Polar Science and Advanced Networking

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Executive Summary

The previous decade saw an enormous explosion in the networking capabilities of computers which helped enable smaller, more mobile devices such as laptops, embedded systems, and PDAs to be very useful in field research. The Internet was forged out of various individual networks (BITNET, ARPANET, SPAN, etc.) and made navigable by early search engines such as Gopher. Very rapidly graphical browsers like Mosaic and Netscape became available and helped make the Internet accessible to casual users. Networking has now become ubiquitous and the Internet has grown from comparatively small usage by technical users to an economic engine used by ordinary people impacting a large portion of the population of the earth, both directly and indirectly.

Even with this ubiquity, there are still problems affecting research: the Internet does not easily reach the Polar regions of the earth, nor is it readily available in remote areas in temperate latitudes. Using wireless technologies such as 802.11xx, experiments can be remotely controlled and monitored, and data can be retrieved with infrequent human contact. However, using this technology over large distances requires more than a simple wireless LAN. There is also the problem of powering various electronic experiments, both attended and autonomous, in the field.

In order to begin a dialog among researchers to identify problems, discuss solutions, and explore innovative usage of various communication technologies, this Polar Science and Advanced Networking workshop brought together an interdisciplinary group of scientists and engineers with backgrounds in Polar research and advanced networking. All heavily rely on various combinations of Internet connectivity and remote sensing either in the field or at established stations. During the workshop common problems (Section 2.4) and possible solutions (Section 6.8) were identified and discussed. Surprisingly, the consensus of the members was that existing off-the-shelf technologies were adequate to solve these problems. Chapter 7 is a distillation of the findings of the workshop.

The major recommendations generated from this workshop are:

- A body should be developed to facilitate operations in polar regions, or funding should be provided for existing bodies to share knowledge and to advise new and potential users.

- A survey of polar projects should be undertaken to identify common computing, networking, and data collection techniques that could be used to better manage network resources.

- Projects performing common tasks such as using store and forward data transfer systems or data archiving could have access to a well-supported suite of software to achieve these tasks.

- Polar web sites and web cams can exist in such a way that bandwidth is not wasted (e.g. web caching and restricted access to "live" resources) if the network provider is involved.

- NSF should work to increase bandwidth and coverage (spatial and temporal).

- It was felt that field camp connectivity should be directed toward an Iridium solution using inverse multiplexing to achieve 24kbs.

- Near-term attention to power systems could prove to be cost effective in both lowering the expense of polar research and in improving the quantity and quality of the obtained scientific information.

- Standard wireless (802.11xx) works well in the field and these small LANS can be connected to the larger WAN by point-to-point connection via microwave or satellite to the Internet.

- A mentor network is proposed to share expertise with new researchers.

- Dissemination of the results of this workshop to the community should be made through various means, including this document, a website, a mentor program, and professional meetings.

- The effort started by this workshop should continue through global connectivity (cyberinfrastructure).

Table of Contents

Chapter 1. Introduction

Communications and networking at US Polar stations are significantly better than in recent years. However, there are still challenges in moving networks into the field, particularly the Dry Valleys and other locations near McMurdo and South Pole. Once such networks are deployed they will provide scientists with not only the benefit of connectivity to the Internet, but also better methods of data retrieval from sensors and interaction with the experiment hardware. In certain circumstances, such as operation in winter, many important scientific areas of study now impossible may be enabled.

This 2-1/2 day workshop drew investigators from two NSF entities: the Office of Polar Programs (OPP) and the Directorate for Computer and Information Science and Engineering (CISE). In addition, several engineers from the business community also attended.

The purposes of this workshop were to:

- Identify specific problems in polar communications and networking, that can possibly be solved by innovative and experimental technology.
- Provide a venue for participants to explore possible solutions.
- Establish teams of interested researchers to work on solving specific problems that might lead to the development of new cross-disciplinary proposals.
- Summarize the current and projected states of wireless, sensor, and power technologies for various field locations.
- Produce a workshop proceedings that would provide an overview of the workshop.
- Produce a compact PowerPoint presentation with notes that can be used by both OPP and CISE members to spread information about the problems of improving communication in polar regions.
- Create a website to present information about the workshop and to provide easy access to the materials that it generated.
- Create a listserv for facilitating discussions among interested researchers.
- To relate the ideas put forward in the NSF Atkins report on cyberinfrastructure to the development of cyberinfrastructure in the polar regions.

Specific topics of discussion were:

- Wireless WAN in the dry valleys
- Wireless WAN in various field camps
- Power solutions for winter operations
- Novel approaches to remote sensing, data retrieval, and experiment control

1.1 Program

The first day of the workshop consisted of 15-minute presentations, each with 5 additional minutes for questions and answers. The presentations served to introduce participants and familiarize the group with the types of research and problems encountered in the various disciplines. While some topics of discussion were generated from these presentations, the major topics were the ones listed in the introduction. The slides presented at the talks and the video of the talks are available on the CD that comes with this report and also at http://polar.umcs.maine.edu/.

1.2 Schedule

Day 1 - Introductions and Presentations

Time	Speaker	Title
8:00 - 8:20	Coffee, Setup, Registration	
8:20 - 9:00	Opening Remarks	
9:00 - 9:20	Darryn Schneider	Computing & Network Requirements of the AMANDA & IceCube Neutrino Telescopes
9:20 - 9:40	Randall Davis	Communications and Networking for Field Biologists: What We Would Like to Have
9:40 - 10:00	Peter Doran	Autonomous Hydrometeorological and Geochemical Measurements in the McMurdo Dry Valleys
10:00 - 10:20	Alan Schoenwald Scott Kulinski	Present and Future Wireless Strategies
10:20 - 10:40	Break	
10:40 - 11:00	Tony Hansen	Better Communications, Technology Development: Empowering Smaller Science in Antarctica
11:00 - 11:20	Jim Moore	Communications in Remote Regions Challenges and Opportunities for Arctic and Mid-Latitude Field Projects

11:20 - 11:40	Todd Valentic	Experiences With Wireless in the Arctic and Remote Data Retrieval Using the Data Transport Network
11:40 - 12:00	Lunch	
1:30 - 1:50	Glenn Prescott	Prism – Polar Radar for Ice Sheet Measurements
1:50 - 2:10	Robert Durst	Delay-Tolerant Networking: An Approach to Communicating in Intermittently Connected Environments
2:10 - 2:30	Frank Vernon	HPWREN and ROADNet – Sensor Network Testbeds
2:30 - 2:50	Tom Williams	Wireless Issues
2:50 - 3:10	David Nagel	Power and Systems for Wireless Sensing
3:10 - 3:30	Break	
3:30 - 5:30	Discussion	

DAY 2 – DISCUSSIONS AND DRAFTING OF REPORT

8:00 - 8:15	Coffee
8:15 - 12:00	Discussion
12:00 - 1:30	Lunch
1:30 - 3:30	Continued discussion
3:30 - 3:45	Break
3:45 - 6:00	Writing summaries of discussion, recommendations, etc.

DAY 3 - DRAFTING OF REPORT

8:00 - 8:15	Coffee
8:15 - 8:25	Organize for writing summaries/recommendations of various discussion topics
8:25 - 12:00	Writing summaries/recommendations

12:00 - 12:30	Wrap-up and summary of workshop
12:30	Workshop ends

1.3 Dissemination of Results

Hard copies of the document produced from the workshop will be distributed to the workshop attendees and other interested individuals. A website will be created that will provide a central source for all presentations, documents, videos, and any follow-up discussions. For more details, see Chapter 6.

Organizers and Editors of Proceedings

Dr. Robert Loewenstein
Dr. George Markowsky

Workshop Invited Contributors

Dr. Richard Beck
Dr. Rhett Butler
Dr. Randall Davis
Dr. Peter Doran
Mr. Robert Durst
Dr. Tony Hansen
Dr. Paul Hanson
Mr. Scott Kulinski
Mr. James Moore
Dr. David Nagel
Dr. Glenn Prescott
Dr. Darryn Schneider
Mr. Alan Schoenwald
Dr. Todd Valentic
Dr. Frank Vernon
Mr. Tom Williams

Other Attendees

Dr. Thomas Green
Dr. Deneb Karentz
Dr. Mari Maeda
Dr. Vladimir Papitashvili
Mr. Patrick Smith
Dr. Luis Tupas

Chapter 2. Survey of Current Situation

This chapter reviews the state of affairs in polar networking and research. This paves the way for various recommendations in subsequent chapters. We review the state of connectivity in the polar regions, the state of power systems in the polar regions, and technical problems that some of the researchers felt needed to be addressed.

2.1 Overview of Polar Communications

In our presentations and discussions the typical applications cited include:

- Intelligent sensors (arrays), networked with adaptable operating configurations
- Low data rate burst telemetry -- environmental sensors
- Store/forward data transfers
- Remote housekeeping
- Remote control
- Low refresh high-resolution Web cams
- On-line broadband Internet for ftp, ssh, http, etc.
- Streaming real-time digital video
- Voice over Internet Protocol (VoIP)
- Educational outreach

Overall, the discussion of communications focused on the use of networking over various distance scales, from very local to global. The difference was recognized between field locations and large, established sites such as McMurdo Station; most discussion centered on field use, both manned and autonomous. For autonomous field sites, dependable power generation was a prime topic.

A distinction was drawn between communications in the Antarctic and Arctic. Some participants felt that, in some ways, Antarctic solutions are facilitated by a central technical agent (RPSC - Raytheon Polar Services Company) which serves the entire continent and research vessels. For grantees, communications solutions may already be worked out and all that is needed is issuance of the appropriate device. The Arctic, having no global counterpart to RPSC, tends to have somewhat more complicated and diverse solutions because the research may extend over many countries with different political, technical and legal infrastructures. In some cases, individual research groups usually work out their own solutions.

For voice systems, the requirement that they be compatible with other systems was stressed. They should fit into the work environment seamlessly, and be interoperable with different user platforms (field, camp, main station). They should be small and portable, reliable, provide universal access, and be able to interconnect with the global public switched telephone network (PSTN). Similarly, networks must provide seamless compatibility with different platforms: data, video and audio, must be able to service mobile field personnel, field camps, animal-borne instruments, and autonomous stations. They must provide broadband capabilities (e.g., capable of real-time 30 fps video), use little power, be portable, be reliable, provide good coverage, be easy to access, and provide global access through satellite and other links.

Details on the listed applications may be found in the on-line documents and videos of the presentations at http://www.polar.umcs.maine.edu/.

2.2 The Problem of Polar Connectivity

Polar research is conducted in continental sized regions at or beyond the reach of conventional global telecommunications infrastructure. Conventional geostationary communications satellites are solutions only to ~ 79° N/S. Terrestrial cables are rare (e.g., Alaska United and Svalbard cable), because scattered population centers provide sparse islands of connectivity. Extended field operations in remote regions, however, require that scientists interact with home institutions for support and administrative purposes. Furthermore, the trend in instrumentation is toward autonomous data collection with remote, on-line interaction.

