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Traffic Reduction Techniques in a Hybrid MMOG Architecture based on Multicast Communication

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Abstract

This paper analyzes the effect of multicast communication on reducing data traffic in a hybrid MMOG(Massively Multiplayer Online Game) architecture that combines the technical advantages of both client-server and P2P(peer-to-peer) models. In this hybrid architecture, the entire game is divided into multiple regions of equal size, and the server designates a specific player in each region as the region server. Even when the number of concurrently active players increases rapidly, the system aims to prevent bottlenecks on the central server by appropriately utilizing both the server's bandwidth and the bandwidth of the players participating in the P2P network, thereby enabling a cost-effective and scalable MMOG with consistent service quality. In this paper, multicast communication is applied in two cases: when the central server transmits the game state to multiple region servers, and when a specific region server retransmits this game state to players within its region. The paper compares and analyzes the bandwidth usage of multicast communication and unicast communication in these scenarios through simulation. In this hybrid MMOG architecture, the intention is to minimize the use of the central server's bandwidth and processing power by leveraging more of the players' bandwidth and processing capabilities.

Keywords: *Traffic, Multicast, Hybrid architecture, MMOG, Bandwidth*

1. Introduction

Games are among the most popular applications on the Internet, accounting for an estimated 8–10% of total network traffic[1]. In particular, MMOGs(Massively Multiplayer Online Games) refer to a genre of online role-playing video games where players can freely create or configure characters in a simulated environment [2]. Since service providers offering games like MMOGs must pay for data transmission, bandwidth requirements are a major concern[3]. In the client-server architecture where a central server manages the game, all players send their updated states to the server, which then generates a new game state and transmits it back to the relevant players. Consequently, in the worst-case scenario, the required upstream and downstream bandwidth at the server increases proportionally to the square of the number of players[4].

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To address this issue, P2P (peer-to-peer) game architectures have been proposed, wherein players distribute the game state processing. Although this increases the overall bandwidth usage, it alleviates the bottleneck on the central server[5]. However, the P2P model has drawbacks: players must manage consistency of game state and event ordering themselves, and it is more vulnerable to cheating. On the other hand, the client-server architecture, despite its bandwidth bottleneck, provides better consistency and security against cheating. This paper proposes a hybrid MMOG architecture that combines the strengths of both the client-server and P2P models.

MMOGs are resource-intensive applications and, unlike conventional software such as web applications that have long been hosted in the cloud[6], they have distinct and unique requirements. This paper assumes that the servers for MMOGs—applications with unique characteristics such as large-scale users and massive system states—are deployed in cloud environments like IaaS (Infrastructure as a Service) or PaaS (Platform as a Service). Therefore, in the proposed hybrid MMOG architecture that integrates the central server function of the cloud and P2P functionalities, the goal is to efficiently utilize the bandwidth of both the players and the server to ensure smooth operation and quality of service.

In the proposed hybrid MMOG architecture, the entire game world is divided into multiple regions of equal size[7], with a designated player in each region serving as a regional server that transmits game state updates to other players in the region. This paper particularly analyzes the significance and roles of minor state changes, such as position changes that do not significantly affect MMORPG(Massively Multiplayer Online Role Playing Game) state, and major state-changing actions that do. It also outlines multicast communication methods[8] between regional servers and players, as well as between the central server and regional servers. Multicast is a standard proposed by the IETF (Internet Engineering Task Force) and has been experimentally implemented on actual MBone networks[9]. When multicast groups are structured in a tree topology, multicast offers an efficient method for group communication[10]. In fact, some ISPs(Internet Service Providers) provide multicast communication techniques on the Internet. The proposed hybrid structure assumes that IP multicast communication[11] is applied between the central server and regional servers, and between regional servers and players. This paper does not consider ALM(Application Layer Multicast) communication, which may experience latency due to indirect IP routing paths.

When the number of players participating in the MMOG increases rapidly, this paper compares and analyzes the transmission volume results using multicast communication versus those using unicast communication, to ensure that communication bandwidth is appropriately distributed between regional servers, players, and the central server.

Chapter 2 describes the hybrid MMOG architecture. Chapter 3 details the multicast communication methods between the central server and regional servers, and between regional servers and players. Chapter 4 presents a comparative analysis of the communication bandwidth required by regional servers and the central server when using multicast versus unicast communication. Finally, Chapter 5 concludes the paper.

