An IT Infrastructure for Responding to the Unexpected

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Table of Contents

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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 Five Annual Report.

The NSF funds ($231,762) from year five (final year of funding) 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 five include 18 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), ENG 100, CSE 294 and CSE 218.* In addition, researcher BS Manoj taught ECE 158B (Advanced Data Networks, which covers challenges in communications during disasters).

We have applied for and received a one-year No Cost Extension for the Responsphere project. This will allow us additional time to seek continuity funding for the infrastructure. As part of this continuity plan, the researchers have applied for an NSF-funded Institutional Infrastructure Enhancement Award under the CNS-CRI program (Proposal 0958520). This proposal will allow us to enhance and repurpose Responsphere to support not only Disaster Response research but research within sentient environments.

Collaborations with industry, government, and other academic organizations continue to be a priority for the Responsphere researchers. We are working with Raytheon Corporation to explore acoustic (speech) based localization techniques for first responders. Raytheon is currently seeking a small amount of funding from their corporate office to support a graduate student for this project.

At UCSD, we have continued to work with Anritsu in gathering and understanding wireless spectrum data using their Electromagnetic Interference Measurement Software for portable spectrum analyzers, and with Nokia Siemens Networks (NSN) on FEMTO Cell Interface Tools and Mobiles In the last year we have also collaborated with SkyRiver Communications, Mushroom Networks and the High Performance Wireless Research and Education Network (HPWREN) on the wireless network deployment for the San Diego Science Festival.

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 during the California wildfires. Currently, we are working with several cities (e.g., Champaign, IL) to deploy this portal for their utilization. The portal is hosted on Responsphere equipment and utilized the infrastructure for connectivity.

Collaboration with UCSD Campus Police and UCSD Emergency Management has continued to evolve. 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 April 4, 2009, the UCSD Responsphere team executed a major deployment in San Diego's Balboa Park for the San Diego Science Festival, providing wireless connectivity for 70+ exhibitors, and also public access for visitors who had mobile devices. The Responsphere team also demonstrated technologies developed as part of the Responsphere, NSF-RESCUE, and NIH/NLM WIISARD projects at an exhibition booth. Over 50,000 people attended this event. At the conclusion of the Responsphere and RESCUE projects at UCSD, we will begin to engage with our campus partners as part of the WIISARD SAGE project.

Technology testing exercises and emergency response drills are another priority of the Responsphere team. We utilize the Responsphere Infrastructure and equipment to test our research ideas and technology in a real-world testbed. In year five, we have conducted 2 major hazardous materials drills (with evacuations) and one Live Burn Exercise and the Orange County Fire Authority (OCFA) training site.

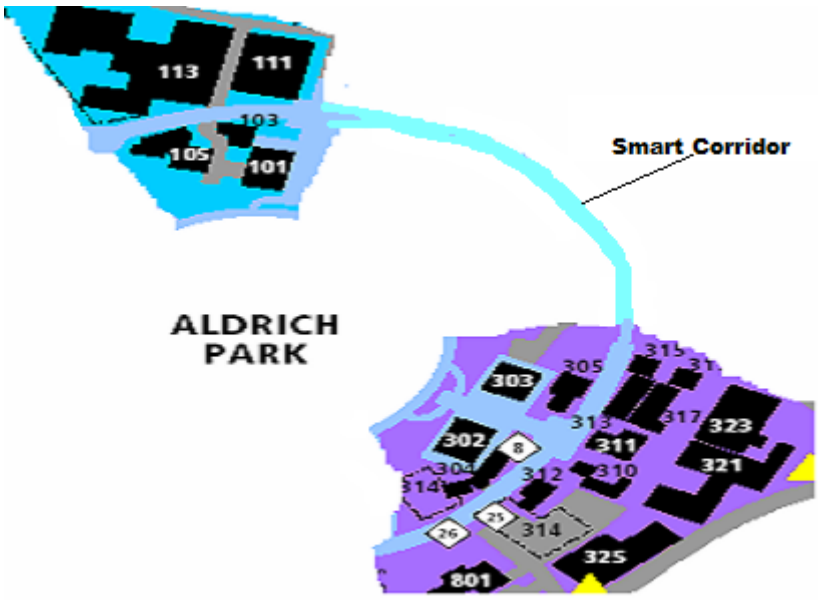
Spending Plan

Spending plans for our final year of funding at UCI will support the personnel required to maintain the Responsphere infrastructure. As indicated in the initial budget proposal, staff salary maintaining the Responsphere will increase during the latter years of the grant. Additionally, we will host a number of drills, exercises and evacuations in the Responsphere infrastructure, as these are drills require staffing and already purchased equipment.

At the end of year 5, UCSD has spent out all funds awarded to us by the Responsphere project.

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."



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 (2008-2009), we received a generous donation from Broadcom Inc. to enhance our server infrastructure. Broadcom donated five multi-processor servers in order to host our SATware middle platform. SATware provides an easy to use, visual interface into the Responsphere infrastructure.

UCSD Summary

Researchers from the UCSD ResponSphere and RESCUE projects participated in the grand finale of the month-long San Diego Science Festival: Expo Day at Balboa Park. More than 50,000 people attended the event held on Saturday, April, 4, 2009, which featured 200+ exhibition booths. Organizers called it "the largest one-day science gathering ever in the United States."

More than three dozen researchers (PIs, faculty, staff, postdocs, graduate and undergraduate students) were on-hand at Balboa Park to run demonstrations, provide information to visitors, and manage the wireless network and the many experiments.

Multiple technologies (devices, software and systems) were deployed and demonstrated, including several versions of Gizmo, Calit2's family of wireless mobile platforms designed to transport cameras, other sensors, and wireless access points to and around disaster sites in order to get communications going again in an emergency. Gizmo put a smile of the face of dozens and dozens of kids, big and small. Children as young as 5 years old waited patiently in line to "test-drive" one. The mobile touchscreen kiosk based on the Gizmo technology also made its public debut in the booth.

In addition, a wide variety of measurements were taken, both on the day of the event and as preparation and reference samples. The huge crowds and changing network environment over the day-long event served as an excellent live real-time testbed, for CalMesh (the wireless ad-hoc mesh network in its largest deployment ever) and other wireless technologies that we have developed for emergency and large-scale response.

CalMesh provided bandwidth to dozens of exhibitors (who otherwise would not have enjoyed high-speed Web access because Balboa Park wasn't equipped for it); some of the access points were open for the 50,000 Expo attendees to use. Calit2's CalMesh network was linked to the Internet via the High Performance Wireless Research and Education Network (HPWREN) and a commercial provider, Sky River. Combined, they channeled 45 megabits per second of bandwidth.

The deployment also provided an excellent opportunity to collect data, to further our research on communications in cases of emergency. Many experiments were conducted and measurements taken on the network and surrounding environment.

Researchers tested how specific wireless technologies performed in identified areas with heavy pedestrian and cellular traffic. We deployed 15 Bluetooth sensor nodes (BlueMap) within the Expo area to record Bluetooth devices in the vicinity of each sensor node and store this data in a central database that can later be used to infer the potential spread of mobile phone virus during a highly populated event. We also conducted electromagnetic emission spectrum analysis (USB WiSpy with a USB GPS operating from a laptop PC, and an Anritsu Portable Spectrum Analyzer with built-in GPS and 3 PCB Log-Periodic Antennas). Data is still being analyzed, but we expect to be able to determine coverage area of our CalMesh, and more importantly, determine the electromagnetic compatibility environment to access the interference perpetrators and the susceptible victims and see if cognitive radio can make use of available white spaces in the radio spectrum.

We also conducted monitoring using CogNet, and on Expo day observed all the channels in the 2.4GHz and 5.2GHz spectrums and sampled network traffic from all the channels. We measured the channels used for CalMesh continuous capture. The results from this measurement are mainly focused on studying the network behavior as well as studying the wireless environment behavior. Finally, we visualized the network traffic environment on a portable visualization display.

Cellular network monitoring was conducted before, during, and after the event using the Qualcomm CAIT tool. We logged physical, mac, and upper layer information such as signal strengths, power control, frame error rates, RLP retransmission, data rates, handoff status to observe differences in the mobile users perceived performance between light load and high load conditions.

The Calit2 San Diego Science Festival Photo Gallery is available here: http://projects.calit2.net/gallery/main.php?g2_itemId=3436. This deployment has resulted in at least one new collaboration.

In addition, before the Expo, we performed a 3-D laser scan (LIDAR) of the CalMesh deployment area in Balboa Park. We used the point-cloud exemplar to model the wireless propagation environment to give a view of theoretical behavior of the system. Post-event processing will enable a comparison of the theoretical vs. actual environments. Press Release on Science Festival/Expo Day. http://www.calit2.net/newsroom/release.php?id=1496

The LIDAR laser scanning equipment and processing continue to be extremely important and are used frequently. They are currently, or have been, used in about 10 different projects (with multiple subprojects), ranging in purpose from assessment of wireless signal transfer, to cultural heritage and art history exploration, and structural analysis of historic buildings and locations. The data across projects has been used for the development of new, rapid meshing techniques.

In the area of Wireless Mesh Network Electromagnetic Interference Analysis, significant cumulative technical progress was made in the following areas: Multiple wireless backhauls for Internet access from the affected area including but not limited to portable low cost satellite date link, portable light weight microwave backhaul, long distance ZigBee control channel, long distance 1xEV-DO, long distance EDGE, and HAM low rate packet radio. Wireless mesh network intra-net connections using 801.11a/b/g/n and BlueTooth, Thermo-Electric generators with DC to DC converters with flex-fuel capability such as charcoal or kerosene.

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 Information Dissemination in K-12 Schools, Sept, 2008
2. Wild land Fires Firefighter Forum, May 2009
3. Earthquakes, Hurricanes, and other Disasters: A View from Space, May 2009

Additionally, we have host two major Hazardous Materials drills within the Infrastructure. These drills allow us to test our technologies (e.g., 802.11 mesh networks) within

a disaster response setting. Finally, we brought our technology to the OCFA and sensorized the firefighters as well as their operating environments in order to study Carbon Monoxide exposure levels as well as study networking dynamics in this type of environment.

