TCP/IP Model for Metaverse Networks and Some Potential Applications

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Abstract: It is well known that internet will play a key role to the infrastructure of metaverse, while different immerging virtual worlds communicate with each other. However, the common TCP/IP model is not suitable enough for metaverse networks. To this end, we explore a preliminary frame of revised TCP/IP model. At first, a new layer called metaverse layer is defined. And then, this layer is placed as the top layer, i.e., the upper of the application layer in TCP/IP model. As a result, a novel network model having the six layers is obtained. Our simulated experiments indicate the feasibility of the new model. Furthermore, we explore several potential application scenes of metaverse networks in this paper.

Key words: metaverse network, virtual world, TCP/IP model, metaverse layer.

1. Introduction

As an emerging and promising concept and technique, metaverse is attracting the attention of the world, including some leading enterprises and academic communities. For example, Facebook is hiring thousands of engineers in Europe to work on it [1], and its's metaverse is coming true [2].

Metaverse is defined as a virtual-reality space in which users can interact with a computer-generated environment and other users, by Oxford English Dictionary [3]. And Nvidia believes that the metaverse is a shared virtual 3D world, or worlds, that are interactive, immersive, and collaborative [4]. Just as the physical universe is a collection of worlds that are connected in space, the metaverse can be thought of as a bunch of worlds, too [4]. Obviously, these worlds in cyberspace will be connected via internet.

For Wikipedia, "Metaverse" is a term to describe the concept of future iteration of the internet [5]. It is made up of persistent, shared, 3D virtual spaces linked into a perceived virtual universe [5]. It does not only refer to virtual worlds, but also inclusive of the augmented reality as well in the whole internet ecosystem [5]. Obviously, internet will provide an underlying infrastructure for metaverse.

In terms of internet, most computers today communicate with each other through TCP/IP, and the TCP/IP model is an important infrastructure in globe cyberspace. It is widely known that TCP/IP model has the five layers, as follows: physical layer, datalink layer, network layer, transport layer, and application layer [6][7].

However, not only application messages prior to a process of immersion, but also virtual-world ones posterior to this process of immersion, need to be transferred on the internet of metaverse, so that users' immerging worlds can interact with each other. A number of studies discussed some issues about the intersection between metaverse and network mechanism [8]-[11].

To the best of our knowledge, the existing works do not directly talk about the core structure and fundamental mechanism of TCP/IP model or protocol in metaverse networks, by searching for SCI/EI literature. The kernel mechanism of metaverse networks seems unclear enough. In this situation, an exploration on TCP/IP-based metaverse networks will be needed. This is the motivation of this study.