The geography of networking bypasses the polar regions, along with other sparsely populated areas. Figure 2.1 is taken from *Modeling the Internet's Large-Scale Topology*[1] by Soon-Hyung Yook, Hawoong Jeong, and Albert-László Barabási. As they point out in their paper: "*Note that while in economically developed nations there are visibly strong correlations between population and router density, in the rest of the world Internet access is sparse, limited to urban areas characterized by population density peaks.*"

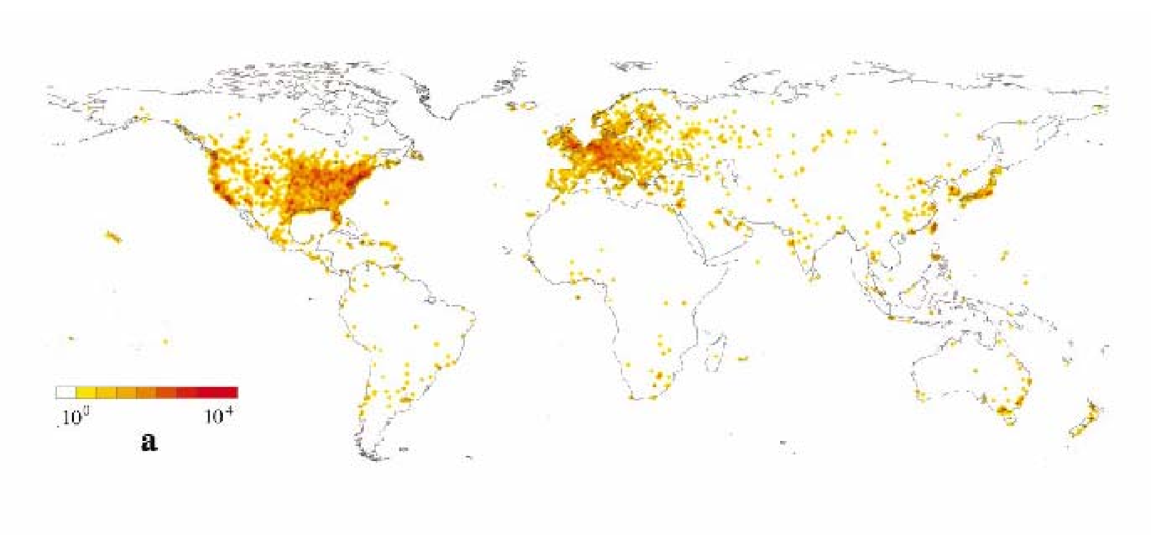

Figure 2.1. Worldwide Internet Router Density

Investigation of coverage provided by satellite, cellular. and fiber in the polar regions shows that coverage is sparse. For the Arctic, some sample networks are provided by SES

[1] http://www.nd.edu/~networks/PDF/Modeling 2002.pdf. The paper appeared in **PNAS**, October 15, 2002, no. 21, 13382-13386.

Americom[2], ACS Wireless Cellular Coverage[3], GCI's Alyeska Fiber[4], and the Alaska United Fiber[5].

2.3 Power Systems for Data and Voice Communications

Currently in Antarctica there are several types of power systems being used with varying degrees of success during the Austral Summer as well as winter. Many of the systems currently in use have evolved over a period of years based on lessons learned with previous attempts at providing power to remote locations. This section provides information on the systems currently in use in Antarctica.

2.3.1 Austral Summer

The current generation of power systems used by repeaters, Optaphone RF telephone systems, Data-Linc 900MHz spread spectrum equipment and 802.11xx equipment have all evolved over the years to fit the specific needs of technicians and limitations set by deployment locations. The current design in use for these various packages all share a focus on simplicity.

VHF repeaters are built to be man-portable weighing in at 180 Lbs. Not counting radios and repeater controller, the only other active components within the repeater package are the charge controller and the low voltage disconnect. Power draw when the radio equipment is at idle averages around 700mA. During transmit the current draw on batteries increases to 5 Amps. (This of course depends upon the level of power which the transmitter is set to.)

Two 100AH Batteries were found to be sufficient to run the repeater for approximately 4 days without a recharge. Larger units that were used in the past incorporating six or even more batteries would carry a load without recharging for a longer time than the current system, however they were found to be more trouble than they were worth. This was often due to the fact that when weather conditions did deteriorate and severe icing occurred, there were no indications that a problem existed until the units actually failed. Weather condition and system health monitoring could have potentially prevented some of these failures, however it needs to be stressed that often times the same poor weather conditions affecting the equipment in the field prevent helicopter flights for repair/maintenance as well.

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[2] http://www.ses-americom.com/
[3] http://www.acsalaska.com/
[4] http://www.gci.com/ & http://www.alyeska-pipe.com/
[5] http://www.alaskaunited.com/

Figure 2.2. Picture of a typical VHF repeater package showing radios, duplexer, repeater controller, batteries, low voltage disconnect, and charge controller.

Figure 2.3. Two pictures showing the same repeater site on the top of Mt. Terror. The snow covering the repeater in the left picture is actually very hard and requires nothing less than an ice axe for removal.

Because of the limited helicopter support, weight and portability were the major issues that pushed the current design used in the field today. Power for the current design consists of two 90 to 110 watt solar panels per unit and a simple solar regulator and LVD (low voltage disconnect) that were found to work well together. Freezing of the batteries has not been a major issue so far with the current design as long as the batteries are being exercised.

Once a prolonged period of inactivity takes place (typically 5-7 days without input from solar panels) batteries do freeze and the approach for repair is a single helicopter flight to the site for battery swap out. The type of battery cells being used for all of the smaller communications packages are of the absorbed glass mat type. The following URLs lead to some of the specific products currently in use.

http://www.lifelinebatteries.com
http://www.bpspowersu.com/products/sunlyte.htm

Figure 2.4. Voice and data equipment installed on a mountain top location.

Currently with the smaller communications packages deployed in the field there is no use of wind energy. Small wind generators have been tried in the past with limited/poor success.

The current design we are using works very well for several reasons.

- In the event that there is a failure, maintenance consists of another unit being brought out to the faulty unit's location and being activated.
- It is cost effective
- Components are available commercially off the shelf
- It is easily manufactured

2.3.2 Austral Year-round

Proven methods that have been used at and around McMurdo Station and are able to provide reliable power throughout the entire year typically consist of much larger systems. Not only are these power systems larger in footprint, they also use a combination of wind, solar and diesel/gas generators. System control and data acquisition is a normal feature found in these hybrid power units and is a useful tool for maintaining the site as well as monitoring the various systems that one would expect with a complex hybrid power station of this type. The battery banks used in these systems were designed to carry a load throughout the winter and are much larger than what one would find in the portable units.

Figure 2.5. Battery bank located at Black Island.

As can be seen from the photos, these larger systems that are designed for winter operations have fairly large investments made in the area of power reserves. Diesel generators provide the majority of power used to recharge the battery banks during the winter.

Figure 2.6. Diesel generators located at Black Island.

Figure 2.7. Fuel reserves at Black Island.

The wind generators used at these larger sites are very large and robust units that are capable of surviving sustained winds in excess of 100MPH. During the winter when solar power is essentially non-existent, wind energy only provides approximately 15% of the power available to recharge the battery.

Figure 2.8. HR3 wind generator

Black Island, Bull Pass, and Mt. Newall are all sites that rely on the use of fuel for power generation during the winter. Gas/Diesel power generation is currently the only proven/truly reliable method of ensuring the survivability of a site during this time of the year. One more thing to keep in mind when looking at these larger sites with 24/7 winter power is that they have been designed for redundancy in the event of a failure. This approach has obvious drawbacks when deploying a smaller system in the field.

2.4 Specific Problems that Need Attention

Besides the general problems faced by polar scientists, the workshop discussion produced some specific problems, which we briefly present below.

Richard Beck felt that attention needs to be paid to increasing bandwidth and mobility.

Rhett Butler felt that there is a pressing need for global telemetry at speeds greater than 9.6 KBps.

Peter Doran felt that there was a need to address the problem of year-round data telemetry of Campbell data logger-based platforms, and two-way communications (e.g. ability to reprogram, control instruments) from some of the Campbell loggers and instruments on various other platforms (e.g. cameras).

Robert C. Durst is looking for a good set of delay-tolerant applications to test our DTN systems with.

Tony D. Hansen is looking for better connection between instrumentation and engineering providers, and science customers.

Paul C. Hanson is looking for good power for winter use, and for methods that route data from diverse sources once it reaches the laboratory.

Scott J. Kulinski would like to see the creation of a technical support R&D group to interface with the researchers, solve problems, etc.

George Markowsky would like to see greater connectivity for field scientists.

James Moore would like to see the following:

- Ingestion of time critical data for operational decision making (e.g. satellite data, severe weather alerts)
- Increased participation by program managers and investigators in project meetings (video conference)
- Mobile capabilities for video conferencing
- Increased opportunities for interdisciplinary data collection/research with better communications, international collaboration/interactions
- Increase outreach and education opportunities
- Use field projects as a test bed for new concepts and implementation strategies
- The implementation of remotely controlled field projects
- Coordination of facilities for multidisciplinary data collection (ships, aircraft, UAVs, RPVs)
- Increased requirements for data collection in multidisciplinary projects (coverage, bandwidth, etc.)
- Capability for in-field quality control and instrument or facility status
- Real-time access to long term monitoring site data (consider larger areal coverage ~50km)
- Network security in a "hacker rich" environment
- Negotiation of short term broadband leases
- Support for complex project command and control capabilities

David J. Nagel is interested in expanding the scope of wireless sensor systems.

Darryn Schneider wants to see 24/7 networks at South Pole that can carry a high volume of data out of pole daily ramping from 9 GB/day in 2005 to 25 GB/day in 2009.

Alan Schoenwald is concerned about financial problems in connection with creating the necessary networks.

Patrick D. Smith wants to see clarity in research communities' needs so as to establish a roadmap to build common infrastructure and then evolve it. The goal should be to provide a utility to the researcher with a common form and function.

Luis M. Tupas wants to see an efficient and reliable voice and data communication at remote field study sites in the Arctic and from research vessels operating in the Arctic Ocean. He that we should address the needs of individual science projects, which rely on human supported or autonomous means to conduct field research and access their staff or instrumentation at these sites. We need to find ways to provide technical resources for scientists to make their work more efficient.

Todd Valentic wants to see the following:

- Methods for dealing with unreliable networks
- Autonomous systems
- Power systems for long-term (~1 year) unattended operations

Chapter 3. Networking Issues

3.1 Workshop Connections developed for Sensor Networks

3.1.1 Overview

At the NSF-sponsored *Workshop on Cyberinfrastructure for Environmental Research and Education* (Oct. 2002), the integrated management of distributed, heterogeneous real-time sensor data was identified as a major research challenge. In the near term, ubiquitous networks of sensors providing real-time information over the Internet will revolutionize our capacity to study and respond to changes in our environment. By integrating real-time data collected for multiple purposes and making that information available to multiple users, an assortment of autonomous environmental-sensing projects will be transformed into a multidisciplinary, real-time data grid for scientific research, emergency response, informed decision-making, education, and outreach.

