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Interaction relationships of caches in agent-based HD video surveillance: Discovery and utilization

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ABSTRACT

In the research of networked HD video surveillance, various *caches* embedded in the *IP camera*, the *data management server* and the *network proxy server* are used for lossless video storage and complete playback. How to utilize agent technology to achieve effective and collaborative caching in the end-to-end process of video capture, network data transmission and video data management, has been considered as an emerging solution. However, on one hand, according to the cache's location in HD video surveillance implementation, all caches can form a top-down hierarchical structure in a vertical direction; while on the other hand, according to the cache's storage performance such as free *storage space*, "similar" caches at the same level can be grouped by clustering in a horizontal direction. Hence, how to discover the complex interaction relationships among caches by considering both vertical and horizontal directions and further effectively make optimized video stream transmission though collaborative caching is still an open and challenging problem. In this paper, we designed an agent-based collaborative caching model, in which three roles of agents: the *Capturer Agent*, the *Transmitter Agent* and the *Manager Agent* are developed for discovering the intrinsic interaction relationships of caches. By utilizing the relationship, approaches to controlling *caching activities* and planning video stream transmission are further proposed. The case study and experimental evaluations demonstrate the capability of the proposed approach for HD video surveillance.

1. Introduction

In response to the increasing concerns for the safety in public places and transportation systems, *automated video surveillance* has drawn significant attention from both research and industrial communities (Collins et al., 2000). Due to the low-maintenance and effective observation on people and objects with visualization on their activities and interactions, *automated video surveillance* has become an important facility in public places such as airports and subway stations for applications such as the *access control*, *crowd flux statistics*, *human behavior analysis* and *crime detection* (Hu et al., 2004).

Since the transformation of the analog surveillance to the digital surveillance, *automated video surveillance* has entered a new stage, also known as *networked video surveillance*, in which the digital video signal will be transmitted to the *data management server* via a computer network such as a *private network*. Moreover, the *mesh network* has also been considered by both academy and industrial communities to realize a more flexible and mobile video surveillance system.

From the architecture perspective, *automated video surveillance* can be classified as the *centralized* surveillance and the *distributed* surveillance. The *centralized* video surveillance utilizes a central video *data management server* to aggregate the data from all the cameras, while the *distributed* video surveillance (Jaynes et al., 2002; Yuan et al., 2003) deploys a number of distributed sub-servers to cooperate with each other for the aggregation of all video data through network protocols (e.g. IP, RTP Schulzrinne, 1996, RTSP Schulzrinne, 1998). Recently the *distributed* video surveillance has become a mainstream research trend. Because the distributed structure can well support distribution of processing capacities over the network and the use of embedded signal processing devices, which will bring the advantages of scalability and robustness potential of distributed video surveillance systems.

However, the growing safety requirements in specialized surveillance systems, such as the train or railway surveillance

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(Sacchi and Regazzoni, 2000), the traffic surveillance (Kamijo et al., 2005), the elevator surveillance (Shao et al., 2000), call for *High Definition* (HD) video signals (Lilienfield and Woods, 1995), which have a higher 720 even 1080 line resolution with one or two million pixels per frame. The HD video can bring two immediate advantages into video surveillance: first, higher picture resolution provides digital surveillance cameras with sharper image capture for clear object identification; second, it can also promote the development of surveillance technology and devices. For instance, new HD digital cameras can scope the same area through the high-speed optical and digital zoom to provide more clear and detailed view.

In the emerging research of HD video surveillance, there usually exist three main devices, as shown in Fig. 1: the *IP camera* (IPC for short), the *network proxy server* and the *data management server*, which are responsible for *video capturing*, *network data transmission* and *data management* respectively. However, it is not trivial to achieve effective connection among the front-end HD *video capturing*, the *network data transmission* and the *data management* for lossless video storage and complete playback, for the following reasons:

- On one hand, HD camera will continuously generate large amount of video stream. When the network bandwidth is inadequate, the overflow of video data will render the surveillance system inoperative.
- On the other hand, the intrinsic dynamics in the network (e.g. the *congestion* and the *interruption*) also requires the transmission to be dynamically adjustable to allow lossless data *storage* (Lawton, 2006).

To address above problem, the method of *caching* has been exploited in many efforts (Rejaie and Kangasharju, 2001; Wang et al., 2002; Shen et al., 2004). Due to their advantages in small size and inexpensive cost, various *caches* can been embedded in the *IPC*, the *network proxy server* and the *data management server* for HD video surveillance for optimized video stream transmission and lossless video storage.