Outreach activities at UCSD included demonstrating our infrastructure and research technologies for industry groups, domestic and international governmental delegations, and conferences that took place at Calit2. The most significant outreach activity was our participation in the 2009 San Diego Science Festival Expo, attended by over 50,000 people. Activities related to the Expo are detailed in the body of the report.

Other collaborative outcomes:

-A follow-on project to WIISARD, which uses the CalMesh Networking platform, was funded by the National Institutes of H6ealth and the American Recovery and Reinvestment Act. The 2-year project will begin on September 1, 2009.

-Based on stellar results from the San Diego Science Festival deployment, members of the Robust Networking Infrastructure team have begun a collaboration with the Balboa Park Online Collaborative (BPOC), an organization comprised of 15 museums in San Diego's Balboa Park. BPOC's mission includes improving museums' technology capabilities and integrating online technologies in the daily operations of museums and their interactions with patrons and collaborators. BPOC has asked the Robust Networking team to help them wirelessly connect museums in Balboa Park to help create a more unified management, and online data sharing and collaboration systems.

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.

Both the UCSD division director and overall director of Calit2 consistently use results from Responsphere in their many talks locally, nationally and internationally to both technical and lay audiences. The technologies and devices developed provide examples for current and future stakeholders (government, industry, academia, and first responders) of what technological advancement can provide applicants and how collaborative multidisciplinary research produces superior results which can be used in the real world.

Responsphere Drills

- February, 2009: A Live Burn exercise was conducted with the OCFA and LA County Fire Departments. The Responsphere team deployed a large-scale mesh network along with a number of human bio-sensors. The SpCO readings from the firefighters as well as environmental CO readings were obtained.
- April, 2009: UCSD Responsphere team deployed a wireless infrastructure in Balboa Park for the San Diego Science Festival, the culmination of a month-long science and education event in San Diego, which was attended by over 50,000 people. The NSF-funded High Performance Wireless Research and Education Network (HPWREN) provided a backhaul link; and several local industry partners also participated. SkyRiver Communications provided an additional backhaul link (for added bandwidth); Mushroom Networks also participated as part of the Responsphere team to help provide additional bandwidth in an area of the park. The Responsphere team also demonstrated some of the technologies developed from the project for many of the families that attended; the

Gizmo remote controlled vehicle/mesh networking platform was especially popular with both school-aged children and adults.

- May, 2009: UCI table-top exercise with our firefighter advisory team. At this exercise, we demonstrated several Responsphere technologies and received feedback from our advisors.
- May, 2009: UCI researchers conducted a Hazardous Materials (HazMat) exercise with an evacuation of two buildings on the campus. The exercise was conducted jointly with the EH&S team.
- July, 2009: A follow-on HazMat exercise was conducted to test improvements in the mesh networking deployment as well as improvements in the Responsphere software.

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)

Name	*Role(s)*	*Institution*
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)

Name	***Role(s)***	***Institution***
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	Postdoctoral 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 Alcantara	Graduate Student	ECE, UCSD
Mason Katz	Senior Software Developer	SDSC, UCSD
Greg Bruno	Senior Software Developer	SDSC, UCSD
Vanessa Pool	Project Support	Calit2, UCSD
Xavier Monraz	Undergraduate Student	UCSD
Jeffrey Cuenco	Software Development Engineer	Calit2, UCSD
Barry Demchak	Graduate Student	CSE, UCSD
Ingolf Krueger	Professor	CSE/Calit2, UCSD
Rajesh Hegde	Postdoctoral Researcher	Calit2, UCSD
Bheemarjuna Reddy Tamma	Postdoctoral Researcher	Calit2, UCSD
Paul Baumgart	Undergraduate Student researcher	Calit2, UCSD
Salih Ergut	Graduate Student	ECE, Calit2
Jim Madden	Administrative Computing and Communications (Infrastructure installation)	UCSD
Patrick Nehls	Administrative Computing and Communications (Infrastructure installation)	UCSD
Nicola Blado	Visiting Researcher	Calit2, UCSD
Jeremy Rode	Graduate Student	ECE, UCSD
Paul Draxler	Volunteer	QUALCOMM, Inc
Myoungbo Kwak	Graduate Student	ECE, UCSD
Jin-Seong Jung	Graduate Student	ECE, UCSD
Myoungbo Kwak	Graduate Student	ECE, UCSD
Aaron Jow	Graduate Student	ECE, UCSD
Manish Made	Graduate Student	ECE, UCSD
Calogero Presti	Graduate Student	ECE, UCSD
Paul Theilman	Graduate Student	ECE, UCSD
Toshifumi Nakatani	Graduate Student	ECE, UCSD
Johana Yan	Graduate Student	ECE, UCSD
Falko Kuester	Professor, Structural Engineering, CSE; Calit2 Professor for Visualization	SE, CSE, Calit2, UCSD
Vid Petrovic	Graduate Student	CSE, UCSD
Kevin Ponto	Graduate Student	CSE, UCSD
Jason Kimball	Graduate Student	CSE, UCSD
Mike Olsen	Graduate Student	SE, UCSD

Responsphere Research Thrusts

The Responsphere Project provides the IT infrastructure for Rescue project. The project is divided into the following four research projects: Stream Acquisition and Transformation Middleware (SATWare), Disaster Portal, 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 year five we have focused on integrating localization technologies into SATware. Using a variety of location based technologies (e.g., speech, Bluetooth, RFID, and WiFi) we can more accurately estimate first responder locations in real time. We incorporated this functionality into SATware and deployed it in this year's drills and technology testing exercises.

Also in year five, we created a smaller, lightweight version of SATware for the Fire Incident Command Board. This version was deployed along with enhanced visualization capabilities for Incident Commanders during our drills. We also demonstrated this during our tabletop exercise with first responders where it received much praise and positive feedback.

Products

Artifact: SATWare – A middleware for sentient spaces

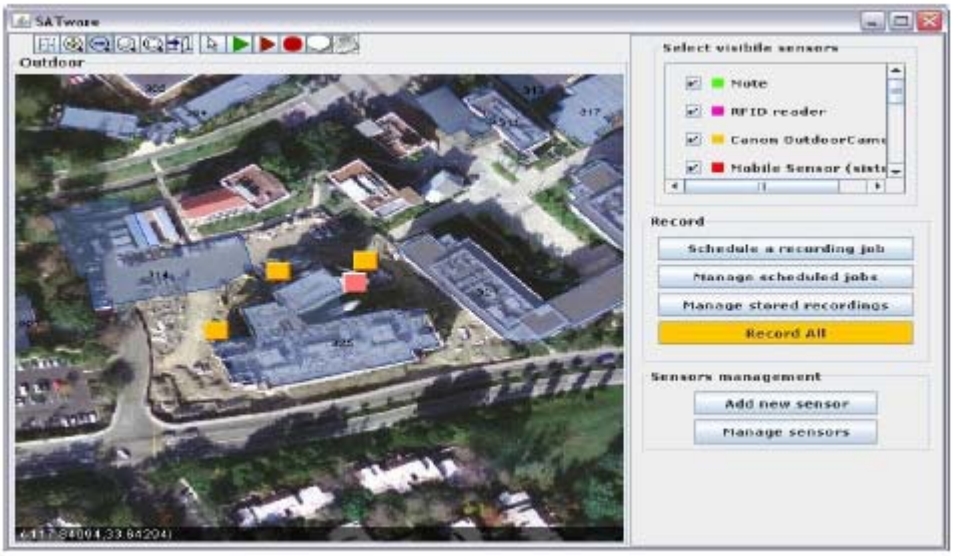
Website: http://ics.uci.edu/~projects/SATware

Contributions

SATRecorder

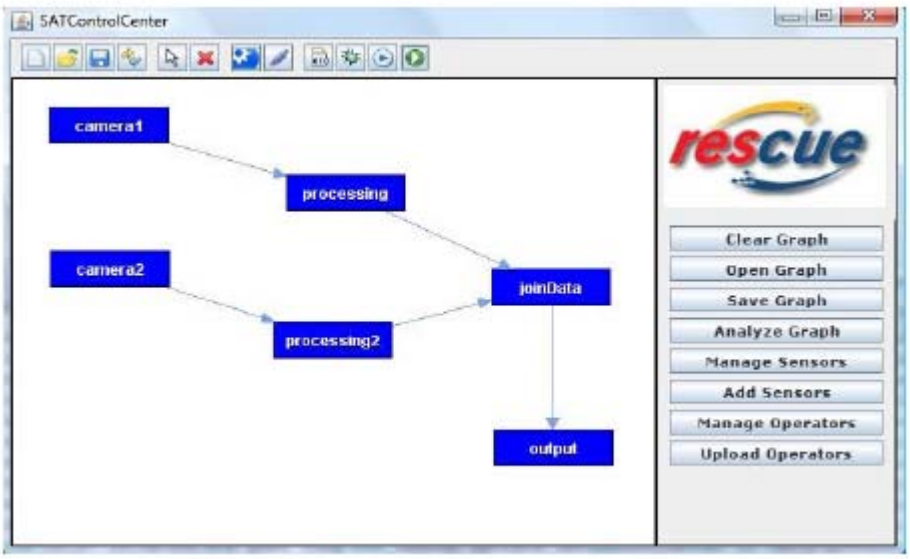
The SATRecorder allows a user to browse through the UCI campus, covering both outdoor and indoor locations. The user can connect to any of the sensors within the Responsphere infrastructure and either display or record what these sensors are sensing. The user can also select to visualize events being 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.



