Data Communications and Networking

Volume I

Michelle Vine

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Edited by **Michelle Vine**

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Preface

The idea that a person can talk to another and convey feelings and ideas is one that never fails to amaze. In today's modern world, this idea has taken on a life of its own and is no longer restricted to face to face information flow. Words and ideas bounce around the world in seconds, while only in the last century it often took days and months for people to be able to communicate with the forms of communication and networking available. A person in Sydney talks to someone in the UK with ease and with no time lag. With the advent of networking and communications in the past few decades, life has gotten much easier and progress is faster than ever. So many advances have been made in this field but most of the research has culminated towards the internet and the phone, two things which embody the tenets of communications and networking at its core. Communication is at its core, the act of conveying information through feelings, words and now, technology. It is the foundation of the advances of human civilization, something which has brought humanity closer than ever before. Nothing embodies the idea of networking better than the internet itself. The concept of linking the world electronically might have seemed outlandish once, but we see it being made into reality every day.

Such ideas and concepts, beginning from its inception to its hopeful destination are collated here and I am grateful to those who made this book a success.

Editor

Contents

Systematic Review of Multiple Contents Synchronization in Interactive Television Scenario

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Context. Interactive TV has not reached yet its full potential. How to make the use of interactivity in television content viable and attractive is something in evolution that can be seen with the popularization of new approaches as the use of second screen as interactive platform. *Objective.* This study aims at surveying existing research on Multiple Contents TV Synchronization in order to synthesize their results, classify works with common points, and identify needs for future research. *Method.* This paper reports the results of a systematic literature review and mapping study on TV Multiple Contents Synchronization published until middle 2013. As result, a set of 68 papers was generated and analyzed considering general information such as sources and time of publication; covered research topics; and synchronization aspects such as methods, channels, and precision. *Results.* Based on the obtained data, the paper provides a high level overview of the analyzed works; a detailed exploration of each used and proposed technique and its applications; and a discussion and proposal of a scenario overview and classification scheme based on the extracted data.

1. Introduction

Multimedia systems allow the data streams integration of different types, including continuous (audio and video) and discrete media (text, data, and images). Synchronization is essential for the integration of these media [1] and is focus of researches for a long time [2, 3]. Most of these works use a common taxonomy proposed by Cesar and Chorianopoulos [4] to classify multimedia synchronization.

This classification [5] is based on multimedia abstraction layers (Figure 1): in the media layer an application operates on a single continuous media stream, which is treated as a sequence of LDUs/MDUs (logical Data Units/Media Data Units); the stream layer allows the application to operate on continuous media streams as well as on groups of media streams; the object layer allows for simpler and exact specification of playout sequences, where each media object relates to a time axis and defines a sequence of events.

In the media layer, the intrastream synchronization deals with the maintenance, during the playout, of the temporal relationship within each time-dependent media stream, that is, between the MDUs of the same stream. In the stream layer the interstream synchronization refers to the synchronization, during the playout, of the playout processes of different media streams involved in the application and live synchronization deals with the presentation of information in the same temporal relationship as it was originally collected. The object layer presents synthetic synchronization where various pieces of information (media objects), at presentation time, must be properly ordered and synchronized in space and time [5].

Previous classification, however, does not consider the problem of synchronizing media streams across multiple separated locations, which can be found in literature as multipoint [6], group [7], or Inter-Destination Multimedia Synchronization (IDMS) [8]. This synchronization level is on top of the object layer and should be presented in what is called semantic layer (Figure 2). The semantic layer allows communication, search, retrieval, and interpretation of playouts and its contents. Besides IDMS, the semantic layer also deals with context synchronization (cross media, mash-ups, etc.). It considers that some authors use synchronization

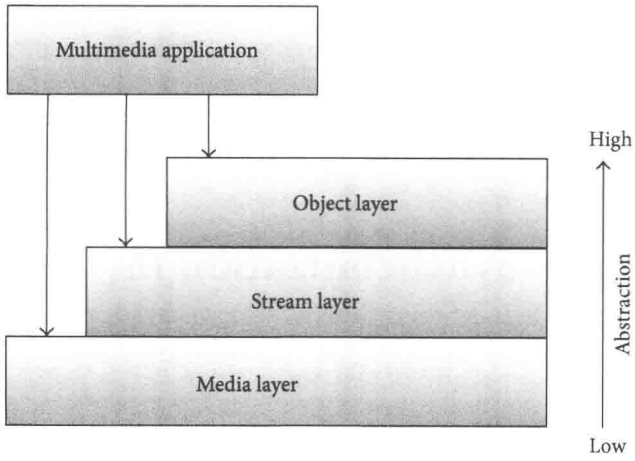

FIGURE 1: Synchronization abstraction layers—[5].

