Highly Efficient 3D Object Transmission System for HTC Services in 6G Networks

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ABSTRACT

In recent years, advancements in technology have brought forth a new frontier in visual communication. Holography is a technique that captures and reproduces threedimensional (3D) images with an unprecedented level of realism and depth, has emerged as a groundbreaking method for conveying visual information. Unlike traditional images and videos, holography recreates scenes with full parallax, enabling viewers to perceive objects from various angles. The transmission of holographic images presents both exciting possibilities and unique challenges. To this end, this article conducts a comparative analysis of a previously developed application system for transmitting dynamic 3D human movements with a ready-made solution for transmitting 2D video streams in order to provide conference calling services. The network characteristics of the systems were collected and compared. The opportunities that programs currently provide and will provide in the future are examined.

KEYWORDS: *Telepresence, Comparative Analysis, MVP, TrueConf, HTC, 6G, Teleconference, 3D images, Conferencing*

INTRODUCTION

With the development of communication networks, users have more and more requests for the provision of various services. This paper will compare two applications from the field of telepresence services, which are still developing. Separately, we can note the direction of Holographic-Type Communication, the development of which is currently happening everywhere in the world [1].

During the pandemic, the need for video conferencing has greatly increased, examples of which have become firmly established in our daily lives: a work meeting, a lecture at the university, friendly communication. Conferencing technology allows for simultaneous communication between multiple users.

At the moment, applications for transmitting 2D images over networks for conferencing are very widespread. One of the popular solutions in this area today is TrueConf - a software platform for video conferencing. It helps employees communicate and work effectively from a distance, as well as easily conduct webinars and remote training.

Another direction of applications for remote work, education, etc. is the remote transmission

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of three-dimensional images, which makes it possible to see human movements in more detail from all angles, and also opens up new possibilities for immersive communications [2,3]. Transferring data about three-dimensional objects in its original form, for example in the format of streaming video from an array of cameras, requires significant bandwidth, so it becomes important to use technologies for converting data received about an object into other formats [3, 4].

This paper aims to investigate and compare the network traffic of several telepresence applications to test whether it is possible to provide a more complex conferencing service than is currently available without significant losses in network traffic. The following will be considered: existing commercial solutions and a self-developed system that provides the opportunity to see a person not only in 2D, but also adds a third plane, allowing you to display a 3D model of a person in augmented reality, mixed reality or any holographic method of providing data.

EXPERIMENTS DESCRIPTION

During a superficial analysis of the network characteristics of other programs for providing conferencing using live video stream transmission, similar to TrueConf, it became clear that any of the advanced applications, such as Zoom, Google Meat, Yandex Telemost, have comparable results. This conclusion made it possible to compare the developed MVP system with a single application that is more convenient to use and test - TrueConf [5].

The research involved two applications:

· TrueConf - a unified communications software system from the company with the same name - TrueConf, using streaming video transmission to a flat surface in 2D to provide conferencing.

· MVP - an application system designed to synchronize control points on the Sender's body and an avatar that simulates movements on the Receivers' devices.

TrueConf, like any other software currently on the market, is a means of transmitting streaming video and audio - this is the minimum set of capabilities for providing conference calls. As you know, streaming video puts a lot of load on network equipment due to its weight. At the time of the transition of the whole world to remote communications, network equipment was not ready to provide the resource for transmitting such an amount of traffic. It was necessary to come up with a new way of transmitting data to provide conference calls. For this purpose, the MVP application system was developed.

MVP is an application system consisting of 3 parts (Sender, Server, Receiver). The Sender collects data from the Kinect camera about the control points of the human body (Atlas of body "Key Points"), groups them into a vector database and sends it to the Server. The Server constantly synchronizes network components on all connected devices at regular intervals; if synchronization of a component fails, a timer is started, after which the user will be disconnected as inactive. The network component on the Receiver's side receives updated data from the Server and transmits it to a 3D avatar that simulates the Sender's movements. Receiver client applications are implemented both on the Standalone system (Windows / Linux / MacOS) and for Android. Moreover, playback on any Standalone machine can be projected onto a holographic cube to achieve a three-dimensional effect (the speaker's avatar can be walked around from all sides), and the Android version uses ARCore to create augmented reality, which will allow the user to place the avatar at any convenient point in his room using your phone camera [6].

It is important to note that unlike TrueConf, the MVP application does not transmit video traffic, but uses data transmission instead. This feature allows us to move away from the usual concept of providing conferencing services and get closer to the full transfer of point clouds over communication networks to support holographic communication [7].