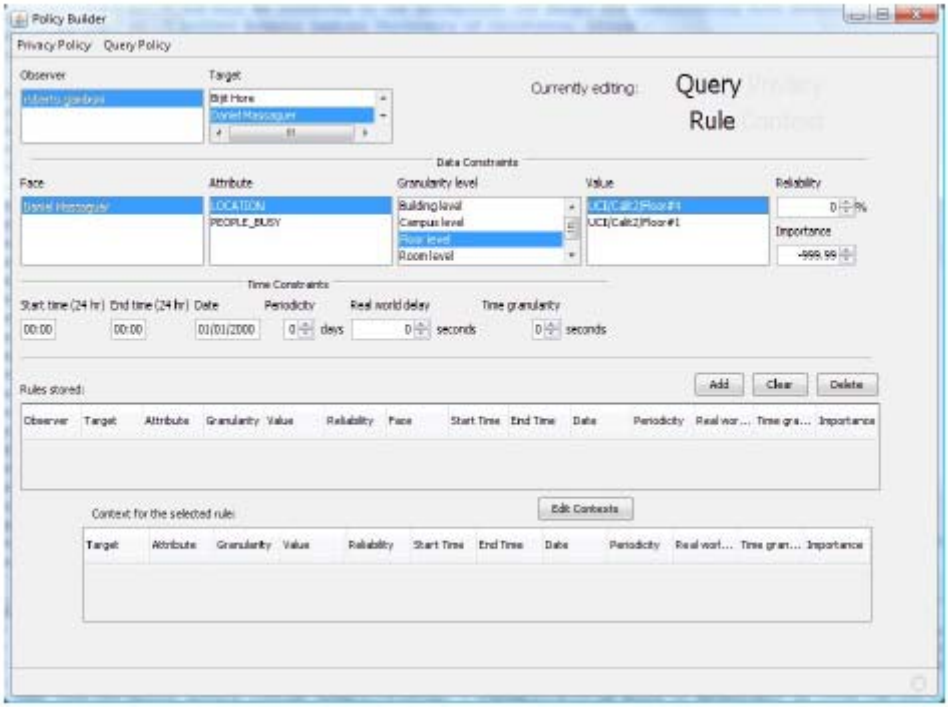
SATControlCenter

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 Disaster Portal (www.disasterportal.org) is an easily customizable web portal and set of component applications which can be used by first-responders to provide the public with real-time access to information related to disasters and emergency situations in their community. Current features include a situation overview with interactive maps, announcements and press notifications, emergency shelter status, and tools for family reunification and donation management. The Disaster Portal dramatically improves communication between first-responders/government agencies and the public, allowing for rapid dissemination of information to a wide audience.

Activities and Findings

Recent development on the Disaster Portal software has focused on documentation and packaging for additional deployments by other city or county governments. Support of the original pilot deployment for the City of Ontario, California has been transitioned to city IT resources, and a new deployment is being made by Champaign, IL. The team is in discussions with the County of San Diego for a possible large scale deployment to that region.

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.

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.

Activities and Findings

The highlight for the UCSD ResponSphere team this past year was our participation in the San Diego Science Festival's Expo Day in April, which included the largest deployment of CalMesh ever. In addition, technical progress was made in a number of areas and refinements of previous technologies continued.

San Diego Science Festival - Expo Day

Researchers from the UCSD ResponSphere and RESCUE projects participated in the grand finale of the month-long San Diego Science Festival: Expo Day at Balboa Park. More than 50,000 people attended the event held on Saturday, April, 4, 2009, which featured 200+ exhibition booths. Organizers called it "the largest one-day science gathering ever in the United States."

More than three dozen researchers (PIs, faculty, staff, postdocs, graduate and undergraduate students) were on-hand at Balboa Park to run demonstrations, provide information to visitors, and manage the wireless network and the many experiments.

The UCSD Calit2 booth featured many of the technologies developed in the ResponSphere and RESCUE projects, including the new mobile touchscreen kiosk based on the Gizmo technology (see section 0) and the new California Traffic Report application for the iPhone (see section 0). Multiple technologies (devices, software and systems) were deployed, tested and demonstrated.

In addition, a wide variety of measurements were taken, both on the day of the event and as preparation and reference samples. The huge crowds and changing network environment over the day-long event served as an excellent live real-time testbed, for CalMesh and other wireless technologies that the UCSD ResponSphere teams have developed for emergency response. Researchers tested how specific wireless technologies performed in identified areas with heavy pedestrian and cellular traffic.

This deployment has resulted in at least one new collaboration. The Balboa Park Online Collaborative (BPOC) is an organization comprised of 15 museums located in San Diego's Balboa Park. BPOC's mission includes improving museums' technology capabilities and integrating online technologies in the daily operations of museums and their interactions with patrons and collaborators. BPOC has asked the Robust Networking team to help them wirelessly connect museums in Balboa Park to help create a more unified management and online data sharing and collaboration systems.

The Calit2 San Diego Science Festival Photo Gallery is available here:
http://projects.calit2.net/gallery/main.php?g2_itemId=3436
press release: http://www.calit2.net/newsroom/release.php?id=1496

Expo Day Deployments, Demonstrations and Measurements by Project

CalMesh
At the request of the San Diego Science festival organizers, we set up a CalMesh ad-hoc wireless network covering most of the exhibit areas along the Prado (around 40+ booths), many of which would otherwise have not had WiFi connectivity or only spotty access to the Internet, much less high-speed web access. The coverage area was along the eastern part of the Prado from the Lilly Pond to the Fountain. This was the largest deployment of CalMesh ever. See Figure 1.1.

The deployment also provided an excellent opportunity to collect data, to further our research on communications in cases of emergency. Many experiments were conducted and measurements taken on the network and surrounding environment.

CalMesh is an affordable mesh networking solution enabling Internet access and team communication where the infrastructure has been compromised or damaged. It is a quickly self-organizing WiFi mesh network of small, lightweight and easily reconfigurable nodes.

The CalMesh network was linked to the Internet via the High Performance Wireless Research and Education Network (HPWREN) and a commercial provider, Sky River, both had access points on the Natural History Museum's roof. An access bonding solution from Mushroom Network Inc. aggregated the two channels together. Combined, they provided 45 megabits per second of bandwidth.

Figure 1.1.1. CalMesh deployment in Balboa Park (approximate node locations). The lily pond is where CalMesh GW4 is located (on the left of the photo), the fountain is on the right, surrounded by a circle of wide concrete. The Prado is the area in between.

For Expo Day, 10 nodes total were deployed: 8 Mesh Nodes (one open access point [AP]) and 2 Stand-alone gateway [GW] nodes (3G access and inside the Natural History Museum). Each box (node) is a WiFi Access point, supporting data, voice and video applications with a 15-hour battery and GPS. The cost is about $1000 per node. CalMesh has multiple interfaces:

Two WiFi interfaces:
- One for Mesh connectivity only where the actual routing protocol runs.
- One for Access Point only, where legacy WiFi clients can connect.

Two Ethernet interfaces:
- Internet connectivity (gateway)
- Wired access to servers
- Node maintenance

One Cellular interface
- Currently USB based cellular data devices are supported

CalMesh uses a variety of ways to connect to the Internet:
- Wired (DSL, Ethernet, Cable)
- WiFi Hotspots
- Cellular (3G)
- Satellite access

Measurements: The internet access providers (SkyRiver and HPWREN) stored traffic logs at their respective network operations centers (NOCs) that are available to us. Each CalMesh node stored traffic traces by the use of tcpdump where the IP addresses and type of traffic of each user can be recorded. In addition, each node stored the number of received and sent packets, sampled at programmable time intervals. All measurements taken in the CalMesh node were timestamped via the Network Time Protocol (NTP). In addition, some of the access points were open for the general public to study how such traffic impacted the network performance. Signal to noise ratio measurements on the move were made along the node placement route by walking up and down the Prado collecting location-aware data. Monitoring of the aggregated traffic through the backhauls was also performed to give us an idea of total bitrate for event, quality and possibly type of traffic. Data analysis is ongoing.

BlueMap
Bluetooth Malware Analysis and Prevention (BlueMap). We deployed 15 Bluetooth sensor nodes within the Expo area to record Bluetooth devices in the vicinity of each sensor node and store this data in a central database that can later be used to infer, among other things, the potential spread of mobile phone virus during a highly populated event.

Analysis of malware spread between mobile phones over short-range wireless links (Bluetooth, WiFi etc.) helps gain a better understanding of the potential for proximity driven malware spread and develops means to both detect and prevent such outbreaks. We saw 440 unique Bluetooth devices during the measurement period between 3 p.m. - 6 p.m.

CogNet Monitoring

On Expo day we conducted network monitoring using CogNet. We observed all the channels in the 2.4GHz and 5.2GHz spectrums and sampled network traffic from all the channels. We measured the channels used for CalMesh continuous capture. The results from this measurement are mainly focused on studying the network behavior as well as studying the wireless environment behavior. In addition, we visualized the network traffic environment on a portable visualization display live at the event.

Testbeds and Data Stats

Four locations were used for the traffic monitoring with a visualization node in the Calit2 booth. There were two types of devices:

- CalNodes for sampling traffic across 11 channels in 2.4 GHz (1:11 ratio)
- CogAP for visualization of Live traffic and Network state prediction using Neural Network based Cognition engine
-

The experimental time period was 8:30 a.m. to 6:00 p.m. on Festival Day and noon to 1:15 p.m. on reference days. The sampling CalNodes collected 7,076,853 packets total. The complete capture CalNodes collected 15,012,407 packets on selected channels (1, 6, 10, 11).

Results Summary

- Significant impact on the cyber world on Expo day when compared to reference sampling prior to and afterward, due to the physical world activity, was observed across several parameters (amount of traffic, number of clients, packet length) which confirmed our past observations made in previous drills.
- Key observations made:
  - Time line of active client association to CalMesh nodes
  - Spatio-temporal traffic characterization of 802.11 b/g channels (11 channels in 2.4 GHz spectrum)
- Successful visualization of Live Traffic and Network State Prediction

Cellular Network Monitoring

EVDO Cellular Network Logging. Cellular network monitoring was conducted before, during, and after the event using the Qualcomm CAIT tool. We logged physical, MAC, and upper layer information such as signal strengths, power control, frame error rates, RLP retransmission, data rates, handoff status to observe differences in the mobile users perceived performance between light load and high load conditions and to observe effects of excess number of users in an EVDO cellular network from mobile point of view.