2. A Frame of Improved TCP/IP Model

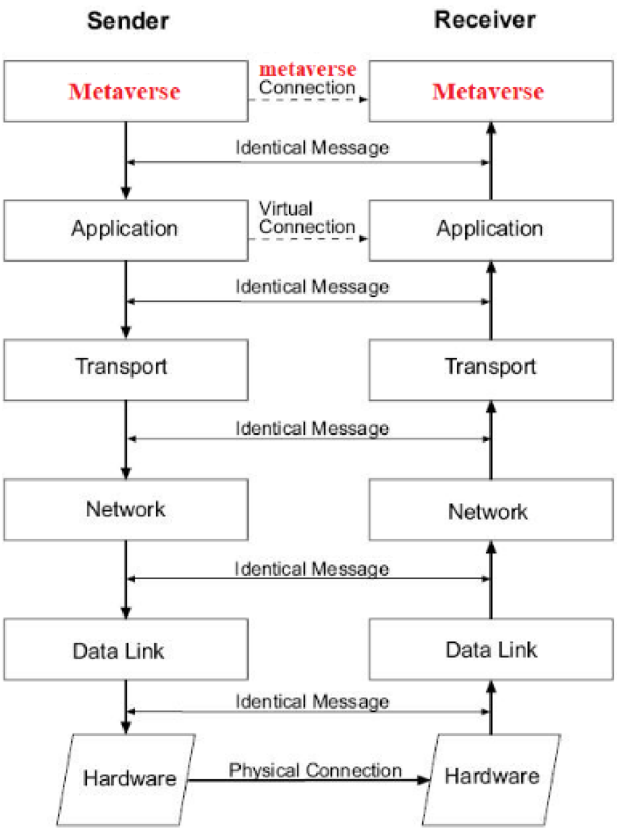


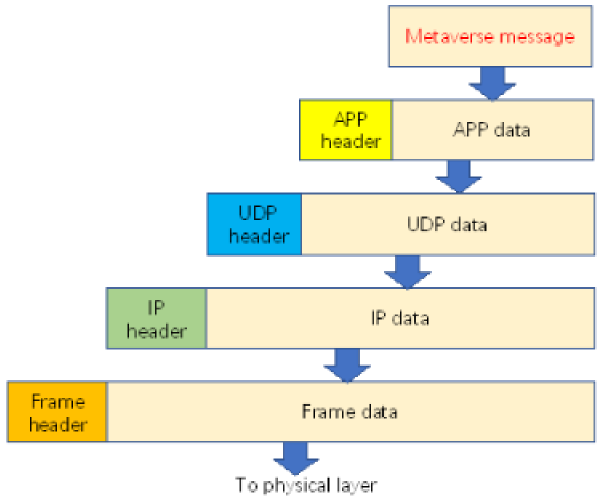
Fig. 1. A frame of the improved TCP/IP model for metaverse networks.

In order to carry and transfer messages about virtual-world produced by a process of immersion, we have revised the original TCP/IP model. And the modified version of this model can be illustrated in Fig. 1. As shown in this figure, the revised version of TCP/IP model has the six layers, as follows: physical layer, datalink layer, network layer, transport layer, application layer, and metaverse layer. The last one is appended to the original version of TCP/IP model, so that a metaverse connection between two virtual-worlds of cyberspace can be performed.

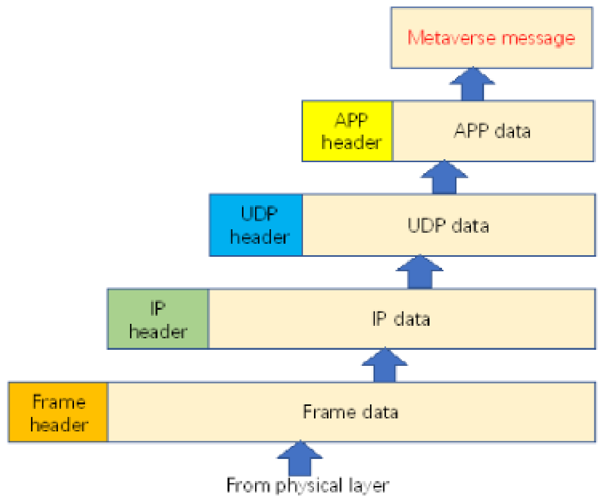
In order to establish a metaverse connection, the structure of messages has been modified, as illustrated in Fig. 2. A message about an user's immerging virtual-world is embedded into an application, and forms a piece of APP data. We can get a piece of UDP data by combining the above APP data with an APP header. The following process is similar to that of the original version of TCP/IP model. The above refers to what will happen if a message is sent. And an opposite process will occur if a message is received.

In fact, Fig. 1 and Fig. 2 depict an approach to send and receive message for metaverse networks. Put simply, the procedure can be listed as follows:

1) Some information depicting virtual world are generated, when a person called Alice gets into her avatar with the assistance of some virtual reality (VR) equipment.
2) The information produced by step (1) lie in the metaverse layer, and they will be embedded into the application layer, as APP data, by appending an APP header.
3) In terms of sender, the standard procedure of ordinary TCP/IP model will be employed, until some signals are ready for transferred in the physical layer.



(a) In terms of sender



(b) In terms of receiver

Fig. 2. The structure of message in the improved TCP/IP model.

4) The signals carrying Alice's information on virtual world will transmit via the physical layer.
5) In terms of receiver, the physical layer will get the above signals, and employ the standard procedure of ordinary TCP/IP model to get the APP data in the application layer.
6) The APP data mentioned above carrying information on Alice's virtual world will be received by Bob, as a receiver, so that Bob can see not only the avatar of himself but also Alice's avatar in the metaverse.
7) A reverse process will make Alice see not only the avatar of herself but also Bob's avatar, in the metaverse.

As a result of step (6) and (7), the different virtual worlds of the different persons can interact with each other, in a metaverse and via a metaverse network.

3. Simulated Experiments

3.1. Experimental Target

In order to make clear the feasibility of the new method, we design and conduct these simulated experiments.

