An Acoustic-Visual Collaborative Hybrid Architecture for Wireless Multimedia Sensor Networks

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ABSTRACT

Prolongation of the lifetime has become a key challenge in design and implementation of Wireless Multimedia Sensor Networks (WMSNs). The energy consumed in multimedia sensor nodes is much more than in the scalar sensors; a multimedia sensor captures images or acoustic signals containing a huge amount of data while in the scalar sensors a scalar value is measured (e.g., temperature). On the other hand, given the large amount of data generated by the visual nodes, both processing and transmitting image data are quite costly in terms of energy in comparison with other types of sensor networks. Therefore, energy efficiency is a main concern in WMSNs. In this paper an energy efficient collaborative mechanism for monitoring is proposed. The proposed scheme employs a mixed random deployment of acoustic and visual sensor nodes. Acoustic sensors detect and localize the occurred event/object(s) in a duty-cycled manner by sampling the received signals and then trigger the visual sensor nodes covering the objects to monitor them. Hence, visual sensors are warily scheduled to be awakened just for monitoring the object(s) detected in their domain, otherwise they save their energy.


INTRODUCTION

A wireless sensor network consists of sensor nodes deployed over a geographical area for monitoring physical phenomena like temperature, humidity, vibrations, seismic events, and so on. Typically, a sensor node is a tiny device that includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission. In addition, a power source supplies the energy needed by the device to perform the programmed task. This power source often consists of a battery with a limited energy budget. In addition, it is usually impossible or inconvenient to recharge the battery, because nodes are deployed in a hostile or unpractical environment. On the other hand, the sensor network should have a lifetime long enough to fulfill the application requirements.

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In recent times there has been increased interest in video surveillance and environment monitoring applications due to the increasing availability of cheap visual sensors (e.g., CMOS cameras) and processors. Visual information may be captured from the environment using the cameras embedded in wireless sensor nodes. Wireless Multimedia Sensor Networks (WMSNs), (Akyildiz, Melodia & Chowdhury, 2007), should be able to process in real-time, retrieve or fuse multimedia data.

One of the main differences between multimedia sensor networks and other types of sensor networks lies in the nature of how the image sensors perceive information from the environment. Most scalar sensors provide measurements as 1-dimensional data signals. However, image sensors are composed of a large number of photosensitive cells. One measurement of the image sensor provides a 2-dimensional set of data points, which we see as an image. The additional dimensionality of the data set results in richer information content as well as in a higher complexity of data processing and analysis. In addition, a camera’s sensing model is inherently different from the sensing model of any other type of sensor. Typically, a scalar sensor collects data from its vicinity, as determined by its sensing range. Multimedia nodes are characterized by a directional sensing model, called Field of View (FoV) and can capture images of distant/vicinal objects/scenes within its FoV from a certain direction. The object covered by the camera can be distant from the camera and the captured images will depend on the relative positions and orientation of the cameras towards the observed object (Soro & Heinzelman, 2005; Tezcan & Wang, 2008; Adriaens, Megerian & Potkonjak, 2006).

Accordingly, the amount of power consumed in the sensing subsystem of a multimedia sensor node is considerably more than of a scalar ordinary sensor. For example, a temperature sensor (Texas Instrument, 2013) as a scalar sensor consumes 6μW for sensing the environment. Cyclops (Rahimi et al., 2005) as a low resolution, low power camera sensor, consumes a mere 46mW and can capture.

CMU-Cams (Rowe, Rosenberg & Nourbakhsh, 2002) are cell-phone class cameras with on-board processing for motion detection, histogram computation, etc. Web-cams can capture high-resolution video at full frame rate while consuming 200mW, whereas Pan-Tilt-Zoom cameras are re-targetable sensors that produce high quality video while consuming 1W. It is noticeable that the mentioned power amounts are the power consumed by the camera sensors without considering the power consumed by the host motes, see (Tavli et al, 2012) for a survey of visual network platforms.

The data created by a multimedia sensor node, for example a captured image, has a massive volume with respect to a scalar sensor that produces a binary number, for instance the sensed temperature. Therefore, on one hand, the sensing and also processing subsystems of the multimedia sensor nodes consume a great amount of energy for image capturing and processing the captured images, and on the other hand, transmitting the huge amount of sensed data by the network nodes toward the base station or the sink is too costly. Since WMSNs are generally supplied by only the batteries embedded in the nodes and thus are extremely energy constrained, energy conservation and maximization of network lifetime are commonly recognized as a key challenge in this kind of networks (Akyildiz, Melodia & Chowdhury, 2007; Anastasi et al., 2009).

Experimental measurements have shown that generally data transmission is very expensive in terms of energy consumption, while data processing consumes significantly less (Raghunathan et al., 2002). The energy cost of transmitting a single bit of information is approximately the same as that needed for processing a thousand operations in a typical sensor node (Pottie & Kaiser, 2000). The energy consumption of the sensing subsystem depends on the specific sensor type. In some cases of scalar sensors, it is negligible with respect to the energy consumed by the processing and, above all, the communication subsystems. In other cases, the energy expenditure for data sensing may be comparable to, or even greater.
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