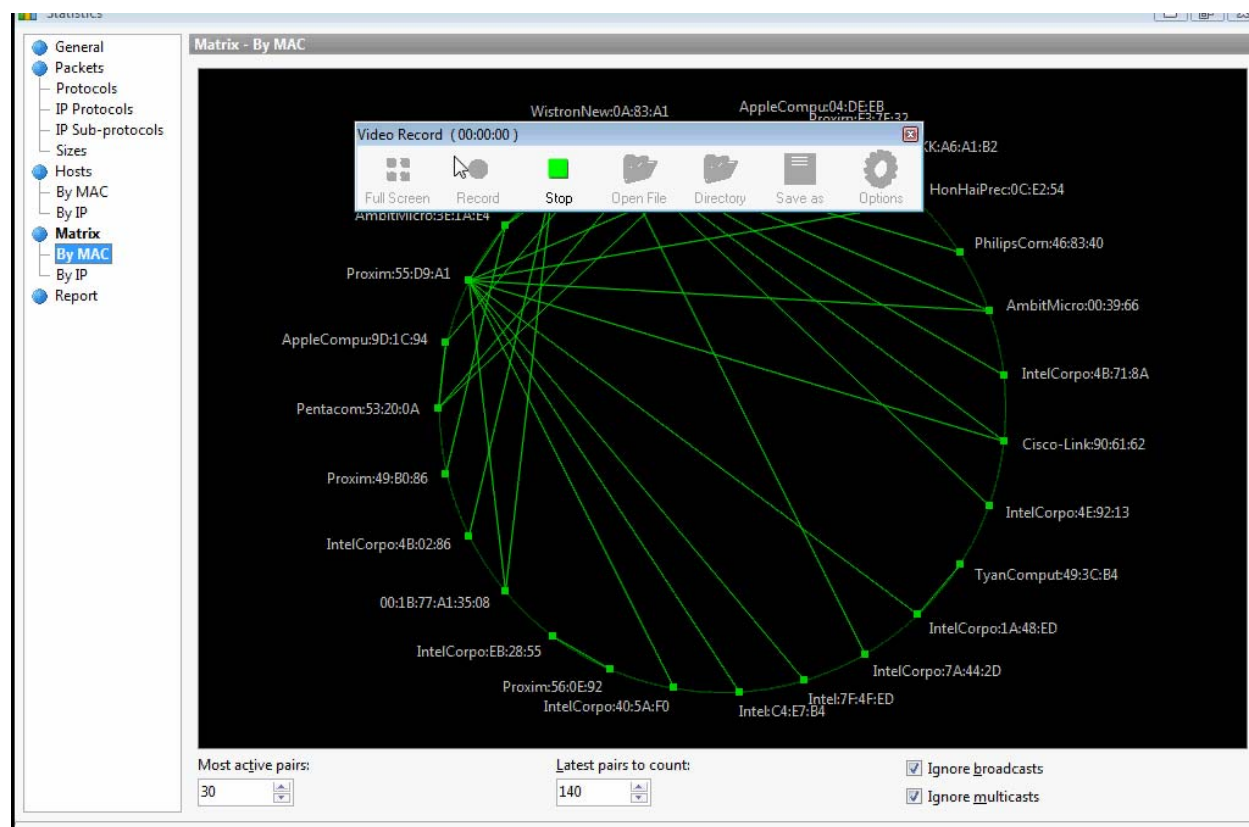


Figure 19. A view of the GUI used for network visualization.

Conclusion

This document is the first draft of our report on the Leichtag drill, during which we conducted extensive network measurement and data analysis exercise. We measured wired network traffic, wireless network traffic inside the building, and wireless mesh network traffic outside the network in addition to the cellular network measurement. The wired network measurements showed us crucial anomaly in the traffic as an impact of the simulated drill. The wireless network traffic inside the Leichtag building did not show much difference compared to the rest of the week. The mesh network measurements gave important information on the functioning of the links as well as the traffic on the links and nodes.

Video imagery gives rich information about the location, behavior, and classification of people in a scene. Automatic analysis of video sequence in on-line as well as off-line mode is very helpful in determining where people move around and accumulate, the actions they are involved in, and reidentify people leaving and re-entering the scene based on their appearance. Here, we describe the capture and analysis of video coverage of the disaster drill. The video analysis involved detection and tracking of moving people, track analysis for determining the paths as well as regions of activity and appearance analysis to classify personnel according to their uniforms. The following sections describe the details of the video capture and analysis.

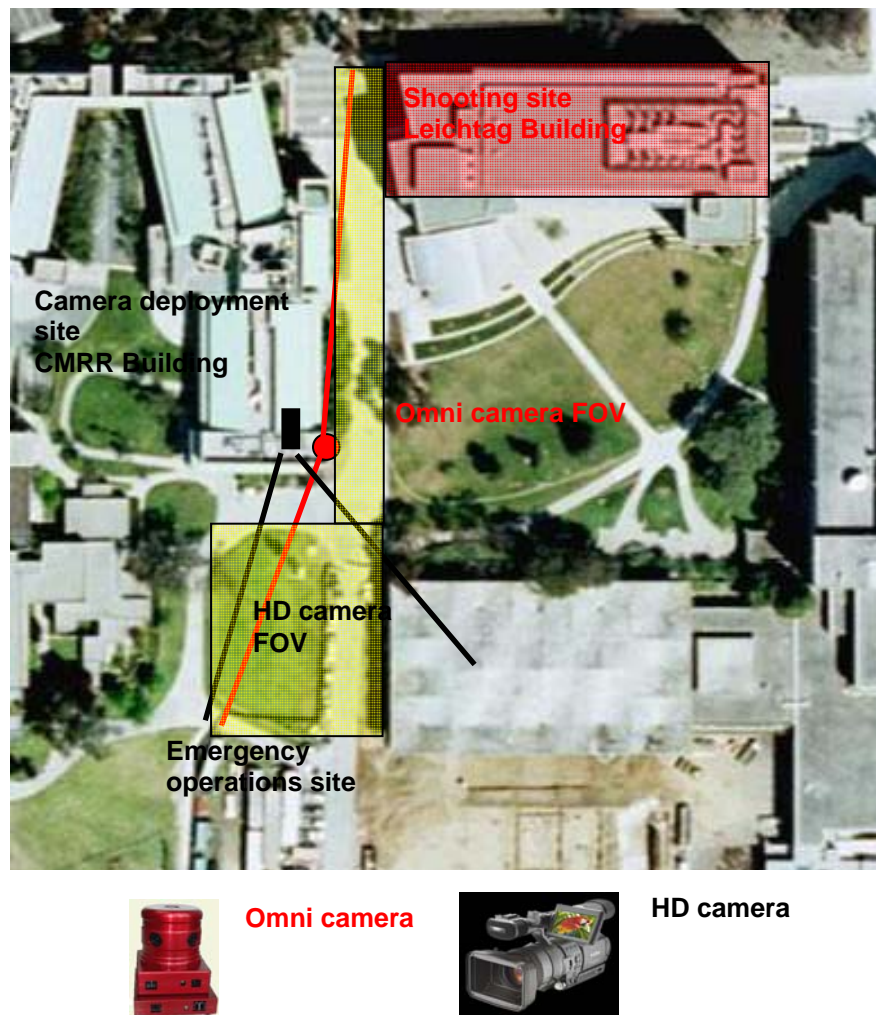


Figure 20. Deployment of video sensors to capture activity in campus drill site.