3.2. Experimental Platform

- CPU: AMD Ryzen 7 4800U with Radeon Graphics 1.80 GHz
- RAM: 16.0GB
- OS: windows 10, 64 bit
- tools: Ookla Speedtest [12], Xfinity Speed Test [13], and Matlab R2017a

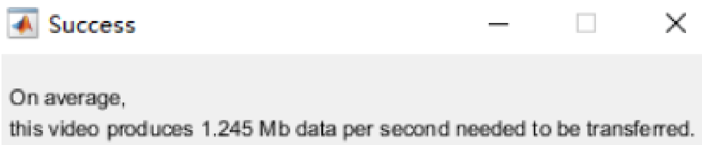
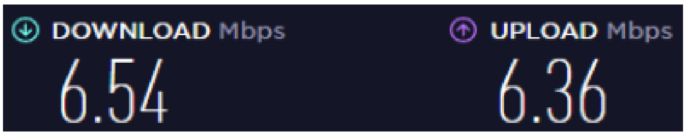


Fig. 3. A result on the file f1.

(a) Source node and destination node



(b) Speed for upload and download

Fig. 4. A test for f1 in the domestic network.

3.3. Experimental Steps

1) One can randomly generate a playable multi-media file f1 consisting of a great number of frames, and each frame express a transient immerging scene in an user's real-time virtual world of cyberspace.
2) One can compute the average size per second, i.e., s (1), for f1, by dividing z(1) by t(1), where z(1) denotes the size of f1 (M bits), and t(1) means how long does it take to play f1 (seconds).
3) One can get the values of the metrics called ua(1), da(1), ub(1), db(1), using Ookla Speedtest and Xfinity Speed Test, where ua(1) denotes the speed of uploading via Ookla Speedtest (Mbps), da(1) denotes the speed of downloading via Ookla Speedtest (Mbps), ub(1) denotes the speed of uploading

via Xfinity Speed Test (Mbps), and db(1) denotes the speed of downloading via Xfinity Speed Test (Mbps).

4) The test for f1 will be success, and flag(1) will be set to "1", if each value of ua(1), da(1), ub(1), db(1) is greater than s(1). Otherwise, flag(1) will be set to "0".
5) The steps 1)-4) are repeated 100 times, and FLAG={flag(1), flag(2), ... , flag(100)} is obtained.
6) The number of successful test and the success rate can be computed, with FLAG.

3.4. Experimental Results

3.4.1. About the file f1

As shown in Fig. 3, s1=1.245 Mbps.

Fig. 4 indicates some results on speeds in terms of f1 test while both sender and receiver are domestic nodes. And Fig. 5 shows some results on speeds in terms of f1 test while sender and receiver are located in the different countries. In other words, ua(1)=6.36 Mbps, da(1)=6.54 Mbps, ub(1)=2.6 Mbps, and db(1)=6.4 Mbps.

Obviously, the test for f1 is success, according to the experimental steps mentioned above.

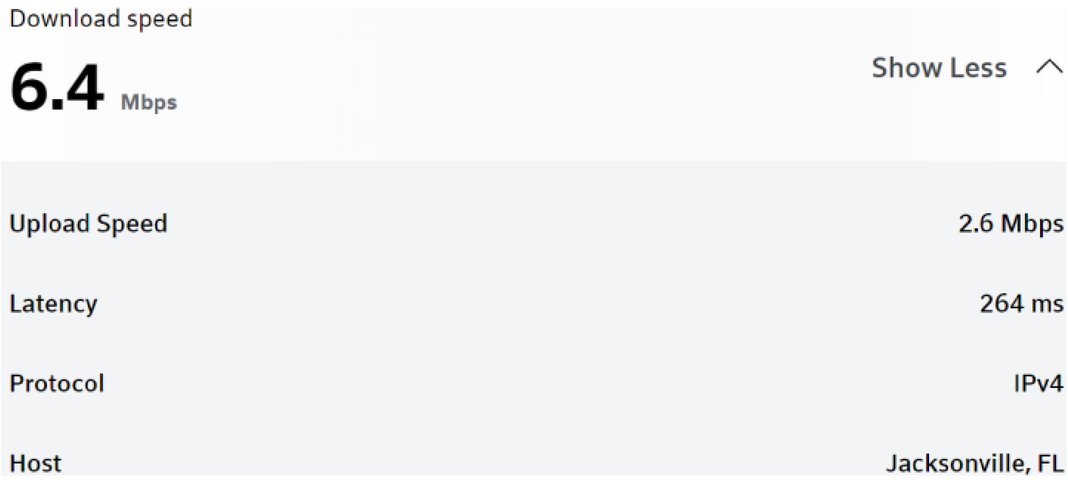


Fig. 5. A test for f1 in international network (between Henan in China, and Florida in USA).