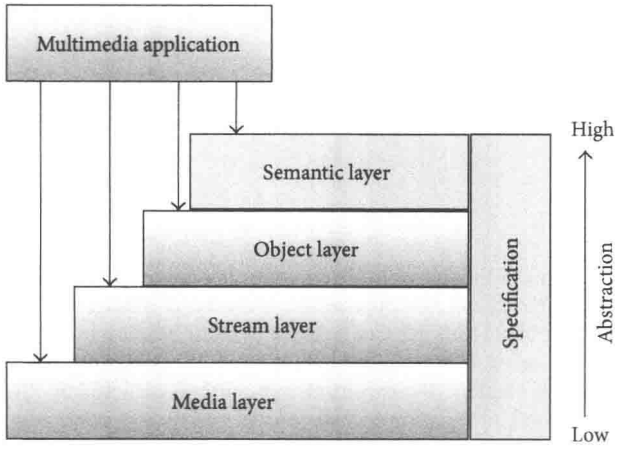

FIGURE 2: Abstraction layers with semantic layer.

in multimedia systems in a more general and widely used sense as comprising content, spatial, and temporal relations between media objects. In Figure 2, specification layer is also considered in the model proposed by Blakowski and Steinmetz [9]. The specification layer is an open layer that contains applications and tools that allow one to create synchronization specifications.

In the model derived from Meyer's one, the specification is not considered an isolated layer but one that is bound to all layers once every layer needs its own specification.

The following case shows that the use of only the three layers may not be sufficient to provide a satisfactory experience to TV viewers.

Figure 3 presents a Digital TV Application being executed on Brazilian Ginga middleware [10]. All media units are being correctly played (media layer); both video and audio are synchronized (stream layer) and the application media and video are correctly positioned and all relations defined by the NCL document are working just as defined (object layer). All three original layers specifications are being accomplished, but the user will notice something wrong at an upper level. While the video, audio, and EPG provides information about

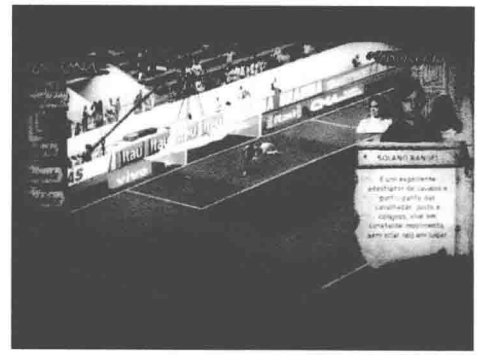

FIGURE 3: Semantic layer specification problem.

a soccer match, the multimedia content of the DTV application transmitted "synchronously" with the match presents info about a soup opera, which will be presented hours later. This problem cannot be tackled using previous media, stream, or object layers, because it is a specification made on demand by the user in the moment that he sees the video, audio, and application. Similar cases happen with mash-up, interdestination, and context based applications.

As one of the many scenarios for multimedia applications, television (broadcast and broadband) has synchronization requirements in all these layers: intrastream synchronization to synchronize presentation of audio and video LDU unit streams; interstream synchronization to lip-sync audio and video; synthetic synchronization to provide interactive applications (Brazilian Ginga, European MHP,...) and enhanced content (subtitles,...); and both IDMS and context synchronization for social sTV, second screen, and mash-ups applications. The focus of this study is to find approaches used to synchronize contents in TV scenario, characterizing the contents and the synchronizing solutions.

This paper is organized as follows: Section 2 introduces the methodology used to perform the systematic review; Section 3 presents the review's results; Section 4 shows a classification derived from the papers analysis; Section 5 briefly comments the research limitation; and Section 6 presents some conclusions.

2. Method

The need to synthesize available research evidence created well-established evidence-based disciplines [11] such as medicine and education research method called systematic literature review. This practice has recently been recognized in several computing disciplines from software engineering [12] to HCI [13]. More recently, a new method derived from systematic literature reviews was introduced: systematic mapping studies. Such studies are more focused on developing classification schemes of a specific topic of interests and reporting on frequencies of publications which cover a given topic of the development classification schemes.