2. Hybrid MMOG architecture

This paper proposes a hybrid MMOG architecture that combines the advantages of both client-server and P2P game models. In particular, the hybrid architecture is designed for MMORPGs, where position-changing actions and state-changing actions are clearly distinguished. In typical RPGs, most actions involve a player moving within the game world without affecting the overall game state—these are referred to as position-changing actions[12]. In contrast, actions such as a player attacking another player or character, acquiring an item, or crossing an important boundary all constitute state-changing actions that alter the game state.

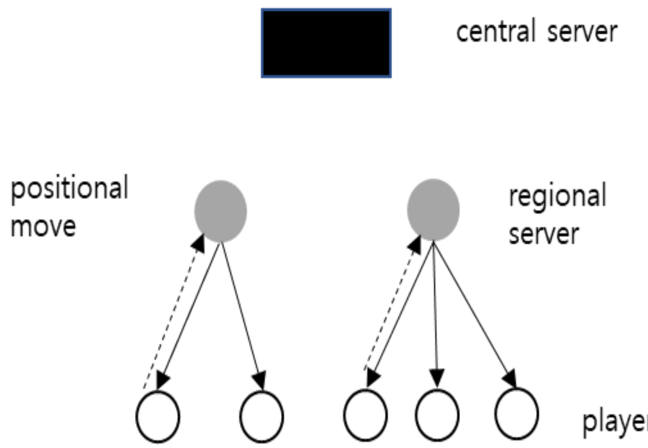

Figure 1. Positional move

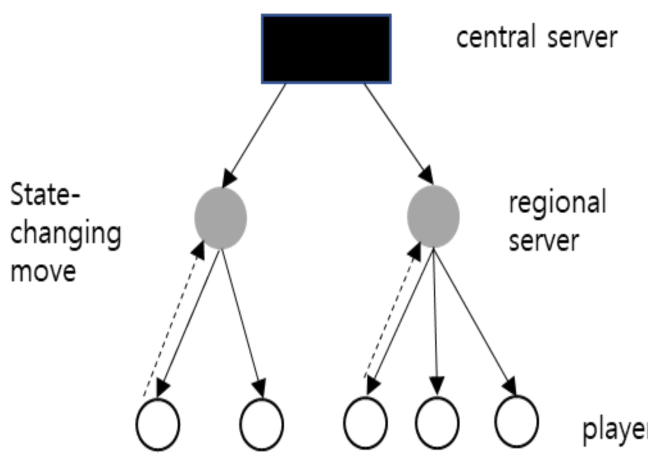

Figure 2. State-changing move

In the proposed hybrid architecture, the central server designates certain players as regional servers responsible for managing position-changing actions within specific regions of the game world(see Figure 1). Whenever a player performs a position-changing action(represented by the dashed arrows in Figure 1), the action is sent to the corresponding regional server, which then forwards the action to other players within the same region (represented by the solid arrows in Figure 1). The central server maintains centralized control to ensure game consistency and prevent cheating, and is solely responsible for managing state-changing actions (see Figure 2). Whenever a player requests a state-changing action, the request is sent directly to the central server(represented by the dotted arrows in Figure 2). If the central server approves the state change, it sends the updated game state to the corresponding regional server, which then delivers the update to the players within that region(represented by the solid arrows in Figure 2). This division of roles between the central server and regional servers significantly reduces the communication load on the central server and enables the system to scale as the number of players increases. In other words, the hybrid game architecture ensures scalability by distributing game update results to players.

To effectively utilize players as regional servers, the central server needs to use active measurement tools capable of determining the bandwidth capacity and latency of potential regional servers. This is critical because a regional server must have sufficient bandwidth to deliver updated game states to the players in its region. Furthermore, low latency from the regional server is important since updated states are transmitted to players via the regional server. However, identifying a regional server with low latency to all players in a region is challenging, as the group of players within a region changes over time and each player's latency must be measured individually. Since updated game states are delivered via the central server, selecting regional servers located near the central server can be a simple yet effective way to reduce overall latency.

One of the major issues with P2P game architectures is their vulnerability to cheating. Since players themselves store and manage the game state, it is difficult to prevent intentional game-breaking behavior by malicious players. However, in the hybrid game architecture proposed in this paper, the central server—hosted on a resource-demanding cloud platform—provides security by controlling access to the game state. In most games, the ultimate goal is to acquire or control state elements such as treasures, computing resources, or other players' lives; therefore, the central server must be equipped with significant processing capabilities.

