Integration of Remote Weather Stations with Advanced Telemetry Options And Remote Image Acquisition

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Abstract: Currently the University of Alaska Fairbanks Water and Environmental Research Center (WERC) maintains over fifty remote meteorological stations in Alaska, ten located on the Seward Peninsula, fifteen on the North Slope of Alaska, two near Ivotuk and over twenty near Fairbanks, Alaska. Due to its latitude and climate, Alaska poses difficult problems that must be solved to successfully power and maintain a remote meteorological station network throughout the year. Many of these solutions can be adapted from arctic to alpine environments. Over the past year WERC has deployed a variety of telemetry systems and has developed new configurations for these systems. The Seward Peninsula Radio Telemetry project utilizes Freewave 900 Mhz spread spectrum radios powered by 12 Volt battery and solar power systems with the overall network encompassing over 5000 square miles. This network is connected to the Internet in Nome. A new radio feature was developed for this project that allows for expanded repeater capabilities, allowing the system to grow beyond pre-existing limits. The North Slope Radio Telemetry project also utilizes Freewave radios, but instead of a going with a traditional hard wired Ethernet connection the radio telemetry network is coupled to a satellite based Internet service provider allowing for deployment of an internet connected radio network virtually anywhere in North America. The development of these networks required new software to control the networks and download data from remote dataloggers. In addition to developing innovative telemetry systems, WERC has developed a low power camera system that can be deployed at a remote weather station and transmit images hourly to the Internet. Pilots, the National Weather Service and most importantly local residents are using these meteorological stations to improve weather forecasts in order to make better travel decisions in remote areas. The first winter of operation has allowed us to learn more about the system installation and work through some of the problems associated with operating remote radio sites in Alaska. The current conditions for our Seward Peninsula meteorological stations may be viewed through the Internet at
http://www.uaf.edu/water/projects/atlas/metdata/atlasmetsitemap.htm
A current image collected at a remote weather station can be viewed at
http://www.uaf.edu/water/projects/cpcrw/metdata/crrel/current.html
Near-real-time telemetry of meteorological data has improved our capability to monitor weather processes, better enabling us to respond to extreme events and allowing more efficient planning of field excursions. Snow scientists and avalanche practitioners could also utilize these telemetry solutions to acquire data in a more timely fashion.

Keywords: Telemetry, climate, meteorological hazards and remote sensing

1. Introduction

Real time meteorological data is a valuable resource for any group that makes critical decisions based upon meteorological events. In the avalanche industry real time data is a valuable part of a forecasting system, providing reliable information about meteorological conditions in avalanche start zones. River warning forecast centers, the National Weather Service, airplane pilots and local residents also benefit by obtaining real time data from remote meteorological stations. The University of Alaska (UAF) Water and Environmental Research Center (WERC) has been upgrading remote meteorological stations with real time telemetry capabilities. These telemetry networks are shown in Figure 1. WERC's mission is to perform basic and applied research related to water and environmental resources, to train graduate students at master's and PhD levels in this field, and to disseminate pertinent research information to the public. These stations provide a necessary research tool and a valuable public service.

Alaska's size, remoteness and climate pose challenges to providing reliable telemetry to remote data logging sites. WERC has been developing new telemetry systems that push the limits of existing technology and also bring together different technologies into hybrid telemetry systems. This paper presents three telemetry projects that WERC has been working on the past twelve months.

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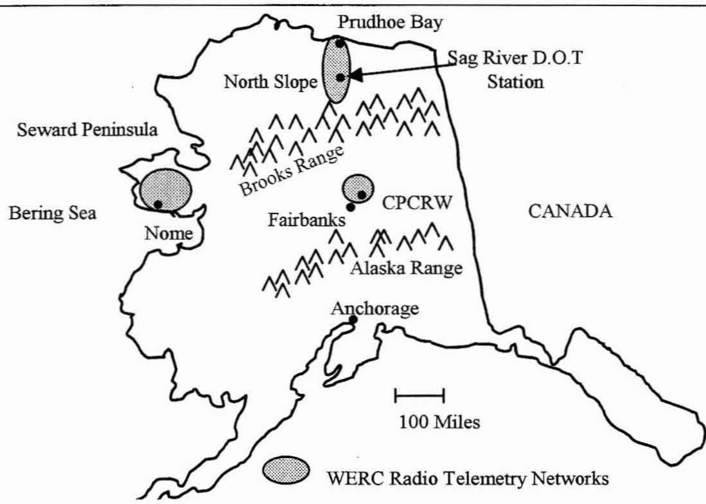

Figure 1: Map of Alaska showing the Water and Environmental Research Center Telemetry Networks.