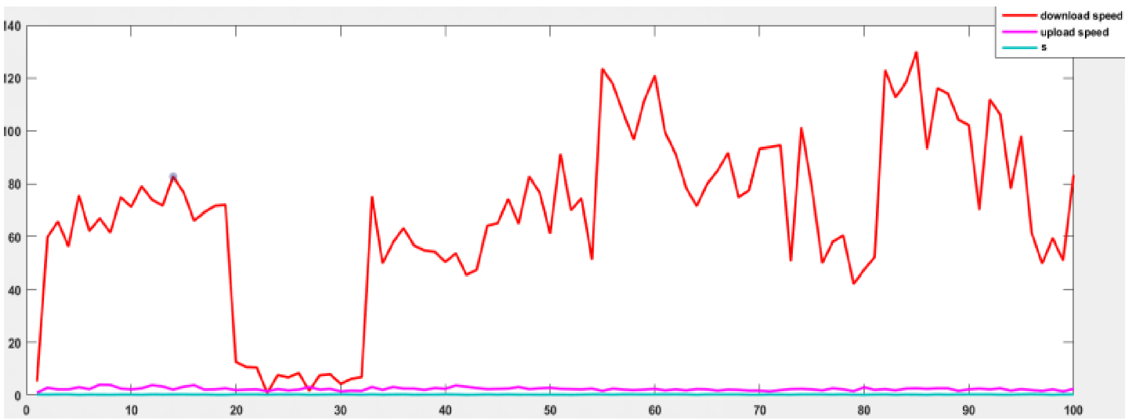


Fig. 6. The one hundred tests and their results of metrics.

3.4.2. About all files

Fig. 6 illustrates information about one hundred tests, where "download speed" means db consisting of one hundred values, and "upload speed" means ub consisting of one hundred values. In a word, all the tests are success, because the green line is always under the red line and the orange one. The principal reason for this is the development and popularization of high-speed networks.

4. Potential Application Scenarios

With the improved TCP/IP model, as the key of metaverse networks, the different virtual worlds can communicate with each other, in a metaverse networks.

In this section, we will explore several potential scenarios of social applications, based on metaverse networks. These scenarios aim to forecast and imply something about some future's cases.

4.1. Visiting Tour Attractions Via Metaverse

Table 1 depicts a comparison among the three different ways of visiting tour attractions.

With the way of metaverse or the non-immersive virtual way, one can visit the world, having an immersive feeling. Even in the period of epidemic, one can still be free to travel somewhere without the affection of virus.

In reality, a travel may cause a high economic cost due to tickets and travel expenses. In contrast, the above expenses will not be considered, causing the economic cost is lower, if a metaverse and/or non-immersive virtual way, rather than a real tour, is employed.

Compared with visiting tour attractions in reality, non-immersive virtual visiting cannot be limited by any objective condition, such as time, space and climate. For example, we can feel a beautiful winter scene in the hot summer, and enjoy the other side of the earth without leaving home.

Table 1. Compared to Other Ways, Metaverses Have Some Advantages and Disadvantages, in Term of Visiting Tour Attractions

	tour via metaverse	tour in real world	Non-immersive virtual tour
characteristic 1	unaffected by the epidemic	affected by the epidemic	unaffected by the epidemic
characteristic 2	realistic & intuitive	fully realistic & fully intuitive	not realistic enough, not intuitive enough
characteristic 3	economic costs are relatively low	high economic costs	low economic costs
characteristic 4	free from time, space and climate	limited by time, space and climate	free from time, space and climate

Table 2. Compared to other Ways, Metaverses have Some Advantages and Disadvantages, in Term of Shopping

	Metaverse Shopping	Real shopping	Non-immersive virtual shopping (Traditional online shopping)
characteristic 1	realistic & intuitive	fully realistic & fully intuitive	not realistic enough, not intuitive enough
characteristic 2	a customer can compare it on the spot, in some cases	it's not easy to compare on the spot, in some cases	hard to say
characteristic 3	free from time and space	more limited by time and space	free from time and space
characteristic 4	saving both time and physical strength	consuming time and physical strength	saving both time and physical strength

Table 3. Compared to other Ways, Metaverses have Some Advantages and Disadvantages, in Term of

Teaching

	teaching in metaverse	teaching in real classroom	non-immersive virtual teaching (traditional online classes)
characteristic 1	information is delivered accurately	information is delivered accurately	some information is conveyed accurately
characteristic 2	vivid & intuitive	fully vivid and full intuitive	not vivid enough, not intuitive enough
characteristic 3	low economic costs	some economic costs are required	low economic costs
characteristic 4	free from time and space	more limited by time and space	free from time and space
characteristic 5	a strong attraction to students	students are used to it	students are used to it

The above is a comparison between the tours via metaverse and the real tours. Next, we will compare tours via metaverse to traditional non-immersive virtual tours.

