Data Network in Development of 3D Collaborative Virtual Environments: A Systematic Review

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Abstract. Background: 3D Collaborative Virtual Environments (3DCVE) have been used to allow multiple geographically distant users to share virtual reality environment. This remote user collaboration requires to deal with network problems. Objective: The objective of this systematic review is twofold: (1) to identify possible solutions to network issues, especially those related to the Internet, such as jitter, latency and packet loss; and (2) to identify the protocols and network topologies commonly used in 3DCVE. Results: We selected 132 papers from the most commonly used search portals, i.e., IEEE, ACM, Scopus, Springer, Science Direct and Web of Science. We also describe the studies conducted over the past 10 years, highlighting the network protocols and topologies, which are commonly used. Finally, we suggest a framework architecture for 3DCVE based on graphic cluster.

1 Introduction

The main feature of 3DCVE is the simulation of immersive and interactive 3D virtual environments, such as serious and multiplayer games. 3DCVE allow multiple users to interact with each other in real time even when they are located in different places. Other features of 3DCVE are the sharing of space presence and time. According to Singhal and Zyda [1], 3DCVE consist of four basic components: graphics engines and display; communication and control devices; processing system; and data network. This review covers the primary studies related to traffic in data networks.

The development of 3DCVE requires knowledge in several areas, such as the design and implementation of network protocols, parallel and distributed systems, computer graphics, multithreaded systems and user interface. Several problems must be resolved regarding the design of 3DCVE, however, most of them related to the network, i.e. consistent management of distributed information, real-time interaction and adaptation of applications to limited network bandwidth. 3DCVE have been

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researched since the 1980s and attracted particular attention in the 1990s thanks to the evolution of data networks. In this study, we present publications covering the last 10 years of research and applications, a period in which data networks have experienced a remarkable evolution.

In recent years, research has been undertaken to minimize the adverse issues of different types of network, particularly the protocols supported by the Internet. This study presents a systematic review of 3DCVE and describes the implementation challenges. The primary studies reviewed summarize some of the problems and possible solutions for treating jitter, packet delivery delay, packet loss, etc. We also reviewed studies that addressed solutions based on network topologies, protocols and implementation solutions, such as buffering and data prediction. This study is not a survey, but a general overview of what has been achieved in the 3DCVE research field in recent years.

With the results obtained from the systematic review, it was possible to characterize values for common problems encountered in the development of 3DCVE. Thus, it was also possible to devise and implement a framework to support the development of 3DCVE in relation to the quality of service connection between distributed graphics clusters.

Section 2 presents the study, planning, execution, reporting and validation of the systematic review. Section 3 presents the architecture of a management connection framework based on graphics clusters, focusing in the results listed in Section 2. Section 4 concludes.

2 Systematic Review

This study has been undertaken as a systematic review based on the guidelines proposed by Kitchenham and Brereton [2]. According to them, three main phases are involved: (1) planning the review, (2) conducting the review and (3) reporting the review. We also used a visual text mining (VTM) technique to support study selection. VTM uses text mining algorithms and methods combined with interactive visualizations. The following sections present details of how each phase was carried out.

2.1 Planning the Systematic Review

In this phase, we defined the review protocol. This protocol contains: (i) the research questions, (ii) the search strategy, (iii) the inclusion and exclusion criteria and (iv) the data extraction and synthesis method. Research questions must embody the review study purpose. Moreover, these questions reflect the general scope of the review study. The scope is comprised of population (i.e., population group observed by the intervention), intervention (i.e., what is going to be observed in the context of the planned review study), and outcomes of relevance (i.e., the results of the intervention). Furthermore, during conduction of this step, it was also necessary to establish the scope of the review study. According to the systematic review process [2], the scope has to be established using the PICO criteria, it is a method of combining a search strategy that allows a more evidence based approach to literature searching (Population, Intervention, Comparison and Outcome).

As described before, the objective of this review is twofold: (i) to find out what are the main issues that someone has to deal during the devising and implementation of a 3DCVE; and (ii) as for the problems ascertaining what are the solutions that were applied to solve them. In order to achieve such objectives we worked out three Research Questions (RQ). The questions are:

RQ1: Which communication protocols are utilized to accomplish the interconnection among 3DCVE?