This work reports the findings of a study that was conducted by combining the methods for systematic literature mapping and review to investigate the current state of

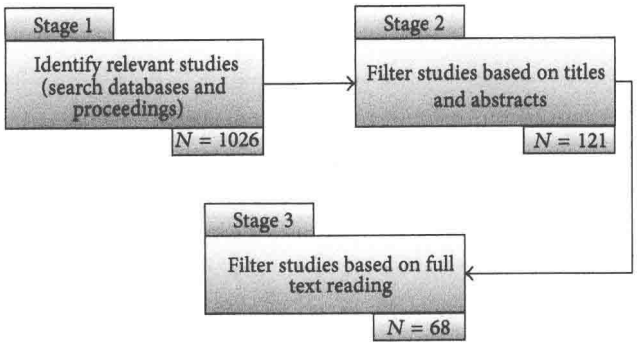

FIGURE 4: Study selection process and the number of works resulted from each stage adapted from [14].

research on Television Multiple Contents Synchronization. The details of research methods are described in the following subsections adapted from [14].

2.1. Study Design. This section presents the main focus and goals, points out the questions this review attempts to answer, and explains what research papers were included and excluded.

The focus of this literature review is based on Cooper's research outcomes, research methods, and practices or applications categories [15]. The research outcomes reveal gaps in the literature with regard to TV contents synchronization. The findings are based on the systematic analysis of data collection of research material. Research methods are analyzed to provide an overview of approach evaluations used by researchers and their contribution focus. The focus on practices and applications shows useful information regarding what type of content is provided in prototypes, where they came from, and where they are presented.

Our goal is to integrate outcomes and synthesize the results. We also attempt to generalize findings across the collected research papers. Another important goal of this review is to identify and characterize synchronization techniques for television multimedia environments and types of contents used in this synchronization, related to the semantic layer.

Finally, a set of important questions to be answered by this review is as follows.

(i) What is the state of synchronization techniques for television multiple contents?

(ii) Which devices are used to present multiple contents?

(iii) What protocols and algorithms are used in the synchronization?

(iv) What applications demand content synchronization?

(v) What kind of synchronization is demanded by contents?

(vi) What contents are being synchronized?

2.2. Data Collection. The data collection followed the process presented on Figure 4.

Stage 1 consists of a database search through academic and state-of-the-art publication databases and a manual search in the proceedings of some of the main symposiums and congresses in TV and multimedia area. Four digital libraries were identified to be searched in a systematic manner:

(i) Engineering Village (http://www.engineeringvillage.com/),

(ii) ACM Portal Digital Library (http://dl.acm.org/),

(iii) Scopus (http://www.scopus.com/),

(iv) IEEE Xplore Digital Library (http://ieeexplore.ieee.org/).

They were chosen because own search engines allow the use of logical expressions or equivalent mechanism, include computer science publications or related topics that are related to the points being researched, allow the search within metadata of publications, and are accessible through the academic research network of the authors. These databases are commonly used sources for conducting systematic surveys in computing research. Not all databases had the same features and search capabilities, so it was necessary to apply modifications on the search for each specific library. The logical Boolean string used in the conducted search is listed below:

(tv OR television OR televisions)

And

(synchronisation OR synchronization OR synchronous)

And

(media OR multimedia OR stream OR flow OR

content OR application OR applications)

To conduct the equivalent of the above search string it was necessary to learn how each of the digital library's advanced search features works. The end result was that all papers retrieved had within their title, abstract, or keywords the combination of the keywords presented in the logical Boolean string. Before proceeding to stage 2, all duplicated publications were removed. Figure 5 shows the intersections between the publications found in the databases and manual research. The number of papers selected after stage 1 was of 1026.

Exclusion and inclusion criteria were outlined in Stage 2 to filter irrelevant studies from Stage 1. The title and abstract of every paper were individually examined for false positives; that is, it was possible for a search result to contain all wanted keywords but without necessarily discussing the points of this review. At this stage, a total number of 121 studies remained. In this group works were included in which one had doubts about inclusion or exclusion. The exclusion and inclusion criteria were:

Inclusion:

(i) discusses solutions for synchronization contents in the television;

(ii) discusses cases that address the synchronization involving TV content;

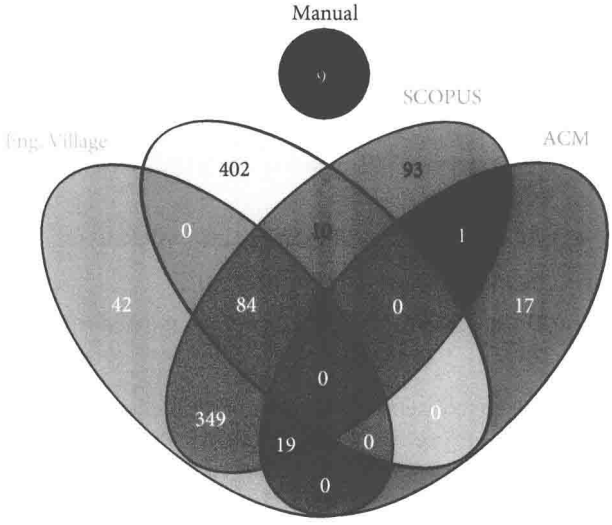

FIGURE 5: Venn diagram showing intersections among resultant publications.