Video Capture

Two types of video sensors were used to capture long video sequences of the scene as shown in Figure 20. The sensors were deployed in the conference room gallery of the Center for Molecular Medicine East (CMME) building near the drill site that was selected based on the visual coverage of the scene.

The first sensor was the Ladybug omnidirectional camera system that generated omnidirectional image of the scene by stitching individual images from six cameras covering different directions. The cameras provide 360 degree field of view out of which approximately 210 degrees covered the drill scene. The images were captured on a computer using Firewire and were stitched with the software accompanying the camera. The second sensor was an HD Video camera that gave smaller field of view with higher resolution that gave more details about the people and other objects in the scene.

Track Analysis

Videos from both sensors were used to track the movement of people and other objects and analyze areas of activity in the scene. The tracking software developed in the Computer Vision and Robotics Research Laboratory was applied for this purpose. Moving objects in the scene were detected by dynamically generating the scene background and subtracting the background from the original scene. The objects were tracked using a dynamic motion model and the tracks were recorded.

The end-points of the tracks were clustered using Gaussian Mixture Model to find the regions of starting and ending of tracks as in. Figure 4 shows the result of tracking and clustering in omni camera. The tracks reveal important information about the paths followed by people as well as the areas of activity in the scene. The density of tracks in any region also corresponds to the activity level occurring in the region. Many of the tracks are concentrated in regions (such as the walkway) corresponding to the paths taken normally by people. The isolated tracks correspond to unusual or anomalous behaviors.

Each of the clusters of track end-points roughly corresponds to a region where personnel are localized. Clusters 1 (RESCUE technology demonstration group), 4 (shooting site), 5 (firemen), and 6 (emergency response) correspond to relatively dense concentrations of personnel in respective regions. Clusters 2 and 3 are sparse. Cluster 2 corresponds to the entry and exit of group deploying mobile communications in the lawn area, whereas cluster 3 mostly contains end-points of broken tracks of people and vehicles traveling on the corridor.

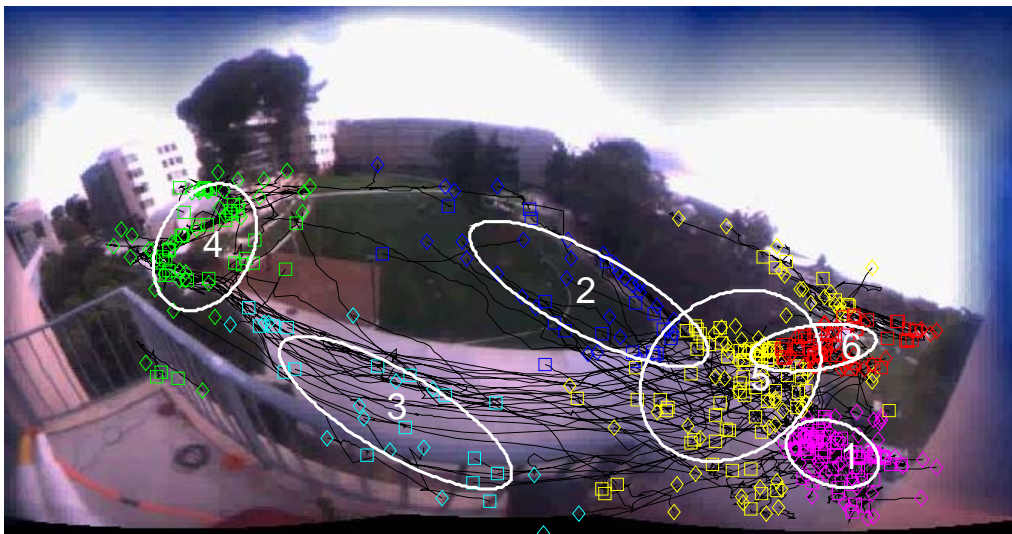
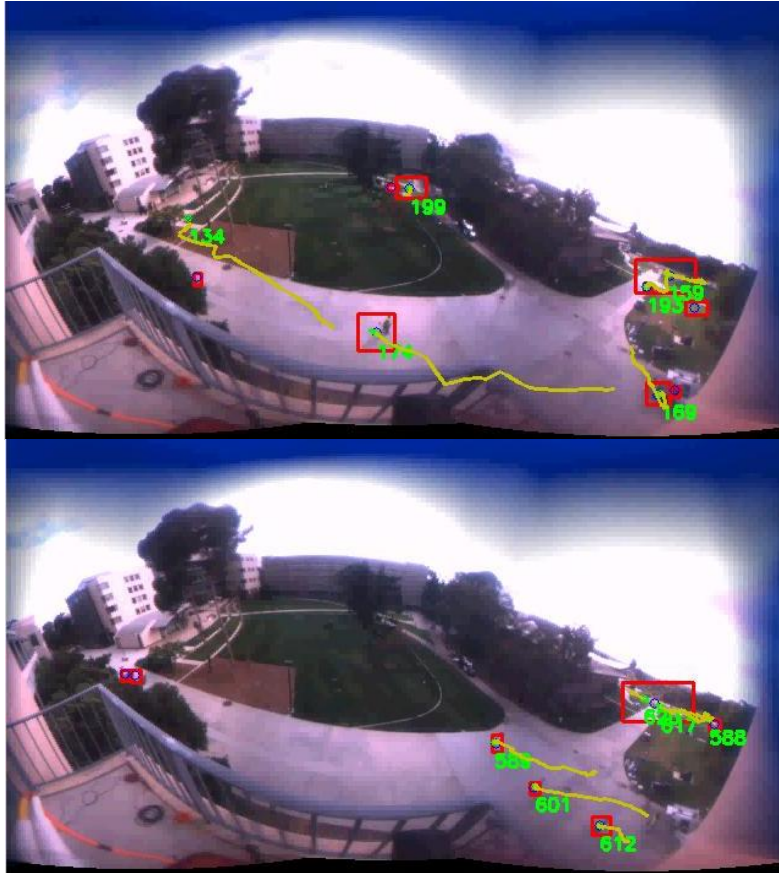


Figure 4. Tracks of people and vehicles observed over a long period in Ladybug omniscience camera. The track start (square) and end (diamond) points are clustered into 6 clusters using Gaussian Mixture Model.



Figure 5. Tracks of people and vehicles observed over a long period in HD Video camera. The personnel can be distinguished from the color of the uniforms. The track start and end points are clustered into 5 clusters using Gaussian Mixture Model.

Appearance Analysis

In a drill scenario, the personnel can be distinguished by uniforms. Appearance modeling of the tracked persons was used to classify the personnel into different categories. Clustering based on color of uniforms was applied to the HD video images since they had sufficient resolution to reliably distinguish between colors.

Person detection and tracking was performed as in the case of omni videos as shown in Figure 5. The approach was used to remove shadows. The foreground pixels in each track over a number of frames were collected and a Gaussian Mixture Model (GMM) was fit to the pixel colors in the track. Agglomerative clustering was applied to the GMMs based on a modified KL distance measure given in. It is seen Figure 23 that there are 3 dominant clusters, with cluster 1 corresponding to fire and ambulance personnel, cluster 2 to fire truck and some fire personnel, and cluster 3 to volunteers from the Technology Demonstration Group.