When players need to interact with the game state, the central server acts as an arbitrator by ordering state-changing events and update actions. Additionally, the central server performs monitoring functions, such as player registration and behavior tracking, and can remove players from the game upon detecting actual cheating behavior. This paper proposes a hybrid architecture that integrates on-demand cloud computing techniques with user-provided peer-to-peer (P2P) approaches for MMOGs.

3. Multicast communication for MMOG

Multicast is a standard proposed by the IETF and has been experimentally operated on the MBone (Multicast Backbone) network[11]. It is important to note that, from the early stages, multicast was recognized as a network service that would be widely used in various applications[8]. As illustrated in Figures 1 and 2, the regional server transmits the results of both position changes and state changes to the players within its region. In the virtual world depicted on the game screen, it may appear as though the regional server and the players are directly connected. However, in the real world where the communication network is composed of actual infrastructure, the regional server and players may be connected through multiple routers. As a result, differences in the structure between the virtual world and the real-world network can lead to variations in transmission time and the required communication load.

Within a specific region, the regional server and players can form a tree structure, where the regional server acts as the root node of the tree, and players—connected through network routers—serve as leaf nodes with no children. Figure 3 presents an example of a tree structure in which a regional server and players are connected via network routers. In the diagram, rectangles represent routers, and each player is depicted as a circle. The 12 players shown in Figure 3 are divided into three groups:

Group G_1 consists of players 1, 2, 3, and 4,
Group G_2 consists of players 5, 6, 7, and 8,
Group G_3 consists of players 9, 10, 11, and 12.

The regional server can communicate with each of these groups using either unicast or multicast communication methods[13]. When using unicast, the average path length between the regional server and the players—i.e., the expected value—is denoted by Lu. In practice, Lu is calculated by summing the lengths between the region server and each player within the group in a tree structure, and then dividing that total by the number of players. In Figure 3, the path lengths between the regional server and each player in G1 are all 1, so the total is 4(=1+1+1+1), and thus Lu=4/4=1. In contrast, when using multicast, the network paths among routers are shared, which reduces redundancy. Thus, the total path cost between the regional server and the players in G_1 is denoted by L_m, which equals 1 in this case. Unlike unicast, multicast enables shared routing paths among the routers when delivering data to multiple players. For a general multicast group consisting of K members, the normalized multicast tree cost L_m can be expressed using Equation (1)[8].

$$L_m=L_u \cdot K^n \tag{1}$$

In Equation (1), n is a value between 0 and 1, representing the degree of economies of scale achieved through shared links in multicast transmission. When the regional server communicates with group G_1 using multicast, the routes among routers are fully shared, so n is 0. Thus, for G_1:

$L_m=L_u \cdot 4^0=1 \cdot 1=1$

This means that for G_1, both L_m and L_u are equal to 1. As a result, if the regional server communicates with the K(=4) players in G_1 using unicast and transmits α bytes of data to each player, the total transmission volume required is 4α(=K·L_u·α=4·1·α). However, if multicast is used, only α(=L_m·α =1·α) is needed, showing a significant reduction in transmission volume.

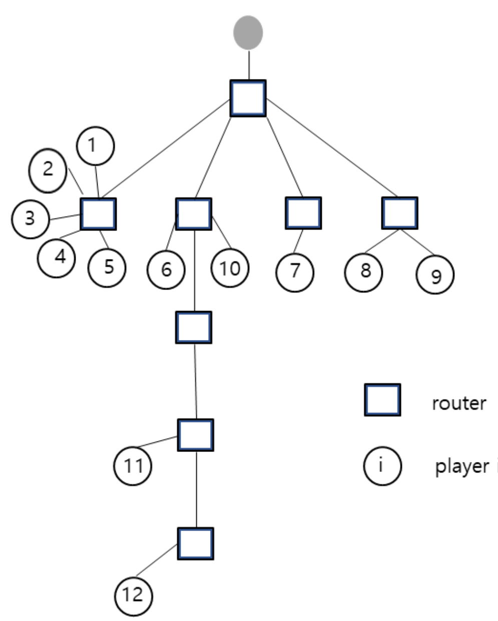

Figure 3. Multicast communication between a regional server and players

When the regional server communicates with the players in G_2 using unicast, each player(players 5, 6, 7, 8) is connected to a different router. The sum of the path lengths with four players is 4, and the average path length L_u divided by K(=4) is 1(=4/4). Since there are no shared paths among routers for multicast, the total multicast tree cost L_m is also 4. In such a case, where no routing paths are shared, n becomes 1, so:

$L_m=L_u \cdot 4^1=1 \cdot 4=4$.