TABLE 1: Number of excluded papers per criteria.

Criteria	Excluded
Hardware/codification/modulation/networking	582
Do not address the TV context	204
Do not discuss aspects of synchronization	51
Only inter- and intrastreams synchronization	39
3D TV	17
Inaccessible	8
Duplicated work	3

(iii) surveys about synchronization that involves TV;

(iv) discusses presentation of TV content with other devices and media;

(v) presents TV as one of the outputs on a synchronization scenario;

Exclusion:

(i) do not address TV context;

(ii) discusses only inter- and intrastreams synchronization;

(iii) do not discusses aspects of synchronization in any level;

(iv) discusses only video coding or transmission;

(v) discusses only hardware or codification or modulation or networking aspects;

(vi) discusses 3D TV.

Table 1 shows the number of papers that fell in each of the exclusion criteria. Additionally to the exclusion criteria, publications that were not accessible (the full text) by any means and duplicated works were also excluded.

Still in stage 2, two surveys were identified. Blakowski and Steinmetz [9] present a survey from 1996. The survey addresses inter- and intrastreams synchronization works, which are not the focus of this review. Boronat et al. [16] present a survey from 2009, which shows papers that addresses interstream and group synchronization (interdestination). The interdestination works would be an additional contribution to this review; however none of the works that addressed interdestination synchronization also addressed the TV scope, so this survey also do not have direct contribution for the current review.

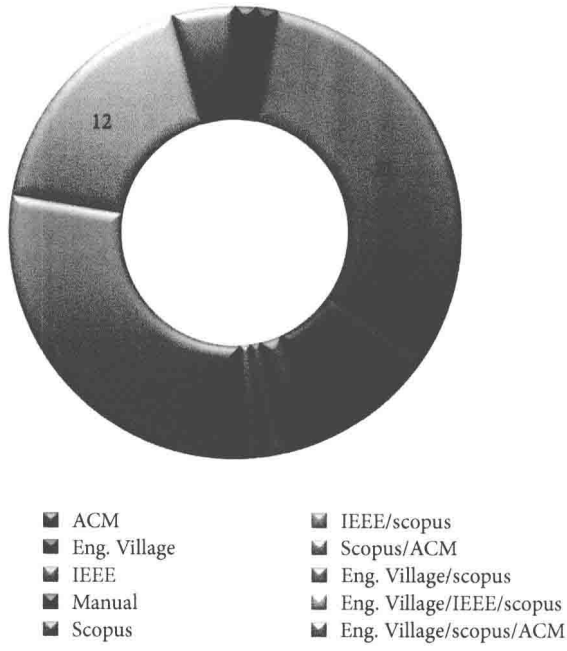

FIGURE 6: Distribution of the selected papers after the 3 stages.

In stage 3, all the 121 remaining papers were read. With the reading of the full text, it was possible to identify new papers that matched exclusion criteria, something that was not possible with the readings of title and abstract only. This stage was also utilized to extract data to be analyzed later. In the end, 68 papers remained and had its data extracted. Figure 6 shows the origin of the resultant papers.

2.3. Data Analysis. A questionnaire was used to extract data from the literature in an iterative process. A first version of the questionnaire was designed and tested on a small subset of collected papers, revealing more variables that were brought to attention. After the refinement the questionnaire was then used to extract data from all collected papers. A digital format for the questionnaire was utilized, using the GoogleForm (http://www.google.com/drive/apps.html) technology. The use of a digital questionnaire allowed that new variables were introduced during the review.

The questionnaire can be summarized as

(1) general Information for the paper:

(a) year of publication;

(b) publication Source;

Table 2: Publication sources of the final selected papers.

Publication source	Papers
International Conference on Consumer Electronics	7
International Conference on Multimedia and Expo	4
International Conference on Interactive Experiences for TV and Online Video	4
International Symposium on Consumer Electronics	4
Consumer Communications and Networking Conference	4
Brazilian Symposium on Multimedia and the Web	3
International Symposium on Multimedia	3
International Symposium on Broadband Multimedia Systems and Broadcasting	3
International Conference on Information and Communication Technology Convergence	2
Others	34

(2) TV contents synchronization specific information:

(a) transport of the synchronization specification;
(b) synchronization channel;
(c) synchronization mechanisms;
(d) synchronization specification methods;
(e) synchronization level;
(f) sources and destination of contents;
(g) control scheme;
(h) qualitative and quantitative evaluation metrics;
(i) applications and cases;
(j) content characteristics;
(k) paper's focus.