Experiment Setup: Laptop; EVDO capable PCMCIA data card; Qualcomm CAIT software, security dongle and GPS receiver. We recorded 15 distinct pilots at Balboa Park during the Science Festival

Observations:

- Forward Link
  - Received power is significantly lower during the science fair (Active sector selection is dynamic)
  - Mobile switches to more distant sectors due to load in the nearby sectors

- Reverse Link
  - Increased transmit power
  - Mobile needs to transmit with more power due to interference in the loaded sector
- Mobile's battery will drain faster to maintain similar QoS on crowded day as compared to a normal day
-

Wireless Network/Coverage Simulation

The unpredictability of wireless environments (RF channel responses, fading, etc.) makes it difficult to deploy any wireless network without good understanding and RF simulation prior to deployment. Because of the randomness and unpredictability of wireless channels, it can 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 emergency scenarios it is impossible to have a long design/performance analysis phase before the rapid deployment. The main idea for this experiment was to define and create a process to use a 3-D laser scanner and quickly scan the deployment environment, input it into the wireless simulation tool and find the optimum locations for temporary deployment of CalMesh nodes. We used the point-cloud exemplar to model the wireless propagation environment to give a view of theoretical behavior of the system. (More information on the scans is in section 0.)

Experiment design: The MAPTEK I-Site 4400 3-D scanner was used before the event, and the data input into the EDX Wireless simulation tool to determine the best locations for CalMesh nodes to maximize coverage and capacity for wireless network during the event. During the experiment the inter-operability between 3-D scanner (formats) and EDX tool needs to be tested. Also, real signal strength and operability of the network during event must be observed to validate accuracy of design.

Outcome: The main parking area scanned successfully and relevant data collected. The size of data was around 500 Mb which was more than other experiments. This was due to extended area we intended to simulate during this event. The output format was ESRI/Arc View ASCII grid format. Since color accuracy was not important for our experiment the total scanning process took less than a day. During scanning process, 6 different points set and scanned before final interpolation to extract the actual data. The data converted to EDX .201 format using EDXCV conversion tool before feeding to EDX. The outcome of simulation indicates optimum locations for our CalMesh nodes during the event.

Observations and Analysis: As it is shown in the following figure, most of the area had a good signal strength (>-45 dBm) and at the corners there were areas with moderate signal strength (<-55 dBm). Based on this simulation results, we were confident that CalMesh locations are optimum locations to provide the best coverage for all exhibits in the central areas of exhibition as it was identified before. Lack of color information for our simulation caused a huge reduction in scanning time; six points of scanning and each about 45 minutes and smaller file size; 500 mega versus terra bytes. EDX was able to consider interference effect of the nodes on each other during simulation.

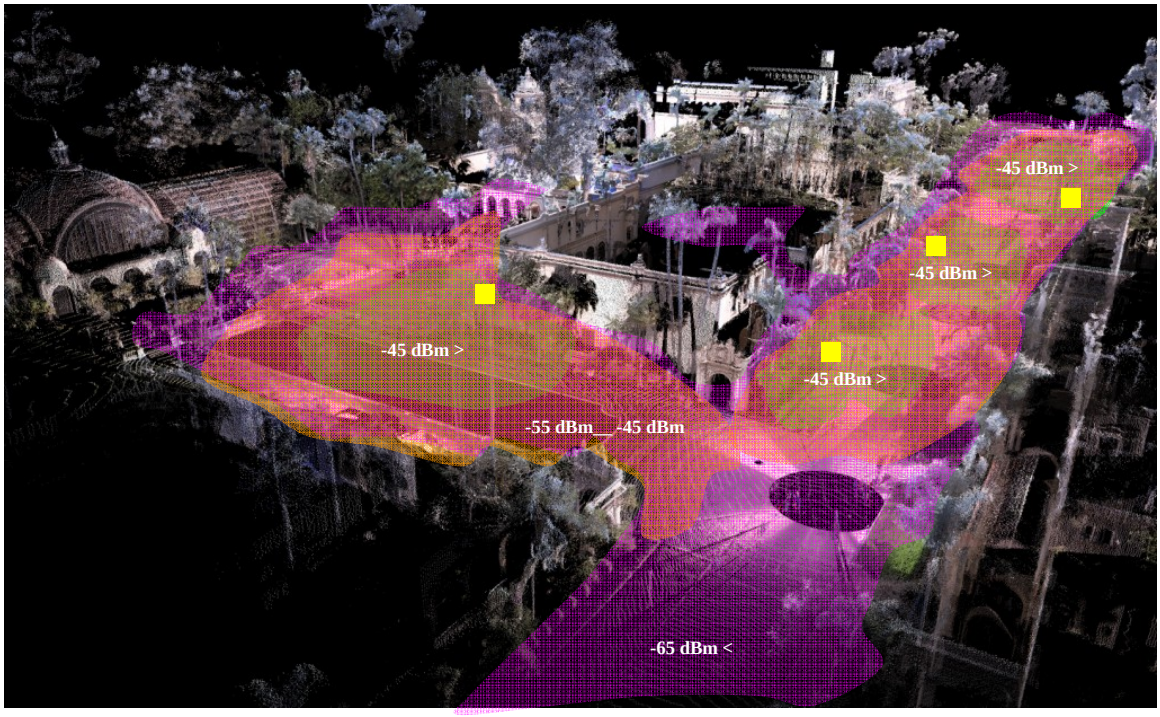


Figure 1.5.1 Overall coverage area

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. We did not use a real-time scan/simulation/deployment approach for this, however, different components tested separately and their interoperability tested in a non real-time scenario.

It is highly desirable to create a platform for:

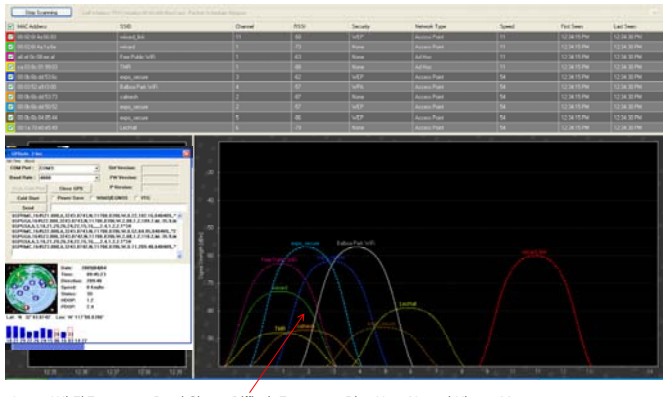
- After any natural or man-made disaster, using a 3-D scanner immediately scan the area, create the 3-D map
- The data feed into wireless simulation platform in a seamless manner to simulate and locate the optimum deployment locations
- Deployed nodes report the performance back to the tool for further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

Wireless Mesh Network Electromagnetic Interference Analysis

More information about the overall issues deploying wireless networks and other details can be found in section 0. Shown in Figure 1.6.1 below is a list graph of the WiFi nodes present during the science festival at Balboa Park in San Diego, CA in April 2009. In this case, the most of the WiFi nodes 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 Balboa Park 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 1.6.2

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.

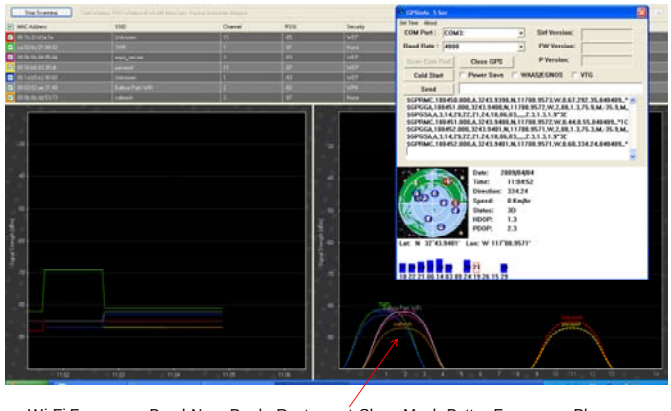
9:45AM inSSIDer & GPS Scan



Lower Wi-Fi Frequency Band Shows Difficult Frequency Plan Near Natural History Museum

3

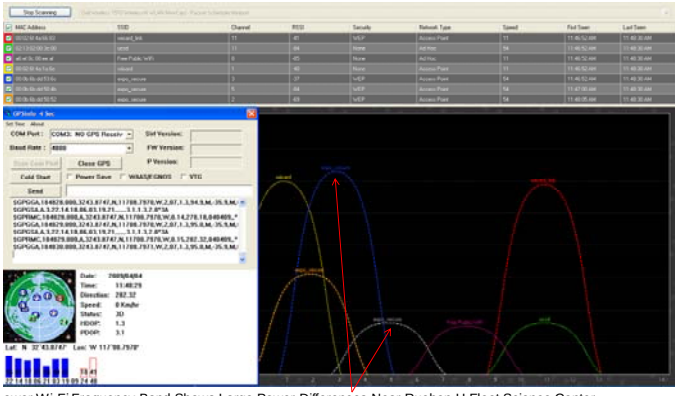
11:05AM inSSIDer & GPS Scan



Lower Wi-Fi Frequency Band Near Prado Restaurant Show Much Better Frequency Plan

4

11:50AM inSSIDer & GPS Scan



Lower Wi-Fi Frequency Band Shows Large Power Differences Near Rueben H Fleet Science Center

5

Figure 1.6.1: San Diego Balboa Park Science Festival, April 2009
WiFi Access Points and Mesh Network Nodes Sorted by Time, Location, and Signal Strength

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. Figure 1.6.3 shows the WiFi frequency bands 2.4GHz and 5.8GHz.. Many times our mesh network nodes will use 5.2GHz and 5.8GHz point-to-point backhauls in the unlicensed microwave band. During festival, no participants were using the 802.11a channels, so that our backhaul throughput was unaffected. In addition, we were able to use only 1 or 2 hop WiFi infrastructures during the festival, so that consistent 11Mb/s or 54Mb/s throughput was achieved with greater than 90% availability.

