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Design, development and assessment of control schemes for IDMS in a standardized RTCP-based solution

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ABSTRACT

Currently, several media sharing applications that allow social interactions between distributed users are gaining momentum. In these networked scenarios, synchronized playout between the involved participants must be provided to enable truly interactive and coherent shared media experiences. This research topic is known as Inter-Destination Media Synchronization (IDMS). This paper presents the design and development of an advanced IDMS solution, which is based on extending the capabilities of RTP/RTCP standard protocols. Particularly, novel RTCP extensions, in combination with several control algorithms and adjustment techniques, have been specified to enable an adaptive, highly accurate and standard compliant IDMS solution. Moreover, as different control or architectural schemes for IDMS exist, and each one is best suited for specific use cases, the IDMS solution has been extended to be able to adopt each one of them. Simulation results prove the satisfactory responsiveness of our IDMS solution in a small scale scenario, as well as its consistent behavior, when using each one of the deployed architectural schemes.

1. Introduction

Research on media synchronization (sync, hereafter) has been primarily focused on orchestrating the playout of incoming media streams locally at single devices. On one hand, intra-stream sync deals with the maintenance of the temporal relationships between the Media Units (MUs), e.g., video frames or audio samples, of a specific media stream. On the other hand, inter-stream sync refers to the preservation of the temporal dependences between MUs of independent, but correlated, media streams, being lip-sync the most representative use case [1,2]. Both types of media sync techniques are essential in distributed media applications.

Recently, novel forms of media sharing applications are gaining momentum [3], allowing geographically distributed users to socially interact (e.g., using text, audio or

Abbreviations: AMP, Adaptive Media Playout; APP, (RTCP) Application-Defined Packet; CBR, Constant Bit Rate; DCS, Distributed Control Scheme; ETSI, European Telecommunications Standards Institute; GoP, Group of Pictures; GPS, Global Positioning System; IDMS, Inter-Destination Multimedia Synchronization; IETF, Internet Engineering Task Force; IPTV, Internet Protocol Television; FTP, File Transfer Protocol; M/S, Master/Slave; MU, Media Unit; NTP, Network Time Protocol; PTP, Precise Time Protocol; RFC, Request For Comments; QoE, Quality of Experience; QoS, Quality of Service; RR, (RTCP) Receiver Report; RTP, Real-Time Transport Protocol; RTCP, RTP Control Protocol; RTT, Round Trip Time; SMS, Synchronization Maestro Scheme; SR, (RTCP) Sender Report; SSM, Source Specific Multicast; TISPAN, Telecoms & Internet Converged Services & Protocols for Advanced Networking; TCP, Transmission Control Protocol; UDP, User Datagram Protocol; VBR, Variable Bit Rate; XR, (RTCP) Extended Report; WebRTC, Web Real-Time Communication.

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video chat) within the context of simultaneous content consumption. Some examples include Social TV, synchronous e-learning, and networked multi-player games. However, many challenges must be faced to enable truly interactive and coherent shared media experiences [4]. One of the major technological barriers is the lack of mechanisms to guarantee a simultaneous sync of the media playout across the involved devices, which is known as Inter-Destination Media Sync (IDMS) [3,5,6]. IDMS is needed to adaptively compensate the end-to-end (e2e) delay variability that is originated when delivering specific media content to a group of distributed devices. Indeed, previous studies have revealed that the magnitudes of these (playout) delay differences are significantly larger than acceptable limits in most of the IDMS use cases (e.g., [3,7]), leading to a severe QoE (Quality of Experience) degradation [8,9].

In [1,10], the authors presented the design, implementation and evaluation of a preliminary version of a centralized IDMS solution, which is based on simple extensions to the RTP/RTCP standard protocols [11]. Experimental tests proved its satisfactory performance in both real, but controlled, scenarios [1] and simulated ones [10]. However, with the advent of distributed media consumption, further requirements emerge. First, inter-operability between (third-party) implementations and devices needs to be guaranteed. Second, some IDMS use cases require very strict sync levels [3], so highly accurate IDMS solutions must be provided. Furthermore, our study in [3] pointed out that a centralized approach is not always the best choice for IDMS, as in some cases distributed solutions are more suitable.

