# Games and Frames: A Strange Tale of QoE Studies

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***Abstract*—Due to the nature of video games and their large diversity, results of past assessments of video game QoE have often been limited to one single game, and were generally difficult to transfer to any other game, even if they seem to be similar on the surface. In addition, studies often did not properly valuate certain game properties, such as the framerate, impacting their credibility.**

**With the help of examples of past literature we discuss the importance of the framerate and its impact on user studies. Furthermore, our simulation model explains the importance of such properties and their handling in objective measures by putting the End-to-End (E2E) lag in relation to the framerate.**

## I. Introduction

Recently, video games have garnered research interest from both the computer networking and the Quality of Experience (QoE) communities, focusing on network-related properties and the resulting Quality of Service (QoS) and QoE of individual video games. A quickly growing number of publications also concern themselves with assessing the QoE of such games. These assessments are usually conducted through user studies, and when set up correctly they can produce meaningful results. However, the inherent diversity of games and their accompanying gameplay mechanics make it difficult to transfer results from one game to another. In contrast to passively consuming videos, games are highly interactive, making the setup of such studies much more difficult. Compared to plain video streaming, underlying properties of video games are also not straight-forward to observe from the outside. Yet, in order to conduct proper measurements, it is essential to understand them. This work aims to critically question past gaming user studies and derive lessons learned, as well as to give insights into some of gaming's core properties. To further this, an E2E lag model is introduced which represents the lag between a user input event and the display of the event's results on the screen. The model describes game lag on the basis of other intrinsic game factors, such as the framerate and tickrate. Initial results with this model confirm the influence of framerate and tickrate on the E2E lag and therefore also on the game's subjective interaction quality. This means that these two parameters need to be tightly controlled in subjective quality assessment studies.

## II. Background

Any game continuously reads player input, updates the game state, and renders new screen contents in a loop. In networked games, the *tickrate* governs the frequency of such server-side game state updates, and the *framerate* determines the client-side update rate of the output image. Popular examples for game tickrates include $64\,\mathrm{Hz}$ or $128\,\mathrm{Hz}$ for CS:GO, $20\,\mathrm{Hz}$ for MINECRAFT, or $30\,\mathrm{Hz}$ for DOTA 2.

Motion in video data is based on the principle of *apparent motion*, requiring a minimum framerate of about $16.67\,\mathrm{Hz}$ for motion perception to work correctly. Video media, playing at framerates of $24\,\mathrm{Hz}$ to $30\,\mathrm{Hz}$, are considered to be at the low end of motion perception. However, stuttering can partially be concealed through motion blur. Video games have to target higher framerates: usually $30\,\mathrm{Hz}$ to $144\,\mathrm{Hz}$, depending on the type of game. Higher framerates are especially important for increasing the interactivity and reactivity as video games constantly require input on short time scales to which the game reacts and displays the feedback.

Lag is a crucial factor for almost all games, as it governs the reaction time to in-game events. In literature, lag is often described solely on the basis of the network delay in an online game, neglecting other components that contribute to the lag, including the input device, the time to sample and process the input, the game engine and server and their tickrates, frame rendering time, and ultimately the time to display the frame on the monitor. The *E2E lag* can only be fully captured if all those sources are factored in. Partial approaches, like software recording of a video game might be the simplest approach to determine video game lag and framerate (e.g., cf. [1]). But only external recording methods can fully capture the E2E lag by simultaneously recording both the screen and input devices (e.g. [2]) and noting the time between action and reaction.

## III. Issues of Past Studies

The outcome of past video game QoE assessments depended strongly on a wide selection of factors (e.g., on the precise setup, the game, and the choice of players), limiting their validity, comparability, and generality. Many past studies exhibit an apparent lack of gaming-specific knowledge manifesting itself in an improper choice of game and study parametrization. E.g., one paper [3] examines user actions in QUAKE 3 running at framerates as low as $3\,\mathrm{Hz}$, which is considerably below the threshold of apparent motion, while [4] attempts to derive "gaming quality" by measuring the PSNR and testing at framerates between $6\,\mathrm{Hz}$ and $25\,\mathrm{Hz}$. Yet, they somehow still note a serviceable quality.

