

Design of an Architecture for Interoperability between heterogeneous Metaverse platforms

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Abstract—One of the biggest technical issues in the upcoming Metaverse-based society is the support of interoperability between different Metaverse platforms. This interoperability will enable users to experience a continuum of platform-independent services and activate a new Metaverse-based ecosystem. In this paper, we propose AIM, an architecture supporting interoperability between different Metaverse platforms, and propose procedures for messaging service between users of different Metaverse platforms and teleporting service to other Metaverse platforms, which are representative services that can be supported based on AIM.

Keywords—Metaverse, platform, interoperability, messaging, teleporting

I. INTRODUCTION

The Metaverse, a term coined by Neil Stephenson in his book *Snow Crash*, has recently become one of the biggest buzzwords in the ICT industry. Neal Stephenson used the Metaverse to refer to a computer-generated virtual world, but it is now defined and used in many different ways in many different fields. However, the Metaverse, as it is referred to by Meta and Microsoft [1], can now generally be defined as the next generation of the Internet, beyond the current mobile Internet, that offers three-dimensional, immersive experiences to users.

Although it is still in early stage, it is predicted that major areas of human life will gradually move into the Metaverse, and within the Metaverse environment humans will create new social, cultural and economic values that integrate the real and the virtual [2]. The Metaverse is still in its infancy, and there are technical, legal, and humanistic issues that need to be resolved before it can evolve into a Metaverse-based society. Especially, from a technical perspective, the issues include scalability, network bandwidth, virtual reality technology, security and privacy, interfaces, interoperability, content creation and management. These are the challenges that need to be addressed to realize the Metaverse society.

Of the technical issues outlined above, interoperability between different Metaverse platforms is a core technical issue that must be addressed if the Metaverse is to evolve into the next generation of the Internet, just as the current Internet is based on the interconnection of billions of Web sites. However, to date, Metaverse services have been still delivered in silos with no support for interoperability. As a result, current users of Metaverse services will not have any continuity of service if the Metaverse platform changes. This has been a critical barrier to the growth of Metaverse users and services [3].

Based on this problem, this paper proposes AIM (Architecture for Interoperability between Metaverse

platforms), an architecture that can support interoperability between different Metaverse platforms. To facilitate deployment, AIM requires minimal changes to the existing Metaverse platform environment. That is, AIM is characterized by the addition of interworking functional blocks to each Metaverse platform and the introduction of an external interoperability server that each Metaverse platform can reference for interoperability.

This paper is organized as follows. Section II summarizes the state of the art in interoperability related research, and Section III discusses the design of AIM, the interoperability architecture proposed in this paper. Section IV describes the procedures of the most basic services that can be provided through AIM: messaging between users of different Metaverse platforms and procedures for supporting the teleporting of digital objects such as avatars from one Metaverse platform to another. Finally, Section V contains concluding remarks.

II. RELATED WORK

Metaverse platform interoperability is naturally closely tied to standardization, as it identifies the protocols that each Metaverse platform should follow. Recently, there have been various activities and initiatives by major Metaverse companies and open source organizations to develop Metaverse interoperability standards to address these issues such as MSF (Metaverse Standardization Forum), W3C-OMI (Open Metaverse Interoperability), OMF (Open Metaverse Foundation), OMA3 (Open Metaverse Alliance for Web3).

The MSF is the representative organization for global Metaverse standardization. The MSF was founded in 2022 as a forum for collaboration between Metaverse companies and related standards organizations to build an open and inclusive Metaverse. Thirty-seven organizations have joined as founding members, including leading Metaverse companies such as Meta, Microsoft, NVIDIA, Unity, and Epic, and standards organizations such as the W3C and the Web3D Consortium. Membership now exceeds 2,400 organizations. The MSF currently has nine groups agreed by the Forum. Their work scope includes 3D Asset Interoperability using USD and glTF, Digital Asset Management, Metaverse Standards Register, Real and Virtual World Integration, Digital Fashion Wearable for Avatar, Interoperable Characters and Avatars, and Technical Interoperability and End-user Trouble-shooting [4].

