Engineering Applications of Artificial Intelligence 25 (2012) 1349–1354

Contents lists available at SciVerse ScienceDirect

Engineering Applications of Artificial Intelligence

journal homepage: www.elsevier.com/locate/engappai

Adaptive frame synchronization for surveillance system across a heterogeneous network

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ARTICLE INFO

Available online 28 February 2012

Keywords:
Surveillance system
Heterogeneous network
Frame synchronization
Playback liveness

ABSTRACT

As mobile techniques are booming, the surveillance function is extended from a stationary mode to a mobile mode. In a heterogeneous network environment, cameras and viewers are located in different networks so that frame synchronization may span across diverse network domains with different transmission capabilities. The mismatch of transmission capabilities may affect the viewing continuity and playback liveness between cameras and viewers. In the article, we propose an adaptive frame synchronization mechanism for frame capturing at cameras based on the network condition to improve the frame synchronization between two sides across a heterogeneous network. Based on a brief theoretical analysis of the asynchronization effect for video communication in a heterogeneous network environment, the proposed adaptive pause time mechanism can be an effective solution to relieve the asynchronization effect in the unmatched transmission rate situation. The evaluation results show that the proposed scheme can achieve a shorter time delay between the captured frames at the camera site and the viewer site.

1. Introduction

With the assistance of Internet, the surveillance system makes a big progress to let surveillance users monitor distant events by a simple browser. Thus the remote live events can easily be seized at anywhere the users access Internet. If the monitoring application can be extended to a handheld device such as a cellular phone, surveillance users can acquire remote events at anytime and anywhere via any available mobile wireless network, such as the General Packet Radio Service (GPRS), Wireless Fidelity (Wi-Fi), and Universal Mobile Telecommunications System (UMTS) to the implementing Worldwide Interoperability for Microwave Access (WiMAX) or 3rd Generation Partnership Project Long Term Evolution (3GPP-LTE). Thanks to the wireless technology revolution, a wireless user can access Internet services via ubiquitous networks by a multi-mode device. J2ME is a typical mobile based development technologies (Read and Maurer, 2003; Kochnev and Terekhov, 2003). A J2ME based wireless intelligent video surveillance system was implemented to make a useful supplement of a traditional monitoring system with its good mobility (Xu et al., 2008). In such a mobile surveillance system, captured frames are normally obtained through a higher speed network in a building and then delivered to the remote mobile users through a lower speed network outside the building. The mismatch of transmission capabilities in different networks which cameras and viewers are attached to would affect the viewing continuity and playback liveness. The unmatched bandwidth at both ends located in different network environments may incur a deferred playback at the viewer site so that the transmitted frame rates should be adapted to the heterogeneous network conditions. Capturing and sending too many frames which cannot be viewed on time by the viewer not only cause frame delay between cameras and viewers but also waste too much power for capturing frames at the camera site. A simple and intuitive way, this issue is adjusting the capturing period by an adaptive pause time control mechanism at the video input end. Hence, this paper proposed a frame synchronization scheme by adaptively pausing some time at the camera side based on the network transmission condition to make the remote viewers obtain the captured frames with more synchronous event information.

The rest of this paper is organized as follows. Section 2 illustrates some related works about surveillance systems. Section 3 illustrates the surveillance system model in a heterogeneous network environment and the proposed adaptive frame synchronization scheme. In Section 4, we theoretically analyze the asynchronization effect of video communication in a heterogeneous network environment and show some simulation results to prove the effectiveness of the proposed mechanism. Concluding remarks are finally drawn in Section 5.

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doi:10.1016/j.engappai.2012.02.001

2. Related work

A typical surveillance system model is sending the captured frames from cameras to viewers for being played back. In a heterogeneous network environment, the quality of frame synchronization is largely affected by various network characteristics, such as a limited channel bandwidth and a variant transmission rate. Therefore, frame synchronization may encounter a frame lag issue while the frame transmission spans across different networks. Many adaptive solutions are proposed for users' dynamic variations in network access capability. Proxy cache based mechanisms are designed for adaptively playing streaming media (Yu et al., 2003; Cha et al., 2006) and reducing the maximum bandwidth requirement subject to QoS-guaranteed video playback (Chang et al., 2007). Some adaption strategies are based on feedbacks from users, such as the packet dispersion feedback (Jammeh et al., 2009), the specific subset of packets that should be delivered (Magharei and Rejaie, 2006), or user specified relevance-distortion policy (Ozcelebi et al., 2007).

