User-Aware Resource Allocation Algorithm for Virtual Reality in Metaverse

Jaechan Lee, Yumi Kim, and Haneul Ko
Department of Electronics and Information Convergence Engineering
Kyung Hee University
Yongin, Korea
{jaechan,yumikim1201,heko}@khu.ac.kr

***Abstract*—Even though introducing the edge computing to support metaverse services, sophisticated resource allocation algorithm is needed due to varied required computation resources and operating environments. In this paper, we introduce a user-aware resource allocation algorithm (UARA) for the metaverse and examine a resource allocation strategy for edge cloud computing. The objective of the resource allocation strategy is to maximize the aggregated quality of experiences (QoEs) for users while ensuring that each user's QoE remains above a certain threshold. Evaluation results show that the proposed resource allocation policy enhances users' QoE.**

***Index Terms*—Metaverse, virtual reality (VR), quality of experience (QoE)**

I. Introduction

The metaverse has attracted significant interest from both academic circles and the industry [1]. It is typically described as a collection of virtual worlds where individuals can engage in work, play, and social interactions via their avatars.

To realize a future metaverse where millions of users' virtual avatars inhabit interconnected virtual worlds that closely link to the physical world, numerous challenging issues still need to be addressed. For instance, the metaverse demands substantial computational resources to seamlessly render 3D virtual worlds. Given the limited computational capacity of extended reality (XR) headsets, these resource-intensive rendering tasks cannot be performed exclusively on the devices themselves. The remote rendering via powerful cloud servers can address the issue of insufficient computational resources. However, cloud-based remote rendering cannot satisfy the ultra-low latency requirements of metaverse services due to the significant distance between the cloud servers and the users.

The edge computing, which situates powerful servers near users, is a promising solution for meeting the metaverse's stringent demands [2]. Even though introducing the edge computing to support metaverse services, there are lots of challenges due to the following reasons. First, the required computation resources can be varied according to users, especially their filed of views (FoVs). In addition, the operating environments (e.g., channel condition) are fluctuating.

In this paper, we propose a user-aware resource allocation system (UARA) for metaverse and investigate a resource allocation policy of the edge cloud. The objective of the resource allocation strategy is to maximize the aggregated quality of experiences (QoEs) for users while ensuring that each user's QoE remains above a certain threshold. Evaluation results demonstrate that the derived resource allocation policy can improve QoE of users. Moreover, it can be found that the proposed algorithm can adaptively adjust the policy according to the environment.

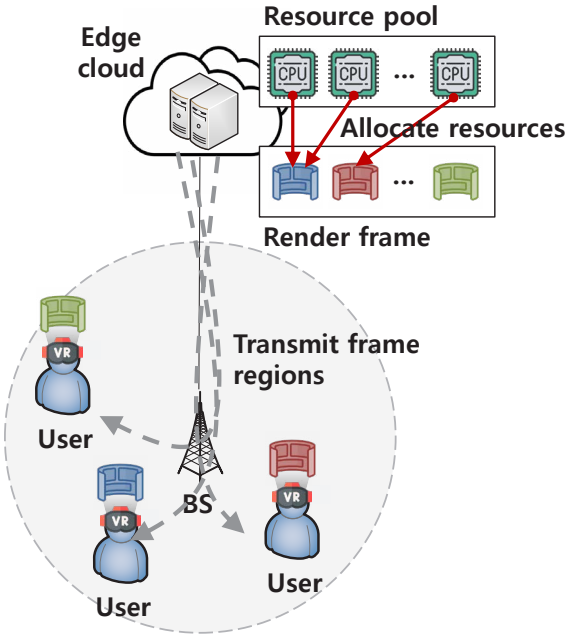


Fig. 1. System model.

The rest of the paper is organized as follows. UARA is described in Section II. The evaluation results are demonstrated in Section III. Finally, the concluding remark is given in Section IV.

