Metaverse optimized distributed systems architectures. Standards for representing the avatars in Metaverse

Diana-Isabela Crainic, Ioan Sava

April 2022

Abstract

The metaverse is regarded as a new wave of technological transformation that provides a virtual space for people to interact with each other through digital avatars. Quite naturally, these avatars will eventually become an integral part of our everyday lives and define who we are. However, there are still hurdles to overcome to create a metaverse accessible to anyone. A hybrid of cloud computing and edge computing may be the solution for an immersive experience.

1 Introduction

A metaverse is a wide expanse of digital space where users can interact with each other in real-time and get similar experiences to what they experience in the real world, and in most cases even more[1].

In the center of the metaverse there are the 'Avatars' that inhabit these immersive virtual environments. Also, the avatars enable necessary interoperability between the metaverse's many features. With the advancement of technology, the Age of Avatars facilitates users to manifest themselves in the virtual world visually. Thus, avatars emerge as a digital identity, an extension of ourselves in the virtual space.

Avatars are on-screen or virtual manifestations of the user, and technically, they can take on any shape or form as long as they have humanoid features such as moveable limbs, upper and lower torsos, and a face capable of expression. Additionally, the avatars support customisation for add-ons like your hair, outfit and many more. In the context of the metaverse, avatars are providing users access to all that the world has to offer.

[1] https://www.techtarget.com/whatis/feature/The-metaverse-explained-Everything-you-need-to-know

2 Metaverse

Metaverse, combination of the prefix "meta" (implying transcending) with the word "universe", describes a hypothetical synthetic environment linked to the physical world. The word "Metaverse" was first coined in a piece of speculative fiction named *Snow Crash*, written by Neal Stephenson in 1992[1]. In this novel, Stephenson defines the Metaverse as a massive virtual environment parallel to the physical world, in which users interact through digital avatars[2]. Since then, various developments have made mileposts on the way toward a real Metaverse, an online virtual world which incorporates augmented reality, virtual reality, 3D holographic avatars, video and other means of communication.

If the Metaverse becomes a widespread reality, it will have virtually countless benefits, because it will provide people with new opportunities and capabilities like nothing they have known yet.

The Metaverse will radically increase the affordability of a wide range of experiences and products, giving poor and middle-class people access to luxuries previously only available to the wealthy. Just like the internet has given much of the human population access to vast libraries of knowledge and entertainment, the Metaverse may allow most of humanity to virtually experience world travel, high quality interaction with family members stuck in distant countries, and so on.

Another advantage of the metaverse centers on specific applications in learning and education. Note that online learning using video conferencing platforms and asynchronous classes are considerably passive and indirect. However, through an immersive virtual environment, the learning experience is more interactive and instruction becomes more engaging.

However, there are still hurdles to overcome on the path to turning the era of the metaverse from fiction into reality. Harmonizing different technological building blocks at different stages of development and ensuring the interoperability of the various services is required.

3 Metaverse optimized distributed systems architectures

It is going to take years to see how the metaverse plays out, but a certainty is that it will accelerate the decentralization of computing, that already is underway thanks to trends like *IoT* and *edge computing*. At the Ignite Conference in 2021, Microsoft chief executive officer Satya Nadella noted this, saying that the industry had reached “peak centralization.” The type of immersive experiences proponents of the metaverse are talking about will need high-bandwidth and low-latency capabilities and that will

require compute to be closer to the end user.

"The idea is that if you're going to have an immersive experience, even like Metaverse is showing, you're going to have to execute a lot of that locally," said Matt Baker, senior vice president at Dell Technologies. "If you look at the current things that we would say are akin to the metaverse, there's a reason why it is largely totems and avatars. It's because it's easy to render these almost comic-like animations of me as an avatar that sort of looks blocky. Why do you do that? It's because you can't render something really sophisticated and three dimensional over distance."

As laid out in a blog post [2] by the same Matt Baker, compute and data will be highly distributed, which will drive the need for a lot of processing capacity in datacenters and at the edge and more powerful PCs and other clients that come with accelerators, more memory and higher core counts. There also will be a need for standards and open interfaces.

Trying to create this 3D world from centralized, far-away datacenters would defy the laws of nature, Baker says. Therefore, a possible solution would be smaller datacenters – or datacenter-like environments – in more places, such as the wireless towers carriers operate, complete with compute, storage and networking. It also will create a world that hyperscalers like *Amazon Web Services*, *Microsoft Azure* and *Google Cloud* will have to adapt to.[3]

3.1 User experienced latency

In the metaverse, it is essential to guarantee an immersive feeling for the user to provide the same level of experience as reality. One of the most critical factors that impact the immersive feeling is the latency, e.g., motion to photon (MTP) latency[4]. Researchers have found that MTP latency needs to be below the human perceptible limit to allow users to interact with holographic augmentations seamlessly and directly. For instance, in the registration process of AR, large latency often results in virtual objects lagging behind the intended position, which may cause sickness and dizziness. As such, reducing latency is critical for the metaverse, especially in scenarios where real-time data processing is demanded, e.g., real-time AR interaction with the physical world such as AR surgeries, or real-time user interactions in the metaverse like multiplayer interactive exhibit in VR[2].