MVP is a platform that can be developed in various directions, from solving problems of reducing network traffic to provide telepresence services using 3D models, to developing a full-fledged holographic application for providing HTC. At the moment, this is a prototype that will allow conducting statistical experiments to test various hypotheses. Comparing the network characteristics of the developed application and a related application (similar application) will give us an understanding in which direction it is worth developing and whether it is worth continuing development at all [8].

Sixteen (16) experiments were carried out, each of which lasted 300 seconds and took place under the same conditions on the same network topology (Fig. 1): Eight (8) experiments for each application (Table 1).

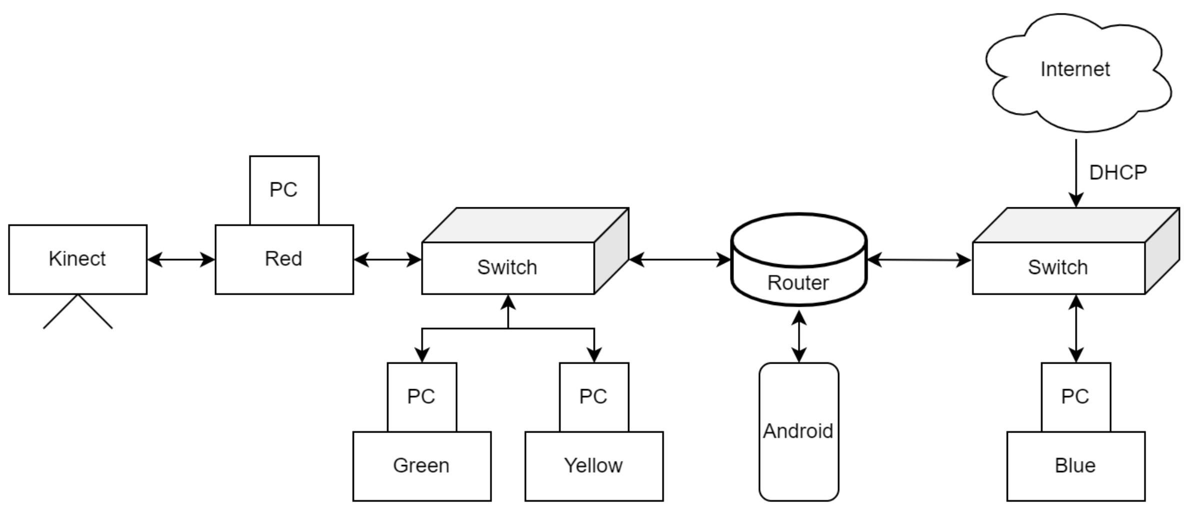

Figure 1. Network Architecture

Red, Green, Blue - different names of computers, corresponding to their color, which is later translated into graphics, Android - designation of a phone with the Android system (indicated in dark green). Idle – a type of experiment in which there is no person in the frame and the picture is stationary, Movement – experiments in which a person actively moves in the frame.

Table 1. Experiments

	Idle	Movement
1 Client	Yellow PC	Yellow PC
2 Clients	Yellow PC + Green PC	Yellow PC + Green PC
3 Clients	Yellow PC + Green PC + Blue PC	Yellow PC + Green PC + Blue PC
3 + 1 Clients	Yellow PC + Green PC + Blue PC + Android	Yellow PC + Green PC + Blue PC + Android

EXPERIMENTS DIFFERENCES

Before moving on to a direct comparison of network characteristics, it is important to note several points that affect the generated traffic, which we will need later.

The big difference between the "Idle" experiments comparing the two applications is caused by the way the applications generate network traffic. The TrueConf application converts the 2D image received from the camera into packets and sends it over the network every unit of time, as in the "Movement" experiment, MVP requires a small bandwidth just to maintain client connections to the server (0-8 Kbps), if this connection is lost, the server will automatically disconnect the user. This feature will be clearly visible in the presented graphs, and on some you may get the feeling that there is no traffic at all, but this is not the case, it is simply extremely small compared to the rest [9].

The experiment presents various devices with different hardware: "Yellow PC" and "Blue PC" interface - "Realtek Gaming GbE Family Controller", "Green PC" interface - "Realtek PCIe 2.5GbE Family Controller", the used phone is "Xiaomi Mi 8" with "Android 9". The network components of the MVP application for smartphones and for PCs are completely identical.

