Chapter 3

Related Work

While the number of sensor network deployments described in the literature has been increasing, little prior work has focused on evaluating sensor networks from a scientific perspective. In addition, the high data rates and stringent timing accuracy requirements of volcano monitoring represent a departure from many of the previously-studied applications for sensor networks.

Low-data-rate monitoring: The first generation of sensor network deployments focused on distributed monitoring of environmental conditions. Representative projects include the Great Duck Island [9, 8, 4], Berkeley Redwood Forest [10], and James Reserve [1] deployments. These systems are characterized by low data rates (sampling intervals on the order of minutes) and very low-duty-cycle operation to conserve power. Research in this area has made valuable contributions in establishing sensor networks as a viable platform for scientific monitoring and developing essential components used in our work.

This previous work has not yet focused on the efficacy of a sensor network as a scientific instrument. The best example is the Berkeley Redwood Forest deployment [10], which involved 33 nodes monitoring the microclimate of a redwood tree for 44 days. Their study focuses on novel ways of visualizing and presenting the data captured by the sensor network, as well as on the data yield of the system. The authors show that the microclimactic measurements are consistent with existing models; however, no ground truth of the data is established. This paper highlights many of the challenges involved in using wireless sensors to augment or replace existing scientific instrumentation.

High-data-rate monitoring: A second class of sensor network applications involves relatively high data rates and precise timing of the captured signals. The two dominant applications in this area are structural health monitoring and condition-based maintenance. In each case, arrays of sensors are used to capture vibration or accelerometer waveforms that must be appropriately timestamped for later analysis.

NetSHM [6, 5, 12] is a wireless sensor network for structural health monitoring, which involves studying the response of buildings, bridges, and other structures to localize structural damage, e.g., following an earthquake. This system shares many of the challenges of geophysical monitoring; indeed, the data rates involved (500 Hz per channel) are higher than are typically used in volcano studies.

NetSHM implements reliable data collection using both hop-by-hop caching and end-to-end retransmissions. Their work explores the use of local computations on sensors to reduce bandwidth requirements. Rather than a global time-synchronization protocol, the base station timestamps each sample upon reception. The *residence time* of each sample as it flows from sensor to base is calculated based on measurements at each transmission hop and used to deduce the original sample time.

Several factors distinguish our work. First, NetSHM is designed to collect signals following controlled excitations of a structure, which simplifies scheduling. In our case, volcanic activity is bursty and highly variable, requiring more sophisticated approaches to event detection and data transfer. Second, NetSHM has been deployed in relatively dense networks, making data collection and time synchronization more robust. Third, to date the NetSHM evaluations have focused more on network performance and less on the fidelity of the extracted data. Other systems for wireless SHM include one developed by the Stanford Earthquake Engineering Center [3, 11] and earlier work by Berkeley on monitoring the Golden Gate Bridge [7].

Condition-based maintenance is another emerging area for wireless sensor networks. The typical approach is to collect vibration waveforms from equipment (e.g., chillers, pumps, etc.) and perform time- and frequency-domain analysis to determine when the equipment requires servicing. Intel Research has explored this area through two deployments at a fabrication plant and an oil tanker in the North Sea [2]. Although this application involves high sampling rates, it does not necessarily require time synchronization as signals from multiple sensors need not be correlated. The initial evaluation of these deployments only considers the network performance and does not address data fidelity issues.

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