3. Results

This section presents the data extracted from publications resultant from stage 3. The general information is first presented about papers and then specific ones.

3.1. General Overview. The distribution of papers collected over the years is shown in Figure 7. It goes from 1998 with SMIL introduction [17] to the papers of 2013, like the work that extends the TV screen through projected screens on the wall around the TV [18].

As seen in Figure 7 most papers appear in the last five years, with a peak in 2012. In 2013 only two papers are seen up to half a year. The low number of papers can be explained by the fact that many proceedings of that year where most papers were found were not published to date.

Table 2 presents the main publications sources (Congresses, Symposiums and Journals) where papers were published.

3.2. TV Contents Synchronization. This subsection reports research results as determined by the analysis. Here aspects of synchronization, devices, sources, and contents are presented as they were extracted from papers.

The contributions of the surveyed papers are applications: the paper focus on the description of a specific multimedia application [18–30]; architecture: the paper proposes an architecture to solve synchronization problems but does not present programming interfaces or formalization [31–39]; framework: the paper presents a framework [40] that developers may use to provide synchronization to their multimedia applications [41–49]; language: the paper presents the description of a programming language that may be used to develop applications [17]; model: the paper presents the modeling of an approach that in theory may be used to bring synchronization to the applications [50–56]; platform/middleware: a platform which provides synchronization functionalities is presented. Also modifications to existing platforms are considered in this category [10, 57–69]; protocol: the paper defines rules and conventions for communication among devices so they may keep synchronization [70–74]; tool: the paper presents a tool with specific functionalities that once executed will provide synchronized contents [75–84]. The distribution of these papers is shown on Figure 8.

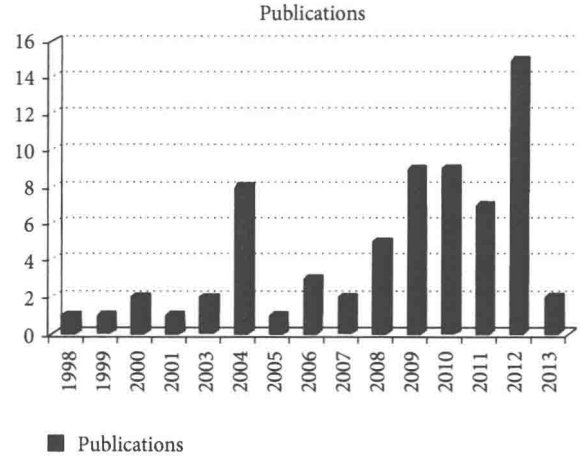

Figure 7: Publication years.

Platforms/middlewares are the majority kind of contribution found. The paper's authors propose a full environment to turn the presentation of contents with television possible. They contribute to the sources, transport, and presentation of contents and synchronization specifications. Hybridcast [67], HbbTV [69], and Ginga [10, 61] are some examples of middlewares. They are commercial platforms that are in

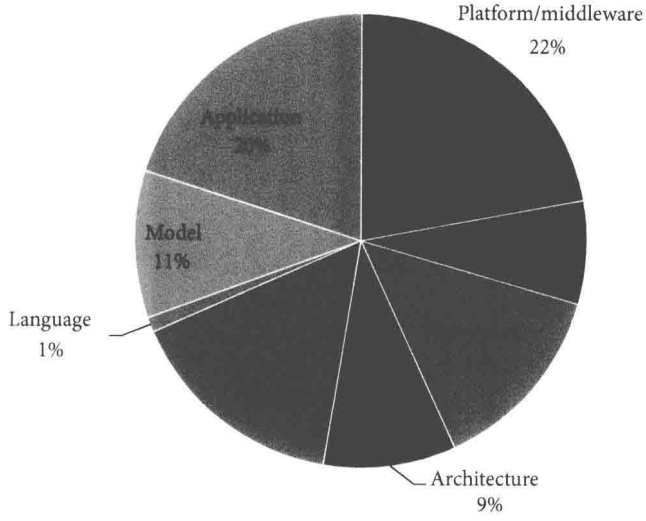

FIGURE 8: Focus of the contribution.