RQ2: Which network topologies are employed to establish interconnection among 3DCVE?

RQ3: What are the challenges of implementing such systems?

A search string was constructed using boolean operators, i.e., AND and OR. The search encompassed electronic databases, which are deemed as the most relevant scientific sources and therefore likely to contain important primary studies [3]. We applied the search string to the following electronic databases: IEEE, ACM, Scopus, Springer, Science Direct and Web of Science.

Then, in order to determine which primary studies were relevant to our research questions, we applied a set of inclusion and exclusion criteria. Inclusion criteria were as follows:

1) Primary studies presenting at least one solution for 3DCVE: such solutions assisted the implementation of 3DCVE in various research fields, i.e., network protocols and topologies.

2) Primary studies presenting at least one type of evaluation for verifying the performance and efficiency of the 3DCVE: without the results of the evaluation it would not possible to make comparisons between different solutions.

Studies had to meet at least criterion (1). If all criteria were mandatory, the number of eligible primary studies would have dropped significantly.

Exclusion criteria were as follows:

1) Primary studies not evincing any innovation in terms of 3DCVE: primary studies that comprised only a case study and did not provide important details about the architecture and development process.

2) Primary studies comprising short papers: papers with two pages or fewer were not considered herein, since we assumed that this kind of study would not offer sufficient information.

During the extraction process, the data of each primary study were independently gathered by five reviewers. The review was started in December 2012 by two Ph.D. students and three post-doctoral researchers in software engineering and distributed systems; the achieved results were crossed and then validated.

2.2 Conducting the Systematic Review

In this phase, we first identified primary studies in the digital libraries. IEEE returned more primary studies than the others (449), i.e., ACM, Scopus, Springer and Science Direct returned 181, 212, 394 and 267 studies, respectively. The digital library that returned the fewest primary studies was Web of Science, i.e., 15 papers. In sum, we obtained 1518 primary studies. Subsequently we selected primary studies by reading the titles and abstracts and applied the inclusion and exclusion criteria. As a result, we obtained 451 primary studies that were read in their entirety, and the final total was 132 studies.

As regards the network infrastructure used, we found studies using the Internet and gigabit networks (local and regional). Generally, for applications running on gigabit networks, we did not identify the same problems found in applications running on the Internet, because they are high-speed and reliable networks. In this kind of network, the protocol normally used is Transmission Control Protocol (TCP) [4], [5], [6], [7], [8], [9], [10], [11].

2.3 Validation

In the validation phase an approach that uses the visual text mining (VTM) technique and an associated tool - Projection Explorer (PEx) - were applied to support the inclusion and exclusion decisions [12]. It was found a great amount of papers and some of them have no relevant information to the research, so the PEx was used to assist the primary classification process.

Figure 1 presents a document map generated from PEx. This map is composed of all primary studies analyzed in the review, highlighting them in different shades of gray to differentiate in which of the stages a study was removed from the review. White points are the papers excluded in the first stage, gray points are the papers excluded in second stage and the black points are the included papers.

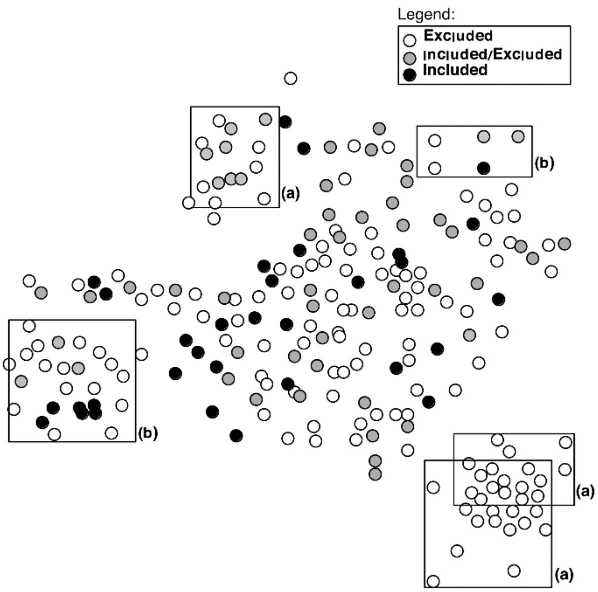

Fig. 1. Document map colored to show the history of the study inclusions and exclusions.

