Qualitative Evaluation of Latency and Packet Loss in a Cloud-based Games

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Abstract **- On-demand multimedia services are more popular than ever and continue to grow. Consumers can now stream music, movies, television, and video games at the push of a button. Such services typically require a minimum connection speed to support streaming. However, transient network effects such as packet loss and delay variation can play a crucial role in determining the user quality of experience (QoE) in streaming multimedia systems. This paper will seek to establish the subjective impact of negative network effects on the user experience of a popular cloud-based on-demand video game service.**

Keywords: **Cloud Gaming, QoE**

1 Introduction

Internet gaming is consistently growing in popularity and shows no signs of slowing. Cisco predicts that Internet Gaming traffic will continue to grow by 43% annually, and will generate 290 petabytes of data a month by 2015 [1]. Cloud gaming (CG) is a relative newcomer to the Internet gaming scene but has shown promising signs of growth, even being labeled by some as a "Console Killer" [2]. Several large CG providers have already launched around the world, including OnLive, Gaikai, and G-cluster, with even more on the horizon [3][4].

Cloud gaming refers to the on-demand streaming of games to the user's thin client, computer, or mobile device. Unlike traditional games, the game processing requirements are almost entirely server-based, thus negating the need for pricey graphics cards or expensive consoles. CG also eliminates the need for a lengthy installation process, allowing consumers to instantly play high-quality games on virtually any Internet device. This feature is also attractive to game publishers: since games are stored server-side, piracy becomes virtually impossible [5]. Despite these advantages, CG remains limited by several key technical challenges. OnLive, currently the largest active CG provider, requires a minimum 2 Mbps broadband Internet connection speed, and recommends a 5+ Mbps connection. OnLive further recommends end-users live within 1000 miles of a data-hosting center [6]. In addition, CG is particularly affected by such network effects as latency, packet loss, and jitter. These network conditions may have a significant impact on the user's Quality of Experience (QoE). QoE generally refers to the range of subjective, user-centric performance aspects of some networked application such as responsiveness, expected performance, and usability [7].

Although Internet gaming in general has been thoroughly researched, relatively few studies have been published specifically regarding cloud gaming. A particularly important area of research seeks to establish the impact of network conditions upon the user's perceived Quality of Experience (QoE) when playing a networked game. It has been shown the type or genre of game being played is the key determining factor of network requirements [8]. A First-Person Shooter (FPS) is a prominent type of game in which gameplay generally focuses on weapon-based combat from a first-person perspective. Popular examples of FPS include the Doom, Half-Life, Halo, and the Call of Duty series. Players of FPS games have been shown to be especially sensitive to network conditions relative to other genres such as role playing games (RPG) or real-time strategy (RTS) games. For example, one study finds that while online RTS games are unaffected by latencies as high as 1000ms, the relatively faster-paced FPS requires a latency of less than 100ms [8]. Whereas an RPG gamer may place a high value on graphical quality and environmental immersion, a typical FPS player places a greater emphasis on accuracy, precision, and responsiveness [8].

Round-trip response time is arguably the most significant contributor to a game's QoE. For example, a round-trip delay of as low as 60 milliseconds (ms) may significantly disrupt a FPS player's experience [9][10]. Another study found a strong correlation between poor network conditions (network delay and jitter) with a user's likelihood of quitting a networked multiplayer game early [11]. While this study explored an online RPG with a latency threshold of 200ms and a 0.1% packet loss rate, it can be predicted that FPS players are even more likely to quit at these levels of congestion. In addition, Chen, et al. have studied the response latency of two prominent Cloud Gaing platforms, including OnLive. In this study, RTT delay measurements were captured and analyzed while playing 3 cloud-based games [12]. However, this study did not directly include QoE considerations.

Another recent study establishes a relationship between network performance and a user's QoE in a CG system. Jarschel, et al. subjected users of a simulated CG testbed to a wide range of network conditions. While the study included the games Pro Evolution Soccer, Final Fantasy XIII (RPG), and Gran Turismo HD (Racing), the study did not specifically test a First-Person Shooter type game. In this study, it was concluded that the type of game had the most significant impact on a user's QoE. The study further found that users were very tolerant of a delay of 120ms. However, the study did not explore the impact of network latency on a cloud-based FPS [13].

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This paper will explore the impact of network latency on a user's Quality of Experience in a real-world, cloud-based First-Person Shooter. Volunteers will play the popular FPS Borderlands using the OnLive CG service. Network Control software will be used to subject the players to a wide range of network effects such as high latency or packet loss. The volunteers will then fill out a QoE survey in order to determine what level of delay or loss begins to significantly degrade a user's experience.