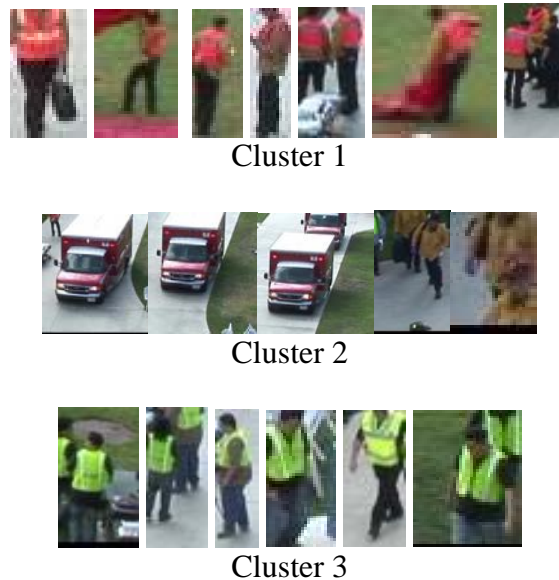


Figure 23. Snapshots of tracked objects clustered using Gaussian Mixture Model of the color pixels.

Conclusion:

Situational awareness of the scene can be very helpful in coordinating emergency operations as well as to perform post-mortem analysis of the operation and identify potential improvements. Video imagery is a valuable source of data for performing situational awareness. Video analysis including person and vehicle detection, tracking, and track analysis would be very helpful in identifying paths taken by the personnel and vehicles, areas of overcrowding, as well as anomalous behaviors. Analysis of activities and interactions between people is an active research topic which has many potential applications in emergency response management.

Products

Products developed with partial or full support from Responsphere

CalMesh, Mesh Networking Platform: <http://calmesh.calit2.net/>

- MACRT, new routing protocol introduced and tested during the Winter/Spring 2008
- IEEE 802.11 Radio Aware MAC: Modified MAC protocol (based on 802.11) denoted ODMLS
- ARP-AODV: A Layer2 AODV based routing protocol for CalMesh
- O3, Object Oriented Operating system for sensor networks.
- Implementation on Atmel RZ200 demonstration kit (802.15.4 compatible 2.4 GHz Radio-Controller Board (RCB) with AT86RF230 radio and ATmega1281V microcontroller, http://www.atmel.com/dyn/products/tools_card.asp?tool_id=3946)
- NetViewer and STAV
- ICEMAN (Inter-layer Communication Enhanced Mobile Ad hoc Networks) architecture

Integrated system of CodeBlue (<http://www.eecs.harvard.edu/~mdw/proj/codeblue/>) Zigbee sensor network and WIISARD Triage Information system.

Pulse oximeter data from a CodeBlue Zigbee multihop sensor network is carried over the CalMesh system and integrated into the WIISARD patient database.

Efficient, low power design and development environment for ZigBee (IEEE 802.15.4) based multihop networks.

Multi-Mode Portable Wireless Mesh Network Nodes

Mesh Network Antenna Caddy

- Stackable Pan-tilt antenna controller: <http://maeprojects.ucsd.edu/mae156/fw2006/group10>
- 35ft segmented antenna mast caddies (3): <http://maeprojects.ucsd.edu/mae156/ws2006/A1/>

Gizmo: <http://Gizmo.calit2.net>

CalMesh Condor WiFli Network Unmanned Air Vehicle (UAV)

Roomba

- Indoor Position Locator System: <http://ece-classweb.ucsd.edu:16080/winter07/ece191/>
- Mobile Operations Platform: <http://ece-classweb.ucsd.edu:16080/spring07/ece191/>

Wireless Communications Mobile Command and Control Vehicle

- Telematics system and new dual solar power system

Portable tiled-display wall for visualization in crisis response - NUTSO (Non-uniform Tiled System Optiportal)

Rich Feeds/ RESCUE ESB integration: <http://rescue.calit2.net>

- ESB Mule virtual machine (VMWare) containing googleDemo (saint-server01.ucsd.edu)
- Documentation describing integration process for new feeds entering Rich Feeds system
- Documentation describing data feeds existing in current Rich Feeds system
- UI Elicitation Ideas Document and Process Document
- AppFuse with Mule and Spring Document
- Windows XP on VMWare Document
- googleDemo Changes Document and How googleDemo Works Document
- Databases and code:
 - RESCUE research feed database on rescue.calit2.net
 - ESB and Javascript residing on rescue.calit2.net

CalNode platform for Cognitive Networking

- CalNode, CalNode client; CalNode-Semi-Mobile (CalNode-SM)
- CogNet data repository. This database contains historical wireless traffic information gathered from the 802.11b/g as well as cellular 1xEVDO spectrum. <http://cognet1.ucsd.edu>

Peer-to-peer information collection system: <http://traffic.calit2.net> or (866)-500-0977

Multiple measurements and analysis datasets for various metrics from the UCSD Campus Drill in October, 2007 and MMST Operation Silver Bullet in January, 2008, are available to outside researchers upon request.

Videos: <http://video.google.com/videoplay?docid=16840444517672655>

Contributions

CalNode platform for Cognitive Networking

We developed the CalNode platform with partial support from Responsphere. CalNode is a cognitive access point which collects, models, and captures the spatio-temporal characteristics of the network traffic in order to optimize network service provisioning. A set of 12 CalNodes have been produced with partial support from Responsphere. These devices are used for building a large scale testbed for enabling research under RESCUE and CogNet, both NSF funded research projects. The traffic pattern obtained has been found to be dependent on the environment, day of a week, time of day, and location. The traffic pattern was different for other days. Therefore, the network optimization such as channel selection, protocol parameter optimization, and network topology reconfiguration can be done based on the traffic pattern. In conclusion, CalNode enables design and configuration of wireless networks by understanding the spatio-temporal characteristics and periodicity of network traffic.

We developed a CalNode-client for enabling distributed experimentation with CalNode testbed. These devices are able to communicate with CalNodes operating in access point mode. About six CalNode-clients are developed for the research as part of CogNet and ITR-RESCUE research.

In addition, we developed a CalNode-Semi-Mobile (CalNode-SM) version of CalNode which does not require wired backbone for data collection. Two prototype devices are created for experimentation with partial support from Responsphere and RESCUE. These devices will soon be deployed in several parts of UCSD campus for wireless network data collection.

Future plans:

3 months:

- To deploy a neural network based cognitive network controller.
- To provide comprehensive analysis of the data collected from UCSD campus.
- To develop comprehensive set of cellular measurement data sets from UCSD campus.

6 months: To create a tactical and emergency response version of CogNet testbed.

12 months: Integration of capabilities of CalNode and CalMesh to a single node.

High Speed Data Capture

The LIDAR (light detection and ranging) sensor- Leica ScanStation2 laser scanner and Panoscan panoramic camera for high speed data capture equipment - has been used to collect a variety of environmental and structural data to be input for network simulation models for multiple projects. In addition to its use with regard to the MMST drill (see previous discussion), some projects have been pioneering the use of these tools for cultural heritage applications (architecture and archaeology). Several major LIDAR acquisition runs have been conducted. We have collected structural data of historical buildings (Palazzo Vecchio and Palazzo Medici in Florence, Italy) and of an archaeological site in the Anza-Borrego desert in southern California.

CISA3 Battle of Anghiari project

As part of a wider 18-month project to re-discover a long-lost Leonardo da Vinci mural, the "Battle of Anghiari" (which has not been seen in nearly 500 years), nearly three weeks in November and December (2007) was spent scanning the interior of Palazzo Vecchio's Hall of the 500.

