

# Chapter 1.5

## Video Delivery in Wireless Sensor Networks

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### ABSTRACT

*Recent advances in wireless communications technology and low-power, low-cost CMOS imaging sensors stimulate research on the analysis and design of ubiquitous video sensing and delivery in wireless sensor networks. However, scalable deployments remain limited or impractical. Critical challenges such as radio interference, limited channel capacity, and constrained energy resources are still barriers to large-scale deployment of these wireless video sensor networks. The solution space can be explored in several dimensions including data compression, video image analysis and extraction, and intelligent data routing. In this chapter we focus on the analysis of video delivery and data routing techniques for wireless video sensor networks. Our work is intended to inspire additional efforts leading to video routing techniques optimized to different topologies, the physical medium, network channels, and energy constraints.*

### 1. INTRODUCTION

Advances in computer and network technology have led to wireless sensor networks – networks comprised of many small, low-power embedded processors capable of sensing and communicating using short-range networking. Today, sensor net-

working has emerged as a frontier interconnecting the Internet to the physical world. For example, one can deploy a series of moisture sensors to monitor soil moisture on a farm, for water management, or in smart grid applications to monitor and control lighting in a home or business. Among the many sensor modalities supported by the sensor devices (or motes—sensor nodes), we concentrate our focus on ones that produce single or multiple

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images in a video stream. With the development of low-power, low-cost CMOS imaging sensors, scientists envision great potential for multimedia streaming applications of wireless sensor networks in the areas of homeland security, habitat monitoring, and image-based monitoring and control.

For these applications a sensor node can capture images, audio and/or video information, and send them in a compressed form to a consumer elsewhere on the network. A user need not wait for the download of the entire video sequence but instead can playback the content immediately once data begin to arrive at the receiver. The flexibility of wireless sensor networks coupled with this sensing modality makes video observation very promising to enable humans to observe phenomena or locations that are otherwise difficult or dangerous to access. For instance, ornithologists might deploy such a system in a bird habitat and watch bird behavior without any human disturbance. This kind of network also exhibits value in the areas of military detection and security surveillance. Broadly speaking, the technology is a variant of sensor networking called wireless video sensor networking (WVSN).

Challenges in providing WVSN have to do with resource limitations. The data intensity of video creates several problems: (1) capturing and compressing continuous video is expensive in terms of energy costs at a sensor node, (2) data transmission over multiple hops from a video node to an arbitrarily-located consumer uses a communication channel that is prone to contention, (3) nodes comprising intermediate hops have limited data buffering capacity, and (4) the existence of multiple video sources and video consumers creates resource management complexity.

Much research has been conducted in the field of sensor networking; considerable effort has also been applied to delivering video in networks. Examples include monitoring near-shore environments (Holman et al. 2003), assisted living for elders (Teixeira et al. 2006), deploying large scale surveillance video sensor networks (Chu et

al. 2004), people counting and indoor localization (Teixeira et al. 2007), multi-target tracking (Kulkarni et al. 2005) and other uses of vision sensing (Rowe et al. 2007).

Many of the WVSN applications above are an integration of Internet video streaming solutions to the domain of wireless sensor networks. Some applications rely on conventional wired video cameras. Others assume wireless communications but do not address scale-up to large numbers of video cameras nor the support of many streams. Two distinguished applications among the above are SensEye (Kulkarni et al. 2005) and FireFly (Rowe et al. 2007). SensEye uses a multi-tier video solution for pervasive video sensing. The low tier network cooperates with the higher tier network to perform the video sensing task. Experiments demonstrate that this network decomposition can result in energy-efficient field sensing. However, the requirement of inter-tier communication and cooperation introduces heterogeneity problems to the network and also increases the complexity and cost of the hardware. FireFly presents an image processing framework with operating system, network and image processing primitives that assist in the development of distributed vision sensing tasks. The success for this application is attributed to the utilization of collision-free TDMA link layer for wireless video streaming. However, the required network-wide synchronization scheme for TDMA link restricts the scalability of the network deployment.

The main obstacle for the scalability here is the lack of mechanisms to manage contention among multiple source-to-destination video streams in the context of sensor network energy and communication constraints. The remainder of the chapter surveys the state-of-the-art of video routing schemes applicable to a WVSN with the intent of guiding the development of new video routing protocols for WVSNs.

The remainder of this chapter is as follows: Section 2 provides a background on video streaming over wireless sensor networks. Section 3 in-

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