Effects of Adaptive Time Delay on Quality of Experience in First Person Shooter Games

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ABSTRACT

Latency impacts individual responsiveness and player-versus-player fairness in first-person shooter (FPS) games, degrading the quality of experience (QoE). Time delay applies a fixed latency to players with lower latency to make the game fair, but has the drawback of adding latency regardless of whether players are interacting or not. Adaptive time delay dynamically adds latency only when players interact, improving average responsiveness while preserving fairness. This study assesses QoE for adaptive time delay with latency with a focus on the potential benefits of dynamically adding latency compared to always having a fixed latency for the round. A 38-person user study with a custom FPS game shows degredations to QoE with latency, but less so for adaptive time delay.

CCS CONCEPTS

• **Applied computing → Computer games**; • **Human-centered computing →** *User studies*; Laboratory experiments.

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1 INTRODUCTION

First-Person Shooter (FPS) games are among the most popular in esports, demanding high levels of precision, quick reflexes, and split-second decision-making, making latency a critical concern for both developers and players [2, 10]. Unfortunately, latency from the network in online multiplayer environments is unavoidable and differences in player latencies can cause unfairness – players with lower network latencies to the server have their actions resolved quicker than players with higher latencies, potentially gaining a competitive advantage [9].

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Time delay is a latency compensation technique [5] that equalizes latency across clients, thereby neutralizing the advantage typically held by players with lower latency. However, with time delay, players with a lower latency have their latency increased even when they are not interacting with the other players. We propose adaptive time delay as a potential improvement over (fixed) time delay. Adaptive time delay dynamically adjusts when to equalize latencies, only adding latency to the lower latency player when interacting with a player with a higher latency. This should preserve the fairness gain from fixed time delay, while improving the average responsiveness and, hence, overall quality of experience (QoE) of players with low network latency.

There are two aspects of adaptive time delay that need to be assessed: 1) how adaptation of added latency – i.e., latency changing from low to high during the course of gameplay – impacts QoE, and 2) how unfair unequal latencies are compared to the equal latencies afforded by fixed time delay and adaptive time delay. This work-in-progress paper studies the first of these: the impact of adaptive latency on QoE. We implement a custom FPS game called *Zombiefield* that pits players against endless hordes of computer-controlled zombies, some of which emulate an interaction thereby triggering adding additional latency when adaptive time delay is enabled. We designed and conducted a user study with Zombiefield where users played with different amounts of fixed and adaptive latency, the game soliciting QoE opinions between rounds. Analysis of data from 38 users shows a degradation in QoE with latency, but adaptive time delay provides an overall better player experience compared to fixed time delay.

2 BACKGROUND

2.1 Responsiveness

Latency in FPS games can impact the players' the game's responsiveness, affecting the player's experience. In FPS games, unresponsiveness due to higher latency can degrade a player's quality of experience (QoE). Quax et al. [7] showed that even network latencies around 100 ms can negatively impact QoE for players of the FPS game *Unreal Tournament 2003*. Liu et al. [4] observed that reducing latencies from 125 ms to 25 ms improves QoE by around 20% for the FPS game *Counter Strike: Global Offensive*.

2.2 Fairness

Latency in FPS games can also impact fairness between competing players. Specifically, disparities in network latencies can provide an advantage to players with lower latencies [9].

Consider the example in Figure 1 where two players are connected to the same server, and Client A has a higher network latency than Client B. The server drops treasure for both players to claim and sends out an appropriate measure and, upon seeing the treasure, both players immediately attempt to claim it. However, due to Client A's higher network latency, its message to the server is delivered after Client B's. Consequently, the player on Client B secures the treasure, leaving the player on Client A empty-handed. This scenario highlights unfairness to Client A who loses out due to having higher network latency.

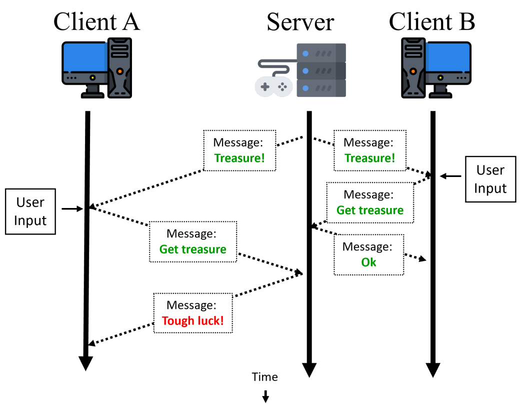

Figure 1: Unfairness due to latency in a network game.

