Simulation of User Arrangement in Virtual Reality for Design Metaverse Network : Focus On Statistical Distribution

Sangwon Oh
Dept. of ICT Convergence System Engineering
Chonnam National University
Gwangju, Korea
osw0788@gmail.com

Ibrahim Aliyu
Dept. of ICT Convergence System Engineering
Chonnam National University
Gwangju, Korea
ibal2010@yahoo.com

Tai-Won Um
Graduate School of Data Science
Chonnam National University
Gwangju, Korea
stwum@jnu.ac.kr

Il-Kwon Jeong
Electronics and Telecommunications Research Institute
Daejeon, Korea
jik@etri.re.kr

Cho-Rong Yu
Electronics and Telecommunications Research Institute
Daejeon, Korea
crryu@etri.re.kr

Jinsul Kim
Dept. of ICT Convergence System Engineering
Chonnam National University
Gwangju, Korea
jsworld@jnu.ac.kr

***Abstract*— Several external factors, including COVID-19, have prompted a trend towards converting existing systems and services into non-contact alternatives. Furthermore, beyond non-face-to-face services for individuals and small groups, such as phone calls and small meetings, efforts are underway to transform non-face-to-face services for large groups, such as classes and concerts. In particular, current virtual reality platforms like metaverse are insufficient to provide non-face-to-face services to large groups, guaranteeing Quality of Service (QoS) for users. Calculating the expected number of users for such services is vital to prepare and design the network infrastructure and resources accordingly. This paper proposes a technique to generate and arrange virtual users who can simulate a real-world environment to design a metaverse network that can accommodate a large number of people. Various large-scale service arrangement techniques are outlined, utilising statistical distributions. Based on the arrangement of users in the XR service, we proposed ways to choose the appropriate servers and channels during the XDN design phase, along with the use of XDN's microservices.**

Keywords—metaverse, simulation, statistical distribution, user distribution, virtual reality

I. Introduction

As the global pandemic limits outdoor activities, many face-to-face services are shifting to non-face-to-face operations, and there is growing interest in metaverse platforms that offer immersive experiences that can overcome the limitations of online environments [1]. The metaverse refers to an immersive space where people can experience life in a way they cannot in the physical world, and is delivered in the form of Extended Reality (XR), which combines the technologies of Virtual Reality (VR) and Augmented Reality (AR) [2-3]. Historically, XR technology has been used to provide immersive services on a small scale, such as small meetings and games, but more recently XR technology has been used to accommodate large groups of people. For example, the concert industry is adopting XR technology to deliver virtual and augmented reality-based immersive experiences to large audiences as they begin to utilize the Metaverse platform to host virtual concerts. They are also looking to network technologies to accommodate large crowds.

Providing an immersive experience for users of non-face-to-face services is a key challenge for Metaverse-based XR services. While traditional streaming services and game engines use content delivery networks (CDN) to deliver recorded video or motion control data to users, XR services need to deliver high-resolution data to large numbers of people, so they must use more advanced networking technologies to meet these requirements. To meet this need, Experience Delivery Network (XDN) technology has recently been developed to provide a more immersive experience than traditional CDN [4-5].

To design an XDN that will provide an immersive experience for a large number of people, there are a number of things to consider. Among them, the target of the XR service should be closely examined to estimate the expected number of users. It is very important to review the network resources and specifications in advance to provide the same immersive experience to all users. In addition, network resources should be prepared in case the number of users fluctuates depending on the type of service or is concentrated in a particular area. In order to check these issues before designing the network, it is very important to calculate the expected number of people through simulation. Especially for XR services, it is essential to simulate users by creating them virtually to ensure quality of service (QoS) for large numbers of people.

The generation of virtual users and the consideration of their distribution in the simulation phase should be based on an analysis of the type of service and the target users. It is difficult to estimate the expected arrangement and size of users in a virtual or augmented reality world. Unless there are special circumstances, the distribution of users may have a general statistical distribution. For example, if people can be clustered around certain points in the world, they may have a two-dimensional normal distribution. Therefore, this paper proposes a method based on statistical models to generate and deploy virtual users in the simulation phase for the design of an XDN providing XR services. This paper is organised as follows: Section 2 describes the network and the statistical model used in this study, Section 3 describes the actual generation examples and experiments. Section 4 concludes with the conclusions of the paper.