The primary goal was to acquire all the data necessary to build a massive, interactive, 3-D computer model of the Hall of the 500. The team acquired some 500 million points in space that constitute the nearest walls, ceilings, etc. The scans and subsequent analysis will be critical to future conservation and renovation efforts. The computer model will be used as a baseline for future work, and everything else can be referenced against it.

They began by sampling points every centimeter (compared to the 5-centimeter resolution-about two inches-of previous scans). By deploying the latest scanning technology, CISA3 was able to execute ever-more-detailed scans, determining points barely one millimeter apart. The LIDAR scans yielded 500 million x-y-z point locations, as well as color and intensity information for each point, providing some insights about the properties of the material.

In the first quarter of 2008, the team is processing the 25 gigabytes of data they collected in Florence, fusing the points and color information. There is a lot of data but much of it has noise in it, so this is being processed out. The research team is also building algorithms and software tools to bring the 3-D model's real-time interactivity to Calit2's 220-million-pixel HIPerSpace tiled display, the highest-resolution multi-tile display in the world. (Additional information on this run follows in the Proof of Concept discussion.)

Proof-of-Concept Studies

We have performed a set of proof-of-concept studies to validate the viability of LIDAR-centric modeling, visualization and analysis in the context of a structural specimen (Figures 2), a NEES field site (Figure 3), a historic hall (Figure 4) and a coastal study (Figure 5). Two different scanners, a Leica ScanStation2 and an iSITE 4400, were used for these studies.

Acquisition tests for the structural test specimen (Figures 2) and at a NEES equipment site (Figure 3), illustrated the importance for a scanner setup and calibration methodology, development of scan procedures and an overall workflow concept supporting streamlined alignment, cleaning, meshing and archiving of the acquired data. In the case of the historic hall (Figure 4), a database containing over two billion points was created for a scan resolution as fine as 1mm. Each point was associated with XYZ coordinates, RGB color values and an intensity signature. To capture important features such as surface cracks on the specimen that may be in the sub-millimeter range and outside the achievable resolution of the LIDAR scanner, high-resolution texture maps (photos) could be draped over the acquired surface model, requiring an adaptive and progressive rendering strategy to allow commodity computers to visualize the resulting massive dataset. The coastal study (Figure 5) also illustrated that outdoor environments

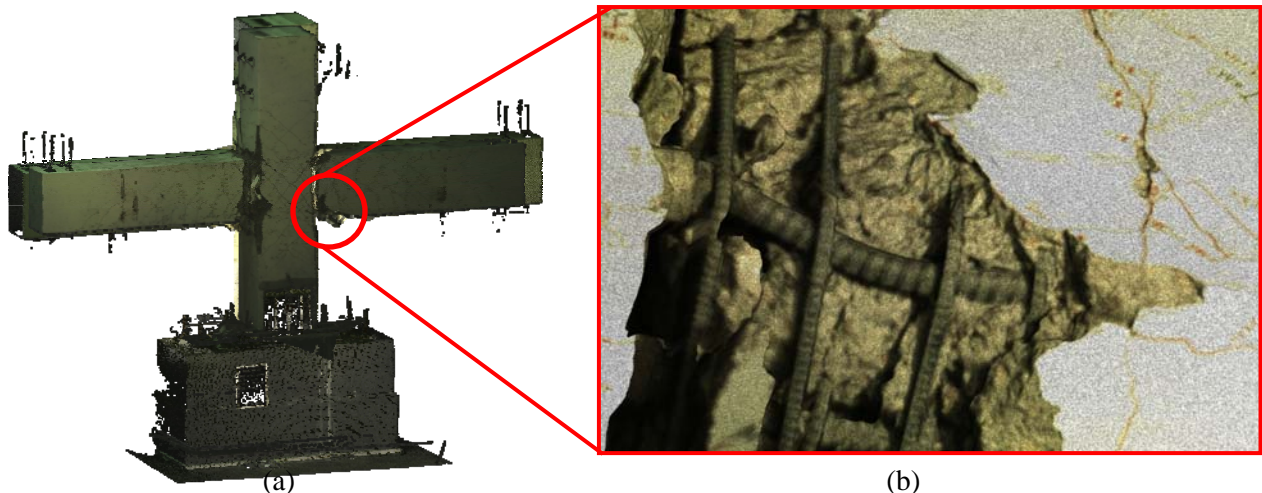


Figure 2: (a) Point cloud of a beam-column subassembly experiment after failure and (b) close-up showing the derived surface mesh with overlaid texture map.

tend to be dynamic and as a result, control points and targets that are commonly used for LIDAR alignment may not be feasible. In addition, applying standard alignment techniques developed for small models or localized studies can produce undesired results and propagations of misalignments over a regional scale. We therefore will develop procedures to obtain appropriate



(a)

(b)

Figure 3: (a) LIDAR point cloud of a NEESR brick wall test on UCSD's NEES shake table and (b) a derived photodraped surface mesh, showing a failed brick wall specimen on the right.

constraints on the data in the field while surveying and to automate georeferencing of the LIDAR data.

Other observations included that LIDAR alignment typically requires careful control of targets or references to merge multiple scans into an accurate and detailed model. Field targets can be difficult to use and match up when scanning larger regions, or complex environments, requiring them to be constantly and consistently moved. When applying LIDAR for change detection (pre- and post-event comparison), the pre-event reference model is no longer a valid alignment source. Furthermore, point clouds will have to be combined, cleaned and triangulated to produce surface meshes for subsequent analysis. Extraction of a surface that removes redundancy while preserving critical features is non-trivial and new techniques will be explored to optimize this

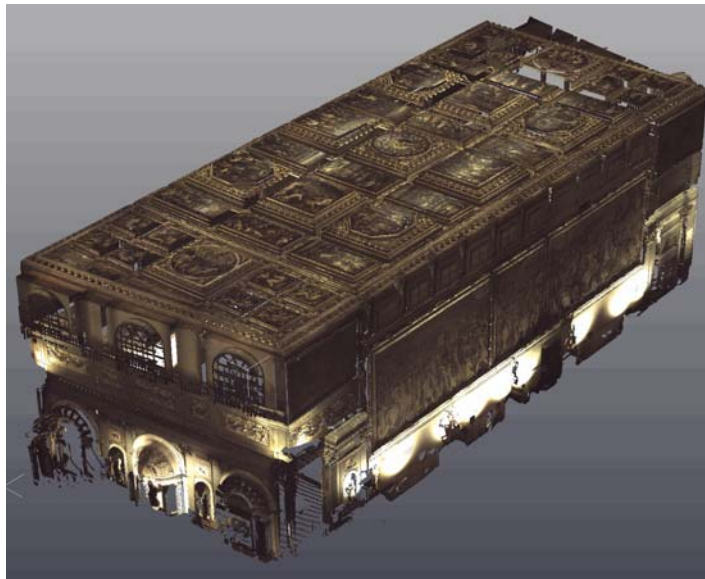


Figure 4: Point cloud dataset for the Hall of the 500 in the Palazzo Vecchio in Florence Italy (20 million point subset)



Figure 5 : Georeferenced point cloud dataset of seacliffs at Solana Beach.

important processing step. Finally, intensity values obtained by laser scanners can be a valuable tool in the automation of classification of data in the scans. Unfortunately, these values are dependent on the range, the angle at which the laser is reflected by the surface, the type of laser pulse, and the surface material. A model to normalize the intensity values such that the only variance in the values is a function of the material properties, is a prerequisite for accurate classification based on the intensity value and will be explored.