Due to the variable and unpredictable high latency, cloud offloading cannot always reach the optimal balance and causes long-tail latency performance, which impacts user experience. Recent cloud reachability mea-

[2] https://www.dell.com/en-us/blog/the-metaverse-isnt-new/

[3] https://www.nextplatform.com/2022/02/24/decentralized-compute-is-the-foundation-of-the-metaverse/

[4] MTP latency is the amount of time between the user's action and its corresponding effect to be reflected on the display screen.

surements have found that the current cloud distribution is able to deliver network latency of less than 100 ms. However, only a small minority (24 out of 184) of countries reliably meet the MTP threshold via wired networks and only China (out of 184) meets the MTP threshold via wireless networks. Thus a complementary solution is demanded to guarantee a seamless and immersive user experience in the metaverse.

Edge computing, which computes, stores, and transmits the data physically closer to end-users and their devices, can reduce the user-experienced latency compared with cloud offloading. As early as 2009, Satyanarayanan et al.[3] recognized that deploying powerful cloud-like infrastructure just one wireless hop away from mobile devices, i.e., so-called cloudlet, could change the game, which is proved by many later works. For instance, Chen et al.[4] evaluated the latency performance of edge computing via empirical studies on a suite of applications. They showed LTE cloudlets could provide significant benefits (60% less latency) over the default of cloud offloading. Similarly, Ha et al.[5] also found that edge computing can reduce the service latency by at least 80 ms on average compared to the cloud via measurements.

3.2 Privacy at the edge

The metaverse is transforming how we socialise, learn, shop, play, travel, etc. Besides the exciting changes it's bringing, we should be prepared for how it might go wrong. And because the metaverse will collect more than ever user data, the consequence if things go south will also be worse than ever. One of the major concerns is the privacy risk. For instance, the tech giants, namely Amazon, Apple, Google (Alphabet), Facebook, and Microsoft, have advocated password-less authentication for a long time, which verifies identity with a fingerprint, face recognition, or a PIN. The metaverse is likely to continue this fashion, probably with even more biometrics such as audio and iris recognition. Before, if a user lost the password, the worst case is the user lost some data and made a new one to guarantee other data's safety. However, since biometrics are permanently associated with a user, once they are compromised (stolen by an imposter), they would be forever compromised and cannot be revoked, and the user would be in real trouble.

Currently, the cloud collects and mines the data of end-users and at the service provider side and thus has a grave risk of serious privacy leakage. In contrast, edge computing would be a better solution for both security and privacy by allowing data processing and storage at the edge. Edge service can also remove the highly private data from the application during the authorization process to protect user privacy.

Due to the distinct distribution and heterogeneity characteristics, edge computing involves multiple trust domains that demand mutual au-

thentication for all functional entities. Therefore, edge computing requires innovative data security and privacy-preserving mechanisms to guarantee its benefit.

3.3 Edge vs Cloud computing

As stated above, the edge wins in aspects such as lower latency thanks to its proximity to the end-users or privacy-preservation via local data processing. However, when it comes to long-term, large-scale metaverse data storage and economic operations, the cloud is still leading the contest by far. The primary reason is that the thousands of servers in the cloud datacenter can store much more data with better reliability than the edge. This is critical for the metaverse due to its unimaginably massive amount of data. As reasoned by High Fidelity[6], the metaverse will be 1,000 times the size of earth 20 years from now, assuming each PC on the planet only needs to store, serve and simulate a much smaller area than a typical video game. For this reason, robust cloud service is essential for maintaining a shared space for thousands or even millions of concurrent users in such a big metaverse.

Besides, as the Internet bandwidth and user-device capacity increase, the metaverse will continue expansion and thus demand expanding computation and storage capacity. It is much easier and more economical to install additional servers at the centralised cloud warehouses than the distributed and space-limited edge sites. Therefore, the cloud will still play a vital role in the metaverse era. On the other hand, edge computing can be a complementary solution to enhance real-time data processing and local user interaction while the cloud maintains the big picture.

4 The Metaverse Avatar

In general, an Avatar is an online representation of an user, which differs from person to person and can either be static or animated. An Avatar in the Metaverse is based on the same principle as other online avatars, but a noticeable difference is the flexibility, more specifically it will be able to cross through various experiences, in different virtual worlds in the entire Metaverse. In addition to this, the avatars are designed to be extremely realistic, being able replicate the entire person and their body movements in order to create a vivid feeling of the actual person being there.[5]

The avatars play a major role in the Metaverse, they are one of the most logical interoperable elements of this digital realm because they represent the identity of the person. Therefore, apart from just playing a few

[5] https://beebom.com/metaverse-avatars-explained/

games like *PokerStars VR*[6], *Golf+*[7], and *Epic Roller Coasters*[8], to various types of other activities in the working field like virtual meetings, being able to meet with the coworkers in a metaverse where everybody is represented as a 3D avatar, will also be reflected onto the avatar and therefore the user. The Metaverse relies on this specific principle of *User equals Avatar* and hence cannot exist without it.