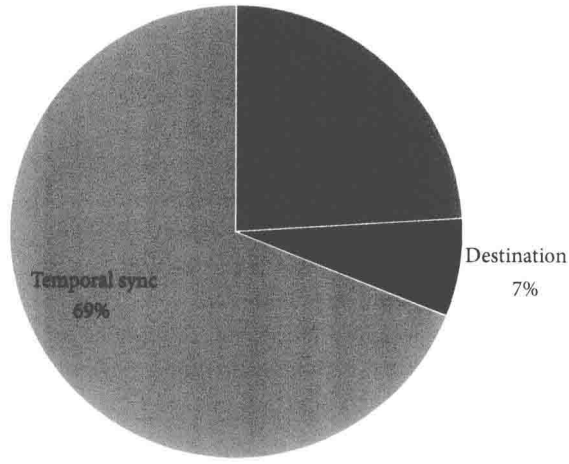

FIGURE 9: Synchronization fsocus.

use in many countries: Hybridcast in Japan through NHK, HbbTV in European countries, and Ginga in Brazil and countries that adopted ISDB-Tb [10].

Application papers mainly present an experience around a specific multimedia application. Being the focus, details about implementation, interface, and tests are more detailed than other papers that only cite what kind of application was used to validate the proposal. There are many cases, but some can be highlighted: [19, 20] present solutions to show medical data within captured video; [24] presents an application to sign language education; [18, 27] present applications to enhance home entertainment exploring ubiquitous applications; and [25] presents the use of social networks application as a mean to measure the "heat" of a topic from TV.

Tools papers present applications which functionalities are not focused on the TV viewer but aim at other users, like the TV station. These papers themes are mainly focused in audience estimation [77, 84]; subtitles/closed caption/sign language automatic generation/synchronization [78, 80, 81, 83]; and video annotation [75, 76, 79].

3.2.1. Synchronization. When utilized, the term synchronization commonly means that something occurs at the same time as something else. This is confirmed by definitions of synchronization extracted from the selected papers.

Brunheroto et al. [31] present synchronization as loose or tight one. Loose synchronization typically depends upon the reception of a message (trigger) or the presence of data and does not require time stamps carried within the data encapsulation. Tightly synchronized data will require the presence of time stamps and careful control of emission and decode timing.

Park et al. [32] present synchronization as asynchronous, synchronous, and synchronized data. Asynchronous data has no time relation to main content being presented; on the other hand synchronous and synchronized data carries timing information so it can be linked to the main content. But the text does not present the difference between synchronous and synchronized.

Lai-Yeung and So [48] classify communication in synchronous versus asynchronous, synchronous: real-time communication among participants who are in different locations at the same time and asynchronous: communication over a period of time among participants in which the communication is characterized by a time lag among parties.

However in a more general sense some authors use synchronization as comprising content, spatial, and temporal relations between media objects [9]. This view presented by Blakowski and Steinmetz is one of the bases to classify synchronization in three categories (Figure 9): content, destination, and temporal synchronization.

Content synchronization papers [21–23, 25, 28, 42, 43, 45, 48, 58, 62, 75, 77, 82, 84] consider semantic relations among contents. These papers take in account the question of *what* is being presented in the main content and *how* to present/generate extra content. Papers consider what is being presented in main content to connect people [23, 25, 28, 42, 43, 48]; measure audience [77, 84]; connect other contents to the MC [21, 22, 45, 58, 75]; and personalize them [62].

Destination synchronization papers [10, 18, 26, 37, 52, 65] focus on *where* to present main content and related contents so they complement each other. Papers approach presentation on secondary devices [10], distribute the presentation of rich multimedia [37, 52], expand the TV screen in projected screens [18], or focus on distributed data for multiple devices [26, 65].

Most of papers approach the temporal synchronization, where the focus is to present all contents in a specific time interval, giving impression that they occur at the same time. The precision time of synchronization presented on papers was an objective of this review. The classification used to analyze the precision was based on [74]: very high synchronization (asynchronies lower than 10 ms), high synchronization (asynchronies between 10 and 100 ms), medium synchronization (asynchronies between 100 and 500 ms), and low synchronization (asynchronies between 500 and 2,000 ms). But as shown in Figure 10, only 15% of papers

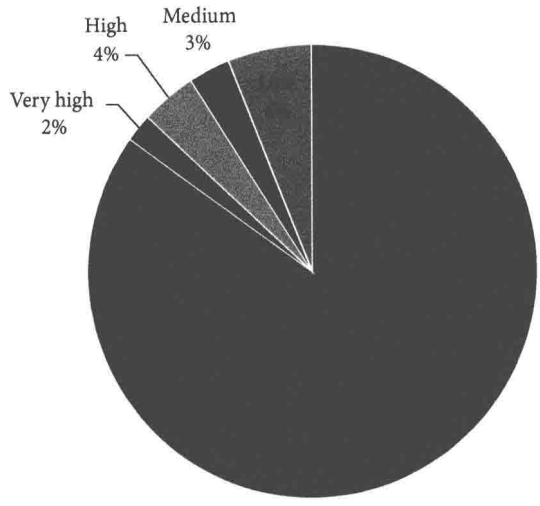

FIGURE 10: Synchronization precision.