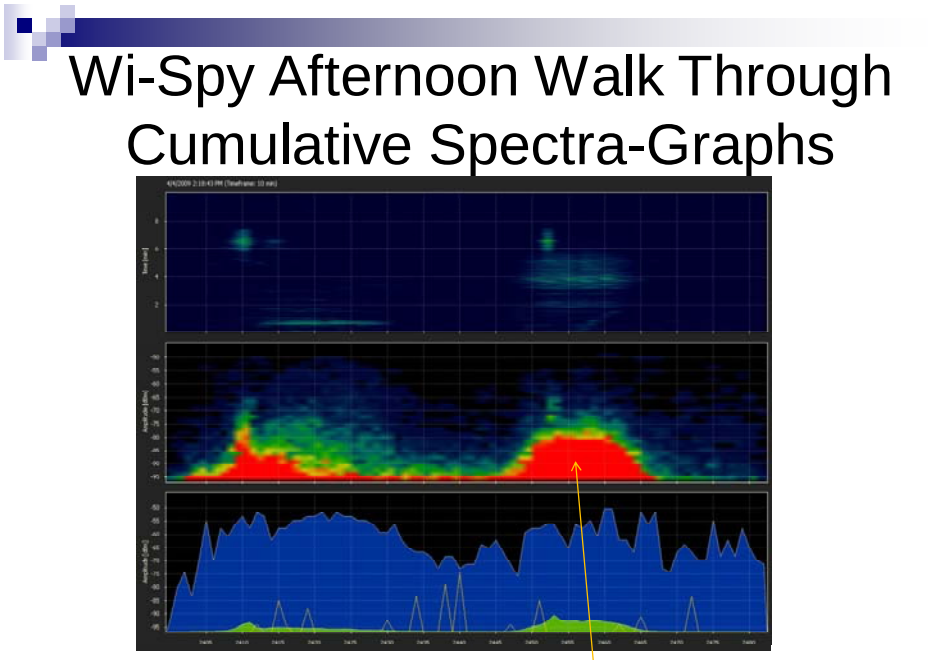


Figure 1.6.2: San Diego Balboa Park Science Festival APR-2009
Top WiFi Averaged Spectrum, Bottom WiFi Peak Spectrum

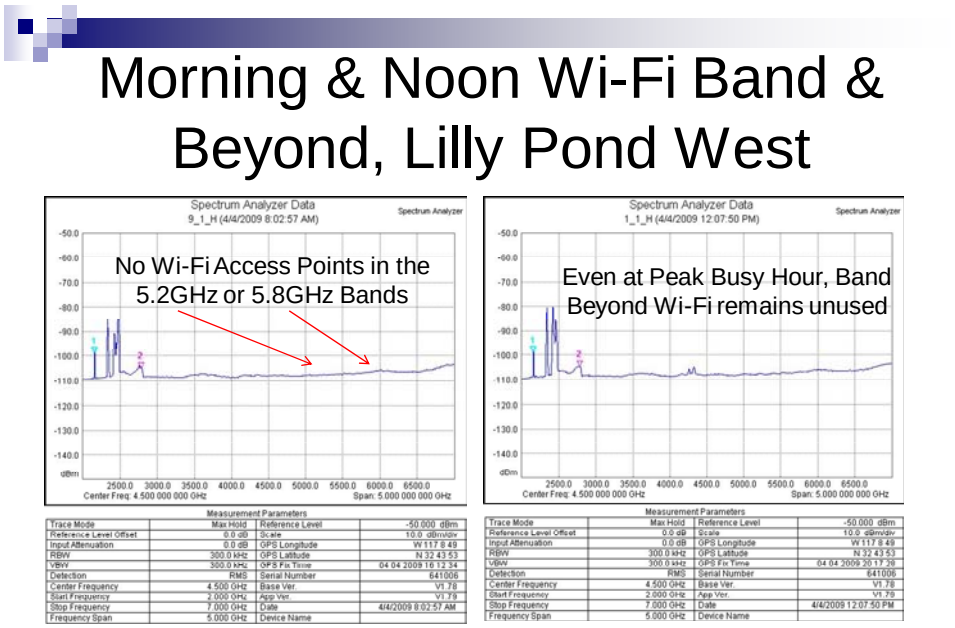
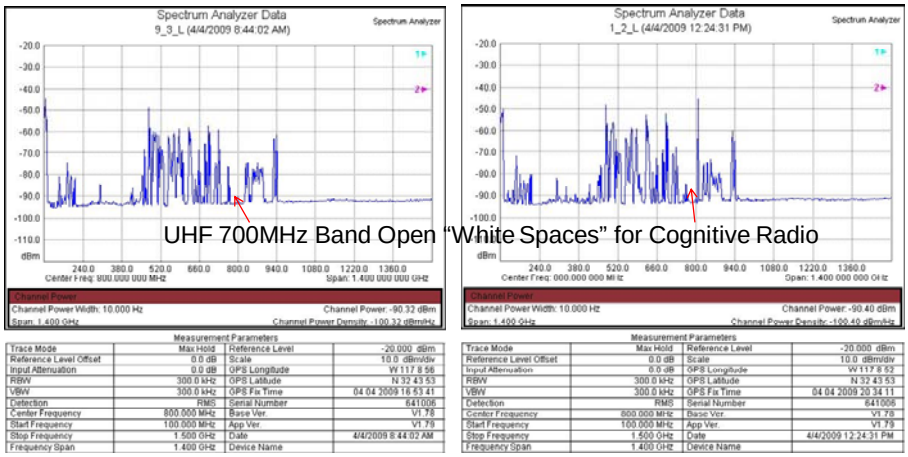


Figure 1.6.3: San Diego Balboa Park Science Festival WiFi Bands 802.11a/b/g/n

In the next set of data we will discuss the science festival measurements conducted at the potentially busiest locations in the wireless networks. Figure 1.6.4 shows the spectrum in the FM Radio, TV, and Cellular bands. In this case, almost all the users were local users with cell phones in the 800MHz CDMA band, resulting in no measurable electromagnetic interference with our network. Our volunteer spectrum measurements students were too busy orienting antennas and optimizing receivers to have time to surf the net during the festival. In some previous events, 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. In this case, we can see the need for a permanent outdoor WiFi infrastructure for the Balboa Park museum campus. Figure 1.6.5 shows the spectrum of our wireless point to point microwave backhaul. 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 demonstrate throughout the mesh during the entire festival. GIZMO is described elsewhere in the annual report in great detail, and is a based on a 1:12th scale 4-wheel drive truck. Figure 1.6.6 shows the WiFi spectrum near the popular Prado restaurant in the park. In order to fully utilize the microwave backhaul maximum data rate of 20.48Mb/s, we equipped our network nodes with 24dB gain antennas elevated on the rooftop of the natural science museum. 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 microwave backhaul reception was better than the cell phone users at the drill.

Radio, TV, and Cellular Bands
Morning & Noon, Lilly Pond West

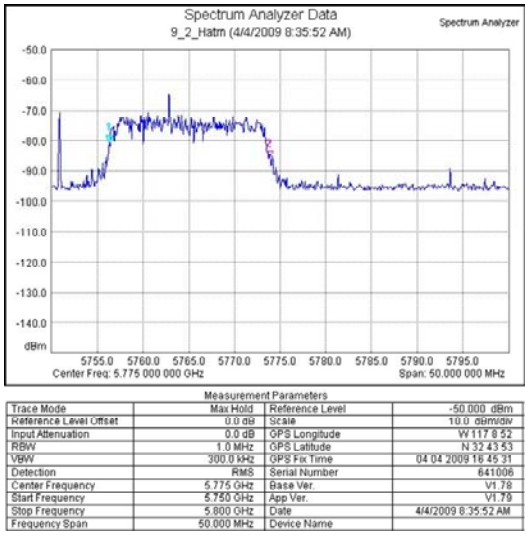


3dB to 6dB Increase in Spectral Power as Busy Hour Approaches

8

Figure 1.6.4: Balboa Park Science Festival
Radio, TV, and Cellular Bands

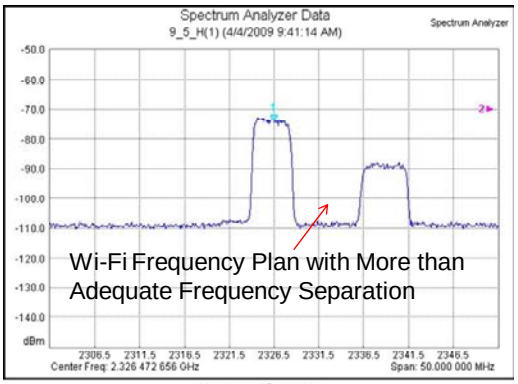
Point to Point SkyRiver BackHaul,
Roof of Natural History Museum



9

Figure 1.6.5: San Diego Balboa Park Science Festival, APR-2009
Point to Point Microwave Backhaul to Down Town San Diego

10AM Prado Restaurant



Measurement Parameters

Trace Mode	Average	Reference Level	-50.000 dBm
Trace Average	10	Scale	10.0 dBm/div
Reference Level Offset	0.0 dB	GPS Longitude	W 117 9 10
Input Attenuation	0.0 dB	GPS Latitude	N 32 43 52
RBW	300.0 kHz	GPS Fix Time	04 04 2009 17 50 52
VBW	300.0 kHz	Serial Number	641006
Detection	RMS	Base Ver.	V1.78
Center Frequency	2.326 GHz	App Ver.	V1.79
Start Frequency	2.301 GHz	Date	4/4/2009 9:41:14 AM
Stop Frequency	2.351 GHz	Device Name	
Frequency Span	50.000 MHz		

10

Figure 1.6.6: San Diego Balboa Park Science Festival, APR-2009
WiFi Band at Busy Location but Without Congestion

Gizmo

The big hit among the crowds of families in attendance was Gizmo, Calit2's family of autonomous multi-radio devices that serve as adaptable and reliable research platforms on wheels to deploy different technologies and gather sensor data in real time. They are designed to transport cameras, other sensors, and wireless access points to and around disaster sites in order to get communications going again in an emergency.