The Real-time Observatories, Application, and Data management Network (ROADNet) Program developed at UCSD and the Data Transport Network developed at SRI International both aim to develop an integrated, seamless, and transparent environmental information networks that will deliver geophysical, oceanographic, hydrological, ecological, and physical data to a variety of users in real-time or near real-time. The technologies developed through these research projects will create systems that will

- dynamically adapt downstream processing, cataloging, and data access interfaces when sensors are added or removed from the system;
- provide for real-time processing and monitoring of data streams--detecting events, and triggering computations and other actions;
- integrate heterogeneous data from multiple (signal) domains; and
- provide for large-scale archival and querying of “consolidated” data.

3.1.2 ROADNet

Southern California’s Real-time Observatories, Applications, and Data management Network (ROADNet) program is developing novel real-time data management technologies. Our research is working toward:

- Demonstrating the feasibility of adapting powerful “Data Grid” technologies to the unique challenges associated with the management and manipulation of real-time data. Our technologies will address the fundamental problems of:
    - Real-time processing – monitoring streams of data, detecting events, triggering computations and other actions;
    - Data integration – handling heterogeneous data from multiple (signal) domains;

  - Distribution – federating multi-domain sensor and embedded system networks for transparent access while providing persistent large-scale archival and querying of "consolidated" data.

- Integrating real-time data collected for multiple purposes, transforming an assortment of autonomous environmental-sensing projects into a multidisciplinary, real-time data grid for research and education. The middleware developed in this program will support scientific research in Southern California, and make information available via the Internet for emergency response, informed decision-making, education and outreach.

- Creating technical solutions that are essential for the success of large-scale NSF initiatives in the Earth sciences (EarthScope), ocean sciences (OOI- Ocean Observatories Initiative), biological sciences (NEON - National Ecological Observatory Network) and in civil engineering (NEES - Network for Earthquake Engineering Simulation). Each of these large scale initiatives aims to collect real-time data from thousands of sensors, and each will require new technologies to process, manage, and communicate real-time multidisciplinary environmental data on regional, national, and global scales.

3.1.3 Data Transport Network

The Data Transport Network is a data retrieval system designed at SRI International accessing instrumentation at remote field sites. A common problem faced by researchers with instrumentation at remote field sites is how to reliably access their data files over network connections that are often unreliable and limited in bandwidth. We experience such issues at the Sondrestrom Incoherent Scatter Radar Facility in Greenland, and have developed the Data Transport Network as a means to overcome them. The Transport Network collects data files written locally by instruments and buffers them up for delivery to other sites across the Internet. The files are sent as attachments in messages posted to news groups over a private network of Usenet server. If the network connection goes down, the files are queued up in the local news server until the network is available. The instruments themselves are insulated from these network interruptions. To reduce the amount of data that needs to be transmitted, we also have the means to integrate post-processing programs. The system has been successfully delivering data from the radar, lidar, and imagers at Sondrestrom for the past couple of years.

Current work on the Transport Network is being funded through a grant from the NSF Information Technology Research program. We have extended it for data delivery and system monitoring of meteor radars at the South Pole and an autonomous instrument platform on the North Slope of Alaska. There have been some novel applications as well, such as a space weather alert system and real-time instrument displays.

3.1.4 Application Examples: Data Traffic Control for Buoys and Spacecraft

In buoy deployments at the Center for Limnology (University of Wisconsin), we have encountered communications challenges that have their roots in data source heterogeneities, as well as diversity of needs by data customers. Our buoys sample lakes in discrete modalities. The sampling frequencies are different among sensors and buoys, and the scheduling of data transmission from buoys varies. The record structures of the data are variable, because they depend on the needs of the science. Thus, software written to debrief buoys and manage data files must be savvy to the heterogeneities in the source data, and must be capable of file management that prevents loss due to simple, but important issues, such as overwriting files. Compounding the difficulty of the scenario is that there are multiple customers of the data. These include technicians monitoring sensor performance and data transmission, software engineers who port data to the Web, scientists who want to view near-live data, and information managers who archive data in relational databases. These issues will ultimately cripple data communications and management as our embedded sensor networks grow in size.

Data Transport Network (newsgroup-based data retrieval system; Todd, SRI) provides a solution to this problem. This software architecture, which was borrowed from newsgroup-based data retrieval systems, acts as a traffic controller for incoming data. It handles data from disparate sources, in different formats, with varying shelf-lives, arriving at differing frequencies. It informs customers of the data that their data has arrived, and it facilitates subscription to data sources from diverse customers. And it scales to the size required for moderate to large embedded sensor networks.

Robert Durst at MITRE is exploring delay tolerant networking methods with applications toward spacecraft communications and Mars rovers. He sees a direct application of the data retrieval strategies for integrating instrument data feeds on the satellite. The concept is to provide a software platform for coordinating the outputs of different instruments with integrated data processing and reduction. We have begun discussions on how to adapt to the smaller constrained computing and power resources present aboard the satellite.

3.2 Network Utilization

3.2.1 Problems

- People resources are wasted by the duplication of efforts to achieve common tasks, such as data archiving and transfer.
- Bandwidth resources are wasted through inefficient practices such as transfers over TCP/IP instead of store/forward systems.
- Polar web sites and web cams are important, especially for outreach. However they are resource intensive in an environment that is resource scarce.
- Users don't do security (and shouldn't have to).

- Lack of knowledge of network capabilities may limit the scope of research proposals.

- In Arctic regions, there is a tension in resource use between the needs of science and the needs of the local community that results in conflicts.

3.2.2 Solutions

3.2.2.1 User-oriented solutions

- A body should be developed to facilitate operations in polar regions, or funding should be provided for existing bodies to share knowledge and to advise new and potential users.

- Projects should be advised on methodologies that are desirable practices when working on polar networks via a Best Practices document.

- Resources are required to help researchers deal with network security in a way that does not impose workloads or restricting science.

3.3.2.2 Infrastructure (provider)-oriented solutions

- A survey of polar projects should be undertaken to identify common computing, networking, and data collection techniques that could be used to better manage network resources.

- Polar web sites and web cams can exist in such a way that bandwidth is not wasted (e.g. web caching and restricted access to "live" resources) if the network provider is involved.

- Projects performing common tasks such as using store and forward data transfer systems or data archiving could have access to a well-supported suite of software to achieve these tasks.

- Increase bandwidth, and coverage (spatial and temporal).

Chapter 4. The Problem of Power

4.1 Abstract

Power and instrumentation support for polar research at remote unattended sites is both critically necessary and amenable to very significant near-term improvements. These improvements fall into two major categories: **improved information and procedures**, and development of **better power sources** and **lower-power instruments**. Recommendations are made in each of these areas. They are likely to be cost effective by both reducing costs and improving polar research.

4.2 Introduction

Electrical power is essential for research in the Antarctic and Arctic. Like data communications, it is a costly and unavoidable requirement, but is inescapably an ancillary 'support' function. Combining these two requirements with that of thermal and environmental management, we arrive at the basic **instrumentation support package**. Improvements in the cost effective provision of power will enable more scientific research to be performed for two reasons. Lower costs for power will, in principle, release operational funds for research. More importantly, increasing the effectiveness and reliability of power sources translates into improvements in the amount and quality of data available to science, regardless of the disciplines involved in the research. However, power and instrumentation considerations are influenced heavily by the research scenarios and activities.

4.3 Three Categories of Deployment Locations

Instrumentation systems for polar research vary widely in the levels of power they provide and many other characteristics. Three primary scenarios for power use are <u>base camps</u>, <u>field sites with people</u>, and <u>unattended field sites</u>.

Power systems for <u>established camps</u> have a long history and are generally adequate. Sources for fieldwork offer the greatest payoff for investment in their development. The power sources for use on traverses and other operations involving people are generally well in hand. Their period of use is often limited by personnel endurance and by weather factors. However, there is always the need for smaller, lighter, and more rugged sources for field use by people. Power sources for remote sites without people, which have to operate for long periods, often with high data rates, are the most challenging and offer the greatest opportunity for high-payback development. The availability of such sources will enable obtaining data from many more locations over longer periods, especially for year-round operations.

4.4 Three Categories of Power Levels

If a histogram were made of the power levels used at camps, manned field sites and remote locations, it would show the very general levels for the operation of scientific instruments and related communications. Powers in excess of many kilowatts are needed for research and operational support in camps. Powers in the range of 100 to 1000 watts are generally adequate for the instruments taken to manned remote sites for periods of days to a few weeks. The power requirements for remote and unattended instruments, both for their operation and for data communications, are usually in the range of 10 to 100 watts. In view of these figures, we argue that the development of robust power sources at the 20, 200 and 2000 watt levels would cover the needs of most scientific research at field sites.

4.5 Energy Sources

The way in which energy is acquired or delivered at field sites, and the nature of the energy, both vary widely. The following table attempts to capture the options for how the energy is handled and its character.

	Chemical	Nuclear	Other
Supplied as Needed			Wired-in Power Microwaves or Lasers
Stored on Site	Batteries Fuel for Generators Fuel for Fuel Cells	RTG Others	
Harvested from Environment			Solar Wind

4.6 Three Categories of Energy Delivery

Options for delivering energy are:

(1) To “pipe” energy to the location for use as needed. This is done with wires in normal environments, but they are not possible for polar field sites. It might be possible to use microwaves or lasers to beam power to remote sites: however, that would require the availability of terrestrial links from some power source through repeater units to the remote instruments. This approach would be inefficient and can be dismissed.

(2) To store energy at the location of the instruments. This can be done with chemical and nuclear materials.

2a. Batteries and fuels for use in generators are the dominant approaches to energy storage. Fuel cells also operate from a reservoir of chemical energy.

2b. The use of nuclear materials is technically attractive, but fraught with political problems. Radio-thermal generators (RTGs) that turn the heat from radioactive decay into electrical power are well developed, and were used previously in Antarctica. They remain very attractive for their technical characteristics. Nuclear sources that use the charges that accompany radioactive decay, or charges that can be produced by the slowing down of energetic emissions in semiconductors, are also technical options.

(3) To gather the energy locally. Even in the polar regions, there is significant energy density available at remote sites for "harvesting." Solar photovoltaic panels and wind turbines are the primary means used to produce renewable energy.

In summary, stored chemical sources, especially batteries and small motor generators, and environmental sources, notably solar and wind, are the most attractive and useable.

4.7 Recommendations

Our recommendations fall into four major categories, two of which recognize that immediate advantages can be obtained without invoking new technologies.

First, we argue for the establishment and maintenance of a technology expertise repository on power sources for instruments and data communications, primarily at and from remote sites in polar regions;

Second, we note the advantages to be gained from reduction in the power requirements, especially for instruments, by the use of modern and/or miniature systems;

Third, we suggest development of power and instrumentation support systems that can include power generation, thermal management, and environmental protection, and status monitors with basic data communications hardware ('State Of Health Reporting').

The **conclusion** argues that near-term attention to power systems could prove to be cost effective in both lowering the expense of polar research and in improving the quantity and quality of the obtained scientific information.

