Poster Abstract:

Sensorcam: An Energy-Efficient Smart Wireless Camera for Environmental Monitoring

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ABSTRACT

Reducing energy cost is crucial for energy-constrained smart wireless cameras. Existing platforms impose two main challenges: First, most commercial smart phones have a closed platform, which makes it impossible to manage low-level circuits. Since the sampling frequency is moderate in environmental monitoring context, any improper power management in idle period will incur significant energy leak. Secondly, low-end cameras tailored for wireless sensor networks usually have limited processing power or communication range, and thus are not capable of outdoor monitoring task under low data rate. To tackle these issues, we develop *Sensorcam*, a long-range, smart wireless camera running a Linux-base open system. Through better power management in idle period and the "intelligence" of the camera itself, we demonstrate an energy-efficient wireless monitoring system in a real deployment.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Wireless communication

1. INTRODUCTION

Wireless sensor networks are becoming the new paradigm for environmental data gathering. In this context, a visual feedback from the monitored area can prove indispensable to access the potentially critical environmental situation (avalanches, rock slides, fires, etc.) or to better interpret the telemetry data (snow vs. rain, clouds vs. sun, and so on). To this end, an autonomous, low-power camera could be installed in conjunction with the sensor network to deliver on-site images or video. However, a monitoring camera generates much higher data volume than the traditional environmental data, while it still suffers from the same challenges including i) low communication rate and ii) limited energy budget.

Ideally, the setup would be similar to that of the sensing stations, i.e., a wireless camera delivers the scene of interest periodically to the base station, using the energy from a rechargeable battery and a solar panel. The camera would need to work autonomously for long periods of time, while it achieves a desired sampling frequency (1-200 images/hour in our case). In order to minimize power consumption and bandwidth requirements, the camera must be "intelligent" to process large amounts of raw data and transmit as minimum bits as possible.

There are some off-the-shelf solutions for wireless cameras, however, all prove to be impractical for this task:

1) Commercial smart phones with image sensor: closed platform and impossible for low-level power management.
2) Image sensing nodes developed for wireless sensor networks like Cyclops [5], CITRIC [1]: limited computing capability or insufficient communication range for outdoor monitoring.

To address these problems, we developed *Sensorcam*, a fully flexible, long-range, smart wireless camera running a Linux-base open system. In Section 2, we first briefly introduce the *Sensorcam* prototype. To demonstrate the advantage of smart cameras over conventional ones, in Section 3, we implement on *Sensorcam* three video coding schemes with increasing "intelligence". The energy profiling at a real deployment shows substantial benefits in overall consumption, including both communication and computation.

2. SENSORCAM PROTOTYPE V.2

Sensorcam includes a master board capable of embedded computing, GSM radio communication and GPS localization. A solar power system is equipped as the energy source. The master board runs an embedded Linux system and is able to control all the hardware peripherals from the software level. The main benefit of the Linux system is that, it can directly adopt libraries and programs from the open-source community. For instance, OpenCV library [4] is extensively used by us for image processing programming. It is also worth to mention that the developers of such libraries have started to release optimized codes for embedded platform, thanks to the emergence of mobile computing.

Fig. 1a shows the master board and its main components. Particularly, it includes: 1) MSP430 micro-controller for power management; 2) Colibri PXA270 module that runs Linux system; 3) Telit GM862 GSM/GPRS module for data communication and GPS localization; 4) Camera interface that connects to a camera module (e.g., Omnivision OV7720); 5) UART/Ethernet interface for debugging during software development; 6) SD card for data storage.