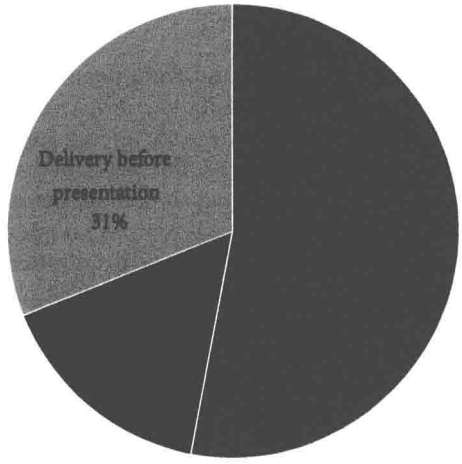

FIGURE 11: Transport of the synchronization specification.

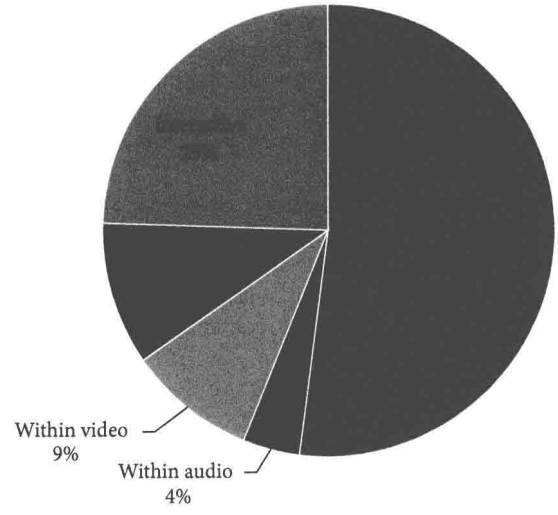

FIGURE 12: Synchronization channel.

presented enough data to achieve this goal; in the others the precision was not specified.

3.2.2. Synchronization Specification. The synchronization specification of a multimedia application describes all dependencies between its multimedia objects. Because the synchronization specification determines the whole presentation order and coordination, it is a central issue in multimedia systems [9].

Some important aspects related to synchronization specification are addressed next: transport of the synchronization specification, synchronization channel, synchronization specification methods, synchronization control scheme, and synchronization location.

3.2.2.1. Transport of the Synchronization. At destination, the presentation platform needs to have the synchronization specification at the moment that each object of the application is to be displayed. Three main approaches that support presentation synchronization are considered [9]: (i) preorchestration of the complete synchronization information before the start of the presentation, (ii) use of an additional synchronization channel, and (iii) use of multiplexed data streams.

Figure 11 shows the number of papers that used each approach. As seen most papers [20, 21, 27, 29, 31–35, 39, 41, 44–47, 49, 50, 54–56, 58, 59, 63, 64, 67–75, 78, 80, 81] have the synchronization specification multiplexed with the data streams. Sending it within the data stream implies that both media and specification are delivered together to the presentation device. The device can use this specification to play media synchronously. These papers commonly use MPEG based technologies (Subsection 3.2.3) or derivations to send the specification with the media.

The delivery of the complete synchronization information before the start of the presentation [18, 22, 24, 28, 30, 37, 48, 60, 61, 65, 66, 79, 83] implies that the full synchronization specification is delivered before any synchronous action is made. Examples of it are the use of NCL and SMIL languages to specify synchronization. In these cases the NCL and SMIL documents must arrive in the device before the synchronization rules starts.

Using an additional synchronization channel implies that the specification will arrive in a different channel than the one transmitting media [23, 25, 26, 36, 38, 42, 43, 62, 77, 82, 84].

3.2.2.2. Synchronization Channel. In this subsection papers are classified based on the channel used to transmit the synchronization specification. The possible channels are (i) an interactive one, within (ii) audio, (iii) data, or (iv) video, and (v) a hybrid approach (Figure 12).

In the case of interactive channel, the multimedia application uses its capabilities of communication with different servers to retrieve media and the specification required to present media synchronously with a main content [22–26, 36, 37, 42, 45, 48, 51, 52, 62, 64, 77, 79, 84]. Some papers use this channel as a way to receive the specification only [26, 64], but

in most cases, besides the specification, the other media are received through this channel.

In a broadcasting transmission, three possibilities to send sync information to the presentation device arise: within audio, video, or data. ASR (Automatic Speech Recognition) can be used on the audio to retrieve the speech of the TV show and this info can be used to synchronize and generate extra content [80]. Another alternative is to use a sample of audios as a dynamic anchor to achieve synchronization among contents [38, 43]. At last anchors can be sent multiplexed with the main content's audio in a way that users does not note the modified audio, but applications may listen to this audio and use it to synchronize contents (audio watermarking) [64].

