Autonomous Dam Monitoring with Integrated Real-time Evaluation: ADMIRE

Kerri Stone, Tracy Camp
Colorado School of Mines
{kstone,tcamp@mines.edu}

A primary failure mode in embankment dams is internal erosion, and current dam monitoring practices are incapable of detecting early onsets of internal erosion. Current dam monitoring occurs infrequently, with limited automation and little adaptability. Dam operators and owners periodically collect measurements from widely-spaced instruments. These instruments, including piezometers, inclinometers, settlement points, and seepage weirs, record widely spaced measurements within a structure composed of heterogeneous and spatially-diverse materials. Beyond this basic level of monitoring, dam owners may also send survey teams to sites to manually collect additional measurements and to perform more in-depth analyses (e.g., geophysical, topographic). The U.S. Bureau of Reclamation (USBR) aims for annual surveys of high-risk dams [3], but the frequency and extent of such monitoring varies significantly. This research is developing a wireless sensor network (WSN) application that allows for continuous non-invasive monitoring and performance assessment of earthen embankment dams. We call the system Autonomous Dam Monitoring with Integrated Real-time Assessment (ADMIRE).

ADMIRE will comprise custom geophysical mote platforms capable of driving seismic, self potential, and seismoelectric sensors. We have developed the custom geophysical mote platform with Earth Science Systems, LLC. The mote platform has an integrated seismic sensor, integrated self-potential electrode connectors, and integrated temperature sensors for self-potential calibration. We have selected the LS Research SiFlex processor and radio module [1] for use on the mote platform for its ample memory, its processing capabilities, and its low power, low frequency, long range radio.

To accurately collect and analyze geophysical signals, such as seismic, the WSN requires time synchronization at levels not yet realized on a wireless platform. One of the time synchronization protocols we intend to model our synchronization algorithm after is Virtual High Resolution Time (VHT) [2] written by UCLA, as VHT realizes synchronization at accuracies exceeding the $1\,\mu$s level. VHT uses ambient temperature readings to calibrate the quartz crystal to account for drift in addition to duty cycling a high frequency crystal to calibrate a lower frequency crystal to decrease energy consumption. Using a local crystal calibration algorithm, as in VHT, allows for less drift and decreases the need for frequent time synchronization packets. VHT as described in [2] realizes sub $1\,\mu$s synchronization in an FPGA (field-programmable gate array) implementation, not in an embedded mote platform implementation. ADMIRE extends the VHT work to an embedded mote platform.

ADMIRE includes a custom geophysical mote platform that is in its early stages of development. This research employs non-invasive sensing techniques into a WSN to autonomously assess the subsurface of dams and levees without drilling or digging to install measurement instruments. Not only will this research advance the state of dam monitoring practices, it will also contribute to wireless sensor network research by providing an embedded time synchronization algorithm capable of synchronization at the nanosecond level. ADMIRE will enable continuous monitoring and performance assessment of dams, allowing for early detection of anomalies in the subsurface, decreasing cost of repair, and lowering the probability of catastrophic dam failures.

References

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