Department of Electrical and Computer Engineering
University of Rochester, Rochester, NY

Ph.D. Public Defense

Wednesday, February 25, 2015

9:00 AM

Hopeman Engineering Building, Room 224

Enabling Energy Efficient Sensing and Computing Systems

He Ba

Supervised by
Professor Wendi Heinzelman

Abstract

Wireless electronic devices are becoming more and more powerful while remaining portable and affordable. Some of the smartphones and tablets on the market today are equipped with multi-core CPUs and GPUs and have comparable computing capabilities to PCs, along with the improved network bandwidth and connectivity provided by cellular networks. Given this state of current technology, in this dissertation we develop a variety of techniques to enable energy efficient sensing and computing systems. As an example of such a system, consider a personal healthcare system, where wireless sensors are used to gather physiological data and send the data to a local cloudlet. The local cloudlet preprocesses the data and transmits the data to a remote cloud server for computation and storage purposes. Data analysis results are sent back to the cloudlet or directly to the user's smartphone for display.

One of the challenges in developing such a system is the data acquisition and processing. For applications like emotion classification or personal health, sensed data are not always gathered in clean environments and therefore are often corrupted by noise. Noisy sensing signals must be processed to improve the signal-to-noise ratio (SNR) in order to extract relevant information. For example, in an emotion classification application, speech data may contain babble noise from people talking in the background. In order to extract pitch, which is a key feature in emotion classification algorithms, from noisy speech data, we developed a hybrid pitch detection algorithm named BaNa. The BaNa algorithm combines the idea of using the ratios of harmonic frequencies and the Cepstrum approach to find the pitch from a noisy signal. We tested our BaNa algorithm on real human speech samples corrupted by various types of realistic noise. Evaluation results show the high noise resiliency of BaNa compared to other state-of-the-art pitch detection algorithms.

The second challenge comes from considering the energy availability. Wireless sensors are usually battery powered and hence have limited lifetime. To extend the battery life of a sensor node, power management approaches have to be utilized. The energy of a node can be saved by putting its radio and other components into sleep mode occasionally. To wake up a sensor node so that it can perform its functionalities, traditionally, a duty cycling approach is used, where an internal timer fires to wake up the sensor node from the sleep state. In this case, the sensor's energy efficiency may suffer from idle listening since it has no knowledge of the channel while sleeping. We created a passive wake-up radio sensor node named WISP-Mote by using a programmable RFID tag as an external wake- up radio for a Tmote Sky sensor node. The wake-up radio reduces the energy wasted on idle listening and hence improves the energy efficiency of the sensor node. We characterized the WISP-Mote's performance by measuring its energy consumption for different operations and assessing its wake-up probabilities in different environments for various WISP-Mote to reader distances. MATLAB simulation results show that the energy efficiency of a sensor network using the WISP-Motes is much greater than when using traditional duty-cycling nodes.

Computation of energy efficient sensing and computing systems can be local on the node, or, for more intense applications, computing can be off-loaded to external computing resources, such as cloud-based resources, to save the energy of the node. However, a traditional cloud is composed of powerful but energy- hungry workstations. The growth of the population of mobile devices such as smartphones and tablets provides a huge amount of idle computing power. We describe the design and implementation of a mobile computing system prototype named GEMCloud that utilizes energy efficient mobile devices (e.g., smartphones and tablets) as computing resources. The computing power and energy efficiency of the mobile devices are evaluated through comprehensive experiments. The results show that a cloud computing system with enough mobile devices working cooperatively is able to save 55% to 98% of the energy consumption of conventional server-based clouds while providing comparable computing speed.

By addressing the challenges of data processing, energy efficient operation and computation off-loading, we have provided the next step forward for energy efficient sensing and computing systems.