The proof-of-concept tests helped with identifying the challenges that will have to be addressed carefully in order to create a new modeling and simulation paradigms.

<i>Preparation</i>	<i>Survey</i>	<i>Data Processing/Analysis</i>	<i>Inform</i>
1. Determine resolution requirements and time constraints 2. Obtain site access 3. Determine setup locations to minimize occlusions	4. Obtain coordinates for scanner location 5. Setup laser scanner (ensuring that it is level) 6. Photograph scene using scanner 7. Perform LIDAR scans 8. Move to next location and ensure there is sufficient overlap and repeat	9. Register scan data to coordinates 10. Edit data 11. Align Data 12. Create 3D surface models 13. Compare with reference models to perform analysis	14. If continually monitoring, modify survey strategy to optimally acquire data 15. Disseminate results

Figure 7: Preliminary LIDAR data collection workflow

CalMesh Condor WiFli Network Unmanned Air Vehicle (UAV)

The project originated with the idea of expanding and improving our network deployment capabilities. As it is often the case, in emergency response environment, not every area is accessible nor is every terrain smooth. Therefore, deployment becomes quite complicated and time consuming. Gizmo helps in facilitating the deployment of the CalMesh network. Even though the new upgraded Gizmo truck can go through rough terrains, it will always be limited by possible obstacles. The WiFli Mesh Condor offers a faster and potentially dependable system.

WiFli CalMesh Condor Specifications:

- Flies around in lazy figure 8's, crossing a GPS coordinate sent from the ground
 - Low altitude, just above the treetops or parking lot light polls
- Forms a ad-hoc mesh network in the sky between our ground based nodes and other CalMesh Condors
 - Forms the famous Calit2 WiFli Network
- Motor turns on and off is a powered sailplane mode of operation, saves battery energy
 - Try to take advantage of thermal updrafts
- 100" Wing Span Electric flying wing – modified Windrider Queen Bee Flying Wing
- Mega ACn 15/25/4 brushless motor in rear with 10x7 folding pusher prop

- 2ea. 5000mah 11.4v lithium Polymer batteries for balance
- Servos are CS703MG, Hi-Torque Metal Gears
- All up weight is 103.17 oz
Surface area is approx. 9-1/2 sq. ft.
Wing loading approx.: 11.8oz/sq.ft.
The climb rate is about 30 to 45 degrees, with current prop.
As far as launches, it's just like any sailplane, except 2 persons are necessary
- Lands by crashing like a Maple Tree Seed, no damage

The WiFli Calmesh Condor has successfully been launched and 802.11b transmission occurs at a data rate and range acceptable for control.

To aid in research, the powered glider will be outfitted with a cargo bay that allows for hardware interchangeability. Also, a pneumatic launching mechanism will accelerate the powered glider to take off speeds. These improvements are realized through a sponsorship program facilitating the senior design course, MAE 156B, offered by the UCSD Mechanical and Aerospace Engineering Department. The team assigned to this project is expected to design, analyze, fabricate and test aforementioned improvements, as well as to assemble another complete powered glider. The glider will have slight changes in the propulsion components, namely: motor, propeller, speed controller, and battery.

The completed platform and launcher will benefit further research regarding automation and data acquisition. These tasks will highlight the upcoming efforts of other team projects, offered by the Electrical and Computer Engineering Department.

Our Future Goal: The “WiFli” system will consist of several planes able to create a Network bubble instantaneously. These planes will be deployed during disasters and emergency situations to support the communication between different response teams such as medial, SWAT, police, and MMST.

The WiFli Mesh Condor will be able to do autonomous station keeping over a designated area, for example: autonomous navigation from launching area to station keeping area and autonomous navigation from station keeping area to recovery area. In flight communications, it will be part of ground based and airborne wireless mesh network. A bungee-like launch will be created.(45 to 60 degrees from vertical),

MetaSim

METASIM is a web-based collection of simulation tools developed to test the efficacy of new and emerging information technologies within the context of natural and manmade disasters, where the level of effectiveness can be determined for each technology developed. METASIM currently incorporates three simulators: i. Crisis simulator InLET, ii. transportation simulator, and iii. simulator for agent based modeling (Drillsim).

A website has been developed in HTML and stored in the backend database to produce web pages on-the-fly through Java script. The web pages call the various simulators and allow users to define parameters for the various simulations. The parameters are saved in user specified scenarios and the simulations are run through the interface. After each run the results are stored in the database and the website calls and displays intermediate and final results.

The application is supported by a DB2 database (with Spatial Extender) and an ArcIMS server that stores geographic data and creates all the different GIS layers through a standard interface. The web application is constituted of an html part and a Java Applet. All of these technologies are part of the ResponSphere infrastructure. While the html part provides the user a simple interface to input configuration parameters, the Java Applet acts as visualization tool for all the different simulators. Through the applet, the user can navigate the map (constituted by a stack of GIS and application layers), input configuration parameters, look at the results and have a direct feedback of a simulation while it is running. For instance while the agent-based evacuation simulation is running, the user can see agents evacuating both at the outdoor level and at the indoor level. For the first version of MetaSIM, geographic extent of the data for implementation is Los Angeles and Orange County area. The transportation simulator and Drillsim have been implemented for a much more focused area around the University of California Campus in Irvine.

Activities and Findings

- Model refinement for crisis simulation, evacuation of individuals and cars, and adaptive cellular networks:

Several model refinements were implemented for individual simulators. For the Crisis Simulator/ InLET, user defined parameters to run a custom scenario were included as a part of the meta-simulation. Definition of evacuation scenario for DrillSim was also implemented. Multi-floor including indoor-outdoor agent evacuation was completed for DrillSim. For the transportation simulator, time synchronization and data exchange with pedestrian network using Whiteboard database was completed. Protocol to inform the MetaSIM testbed along with technology assumptions was explored for Adaptive Cellular Networking System.

- Development of Relational Spatial Data Model

A new Relational Spatial Data Model was developed to overcome the challenges associated with varied spatial data and multiple simulator integration within MetaSIM. This new

standard for model integration enables MetaSIM as a testbed for technology testing by addressing the following:

- Integration of multiple geographies

Within MetaSim, agents move across a hierarchy of heterogeneous geographies. These could be indoors grids, outdoor resistance grids, networks (transportation or pedestrian network). Every geography is associated with a different format for the underlying data (raster files, shape files, imagery, etc.), but every kind of data has been loaded into a common DB2 database, so to have a common geographic structure. The database is also able to link each geography to a particular region through the concept of "prefix". The "UCI" prefix for example means that the geography is part of the UCI area. A common Java interface able to access database tables and to retrieve meaningful data about these geographies is also implemented. Agents can move from one geography to another one through the concept of wormhole: a wormhole is a waypoint between two geographies. We can think at a door between indoor and outdoor, stairs, elevators, etc. Every agent needs to find a wormhole in order to get to a new geography.

- Integration of a variety of spatial data models- Vector, raster, network

Data is represented in different simulators using different formats and precisions. In addition different representation schemes are used. For instance one simulator can output the plume data as a vector shape file while another as a raster matrix. It is essential to identify the differences and be able to translate to the right format or representation. The wide array of geographic, CAD and network data is translated and stored in DB2 tables using spatial extender. An ArcIMS map service has been set up to serve this data.

- Integration of multiple simulators

MetaSIM uses a tightly coupled integration of different simulators, where the integration is dependent on data synchronization. The relational spatial data model provides the framework for data synchronization by addressing data exchange, translation, and managing coherent input and modeled output.