This implies that for group G_2, both unicast and multicast require the same total transmission volume of 4α.

When the regional server communicates with G_3 using unicast, the path lengths to players 9, 10, 11, and 12 are 1, 1, 3, and 4, respectively. The total path length is 9, and the average path length is: L_u is 2.25(=9/4). If multicast is used, the shared path lengths to players 9, 10, 11, and 12 are 1, 1, 2, and 1, respectively, so the total multicast cost L_m is 5. Hence, when using the unicast method, the regional server needs a transmission volume of $9\alpha(=K \cdot L_u \cdot \alpha=4 \cdot 2.25 \cdot \alpha)$ for the players in G_3, whereas with the multicast method, it only requires $5\alpha(=L_m \cdot \alpha=5 \cdot \alpha)$.

In the multicast method, routers can share paths, so the value of n in Equation 1 for G_3 is determined as follows.

$$5=2.25 \cdot 4^n$$

$$4^n=\frac{5}{2.25}$$

$$n=\frac{\log\frac{5}{2.25}}{\log 4} \fallingdotseq 0.575$$

When the value of n is close to 0, it indicates a high degree of link sharing within the network, which significantly reduces communication cost that is proportional to the amount of data transmitted. Conversely, when n approaches 1, little to no link sharing occurs, leading to higher communication costs. Although the specific structure of communication networks like ARPANET and MBone can introduce some variation, empirical studies suggest that the value of n is typically limited to around 0.8[8].

When multiple players are connected to the same router, the number of distinct routers, $K_R(\leq K)$ becomes more relevant than the total number of players K. Equation (2) is a modified version of Equation (1), replacing K with K_R :

$$L_m=L_u \cdot K_R^n \quad (2)$$

The ratio K_R^n — representing the ratio L_m/L_u — increases exponentially with respect to n. In this paper, we assume that each player is connected to a different router. Therefore, K and K_R are considered to be equal.

4. Performance Analysis

4.1 Experimental Environment and Variables

This paper assumes a model in which a virtual MMOG is implemented using the proposed hybrid architecture[14]. For example, when a player in the game walks through a hallway, the continuous position-changing actions are transmitted to the regional server of the player's designated region. On the other hand, when a player picks up a coin from the ground, a state-changing action is triggered and sent directly to the central server. The central server first sends the updated game screen (where the coin no longer exists) to the corresponding regional server, and the regional server then transmits the update to the players within its region [15].

In this paper, the data size for a position-changing action is assumed to be 20 bytes, and the data size for a state-changing action related to an object is assumed to be 320 bytes[4]. It is also assumed that each player performs 5 position changes per second on average and 6 state changes per minute, or 0.1 state change per second. Let K represent the number of players in a region excluding the regional server. For a non-regional-server player, the transmission volume per second for position changes sent to the regional server is:

$T_{pp}=100(=20\times5)$ bytes/sec.

The transmission volume for state changes sent directly to the central server is:
T_{ps} =32(=320×0.1) bytes/sec

A player serving as the regional server must transmit the results of the position changes sent by the K players to all K players again, and also transmit the results of state changes processed by the central server to the same K players. The average transmission volume handled by the regional server is:

$$\begin{aligned} T_{rs} &= K\cdot (T_{pp}\cdot K+T_{ps}\cdot K) \\ &= K\cdot (132\cdot K) \\ &= 132\cdot K^2 \end{aligned} \tag{3}$$

T_{rs} is the result of the area server transmitting to K players within the area using the unicast method. When the area server transmits to K players using the multicast method, the required bandwidth T_{rs_m} is given by Equation (4), which incorporates the variable n($0\leq n\leq 1$) from Equation (1). Equation (3) corresponds to the case where the value of n in Equation (4) is equal to 1.