The exploration of a document map is conducted in two steps: (1) a clustering algorithm is applied to the document map, creating groups of strongly related documents; (2) the resulting clusters are analyzed in terms of pure clusters - all documents belonging to a cluster have the same classification (all included or excluded, regardless of exclusion stage) - and mixed clusters - which represent documents with different classifications in the same cluster. These cases are hints to the reviewer, and the studies grouped should be reviewed following the traditional method. In order to facilitate visualization, in Figure 1 just five clusters generated by PEx are depicted. Examples of pure clusters (all excluded) are identified in Figure 1 by label "(a)" and therefore did not need to be reviewed. Mixed clusters (clusters containing black (included) and white or gray (excluded) studies) are identified by label "(b)" and they were reviewed by the authors of this paper. In the end, we kept the initial classifications, which had been conducted manually.

2.4 Reporting the Systematic Review

This section presents an overview of the researches conducted in the last 10 years concerning 3DCVE, especially covering use of network protocols and topologies. Furthermore, the information collected from primary studies was used to answer the research questions.

Most primary studies selected were published on the IEEE website (48 studies). The other studies were selected from ACM, Scopus, Science Direct and Springer, numbering 34, 23, 19 and 8, respectively. We selected primary studies published in conferences, workshops and journals. Most studies were on conferences (75) followed by journals (30), books (15) and workshops (12).

Results presented in primary studies were classified as experiments, case studies or unspecified. In order to answer the research questions we analyzed 132 papers individually. Some primary studies presented experiments that gave information about traffic rate, latency, package loss and comparisons between different protocols [10], [13]. Some contained case studies that presented examples of the use of 3DCVE: medicine [14], [15], [16], [17], engineering [18], [19] and education [20], [21]. Not all papers are referenced in this paper because of space limitations, but the complete research can be visualized in: omitted due to blind review.

The frequency of publications that uses different protocols for developing 3DCVE is presented in a bubble plot in Figure 2. The bubble plot consists of two axes (X and Y), in which bubbles represent categories. The bubble size determines the number of primary studies that were classified as belonging to a category (protocols). This summary provides a visual overview that helps to identify which categories have been emphasized in recent research, with gaps and opportunities for future research. Figure 2 has two coordinates, one representing the year of publication and other the protocols, showing the most used protocols in the implementation of 3DCVE, and answering RQ1.

The protocols found in the studies were: TCP, User Datagram Protocol (UDP), AppTraNet, Stream Control Transmission Protocol (SCTP), Real-time Transport

Protocol (RTP/RTCP), Real-Time Events Protocol (RTEP), Pragmatic General Multicast (PGM), Interactive Stream Transport Protocol (ISTP) and Quanta Framework.

The protocol most frequently used was UDP, found in eight primary studies. The high frequency is related to two factors: in networks where the access is reliable UDP can be used, because these environments are exempt, or have no significant package loss; it can also be used in networks based on the Internet, because it is based on datagrams and does not perform verification of delivery, increasing the flow of information, leaving to the application the verification of packages that were not delivered and the order of arrival.

The second most commonly used protocol was TCP. 3DCVE that are implemented on high-speed networks are not affected by steps that a message has to take when it is a TCP connection. The use of the TCP protocol in data networks based on the Internet is not indicated, because the size of the header and ACK are responsible for reducing the package flow capacity [10]. For this kind of environment, as mentioned, the UDP protocol is more suitable. Some studies showed comparisons between UDP and TCP [10], [5]. The UDP protocol had better results (if we consider only the data flow in experiments realized on Local Area Network (LAN)). The most suitable protocols used for communication in 3DCVE were, however, SCTP and RTP/RTCP, because they combine features of TCP and UDP, optimized for multimedia applications (stream and real-time). According to Boukerche and colleagues [22], SCTP provides a reliable delivery system for key packages and unreliable delivery for normal update packages. Smoothed SCTP, that adds strategies for dealing with jitter, implements a small buffer at the client side.