2.3 Time Delay

Competitive FPS games implement latency compensation techniques to mitigate some of the effects of network latency, showing the industry's interest in improving competitive play in the presence of network latency [5]. Time delay aims to address unfairness due to differences in network latencies between clients by artificially adding delay to messages for players with lower network latency, thereby equalizing latencies [1, 3, 6, 8].

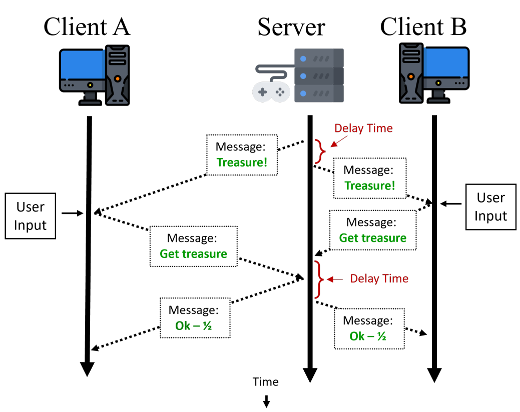

Figure 2: Fixed time delay to improve fairness.

Figure 2 depicts an example of using time delay for the example in Figure 1. Here, the server intentionally delays messages to Client B by the difference in latency between Client A and Client B so that both clients receive messages at the same time. This way, if both players immediately acquire the treasure, they each obtain half,maintaining fairness. Note, that this adjustment increases Client B's response time over their base network latency, thereby decreasing their responsiveness.

We propose adaptive time delay as a potential improvement over (fixed) time delay by dynamically adding latency only when players interact, rather than applying a fixed delay for all player actions. Figure 3 illustrates an example, where time delay is activated on the left when opposing players can see each other but is deactivated on the right when an obstacle blocks the interaction between the two players. Adaptive time delay should provide players with lower network latencies improved responsiveness when not interacting with other players, while preserving fairness when players do interact.

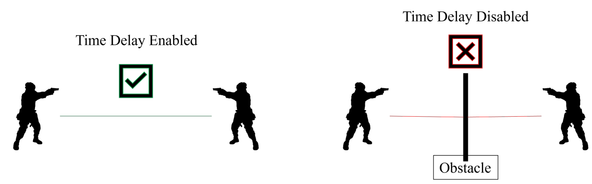

Figure 3: Adaptive time delay to improve responsiveness while maintaining fixed time delay fairness.

3 METHODOLOGY

Our methodology to evaluate the impact of adaptive time delay on player QoE is to build a custom FPS game named *Zombiefield* with features to support assessment, design and conduct a user study, and analyze the results.

3.1 Game Environment

Zombiefield is a single-player FPS game developed in Unreal Engine to evaluate the effects of latency on FPS game players. Figure 4 shows a screenshot of Zombiefield. The player interacts with the game from a first-person perspective, viewing the dark game world, enclosed in map where players combat endless waves of zombies, scoring points by surviving and killing zombies. Zombiefield supports fundamental FPS actions – moving and shooting – as well as sprinting and scoped aiming, in addition to settings for experimental conditions.

Zombiefield has two distinct types of AI-controlled zombies: standard zombies that do not require player interactions to go to the server (i.e., no network latency is required to resolve interactions with them) and network zombies that require player interactions to go to the server to be resolved. With no network latency, interactions with all zombies is minimally delayed. With network latency, interactions with network zombies gets less responsive. With time delay, interactions with all zombies is always lagged by the highest network latency. With adaptive time delay, interactions with zombies are only lagged when network zombies are visible.

Zombie spawning occurs in cycles, each lasting between 5 to 10 seconds, during which zombies are randomly spawned based on specific probabilities: there's a 50% chance of spawning three weak

Figure 4: Zombiefield screenshot showing the player in first-person combat with AI-controlled zombies.

(standard) zombies, which are the slowest and have 2 HP each, or one strong (networked) zombie with 5 HP, along with a 10% chance for the spawn of an ultimate (networked) zombie, the fastest and having 15 HP. Each bullet inflicts 1 damage on any type of zombie.

3.2 Experimental Design

For our study, Zombiefield was modified to have fixed-length rounds (75 seconds) with configurable latency and time delay parameters. The experiment has three distinct gameplay conditions to assess the effects of the latency compensation techniques:

(1) **Control Condition**: Gameplay with no added latency.
(2) **Fixed Time Delay**: Fixed amount of added latency for the entire round, representing the standard time delay technique.
(3) **Adaptive Time Delay**: Dynamic amount of added latency based on player interactions.