To help design a collaborative caching mechanism, the *multi-agent* technology, which provides methods of building agents capable of autonomous decision making and collaborative data mining, has been successfully utilized for video stream transmission (Tran et al., 2003; Wang et al., 2010), for its characteristics:

- Through their inherent autonomous and distributed computing ability, agents can proactively sense the latest dynamic changes in resources such as the storage space and the transmission bandwidth, and further process the corresponding data or make reasoning-based decisions.
- Through their reasoning ability, together with *clustering* (Wang et al., 2012), agents can proactively cooperate with each other to achieve intelligent video transmission.

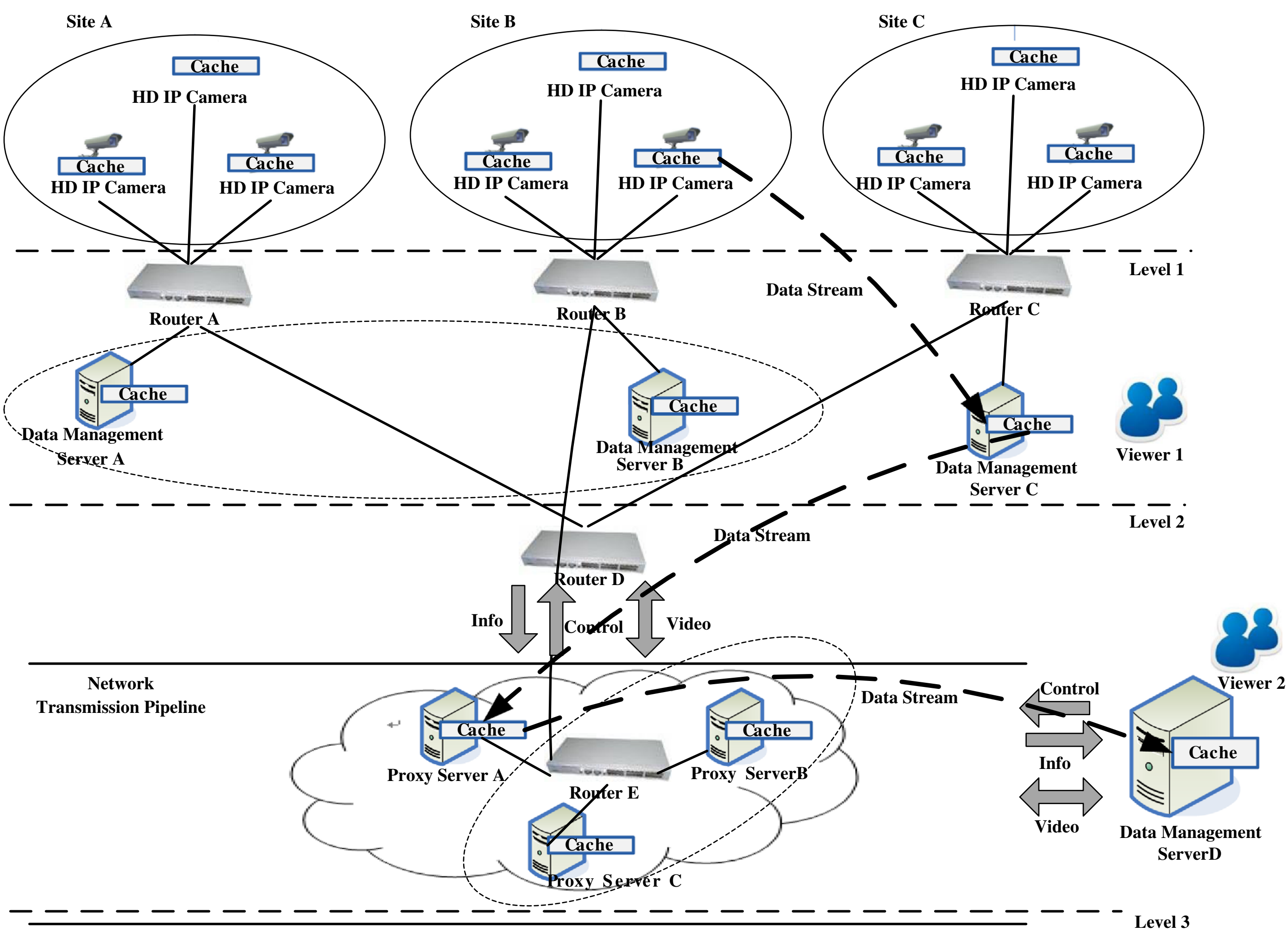

Fig. 1. A caching example scenario of HD video surveillance.