$$\begin{aligned} T_{rs\_m} &= K^n\cdot (T_{pp}\cdot K+T_{ps}\cdot K) \\ &= 132\cdot K^n\cdot K \\ &= 132\cdot K^{n+1} \end{aligned} \tag{4}$$

In this paper, it is assumed that the game world of the MMOG is composed of a total of R (=1000) regions, and each region consists of K+1 players, equally. When the central server receives and processes state change actions requested by the K+1 players, including the region server, in an arbitrary region, the amount of data that needs to be transmitted back to the R region servers is given by Equation (5) for T_{cs}.

$$\begin{aligned} T_{cs} &= R\cdot R\cdot (K+1) \cdot T_{ps} \\ &= 32\cdot (K+1) \cdot R^2 \\ &= 32\cdot (K+1) \cdot 1000^2 \end{aligned} \tag{5}$$

T_{cs} is the result of the central server transmitting to R regional servers using the unicast method. When the central server transmits to R regional servers using the multicast method, the required transmission amount T_{cs_m} becomes Equation (6), which incorporates the value of n from Equation (1). Equation (5) is equivalent to Equation (6) when the value of n is 1.

$$\begin{aligned} T_{cs\_m} &= R^n\cdot R\cdot (K+1) \cdot T_{ps} \\ &= 32\cdot (K+1) \cdot R^{n+1} \\ &= 32\cdot (K+1) \cdot 1000^{n+1} \end{aligned} \tag{6}$$

4.2 Communication Traffic Analysis

In this study, it is assumed that the number of players within a region, including the regional server, increases proportionally, with measurements taken at values of 50, 100, 150, and 200. The transmission amount T_{rs}, when the regional server transmits to players using the unicast method, and the transmission amount T_{rs_m}, when using the multicast method (with n in Equation (1) set to 0.8 and 0.6), are compared in Figure 4 in units of KB/s.

When the regional server transmits using the unicast method, the transmission amount T_{rs} is proportional to the number of players, K^2. However, when using the multicast method, the transmission amount T_{rs_m} is proportional to $K \cdot K^n$ $(= K^{n+1})$, resulting in a significant reduction. A smaller value of n indicates that more network links are shared, so when n is 0.6, the required transmission is much lower than when n is 0.8. Additionally, as the number of players K+1 increases, the difference in transmission amounts between the unicast and multicast methods becomes more pronounced. When K+1 is 200, T_{rs_m} with n = 0.8 is approximately 34.7% of the unicast transmission amount T_{rs}, while T_{rs_m} with n = 0.6 is approximately 12% of T_{rs}.

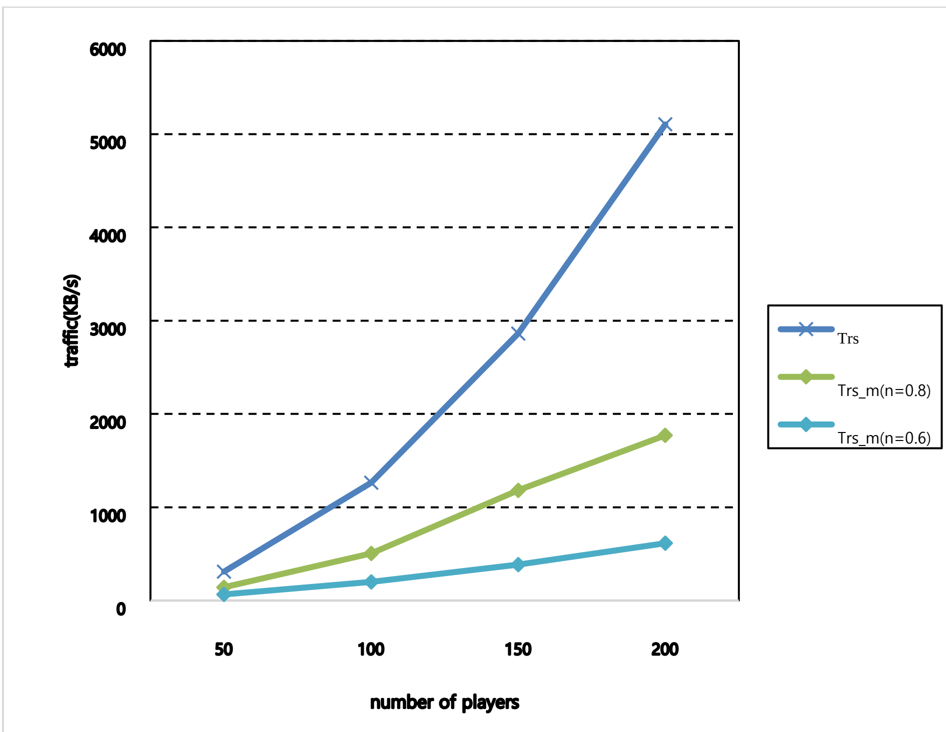

Figure 4. T_{rs} and T_{rs_m}, traffic of a region server for K+1, number of players