The experimental parameters are:

- Latency: 0 ms, 50 ms, 100 ms, 150 ms.
- Compensation: none, fixed time delay, adaptive time delay.

Our experimental setup had a high-performance computer equipped with an RTX 2080 graphics card, an Intel Core i9 11900K processor, 32 GB of Corsair Vengeance DDR4 RAM, a Samsung 970 EVO SSD, a Logitech gaming keyboard and mouse, along with a Lenovo legion monitor with 1920x1080 pixels at 240 Hz.

After a brief tutorial,[1] participants played for 4 minutes of practice with no added latency before the main game rounds. Then, each participant played 10 rounds of the game, each round 75 seconds long, going through all combinations of the experimental parameters. The round order was shuffled randomly for each participant.

Zombiefield solicits in-game feedback from players between each round, using a Likert scale to assess QoE and a binary question to assess acceptability of the round conditions. The questions were:

- Slider from (low) 1-5 (high), how was your experience?
- Was the round acceptable? (Yes/No)

Participants were recruited using university mailing lists targeting individuals with varying amounts of FPS gaming experience. Pre-game data collection had optional questions about participant age, gender, and self-rated gaming skill. We also collected participants' reaction times using a custom tool that measures user response time to color changes in a web browser[2].

[1]Zombiefield Tutorial - https://youtu.be/ouSVDV2TYQk?si=4b9GIHB-DZUeitqs
[2]Reaction Time Test - https://web.cs.wpi.edu/~xxu11/

The study was approved by our Institute Review Board (IRB). Participants gave informed consent prior to starting and were told they could withdraw at any time.

4 RESULTS

4.1 Demographics

A total of 38 users participated in the study. Table 1 summarizes their demographics. Numeric values are means with standard deviations in parentheses. The average age was about 20 years (M=20.2, SD=3.8), with a range of 17 to 37 years and nearly all reported as male (94.7%). "Gamer" and "FPS" were self-rated answers (1 low to 5 high) for experience as a gamer and FPS player, respectively – players were experience gamers and many were experienced FPS players. "Reactions" was the average reaction time, in milliseconds – reactions were fast, on average, typical of experienced gamers.

Table 1: Participant demographics

Users	Age	Gender	Gamer	FPS	Reactions
38	20.2 (3.8)	♂36 ♀2	3.7 (0.9)	2.9 (1.1)	195.6 (24.1)

4.2 Quality of Experience

Figure 5 depicts QoE versus latency for the different techniques. The x-axis is the added latency in milliseconds and the y-axis is the QoE (1-low to 5-high). There are two sets of data: blue is fixed time delay and green is adaptive time delay. Each point is the mean value across all users for that condition, bounded by a 95% confidence interval. The graph indicates that the QOE generally decreases as latency increases, which is consistent with expectations and prior work. The slight separation in the blue and green trendlines indicates that overall, users reported a better experience with adaptive time delay compared to fixed time delay.

An unpaired t-test for the QoE between without time delay (M=4.2, SD=0.6) and with fixed time delay (M=3.5, SD=1.1) conditions shows a significant difference; $t = 4.99$, $p < 0.001$ at $\alpha = 0.05$, as does a comparison between without time delay (M=4.2, SD=0.6) and adaptive time delay (M=3.7, SD=1.0); $t = 3.77$, $p < 0.001$ at $\alpha = 0.05$. However, there was no statistically significant difference for fixed time delay (M=3.5, SD=1.1) and adaptive time delay (M=3.7, SD=1.0); $t = -1.53$, $p = 0.13$ at $\alpha = 0.05$.

Figure 6 shows QOE CDFs for fixed time delay and adaptive time delay. Despite the lack of statistically significant difference, in the CDFs it appears that adaptive time delay has a slightly better QoE overall (the distribution is shifted down and to the right.

After each round, users rated their experience on a scale of 1-5 and indicated if they found the round acceptable. Figure 7 shows user acceptance versus QoE rating. From the graph, there's more variation in acceptability for lower QOE scores (1-2.5). Acceptance rates increased from 0 to 0.6 as QoE scores rose from 1 to 2.5, suggesting users were more likely to view the game favorably as QOE improved from low to mid-range. Most users found the experience acceptable as QoE increased above 3.0.

