Distributed Metaverse: Creating Decentralized Blockchain-based Model for Peer-to-peer Sharing of Virtual Spaces for Mixed Reality Applications

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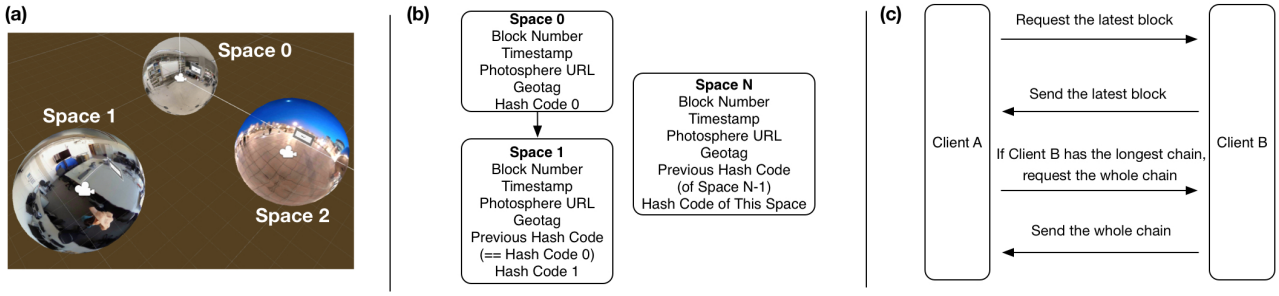

Figure 1: (a) Example of multiple mixed reality spaces in a single metaverse, (b) blockchain example and block content outline, (c) blockchain synchronization protocol

ABSTRACT

Mixed reality telepresence is becoming an increasingly popular form of interaction in social and collaborative applications. We are interested in how created virtual spaces can be archived, mapped, shared, and reused among different applications. Therefore, we propose a decentralized blockchain-based peer-to-peer model of distribution, with virtual spaces represented as blocks. We demonstrate the integration of our system in a collaborative mixed reality application and discuss the benefits and limitations of our approach.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing systems and tools**; *User interface management systems*;

KEYWORDS

Spatial Media, Mixed Reality, Social Media, Telepresence, Mobile Computing, Groupware, Blockchain, Photospherical Imagery

AH2018, February 7–9, 2018, Seoul, Republic of Korea

ACM Reference Format:
Bektur Ryskeldiev, Yoichi Ochiai, Michael Cohen, and Jens Herder. 2018. Distributed Metaverse: Creating Decentralized Blockchain-based Model for Peer-to-peer Sharing of Virtual Spaces for Mixed Reality Applications. In *AH2018: The 9th Augmented Human International Conference, February 7–9, 2018, Seoul, Republic of Korea.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3174910.3174952

1 INTRODUCTION

Mixed reality telepresence is becoming an increasingly popular alternative to regular monoscopic videoconferencing in social media and collaborative applications. Called "the future of remote collaboration"[1], mixed reality applications use virtual spaces in which both local and remote users can collaborate. In most cases such space would contain a photospherical background image or video stream of a real location in which users are placed, and optionally such data as real-world coordinates and the time and date of when the space was created.

Since we believe that collaborative applications will be more commonplace in the near future, we are interested in how virtual spaces can be archived, recycled, and shared among different mixed reality applications. The availability of "metaverse," a persistent and constantly updated collection of mixed reality spaces mapped to different geospatial locations, could decrease the computational

costs for mobile mixed reality applications and expand available interactive space.

We propose a solution that uses a decentralized blockchain-based peer-to-peer model of distribution, where spaces are represented as blocks containing necessary information (such as links to photospherical imagery, geospatial data, timestamps, etc.), synchronized among connected users. To test the validity of our approach we integrated our solution into a collaborative mobile mixed reality application, and are currently designing a user study that evaluates its effects on user experience. Believing that our approach presents a glimpse into the future of decentralized social media and collaborative applications, we discuss the benefits, limitations, and applications of our solution.

2 BACKGROUND

The proposed solution combines several key concepts: remote collaboration through mobile mixed reality telepresence and decentralized blockchain-based storage.