2 Experiment Description

This study will utilize the largest active cloud gaming provider [6], OnLive, to explore the impact of network latency and packet loss on users of the FPS game *Borderlands*. Figure 1 below demonstrates the test bed setup.

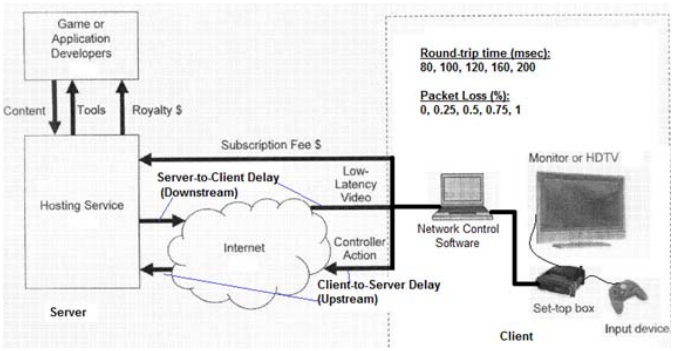

Figure 1. Experiment Setup.

As shown in Fig. 1, network control software will be used to introduce network delay and packet loss. Volunteers will be using the OnLive set-top box (thin client) to play Borderlands on a 1080p HDTV connected via HDMI cable. The test administrator will use the network control software to subject players to a round-trip time (RTT) of 80, 100, 120, 160 or 200 milliseconds and a packet loss rate of 0, 0.25, 0.5, 0.75, or 1%. Ordinary (non-controlled) network conditions were excellent, with typical round-trip times of roughly 50ms and 0% packet loss. However, since the purpose of this study is to determine QoE near previously established network performance thresholds, these network conditions were not evaluated in the test. Each play session will be 10-15 minutes long at a randomly-selected RTT and packet loss rate. Each RTT/ packet loss scenario will be tested only once. A volunteer may play multiple test sessions. Following each session, the volunteer will be asked to fill out a Quality of Experience survey.

Twenty five volunteers were selected to participate in this study. Seventeen of the volunteers considered themselves to be "experienced" gamers, while the remainder labeled themselves as "novice" or "casual". None of the volunteers had experience playing a cloud-based game, although all had experience playing multiplayer networked FPS games. A total of 50 test sessions were conducted overall. Each playtest concluded with a QoE survey, wherein players were asked to subjectively rate the Quality of Experience of their playtest session in 8 categories: Loading Times, Responsiveness, Image Quality, Sound quality, Choppiness/ Stuttering, Game freezes/ Disconnections, Overall experience, and Likelihood to play again.

The particular choice of metrics for the QoE Index was based, in part, upon the aforementioned subjective criteria traditionally used to evaluate online multiplayer First Person Shooter games. The QoE Index is intended to merely provide an overall snapshot of the player's subjective experience, rather than a comprehensive evaluation of all possible measures of gaming enjoyment. Future studies may refine these metrics as needed to adequately measure the subjective experience of playing a wide genre of multiplayer games.

The Quality of Experience Index categories were briefly summarized for each player. For example "responsiveness" refers to the immediacy of the game responding to a player control input, while "choppiness" generally includes any jerkiness/ stuttering of an animation or inconsistent firing rate of a weapon. Each participant was asked to verify understanding of these categories before each play test session. The player's ratings across all 8 categories were averaged to find the test scenario's overall QoE Index.

3 Experiment results

For brevity and clarity, only key results will be presented here. Discussion and analysis of these results will be included in the next section. Below, Figure 2 illustrates the QoE Index across all test scenarios. Recall that the QoE Index is the average all of ratings within a particular play test scenario.