4.7.1 Expertise Database

Background

Power, shelter, and thermal management are essential for the operation of all scientific instruments, field parties, and camps in Antarctica. The nature of the environment leads to special demands on equipment systems, including survivability against low temperatures, high wind speeds, lengthy darkness, and inaccessibility. Scientific instrument deployments need to be considered as complete systems that include consideration of power source, power duration, thermal and environmental protection, and (at minimum) state-of-health data reporting. In a few cases at larger camps, or for large projects, complete systems have been developed. However, in a majority of cases for smaller projects, the power and instrumentation systems are assembled in an ad-hoc manner. This is frequently performed by a combination of the grantee (PI and associated personnel) at the home institution, and the support contractor (presently RPSC) at McMurdo Station. The grantees may or may not have ongoing experience of Antarctic research, and/or any knowledge of electrical engineering and instrumentation systems, and/or any access to engineering resources. In some of these cases, the research group may rely upon a few or no technicians, folklore, a toolbox, and belief in manufacturer's literature, with the hope that everything will work when connected together.

The logistics contractor is tasked in a 'support' role with physical facilities located primarily in Antarctica. Consequently, power systems are often assembled by technicians in McMurdo from whatever available materials are on hand at the end of a 2-year supply chain. The people are enthusiastic and usually have good experience of the rigors of Antarctic deployment, but are not necessarily expert at instrumentation systems. They have to work (or make do) with whatever they have, both components and facilities. They do not have facilities for basic systems development, but are configured primarily for 'point-of-sale' issuance and repair of standardized hardware. The 'invisible' costs of doing business in Antarctica – financial, time-delay, and skill limitations – are frequently not apparent when something out of the ordinary is called for.

The result of this is that there are numerous instances where *ad-hoc* engineering leads to power and systems failures in the field: **engineering failures** that lead ultimately to **loss of science**. **These engineering failures could (in many cases) have been avoided by better dissemination of working knowledge.**

Recommendations

We recommend that a comprehensive database of experience and working knowledge be compiled to cover the needs of power and instrumentation systems for Antarctic field science.

Demand: The '**demand'** side of the database will have a number of dimensions, including (but not limited to) the size of the power load; the duty cycle of power consumption; the elasticity of this demand, i.e. its potential for reduction or modification by changing the technology; the duration of deployment, typically weeks (point field project), months (season-long deployment), or year-round; accessibility requirements; and any ambient or environmental conditions that will affect the power and instrumentation installation. This data will be collected from pre-existing projects, and also from a grantees' 'wish list.' In the course of collecting data from grantees, take the opportunity to inform and educate them about power and instrumentation topics, in the context of improving and enhancing their own research.

Supply: The '**supply**' side of the database should list technologies and solutions, together with their degree of development and annotations as to the efforts required to implement them in a field project with reasonable hope of success. These entries will include power source, magnitude, temporal variability (with typical statistics, including extreme cases), geographic or situational applicability, fuel or consumables requirements, installation requirements, portability, environmental considerations; failure modes and historical statistics; maintenance requirements; cost; and, importantly, an objective assessment of the ease of implementation, reliability, and overall demands upon team expertise to make it work.

<u>R&D Roadmap</u>: we recommend that a strategic plan be developed to highlight the areas of power and instrumentation systems that are not covered by COTS technology. This roadmap should be accompanied by a statement of recognition of the essential science enablement that is the underlying objective, together with reasonable financial and organizational commitments to make it happen. The R&D Roadmap will identify areas in which work is required, the science benefits that will accrue, and will lay out a strategy for achieving those ends.

<u>**Consultancy** and **Services**</u>: In parallel with this, a separate section of the database will address the issue of providing services representing <u>existing</u> knowledge and skill, addressing <u>known</u> problems, for the benefit of meeting the scientific project requirements of grantees who are <u>not</u> electrical engineers. This can include resources at NSF, RPSC, and associated consultants or collaborating institutions. Services will include 'verbal consulting' advice, recommendations for equipment alternatives or substitutions, warnings or cautions, as well as 'delivered services' which could include the construction and commissioning of custom systems as well as the re-engineering of scientific equipment to make it more amenable to the Antarctic operational environment.

4.7.2 Power Demand Reduction

There are generally two approaches to meeting requirements. The first is to provide whatever is requested. The second is to re-examine the requirements. It has been common practice for polar research support contractors to attempt to meet every stated need of scientists. Exceptions have occurred when that was not possible, or when the experience of the support personnel made it clear that requirements could be reduced. The knowledge repository recommended above would go a long way towards new grantees making realistic requirements, and considering energy management as part of their participation in polar research. Here it is noted that development or use of instruments that require less power would make the provision of power cheaper and easier.

Very often, there is no chance of decreasing the power requirements for scientific instrumentation. Even when it is possible, data communications may be the dominant power consumption. However, the relatively recent use of techniques growing out of the semiconductor electronics industry has produced many really compact, low-power instruments for analysis and other applications. These compact devices can have two potential impacts. The first is to *enhance* the performance of relatively large scientific instruments, which might be on the scale of a desktop system. The second is to *enable* the development and use of new and very small devices, which are commonly shoebox sized or even hand-held systems.

The recommendation here is to consider means to insure that polar researchers are aware of advances in and commercial availability of energy-efficient or miniaturized instrumentation. This could be done by use of a web site, or by the presentation of overview talks at conferences on polar research. Small analytical instruments, being developed for medical and other communities, are of interest. So also are very small weather instruments. It is highly likely that relatively straightforward integration of very small sensors specifically for use in polar research would pay off in new knowledge.

4.7.3 Power and Instrumentation Systems Development

Section 2.3 discusses the current power modules used in the field. The Antarctic can benefit from its contractor (RPSC) support because it can serve as a knowledge and equipment repository for all grantees in the Antarctic program.

Common facilities such as cold-room testing at CRREL[6] could aid in equipment testing prior to deployment. Standardized communications packages such as Iridium or Orbcomm supported by the contractor could simplify communications.

Research in the rapidly evolving development of more efficient power sources capable of operation in the polar regions should be actively pursued. These power sources include wind turbine bearings, fuel cells, integrated power/thermal/communications modules, thermal enclosures for extremely cold locations, and systems for high-wind-speed locations.

Just as this workshop has brought many diverse researchers together to begin this solution dialog and to share knowledge, we recommend periodic engineering meetings to bring experts together.

4.8 Conclusion

We have focused primarily on power and instrumentation systems for use at remote, unattended sites. This is currently the arena in which improvements in technology offer the greatest near-term payoff. There are several clear programmatic actions that should be taken soon. Funding the development and testing of remote power sources would both increase the number of sites that could be instrumented, and the time over which they would return data. The "power" of numbers, which drives down the costs of everything from cars to computers, could be exploited if well-engineered power modules were available at common power levels for use at remote sites.

The development of reliable and integrated power and instrumentation modules offers an opportunity for a straightforward "business" analysis on the return on investment for their development. A near-term investment in the development and field-testing of power sources at a few commonly used levels would cost a certain amount; say $500K for purposes of discussion. It would improve the amount and quality of returned data for at least a decade, and would offset operational expenses and the sunk cost of failures. However, the impact on enabling the use of more stations over longer periods would be the real payoff. The cost benefit of this aspect of power source R & D is harder to quantify. It would be in addition to the cited improvement in the current programs.

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[6] U.S. Army Cold Regions Research & Engineering Lab (http://www.crrel.usace.army.mil/)

Chapter 5. Connecting to the Internet

There is a problem addressed of managing spatial scales with regard to communication networks in the polar regions. Our interpretation of spatial scales is to mean the progressive levels of interconnectivity that are needed in order to support scientists in the field in all of their endeavors. These levels can be defined as three distinct problems as described below:

- Providing connectivity for a field camp back to a main base
- Providing scientists with computer-to-computer connectivity within a small group
- Connecting one scientist to a sensor via a communication link

In order to establish a context for these issues, some background information on operational conditions for research conducted from small field camps in Antarctica is in order.

The National Science Foundation administers three large research stations in Antarctica: McMurdo, South Pole, and Palmer. During the austral summer, the number of scientists and logistical support personnel at these stations ranges from about 100 (Palmer) to 1200 (McMurdo), with winter numbers being much smaller. These stations are logistical centers for many smaller field camps that are typically located within 200 miles (i.e., the operational range of helicopters) from the main station and consist of up to 15 people. These camps are often self-contained and can support continuous occupation from days to months. Personnel range up to 20 miles from these field camps to conduct their research, usually returning within a 12-24 hour period.

One of the challenges for networking in remote field camps is difference in spatial scale. For example, field camps may be up to 200 miles from each other and the main station. In contrast, local area networking may be needed for spatial scales ranging from a few feet to 20 miles. Computers have been used in small field camps for over a decade. However, Internet access and local area networking have only recently become possible. Since the mid-1990s, computers in field camps have been networked using Ethernet. Networking with other field camps and the main station used modems and a UHF (400 MHz) radio telephone (Opti-phone). This approach was reasonably reliable and easy to use. However, it is line-of-sight, not intended for mobile platforms and slow (9600 baud) for web and unusable for video. In 2002, wireless technology (802.11b) was tested at a number of field camps ranging from several miles to about 60 miles from McMurdo Station. Although some difficulty was initially experienced in setting up the network, in many cases a high-speed connection (point-to-point) from the field camps and McMurdo Station and the Internet (via satellite link from McMurdo) was established. This enabled the transfer of large data sets in near-real time as well as limited video conferencing from one field camp to McMurdo Station. In the latter case, refresh rates were reasonable but not optimal (30 fps).

With a few exceptions, scientists working in polar field camps have collected data manually or with instruments that archive data to electronic memory. Acquiring data in this manner is logistically costly, is labor intensive, prevents timely acquisition, and often prevents operation during the winter. Recording instruments that have wireless connectivity will enable scientists to remotely access data in real-time or on flexible, operator-determined schedules over variable distances. In addition, the operational status of recording instruments can be monitored to determine whether they are functioning properly. Satellite-linked, autonomous systems (e.g., meteorological stations) have been installed in deep-field locations. However, until recently they have suffered from very limited data transmission rates (Argos System). The Inmarsat satellite communication system provides higher rates of data transmission, but the low-latitude, geosynchronous orbits of the satellites create problems with terrain-blockage that can make data transfer intermittent or unreliable. The Iridium System also offers higher rates of data transmission, but still lacks the bandwidth of wireless connectivity. In addition, the reliable availability of the Iridium service has been uncertain because of the company's financial problems. Nevertheless, Iridium still offers the best solution when very long distances (e.g., hundreds or thousands of miles) must be connected.

Returning to the three issues described above, the simplest problem, data communication within a small group – typically among scientists at a field site – has essentially been solved. The current accepted solution is the use of the ubiquitous 802.11b wireless network consisting of a suitable number of wireless access points connected to a router, switch, or other suitable network hardware. Simple PCMCIA or PCbus plug-in cards provide user connectivity with no need for amplification or antennas. Within a small group, the primary requirement will be to support computer (including PDA) connectivity for exchanging files, logging data events, and seamlessly connecting to other groups of users back at the base camp or in a nearby field camp.