The 4-wheel drive 4-wheel steering Gizmo put a smile of the faces of dozens and dozens of kids, big and small. Children as young as 5 years old waited patiently in line to "test-drive" one (queues of a dozen or so were common throughout the day).

The mobile touchscreen kiosk based on the Gizmo technology (the Nokia Siemens Networks Gizmo operator) also made its public demo debut in the booth. A “Backpack Cam” video feed device, which could be worn while walking around the festival, was created from a Gizmo-based webcam.

Rich Feeds Integration and NUTSO/Optiportable

Rich Feeds was used to display a variety of live and real-time data (with and without terrain overlay); clicking on the indicators (tacks) revealed the data and/or detail. The data was also archived for future analysis. The following technologies were integrated:

- maps of node locations
- radio frequency (RF) spectrum sampling points
- GPS location- based tracking technology in vehicles showing the location of the Calit2 vehicles at the scene

Optiportable was deployed, using both CGLX and XDMX to show off the system's capabilities, in the booth in a 5x3 configuration (5 30"-screens across, 3 down). Various webpages, both static and dynamic (including live CogNet monitoring data graphs) were displayed, as well as the "Backpack Cam" video feed, on the XDMX side. We were also able to pull up several extremely high resolution images on the CGLX side (spread across several screens) and zoom in as far as the image resolution would allow. (You could see hikers in photos of Half-Dome in Yosemite that were too small in normal resolution.) Early in the day, there were some serious issues which were resolved by the team using an advanced configuration of the nearby MESH node using NAT, and some quick reconfiguration of Optiportable's routing.

Like NUTSO, Optiportable is portable visualization system consisting of fifteen 30-inch displays. It runs the same core system and software that NUTSO does (Rocks 5.1 x86_64, Viz 5.0, latest Hiper [CGLX])

Additional Technology Development

Laser Scanning

The laser scanning equipment and processing continue to be extremely important and are used frequently. They are currently, or have been, used in about 10 different projects (with multiple subprojects), ranging in purpose from assessment of wireless signal transfer, to cultural heritage, art history, archaeological exploration, and structural analysis of historic buildings and locations. The data across projects has been used for the development of new, rapid meshing techniques.

Powell Laboratory

The Powell Laboratory scans were performed on a structural test specimen before and after a test to determine the effectiveness of beam-column joints during earthquake loading. Using the scan data, damages were quantified by determining the amount of concrete spalling and analyzing the deflections and rotations of the specimen, and compared to common photographic techniques.

Figure - Structural specimen point cloud after failure

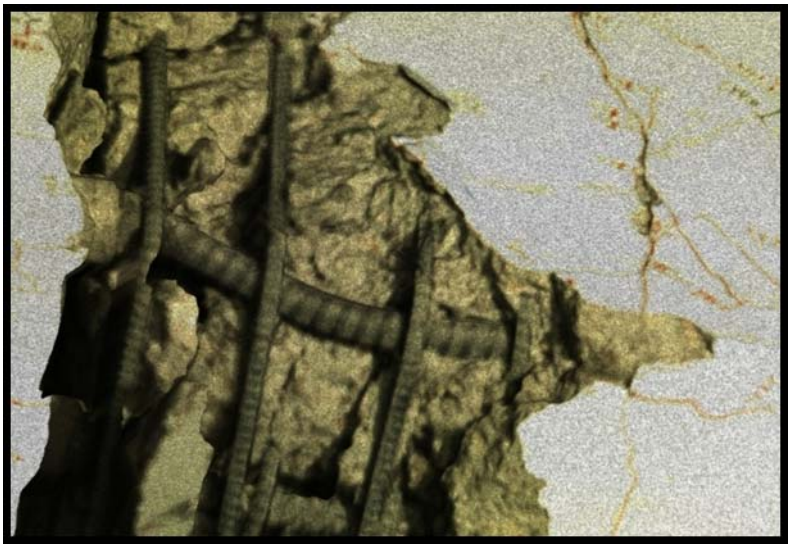


Figure - Close-up of surface mesh of failed structural specimen with overlaid texture map.

Palazzo Vecchio

The laser scanning of the Palazzo Vecchio was performed for several important reasons. First, as part of an art history exploration, the data provides a 3-D model to calibrate multi-spectral imaging for a search for a lost da Vinci painting. Additionally, some rooms have experienced substantial cracking in the walls as a result of an explosion set off in a near-by building. The laser scan data provides spatial and dimensional information about the size of the cracks and can be used with subsequent surveys to determine if the cracks are expanding. Additionally, the laser scan data are used to study the deflections of ceiling paintings. This information will be useful to art conservationists and structural engineers looking at ways to preserve both the building and the artwork for future generations to enjoy.

Figure – Laser scanning of crack in Stanza Delgi Elimente in the Palazzo Vecchio.

Palazzo Medici

The Palazzo Medici data provides important information to engineers who are currently planning and overseeing the remodeling of parts of the building. It will also be used in a similar fashion as the Palazzo Vecchio data to understand the health and condition of the building. It will also be used for art history investigations to understand various renovations and restoration attempts performed throughout the century.

Convent

The Convent of St Ursula in Florence Italy was scanned at the request of several engineers and architects employed by the Province of Florence. The engineers have been discussing the possible renovation of the building. The laser scan data provided a survey of the condition of the building and CAD information for possible building renovation strategies, as well as a first opportunity for the Italian team to see the technical capabilities of using 3D laser scanning technology.

San Diego Museum of Art (SDMA)

Three rooms and a hallway of the SDMA were scanned to assist the museum director in developing virtual plans for exhibits. By using the 3-D models, the museum director can digitally move and re-arrange paintings around the room to see in advance what an exhibit will look like before having to do the legwork of moving the actual paintings. This helps ensure that the exhibit flows in a smooth fashion and that the neighboring paintings enhance one another. This is commonly done only by looking at a plan view of the room and moving papers with labels of the paintings they represent around to decide the overall layout. Thus, this new method provides a more intuitive and more realistic way to explore options for an art gallery. Additionally, one of the paintings was scanned at high resolution (100 micrometers) to analyze its condition and generate a 3-D model to describe its condition. The canvas of this particular painting has been substantially warped. The 3-D information can be used by restoration experts to decide how to ultimately repair the painting.

Figure – 3-D model of Crivelli's

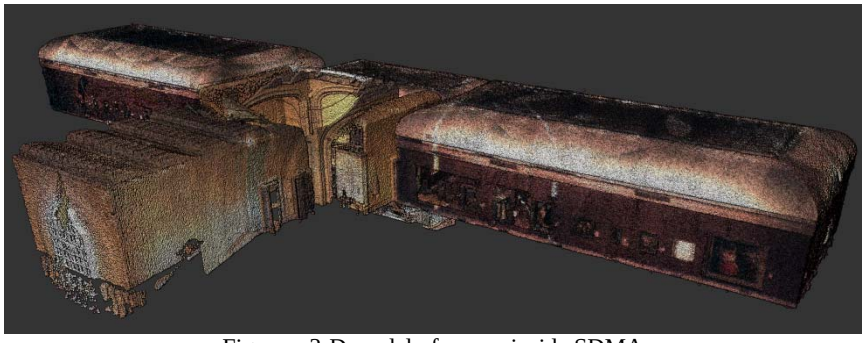


Figure – 3-D model of rooms inside SDMA

Shake Table Masonry Wall Tests

3-D laser scanning was used on this project to look at the change of masonry walls before and after they experience an earthquake. Three sets of scans were performed. One before the tests, one after the initial tests, and one after all of the tests were done and the walls were brought to failure. The scan data provides useful information about the deformations experienced by the walls from the earthquake.

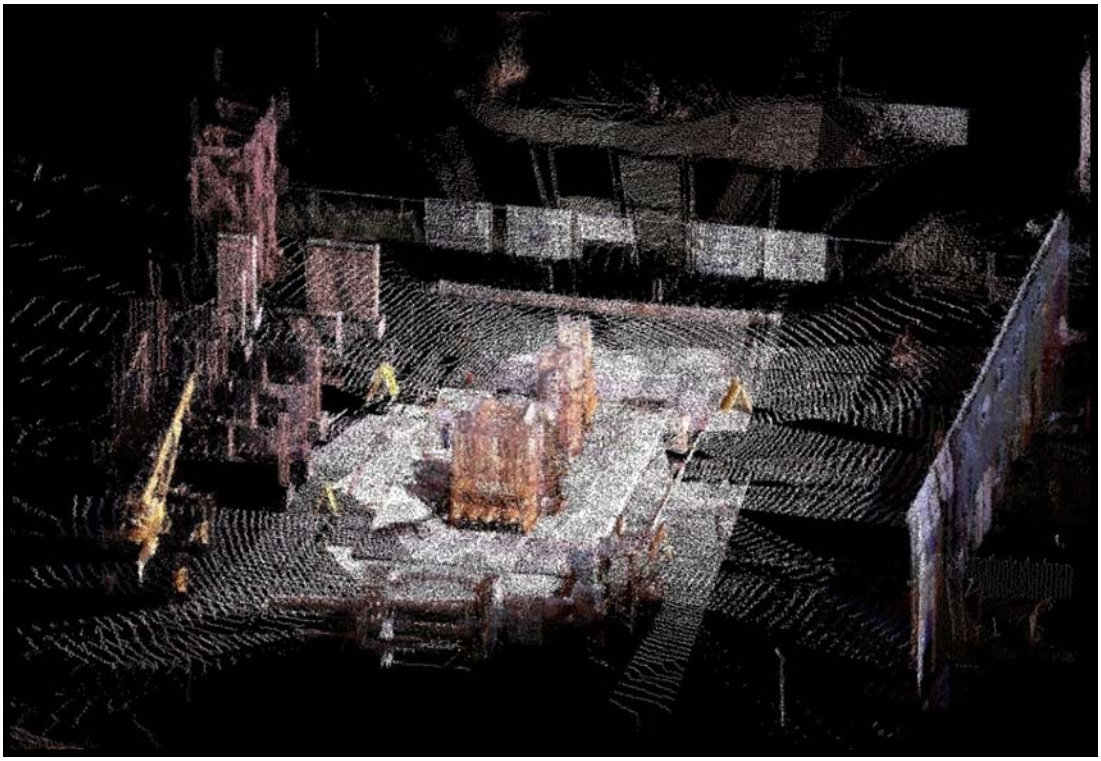


Figure - (A) LIDAR point clouds of structural specimens on the UCSD Outdoor Shake Table (B) with photodraped surface mesh

Balboa Park

The Balboa Park dataset was collected to provide detailed 3-D information to wireless engineers so that they could determine the optimal locations to set up WiFi antennas to provide a WiFi service for the park. Only a portion of the park was scanned to create a georeferenced baseline so that future work and higher resolution scans could then be performed. The data will also be important for cultural heritage work and virtual tourism of the park. See image in section 0.