2. Remote Image Acquisition

Images are a valuable piece of data that can be collected from a remote site. Typical uses for images are to: determine the general weather conditions at a remote site, observe avalanche start zones for changes in snow deposition or avalanche release, determine flying conditions at a particular site and gather time series images for scientific use. It is important to distribute these images in timely fashion to potential users.

WERC has developed a remote low power camera system that can be easily interfaced with existing dataloggers and telemetry systems. The system uses approximately 0.25 Whr of power to capture and transmit an image back to a base station. Figure 2 shows a schematic for a site at Caribou Poker Creek Research Watershed (CPCRW) that currently uses this system. The image sensor is based on Fujitsu's SPARCLite microprocessor. The datalogger and camera are connected by radio telemetry to a base station at UAF's Poker Flat Rocket Research Range. This base station is connected to the Internet via an

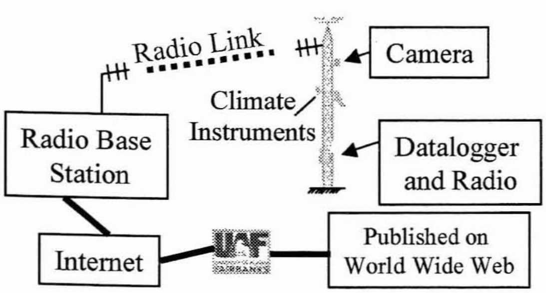

Figure 2: Schematic of the data path for a site at Caribou Poker Creek Research Watershed that includes remote image acquisition.

Ethernet device server. The radio system consists of Freewave 900 Mhz spread spectrum radios that function as a transparent RS232 link. The end to end reliable communication of Freewave radios combined with TCP/IP Internet protocol allow for error free images to be collected hourly. A dedicated computer located in Fairbanks controls the system. Software was developed that can both query and download the datalogger and then also query and download an image during one connection to the site. This image is transferred as a binary *jpeg* file. Due to their large size, (70-500 Kbytes) it is preferable to transfer image files directly to the system control computer in Fairbanks rather than storing them locally on the remote data logger. Table 1 shows the sequence of events with the typical duration of each step during an hourly download sequence.

Table 1: Download Sequence for CPCRW Site

	Event	Duration (seconds)
1	Open TCPIP Socket	1
2	Establish radio connection	1-2
3	Download datalogger	5-10
4	Switch communications to remote camera	1
5	Query camera and capture image	3
6	Download image	150

The duration of time needed to download the image depends on both Internet traffic and strength of the radio connection, with the maximum transfer rate limited to 9600bps, the maximum communication rate of the data logger. Once the image and data are downloaded, they are transferred to a public web page on the university's web server. Meteorological data and hourly images from CPCRW can be viewed at http://www.uaf.edu/water/projects/cpcrw/metdata/crr-el/current.html

3. Seward Peninsula Telemetry Network

The Seward Peninsula is located on the west coast of Alaska. The topography of the area includes broad uplands of convex hills and flat divides interspersed with several mountain ranges (800-1400 m). WERC installed six meteorological stations during 1999 as part of the National Science Foundation Arctic Transitions in the Land Atmosphere System (ATLAS) project. Three stations are located approximately eighty miles north of Nome, near the Quartz Creek runway and three stations are located eighty miles east of Nome near Council. In 2001 a radio telemetry system was installed and connected to the Internet at University of Alaska's Northwest Campus in Nome. The radio system consists of Freewave 900 Mhz radios and is connected to the Internet with an RS232 to Ethernet device server.

Repeater site selection was done using computer software to analyze a digital elevation model of the Seward Peninsula. Sites were selected with respect to adequate radio propagation paths. The transmit power for Freewave radios is limited to 1 Watt. Therefore the radios require line of sight propagation paths for long link distances. The longest distance from radio to radio in this network is 65 km (Figure 3). The entire network is shown in Figure 4.

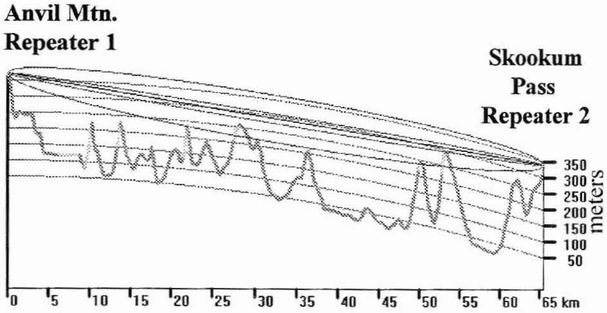

Figure 3: Radio path from repeater 1 to repeater 2 calculated using GIS software. The radio path is the straight line from left to right, bracketed with curves representing the first two fresnal zones. The undulating terrain is represented below the radio path.

In order to reach one of our sites, Freewave Technologies Inc. developed a new operating system that is capable of utilizing up to four repeaters when connecting to a remote radio. During the first winter of operation, reliable communications were interrupted twice due to icing events. Communication was lost for approximately two days during the first event and approximately eight days during the second event.