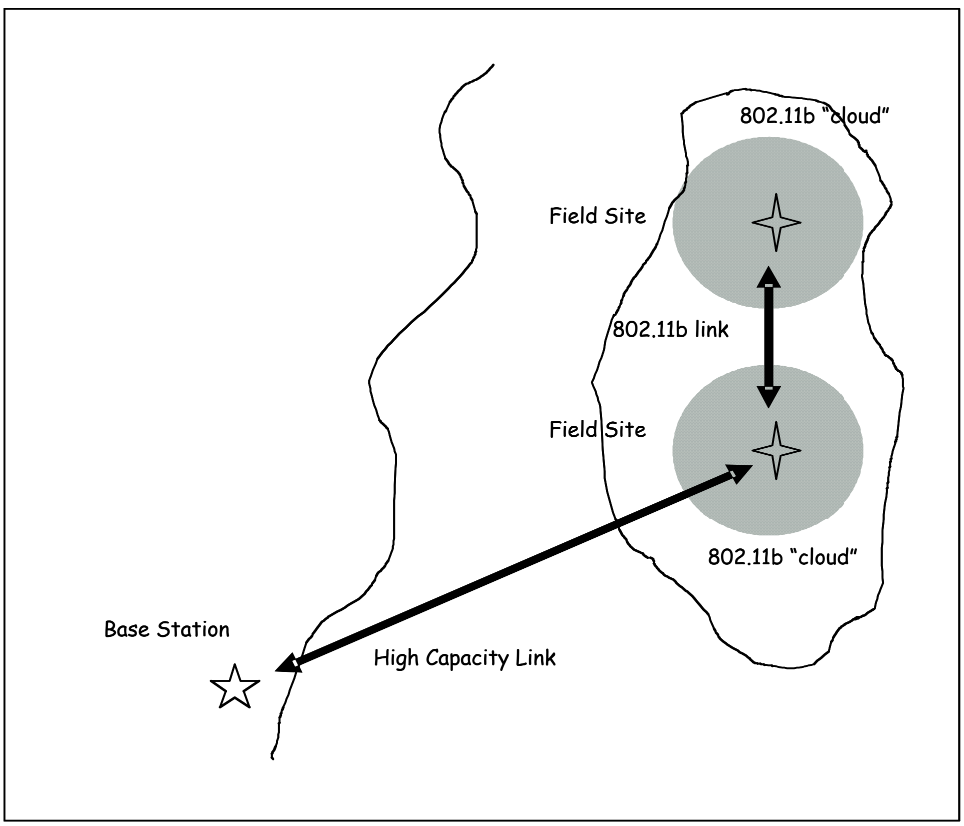

Figure 5.1. Wireless Connectivity in the field at various spatial scales.

Figure 5.1 is a schematic that helps to illustrate the spatial scales of the various connections. Each access point essentially creates a "cloud" of connectivity within a region of operation extending no more than hundreds of meters. To extend the radius of the cloud, the access point can be connected to an elevated omni-directional antenna. In some circumstances it may be useful to connect a low power amplifier to the access point, although this approach has limitations since the power output level of each user's 802.11b card will limit the maximum communications range in this situation.

The 802.11b solution appears to be quite satisfactory in that the capacity provided is currently adequate. This system provides reliable connectivity at a rate of 1 to 11 Mbps with a capability to adapt its data rate to maintain a constant quality of service. Furthermore, the use of spread spectrum modulation helps improve multipath performance of the system, although this may not be a significant issue with small groups of closely spaced users. Wireless technology continues to evolve, and 802.11g is currently displacing 802.11b as the standard off-the-shelf technology. For this reason we will refer to current, standard wireless technology as 802.11x to cover the entire spectrum of compatible wireless devices.

An interesting extension to this concept occurs when two or more field sites require connectivity in order to operate as one integrated network (see Figure 5.1). In this case at least two or more wireless access points will be needed – one to service each encampment. To interconnect the two clouds, a link needs to be established between access points. When the clouds are in reasonably close proximity this interconnection can be accomplished with 802.11x network devices operating with a connecting 802.11x link. This can be accomplished by assigning different channels to each user group as well as the connecting link. With this approach the clouds can blend together without the need to keep the clouds separated. It is possible to chain together several clouds to create extended coverage over several encampments.

When field experiments are to be performed, scientists may have the need to move out from the field camp to collect data. Under these circumstances the coverage cloud may need to be extended to follow these remote missions. Rather than extending the radius of coverage of the field camp, a more suitable solution would be to implement a directional link using 802.11x networking hardware. By using a low power amplifier (1 W) and an omni-directional antenna, connectivity can be provided over several kilometers. This scheme would require one wireless access point connected to the amplifier and antenna. This access point then serves the needs of the scientist on this mission. Data can be linked back to the field site for information or data storage, and voice (or video) can be supported as well.

The next issue is to understand how sensors and telemetry activities will be impacted by the availability of a network activity that is extended directly out to the point of data collection. It is conceivable that 802.11x-type devices might actually be an integral part of sensors in the future. Although the high capacity of such a scheme may far exceed the data handling requirements, the low cost, size, and weight of these devices may make them the best choice. As an example, consider an experiment that uses a typical data logger, such as the Campbell Scientific CR10X. This device uses a serial interface (either RS232 or, in Campbell's case, a closely related proprietary wiring scheme) to communicate with a computer or network. The data loggers can connect to an 802.11x serial adaptor, such as an Orinoco EC-S, and from there be accessed via IP address and port number as if on a serial terminal server. Thus the data gathering is on the same wireless LAN as the users. Since the data network itself has a point-to-multipoint topology, data gathering stations can be added to it dynamically on an ad hoc basis, at the same time releasing the scientist from regular manual attendance.

The third issue is the long haul connectivity between a field site and the base station, or perhaps between two field sites separated by tens or hundreds of kilometers. In these cases the solution is to concentrate the data from all users within a specific cloud into a single radio frequency link that connects the two groups. The technology used to accomplish this is dependent upon the distance of separation, and therefore, this part of the problem lends itself to a variety of solutions. For links less than 10 kilometers, extended 802.11x networks are appropriate. Communication over distances exceeding tens of kilometers could be implemented using simple, commercially available microwave systems.

Currently McMurdo station is operating a 100 Km link using point-to-point 802.11b technology in a system implemented by Raytheon. Future plans may include implementing the point-to-point link with Proxim's Tsunami microwave radio operating at 45 Mbps.

Chapter 6. Outreach and Outcomes

This workshop provided many interesting talks and discussions. In a number of cases people found other people who already had practical solutions for the problems that they faced. It is the firm belief of the participants in the workshop that other researchers in polar research would benefit from the materials generated at this workshop. In addition, researchers in computing can find a challenging environment for testing their understanding of communications systems.

6.1 Website, Proceedings, Posters, and PowerPoint™ Presentation

A key step toward disseminating the materials is to create an appropriate website to host all the materials. The site http://www.polar.umcs.maine.edu has copies of the slides presented at the workshop, as well as the slides for a talk that was not presented at the workshop. This website also has copies of the videos of the talks at the workshop. All of the materials from the website are also available on the CD that comes with this report.

This report is another important part of the dissemination plan. Bob Loewenstein and George Marksowsky will also produce posters and a PowerPoint™ presentation with notes that can be used by interested people to spread the word about this workshop. These posters and the presentation will be available at http://polar.umcs.maine.edu.

6.2 The Polar Mentor Network

Significant intellectual resources pertinent to wireless communication are resident in the individual scientists who attended the workshop. Transfer of that expertise to peers often can be attained only through personal interaction. We believe that the proposed mentoring program based on person-to-person communication will promote the transfer of expertise in wireless communications to field scientists.

The Polar Mentor Network (PMN) initially consists of participants in the workshop who are willing to share their expertise with others. In time, we hope that other people will join this network providing much needed help to people wrestling with communications issues related to polar research, and that the Polar Mentor Network will develop into a permanent organization that will help support Polar Research. The list of mentors, and the topics for which they feel comfortable mentoring is provided as Appendix B. The Polar Mentor Network will create a web-based mechanism for sharing technological experiences.

In addition to facilitating knowledge transfer, the PMN fosters human networking among individuals with common technological needs, but whose scientific disciplines may be disparate. Any member of the scientific community interested in polar research can call on these individuals for advice on dealing with communication problems related to their research.

For example, researchers in Wisconsin have spent considerable resources designing and deploying remote sensors on lakes. These systems can be assembled, deployed, and operated by a small staff, using mostly off-the-shelf components. They are autonomous systems that can be configured and debriefed through 900 MHz digital spread spectrum communications. They include software to automate data debriefing and archiving. Through developing these sensor systems, the Wisconsin scientists have gained experience that cannot be described adequately in manuals or white papers. They have agreed to mentor others who would like to install similar systems in other locations. An example application would be autonomous stream and lake sampling, along with automated data debriefing, in Antarctic streams and lakes.

6.3 Using NSF Resources for Dissemination

The NSF OPP website can play an important role in the dissemination of results from this workshop. It is recommended that the report from this workshop be accessible and downloadable from the site. It should also be possible to link http://polar.umcs.maine.edu to the OPP site for easy user reference. It as also noted that there seems to be a lack of information on Arctic research support as compared with similar information for the Antarctic. It is recommended that more information about Arctic research be placed on the OPP website.

The workshop participants discussed the possibility of providing specific references on communications and networking support in NSF research Announcement of Opportunities (AOs) for all polar work. This would be one way to alert investigators of information available to them regarding network and communications capabilities. It will be important to provide specific useful information such as contacts, regional expertise, and hardware components. The members of the Polar Mentor Network could play a valuable role here.

6.4 Using Existing Groups for Dissemination

One of the conclusions of the group is that it is important to summarize actions and outcomes of the workshop and get the information to a broad audience of polar researchers. The Arctic Consortium of the US (ARCUS) (http://www.arcus.org/) provides information distribution services for the arctic research community (nearly 3600 researchers. The Texas A and M University Geochemical and Environmental Research Group has just started a similar Antarctica NewS WEbsite and Registry (ANSWER) system (http://www.gerg.tamu.edu). The Byrd Polar Research Center at Ohio State also provides a resource for Antarctic investigators. (http://www-bprc.mps.ohio-state.edu). An announcement of results, website, and other details from the workshop should be distributed via these list servers. We will explore dissemination possibilities with Raytheon and Veco.

6.5 Presentations at Polar Research Oriented Meetings

Two principal means by which scientists share their findings are oral presentations and posters at scientific meetings. As noted earlier, we will prepare materials for poster sessions as well as a PowerPoint presentation with notes that can be presented by interested researchers at meetings that they will be attending.

Nearly every discipline has at least one membership meeting per year to serve as forums for presenting research results, discussing important issues in the discipline, and developing human networks among individuals with common interests, needs, and goals. Because the technology of wireless communication is of interest to all field sciences, discussing the workshop findings at these meetings may be an effective way to reach a large and interested audience.

ARCUS has an Annual Meeting each spring to bring the community together to discuss topics of mutual interest. It is recommended that presentations and posters from this workshop be presented there to share information on capabilities available to them.

The NSF ARCSS Program convenes "all-hands" meetings about once every 2 years to discuss and review science progress and other issues. These meetings provide a unique opportunity to present results from workshops such as this one. It is recommended that posters and presentations be prepared and presented at these meetings to help raise community awareness of communications and networking capabilities that are available to aid in the achievement of their science objectives.

Examples of meetings that include interdisciplinary researchers who would be interested in the results of this workshop include SEARCH, the Long Term Ecological Research All Scientists Meeting, and AGU. We will seek to find workshop participants who can present the results of this workshop at the various meetings.