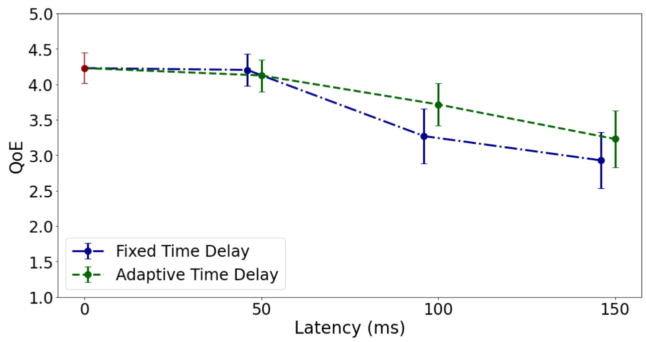

Figure 5: QoE versus latency.

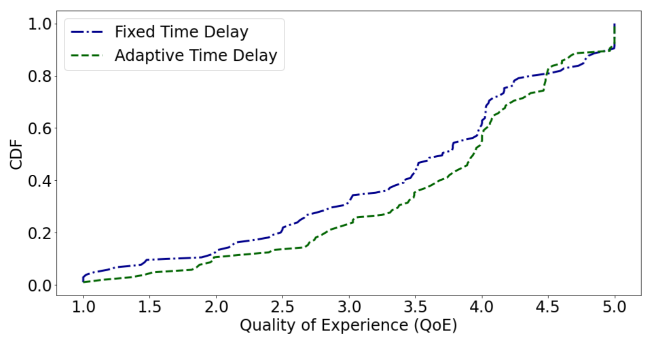

Figure 6: Distribution of QoE scores.

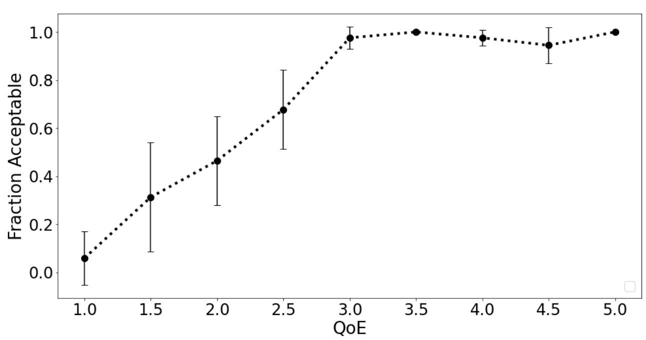

Figure 7: Acceptable fraction versus QoE.

5 DISCUSSION AND LIMITATIONS

On the surface, adaptive time delay should be better for player performance and experience than fixed time delay since the average latency is lower. However, since the latency adapts frequently – i.e., goes from low to high and back – as players interact, the actual benefits are less clear. In some cases, the varying latency values caused by adaptation may be worse for players than a fixed latency.

The results show both of these aspects. Adaptive time delay provides for better QoE than does fixed time delay. However, the benefits are slightly worse than would be for a fixed (i.e., constant) latency at the average adaptive value. This indicates that the first aspect of adaptive time delay – that the player experience for fixed time delay can be improved – can be realized. The second aspect of adaptive time delay – that players with different network latencies can have a fair gaming experience – is our current, ongoing work.

A limitation of the current work is that the Zombiefield game is single player. Thus, while it does provide for assessment of adaptive versus fixed time delay, it only emulates an FPS game with player-to-player interactions. Moreover, Zombiefield has only one weapon – a fully automatic rifle – whereas typical FPS games have multiple weapon choices, which players may switch to based on their network latency. Zombiefield has only one map, too, whereas typical FPS games are played over a range of maps styles, the size and terrain may impact latency's effects.

6 CONCLUSION

Network latency significantly affects player experience in FPS games, degrading responsiveness and fairness for PvP encounters. To address unfairness, time delay adds a fixed amount of latency to players with low latency to bring their total latency on par with players with the highest latency. While fair, this degrades the low-latency player experience even when they are not interacting with high-latency players. We propose adaptive time delay, a form of time delay where equalizing latency is only added to a low-latency player when interacting with a higher-latency player. We evaluate the potential benefits of adaptive time delay to player Quality of Experience (QoE), leaving the impacts on fairness as future work.

A 38-person user study had participants play short rounds of our bespoke FPS game *Zombiefield*, each round with different amounts of latency and compensation (fixed time delay, adaptive time delay or none). Analysis of the results indicates adaptive time delay has the potential to improve player quality of experience over fixed time delay. Our current ongoing work is to assess adaptive time delay in a PvP FPS game setting, where latency is added gradually only when the players can interact (e.g., see and shoot each other).

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