Fig. 1b shows the solar power system we used. Using solar radiation data collected from the deployed system, we calculate the average energy supply during the winter period (most adverse period) from 15th Jan 2011 till 17th Mar 2011. The energy budget and other important specifications of *Sensorcam* are listed in Table 1. Particularly, through

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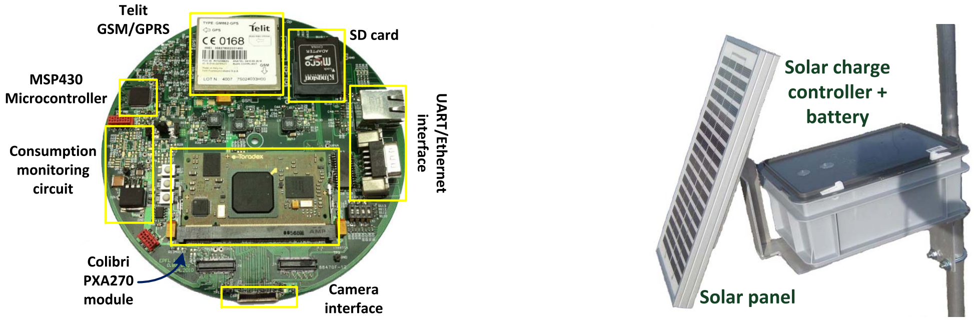

(a) (b)

Figure 1: *Sensorcam* v.2 prototype: (a) Master board. (b) Solar power system.

Table 1: Specifications of *Sensorcam* v.2

CPU	520 MHz
SDRAM	64 MBytes
Flash memory	32 MBytes
GSM/GPRS uplink speed	∼16 Kbps
Resolution of camera OV7720	640×480
`average energy supply in winter`	
2.4W solar panel	12.6 KJ/day
`typical system consumption`	
CPU normal, radio on (Transmitting)	900∼3000 mW
CPU busy, radio off (Computing)	900 mW
CPU sleep, radio off (Idle)	40 mW

precise power management of all hardware peripherals before the system goes to sleep state, we minimize the system consumption in idle mode to 40 mW (250 mW for commercial product like EZ camera [3]).

3. BENEFIT OF INTELLIGENCE

Due to considerable complexities of video coding algorithms like H.264, most of standalone cameras in market cannot afford real-time encoding at 30fps. However, even in the scenarios where real-time is not a requirement (e.g., lower fps or latency permitted), current wireless surveillance cameras does not fully take advantage of the computation power on board. For instance, at a similar consumption rate of *Sensorcam*, EZ camera [3] employs the simplest Motion JPEG to compress captured image sequences. To demonstrate the benefit of using computation power of a camera, we implement three video coding schemes on *Sensorcam* with increasing "intelligence" to deliver potential events of interest to the end-user, namely: (1) Motion JPEG (MJPEG); (2) H.264/AVC High Profile; (3) Event-driven video coding (EVC) as proposed in our work [2].

In the experiments, the camera is programmed to capture an image of a parking lot at every T minutes. During standby period, the minimum configuration of the circuits is put into sleep mode and the rest is shut down. We connect an energy meter at the power source to measure the overall energy consumption during each experiment. Figure 2 shows the consumption per frame of three schemes. We can see that the overall consumption decreases substantially as the "intelligence" of camera increases.

4. CONCLUSIONS

We present *Sensorcam*, a smart wireless camera designed for environmental monitoring. Unlike existing platforms, it is fully flexible in both software and hardware levels. To minimize the energy leak during the idle period, we keep the minimum configuration of circuits in sleep mode and all the rest is shut down. In a real deployment, we show that the energy efficiency can be achieved by exploiting the "intelligence" of the camera itself. Despite its original motivation, using the on-board GPS, *Sensorcam* has also the potential to be used in a broader range of applications like outdoor surveillance, mobile sensing, etc..

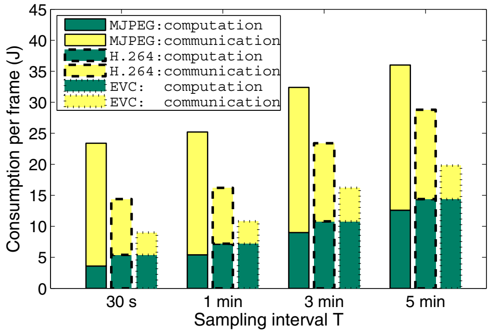

Figure 2: Energy profiling of EVC, H.264 and MJPEG on *Sensorcam*.

5. REFERENCES

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