6.6 Building Bridges between the Polar and Computing Communities, and Other Communities with an Interest in Computing

The Polar Science and Advanced Networking workshop is the first step in increasing communication between the polar and computing research communities. In particular, it is likely that the best way to provide greater connectivity to polar researchers is to improve global connectivity. Many countries, and in particular island regions (Puerto Rico, Hawaii), suffer from poor connectivity, and are eager to improve their connectivity. Satellites are very useful for reaching remote sites, but satellites do not just cover polar regions. Connectivity is a global problem, and by building a global initiative for greater connectivity polar researchers would benefit

It is important that additional steps be taken. In particular, NSF is working on a large cyberinfrastructure initiative as a result of the Atkins report, and the cyberinfrastructure needs of the polar research community should be considered in the overall strategy. George Markowsky gave a presentation on the need for improved global connectivity at the *Workshop on EPSCoR Cyber Infrastructure for Large-Scale Science and Engineering* which was held April 27-29, 2003 in Arlington Virginia. His presentation is available as Appendix D. It calls for an effort that would begin immediately to improve global connectivity with the goal of achieving significant improvements by the year 2007 to coincide with the International Polar Year (IPY). His presentation calls for broadening the scope of the IPY into an International Year of Science and Technology.

6.7 Additional Approaches to Dissemination

In addition to the above activities, we plan to establish a newsgroup and a listserv for interested researchers.

6.8 Outcomes

During the course of this workshop some of the participants were able to solve some of their problems. Below are descriptions of some of the problems solved as a result of the workshop, along with the names of the people who found the solutions. Biographies of the participants and contact information can be found in Appendix A.

Richard Beck found vendors for some services and equipment.

Rhett Butler felt that the workshop focused NSF on providing telemetry throughout the polar regions.

Peter Doran felt that the workshop provided very broad coverage of what is possible. The major development seems to remain mainly in creating winter-over networking capabilities in the dry valleys

Robert C. Durst is active in the Consultative Committee for Space Data Systems (CCSDS), a standards body addressing the problems of spacecraft data management and transfer. He found that many of the techniques that were discussed for polar data management are of potential use in spacecraft operation. He was glad to have had the opportunity to participate in this workshop.

Tony D. Hansen obtained an improved realization of the essential enabling role played by technology to underpin basic research.

Paul Hanson found that Todd Valentic's Newsgroup solution can provide a solution to the problem of routing data from diverse sources. He intends to implement this Newsgroup solution in his limnology projects.

Scott J. Kulinski was happy to see that people from different disciplines started to communicate and work toward common goals. He wants this effort to continue.

James Moore found that some specific items related to use of technology in certain deployment applications were presented and shown to be applicable in other areas.

Glenn Prescott felt that the primary problem solved at the workshop was a heightened realization of the problems and the fact that a lot of the communications have been solved by simple off-the-shelf solutions. He learned that most, if not all, of the communication problems are, or can be, solved with current technology. The biggest problem appears to be the reachback connection to the CONUS.

Darryn Schneider felt that the workshop demonstrated that most, if not all, requirements can be technically achieved. To solve problems efficiently requires coordination and cooperation between the research community, NSF, and support contractors.

Patrick D. Smith felt that the workshop:

- Verbalized the issues.
- Introduced disparate communities with common interests.
- Established momentum to move the community discussion forward.
- Created a roadmap for next steps for action.

Luis M. Tupas found that the workshop was successful at information dissemination, and scientific and technological collaboration.

Todd Valentic found people dealing with very similar data retrieval needs. He felt that it was interesting to see the approaches that they developed. He has been involved in several discussions about collaboration on future projects.

Chapter 7 -- Findings and Recommendations

This chapter briefly summarizes some of the findings and recommendations for future action.

7.1 Findings – Scope

The demarcation point appears to be the individual researcher's instrumentation. There was little discussion regarding computational/networking advances that could occur within the internals of instrumentation, since the focus seemed to be what happens once the instrument needs to interconnect with the outside world. Most of the participants at the workshop were so hampered by the lack of fundamental connectivity, that there was a genuine consensus that the problem of basic connectivity must first be solved before progress on other fronts can take place. It was also noted that there are significant differences between Arctic and Antarctic infrastructures.

7.2 Findings – Connectivity

Global Grid connections will dominate requirements. As noted above, connectivity was viewed as the main technical challenge. The communication needs range from bps to Mbps. In particular, many field scientists presently have nothing! It was noted that islands of connectivity exist in both polar regions (select population centers, stations, etc.), and that new mobile satellite systems (e.g., Iridium in particular, plus possibly others like Globalstar and INMARSAT) offer opportunities for connectivity in hard to reach high latitudes.

7.3 Findings – Coverage

It was concluded that fixed-point solutions are easier to solve, but that roaming regional wireless networking (voice & data) covering research areas of interest has great potential and has not adequately been addressed. The existing islands of connectivity are not well exploited for extending the reach of the network fringe.

7.4 Findings – Technology

Unfortunately this workshop did not provide a summary of existing technology being used in Arctic research. While similarities exist in Antarctic and Arctic conditions, the information gleaned from the discussions during the workshop showed that sometimes the same problems had different solutions. A recommendation is to create a survey of field technology, particularly that relating to power supply packages.

Many, if not most, research requirements can be solved using available off-the-shelf networking products. Clearly, IEEE 802.11xx standards dominate the thinking of most practitioners. At this time the preference is for "stretching" the state-of-the-market with modifications as opposed to R&D for totally new systems. Many researchers felt that FCC power emission limits on commercial unlicensed band equipment sited were a serious impediment to field science. Finally, power systems identified as a critical enabling technology. It is essential that solutions suited for polar region applications be found.

7.5 Findings – “Sociology”

Not surprisingly, it was found that some polar researchers are more network-savvy than others. Unfortunately, those who are not are often at a loss for gaining expert assistance. Self-help or other forms of design and technical assistance are needed in a sustaining sense. In this regard, the needs of Arctic and Antarctic researchers are viewed as being very similar.

7.6 Findings – Ideas

The Space Internet initiative has a correlation with polar region networking needs for thin and episodic connections. Out-of-box thinking could result in novel approaches to solving niche coverage needs (e.g., “ReindeerNet”). An endorsement was given to OPP for its build-out plan for wireless networking in/around McMurdo Station (sea ice, Dry Valleys research sites). It was felt that getting good Dry Valley Internet connectivity can be basically solved with appropriate funding. The technology is straightforward and at least one user of the demonstrated system endorses Raytheon Polar Service Company's effort. It was felt that field camp (bipolar) connectivity should be directed toward an Iridium solution using inverse multiplexing to achieve 24kbs.

7.7 Workshop Follow-on

As follow-ons to the workshop, the following activities (described in greater detail in Chapter 6) were proposed:

1. Finalize and disseminate the proceedings.
2. Distribute the materials from this workshop through a website and through the OPP and CISE websites.
3. Consider creating a discussion group, and a listserv.
4. Create a Polar Mentor Network (see Appendix B).
5. Work toward Global Connectivity – “International Science and Technology Year” (see Appendix D).
6. Human networking with the Cyberinfrastructure community (see Appendix D).
7. Prepare posters and PowerPoint presentations that volunteers can take to meetings & conferences.
8. Target professional organizations’ conferences (e.g., LTER, AGU, SEARCH).
9. Keep the inter/intra community dialog going.

Appendix A. Participants

This appendix contains contact information and biographies of the participants. Some NSF staff attended briefly, but did not leave contact information.

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Brief Biography
I am interested in the integration of remote sensing, GIS, and wireless (mobile) networking for calibration and validation studies.

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Brief Biography
I am the Program Manager for the Global Seismographic Network. The GSN has 128 stations uniformly distributed globally. Over 75% of the GSN sites have real-time telecommunications via the Internet or VSAT. I am also the PI for GSN facilities in Antarctica, including the quiet sector site at the South Pole and am also responsible for scientific efforts to reuse retired submarine telecommunications cables. I am an adjunct geophysicist at the University of Hawaii.

Dr. Randall Davis
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Brief Biography
I received my doctorate in Physiology from the University of California at San Diego in 1980. I am currently a Professor in the Department of Marine Biology at Texas A&M University. My Antarctic activities include nine field seasons in McMurdo

Sound studying the diving physiology and behavior of Weddell seals. In 1981, I spent the winter in a small field camp at White Island, located eight miles south of McMurdo Station, studying the winter behavior of Weddell seals. I have also spent three field seasons on the British-administered subantarctic island of South Georgia studying Antarctic fur seals and Macaroni and gentoo penguins. My research focuses on the behavior, physiology and ecology of air-breathing, diving vertebrates.

Dr. Peter Doran

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Brief Biography

I have a Ph.D. in Hydrogeology from the University of Nevada, Reno. I have very broad research interests focused on field techniques in aquatic and Quaternary sciences. I have conducted several field seasons in the Canadian High Arctic and in the Antarctic in this pursuit. Specific research areas include modern hydrological and biogeochemical processes in polar lake systems and the use of this modern calibration in paleoenvironmental reconstruction sedimentology of high arctic lakes paleolimnology and sedimentology of perennially ice-covered Antarctic lakes problems in Quaternary dating in the Antarctic dry valleys the origins and nature of boulders and glacial till on perennial lake ice biogeochemistry of deeply ice-covered lakes physical controls on and ecological impact of persistent lake ice covers modern controls on carbon isotopic signatures in lacustrine systems paleolake deposits in the Antarctic dry valleys and their significance to the search for evidence of past life on Mars and the nature and sedimentological signature of extreme cold aquatic environments. I have also conducted research in microclimatology of polar regions using automated weather stations. This research has been mostly connected to defining the climate controls on ice covers and modeling these lake systems. I am currently a co-PI on the McMurdo Long Term Ecological Research (LTER) project in the McMurdo Dry Valleys of Antarctica PI on a NASA Exobiology project investigating dry valley lakes in the context of the past lakes on Mars PI of an NSF OPP project to evaluate past climate change sediment cores in the dry valleys co-PI on a project looking at the biogeochemistry of coastal ponds in Victoria Land and PI on a NASA ASTEP (Astrobiology Science and Technology for Exploring Planets) project to do life detection in an ice-sealed lake.

Mr. Robert C. Durst
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Brief Biography

I am a Senior Principal Engineer in MITRE's Networking and Communications Engineering Department of the Information Systems and Technology Division in the Washington C3 Center. I am responsible for MITRE's support to NASA's Jet Propulsion Laboratory developing communication protocols for providing Internet access to near-earth spacecraft and to deep space assets. I am an active member of the Interplanetary Internet development effort at JPL and of the Internet Research Task Force's Delay-Tolerant Networking Research Group and leading an effort to generalize their architecture to broader classes of delay-tolerant communication in extreme networking environments. I am also the Principal Investigator for MITRE's Mobile Ad Hoc Networks for the Transformed Army research project, have led MITRE's support to various DARPA research programs, and am actively developing routing protocols for Army satellite networking. I received the Bachelor of Science Degree cum laude in Electrical Engineering from the University of Missouri in 1978. My research interests include design and evaluation of distributed computer communication systems and protocols. My current research interests include networking in intermittently connected environments; multicast data transmission, congestion and error control in mobile ad hoc networks and satellite communications.