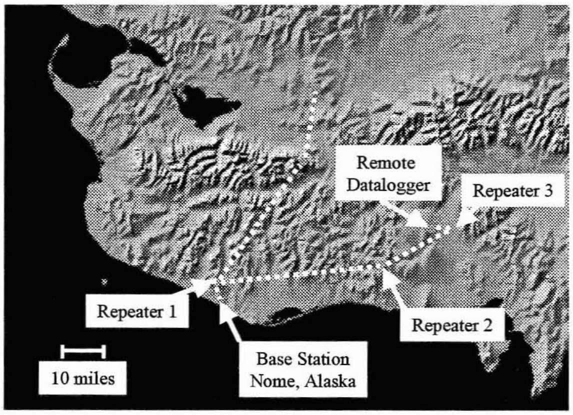

Figure 4: The Seward Peninsula radio telemetry network showing the use of multiple repeaters. A new radio feature was developed to allow for more than two repeaters in a path.

One significant difference between the Seward Peninsula network and the CPCRW network is that all communications, including the Internet connection to Nome are through a satellite. This introduces some additional latency to the system, varying between 600 and 1000 milliseconds.

All of WERC's remote sites are battery powered. One of the constant challenges when designing any remote 12 volt remote power system in Alaska is supplying enough energy to operate the site through the winter months. Figure 5 shows a plot of solar

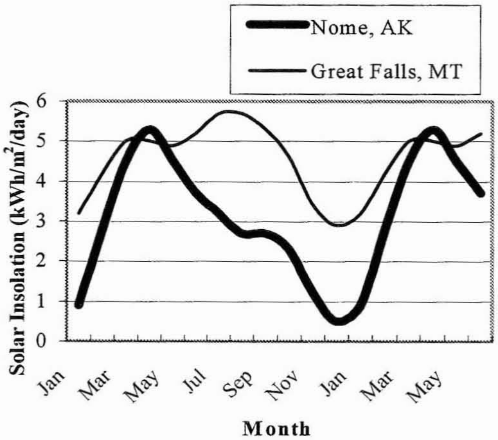

Figure 5: Average 30 year (1961-1990) solar insolation values for a flat plate collector for Nome, Alaska and Great Falls, Montana.

insolation for Nome, Alaska and Great Falls, Montana for comparison. Mid winter solar insolation for Great Falls is comparable to April and August solar insolation values for Nome. During January the average solar insolation drops to 0.5 $kWh/m^2/day$ with a minimum of

0.2 kWh/m^2/day. During January, a 10-Watt solar panel will produce approximately 1.5 Watt hours of power each day. This information represents thirty years of data and was obtained from the National Solar Radiation Data Base (NSRDB, 1994), which is produced by the National Renewable Energy Laboratory's Analytic Studies Division. These data illustrate the difficulties maintaining an adequate power supply for a remote system using photovoltaic cells. The United States Geological Survey recommends the following to size a PV system for remote power: use a 30 Watt solar panel and 100 Ah of batteries for each 2 watts of average load (McChesney, 2000). These values are intended to be used in the continental U.S. No published values for Alaska were found. The measured energy consumption for a Freewave Radio was 0.75 watts at 25 °C when idle or 18 Watt-hours per day. Average energy consumption is slightly higher than this. Using the USGS guidelines and neglecting icing conditions, a 11.25 Watt solar panel and 37.5 Ah of battery capacity would be recommended for our sites. A more conservative estimate for Alaskan conditions would be a 40 to 60 watt solar panel for each 2 watts of average load and enough battery reserve to power the site for 120 days without any solar power input to the system. Additionally, on the Seward Peninsula sites should be able to operate up to six months without any solar gain. This is due to the frequent and heavy rime ice conditions in the winter, which can obscure solar panels. Each datalogger site on the Seward Peninsula is powered by a combination of photovoltaic cells and absorbed glass mat (AGM) lead acid batteries. Typically each site has one 55 Watt solar panel and 320 Amp hours of battery reserve. AGM batteries were chosen for their ability to be transported by air carriers as non-hazardous materials. Powering the radios for only 2-10 minutes each hour also reduces the energy consumption of the radios during the winter. This significantly reduced the average energy consumption of these remote systems.