Figure 5 shows a comparison of the transmission amounts Tcs (unicast) and Tcs_m (multicast) in MB/s when the number of players K+1 increases, with the central server transmitting to R (=1000) regional servers. The central server receives 32 bytes of state update action data from each of the K+1 players in each of the 1000 identically configured regions. When using the unicast method, the central server must transmit 32 · (K+1) · 1000 bytes to all 1000 regional servers. However, when using the multicast method, if n is 0.8, then 10000.8 is approximately 251, resulting in Tcs_m being about 25.1% of Tcs. When n is 0.6, 10000.6 is approximately 63, so Tcs_m is reduced to about 6.31% of Tcs.

In other words, when the central server uses the multicast method to send state update action data to regional servers, the transmission amount is significantly reduced compared to the unicast method, leading to lower communication costs proportional to the data volume.

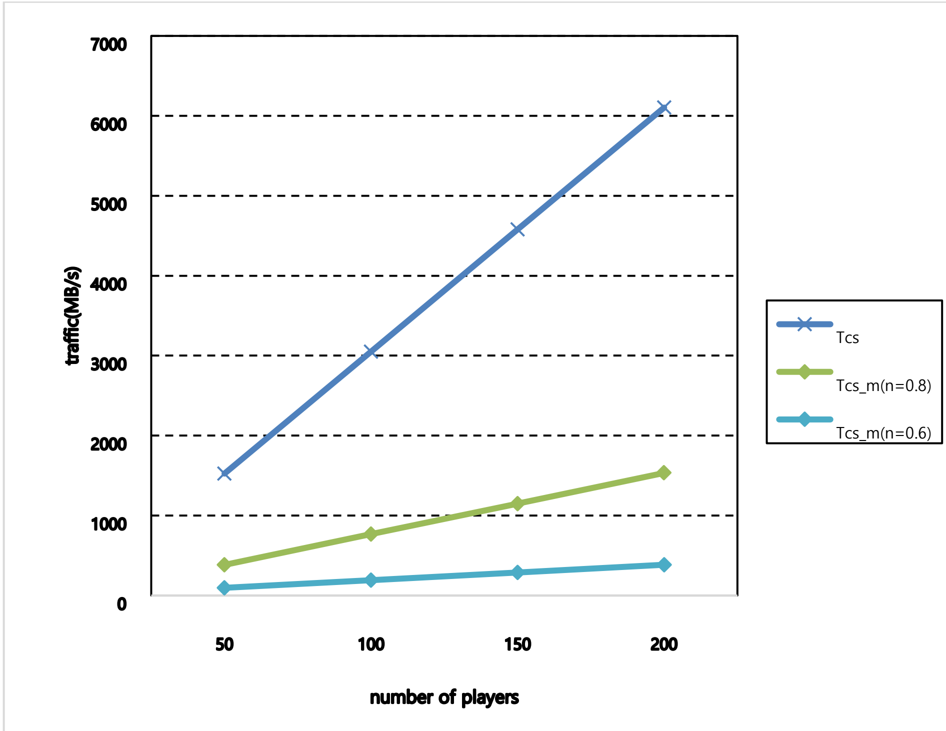

Figure 5. T_{cs} and T_{cs_m}, traffic of a central server for K+1, number of players

5. Conclusion

This paper proposed a hybrid MMOG architecture that integrates a centralized server in a cloud computing environment with a P2P approach, in order to enhance game security and maintain the accuracy of the game state. In this MMOG structure, which is composed of multiple regions, all state-changing actions performed by players are transmitted directly to the central server, while position-changing actions are sent to the regional servers. Each regional server, designated per region, is responsible for periodically broadcasting both the position-changing actions and the results of state changes to the other players in its region. When regional servers use the multicast communication method—which allows greater link sharing in the network—instead of unicast, the required transmission volume is significantly reduced, leading to lower communication costs proportional to the data volume.