- Integration with online mapping and visualization interface

Over the past several years, the use of Information Technology (IT) has become increasingly widespread at all levels of disaster management and several new innovations in IT are being developed that have enormous potential for the emergency response and management community. One such area is online mapping and visualization that have made major advances in the past few years. Current online mapping applications such as Virtual Earth and Google Earth offer rich representation of information layers including base layers of road, aerial and satellite imagery. Technologies for data access, sharing and distribution securely over the internet make it possible to push information to a large population at a very rapid rate. All these factors combined with the reduction in hardware costs have created an environment where an online loss estimation program like InLET provides greater flexibility to the disaster management and response community. Because GIS software is not required by the end user, it can be used widely throughout an organization or can be accessed via the internet without the need for specialists. Implemented over the popular online Virtual Earth mapping interface, InLET results are presented overlaid on a rich layer of Virtual Earth data and imagery.

- Testbed architecture of distributed simulations

Distributed, plug-and-play simulators for researchers

METASIM is a collection of plug-and-play simulation tools connected by a database. In its final form, definition of inputs, outputs, timing, and scale, the results of each simulation component will be available for iterative use by each of the other simulation models. Registering and synchronizing transactions between various simulation engines and assuring proper use of scale will be addressed by the data exchange architecture and the time synchronization module.

- Open architecture, expandable by the community

MetaSIM is developed with open software architecture to enable modules to share data in real time. The platform and protocol designed for METASIM's data exchange support modular and extensible integration of simulators for the scientific, engineering, and emergency response communities.

Exploring various domains for MetaSIM application:

Four major domains for applying MetaSIM are identified and explored through collective discussion of the RESCUE-MetaSIM group:

- Loss Estimation Software

The target user group in this domain is local, state or federal government agencies involved in emergency management, mitigation planning, post disaster response and planning, private businesses conducting training, consulting and response activities. What differentiates MetaSIM from other loss estimation or micro/macro simulation tool is that it is an online system with a flexible plug-and-play architecture. It offers a framework for a comprehensive planning, training and management tool. The link with USGS ShakeCast system and the testbed architecture for technology testing such as warning systems, routing algorithms for evacuation, adaptive cellular networks makes MetaSIM unique.

- Disaster Gaming Tool

The target users for a disaster game will be gamers of all ages, serious gamers, government and private agencies involved in conducting training and response activities. As a gaming tool it may also be used as a multi-media virtual learning environment to teach our youth and encourage them to explore emergency preparedness and crisis response. By combining the game-like atmosphere of a video game such as SimCity with the existing disaster modeling software, MetaSIM will provide students with a crucial educational opportunity that is largely absent in the K-12 curriculum. An easy-to-explore virtual environment, MetaSIM framework will be simplified and broadened in scope to meet the educational needs of school age children and youth. It will offer an inquiry-based learning on a variety of topics including decisions regarding evacuation, mitigation of buildings and critical infrastructure, communications, modeling, basic databases and GIS mapping technologies.

- Modeling Tool for Online Services

The target clients for this tool or service will be insurance/ re-insurance professionals, real estate professionals, marketing firms, satellite companies, companies with a substantial web presence like Google, Yahoo, Microsoft. This tool will be developed as a Web 2.0 portal offering

location based data and analytical services for real estate, insurance, marketing/ PR firms. This product will supplement existing online mapping tools with modeling capabilities, appealing to user's needs to answer more complex disaster questions or routing inquiries. This will be targeted to be used by the risk-adverse or community activists to make a case for mitigation. This may be seen as the equivalent of what Google is doing by putting the SLOSH model online for community users to look up their storm surge vulnerabilities in hurricane prone areas.

- Architecture for Integration

The primary users for this are researchers and research organizations. This area of investigation will offer MetaSIM as an expandable open modeling architecture that will be used for integrating heterogeneous simulators, including legacy products. It will be different from other existing architecture due to its flexible plug-and-play nature and its online capabilities. It will also bring together various scales of simulation models such as regional (macro) and local (micro) models. With highly optimized processing time, this online system will ensure consistent use of loss estimation modules and inventory data.

- Conducting outreach activities for possible MetaSIM implementation:

Several high level meetings have been conducted with State and Federal officials in emergency management. RESCUE team members have demonstrated the capabilities of MetaSIM to the GIS and Earthquake/Tsunami program managers at the California State Office of Emergency Management, and Mitigation officer at FEMA/DHS. An Adobe Flash demonstration with the existing METASIM functions and modules has been created and distributed through the RESCUS website. Several meetings are planned with various government agencies and first responder communities to discuss potential of MetaSIM as a decision support and training tool. Several papers are planned for completion and publication in IT, Simulation, Natural Hazards, Loss Estimation and GIS journals and conferences over the next several months.

Challenges:

Simulation interoperability is a major and over arching challenge for MetaSIM. Integration of different simulators into the METASIM framework, especially at the level which is required in the emergency management context is daunting. The following are the elements of the challenge of integrating the different simulators:

Time Management: Time management must be incorporated to enforce temporal characteristics of the problem domain are correctly represented in the simulation. In absence of time management functionalities, it is not possible to preserve causality of events and provide consistency of results between different runs of the same simulation.

Data Exchange Architecture: The series of simulators within the METASIM framework use heterogeneous data sources (CAD vs. GIS) in multiple formats representing different models of the world (network, raster, mathematical). A data exchange architecture for the integration of the various simulation engines needs to be incorporated to establish communication between simulators including managing the various input and output results that are exchanged between the simulators.

Added layers of complexities exist for applying MetaSIM to any specific domain. For example, expanding the loss estimation capabilities nationwide or even globally is a challenge from a modeling and inventory data standpoint. Extensive effort will be necessary to expand MetaSIM to address flood, hurricane and other natural hazards. To transform MetaSIM into a disaster gaming tool, several questions need to be answered. Some of these include the level of effort required to create these disaster games, the interest and user base for similar existing games, and the success of games as educational or training tools.

METASIM components including crisis simulator InLET, DrillSim, and the transportation simulator currently run on the server provided by Responsphere. InLET version 2 has been developed as a stand alone module for loss estimation. METASIM is built on the transportation testbed, and will provide a platform for testing the integration of technologies on many levels.

In summary several key elements have been developed as a part of the MetaSIM framework and have potential as standalone products. These are:

- Testbed architecture for distributed simulators
- Relation Spatial Data Model
- Visualization platform that leverages online mapping applications such as Virtual earth and Google earth

Future Planning:

Anticipated Outcomes: Various options are being evaluated for deploying the core components of MetaSIM individually as well as a complete system. We seek to leverage the capabilities of METASIM and transform it into a tool for one or several potential areas of use. The major options that seem viable include:

Loss estimation and decision support tool for public agencies:

Use MetaSIM for as a government tool for general public awareness or response before, during or after disasters.

Training tool for first responders:

Use MetaSIM as a training tool to teach first responders the various steps and procedures of the disaster response cycle.

Modeling tool for online services:

Create a Web 2.0 application for hazard assessment, loss estimation and evacuation modeling for real estate, insurance or the transportation industries.

Online disaster game for the gaming industry:

Modify MetaSIM into a gaming tool or a multi-media virtual learning environment to teach about emergency preparedness and crisis response to the youth or people in emergency response and management.