While the type of avatars out there is plentiful in their creation and variety, the Metaverse will most likely focus on 2 types: *VR Avatar* and *Full Body Avatar*. A VR avatar is a first-person rendition where the user sees the world from the avatar's point of view. Other world participants can see the upper torso part of the avatar, along with arms, but without the lower limbs. This type is found in most rudimentary VR apps, which do not require complex leg movements or in-world mobility. In a full-body avatar, sensors replicate and recreate the entire body's movements through a kinematics system. As a result, the user has greater freedom of mobility inside the virtual world and can use all limbs to interact with digital assets. Sophisticated VR games typically use this type, and Facebook's Metaverse will likely choose this route as well.[9]

To carve out an authentic digital identity, customization of avatars is the most important requirement. In fact, 92% of the respondents of a study by the *Institute of Digital Fashion*[10] proclaimed the importance of customizing their avatars to identify with them genuinely. Bringing humans into the Metaverse and digitizing their identity for a genuine representation requires presenting them as organically as possible.

The respondents of the survey also showed a particular awareness of the underrepresentation of women, disabilities, and the LGBTQ+ community: 70% of them "expressed that gender representation within virtual experiences was vital to them," and 60% were "concerned about the increased potential for bullying and discrimination against disabled people within virtual worlds." As one anonymous respondent wrote, "People with disabilities are definitely an underrepresented social group in both real and virtual spaces. Virtual spaces can fix this problem by shedding new light on underrepresented voices and sharing insight on their stories."[11]

Respondents indicated an "almost unanimous agreement that skin color should be as diversely represented as possible" and responses reflected a "visible demand for non-gendered clothing" in the Metaverse, according to the report. Ultimately, the report's conclusion indicated con-

[6] https://www.oculus.com/experiences/quest/2370815932930055

[7] https://www.oculus.com/experiences/quest/2412327085529357/

[8] https://www.oculus.com/experiences/quest/2299465166734471

[9] https://skywell.software/blog/3d-avatars-in-the-metaverse-everything-you-need-to-know/

[10] https://www.voguebusiness.com/technology/shaping-online-avatars-why-our-digital-identities-differ

[11] https://www.wundermanthompson.com/insight/representation-in-the-metaverse

sumers value the importance of choice.

5 Conclusion

The metaverse is a massive virtual environment parallel to the physical world, in which users interact through digital avatars. If the metaverse becomes a widespread reality, it will have virtually countless benefits, because it will provide people with new opportunities and capabilities like nothing they have known yet. However, there are still technological challenges to overcome to turn the metaverse from fiction into reality.

Edge computing is a promising solution to complement current cloud solutions in the metaverse. It can reduce user experienced latency for metaverse, task offloading and improve privacy and security for the metaverse users. Indeed, the distribution and heterogeneity characteristics of edge computing also bring additional challenges to fully reach its potential.

As the examples mentioned above demonstrate, the potential use-cases of an avatar-enabled metaverse are enormous. On the one hand, it will pave the way for more immersive and interactive experiences in virtual conferences. On the other hand, video games will become even better with advances in VR-AR technologies. Further expansion of the metaverse will also lead to a growth in virtual storytelling and digital celebrity culture.[12]

As the metaverse brings together thousands of apps and multiple virtual worlds, the avatar can act as your single point of entry and persistent identity, while you explore, interact, and engage.

[12] https://www.nasdaq.com/articles/how-are-avatars-constructing-digital-identities-in-the-metaverse

References

[1] Judy Joshua. Information Bodies: Computational Anxiety in Neal Stephenson's Snow Crash. Interdisciplinary Literary Studies, 19(1):17–47, 2017. Publisher: Penn State University Press.

[2] Lik-Hang Lee, Tristan Braud, Pengyuan Zhou, Lin Wang, Dianlei Xu, Zijun Lin, Abhishek Kumar, Carlos Bermejo, and Pan Hui, Fellow, IEEE (2021) All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda

[3] Mahadev Satyanarayanan, Paramvir Bahl, Ramon Caceres, and Nigel Davies, The case for vm-based cloudlets in mobile computing. IEEE Pervasive Computing, 8(4):14–23, 2009.

[4] Zhuo Chen, Wenlu Hu, Junjue Wang, Siyan Zhao, Brandon Amos, Guanhang Wu, Kiryong Ha, Khalid Elgazzar, Padmanabhan Pillai, Roberta Klatzky, Daniel Siewiorek, and Mahadev Satyanarayanan. An empirical study of latency in an emerging class of edge computing applications for wearable cognitive assistance. In Proceedings of the Second ACM/IEEE Symposium on Edge Computing, SEC '17, New York, NY, USA, 2017. Association for Computing Machinery.

[5] Kiryong Ha, Zhuo Chen, Wenlu Hu, Wolfgang Richter, Padmanabhan Pillai, and Mahadev Satyanarayanan. Towards wearable cognitive assistance. In Proceedings of the 12th annual international conference on Mobile systems, applications, and services, pages 68–81, 2014

[6] Yahoo. How big is the metaverse?, July 2015.