Also, the devices are located in different places in the network topology (Fig. 1); in all experiments, the server and sending client were deployed on the "Red PC", after which the traffic went to the "Aruba 2930F JL259A" switch device, to the "Green PC" and " Yellow PC", then comes the "Xiaomi Mi AIoT AX3600" router, it transmits data to Android; from the router, network traffic goes to the next "Catalyst 3750G" switch, from switch to the "Blue PC" end device.

COMPARISON OF NETWORK CHARACTERISTICS OF DIFFERENT SYSTEMS

The catalyst for developing a functionally new video conferencing application was the urgent need to reduce network video traffic, given the transition of a large number of people to remote work and education.

In the realities of the need to write an application "here and now" many auxiliary systems and libraries were used that lower final performance for the sake of faster application writing.

The developed system does not utilize all the capabilities of the physical layer of the OSI model, specifically the Ethernet frame length. In most cases (62%), only half of the Ethernet packet is used, which is approximately 700-750 bytes (Fig. 2). This underutilization of the packet means that, at any given time, we have the potential to transmit more useful information than we currently do (a path for transmitting more points), without compromising Quality of Service (QoS) and network characteristics. In contrast, a more optimized TrueConf application uses the full packet length of 1550 bytes in 54% of cases, and cannot transmit a greater amount of data in a single packet, i.e., it cannot increase the ratio of useful information to the total packet length with headers (Fig. 3).

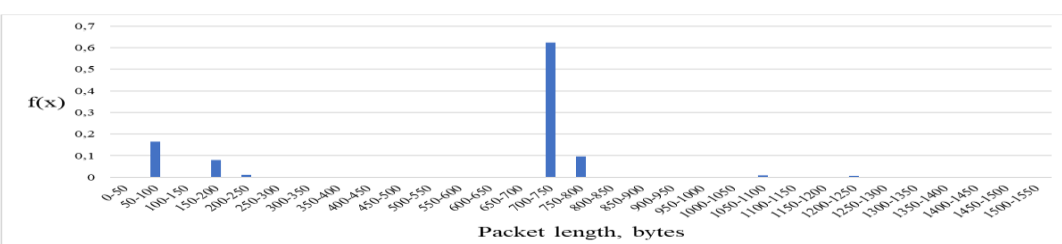

Figure 2. MVP, 3 + 1 Clients, Packet length

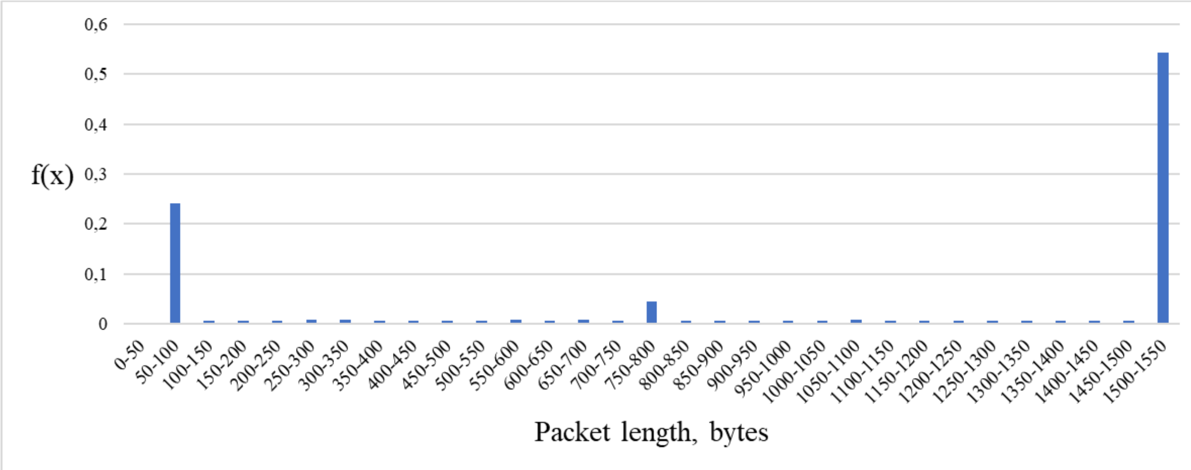

Figure 3. TrueConf, 3 + 1 Clients, Packet length

The described features can be observed in the comparative graph of the Average Packet Size in Bytes (Fig. 4). The average packet size values, as well as their distributions, have a small margin of error and are independent of the number of connected devices.

