Demo Abstract: A Storage-centric Camera Sensor Network *

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Abstract

Improved energy-efficiency and storage capacity of new-generation NAND flash memory makes a compelling case for storage-centric sensor networks. Such a storage-centric sensor network emphasizes the use of platforms with larger storage and more extensive use of the storage capacities on sensors. We demonstrate the feasibility of storage-centric sensor networks using an instance of a storage-centric camera sensor network that is more energy-efficient in comparison to a traditional camera sensor network. We demonstrate multiple camera sensors, each consisting of a Cyclops camera attached to a MicaZ mote, using motion-triggered image capturing. The captured images are archived locally on flash storage and summaries of detected events are transmitted to the base-station. The base-station picks the events of interest from the summaries and requests the original captured image from the sensor as required. The use of high-capacity energy-efficient flash storage at the sensor allows us to trade-off expensive radio communication for cheaper local storage, improving the life-time of the battery and consequently, the life of the storage-centric camera sensor network.

Categories and Subject Descriptors

C.2.1 [**Computer Systems Organization**]: Computer-Communication Networks Network Architecture and Design Distributed networks

General Terms

performance, experimentation, measurement, design

Keywords

flash memory, storage, camera sensor network, energy efficient

1 Introduction

Until recently, sensor applications and systems were designed under the assumption that computation is significantly cheaper than both communication and storage, with the latter two incurring roughly equal costs. However, the emergence of a new generation of high-capacity energy-efficient NAND flash storage has significantly altered this trade-off, with our recent study showing that NAND flash storage is now *two orders of magnitude cheaper* than communication and comparable in cost to computation [3]. This observation challenges conventional wisdom and argues for redesigning systems and applications to exploit local storage and computation whenever possible in order to reduce expensive communication.

We demonstrate the benefits of in-network local storage using a sample camera sensor network application that trades expensive radio communication costs for comparatively cheaper local storage. This reduces the net energy consumption of the application, leading to an increase in lifetime of our storage-centric camera sensor network. Using our Capsule [2] storage library for storage and retrieval of data from energy-efficient high-capacity NAND flash allows us to demonstrate the energy benefit of using storage-centric sensor networks.

2 Demo Description

A typical camera sensor network [1] consists of a number of nodes that capture images when motion is detected. The lack of energy-efficient high-capacity local storage requires the sensor to then transmit the images to a base-station (or a cluster-head) for analysis and archival. Some of the issues that arise are described here.

- The low-cost commodity hardware used in sensor platforms results in a large number of false-positive or false-negative detections (the number is as high as 21.6% for the Cyclops [4] camera). The transmission of large camera images for each of these false alarms wastes energy, which is a precious resource.
- The movement of a single object through the field of view of a camera often generates multiple image frames, though all of them correspond to a single event. The lack of storage capability at the sensor requires all the images corresponding to a single event to be transmitted to the base-station. In most cases, only one (or a few) of the images is required to identify the object. Thus, the transmission of all the images also results in an unnecessary expenditure of energy.

Our storage-centric design uses high-capacity energy-efficient NAND flash storage at the sensor to address both

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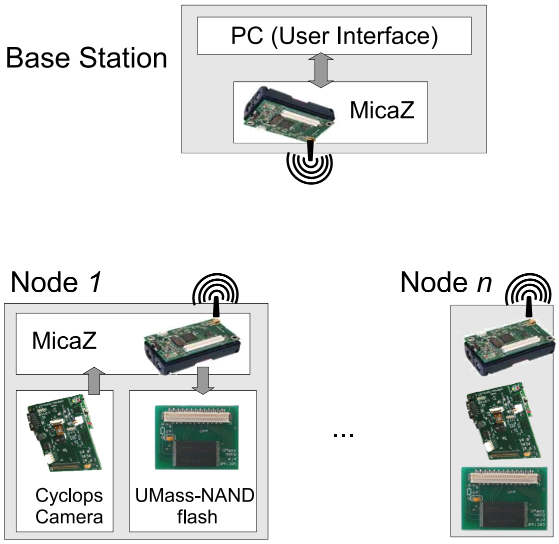

Figure 1. Setup of the storage-centric camera sensor network.

of these issues. The images captured by the camera are all *archived locally* on the flash. Instead of transmitting all captured images, only an *event summary* is sent to the base-station consisting of a single sub-sampled image along with other event information (such as time and duration). If the image or event is not of interest to the operator, the event can be discarded. However, if the event is interesting the actual image can be requested. If necessary to identify the object, more images corresponding to the event can be requested one at a time until the object can be successfully identified. By requesting images on an as-needed basis, extraneous images for object and event detection need not be transmitting on the power-hungry radio, resulting in energy savings.

2.1 Demo Setup

We demonstrate the benefits of in-network local storage in this setting. Our setup is shown in Figure 1 and discussed in detail below.

Sensor node: The sensor comprises a Cyclops [4] camera attached to a MicaZ [5] mote. The sensor is also equipped with a NAND flash adapter [3] fabricated by us that has a storage capacity of 512MB and is interfaced through the Mica2 expansion connector.

The sensor captures motion-detection triggered images that are stored locally on the NAND flash using our Capsule[2] storage system. The images are stored in a *Stream* object and an *Index* object is used to catalog the images based on time or features. Sub-sampled versions of the stored images at each motion-event are created and transmitted to the base station. These images are smaller than the original images taken by the camera and hence require less energy to transmit. Our camera sensor network employs multiple such sensors.

Base-station: There is a single base station comprising a MicaZ mote attached to a PC through a programming board. The MicaZ can communicate with the PC using the serial port and the PC runs an application that allows the user to interface with the sensor network.

The base-station receives the sub-sampled images sent by the sensor nodes when motion is detected and the operator can look at the images and determine if there are any events of interest – *e.g.*, a person walking by is an event of interest but a pet moving around is not. The base-station keeps a distributed index of received images over all the sensor nodes and this is used to retrieve the full resolution image from the local storage of the sensor for further analysis.

2.2 Demo Contributions

The goal of our demonstration is to show the feasibility of a storage-centric model for sensor networks, taking camera sensor networks as an example.

1. We demonstrate an energy-efficient redesign of a traditional camera sensor network to a more storage-centric network. The use of pull-based techniques give us the improved efficiency over the traditional push-based approach. We use efficient search techniques to locate data using distributed indexing at the base-station and archival at the local sensors.

2. We showcase the use of our Capsule [2] storage system for performing local data archival at the sensor. It offers an intuitive object-based storage abstraction that speeds up sensor application development – we use the *Stream* object to store captured images and use the *Index* object to locate an image when requested by the base-station.

3 References

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