Possible Technical Challenges:

Different levels of complexities exist for implementing the core components of the MetaSIM for the various options which are being evaluated. The fundamental challenges of data exchange and time management underlie each option. Added layers of complexities such as developing a virtual environment for training or teaching, online visualization interface that support rich data representation are possible challenges given the implementation environment and intended user groups.

Potential end-users:

For the scientific research community the MetaSIM architecture supports modular and extensible integration of simulators. Beyond the research community, MetaSIM is designed to be used by first responders, planners, and people involved with the emergency response process. It will be used as a decision support tool to see where the damage will be likely to occur in case of a disaster and plan accordingly. It is also anticipated that MetaSIM will be used by emergency managers and responders to develop training scenarios.

Educational outcomes and deliverables, and intended audience:

In its completed form, METASIM is intended to be used as a training tool for first responder community.

Products

MetaSim: <http://rescue-ibm.calit2.uci.edu:8280/metasim/home.htm>

METASIM components including crisis simulator InLET, DrillSim, and the transportation simulator currently run on the server provided by Responsphere. InLET version 2 has been developed as a stand alone module for loss estimation. METASIM is built on the transportation testbed, and will provide a platform for testing the integration of technologies on many levels.

In summary several key elements have been developed as a part of the MetaSIM framework and have potential as standalone products. These are:

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Contributions

Crisis Simulator/ InLET

The Crisis Simulator currently simulates an earthquake event and estimate damage and casualties for Los Angeles and orange counties. The crisis simulator integrates the earthquake loss estimation components of InLET, the Internet based Loss Estimation Tool, created and designed

under project RESCUE in Year 3. Later additions to the crisis simulator include a real-time link to USGS Shakemaps, and a restructuring on the online code to accommodate multiple users.

DrillSim

DrillSim is an agent-based activity simulator that models human behavior at the individual, or micro level. DrillSim tests IT solutions by modeling situation awareness and providing it to the agent to react accordingly. For example, an early warning system might be used to modify the timing of agent evacuation. Micro-level activity modeling provides the ability to mimic agent behavior in crisis, as well as interactions between people during crisis, thereby providing a more robust framework for integrating responses to information and technology. DrillSim uses a grid-based representation of indoor and outdoor spaces. Recent improvements to DrillSim include expansion to multiple floor levels, indoor and outdoor representation, and integration with the MetaSim framework. Additionally, agent behavior has been refined from actual drills conducted at UCI.

Transportation Simulator

Transportation simulator consists of an integrated model of simplified quasi-dynamic traffic assignments, and a destination choice model. Information that becomes available through IT solutions is simulated through parameters, such as subscription to routing support information via cell phone or email, information arrival time and update frequency, system credibility and acceptance, to reduce uncertainties associated with decision making when evacuating a congested network. The key parameters are available as adjustable inputs to the model, for users to assess the efficacy of different methods of integrating IT into emergency response.

GIS Applet for Visualization

A GIS applet has been developed for the crisis simulator for visualization of the different geographic data layers and the simulation results. In addition, the applet provides tools for users to interact with the map and to define a crisis simulator request for a scenario. Users can select events that have been pre-calculated, or define a new event by entering a magnitude and depth and selecting an approximate epicenter location on the map. The applet also allows users to delineate evacuation zone for the transportation simulator.

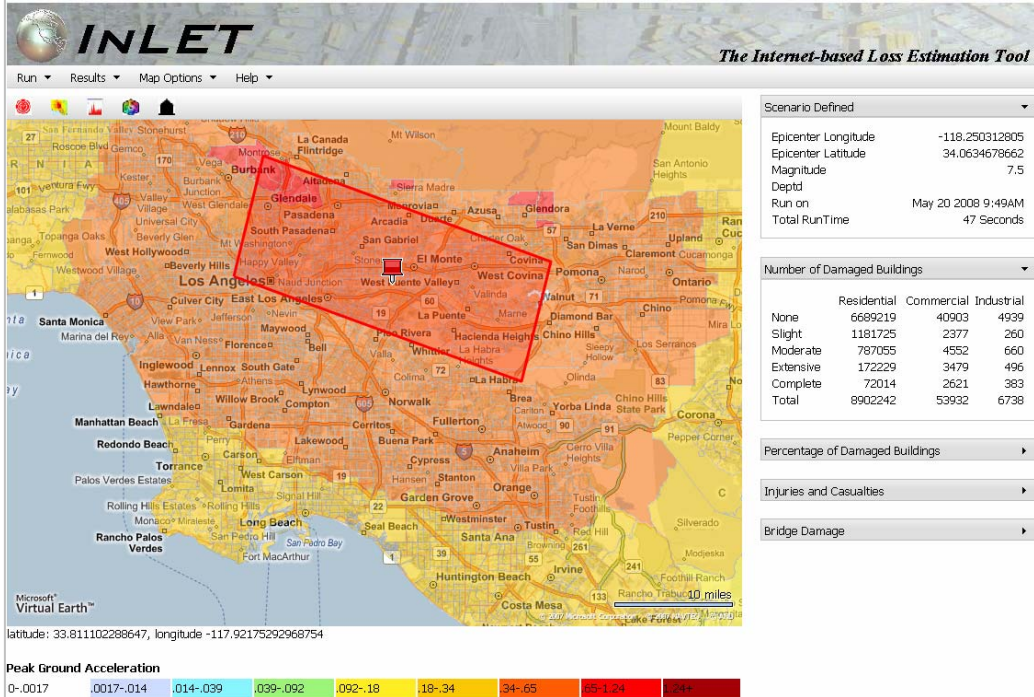
InLET version 2

MetaSIM architecture supports modular and extensible integration of simulators. A more refined crisis simulator or InLet version 2 has been developed for integration into the MetaSIM framework to replace the existing damage and loss modeling simulator. Several changes has been made to the database queries, mapping interface, and the coverage area in the new version of InLET and these are summarized below.

InLET has been expanded from its previous implementation for Los Angeles-Orange County to cover earthquake hazards throughout California. InLET provides rapid results by simplifying the

HAZUS damage functions and porting the algorithms to a database environment. The SQL server database queries have been restructured to optimize running time and take full advantage of the database functions. Given the advances in online mapping and the availability of GIS data through various online platforms, the visualization component of InLet has been implemented over the popular online Virtual Earth interface. InLET results and base data for the simulator are presented overlaid on a rich layer of Virtual Earth data and imagery. Because GIS software is not required by the end user, it can be used widely throughout an organization or can be accessed via the internet without the need for specialists.

The new InLET results have been compared with some of the known events and planning scenarios. Results are generally within 5% for most development types. An example is provided for the little known Puente Hills Fault that runs under downtown Los Angeles. Figure 1 depicts a magnitude 7.5 earthquake was placed on the Puente Hills Fault, and the resulting fault rupture is indicated in red. The color-coded census tracts indicate the estimated number of damaged buildings in each tract. This loss estimate for Puente Hills predicts approximately 7,000 fatalities. Residential structural damage is estimated as 70,000 completely damaged structures, 160,000 extensively damaged structures, and 700,000 moderately damaged structures. The results generally agree with the 2005 SCEC Puente Hills scenario. SCEC estimated 3,000-18,000 fatalities and 142,000 to 735,000 displaced households. Extensive studies which produce an entire suite of estimates using the best data and models available may be more appropriate for some applications.