The OMF is a project founded in 2022 by the Linux Foundation based on the consensus that the Metaverse is still in its infancy and should evolve into an open Metaverse for all. The issues that OMF currently works on are User Transaction, Digital Asset, Virtual Worlds and Simulations, Artificial

Intelligence, Networking, Security and Privacy, and Legal and Policy [5].

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OMA3 is a collaboration of developers of Web 3.0-based decentralized Metaverse platforms and was established in 2022. A decentralized Metaverse service is a decentralized structure, usually implemented using blockchain technology, that is not controlled by a single entity and differs from other server-based Metaverse services in that users take ownership of their digital assets. The current scope of OMA3 includes Asset Transfer, Ecosystem, Legal Participant Safety, and Portaling & Mapping [7].

In summary, work on Metaverse interoperability is still in its infancy and there are no concrete agreed technologies or standards for providing interoperability. Therefore, the first step in advancing Metaverse interoperability will be to build consensus on the overall architecture, which will include an architecture and associated basic procedures for providing interoperability between heterogeneous Metaverse platforms.

III. DESIGN OF AIM

This section describes the considerations for the design of the AIM proposed in this paper.

A. Interoperability Levels

There could be several levels of interoperability between Metaverse platforms. Table I summarizes the levels of interoperability between Metaverse platforms from the perspective of identifier and digital objects such as avatar, scene, currency. Note that the levels of interoperability can be further categorized as the digital object is subdivided.

TABLE I. THE LEVELS OF METAVVERSE INTEROPERABILITY

Level	Identifier	Digital Object
0	Not support	Not support
1	Support	Not support
2	Support	Support

In Table 1, interoperability level 0 does not support interoperability of user identifiers or digital objects between Metaverse platforms. In this case, if a user changes services from one Metaverse platform to another, they will need to re-login to the new Metaverse platform environment with a new user identifier. Level 1 is when the participating Metaverse platforms in an interoperability share a single identification system. In this case, users do not need to change their identifiers when moving between Metaverse platforms. However, when moving from one Metaverse platform to another, digital objects such as avatars, scene, currency, etc. that were used on the previous Metaverse platform will need to be adapted to the new environment. At Level 3, a user's identifiers and associated digital objects are fully interconnected, and the user is provided with a continuous experience across Metaverse platform changes. In terms of the Metaverse interconnection levels mentioned above, Level 0 is the level of interoperability that is currently provided, and

Level 3 is the goal that should eventually be achieved through interoperability.

B. Design Principles

AIM has been developed according to the following design principles

1) *Level 1 of interoperability*: Since interoperability level 3 may be a long-term goal, AIM has a design goal of achieving level 2.

2) *External common ID system*: Because user identifiers can be easily determined by agreement between Metaverse platforms, AIM uses an externally provided user identifier system. This may include already standardized URIs/URLs or W3C DIDs [8].

3) *Infrastructure-based*: AIM provides an external entity that can be referenced by all platforms participating in the interoperability to provide efficient interoperability capabilities.

4) *Minimal additional interoperability entities*: To facilitate deployment, AIM minimizes the implementation of additional functionalities.

5) *Trust relationship between interoperability entities*: To ensure secure communication and user privacy, all entities involved in the interoperability, such as the Metaverse platforms and the interoperability server, perform pre-established secure communication with each other.

C. AIM architecture

Figure 1 shows the rough structure of the AIM proposed in this paper. As shown in the figure, AIM adds an interoperability function (IF) to each Metaverse platform, and externally shares a server (IS: Interoperability Server) that manages information that Metaverse platforms can refer to for interoperability.

With the FIs and IS provided by AIM, a user being severed by a Metaverse platform can exchange messages with users on other Metaverse platforms, or teleport to another Metaverse platform if necessary.