Anza Borrego

The work in the Anza Borrego desert provides a unique opportunity to explore a site which was a home for Native Americans. The scan data were collected to map the location of small holes in the rocks, which were used by the native Americans to crush their Yucca plants for food.

Coors Amphitheater

The Coors Amphitheater dataset was collected to provide detailed 3-D topographical information to wireless engineers to setup a wireless emergency response unit.

Table 1 - Summary of Laser Scan Projects and Progress Report

Project	Phase	Dates	Scanner	# scan setups	# points (millions)	Resolution on target	Purpose
Powell Laboratory	Pre-test	12/3/2007	Leica ScanStation 2	8	80	5mm	Structural Analysis
	Post-test	1/18/2008	Leica ScanStation 2	11	180	1 mm	Structural Analysis
Palazzo Vecchio	I – Hall of 500, Stanza Delgi Elimente	11/21/2007-12/5/2007	Leica ScanStation 2	39	1,500	1mm on murals, <1cm elsewhere	Art History/ Cultural Heritage
	II - Hall of 500, Stanza Delgi Elimente	5/12/2008	Leica ScanStation 2	10	~200	1mm on murals, <1cm elsewhere	Art History/ Cultural Heritage
Palazzo Medici	I - Several courtyards, rooms	5/1/2008-5/12/2008	Leica ScanStation 2	25	190	1-3cm	Art History/ Cultural Heritage
	II – Rooms, staircase,	5/16/2009-Present	Leica ScanStation 2	25	~300	1-3 cm	Art History/ Cultural

	museum						Heritage
Convent	Preliminary Investigation	5/16/2008	Leica ScanStation 2	3	25.5	1-3cm	Art History/ Cultural Heritage
SDMA	Rooms	10/23/2008	I-Site 4400	13	11.4	5-10cm	Art History/ Cultural Heritage
	Crivelli painting	1/9/2009	NextEngine HD Scanner	26	11.8	0.1-0.2 mm	Art History/ Cultural Heritage
Coors Amphitheater	Parking Lot	12/19/2007	Leica ScanStation 2	2	7.6	<10 cm	Wireless signal transfer
Balboa Park	Museum section	3/26/2009	I-Site 4400	12	11.5	5-10 cm	WiFi signal transfer and degradation
Shake Table	Pre-test	9/24/2007	I-Site 4400	6	2.3	2-5 cm	Structural Analysis
	Intermediate	9/24/2007	I-Site 4400	6	1.6	2-5 cm	Structural Analysis
	Post Test	9/24/2007	I-Site 4400	7	2.6	2-5 cm	Structural Analysis
Anza	Site Exploration	4/24/2008	Leica ScanStation2	7	37	1mm on artifacts, 2-5 cm rest	Archaeology/ Cultural Heritage

Wireless Mesh Network Electromagnetic Interference Analysis

We have deployed dozens of wireless mesh network nodes at various locations and activities throughout San Diego, CA, with Expo Day this year. (For more about the Expo day deployments, see 0.) Detailed measurements of electromagnetic wireless spectrum were performed during and before these activities to improve frequency and spatial network planning. Packet losses from were reduced from 3% to 0.3% by avoiding interference caused by wireless electromagnetic signals from incumbent transmitters. Packet losses of greater than 3% 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 museum venues and rooftops with interviews of museum personnel who wish to use and deploy wireless networks. Most of these museums are operated by city commissions and private foundations with a strong interest in educational outreach. Most of the museums utilize 2.4GHz WiFi indoor communications, WLAN 10Mb/s indoor CAT5 networks, with ADSL backhauls up to 1.544Mb/s These medium-band wireless communications systems do not interfere with interfere with our mesh network node within a distance of 10m or more by virtue of their low transmit power (23-DBm) that are within the dynamic range of our low noise amplifiers in our receivers Surprisingly, the most significant communication degradation is the channel fading caused by the moist Benjamin Focus trees that obstruct wireless communications from rooftop to ground within 30m of ground based mesh network nodes. The solution is to site the mesh network node antennas at distance of 3m or more from the trees so that they remain away from the scattering leaves. The exceptions are numerous Lemon Eucalyptus trees that are transparent to our wireless mesh network nodes. We employed sufficiently directional antennas that are directed in corridors down the outdoor promenade to provide wireless network coverage to the science exhibitor's tents. We did not use our wide area coverage nodes with our 10 meter tall antenna caddy since we had adequate roof access.

Vehicles at the festival 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. See section 0 for more information.

Publications: "On the Viability of Wireless Mesh Networks for International Relief Efforts" ,Donald Kimball of Calit2 University of California San Diego, CA 92093-0436, May-2007, DSRC Wireless Communication Disaster Preparedness Workshop, Washington, DC, Email: dfkimball@ucsd.edu

Products Developed: Robotic control of mobile platforms for experimental verification of artificial intelligence algorithms requires multi-mode platforms that can accept a variant of options depending on the sensors and control channel desired. This report discusses two platforms for this purpose; Gizmo scale model "monster truck" for ground mobile experiments and Condor for air mobile experiments.

Gizmo

This year a mobile touchscreen kiosk based on the Gizmo technology (the Nokia Siemens Networks Gizmo operator) was developed and made its public demo debut in the Calit2 Expo day booth. Gizmoi was upgraded for use in rough terrains. Also, a "Backpack Cam" video feed device, which could be worn while walking around the festival, was created from a Gizmo-based webcam. See section 0 for more information.

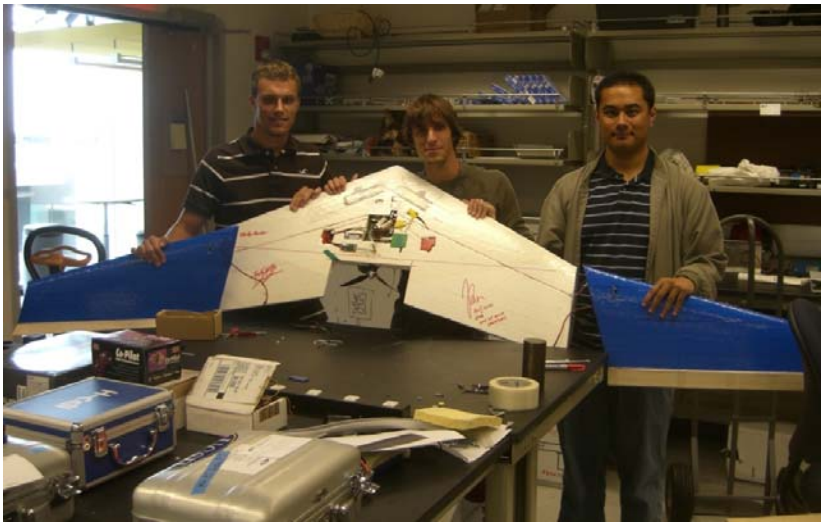
The underlying motivation of the Gizmo project is to create an autonomous multi-radio platform that can be controlled by many kinds of interfaces and can be used for a wide variety of applications, such as, disaster response environments, radio frequency (RF) mapping, remote sensors gathering data in real time, and educational purposes, as well as others.

Land Mobile: We built 3 Gizmos configured with 2.4GHz WiFi communications and control, 75MHz PCM control only, Video pan tilt 640x480 60fps, Audio ADPCM. Battery life will be increased to 4 hours by the use of duel Lithium Polymer battery packs. Include spare parts for 1 more Gizmo. Two persons will be assigned to design, build, and test these platforms.

Gizmo

Condor

The project WiFli CalMesh Condor was 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 really complicated and time consuming. Gizmo and MOP projects helped in facilitating the deployment of the CalMesh network. Even though the newly upgraded Gizmo truck can go through rough terrains, it will always be limited by possible obstacles. The WiFli CalMesh Condor offers a faster and dependable system.
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.


WiFli CalMesh Condor (with CalMesh box in foreground)

The WiFli CalMesh Condor will be able to perform autonomous station keeping over a designated area, autonomous navigation from launching area to station keeping area, and autonomous navigation from station keeping area to recovery area. In flight communications as part of ground based and airborne wireless mesh network. Bungee launch, 45 to 60 degrees from vertical with Maple seed twirling recovery.

Air-Mobile: We built 2 Condors configured with 2.4GHz WiFi communications and control, 2.4GHz Spread Spectrum control only, video pan tilt 640x480 60fps, Audio 32kb/s ADPCM. Autonomous control will be provides by GPS and stabilization autopilot. Take-off and landings accomplished with a human-in-the loop. Two persons will be assigned to design, build, and test these platforms.

- 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 an ad-hoc mesh network in the sky between our ground based nodes and other CalMesh Condors
- Forms up 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

Requirement Compliance: The topic description provides a framework for listing the advantages of Calit2's implementation in relationship to the technical and physical requirements. Table below provides a summary of compliance to the requirements.