Within video [20, 29, 30, 41, 70, 82], the synchronization specification can be sent directly in the video, where both user and applications can see the anchors for synchronization as presented in [82], which uses QRCodes to make the synchronization and in [30] there is a call inviting the user to connect his phone with the application. [29] presents a solution using steganography where only the application notices the anchors used in the synchronization. [20, 70] personalize mpeg standards introducing information into the video frames and extracting it before presentation. [41] uses digital image processing to track video objects and create multimedia anchors.

Within data [10, 17–19, 21, 27, 28, 31–35, 39, 44, 46, 50, 53–56, 58–61, 66, 68, 71–76, 78, 81, 83], the specification is included with the data sent with the broadcasting. In this case the specification is sent with the protocol headings (e.g., RTP/RTCP in [73]), as content transferred by the transmission (e.g., Ginga documents [10]) or as metadata information (e.g., used with mpeg solutions [46]).

In hybrid approaches the synchronization specification is sent through both broadcasting and an alternative channel. [63, 65] present solutions that use the second screen concept (the use of a second device, besides TV, to interact with the content presented in TV screen) to synchronize contents. In this case the second screen communicates with TV to receive the synchronization specification from it and also communicates with a remote server to receive the synchronization specification for the extra content. [49, 67, 69] use the hybrid platforms (HbbTV and Hybridcast) to synchronize contents. These platforms directly receive the broadcasting and broadband contents and synchronize them with its specifications. MITv [57] is a platform that sends interactive content within the broadcasting or an interactive channel. The channel used depends on the demand of the extra content: if the demand is huge it uses the broadcasting, if not it uses the interactive channel. Margalef et al. [47] proposes an interactive platform for DVB-H that sends interactive content through interactive channel and receives main content through broadcasting.

3.2.2.3. Method. For the specification of multiple object synchronization, including user interaction, various specification methods must be used [9]. Table 3 shows how the selected papers were categorized among the six synchronization methods.

In event-based synchronization, the presentation actions are related to synchronization events [26, 30, 36, 45, 53–55, 66, 77]. Typical presentation actions are start and stop a media presentation, wait a user interaction, and so forth.

Table 3: Synchronization specification methods.

Method	Number of Papers
Event-based synchronization	9
Hierarchical specification	16
Reference points	30
Synchronization based on a global timer	10
Synchronization based on virtual axes	4
Contextual rules	2

In hierarchical synchronization, media objects are regarded as a tree of nodes [10, 17, 22, 28, 37, 42, 48, 51, 52, 58, 60, 61, 76, 79, 83]. Hereinto, the leaf node can be single media processing and also can be user input or delay. Hierarchical structure is easy to compute storage and handle, so it has been widely used. The limitation of hierarchical structure is that each movement only can be synchronized in its beginning and end [85].

For synchronization based on a global timer, all objects are attached to a time axis that represents an abstraction of real time [19, 20, 27, 35, 49, 69, 71–73]. In virtual time axes specification method, it is possible to specify coordinate systems with user-defined measurement units [56, 59, 63, 64].

In the case of synchronization via reference points, objects are regarded as sequences of LDU's [18, 21, 24, 29, 31–34, 38, 39, 41, 43, 44, 46, 47, 50, 57, 67, 68, 70, 74, 75, 78, 80–82, 84]. The start and stop times of the object are called reference points.

In [23, 65] synchronization is dictated by the use of contextual relations. When a specified contextual situation occurs, like the use of users position [23], a synchronization action takes place.

3.2.2.4. Control Scheme. Generally, three schemes are employed to perform synchronization control (Figure 13) [74]: two centralized schemes (i) Master/Slave or M/S Scheme and (ii) Synchronization Maestro Scheme or SMS and (iii) one distributed scheme, Distributed Control Scheme or DCS. Besides the three control schemes, this review adds two derivations for the SMS Scheme that are described next: (i) Blind Maestro and (ii) Passive Producer. Papers were classified using these schemes considering broadcaster's main content as media source and user devices as receivers (Figure 14).

Works that use DCS [36, 59, 64, 65, 79] have all the receivers multicast feedback information about their playout to all the other receivers and each one of them selects the synchronization reference from among its own playout timing and those of the other receivers.

In M/S Scheme [19, 20, 22, 27, 32, 42, 56, 72, 73], receivers are differentiated into master and slave. The master receiver multicasts feedback control messages about playout timing to all the slave receivers. Accordingly, each slave receiver adjusts its own playout process to the reference playout process of the master.