Likewise, the central server can also reduce its transmission volume by sending state change updates to multiple regional servers using multicast instead of unicast. The more routing paths are shared among the routers that form the network, the greater the reduction in transmission volume achieved by the multicast approach in MMOGs. In conclusion, applying multicast communication to future hybrid MMOG deployments is expected to reduce communication costs and improve overall performance.

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References

[1] D. Moon, "Network Traffic Characteristics and Analysis in Recent Mobile Games," *Applied Computing and Machine Intelligence, Vol. 14, No. 4,* 2024, DOI:https://doi.org/10.3390/app14041397.

[2] Y. Sun and J. Y. Leu, "Deploying a massively multiplayer online game with a low-latency server infrastructure," *Information Technology Management, Vol. 12*, pp. 35-47, 2011, https: //doi.org/DOI:10.1007/s10799-011-0084-7.

[3] A. Gupta and S. Kar, "Analysis of Packet Aggregation on Cloud Games," *IEEE 17th India Council International Conference*, pp. 1-31, 2020. https://doi.org/10.1109/INDICON49873.2020.9342583.

[4] J. Jardine and D. Zappala, "A Hybrid Architecture for Massively Multiplayer Online Games," *ACM SIGCOMM Workshop on Network and System Support for Games*, pp. 60-65, 2008. https://doi.org/10.1145/1517494.1517.

[5] B. Knutsson, H. Lu, W. Xu, and B. Hopkins, "Peer-to-Peer Support for Massively Multiplayer Games," *23rd Annual Joint Conference of the IEEE Computer and Communications Societies*, 2004. https://doi.org/ 10.1109/INFCOM.2004.1354485.

[6] N. Kasenides and N. Paspallis, "A Systematic Mapping Study of MMOG Backend Architectures," *Information, Vol. 10, No. 9*, pp. 1-31, 2019. https://doi.org/10.3390/info10090264.

[7] H. Kavalionak, E. Carlini, L. Ricci, A. Montresor and M. Coppola, "Integrating Peer-to-Peer and Cloud Computing for Massively Multiuser Online Games," *Peer-to-Peer Networking and Applications, Vol 8, No. 2*, 2013, https://doi.org/10.1007/s12083-013-0232-4..

[8] J. Chuang and M. Sirbu, "Pricing Multicast Communication: A Cost-Based Approach," *Telecommnication Systems, Vol. 17*, pp. 281-297, 2001.

[9] H. Eriksson, "Mbone: the Multicast Backbone," *Communication of the ACM, Vol. 37*, pp. 54-60, 1994, https://doi.org/10.1145/179606.179627.

[10] C. Griwodz, K. Vik and P. Halvorsen, "Multicast Tree Reconfiguration in Distributed Interactive Applications," *3rd IEEE Consumer Communications and Networking Conference*, 2006. https://doi.org/10.1109/CCNC.2006.1593232

[11] S. Deering, "Host Extensions for IP Multicasting ," RFC 1112, 1989.

[12] B. Knutsson, H. Lu, W. Xu, and B. Hopkins. "Peer-to-Peer Support for Massively Multiplayer Games," *in Proc. 23rd Annual Joint Conference of the IEEE Computer and Communications Societies*, 2004. DOI:https: //doi.org/10.1109/INFCOM.2004.1354485.

[13] C. Shin, "Simultaneous Transmission of Multiple Unicast and Multicast Streams Using Non-orthogonal Multiple Access," *The Journal of Korea Academia-Industrial cooperation Society, Vol. 22, No. 2*, pp. 11-19, 2021. https://doi.org/10.5762/KAIS.2021.22.2.11.

[14] J. Kim, "A Scalable Hybrid P2P MMOG Cloud Architecture for Load Management in a Region", *International Journal of Internet, Broadcasting and Communication, Vol. 22, No. 3*, pp.83-91, 2022. https://doi.org/10.7236/JIIBC.2022.22.3.

[15] R. Joshi1, D. Patel, and S. Naik, "Implementation of Peer-To-Peer Architecture in MMORPGs", *International Journal of Science and Research, Vol. 5, No. 10*, pp.1541-1546, 2016.