The way of visiting tour attractions via the metaverse will make a tourist having an immersive experience close to reality, and a relatively realistic feeling. And the traditional non-immersive virtual way cannot do that.

4.2. Shopping in a Metaverse

Table 2 depicts a comparison among the three different ways of shopping.

Now, let ‘s image that a customer want to buy some items, such as furniture. And he or she will select a satisfactory item using one of the three different optional ways.

If the customer does it in reality and he or she is on the spot, he or she may only feel an application scene of the furniture in a model room in a mall, rather than a scene at home. Thus, he or she can only make a decision by imaging whether or not this target furniture match with other furniture at home. If a metaverse is employed, the customer can move the target good into his or her home virtually, to observe the layout. Obviously, the way of metaverse instead of a traditional online shopping way has the above advantage. If the traditional online shopping way is used, it will be convenient to judge whether or not the target furniture match with the existing furniture at home in terms of color, and it is difficult to judge whether or not they match with each other in terms of size and layout. However, the way of metaverse does not suffer from this problem.

With real shopping, a customer may be affected by several objective factors such as bad weather and remote shopping place, when he or she is selecting target items. With metaverse and non-immersive virtual way, the customer does not need worry about the above objective factors.

In real shopping, more time and energy may be consumed due to waiting in line, tired walking and carrying heavy things. With shopping in metaverse and non-immersive virtual environment, one can stay at home, saving his or her time.

4.3. Teaching in a Metaverse

Table 3 depicts a comparison among the three different ways of teaching.

Teaching in the metaverse is close to teaching in reality. Compared with the traditional online teaching, teaching in the metaverse is more vivid and intuitive, and more information will be transmitted in a classroom.

In reality, teaching about some subjects needs to carry out scientific experiments, and their operations may incur some economic costs. For example, physical experiments often need to use various experimental instruments, while the virtual experimental operations in the metaverse do not need these instruments, reducing the cost.

In reality, teachers and students may not be able to concentrate in the same physical location (classroom) due to the epidemic or other reasons. With the metaverse-based approach, they can be conveniently placed in the same virtual learning place. As a result, no affection on the normal class will be occurred.

In the metaverse, all students and teachers can virtualize him or her into various different avatars in the metaverse world, making an ordinary class more vivid and interesting, attracting students' attention and achieving a better effect of learning. By contrast, the real-world class and the traditional online class do not have this advantage.

5. The Related Works

Some great studies talked about metaverse in terms of technique. However, the majority of them pay close attention to VR [14]-[16], since this technique provides a basis of immerging for metaverse. Compared with these works, we focus on networks rather than VR in this study, since the former is a basis of transmission for metaverse.

Parr *et al* proposed a three-dimensional markup language [8]. It is meaningful and interesting, although there is no indication that immerging mechanism has occurred. Furthermore, Shi et al presented routing service for immersive environments [9], relating to metaverse. However, no network model, protocol, or structure is involved, as basic facilities. By contrast, we investigate TCP/IP model under the circumstance of metaverse, in this study. These are the key differences between the existing works and the new one.

Some other studies talked about the social application of metaverse, such as museum exhibitions via metaverse [17], and privacy of social metaverse [18]. These works are very important. On the basis of it, this study explores more possibility of social applications of metaverse.

6. Conclusion

In this work, the famous TCP/IP model is adapted for aiming to future's metaverse networks. As a result, we have taken a step on the road to the metaverse networks, in terms of basic principle of this sort of network. Furthermore, some perspective visions using metaverse networks are suggested and looked forward, in terms of creative social applications, in this study. Considering that prospects of metaverse networks are generally favored by the community, these facts can help us understand the possible benefit of using the newly proposed model in the future.

Next, we will explore more technological mechanisms of metaverse networks, especially for various specific conditions of networks, based on the adapted TCP/IP model. It will be a further study.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

X Liang and M Chen executed the experiments; W Zhu conceived the idea and drafted the paper; Y Wang participated in writing and revising the paper; Z Luo, M Xu and J Wang verified and analyzed the data; all the authors had approved the final version.

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