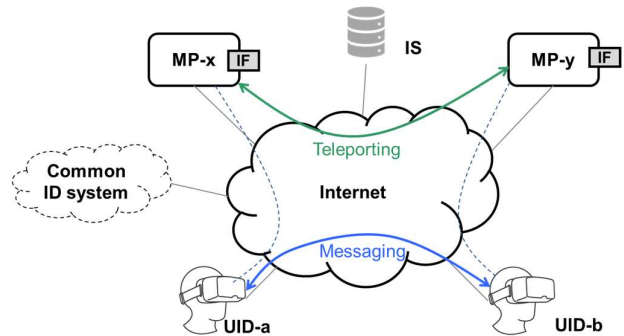


Fig. 1. Architecture of AIM

Figure 2 shows the internal organization of an IF. As shown in the figure, the IF consists of a Message Processing entity that handles messaging processing, a Teleportation Processing entity that handles teleporting-related messages, a Peer List that maintains a list of peer Metaverse platforms participating in the interoperability, a Location Cache that temporarily maintains a list of users with whom it has previously exchanged messages, and a Network entity for communication with other IFs and an IS. Note that the

communication between each block, IFs and IS, is done using a pre-agreed standard data format.

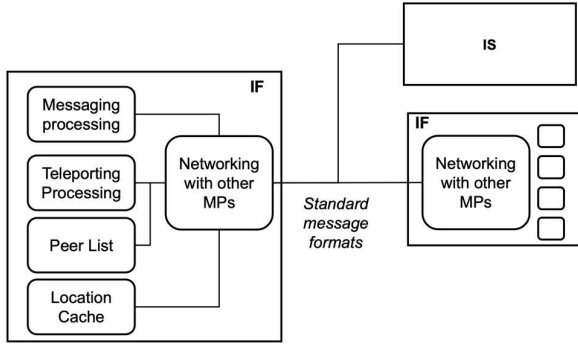


Fig. 2. Functional entities in IF

Table II shows an example of the database of a Peer List.

TABLE II. PEER LIST DADABASE

Peer Platform Name	Location
MP-1	LOC-1
MP-2	LOC-2
...	...

The Peer List basically maintains the unique names of the identifiable peer Metaverse platforms (MP-1, MP-2, etc.) and the locations of those Metaverse platforms (LOC-1, LOC-2, etc.). The location information is usually the URL information or IP address of the Metaverse platform that is actually capable of delivering of packets.

Table III shows an example of the database of an IS.

TABLE III. INTEROPERABILTY SERVER DATABASE

User ID	Serving Platform Name
UID-1	MP-1
UID-2	MP-2
...	...

This database basically holds the mapping information between users and the names of Metaverse platforms serving them. A user is identified by a unique user ID agreed upon all Metaverse platforms such as W3C DID.

IV. PROCEDURES FOR MESSAGING AND TELEPORTING

There are a number of different Metaverse platform interoperability service scenarios that can be provided on the proposed AIM architecture. This section describes the procedures for two of the most basic service scenarios. The first is a messaging service between users being served by different Metaverse platforms, and the second is a teleporting service scenario that supports the instantaneous movement of a user from the Metaverse platform currently being served services to another Metaverse platform.

A. Messaging

Figure 3 illustrates the messaging service procedure between two users who are being served by different Metaverse platforms.

In the figure, User1 connects to a specific Metaverse platform (MP-A) with his/her identifier (UID1) to receive services (1). The MP-A serving User1 now registers the user information with the IS (2). The registered user information basically includes the user's identifier and the Metaverse platform being serviced. After registering the relevant information, the IS responds with a registration confirmation message (OK) (3). The IS stores the mapping information of User1 to the platforms it serves in its database (UID1:MP-A) (4). Later, User2, who is being served by another Metaverse platform, requests a message about User1 from his Metaverse platform using the User1 identifier (UID1) (5). When the MP-B receives a message delivery request, it first searches its database to determine if it is serving User1 (6). MP-B queries the IS for information about User1 using User1's identifier if User1 is not a user it is serving (7). The IS retrieves information about User1 from its database (8). The IS finds the relevant information (UID1, MP-A) back to MP-B (9). MP-B then forwards User2's message to MP-A, which is currently being served by User1 (10). MP-B then caches the location mapping information for user1 (UID1:MP-A) for a period of time for future use (11). Upon receiving the message from MP-B, MP-A verifies that User1 is the user it is serving (12). MP-A forwards the message to user1 if user1 is a user it is serving (13). MP-A caches information about user 2 for a period of time for future use (14). User1 and User2 can then exchange messages directly using the verified mutual information (15).