Requirements	Details	Section
Wireless Communication & Control, Air and Ground	2.4GHz 802.11b/g, client, or peer-to-peer, fixed IP. 1 or 2 simultaneous channels (e.g Ch 1 Control & Ch 11 Video)	1.2.1, 1.2.2
Wireless Control, Ground	75MHz PCM for Human in the Loop testing	1.2.1
Wireless Control, Air	2.4GHz Spread Spectrum	1.2.2
Video	640x480 60fps	1.2.1,1,2.2
Audio	32kb/s ADPCM	1.2.1, 1.2.2

Technical Objectives: The overall performance requirements of Gizmo are as follows:

- Frequency Plan: 2.4GHz WiFi and 75MHz PCM
- Average Power Consumption: 10W
- Peak Power Consumption: 100W
- Video: 640 x 480 60fps
- Audio: 32kb/s ADPCM
- Memory: 1Gbyte
- Processor Speed: 1GHz
- Range: 100 ft indoors, 100yds outdoors
- Endurance 4 Hours

The overall performance requirements of Condor are as follows:

- Frequency Plan: 2.4GHz WiFi and 2.4GHz Spread Spectrum
- Average Power Consumption: 100W
- Peak Power Consumption: 300W
- Video: 640 x 480 60fps
- Audio: 32kb/s ADPCM
- Memory: 1Gbyte
- Processor Speed: 1GHz
- Range: 100 ft indoors, 100yds outdoors
- Endurance: 40 min no thermals, 4 hours with thermals

ResponSphere Pick-Up Truck Upgrades

The ResponSphere Chevrolet 3500 crew-cab pickup truck has added a solar powered toolbox to keep the battery charged for continuous telematics monitoring through GSM/GMSK even with the truck turned off. A NetBook interface has been added to the cab for low power net surfing with our CalNode Mobile WiFi network, and supplements our MacMini armrest computer. The Diesel truck has also been running on vegetable oil fuel for about 1 year with no degradation in performance.

Potential End-Users beyond Academic Community: Police, Firefighters, and Paramedics could utilize our vehicles in both their drills, and long term deployments. For example, this vehicle could be utilized near forest fires lasting several days, or hurricane aftermaths lasting several weeks. With the increase in Homeland Security cooperative drills, we can place our Wireless Command and Control Vehicle in the hands of end users without commercial “buy it now” pressures. For example, instead of UAVs, we could utilize the Civil Air Patrol’s light aircraft to act as a communications relay for Red Cross logistics support. Our test bed will encourage criticism and feedback from multiple agencies without intimidation. Being a university we are a neutral party that is not a threat to any agencies’ jurisdiction.

Peer to Peer Traffic System

Our automated peer to peer traffic system (http://traffic.calit2.net) has been further disseminated with an iPhone app: commuters in California equipped with the Apple iPhone can now get personalized traffic information via the "California Traffic Report," the first iPhone application from Calit2 at UCSD. In the first ten days since the app became available through Apple's App Store on Feb. 7, roughly 2,650 people have downloaded the application, and downloads continue to run at a clip of roughly 250 per day. The California Traffic Report made it into the first page of "Top Free" apps in the Travel section of the App Store. (ref: http://www.calit2.net/newsroom/release.php?id=1471)

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.

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.

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
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- 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

In year five, the core earthquake loss estimation component, InLET, has been decoupled from the MetaSIM modeling environment, and ported to Microsoft Virtual Earth. InLET was deployed at the Great Southern California ShakeOut Exercise for two agencies: i. City of Inglewood, ii. CalEMA (California Emergency Management Agency). InLET was used to assess preliminary damage and generate situational awareness for the responding agencies and the local residents for the simulated earthquake measuring 7.8 on the Richter scale. A custom version of InLET was developed with the City's building and lifeline inventory for the ShakeOut scenario. Demonstrations were made to several high profile public and private agencies, as well as NGOs. The resolution of base data was expanded to the building parcel level for the City of Inglewood, demonstrating that the platform could produce and map building level results.

In addition, the InLET platform was presented to several City of Los Angeles staff and is currently being considered for integration into the Emergency Operations Center. Participants included- Nekpen Aimiuwu, Department Emergency Coordinator, City of Los Angeles, Planning Dept; Arif Alikhan, Deputy Mayor, City of Los Angeles; Todd Chamberlain, Captain, LAPD Special Operations Bureau; Scott Kroeber, Commander, LAPD Special Operations Bureau; Olivia Mitchell, Deputy Director, City of Los Angeles Community Development; Andy Neiman,

Lieutenant, LAPD Special Operations Bureau; Richard Roupoli, Deputy Chief, LAPD Special Operations Bureau; and Tony Varela, Assistant Chief, LAFD Homeland Security. These high level end users were able to walk away with a clear understanding of how the results of research could practically be integrated into their organizational structures, as well as provided critical feedback for refining technology for end users.

Products

The primary artifact of the project is 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 incorporates a crisis simulator, a transportation simulator, and a simulator for agent based modeling (Drillsim). METASIM is envisioned as a comprehensive modeling platform for plug-and-play simulation tools for emergency managers and first responders to support response, recovery and mitigation activities.

A preliminary 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.

A description of the individual simulators and components integrated into the METASIM framework is provided below:

a) Crisis Simulator

The Crisis Simulator currently simulates an earthquake event and estimate damage and casualties at a regional scale. The crisis simulator integrates the earthquake loss estimation components of InLET, the Internet based Loss Estimation Tool.

b) 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.

c) 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.

d) 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..

Contributions

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.

Methods incorporating damage and situation assessments using simulation tool such as InLET, MetaSIM, and observation oriented remote sensing/ GIS data with GPS referenced ground photographs collected by field teams, represent a new way of generating estimates of disaster damage, when access to the affected area is restricted. Results are extremely useful to the first responder community and platforms for online visualization of damage have been implemented and used for two major earthquake events, the 2009 L'Aquila Earthquake and the 2008 Wenchuan Earthquake.

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. Bhorkar,Abhijeet; BS,Manoj. Selection Diversity based MAC Protocol for MIMO Ad hoc Wireless Networks, IEEE Globecom 2008,2008-11
2. Jafarpour,Hojjat; Hore,Bijit; Mehrotra,Sharad; Venkatasubramanian,Nalini. Subscription Subsumption Evaluation for Content-based Publish/Subscribe Systems, ACM/IFIP/USENIX Middleware 2008,2008-12
3. van der Horst,Timothy W.; Seamons,Kent E.. pwdArmor: Protecting Conventional Password-based Authentications, 24th Annual Computer Security Applications Conference (ACSAC 2008),2008-12
4. Vaisenberg,Ronen; Mehrotra,Sharad; Ramanan,Deva. Exploiting Semantics For Scheduling Data Collection From Sensors On Real-Time To Maximize Event Detection, 2009 MMCN Conference on Multimedia and Computer Networks,2009
5. Dilmaghani,Raheleh B.; Rao,Ramesh R.. A Systematic Approach to Improve Communication for Emergency Response, 2009 Hawaii International Conference on System Sciences,2009-01
6. Kalashnikov,Dmitri V.; Chen,Zhaoqi; Mehrotra,Sharad; Nuray-Turan,Rabia. Web People Search via Connection Analysis, The IEEE Transactions on Knowledge and Data Engineering,2009-01-01
7. Behm,Alexander; Ji,Shengyue; Li,Chen; Lu,Jiaheng. Space-Constrained Gram-Based Indexing for Efficient Approximate String Search, ICDE 2009,2009-03-29
8. Kalashnikov,Dmitri V.; Chen,Zhaoqi; Nuray-Turan,Rabia; Mehrotra,Sharad; Zhang,Zheng. WEST: Modern Technologies for Web People Search., In Proc. of IEEE International Conference on Data Engineering (IEEE ICDE),2009-04
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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 MAE 156B, UCSD ENG 100,UCSD ECE 158B, UCSD CSE218, UCSD CSE294

Equipment

The following table summarizes the types of equipment the UCI and UCSD Responsphere teams obtained for the project. Major purchases for UCSD in year 5 included components to help update the CalMesh and Gizmo systems and prepare them for deployment in Balboa Park for the San Diego Science Festival. In all cases, education pricing and discounts were pursued during the purchasing process.

UCSD Equipment Fabrications		
Quantity	Equipment	Usage
4	Gizmo	Test platform for self-deploying, remotely controllable wireless network nodes equipped with various kinds of field sensors Major purchases included A123 Lithium Iron Phosphate (LiFePO4) cells, Electronic Speed Controllers, 3-Phase Neodymium Permanent Magnet brushless motors, gear boxes, wheels, propellers, servos, single board Linux computes, miniPCI wireless cards, gas sensors, sonic sensor, light sensors, USB cameras, USB audio, DC-DC converters, discrete electrical and mechanical components

1	Vehicle	Components purchased and fabricated include: high efficiency polycrystalline silicon solar panels, new audio speakers, net-book PCs, high efficiency DC-AC inverter, and dual gel-cell lead-acid 12Vdc batteries, and solar to gel-cell charging modules
2	CalMesh WiFli Condor	Components purchased included Electronic Speed Controllers, propellers, servos, single board Linux computes, miniPCI wireless cards, USB cameras, USB audio, DC-DC converters, discrete electrical and mechanical components,
10	CogNodes	Cognitive radio network nodes for network traffic monitoring and measurements. Components were purchased to produce 10 additional nodes that were deployed at the Science Festival Expo.
10	CalMesh	10 Wireless ad-hoc mesh networking nodes were upgraded in preparation for deployment at the Science Festival Expo. Components purchased included power supplies, wifi cards, compact flash cards, antennae, cables,
10	BlueMap	Bluetooth Malware Analysis and Prevention nodes. 10 new nodes were fabricated for experiments/deployment on UCSD campus and also at the Science Festival. Components included enclosures, system boards, cables, heatsinks, antennae, netbook computer to drive monitoring software
UCI Equipment Fabrications		
Quantity	Equipment	Usage
4	Motes	Creation of CO sensing platform for first responders
2	CO Sensors	These sensors were wired to the motes in order to sample environmental CO levels.
2	Antenna Hardware	We fabricated outdoor antennas for our mesh routers in order to increase coverage and penetration of our network.