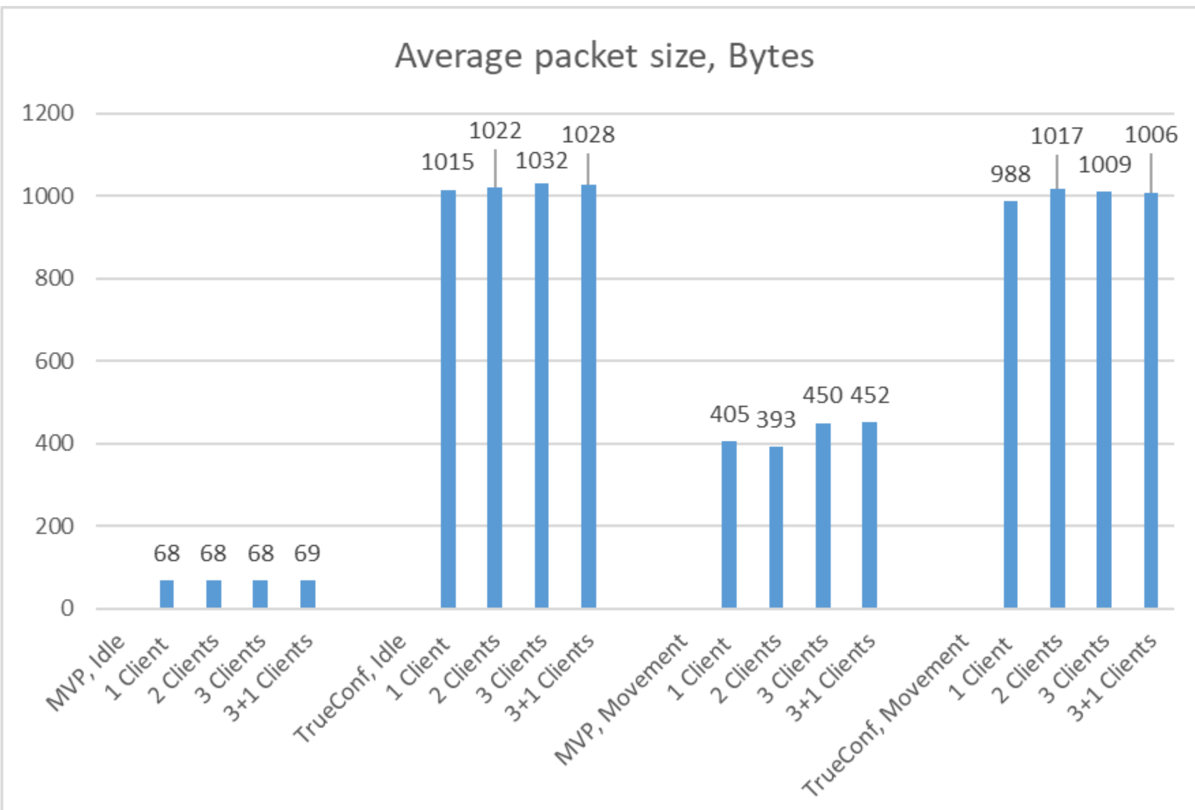

Figure 4. Average packet size, Bytes

The intensity refers to the number of packets transmitted per unit of time, in this case, per second (Fig. 5). The graph shows that the developed system imposes a lighter load on the network compared to TrueConf, and this difference is particularly noticeable when there is no person in the frame, as mentioned earlier.