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Figure 1. INLET interface showing PGA map of the 7.5 M Puente Hills Fault planning scenario

Responsphere Papers and Publications

The following list of papers and publications represent additional research work for the 2007-2008 research papers and publications efforts utilizing the Responsphere research infrastructure:

1. Butts, Carter T. (7/2007). ``Improvisation in Disaster Response. Invited Panelist, 32nd Annual Hazards Research and Applications Workshop, Boulder, CO.
2. Jammalamadaka, Ravi Chandra; Gamboni, Roberto `.; Mehrotra, Sharad; Seamons, Kent; Venkatasubramanian, Nalini. gVault: A Gmail Based Cryptographic Network File System, 21st Annual IFIP WG 11.3 Working Conference on Data and Applications Security, 2007-07
3. Butts, Carter T. ``A Relational Event Model for Social Action. (8/2007). ASA Meeting, New York, NY.
4. Hasan, Ragib; Winslett, Marianne; Sion, Radu. Requirements of Secure Storage Systems for Health-care Records, 4th VLDB accepted for publication, Workshop on Secure Data Management (SDM), in conjunction with 33rd International Conference on Very Large Data Bases (VLDB), University of Vienna, Austria, September 2007., 2007-09
5. Li, Chen; Wang, Bin; Yang, Xiaochun. VGRAM: Improving Performance of Approximate Queries on String Collections Using Variable-Length Grams, VLDB 2007, 2007-09
6. Han, Qi; Mehrotra, Sharad; Venkatasubramanian, Nalini. Application-aware integration of data collection and power management in wireless sensor networks, Journal of Parallel and Distributed computing, 2007-09
7. Hasan, Ragib; Winslett, Marianne; Sion, Radu. Requirements of Secure Storage Systems for Health-care Records, 4th VLDB Workshop on Secure Data Management (SDM), in conjunction with 33rd International Conference on Very Large Data Bases (VLDB), 2007-09
8. Van der Horst, Timothy W.; Seamons, Kent E.. Simple Authentication for the Web, 3rd International Conference on Security and Privacy in Communication Networks, 2007-09
9. Zhou, Ping; B.S., Manoj; Rao, Ramesh. On Gateway Placement in Wireless Mesh Networks, Proceedings of ACM WiCON 2007, 2007-10
10. Lee, Adam J.; Winslett, Marianne. Towards an Efficient and Language-Agnostic Compliance Checker for Trust Negotiation Systems (Extended Version), UIUC Dept. of Computer Science Technical Report, 2007-10
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15. Ihler,A; Hutchins,J; Smyth,P. Learning to detect events with Markov-modulated Poisson processes, ACM Transactions on Knowledge Discovery from Data, Volume 1 , Issue 3,2007-12
16. Shivappa,Shankar T.; Rao,Bhaskar D.; Trivedi,Mohan M.. An Iterative Decoding Algorithm for Fusion of Multimodal Information, EURASIP Journal on Advances in Signal Processing,2008
17. Lee,Adam J.; Winslett,Marianne. Enforcing Safety and Consistency Constraints in Policy-Based Authorization Systems, ACM Transactions on Information and System Security (TISSEC),2008
18. Mitra,Soumyadeb; Winslett,Marianne; Hsu,Windsor W.. Query-based Partitioning of Documents and Indexes for Information Lifecycle Management, ACM SIGMOD Conference on Management of Data,2008
19. Hariharan,Ramaswamy; Hore,Bijit; Mehrotra,Sharad. Discovering GIS Sources on the Web using Summaries, 2008 IEEE Joint Conference on Digital Libraries,2008
20. Jafarpour,Hojjat; Hore,Bijit; Mehrotra,Sharad; Venkatasubramanian,Nalini. Subscription Subsumption Evaluation for Content-based Publish/Subscribe Systems, none,2008
21. Jin,Yuzhe; Rao,Bhaskar D... Performance Limits of Matching Pursuit Algorithms, 2008 IEEE International Symposium on Information Theory,2008
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31. Lee, Adam J.; Winslett, Marianne. Towards Standards-Compliant Trust Negotiation for Web Services (Extended Version), UIUC Dept. of Computer Science Technical Report, 2008-03
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37. Jammalamadaka,Ravi Chandra; Gamboni,Roberto; Mehrotra,Sharad; Seamons,Kent E.; Venkatasubramanian,Nalini. iDataGuard: Middleware Providing a Secure Network Drive Interface to Untrusted Internet Data Storage, none,2008-03
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61. Mirko Montanari, Sharad Mehrotra, Nalini Venkatasubramanian: Architecture for an Automatic Customized Warning System. ISI 2007: 32-39
62. Zhaoqi Chen, Dmitri V. Kalashnikov, Sharad Mehrotra: Adaptive graphical approach to entity resolution. JCDL 2007: 204-213
63. Bijit Hore, Ravi Chandra Jammalamadaka, Sharad Mehrotra: Flexible Anonymization For Privacy Preserving Data Publishing: A Systematic Search Based Approach. SDM 2007
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67. Bo Xing; Nalini Venkatasubramanian; Sharad Mehrotra : On Achieving Deterministic Reliability for Application Data Broadcast in Ad Hoc Networks ResCUE Technical Report, 2007

Courses

In fulfillment of our academic mission, the following undergraduate and graduate courses are facilitated by the Responsphere Infrastructure, use Responsphere equipment for research purposes, or are taught using Responsphere equipment:

UCI ICS 214A, UCI ICS 214B, UCI ICS 215, UCI ICS 203A, UCI ICS 278, UCI ICS 199, UCI ICS 290, UCI ICS 280, UCI ICS 299.
UCSD ECE 191, UCSD ECE 294, UCSD MAE 156B, UCSD CSE 218.

Equipment

The following table summarizes the types of equipment the UCI and UCSD Responsphere teams obtained for the project. The most significant purchases in year 4 include a deployment of motes sensors throughout the infrastructure as well as a significant increase in optical, acoustic, and mobile sensing. In all cases, education pricing and discounts were pursued during the purchasing process.

UCI

Date	Equipment	Usage
	Web Portal	
9/1/2007	upgrades	www.responsphere.org
10/1/2007	NavTech	GPS software
12/1/2007	CrossBow	x-bow motes
12/11/2007	D-Link	optical/acoustic sensors
1/1/2008	NACS	Co-Location for network Backup Storage - Yearly
3/2/2008	Dell	Computing: Responsphere Infrastructure
	Dell - Computer	
4/2/2008	Store	Computing: Privacy Preservation
4/27/2008	Dell	Computing: Responsphere Infrastructure
5/1/2008	Canon	Pinters: Research reporting
	AllRound	
5/1/2008	Automations	Video Processing Software
5/10/2008	Microsoft	Software licensing - Annual
Date	Equipment	Usage
	Web Portal	
9/1/2007	upgrades	www.responsphere.org

UCSD Equipment Fabrications		
Quantity	Equipment	Usage
1	Gizmo	Test platform for self-deploying, remotely controllable wireless network nodes equipped with various kinds of field sensors; improvements and additional features for the 3 Gizmos that were built in Year 3
1	Vehicle	Components purchased and fabricated include: Wiring Solar panels Controllers to interface Gizmo, Wifli Condor, CalMesh nodes with the truck's communication
1	Leica ScanStation2	laser scanner for environmental/structural data acquisition
1	Panoscan	panoramic camera for high speed data capture
1	Software defined radio nodes	CalRadio nodes (for networking infrastructure and RF modeling research)
1	CalMesh Wifli Condor	Components to build one additional Wifli Condor – motors, batteries, gears, etc (aerial version of Gizmo)