II. User-Aware Resource Allocation System

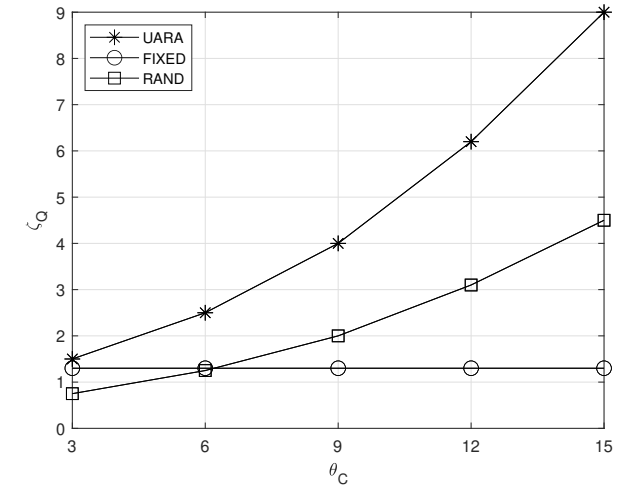
Figure 1 shows the system model in this paper. To save the computational resources, we consider FoV rendering. That is, the edge cloud does not conduct the rendering for full-view of spatial sphere. Instead of that, the edge cloud conducts the rendering only for the frame region of FoV. Then, the edge cloud transmits the frame region of FoV to users (i.e., XR headsets). The rendering and transmission should be

completed within a specific duration τ to provide a smooth experience to users. However, the rendering and transmission times can be varied according to FoVs and channel gains of users, respectively. This indicates that the rendering and transmission cannot be completed within τ if the constant resources are allocated to users without consideration of FoVs and channel gains of users. To mitigate this problem, the edge cloud collects the FoVs and channel gains of users and allocates appropriate amount of resources to render the frame. For the optimal resource allocation, a reinforcement learning approach can be exploited [3], but it is omitted in this paper due to the page limitation.

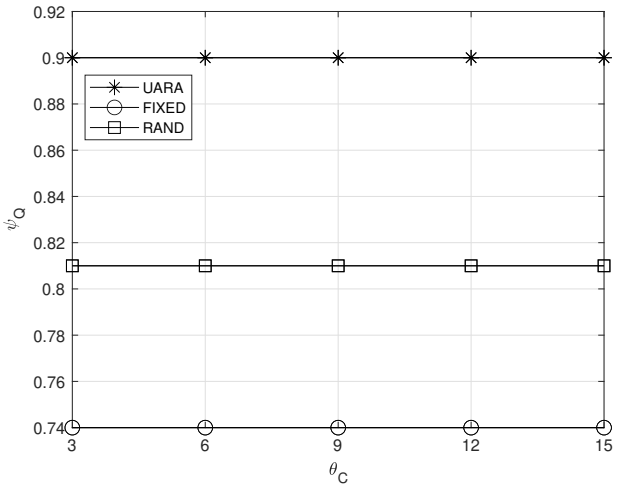
III. Evaluation results

For performance evaluation, we compare UARA with the following two schemes: 1) FIXED where the edge cloud allocates the same amount of resources to users; and 2) RAND where the edge cloud allocates the random amount of resources to users.

Figures 2(a) and (b) show the effect of the upper resource limit for metaverse service θ_C on the aggregated QoE and a specific user's QoE, respectively. From Figures 2(a) and (b), it can be found that UARA can maximize the aggregated QoE while maintaining QoE of a specific user above its target. This is because UARA allocates appropriate amount of resources to users by considering the FoVs and the current channel status of users. For example, if a certain user has poor channel quality, UARA allocates lots of computing resources to that user. Meanwhile, since the other schemes follow the fixed policy without the consideration of the operating environments (i.e., resource limitation), their performances are constant regardless of θ_C.



(a)



(b)

Fig. 2. Effect of the upper resource limit for metaverse service. (a) Aggregated QoE (b) QoE of the first user.

IV. Conclusion

In this paper, we propose a user-aware resource allocation algorithm (UARA) for the metaverse and explore a strategy for resource allocation in edge cloud computing. We define the resource allocation problem as a constrained Markov decision process (CMDP) with the goal of maximizing the overall quality of experiences (QoEs) for users while ensuring that each user's QoE exceeds a specified threshold. To solve the CMDP, we convert it into a linear programming (LP) problem and solve the converted problem by utilizing a standard LP solver. Evaluation results demonstrate that the proposed resource allocation policy improves users' QoE. In our future work, we will extend our system to consider users' attentions.

Acknowledgement

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