Group Synchronization for Multimedia Systems

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INTRODUCTION

An important feature of multimedia applications is the integration of multiple media streams that have to be presented in a synchronized fashion (Li *et al.*, 1997). Synchronization is mainly the preservation of the temporal constraints within and among multimedia data streams at the time of playout. Temporal relations define the temporal dependencies between media objects (Blakowski & Steinmetz, 1996). An example of a temporal relation is the relation between a video and an audio object that are recorded during a concert. If these objects are presented, the temporal relation during the presentations of the two media objects must correspond to the temporal relation at the time of recording. Discrete media like text, graphics, and images are time-independent media objects, while the semantic of their respective content does not depend upon a presentation to the time domain. A discrete media object is frequently presented using one presentation unit. On the contrary, a time-dependent media object is presented as a media stream. In a continuous media stream (e.g. video), the presentation durations of all units of a time-dependent media object are equal (Li *et al.*, 1997). For example, a video consists of a number of ordered frames. Each of these frames has fixed presentation duration.

Most of the components of a multimedia system support and address temporal synchronization. These components include the operating system, communication subsystem, databases, documents and even applications. In distributed multimedia systems, networks introduce random delays in the delivery of multimedia information, and there are four sources of asynchrony that can disrupt synchronization (Akyildiz & Yen, 1996):

- Delay Jitter and Local Clock Drift.
- Different Initial Collection Times. Let us consider two media sources, one providing voice and the other video. If these sources start to collect their media units (MUs) at different times, the playback of the MUs of voice and video from the two sources at the receiver loses semantic meaning.
- Different Initial Playback Times. If the initial playback times are different for each user, then asynchrony will arise.

To ensure synchronized delivery of multimedia information, intelligent synchronization protocols/techniques are required. This article illustrates various issues on intra- and inter-media synchronization and presents the basic schemes for inter-destination media synchronization (IDMS). It presents IDMS standardization efforts and novel solutions for new multimedia applications. Finally, it outlines future research directions for IDMS.

BACKGROUND

Intra-Media Synchronization

Intra-media synchronization refers to the time relations between the presentation units of one time-dependent media object. An example is the time relations between the single frames of a video sequence. The spacing between subsequent frames is dictated by the frame production rate. Jitter

may destroy the temporal relationships between periodically transmitted MUs that constitute a real-time media stream, thus hindering the comprehension of the stream. *Playout adaptation algorithms* undertake the labor of the temporal reconstruction of the stream, which is referred to as the *restoration of its intra-stream synchronization quality* (Park & Choi, 1996). *Adaptive media playout* (AMP) improves the media synchronization quality of streaming applications by regulating the playout time interval among MUs at a receiver. To mitigate the effect of the jitter, MUs have to be delayed at the receiver in order a continuous synchronized presentation can be guaranteed. Therefore, MUs have to be stored in a buffer and the size of this buffer will correspond to the amount of jitter in the network. As the synchronization requirements can vary according to the multimedia application on hand, we must control the individual synchronization (delay sensitivity, error tolerance etc.) for each media separately. To this direction, Park and Choi (1996) investigated an efficient multimedia synchronization method that can be applied at intra-media synchronization in a consistent manner. They proposed an adaptive synchronization scheme, based on the delay offset and playout rate adjustment that can match the application's varying synchronization requirements effectively. Park and Kim (2008) introduced an AMP scheme based on a discontinuity model for intra-media synchronization of video applications over the best-effort networks. They analyzed the temporal distortion (i.e., discontinuity) cases, such as playout pause and skip, to define a unified discontinuity model. Finally, Laoutaris and Stavrakakis (2002) surveyed the work in the area of playout adaptation.

Inter-Media Synchronization

Inter-media synchronization refers to the synchronization between media objects of a multimedia object. An example of inter-media synchronization is the *Lip Synchronization* that refers to the temporal relationship between an audio and video stream for the particular case of human speak-

ing (Aggarwal & Jindal, 2008). There are many systematic specification methods to describe synchronization problems. Blakowski and Steinmetz (1996) illustrated the main synchronization specification methods: interval-based specifications, control flow-based specification, axes-based synchronization, event-based synchronization, scripts, and comments. A *Synchronization Specification* of a multimedia object can describe all temporal dependencies of the included objects in a multimedia object. It is comprised of:

- Intra-object synchronization specifications for the media objects of the presentation.
- Quality of Service (QoS) descriptions for intra-object synchronization.
- Inter-object synchronization specifications for media objects of the presentation.
- QoS descriptions for inter-object synchronization.

To achieve inter-media synchronization various algorithms have been applied. There are several types of synchronization control such as *Skipping* (Ishibashi et al., 2002a), *Buffering* (Ishibashi et al., 2002a), *Adaptive Buffer Control* (ABC) (Wongwirat & Ohara, 2006), *Queue Monitoring* (QM) (Hikichi et al., 2002), *Virtual-Time Rendering* (VTR) (Ishibashi et al., 2002b), and *media adaptive buffering* (Isomura et al., 2011). Boronat *et al.* (2009) have reviewed the most powerful inter-media synchronization algorithms. The building blocks of these algorithms are the synchronization techniques utilized both at the sender and receiver sides. These algorithms can use multiple of synchronization techniques to achieve the synchronization mechanism even from different categories (Din & Bulterman, 2012).

Classification of Inter-Media Techniques

Synchronization techniques can be categorized according to the '*location*', '*purpose*', '*content*', and '*information* used' (Boronat *et al.*, 2009).

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