II. Related Works

A. XDN(eXperiences Delivery Network)

Extended reality (XR) is a hyper-realistic technology that uses mixed reality (MR) technology, which combines virtual reality (VR) and augmented reality (AR) to deliver immersive content to users. Services that support XR, such as virtual concerts, face challenges such as accommodating large amounts of user-generated content, synchronising content with real-time interactive experiences, and creating 360-degree views. To address these challenges, Experience delivery networks (XDN) are proposed to overcome the limitations of traditional content delivery networks (CDN). XDNs leverage 5G and edge computing technologies to enable immersive content experiences such as XR and metaverses. For example, XR-based services using XDN can provide users with more immersive content experiences by delivering ultra-high-definition streaming data with 360-degree views and overlay delivery of additional content data. The Media Control Function (MCF) provides functions to control authentication, session management, and clustering of virtual concert audiences and Zones, processed at the edge close to content providers and consumers. The Media Distribution Function (MDF) has adopted viewport-dependent streaming based on a tile-based structure to ensure compat-ibility and scalability with the standardized format, which supports 360 media. Using this format and streaming, it handles the distribution of specific media. The Media Ingestion Function (MIF) deals with the ingestion of various types of media depending on the environment of the users. Figure 1 shows how the previous microservices tasks [6-8].

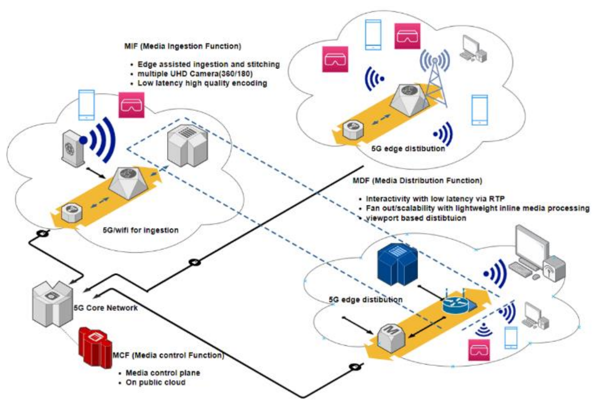

Fig. 1. XDN(Expericene Deliverye Network) configuration.

B. Maintaining the Integrity of the Specifications

When constructing an XR world, distributing network resources based on location, or performing additional design tasks, it is common to need to estimate where users congregate. This is usually done by generating random numbers and assigning them to locations and setting up dummy users, but as the number of users grows and becomes statistically significant, you should consider following a distribution. The location of users does not follow a specific distribution if there are no external factors or objectives and they are randomly respawned when they connect. However, if there are factors that force them to cluster or preclude them from moving to a specific area, they will inevitably move to the place where they are respawned, and as this scale grows, the distribution will become point-like.

III. Scenario and Used Probability Distributions

To generate the locations of the dummy users, we used two scenarios. The first is user arrangement in the form of clustering at a specific point. In an XR service with events and services that occur at a specific point, such as a performance or class, users will travel to that point to experience the service. The second type of user arrangement is moving away from a particular point. If an XR service applies a prohibited area or a disadvantage for being in such an area, we can see the arrangement of users collectively moving away from a particular point. In this experiment, we applied both scenarios by setting the central location of the world to a specific point. The two figures below show the appropriate probability distribution-based arrangement methods chosen to implement user arrangement for each scenario.