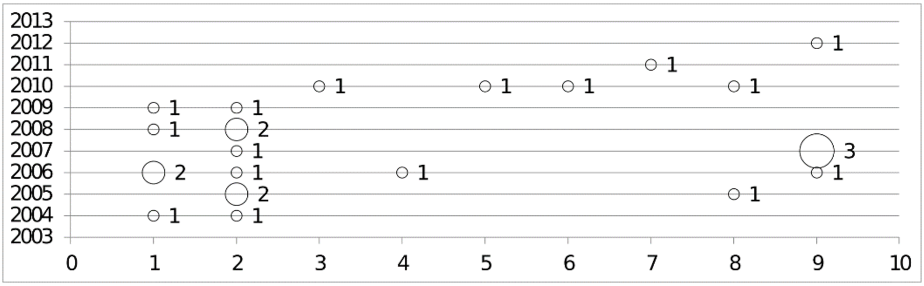

Fig. 2. Frequency of use of protocol (by year)

Some protocols were found only in one primary study. These can be considered “evidence deserts” (which should be performed as new or improved research). Protocols with only one occurrence were: AppTraNet, RTP / RTCP, RTEP and PGM. Some experiments were performed with the RTEP and ICMP. The RTP/RTCP, despite being used in a recent study [13], only occurred once, but it is cited in some textbooks and studies as a trend [23], [24], [25]. PGM was used in conjunction with QUANTA to develop the network module iTILE [26]. ISTP was used to encapsulate the packages to be exchanged among nodes of 3DCVE, although, if the message type is a key state, it needs to be transmitted in a reliable way (ACK and NACK) [9].

Internet Control Message Protocol (ICMP) had two occurrences, but in both studies was used as a benchmark for other protocols [13], [27], because it is not used to exchange data.

The QUANTA framework appeared in some studies [26], [8], [10], [28]. QUANTA is a network framework created by the National Science Foundation (NSF). It provides an easy way to transfer data in distributed systems. The transfer is done at a high level of application, being invisible to the developer. In this review, QUANTA is presented in the bubble plot (Figure 2); although it is not a network protocol, it can be used instead of network protocols.

The majority of primary studies reviewed used data networks with high speed and reliable characteristics, or local and/or regional networks interconnected by optical fibers. The main focus of this review was to find possible solutions for data networks based on the Internet, in order to present the problems and solutions discussed.

An important feature that should be defined at the beginning of implementation of an 3DCVE is the network topology that will be used. Four principal topologies were used in the primary studies. The physical topologies most used were: mesh, star, hybrid and peer-to-peer. Logical topologies were: intra-domain, inter-domain metadata overlay and overlay. This answers RQ2.

Peer-to-peer topology was the most common in recent years in the design of 3DCVE, because it allows full distribution, low latency and efficient management of messages, if implemented with some care. Wang and colleagues [29] used peer-to-peer topology to propose an architecture for a 3DCVE that explores user location in the environment. The user node only receives information about nodes that are close to the user in the environment. Steiner and Biersack [30] used a peer-to-peer topology based on Delaunay triangulation. The algorithm is dynamic with respect to the connecting nodes of a 3DCVE. The basic idea of the algorithm is to classify links that connect nodes in an intra-cluster or inter-cluster.

Implementing 3DCVE in data networks based on the Internet has some challenges, such as package loss, latency and jitter. This answers RQ3. Some primary studies discussed issues related to package loss [8], [28], [31], [32], [9], [5], [29]. Nevertheless, none of them presents experiments in a real environment, but only simulated results. Package loss is not the most harmful problem in the implementation of 3DCVE, however, and can be solved by certain prediction techniques [22].

With respect to network latency, researchers assume that more than 200ms can influence the user experience in a 3DCVE [31]. It is, however, possible to find latency of 600ms in intercontinental connections over the Internet, so this is one of the main challenges to implementation. Among the challenges, jitter is the most harmful, because in 3DCVE it is important to maintain constant speed for the delivery rate of packages. Some researchers have solved jitter problems with buffering techniques [27], [22]. In gigabit networks, such problems were not found; some authors even claimed that the bottleneck caused by the network would not matter in the near future. DeFanti and colleagues [33] claim that the bottleneck is owed to bus, network interfaces and protocols.

3 The Proposed Framework

As shown in the previous sections there are several solutions to problems related to data networks. All solutions are treated in isolation. The integration of these solutions into a single framework can facilitate the development of 3DCVE based on graphics clusters, which are clusters tailored to computer graphics applications. This proposal describes an architecture for a framework designed to help developers and researchers to develop 3DCVE. The systematic review identified problems and solutions to problems in the context of 3DCVE development. It was possible to identify acceptable values, such as package delivery delay.