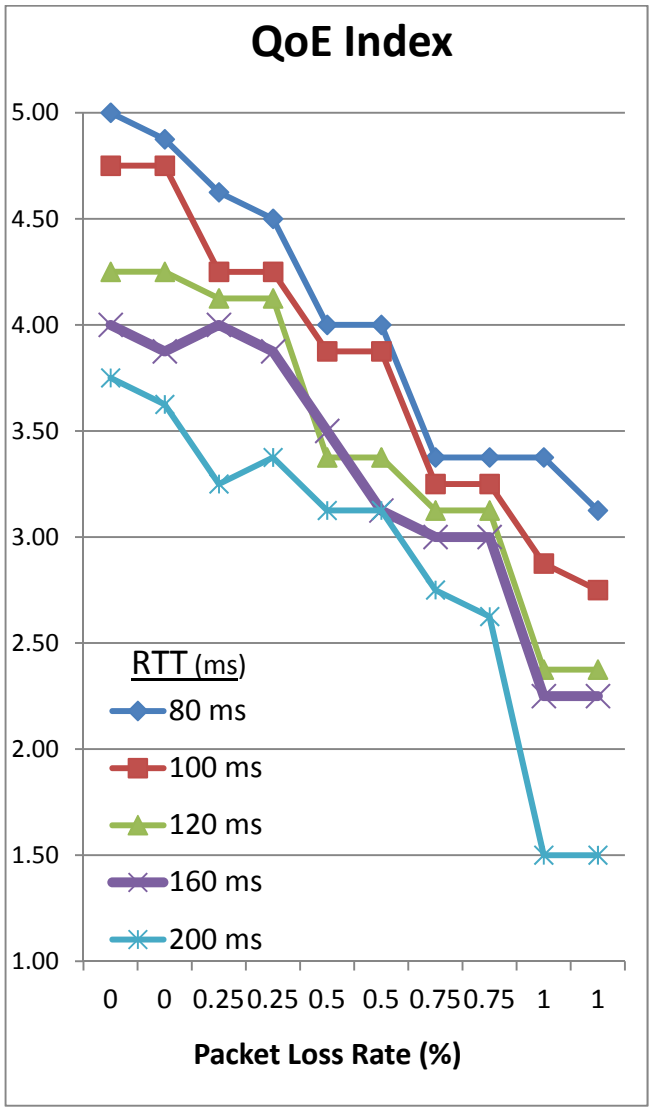

Figure 2. QoE Index Results.

As shown in Figure 2, player Quality of Experience is significantly affected by dropped packets. Regardless of round-trip time, player experience is routinely degraded by increasing rates of loss. For example, testers reported a better QoE at a relatively high latency (200 ms), but lossless connection, than a speedy connection dropping just 0.75% of packets. Furthermore, although the QoE Index drops by 25% from 80ms to 200ms, at 1% loss the QoE degradation exceeds 50%. The game became virtually unplayable at 200ms RTT with 1% loss, with testers reporting repeated instances of game freezes, choppiness, and long loading times. Conversely, testers tolerated relatively long round-trip times well, with an overall QoE well above average.

The volunteers were asked to give subjective ratings in 8 categories. Figure 3 below represents the relative average ratings of each category. The ratings are given on a scale of 1-5, with 5 representing the best possible experience.

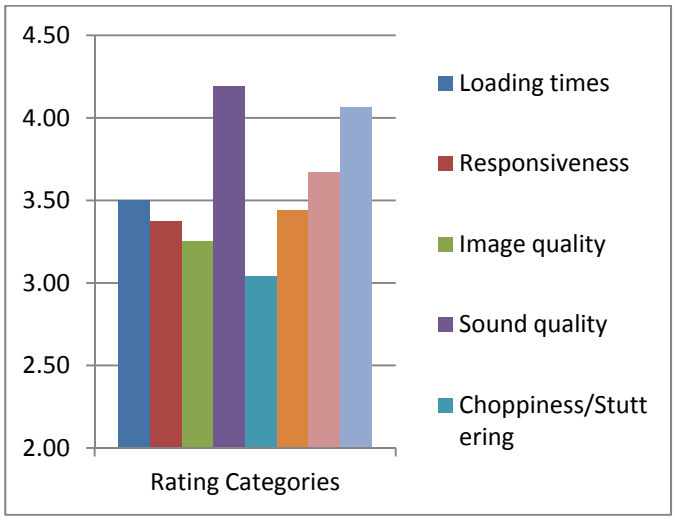

Figure 3. Relative Ratings.

As seen in Fig. 3, players were generally very satisfied with the sound quality of the OnLive system. Players also routinely reported a good to very-good overall experience and a high likelihood to play the game again. However, the worse-case scenarios of high delay and loss significantly affected image quality and caused severe choppiness and stuttering to the game. This is reflected in the merely average ratings in these categories.

Finally, the volunteers were given an exit survey at the conclusion of their final test session. Of the twenty five total volunteers, 24 (96%) were "impressed" or "very impressed" by the CG system, and seventeen (68%) would consider paying for such a platform. However, less than half (11 total) volunteers considered cloud gaming a viable alternative to traditional PC or console-based gaming. Graphics quality was uniformly cited as a primary concern. All volunteers indicated interest in participating in future test sessions.