4. North Slope Radio and Satellite Hybrid Telemetry system

The WERC has been collecting hydrology and environmental climate data on the North Slope of Alaska for almost twenty years. The study sites are in close proximity to the Dalton Highway and go from the foothills of the Brooks Range to the Beufort Sea, approximately 200 miles to the north. This remote area is not well connected to existing communications infrastructure. There is Internet access and cellular phone coverage in the Prudhoe Bay area, which is the northern extent of WERC's research sites. South of

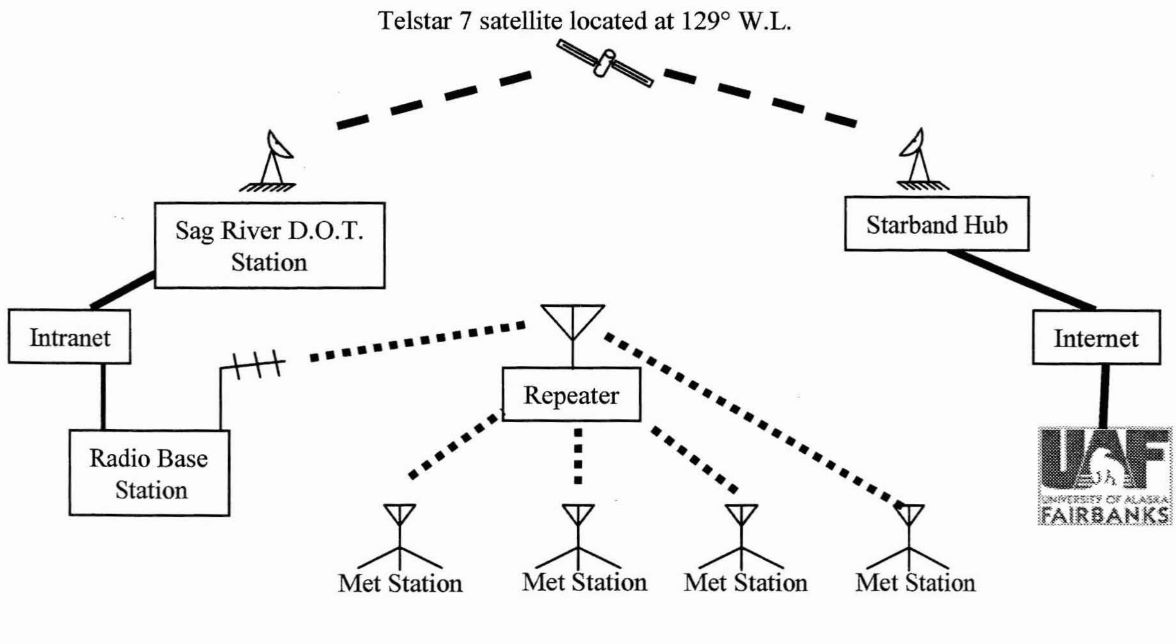

Figure 6: Schematic of the North Slope telemetry system. The Freewave radio network is connected to the Internet with the Starband system located at the State of Alaska Sag River Department of Transportation System. (Starband installation July 2002)

Prudhoe Bay, there are no year round telephone or Internet connections available.

During the spring and summer of 2002, a telemetry system was installed that provides remote connectivity to fifteen of WERC's meteorological and hydrologic sites on the North Slope. The radio system is similar to both the CPCRW system and the Seward Peninsula system. During the summer 2002 the radio telemetry system will be connected to the Internet in Prudhoe Bay with a RS232 to Ethernet device. This will provide a reliable link back to UAF at the northern end of the study area. The southern end will be connected Starband, a commercially available satellite Internet service provider (July, 2002). A diagram of the system is shown in Figure 6. A 1.2 m satellite dish will be located at the Sag River D.O.T. station. This will connect the remote Freewave radio network to the Starband Internet system, which provides unlimited Internet access. The system will be operational by the middle of August 2002. The connection sequence to reach a remote data logger will be similar to Table 1. State of Alaska workers at Sagwon will also utilize the Starband system, though the system is configured to give WERC data requests priority. The advantages of using the Starband system are: unlimited Internet access with a low monthly fee, two-way communication to any site throughout North America and it is designed for both commercial and residential applications. Pairing of the Starband system with a Freewave radio network supporting Campbell dataloggers demonstrates a unique hybrid solution to support extremely remote meteorological sites with two-way communication.

5. Conclusions

Over the past several years a variety new telemetry options have been introduced by manufactures for collecting data from remote sites. This newer technology has allowed users to collect data from sites that were once unreachable. It has also increased the reliability and the speed of communications to remote data collection platforms. This paper presents the merging of several telemetry options in order to acquire environmental data in near real time so that it may be utilized for making time critical decisions. Images from remote weather stations could potentially provide valuable information about snow loading patterns and recent avalanche activity. Alaska with its size and lack of transportation and communication infrastructure could benefit greatly from improved remote sensing of avalanche activity.

6. Acknowledgments

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7. References

Dunlap Mary Anne, 1994. Solar Radiation Data Manual for Flat-plate and Concentrating Collectors. National Renewable EnergyLaboratory Analytic Studies Division.

McChesney, P.J. 2000. Solar Electric Power for Instruments at Remote Sites. United States Geologic Survey. Open File Report 00-128.