3.1 Dynamic-Adaptive Framework

Virtual environments are rendered, and thus one of the ways to accomplish that is by using graphics clusters. These are composed of hardware and software combined. The software components that make up a graphic cluster can be classified in four categories: applications, visualization tools, cluster system management and operating system.

In this proposed framework, the focus is on the graphic cluster management layer. This layer is responsible for communication between the nodes and for abstracting the ways of communication between these nodes, including inter-cluster communication (server to server).

This paper proposes a framework for 3DCVE development, which allows adjustments in the runtime of the settings of the connections between remotely located

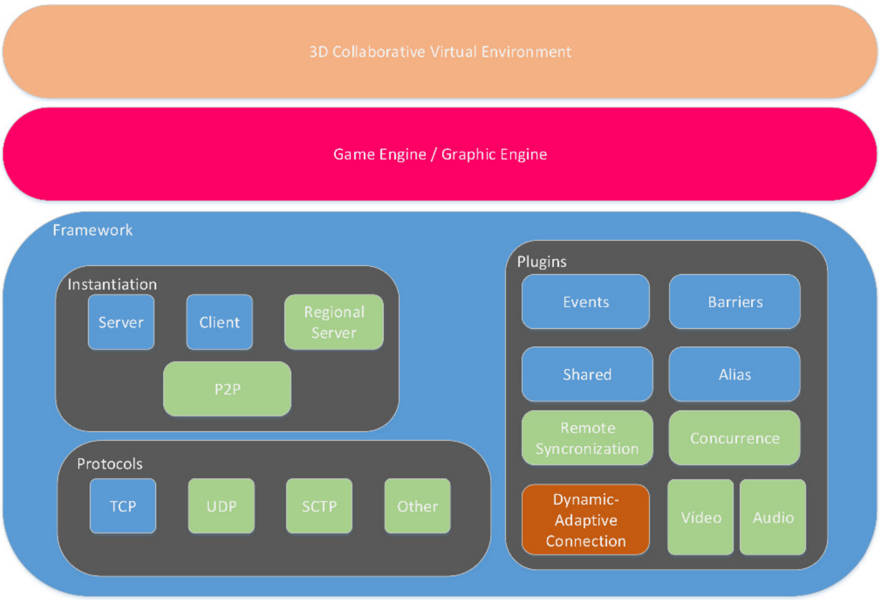

Fig. 3. Architecture of Framework

graphics clusters. We call this layer dynamic-adaptive connection management, given that the adjustments are made at runtime and aim to provide quality of connection. Figure 3 depicts the proposed framework.

The framework was developed by means of libGlass [34]. Some of the modules described in Figure 3 have been extended to provide quality of service to 3DCVE. The framework is divided into three modules:

- The Instantiation module is responsible for implementing the topology connection between clusters and their rendering nodes;
- The Protocol module provides the protocols used in the communication between clusters and their nodes. The protocols developed so far are TCP, UDP and STCP. This component has a packing/unpacking infrastructure for messages, which supports all basic types (integer, float, string, etc.); in addition, one can define one's own types. This packer/unpacker ensures interoperability between operating systems; and
- The plug-ins are intended to provide support for cooperative, synchronous/asynchronous applications, and allow users, geographically distributed, to perform activities or achieve common goals. Some of the plug-ins available in libGlass have been extended. The plug-ins provide services such as: transmission of Events (Events plug-in), data sharing (Shared plug-in), barrier synchronization (Barriers plug-in) and association functions (Alias plug-in).

3DCVE development requires certain characteristics so libGlass has been extended. Some plug-ins were created or modified. The plug-ins are:

- Remote Synchronization: the Shared plug-in has been extended from libGlass, allowing each local server to synchronize with remote servers. The server receives the data from the local nodes and sends them to remote servers;
- Concurrence: the plug-in which provides concurrent access for shared objects for each location. So libGlass is compatible with various types of cooperative applications, various methods should be available. Initially, we implemented the non-optimistic locking method (which ensures that all events are always executed in the correct order for all users, not allowing events to be executed out of order);
- Control of Users: the plug-in that enables the management of users through services such as adding a new user, banning users, storing users in a session and updating the users on all instances of the application;
- Video: the plug-in that allows each site to transmit or receive videos. This plug-in is an extension of plug-in Event;
- Audio: the plug-in that allows each site to transmit or receive audio. Thus, like the Video plug-in, this is also an extension of plug-in Event; and
- Dynamic-Adaptive Connection: the plug-in that allows the checking of network adversities at runtime, allowing different connection configurations to be used. The log files generated during the execution of a 3DCVE are analyzed, enabling adjustments. The analysis of the connection is done through inferences based on fuzzy logic.