The exact choice of game and methodology also critically impacts the results, which are almost always non-transferable to any other setup or game, even in the same genre. This circumstance is neglected in most works as they overly generalize

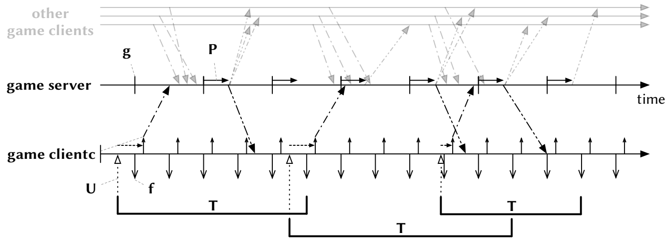


Figure 1: Exemplary flow of events in an online client-server game. Framerate $f$, tickrate $g$, user input event $U$, server processing time $P$, resulting E2E lag $T$.

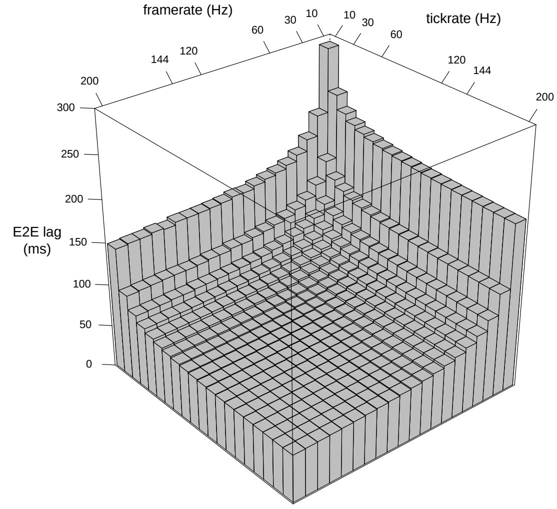


Figure 2: Influence of client framerate and server tickrate on the median E2E lag in the online game scenario, with the mean network round-trip delay and processing time set to $43\,\mathrm{ms}$.

their results. Other publications also have selected entirely questionable metrics to observe gaming QoE, e.g. attempting to measure the influence of and tolerance to network delay with a metric that operates on a scale of tens of minutes (as observed in [5]). The challenges such work faces is easy to understand, considering the complexity and variability of video games and the difficulties of finding and setting up good comparable scenarios and testbeds. This makes it much more important to better understand the basic components and underlying objective metrics.

## IV. E2E Lag Investigations

To further the understanding of the fundamental mechanisms behind E2E lag, a simplified model and simulation was set up to investigate lag in both offline and online games, and explore its relationship with the framerate and tickrate. Figure 1 shows an exemplary flow of events between game client and server for the simplified case of an online video game. The model's behavior is then implemented and tested in a simulator[1]. Consider the scenario of an online video game, where the game state is updated at a remote game server (following the server's tickrate), and the game client connects to the server across a network. Figure 2 evaluates the resulting lag as a function of framerate and tickrate for fixed distributions of the network and processing delay. It can be noted that the framerate has a larger influence on the lag than the tickrate. Second, the impact of low framerates and tickrates on the E2E lag by far exceeds (and thus masks) the typical ranges of RTT in a wired access network. Only if both rates are high enough, the network delay will play a more significant role.

This masking effect has large implications for video games and their evaluation. Many approaches only examine the influence of the network delay, without considering other contributing lag factors. Our model and simulation results indicate that this might not be the best course of action. Another noteworthy result is the much larger variance of lag in the framerate dimension when compared to the tickrate. This requires video game studies to have a very high repetition rate to provide meaningful results. Furthermore, this also implies the necessity of a tight control over game parameters, such as the framerate, resolution, or input devices.

[1]https://github.com/mas-ude/onlinegame-lag-sim

## V. Conclusion

The current state of QoE research of networked gaming leaves lots of room for improvements. Issues with past works include inapt metrics, trial conditions that are unrealistic or unrepresentative for games, and disregard of relevant components of lag in games besides network delay (i.e. framerates and tickrates in particular). Our contribution is a simplified E2E lag model and simulation which aims to uncover and correct these shortcomings.

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