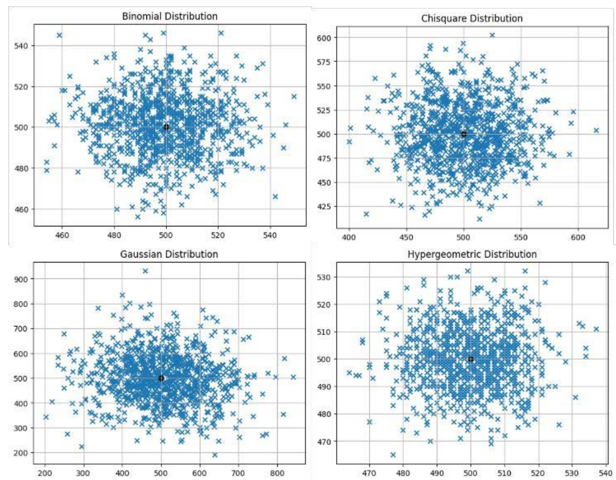

Fig. 2. Examples of User Arragement for Scenario 1

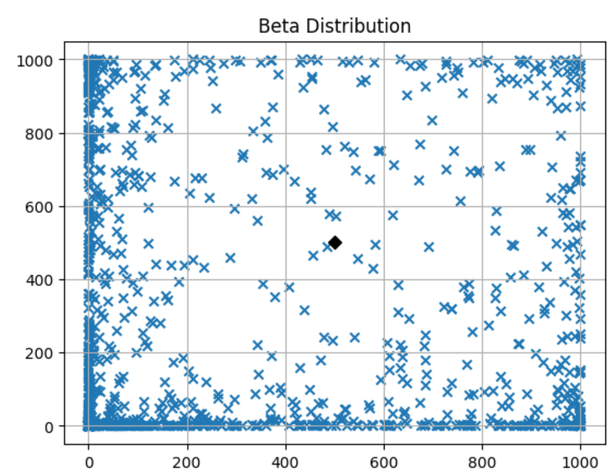

Fig. 3. Examples of User Arragement for Scenario 2

We developed a 1000 * 1000 map and randomly placed 1000 users on it, in order to create the world. Figure 2 presents the user positioning for the first scenario, whereas Figure 3 illustrates the user placement for the second scenario. The blue x's represent the dummy users, and the black diamonds depict specific points. In scenario 1, we used four probability distributions, including the normal(gaussian) distribution. In scenario 2, we employed the beta distribution.

IV. Application of User Arrangment for XDN

Analysing the User Arrangements outlined in Chapter 3 allows us to calculate the capacity of the XR service in terms of the number of users and network resources it can manage. This fact shapes the development of the XDN framework. This section proposes the utilisation of microservices in XDN to distribute network resources based on the anticipated user arrangement. Figure 4 illustrates the functions of the control plane and data transmission processes. Nevertheless, end-to-end diagrams, such as those depicting clients and main servers, are not included in it.

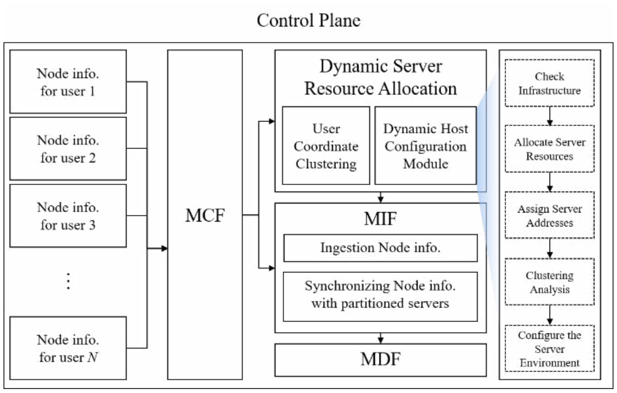

Fig. 4. Proposed Application of Method for Using User Arrangement in XDN.

After the Control Plane receives access environment and location information for the users (nodes), the MCF collects and manages a bulk of the nodes' data. The MCF defines and stores data pertaining to the nodes and media protocols required for delivering an immersive experience. If the user's location information is not clustered within the virtual reality, the node information is sent to Dynamic Server Resource Allocation, or directly to MIF if the dynamic server is ready. To distribute server resources dynamically, virtualized servers are generated in the Dynamic Host Configuration Module, which clusters users based on their location information, and distributes server resources dynamically. First, the infrastructure of the network is checked, server resources and addresses are allocated, and then an environment is constructed through virtualization of an appropriate number of servers, based on the clustering results. Matching and synchronizing the nodes and partitioned dynamic servers occur in MIF, and they are then transferred to MDF to provide an immersive experience by serving media and other relevant data.

In addition to this method, statistical user arrangements can be utilized to design networks that can secure QoS for large numbers of users when operating location data-sensitive XR services. For example, the methods proposed in this study can be used to provide services that connect more than 100 people to a world, such as virtual performances or virtual classes.

V. Conclusions

This study proposes a method for generating user arrangements based on statistical distributions, allowing the reproduction of user arrangements to test the acceptability of considerable number of people when simulating the intended service's purpose. Due to the growing significance of designing networks capable of accommodating massive crowds for XR services, it becomes vital to simulate the ability to offer high-resolution, high-dimensional data to a large number of users to provide an immersive experience. We calculated target scenarios for user arrangements in XR services that generally access virtual reality. For each scenario, we explored and implemented suitable statistical distributions.

Additionally, to practically apply the simulation results based on user arrangement to XDN framework, we proposed a method to compute XR services that are location-sensitive and utilize the outcomes of User Arrangement through microservices provided by XDN. Furthermore, we anticipate that virtual reality services that exploit user location information can utilize the user arrangement technique proposed in this study, in addition to the proposed method.

As future research, we will explore XR services in actual operation to obtain more scenarios. We will also define a metric to evaluate users' arrangement techniques in the simulation phase and develop a model to adopt the optimal arrangement method among several cases. Additionally, we aim to analyze the causal relationship between the results of the probability distribution and the maximum capacity of XDN. We plan to generalize the findings by formulating a formula.

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