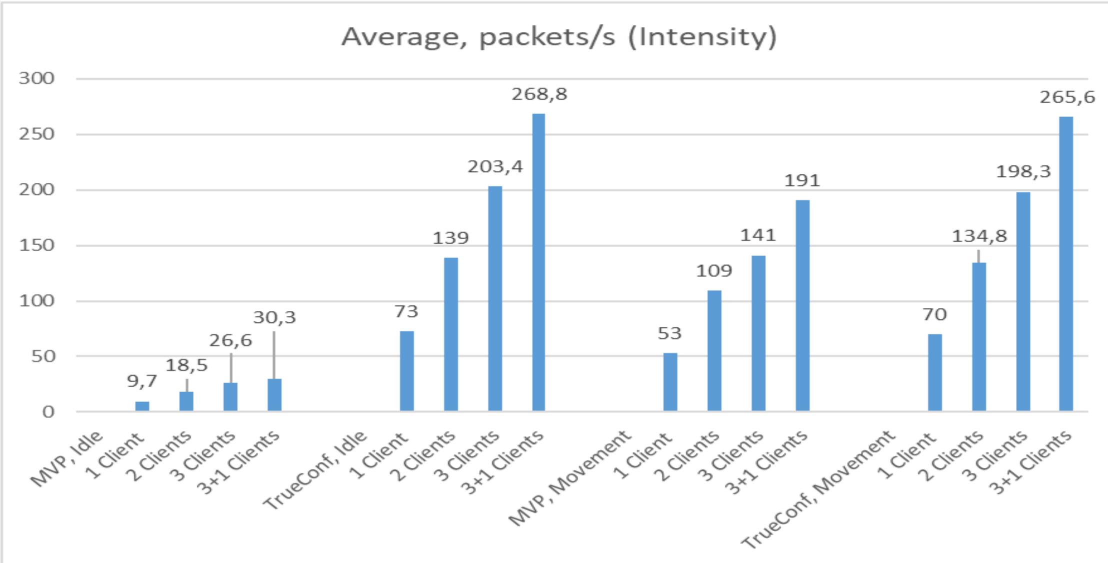

Figure 5. Average, packets/s (Intensity)

Data transfer rate, which measures the quantity of data transmitted within a specific timeframe, in this case, the number of bits sent per second, already exhibits a substantial advantage in terms of the volume of information transmitted (Fig. 6). This advantage is contingent on the fact that the developed MVP system conveys data about the 3D model, which can be processed and displayed to the user in various ways, in contrast to TrueConf, which only transmits 2D video.

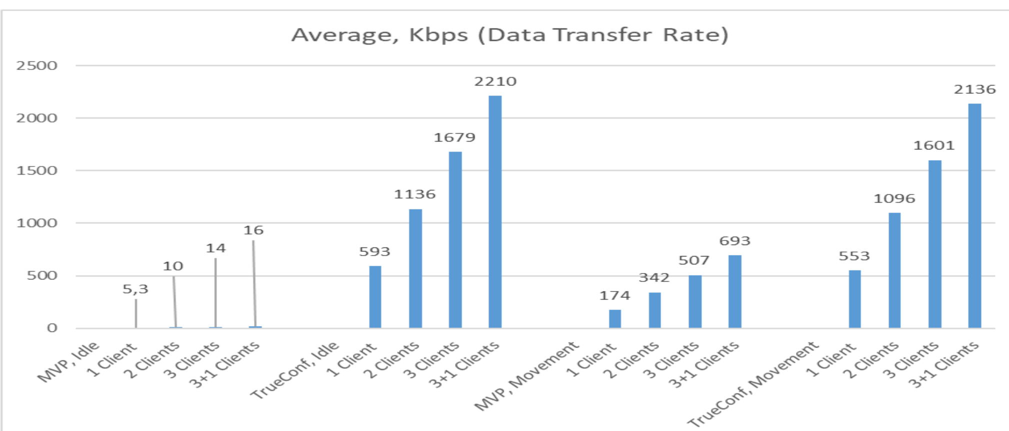

Figure 6. Average, bps (Data Transfer Rate)

The chart representing the transmitted data (Fig. 7) displays the volume of bytes transmitted throughout the entire five-minute application lifecycle, encompassing startup, connection, data transmission, and disconnection. This graph effectively illustrates the reduction in data transmitted over the network. When considering only the "Movement" experiments, the data reduction factor consistently exceeds 3. This implies that regardless of the number of connected devices, when a person is in the frame, the developed system transmits three times less information over the network than TrueConf. As for the "Idle" experiments, in these cases, the factor hovers around a value of 130, which is noteworthy but less significant, given the absence of the transmission of useful information.