The main goal of this work is to meet the above requirements. Accordingly, the contribution of this paper is threefold. First, novel standard compliant RTCP extensions[1] for IDMS have been designed to guarantee compatibility and high accuracy. Second, our RTP/RTCP-based IDMS solution has been extended to be able to adopt different control or architectural schemes. This allows our IDMS solution to be adaptive and flexible enough to be efficiently deployed in different networked environments. Likewise, newer aspects and functionalities have been added to improve its performance, for each scheme in use. Third, our RTP/RTCP-based IDMS solution has been implemented in a simulation framework and its consistent behavior and satisfactory responsiveness are proved through simulation tests in a small scale setup. Further research will be targeted to analyze the scalability and adaptability of our IDMS solution by performing a thorough evaluation in large scale and dynamic settings.

The structure of the paper is as follows. In the next section, the state-of-the-art regarding IDMS is reviewed. In Section 3, we describe the main components of our IDMS solution, for each control scheme. Section 4 gives performance results. Finally, Section 5 provides our conclusions and a discussion of future work.

[1] Both ETSI [12] and IETF [13] standardization bodies have adopted our RTP/RTCP-based technology for IDMS.

2. Related work

Due to the increasing relevancy of IDMS, several works have addressed this topic. In [5], authors presented a survey of IDMS solutions, while in [3] we presented a compilation of IDMS use cases. Besides, the recent work in [6] provides a historical review of multimedia sync techniques (including IDMS).

Two main categories of IDMS solutions can be distinguished (see [5,6]): *axis-based*, which aim to continuously align the presentation of media streams along either a virtual or a wall-clock timeline axis; and *control-based* (a.k.a. *event-based*), which handle the sync of media streams over a discrete set of reference control points or events.

In general, existing IDMS solutions were designed for specific applications, such as audio/video streaming (e.g., [1,2,9,14]), conferencing (e.g., [15–18]), gaming (e.g., [19–22]), collaborative virtual environments (e.g., [23,24]) or synchronous e-learning (e.g., [15,17]). Likewise, these solutions involve different types of media streams, such as audio, video, haptic media (e.g., [16,17]), and user-generated events (e.g., [4,20,21]). It is important to note that most of them are ad-hoc solutions, rely on the definition of new (application-specific) proprietary protocols, and make inter-operability between implementations and domains very difficult.

In addition, as such solutions were devised for specific networked environments and for meeting specific requirements, they differ on the adopted architectural approach to exchange the required information about IDMS. In this context, three main IDMS control schemes have been identified (see Fig. 1): two centralized (Master/Slave, or M/S Scheme and Sync Maestro Scheme or SMS) and one distributed (Distributed Control Scheme or DCS). Readers are referred to [3] to find an exhaustive description, classification (summarized in Table 1) and a qualitative comparison among these IDMS schemes. Even though it was concluded in that work that SMS is, in general, the best-ranked scheme for IDMS, the appropriateness of DCS and M/S Schemes for specific use cases was also identified. On one hand, M/S Scheme outperforms SMS in terms of scalability, traffic overhead, interactivity and causality. On the other hand, DCS can provide better performance than SMS in terms of robustness, scalability, interactivity, flexibility and fairness.

In general, the specification of an IDMS solution is highly dependent on the context and environment for which it is going to be deployed. For instance, some applications can be small-scale, while others can be deployed over large-scale settings. Some others require the achievement of stringent sync levels, while lower sync accuracy may be acceptable in other solutions. Bandwidth availability and multicast feedback capabilities can be an issue (or not) in specific scenarios. Likewise, other aspects, such as delay minimization or robustness, can be especially relevant in particular environments. At the end, the targeted use cases dictate the requirements, which will determine the necessary characteristics and functionalities of the media sync solution under design.

Our intention was to design a highly accurate, wider applicable (i.e., easy to deploy and valid for different use cases) and inter-operable IDMS solution, by using standard