In a traditional surveillance system (Foresti, 1998; Esteve et al., 2007), many fixed cameras are pinned at fixed locations to capture events. Users then keep a close watch on the videos sent from these cameras via a monitor at a fixed location. Application for surveillance system such as vehicle classification by road lane detection and model fitting using a surveillance camera is shown in Shin et al. (2006). Tracking human facial expression within a video image has many useful applications, such as surveillance and teleconferencing. Using the Active Appearance Model to recognize human facial expression in a video image (Jo and Kim, 2010) is proposed. Internet indeed facilitates the remote monitoring but it still lacks some flexibility. In the past, many efforts are put on improving the inflexibility in a traditional surveillance system. A web-based surveillance system in Imai et al. (2008) was proposed for surveillance viewers to perform monitoring and controlling remotely by cellular phones. However, if the both sides—cameras and monitors can become movable, the monitoring area can become wider and the viewer can obtain the events remotely anytime and anywhere.

A network camera equipped on a mobile robot (Leu et al., 2011) can help capture events in wider and more dynamic angles. As hardware costs are coming down dramatically and capabilities of robot are increasing fast, robotics is becoming more important in everyday life. A robotic dual-camera vision system (Tonet et al., 2008) is built by composing a telephoto camera whose field of view can be moved within a larger view field of a wide-angle camera. Meanwhile, movable robots can be a good facility to broaden the monitoring vision by carrying the event capturing camera. An autonomous mobile robotic system (Paola et al., 2010) developed on a multisensory mobile platform can autonomously navigate in the environment and perform surveillance activities. With the integration of current wireless network technology, a robotic surveillance system can extend the security sensing within a home or building environment. Meanwhile, Handover between different wireless networks is also an issue in autonomous mobile robotic system. An enhanced technique for vertical handover of multimedia traffic between WLAN and EVDO (Javed et al., 2010) is proposed. To maintain the connectivity of an established multimedia traffic between two different networks using mobility management, the authors propose an efficient algorithm which maintains the real time connection as well as preventing the data loss during transition from WLAN to Evolution-Data Optimized (EVDO).

On the other hand, the unmatched bandwidth at both ends which are located in different network environments may incur a deferred playback at the viewer side, the transmitted frame rates should be adapted to the heterogeneous network conditions. Adaptive Wireless Multi-level ECN (AWMECN) in Karimi and Fathy (2010) is proposed to conduct rate adaptation and quality adaptation in the application layer for a better Quality of Service (QoS) on delivering multimedia over heterogeneous wireless networks. Owing to the next generation of mobile wireless systems targets to obtain ubiquitous connectivity services for mobile users through heterogeneous wireless networks (HWNs), which integrate cellular network, WLAN, WiMAX, and MANET. In Xie et al. (2010), the authors discuss the security characteristics unique to HWNs. For reducing the computational time, Sathappan et al. (2011) address the problem of task scheduling in heterogeneous distributed systems with the goal of maximizing the system reliability and decreasing the makespan. On the other hand, when a user wishes to minimize the energy consumption for an application running on a handheld device, the user may choose to set the processor speed to its slowest level. An energy conservation DVFS algorithm (Liang et al., 2010) is proposed to maximize energy saving. A more simple and intuitive way for the rate adaptation is adjusting the capturing period by a adaptive pause time control mechanism at the video input end. Following the above design issues, our work presented in this paper aims to design a recognition assisted dynamic surveillance system by fully integrating wireless, robotics, image processing, and mobile phone techniques.

3. System model and proposed scheme

A generic surveillance system architecture in a heterogeneous network is illustrated as Fig. 1 shows. Two parties—Viewer and Camera in the surveillance system are bridged by a Proxy gateway and are normally located in different networks with different access capabilities and access rates. Without losing the generality, we assume that the network transmission rate under the network which the camera is attached to is higher than the one under the network which the viewer is attached to. For example, the camera may access the Internet via a Wi-Fi network with a higher access rate while the mobile viewer may access the Internet via

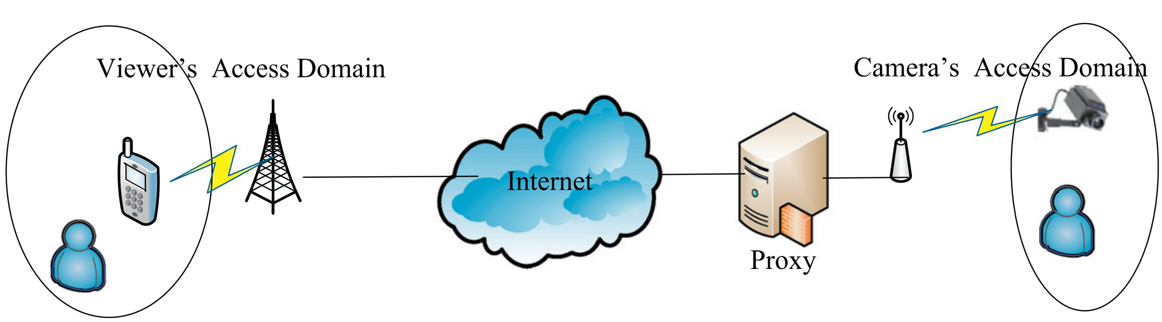

Fig. 1. A generic surveillance system architecture.