These features may not be sufficient to meet all the requirements of cooperative applications, so with the emergence of new services and requirements, new features can be proposed and implemented in the framework.

3.2 Dynamic-Adaptive Connection

This plug-in is responsible for maintaining the quality of the connection between the servers of the graphics clusters. In order to classify the connection, and to maintain the quality of connection. Concepts of fuzzy logic are used to evaluate the state of the connections.

According to results shown in the systematic review, it was possible to estimate the connection quality in relation to the connection delay, package loss, jitter, etc. A connection may have many values for each of the mentioned items, however, and thus the use of a fuzzy inference system assists decisions.

Fuzzy logic allows the subjective concepts of a specialist to be expressed and provides assistance with these concepts mathematically, i.e., translation of human knowledge. It is well suited for certain classes of objects that do not respond to conventional treatment [35], such as empirical systems, vague systems, imprecise systems and some situations which it is difficult to model using conventional methods. Thus, it is possible to model the behavior of the connections, adapting them according to linguistic terms.

Linguistic variables were created in order to assess the quality of interconnection between the servers (P2P) and nodes (client-server) of graphics clusters. Variables were divided into two categories: input and output. Input variables (Table 1) are used to measure the main problems encountered in 3DCVE, according to the papers reviewed. These problems should not be classified as present or not, whereas intermediate values can be taken into account. Many problems can also be evaluated in combination, thus allowing different actions to be taken. The input variables identified so far are:

- Package delivery delay: this variable takes into account the package delivery delay between servers (P2P) and can be classified as Harmful, Not harmful and Highly Harmful;
- Time variation in package delivery: this variable takes into account the average time of package delivery between servers. It is classified as Slightly harmful, Harmful and Highly harmful; and
- Package loss: this variable takes into account the packages that are lost in the connections between servers. It is classified as Low, High, and Without loss.

The output variables (Table 2) are used in order to apply actions in the environment according to the ranked values from input variables. The output variables identified and implemented so far are:

- Change the amount of data of the data packages: this variable determines if the package configuration is consistent with the state of the network at a given time. The following linguistic terms have been classified:
  - No: the packet is not changed. A default size is used (1500 bytes). Only one update message is sent by package;
  - Medium: the packet is modified when necessary being used to sending multiple messages, but the size is still the default; and
  - Big: the packet size and configuration (data) has increased according to need.

- Use another communication protocol: this variable determines which network protocol may be used for interconnection servers and nodes of the graphics clusters. The following linguistic terms were classified:
  - UDP: the standard protocol is maintained;
  - TCP/UDP: according to the combination of values classified by the input variables, different protocols may be used. The TCP/UDP combines TCP and UDP. TCP to transmit key packages and UDP to transmit update packages;
  - SCTP: similar to TCP/UDP, it uses features present in both protocols, but provides other solutions, like buffering.
- Buffer: this variable determines if the use of buffering is required. The following linguistic terms were classified:
  - No Buffer: the default connection mode is maintained;
  - Level 1: state update packages are buffered, in order to keep the refresh rate of environments without sacrificing frame rate presented to the participants of the 3DCVE; and
  - Level 2: a small buffer is used on the client side. We used strategies from SCTP protocol for the buffering.
- Predict package: this variable is responsible for predicting lost packages during the connection between the servers. The following linguistic terms were classified:
  - No Predict: the default connection mode is maintained;
  - Level 1: a linear prediction algorithm has been used, where the lost update packages are predicted from the received packages [22]; and
  - Level 2: here we used reactive latency compensation, the dead reckoning algorithm. It solves two problems simultaneously: reduced bandwidth consumption and mitigation of the effect of network delay.