4 Discussion

While Jarschel, et al. have examined the effect of latency and packet-loss on various cloud-based games, this study did not specifically include a First-Person Shooter. Jarschel et al. find that players of a cloud-based soccer game will merely repeat a button press in the case of a missed input due to packet loss. Jarschel further finds that delays of less than 200ms are tolerable, and that a delay of 120ms is "hardly noticeable." The racing game is also found to be fairly resilient to packet loss [13]. However, players of FPS games are generally less tolerant of network delay than other game genres [8].

As can be seen in Figure 3 above, player QoE in a FPS is drastically affected by both network latency and packet loss. In fact, just a 0.75% loss rate can significantly degrade a player's experience. At 200ms, 1% packet loss caused over a 50% decrease in player QoE Index, with "poor" to "very

poor" ratings in every subjective category. Although increases in round-trip time cause similar decreases in QoE, the effect is much less pronounced. For example, even a 200 ms RTT received an above-average QoE Index, assuming no delay. In order to ensure optimal Quality of Experience, a lossless connection with round-trip times of less than 120ms is desirable for fast-paced First-Person Shooters. These results closely match previous studies of traditional, non-cloud-based FPS games [10] [11] and suggest even stricter network performance requirements than suggested by Jarschel, et al.

Anecdotally, it was reported that players were able to quickly adjust to a uniform delay in responsiveness. For example, players reported simply firing a weapon sooner or "leading" an enemy target by firing at the target's predicted future location. One player likened the situation to the familiar satellite delay seen on television news interviews. In such interviews, initial confusion is seen as participants adjust to the satellite delay, but quickly become accustomed to the longer pause before responding. However, in the case of dropped packets, players were unable to reliably compensate for the relatively wide variances in performance and responsiveness. This uniformly resulted in greater frustration and subsequent low QoE ratings.

When considering the commercial viability of cloud gaming, the likelihood to play again is arguably the most important measure of a player's experience. In this respect, the OnLive platform delivered excellent results. In all but the worst-case scenarios, players generally indicated a high or very high likelihood to play the game again. In addition, the exit survey shows players as being impressed with the system, and very willing to participate in future playtest opportunities. In addition, fourteen of the twenty-five volunteers indicated an interest in purchasing the platform, although no information was provided regarding cost or available game titles. Both "casual" and "experienced" players were able to quickly understand and operate the system.

In addition, players were generally very satisfied with the sound quality and relatively quick loading times of the system. Neither of these categories received a "very poor" rating even under worst-case scenarios. However, players were less impressed with the image quality; this category received a single perfect score only under the best-case scenario. Video Quality was also indicating as a primary concern amongst volunteers when considering GG as a viable replacement for traditional console-based game systems. It is important to note that although OnLive advertises full 720p HD video [2], the veracity of this claim was not a subject of this particular study.

As previously mentioned, the QoE Index presented in this study is intended to represent merely an overall snapshot of the many subjective measure of a player's gaming experience. It has been shown that competitive FPS player often value responsiveness over graphics quality, while RPG players may primarily value graphics for optimal immersion [8]. Future studies may adjust weighting of particular subjective categories in order to more accurately reflect a player's overall QoE. Additionally further QoE metrics and aggregation algorithms may be used in order to establish a more uniform and consistent QoE analysis [15].

Future studies may also introduce a wider variety of negative and transient network effects, such as jitter or one-way delay. Additional play test sessions across a wider range of network performance measures will further illustrate impact of network quality on player QoE. Although the game tested here, Borderlands, is a popular FPS, even faster-paced shooters such as the Call of Duty franchise may require even higher network performance in order to satisfy competitive players.

5 Conclusion

Cloud-based gaming is growing in popularity and may one day even challenge the ubiquitous video game console. Several service providers have already launched across the world with more on the horizon. Cloud Gaming offers consumers a wide-range of high-quality games available on virtually any Internet device. Yet, poor network performance can have a significant impact on a user's Quality of Experience. This study has shown that players of cloud-based FPS games are less tolerant of network latency and packet loss than players of other game genres such as Role-Playing Games. Furthermore, packet loss can dramatically impact a player's experience with loss rates of just 1% rendering a game nearly unplayable. However, in all but the worst-case scenarios, gamers are very impressed with the overall experience of cloud gaming and highly likely to continue playing. If certain minimum network performance requirements can be met, it may be clear skies ahead for Cloud Gaming.