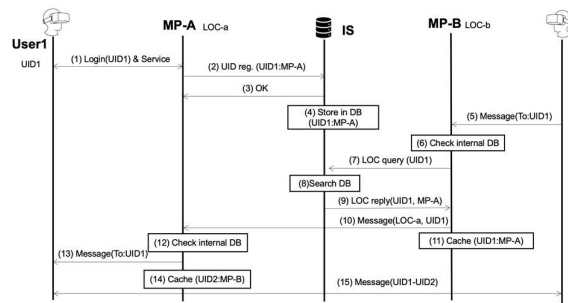


Fig. 3. Messaging procedure

B. Teleporting

Figure 4 shows the procedure for teleporting between Metaverse platform

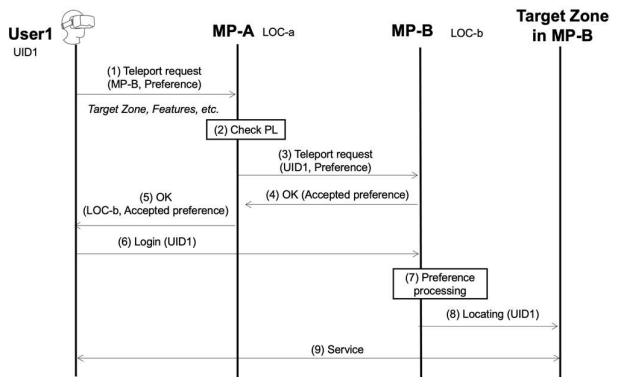


Fig. 4. Teleporting procedure

In the illustration, User1, a user of the MP-A Metaverse platform, wants to move immediately to the MP-B Metaverse

platform. To do this, User1 requests a move to MP-B from MP-A, which is serving him (1). If there is a specific zone in MP-B that the user would like to be moved to, the user can include them in the preference information to request the move. Also, as described in Chapter 3, AIM assumes level 1 interconnection, so MP-A's service environment may be different from MP-B's service environment. Therefore, User1 can also include information such as the type of avatar at MP-B in its preference when requesting teleportation. When MP-A receives a teleportation request from User1, it first searches its Peer List to see if the destination Metaverse platform is in its interoperability list and, if so, where it is located. Once the destination platform is identified in the Peer List, MP-A forwards User1's teleportation request to the destination Metaverse platform (MP-B) (3). MP-B checks User1's preference information and approves the teleportation request to MP-A, including the acceptable preference level (4). MP-A forwards the teleporting reply message received from MP-B to User1, including MP-B's location information (5). User1 uses the information received from MP-A to request a login to MP-B (6). MP-B performs processing for destination zone, avatar shape, etc. based on the authorized preferences for User1 (7). Based on the processed preference information, MP-B places the user in the target zone (8). User 1 is then served by MP-B (9).

V. CONCLUSIONS

One of the biggest technical issues in the upcoming Metaverse-based society is supporting of interoperability between different Metaverse platforms. This interoperability will enable users to experience a continuum of platform-independent services and populate a Metaverse-based ecosystem. In this paper, we proposed AIM, an architecture to support interoperability between different Metaverse platforms, and proposed procedures for messaging services

between users of different Metaverse platforms and teleporting services to other Metaverse platforms, as representative services to support based on AIM.

In order to validate the proposed structure and identify technical issues, it is necessary to build a testbed and implement it in practice. We plan to implement the proposed AIM structure and associated service procedures based on more than two open source-based Metaverse platforms. In addition, as discussed in Section I, interoperability issues are closely related to global standardization. Therefore, we also plan to contribute to the international standardization, e.g., MSF, ITU-T, IETF, of the proposed AIM structure based on the implementation results.

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