Table 1. Input Variables

	Input Variables	
Name of variable	**Linguist terms**	**Degree of relevance**
	Not harmful	[0, 60]
Package delivery delay	Harmful	[55, 200]
	Highly harmful	[190, 600]
	Slightly harmful	[0, 5]
Time variation in packages delivery	Harmful	[4, 10]
	Highly harmful	[9, 100]
	Without loss	[0, 3]
Loss of package	Low	[2, 6]
	High	[5, 20]

The membership function used is the trapezoidal (1). It results from the relevance degree where a, b, c and d are the edges of the trapezium. The x is the domain. The membership function is crucial to the use of fuzzy logic [35].

$$trapmf = (x, a, b, c, d) = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right). \quad (1)$$

The combination of different values of input variables generates different outputs. Table 3 presents examples of the Fuzzy Rules created for the inference system. The rules were descripted using the Fuzzy Control Language (FCL). The complete list of rules can be visualized in: http://54.213.29.17/rules.fcl.

Table 2. Output Variables

	Output Variables	
Name of variable	**Linguist terms**	**Degree of relevance**
Changes the amount of data of the data packages	No	[0, 0,3]
	Medium	[0.28, 0.6]
	Big	[0.55, 1.0]
Use another communication protocol	UDP	[0, 0.3]
	TCP/UDP	[0.25, 0.6]
	SCTP	[0.55, 1.0]
Buffer	No Buffer	[0, 0.3]
	Level 1	[0.28, 0.7]
	Level 2	[0.68, 1.0]
	No Predict	[0, 0.3]
Predict package	Level 1	[0.25, 0.6]
	Level 2	[0.55, 1.0]

Table 3. Fuzzy Rules – just some examples

Fuzzy Rules
RULE 1: IF delay IS harmful AND time_variation IS slightly_harmful AND loss IS low THEN buffer IS level_1;
RULE 2: IF delay IS harmful AND time_variation IS slightly_harmful AND loss IS low THEN predict IS level_1;
RULE 3: IF delay IS harmful AND time_variation IS slightly_harmful AND loss IS low THEN protocol IS tcp_udp;
RULE 4: IF delay IS harmful AND time_variation IS slightly_harmful AND loss IS low THEN data_packages IS medium;
RULE N: …

Figure 4 depicts the input and output variables of the Dynamic-adaptive module proposed. This figure was plotted by using the values present in both Table 1 and Table 2. The top of trapezoid represents the value 1.0 for the membership function, that is, total inference.

Figure 5 shows the simulated results for three different sets of values. These parameters were found in connections between the graphic clusters of our research partners. The sets of values are: Delay 12ms, Time variation 0ms and Packet loss 0 (left); Delay 100ms, Time variation 3ms and Packet loss 0 (right); and Delay 300ms, Time variation 6ms and Packet loss 5 (bottom). The results confirm the expected values when compared to the output values (Figure 4).

