GEOPEBBLES: WIRELESS SENSOR NODES FOR SEISMIC MONITORING OF ICE SHEETS

Jerome Mitchell*, Peter Burkett**, Sridhar Anandakrishnan**
The University of Kansas, The Pennsylvania State University

jemitchell@cresis.ku.edu, burkett@essc.psu.edu sak@essc.psu.edu

The Center for Remote Sensing of Ice Sheets (CReSIS) addresses the recent concern about climate change by predicting the role of ice sheets in Greenland and Antarctica while developing systems to track its large-scale affects on global conditions. The melting of large glaciers in both the Arctic and Antarctic regions would cause large-scale sea level increases and threaten highly populated areas to be submerged underwater. However, quantifying the rate of glacier ice thickness and melt is a challenging problem given the harsh conditions of the polar climates. Much progress has been attributed to satellite remote sensing, which measures the flow speed variability but is difficult because of the long repeat times of those sensors and measuring the spatial pattern of these signals with ground-based, high-precision GPS is also difficult because of high costs and potentially low accuracy.

A sensor technology used to measure the ice thickness and flow rates (> 1 m/day) of glaciers in the Polar Regions lies in the field of seismology. Seismic sensors, which consist of a three component geophone and is adequately suitable for microseismicity associated with surges and slips of glaciers use the reflection of acoustic sources to measure ice thickness and pose a great impedance because of the need for many (on the order of tens to hundreds) to monitor the phenomena. This paper details the development of GeoPebble, an autonomous, inexpensive combined single-frequency GPS and short-period seismic sensor. The first version of the sensor was wirelessly connected and transmitted a digitized seismic signal and GPS phase measurements to a base station by an off-the-shelf 802.11 mesh node. As a consequence to the high energy consumption and concurrent node support issues from this design, a second version led to a different network architecture using Zigbee radios (802.15.4) on each sensor node. The nodes in the sensor array should have the ability to transmit stored and processed data harbored on each node to a monitoring node in real-time, so scientists can have feedback and real-time imaging on the performance of the seismic tests. Essentially, the sensors need to be arrayed into a wireless sensor network.

This is challenging, however, due to the large amount of data collected per node. For example, the seismic sensor nodes are expected to each collect 24 bit samples at a rate of 10 kHz, resulting in a data generation rate of 240 bps per node. In addition to the high data rates, transporting batteries into the Polar Regions is difficult, therefore, it is desirable for each node to be able to function for days at a time without losing battery power. Current low-power radios, such as Zigbee, however, operate at low data rates, leading to a further design challenge.

Each GeoPebble has a twenty-four bit Sigma-Delta analog to digital converter and two Propeller CPUs, one to operate the backplane and one to handle the datalogging and wireless communication functionality. The Propeller microcontroller has 32 I/O pins and was hosted on a SpinStudio mainboard, which contains power regulation circuitry and connections for peripheral modules, as well as an EEPROM socket, crystal, and programming header. The wireless communications hardware consist of the XBee Series 2 RF modules and are 0.960 x 1.087 inches in size. Power requirements of these nodes are from 2.8-3.4 V. The nodes are able to transmit and receive at 40mA (@3.3V) with either an integrated whip or chip antenna. The hardware specifications for the data collection functionality include a memory stick datalogger, which is a USB host bridge and supports a mass storage devices to operate from a propeller microcontroller.

A LabVIEW interface was also designed for displaying real-time data from the sensor network. A multi-channel diversity routing algorithm was developed to help support high data rates across the sensor network. Essentially, on network setup, three leader nodes were elected, each one operating on a different channel. Then, based on load and interference information, each node joined one of the three leaders. The sink node in the network operated on all three channels and collected data from the entire network for real-time display. Also, a wave-form compression algorithm was used to reduce the amount of data transmitted by each node to further optimize the use of the network.

For the datalogging functionality, all of the raw data collected by the geophones was recorded to USB drive along with GPS location and time information. The disk was formatted with FAT32 and the files were written to be accessible by removing the USB drive from the GeoPebble and inserting them into a computer running either Windows or Linux with FAT32 support.

The contribution of this work was the design and implementation of a sensor node capable of supporting high data rates for use in inhospitable environments, such as Greenland and Antarctica. The project utilized a low cost, low power radio for high data rates and multi-channel diversity, coupled with data fusion techniques to provide real-time monitoring of seismic data. In addition to the data collection pillar, the seismic surveys have the flexibility to operate at longer and unconstrained limits due to the absence of a cable boundary. The sensor nodes supported high-speed USB data logging to a USB jumpdrive; this allowed data recorded by the sensor node to be easily imported to a PC running either Windows or Linux.