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Brief Biography

BA Physics, Oxford, UK, 1972,
PhD Physics, UC Berkeley 1977
Environmental Research, LBNL, 1977-1990
Environmental Instrumentation Company (Magee Scientific Co.) 1990-present
Instrumentation Group for Biotechnology, LBNL 1990-2001
USAP grantee, 1996-present

Dr. Paul C. Hanson
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Brief Biography
I have worked at the UW-CFL for over 10 years in direct technology support of research. For the past few years, I have coordinated limnological research on lake metabolism and landscape carbon cycling.

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Brief Biography
After receiving my doctorate in 1973 in Space Physics and Astronomy at Rice University, I began work at the University of Chicago. I am an infrared astronomer, having spent over 25 years doing airborne astronomy using the NASA Lear Jet Observatory and Kuiper Airborne Observatory. My Antarctic activities began in 1991 and have included the position of Director of Computing and Communications for the Center for Astrophysical Research in Antarctica (CARA), PI of the South Pole Infrared Explorer (SPIREX) telescope, and co-PI of the Advanced Telescope Project (ATP) as well as serving on both the South Pole and McMurdo Area Users' Committees.

Dr. George Markowsky
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Brief Biography
After receiving my Ph.D in mathematics from Harvard University in 1973, I stayed for an additional year as a postdoc. Following that I spent 10 years at IBM's Thomas J. Watson Research Center. I then came to the University of Maine to chair their Computer Science Department. I am currently also chairing the Department of Mathematics & Statistics. I have several companies (Trefoil Corporation and Ayers Island, LLC) and am very active in the homeland security area.

Mr. James Moore
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Brief Biography
I am the Field Operations Manager for JOSS. I provide advice and direct support to investigators planning and conducting field projects. I have 25 years experience planning and have participated in more than 40 field projects in mid-latitudes and the Arctic. I have specific understanding of operations support communications and data management considerations for field projects in the US and worldwide.

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Brief Biography
I have degrees in Engineering Science, Physics and Engineering Materials. I worked at the Naval Research Laboratory for 36 years, performing various functions in a variety of disciplines. I was the leader of a 140-person division for over a dozen years at the Naval Research laboratory. I served 30 years as a Naval Officer and retired with the

rank of Captain. For the past four years, I have been a Research Professor in the Department of Electrical and Computer Engineering at the George Washington University focusing on applications of MicroElectroMechanical Systems.

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Brief Biography

I am currently Professor of Electrical Engineering at the University of Kansas where I teach classes in digital and wireless communications and digital signal processing. My research agenda includes military communications (covert and low probability of intercept signal analysis), wireless communications (development of software radio systems) and radar signal processing. I am also investigating the application of novel signal processing techniques to radar scatter data collected from ice sheets and glaciers. I also serve in an appointed position as Program Executive for Technology at the NASA Office of Earth Science where I assist in the planning the research agenda in information technology for NASA's future Earth observing satellites.

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Brief Biography

I have a PhD in Plasma Physics from the Australian National University. I worked for the Australian Antarctic Division as winter-over physicist operating the geophysical observatory. I was the Senior winter-over Scientist at Casey Antarctica in 1996. I was at South Pole for the AMANDA Project in 2000. I am currently pursuing research on AMANDA/Ice Cube and am the manager of Ice Cube data handling, computer infrastructure and WO operations.

Mr. Alan Schoenwald

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Brief Biography

I have spent 13 years with the U.S. Antarctic program. I started in the Navy with high power transmitter in CHCH. Several years ago I migrated toward land mobile communications and field support for grantees.

Mr. Patrick D. Smith

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Brief Biography

I am the program manager responsible for IT & telecommunications infrastructure for the U.S. Antarctic Program. I have been employed at NSF/OPP since 1990. I was formerly a research engineer associate at the University of Texas/Austin Applied Research Labs (1978-1990). I have wintered over twice as a UT/ARL grantee team: Palmer Station (1973) and McMurdo Station (1982), and personally had to use radioteletype to transmit data. My personal mission has been to transform the USAP infrastructure with modern IT & communications, to constantly push the envelope, and to enhance/enable/transform the science done.

Dr. Luis M. Tupas

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Brief Biography

I have a Ph.D in Oceanography. My interests are biological oceanography, microbial ecology and biogeochemistry. I have been active as an Arctic and Antarctic researcher.

Dr. Todd Valentic

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Brief Biography

I work as a research engineer in the GeoSpace Sciences group at SRI International. We provide the communications and technology support for VECO Polar Resources, the NSF arctic research logistics contractor. My personal research involves radar remote sensing of the upper atmosphere and data retrieval methods from remote instrumentation. I have a PhD in electrical and computer engineering from the University of Colorado at Boulder.

Dr. Frank L. Vernon

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Brief Biography

I am a research seismologist who has deployed field experiments on every continent except Australia and Antarctica. I have specialized in real-time data systems and various wireless telemetry systems. Currently I am a PI on the NSF funded High Performance Wireless Research and Education Network (HPWREN http://hpwren.ucsd.edu) project and the Real-time Observatories, Application, and Data management Network Program (ROADNet http://roadnet.ucsd.edu).

Mr. Tom Williams

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Brief Biography

After 19 years as a computer programmer and college administrator, I made a career change in 2001, starting with a position as "Special Assistant" (actually, understudy) to 73-year-old wireless networking guru David Hughes. My primary project within that assignment was the establishment of a wireless Internet cloud on an uninhabited, unpowered barrier island off the coast of Virginia. Since the completion of that 14-month grant-based position, I have worked as an independent wireless networking consultant for sites in Wisconsin, Minnesota, and Costa Rica, as well as continuing assignments with UVA in wireless networking, data gathering, and education projects.

Appendix B. The Polar Mentor Network

During the workshop we established the Polar Mentor Network consisting of experts willing to help others with their polar networking problems. Below is a list of people with their contact information, along with their fields of expertise. For biographical details see Appendix A.

Dr. Richard Beck

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Areas of Expertise

General integration of sensors and wireless networks for remote sensing and GIS.

Mr. Robert C. Durst

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Areas of Expertise

Internet over satellite, mobile networking, intermittent connectivity networking problems.

Dr. Tony D. Hansen

Staff Scientist Lawrence Berkeley National Lab
Principal, Magee Scientific Co.
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ADHansen@lbl.gov
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Areas of Expertise
I am interested in small scale custom instrumentation design and construction. I have the ability to listen to a scientist, interpret needs, translate those needs to engineering terms, and think of new stuff.

Dr. Paul C. Hanson
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Areas of Expertise
Combining sensors, loggers, and serial wireless communication.

Mr. Scott J. Kulinski
Chief Technical Architect
Raytheon Technical Service Co.
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Centennial, CO 80112
720-568-2007
Scott.Kulinski@polar.org
http://www.polar.org/

Areas of Expertise
Technology—Communications, distribution of data outreach to the research community.

Dr. Robert F. Loewenstein
Senior Research Associate
Yerkes Observatory
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262-245-5555
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http://astro.uchicago.edu

Areas of Expertise
Various network related problems, instrument remote control, and data acquisition.

Mr. James Moore
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Areas of Expertise

Assist investigators with developing field project plans, deployment strategies, and in-field support. This includes logistics, operations support, communications, and data management.

Dr. Glenn Prescott
Professor of Electrical Engineering
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Areas of Expertise

I can solve problems dealing with the need for communications, whether it be voice communications, data (computer to computer) communications, or specialized telemetry applications.

The team of engineers and researchers at my laboratory build radar and radio prototypes. Most of the research efforts we are involved in require construction of specialized communications network and radar systems. We can provide advice on telemetry issues for remotely collecting data including processors, electronic circuitry, transmitter/receivers, and data storage. Simply stated, we build specialized systems to support our research. When components are available off the shelf we use these or adapt them for our applications.

Dr. Darryn Schneider
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Areas of Expertise
Data archiving, documentation and handling of all size data sets from South Pole.

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Areas of Expertise
Data transport/retrieval, remote instrument control, and wireless systems

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Areas of Expertise
Wireless networking, and real-time data systems.

Mr. Tom Williams
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Areas of Expertise
Data gathering, interfacing, and wireless digital communications.

Appendix C. Abstracts of Talks

The videos and PowerPoint slides for the following talks are available at http://www.polar.umcs.maine.edu.

Wireless Arctic Prototype
(This talk was not delivered at the workshop, so no videotape is available.)
Dr. Richard Beck
University of Cincinnati
Abstract
A discussion of a prototype wireless system for the Arctic.

Autonomous Hydrometeorological and Geochemical Measurements in the McMurdo Dry Valleys
Dr. Peter Doran
U. of Illinois at Chicago
Abstract
The dry valleys are currently the site of one of the 24 Long Term Ecological Research (LTER) sites globally. We have been operating in the dry valleys for 10 years and will soon propose to continue operations at least through 2011. We have a number of data loggers operating in the dry valleys to measure a wide range of environmental variables. We are currently planning on expanding our autonomous sampling. There is a great need to telemeter data year-round and a lesser need to be able to reprogram and control instruments remotely.

DELAY TOLERANT NETWORKING: An Approach to Communicating in Intermittently Connected Environments
Robert C. Durst
Senior Principal Engineer
The MITRE Corporation
Abstract
The Delay Tolerant Networking system that is described in this talk is an outgrowth of the Interplanetary Internet project that was jointly funded by NASA and DARPA (as part of the Next Generation Internet program). DTN describes an architecture and specific protocols to define an overlay network that allows operation over a heterogeneous concatenation of Internet sensor nets and other appropriate networking technologies for store and forward message-oriented data transfer. The DTN is cognizant of many different types of intermittent connectivity including scheduled contacts, opportunistic contacts, on-demand (e.g., Iridium) contacts, and of the characteristics of those contacts (expected error rate, data rate, duration, etc.). This allows the DTN to make informed routing choices based on data class of service requirements (priority, normal bulk) in assigning data to routes through the system. Integral to this system is a security architecture that provides authenticated forwarding. Architectural definition protocol specs and prototype software are available from http://www.dtnrg.org/.

Better Communications, Technology Development: Empowering 'Smaller' Science in Antarctica

Tony D. Hansen
Staff Scientist Lawrence Berkeley National Lab
Lawrence Berkeley Natl. Lab
Principal, Magee Scientific Co.
Magee Scientific Co.

Abstract

Rivets and Wires. Described observations of need and application of engineering technology to Antarctic science on smaller scales: example of life sciences projects that are not data-centric and in which the PIs are not necessarily engineers. Ability to enable them to do things better or under previously impossible conditions. Concrete examples of autonomous wireless-linked webcam units in the Dry Valleys: preconfigured wired ready to go delivered to the field.

Toward Embedded Sensor Networks In North Temperate Lakes

Paul C. Hanson
Information Processing Consultant
U. Wisconsin -- Madison, Center for Limnology

Abstract

NTL-LTER has made tremendous progress in growing from single buoy deployment to multi-buoy deployment. We have used both 900 MHz and 2.4 GHz DSS solutions to facilitate remote configuration of buoys and automatic data retrieval. As we begin to develop more extensive wireless sensor systems we will employ both network topology and AI techniques through collaborations with colleagues in ECE.