Mixed reality was first defined in [9], representing various blends between real and virtual worlds (e.g., augmented reality and augmented virtuality). In subsequent years researchers succeeded in using mixed reality for collaborative applications, such as real-world annotations, [3, 6, 8] and mobile telepresence, where users were "teleported" to a remote location in mixed reality where they could collaborate together [7, 10].

The presented studies revealed several limitations. For instance, since the applications often did not save the imagery captured in collaborative sessions, each mixed reality space had to be recreated from scratch, requiring additional processing power. Furthermore, the presented applications worked only with one mixed reality space per session, and did not allow users to traverse among multiple active spaces, although studies indicate that remote collaboration can benefit from multi-space and multi-viewpoint [4] interactions with enriched spatial context (e.g., combining video streams with geospatial updates).

However, introducing such mapping functionality poses an architectural challenge: a public system that stores metaverse should be resilient, in case of a large amount of requests, and immutable, to prevent alteration of previously archived spaces by third parties. These issues were partially addressed in social virtual reality network Decentraland [11], which used distributed storage paired with blockchain, a continuous immutable ledger of unique transactions, to ensure the delivery of a single virtual space to multiple users. Similarly, benefits of blockchain technology for content delivery have been suggested in [2, 5].

3 IMPLEMENTATION

Based on such observations we propose a model for decentralized mixed reality space storage and distribution. Since in our case a metaverse does not need to ensure validity of user transactions, we decided to move the space-related data into the blockchain payload itself. Such approach provides the following advantages: the blockchain can provide unique identifiers for each created space via generated hash codes; it would be immutable, since changing the payload would invalidate the chain; and it is relatively easy to store, update, and share the spaces since it is stored in a form of a plain text JavaScript Object Notation (JSON) array.

To validate our approach we integrated this system into a mobile collaborative mixed reality application introduced in [13]. In this application all session participants connect in a peer-to-peer fashion via Web Real-Time Communication (WebRTC) protocol. Each time a new space is created, the application generates a block containing the URL to the photospherical image, its geographical coordinates, and the time it was created. Then it sends the created block to all connected users in a session, updating the blockchain. Whenever a new user joins the session, their application requests blockchains from all connected peers and downloads the longest valid chain.

We also updated the application interface to support multiple collaborative spaces in a session. Currently users can either see all available spaces sorted by locations and select them in a list, or enables a mode which embeds the icons of spaces adjacent to user's current location, based on geographical coordinates of the space they are currently located in. Users located in a single space can collaborate together in realtime through audio and video streaming, as well as three-dimensional annotations in virtual space.

4 CONCLUSION AND FUTURE WORK

We proposed and implemented a first prototype for distributed blockchain-based model for peer-to-peer archiving, recycling, and sharing of virtual spaces for social and collaborative applications in mixed reality. Although the current implementation is rather simplistic and does not provide such additional layers of protection against "spamming" attacks as proof-of-work or proof-of-stake, we believe it is sufficient enough to highlight the research interest towards decentralized peer-to-peer models of storage for persistent mixed reality spaces.

We also found our model to be beneficial in several use-cases. First of all, due to the limited availability of photospherical imagery on such services as Google Maps or Bing Maps (e.g., Google Maps does not necessarily have a photosphere of a certain building's interior), our solution serves as an alternative source of photospherical imagery for mixed reality spaces, creating an independent and self-sustaining archive of geotagged URLs, which can be reused for various navigational applications similar to [12]. Secondly, due to the fact that the whole metaverse is stored in a JSON array, it can be easily stored and shared in a plain text form. We imagine that in the future such collaborative spaces will be distributed as QR-codes in public spaces where users can freely download them and use in mixed reality applications (for instance, using a code in a store to call staff that would help a user to locate an item by annotating a certain area of a mixed reality space).

Finally, we are interested in how persistent multi-space mixed reality environments can benefit remote collaboration. We are currently designing a user study that can evaluate cognitive workload, spatial and situational awareness, in comparison with a single-space collaborative mixed reality application.

ACKNOWLEDGMENTS

This work was partially supported by the grant 17K00509 of Japan Society for the Promotion of Science (JSPS).

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