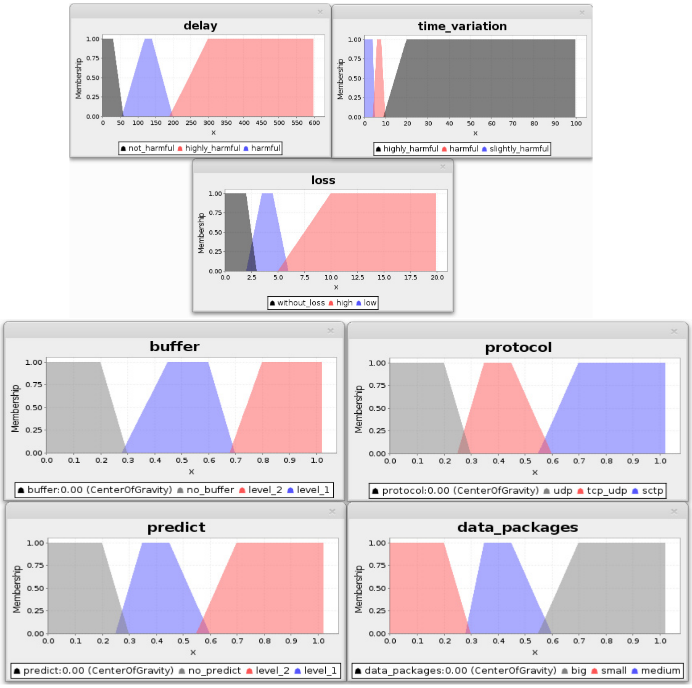

Fig. 4. Input and Output Variables of Dynamic-adaptive solution

4 Final Remarks

The process described by Kichenham and colleagues [2] was followed as standard for the conduct of the review. We examined 132 primary studies and found four physical topologies and nine protocols that had been used in the last 10 years. We also identified some algorithms that aimed to minimize network issues. It is hoped that researchers can use this document as a basis to advance their researches and developers can use it to identify problems and solutions already consolidated. Thus, this systematic review is of relevance to both academic and professional areas. It presents possible solutions to the implementation of 3DCVE, focusing on a variety of network protocols and topologies.

The review showed that the most commonly used physical topology was peer-to-peer, used to mitigate the problems occurring in networks based on the Internet. For the most part, however, the topology used was not mentioned. In some primary studies the authors mentioned the use of a centralized server; thus, we can assume that they used a star topology or mesh type.

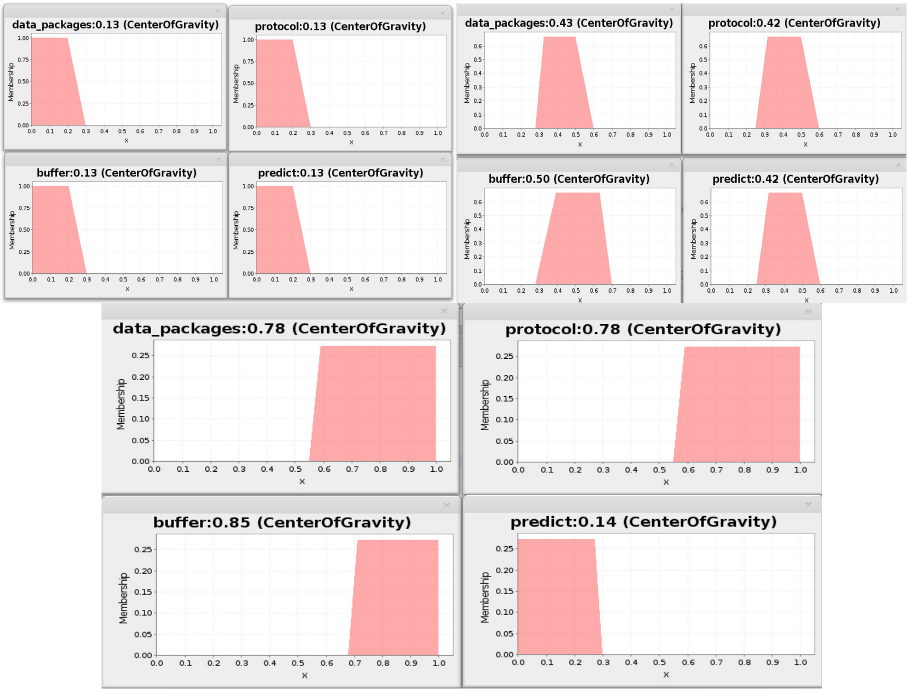

Fig. 5. Output Variables of Dynamic-adaptive solution. A) Data packages (No) / Protocol (UDP) / Buffer (No Buffer) / Predict (No predict). B) Data packages (Medium) / Protocol (TCP/UDP) / Buffer (Level1) / Predict (Level1). C) Data packages (Big) / Protocol (SCTP) / Buffer (Level2) / Predict (No predict).

The UDP protocol was used most often. In architectures based on gigabit networks, was identified the suitable for this kind of application, or just require further research. The SCTP protocol, for example, was cited as popular in some papers, but was found in only one study. The protocol list presents the QUANTA framework; although not a protocol it has been used to resolve various issues and is much in evidence in the last few years.

The proposed framework is under development and testing. Solutions discussed in this systematic review are currently being implemented or extended. It is hoped that those based on peer-to-peer and client-server topologies will be sufficient to meet the challenges in the development of 3DCVE based on graphic cluster over the Internet.

The management adaptive-dynamic connection plug-in is expected to provide quality service to 3DCVE based on graphics clusters in execution time. The use of fuzzy logic is a feasible approach, allowing different configurations to be tailored to the features found in the environment.

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