2002/2003 Wireless Technology in Antarctica

Scott J. Kulinski
Chief Technical Architect
Raytheon Polar Services

Abstract

An overview of wireless in Antarctica directed toward the user. This depicts a wireless strategy, services offered today and services that are being looked at for the future.

Communications in Remote Regions: Challenges and Opportunities for Arctic and Mid-Latitude Field Projects

James Moore
Field Operations Manager
UCAR Joint Office for Science Support

Provided a brief overview of Joint Office for Science Support (JOSS) capabilities for supporting field projects. Discussed field project lifecycles and typical issues that need to be addressed when providing comprehensive support to the project. Arctic PIs were contacted and asked to provide specific comments on communications and networking issues. A list of challenges and opportunities based on PI input and JOSS experience was provided and discussed.

Power and Systems for Wireless Sensing

David J. Nagel
Research Professor
The George Washington University

Abstract

A great deal of COTS (commercial off-the-shelf) power hardware is available from many sources. Suitable components should be chosen, creatively integrated and tested in polar research scenarios for powering the instruments and communications from remote and unmanned field sites to determine the best systems for various applications.

There are many emerging uses of wireless sensor systems. They range in number of nodes from a few to several thousand and in size from a few meters squared to global. The hardware and protocols in some of the larger systems should be examined for potential application to polar research requirements.

Polar Radar for Ice Sheet Measurements

Glenn Prescott
Professor of Electrical Engineering
University of Kansas Information & Telecommunications Technology Center

Abstract

Presented a brief overview of a current NSF funded project entitled Polar Radar for Ice Sheet Measurements underway at the University of Kansas. Described the problem of sea level rise and showed how we are going to use two innovative radar systems to make measurements which we anticipate will lead to a greater understanding of the contribution of glaciers to this problem. Focus was on the communication aspects of this project, which include communications between two vehicles as they move across the ice sheet, and a reachback system that provides a web-based presence for this experiment. The reachback system, which employs Iridium satellite phones operating in parallel under control of a Multi-link Point-to-Point Protocol was discussed.

Computing & Networking Requirements of the AMANDA & Ice Cube Neutrino Telescopes

Darryn Schneider
Research Scientist/Data Handling Manager
University of Wisconsin Ice Cube Project

Abstract

An overview of the AMANDA and Ice Cube Neutrino telescope projects.

Wireless in Arctic and Remote Data Retrieval using the Data Transport Network

Todd Valentic
Senior Research Engineer
SRI International

Abstract

This talk describes some of the wireless deployments that we have made in the Arctic for VECO Polar Resources and the NSF Arctic Research Logistics support program. The use of wireless at the Greenland Summit Camp and ship-to-ship networking on the USGC HEALY are highlighted. The second part of the talk details the Data Transport Network. This system is a newsgroup-based approach to remote data retrieval over unreliable networks.

High Performance Wireless Research and Education Network
HPWREN and ROADNet – Sensor Network Testbeds

Frank L. Vernon
Research Seismologist
Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California at San Diego

Abstract

An unresolved and underdeveloped area for the evolving Internet remains to be the issue of ubiquity, with rural areas across the nation affected by the lack of broadband network access - areas where currently no commercial business case exists. Not only does this lack of rural ubiquity impact the residents of such communities, but also field scientists and distance educators in these areas are also negatively impacted when they are not afforded access to the high-speed Internet as are their urban peers. High-speed networking needs encompass a wide array of applications - ranging from remote research such as large numbers of autonomous telemetry sensor stations, distance education such as webcast tutoring programs, and observatories with requirements to transfer vast amounts of data. The primary goal of the NSF/ANIR-funded High Performance Wireless Research and Education Network (HPWREN, http://hpwren.ucsd.edu) project is to evolve toward a substantial and robust wireless backbone network in various remote environments for high-performance real-time bidirectional traffic flows, while advancing various realms of remote field research and prototyping collaborations. Foci encompass synergies of science, education, and crisis management networking applications in the southern California counties of San Diego, Riverside, and Imperial Valley. Principal collaborators include field scientists from disciplines such as geophysics, astronomy, and ecology.

The Real-time Observatories, Application, and Data management Network (ROADNet) Program aims to develop an integrated, seamless, and transparent environmental information network that will deliver geophysical, oceanographic, hydrological, ecological, and physical data to a variety of users in real-time. ROADNet is a multidisciplinary, multinational partnership of researchers, policymakers, natural resource managers, educators, and students who aim to use the data to advance our understanding and management of coastal, ocean, riparian, and terrestrial ecosystems in Southern California, Mexico, and well off shore. The project is building on these accomplishments and, for the first time, is demonstrating the feasibility of adapting powerful "Data Grid" technologies to the unique challenges associated with the management and manipulation of real-time data. Current "Grid" projects deal with static data files, and significant technical innovation will be required to address fundamental problems of real-time data processing, integration, and distribution. The technologies developed through this research will create a system that will:

- Dynamically adapt downstream processing, cataloging, and data access interfaces when sensors are added or removed from the system;
- Provide for real-time processing and monitoring of data streams--detecting events, and triggering computations and other actions;
- Integrate heterogeneous data from multiple (signal) domains; and
- Provide for large-scale archival and querying of "consolidated" data.

Some Examples of Wireless Networks for Field Science

Tom Williams
Consultant
Air Networking

Abstract

The talk discussed telemetry and communications environments set up in Alaska, Puerto Rico, and Virginia, with emphasis on data bandwidth and how it affects both research and operations in the field.

Appendix D. Global Connectivity

From April 27 through April 29, 2003, the EPSCoR Foundation and NSF supported a workshop entitled: *EPSCoR Cyber Infrastructure for Large-Scale Science and Engineering.* George Markowsky was part of the organizing committee and was supposed to give one of the presentations. He used the opportunity to talk about the results of the *Polar Science and Advanced Networking Workshop*, from the point of view of highlighting the need for global connectivity. Below is a summary of that presentation. The slides can be found at http://www.polar.umcs.maine.edu.

On p. 35 of the *NSF Cyberinfrastructure Atkins Report*[7] it states that: *A major shift in computing has come from the practical availability of high-bandwidth data networks. Network connections up to 45 megabits are* ***easily*** *available, connections over 155 megabits/s are still aggressive, and some research institutions are beginning to connect at 2.5 Gb/s and faster.* It is clear from our workshop, and an earlier workshop[8], that the picture for field science is not as rosy as the picture painted by the Atkins report. In particular, connectivity is a real issue for polar research programs. Antarctica and the Arctic are continental in size with marginal connections to the rest of the world. In fact, even as seen in Figure D.1, the existence of the HPWREN project in California shows that the home state of the computer industry suffers from connectivity problems for field science. Figure D.2 shows the various locations that are part of the Longterm Ecological Research Network (http://lternet.edu) -- all of these sites would benefit from increased connectivity.

As Randall Davis stated in his talk (see Appendices A & C), what field biologists would like to have is an "integrated system for seamless local area (50-100 mile radius) and global communications and networking." One especially interesting application of high-speed connectivity discussed by Randall Davis is shown in Figure D.3. As the many speakers noted there are many critical issues that field biologists are working on including sea level rise, long-term climate changes, and the ozone hole. All of these research endeavors and many others have a critical need for bandwidth and connectivity.

In short, global connectivity is needed for scientific research, education (especially distance education), telemedicine, homeland security, and economic development. A brief survey shows that global connectivity is not very good -- one need only ask people who live on islands such as Puerto Rico and Hawaii. Our goal should be consistent with the statement found on page 2 of the *Executive Summary* of the Atkins Report: *The emerging vision is to use cyberinfrastructure to build more ubiquitous, comprehensive digital environments that become interactive and functionally complete for research communities in terms of people, data, information, tools, and instruments and that operate at unprecedented levels of computational, storage, and data transfer capacity.*

[7] http://www.cise.nsf.gov/sci/reports/toc.cfm

[8] *ANYWHERE, ANYTIME, ANYSIZE, ANY SIGNAL: Scalable Remote Information Sensing and Communication Systems.* http://homeland.maine.edu/anywhere.htm

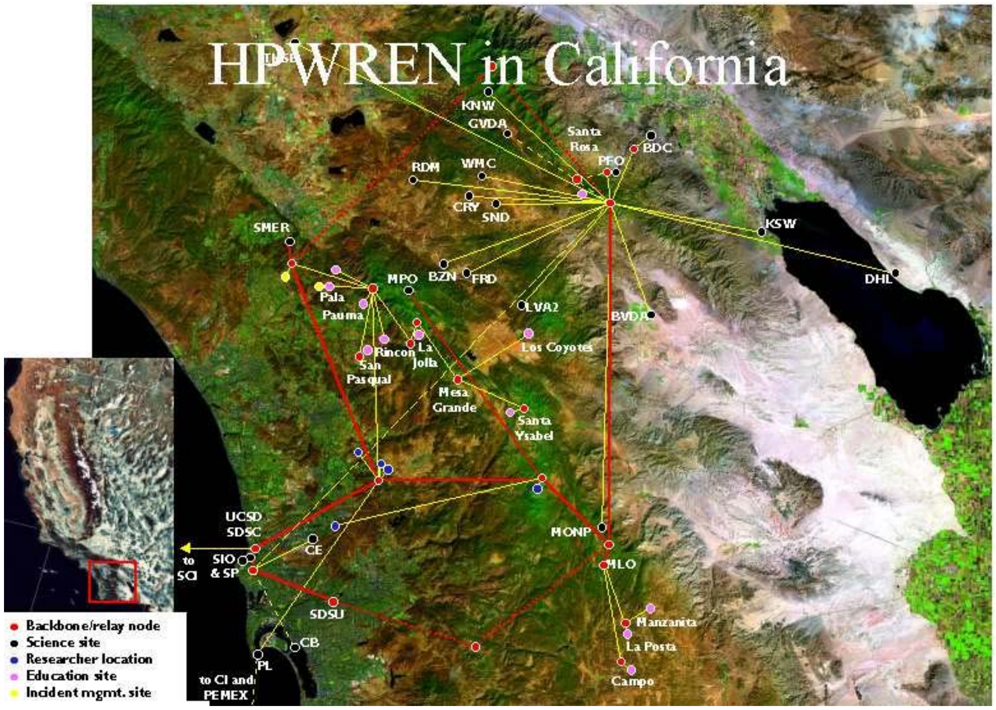

Figure D.1. The HPWREN Project in California provides much needed connectivity for field scientists.

Figure D.2. The Long Term Ecological Research Network

Figure D.3. One of the many uses for high-speed connectivity in field biology.

The presentation suggested that the EPSCoR states adopt as their mission the goal of achieving true global connectivity by the year 2007, which is scheduled to be an International Polar Year (IPY)[9]. In the same way that that the IPY of 1957 grew into the International Geophysical Year[10], perhaps it is time that IPY 2007, grew into ISTY 2007 (International Science and Technology Year). This would be a wonderful worldwide activity.

[9] http://ipy.gsfc.nasa.gov/
[10] http://www.nas.edu/history/igy/