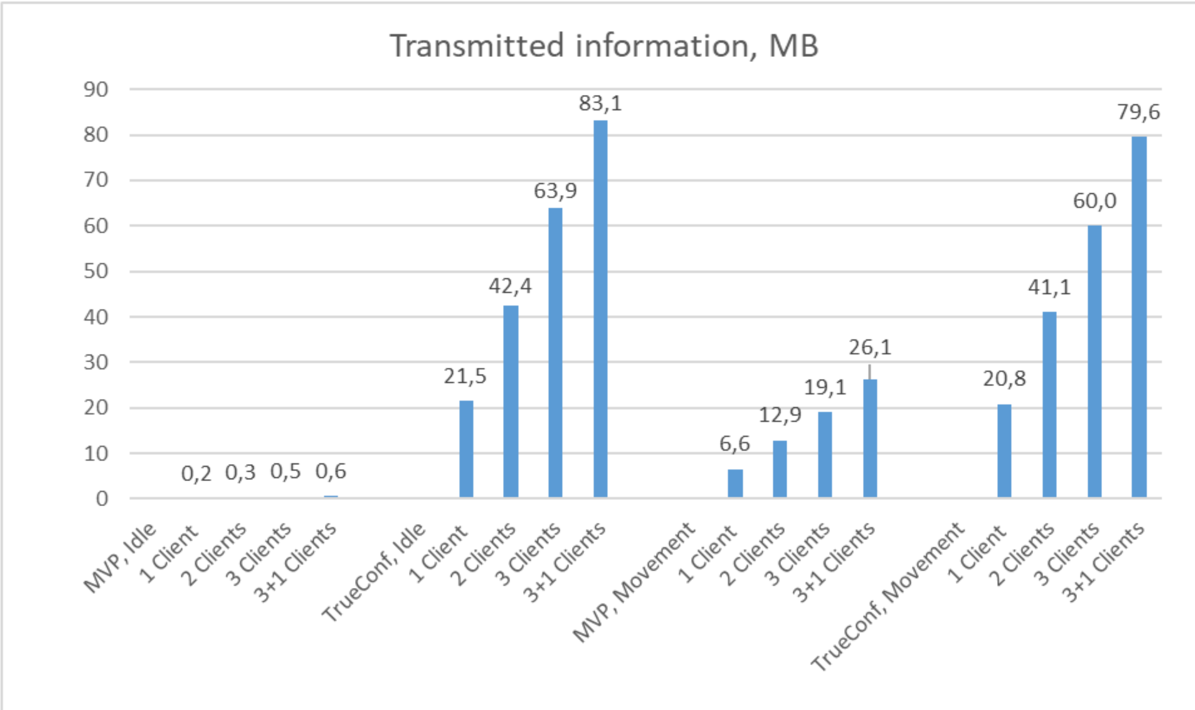

Figure 7. Transmitted information, Bytes

The chart (Fig. 7) illustrates that the volume of transmitted data increases linearly with the number of connected devices, both for the developed application and TrueConf. This information will be valuable for future network load forecasting when necessary.

Figure 8. MVP, 3 + 1 Clients, Movement, Packets per second

Figure 9. TrueConf, 3 + 1 Clients, Movement, Packets per second

The figures 8 "MVP, 3 + 1 Clients, Movement, Packets per second" and 9 "TrueConf, 3 + 1 Clients, Movement, Packets per second" display the graphs depicting the relationship between the number of received packets per second over time for the two most demanding experiments, one for each of the compared applications. It's immediately evident that the developed application uses the UDP protocol for data transmission, resulting in a "smooth" traffic pattern, while TrueConf uses TCP, as shown in the second graph, resulting in a "choppier" traffic pattern. Additionally, there's a notable difference in the scale of values between the two graphs, indicating that TrueConf utilizes the available bandwidth more aggressively.

The primary achievement of MVP at this stage is its low network resource consumption compared to applications providing 2D video communication services. The developed system not only outperforms in terms of network characteristics but also introduces revolutionary new capabilities for holographic communication services by transmitting control points of a person. There is potential for further development to enable the transmission of complete holograms or a cloud of points representing an entire individual [7].

CONCLUSION

In this paper, we have described the results of a comparative analysis of two conferencing applications: the self-developed MVP application and the commercial product TrueConf. The research has clearly shown that MVP surpasses TrueConf not only in offering more extensive services, including the transmission and display of a 3D model of a person for augmented reality and holography but also in terms of network characteristics.

The key findings of this comparative analysis are as follows: MVP's data transmission efficiency reduces the required amount of transmitted information by a factor of 3 compared to TrueConf. This would indicate a more optimized data transmission if both applications were transmitting video traffic. However, the MVP system was developed with the goal of reducing network load and replacing such traffic with a data stream, which can be particularly valuable in conditions of limited network bandwidth. The number of packets transmitted by MVP is also lower in this comparison, reducing the number of transmitted packets by 1.3 times. This parameter can be further improved by more efficient utilization of network resources and packet filling. This study touched upon the issue of QoS, but it was not fully explored. Further research should address the question of minimizing the risk of potential jitter during conferencing.

These results underscore the importance of developing and optimizing the next generation of conferencing applications, especially in cases where data transmission and functionality requirements are critical. MVP demonstrates the potential to provide a wider range of services and better network characteristics, which can be beneficial in various fields, including education, healthcare, and business. This development is ready to lead the way for the future of networks in 2030 and the world of HTC.

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