6 References

[1] Cisco, 2011. "Cisco Visual Networking Index: Forecast and Methodology, 2010-2015." < http://www.cisco.com>.

[2] Shiels, Maggie, 11 Mar 2010. "'Console killer' OnLive to launch in June". BBC, <news.bbc.co.uk>. Retrieved 23 Mar 2012.

[3] Brown, Rich, 27 Feb 2011. "Gaikai launches its game-streaming service with free trials." CNET, <http://news.cnet.com/gaikai-cloud-gaming-service-goes-live/8301-17938_105-20036987-1.html>. Retrieved 23 Mar 2012.

[4] Ojala, A. & Tyrväinen, P. (2011). Developing Cloud Business Models: A Case Study on Cloud Computing. In *IEEE Software*, Vol. 28, Issue 4, pg. 42-47.

[5] Lynley, Matthew (14 Jul 2011). "Cloud-based video games will put pirates out of business." VentureBeat, < http://venturebeat.com/2011/07/14/cloud-gaming-piracy>. Retrieved 26 Mar 2012.

[6] Krenz, et al., 2011. "Consumer Acceptance of Cloud Computing Based Gaming." Jonkoping International Business School, Jonkoping University, Sweden.

[7] Wanmin Wu, Ahsan Arefin, Raoul Rivas, Klara Nahrstedt, Renata Sheppard, and Zhenyu Yang. 2009. Quality of experience in distributed interactive multimedia environments: toward a theoretical framework. In *Proceedings of the 17th ACM international conference on Multimedia*(MM '09). ACM, New York, NY, USA, 481-490.

[8] Mark Claypool and Kajal Claypool. 2006. Latency and player actions in online games. *Commun. ACM* 49, 11 (November 2006), 40-45.

[9] Jeremy Brun, Farzad Safaei, and Paul Boustead. 2006. Managing latency and fairness in networked games. *Communications of the ACM* 49, 11 (November 2006), 46-51.

[10] Peter Quax, Patrick Monsieurs, Wim Lamotte, Danny De Vleeschauwer, and Natalie Degrande. 2004. Objective and subjective evaluation of the influence of small amounts of delay and jitter on a recent first person shooter game. In *Proceedings of 3rd ACM SIGCOMM workshop on Network and system support for games* (NetGames '04). ACM, New York, NY, USA, 152-156.

[11] Kuan-Ta Chen, Polly Huang, and Chin-Laung Lei. 2006. How sensitive are online gamers to network quality?. *Commun. ACM* 49, 11 (November 2006), 34-38.

[12] Kuan-Ta Chen, Yu-Chun Chang, Po-Han Tseng, Chun-Ying Huang, and Chin-Laung Lei. 2011. Measuring the latency of cloud gaming systems. In *Proceedings of the 19th ACM international conference on Multimedia* (MM '11). ACM, New York, NY, USA, 1269-1272.

[13] Michael Jarschel, Daniel Schlosser, Sven Scheuring, Tobias Hoßfeld. "Gaming in the clouds: QoE and the users' perspective." Mathematical and Computer Modelling, Available online 21 December 2011, ISSN 0895-7177, 10.1016/j.mcm.2011.12.014. Retrieved 26 Mar 2012. http://www.sciencedirect.com/science/article/pii/S0895717711007771.

[14] Periman et al. "Method for Multicasting Vies of Real-Time Streaming Interactive Video." US Patent Application Publication US 2009/0119729. 2009.

[15] Peng Chen and Magda El Zarki. 2011. Perceptual view inconsistency: an objective evaluation framework for online game quality of experience (QoE). In *Proceedings of the 10th Annual Workshop on Network and Systems Support for Games* (NetGames '11). IEEE Press, Piscataway, NJ, USA, , Article 2 , 6 pages.

[16] Michael Jarschel, Daniel Schlosser, Sven Scheuring, and Tobias Hoβfeld. 2011. An Evaluation of QoE in Cloud Gaming Based on Subjective Tests. In *Proceedings of the 2011 Fifth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing*(IMIS '11). IEEE Computer Society, Washington, DC, USA, 330-335.

[17] Shaoxuan Wang and Sujit Dey. 2009. Modeling and characterizing user experience in a cloud server based mobile gaming approach. In *Proceedings of the 28th IEEE conference on Global telecommunications* (GLOBECOM'09), Mehmet Ulema (Ed.). IEEE Press, Piscataway, NJ, USA, 4231-4237.

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