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Influence of Network Delay and Jitter on Cooperation in Multiplayer Games

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Abstract

Like most applications deployed on the Internet, modern multiplayer games are subject to the impact of transmission delays and the variability thereof. These delays can be introduced either by the physical limitations of signal transmission speed or overload and queuing problems in intermediate nodes. The influence of this delay is far-reaching and impacts most interactive applications. More specifically, quantitative and qualitative studies have been conducted on competitive game genres, such as first person shooter and racing games. In contrast, this work investigates how network delay affects player experience in cooperative games, where players have to interact with shared objects and obstacles. In this game genre, one might expect an increased sensitivity to detrimental network factors due to the reliance on the (near-)perfect synchronization of actions between participants. In this paper, a series of consecutive user tests were carried out with one of the most recent games, Little Big Planet 2; which focuses primarily on the cooperative aspect. Analysis has shown that delays over 100 ms significantly decrease player performance and the way in which network quality is perceived. At the same time jitter negatively affects user performance, though players do not perceive this impairment as disturbing.

Keywords: Multiplayer video games, cooperation, delay, jitter

1 Introduction and Related Work

In recent years there has been a substantial growth in the popularity of interactive multiplayer online games, which have become a considerable part of the Internet applications. Unfortunately, applications deployed on the Internet are often affected by network delay and jitter. In general, these factors play an important role in decreased user performance and experience. This is particularly true for multiplayer video games, given the high level of interaction between players.

Multiplayer capabilities in current games are an increasingly important revenue factor for developers, because they stimulate players to keep on playing the game after the initial release period. This leads to the users buying DLC (DownLoadable Content) and in their continued subscription to specialized networks such as Xbox Live. Typically these games focus on competitive gameplay (e.g. first person shooter games in which players are individually competing against one another).

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In more recent releases and genres, cooperation between players is being utilized as the selling factor (USP). In cooperative games it is often impossible to succeed without help of others. One might imagine that these kinds of games are more sensitive to the network quality, as they may require very intricate and synchronized actions between several players. If one (or more) players are impaired by noticeable network delay, the gaming experience might become annoying or it can be even impossible to complete the game.

A substantial number of studies investigating the influence of network impairments (delay and jitter) on the player performance in highly-interactive non-cooperative video games [Dick et al. 2005; Garapati 2009; Steed and Oliveira 2009; Quax et al. 2004] are available. It is shown that games such as first-person shooter or sports games have the lowest tolerance in terms of delay, mainly because the player has direct control over his avatar. In contrast to directly controlled games, real-time strategy games do not have such strict delay requirements. Here, delay may be higher without interfering with the enjoyment of the player since he just controls the units indirectly.

While being an important characteristic, jitter has not been studied so widely. In [Dick et al. 2005] authors have shown that jitter has a negative influence on the gaming experience in general, but even with values up to 150 ms the environment remains acceptable. Similar results are obtained in [Quax et al. 2004]. Here authors have shown that jitter is less significant than the delay for interactive games.

Although previous works touch different genres of highly interactive games like racing or shooter games (which are mostly competitive in nature), the influence of network quality on cooperation in games has not been widely covered. There are several works in existence regarding the effect of network characteristics on cooperation in shared virtual environments [Stuckel and Gutwin 2008]. They have shown a significant influence of network delay and jitter on the user performance, even though the focus of these studies was clearly outside the gaming context. To our knowledge, the impact of network conditions on games that focus on cooperation has not yet been studied. Due to their nature, one might expect that cooperative games are even more sensitive to network impairments (both delay and jitter).

To investigate the impact of delay and jitter on cooperation, a series of consecutive user studies have been conducted with one of the recent cooperative games, Little Big Planet (LBP) 2. The aim is to see to what degree the player performance and experience depends on varying levels of network delay and jitter. A randomized group of players was placed in a controlled network environment. Their gaming session was impaired by introducing delay and jitter in the network connections. During these experiments, the focus was twofold: obtain objective measures (game score and task completion time) and subjective experience details (to ascertain the way in which players perceived the network quality).

2 Measurement Setup and Procedure

A two-staged process is used to quantify the impact of delay and jitter. In the first experiment, a rough idea had to be gathered on

what values of a more or less constant delay would lead to a decrease in experience and performance. Once these boundaries are established, the second study additionally investigates the impact of jitter on the gameplay. The main goal of this study is to determine whether or not any influence of jitter (defined as variability of the delay) on cooperation in games exists (part 1) and where its threshold of acceptability (part 2) lies. Jitter is an important factor that is typically dependent on the last-mile technology in use (e.g. DSL, cable or wireless connections). The goal is to investigate how this disparity between players influences the group outcome of the game. For the detailed description of each study and the complete results we refer the reader to the technical report available at www.uhasselt.be.

2.1 Study 1: Influence of Network Delay

Thirty two participants were randomly grouped in pairs and played Little Big Planet 2 using two separate Sony PlayStation (PS) 3 consoles that were connected to each other over a dedicated local area network. An uplink was provided to connect both to the PlayStation Network (required for matchmaking purposes). As the traffic associated with the game is sent directly between the consoles, the presence of a single impairment node (a linux system running the NetEm [Hemminger 2005] software) suffices to introduce network anomalies for this setup. Care was taken to choose delay and jitter values representative for current-generation network conditions (i.e. excessively high values were not considered) [Steed and Oliveira 2009]. To ease observations, the participants were located in the same room separated by a portable wall.

To measure the effect of delay, different network conditions were simulated: 10, 20, 40, 60, 80, 100, 200 and 300 ms (all numbers stated as one-way). For every pair two out of eight values of delay were chosen in a random order. Players were not aware what value of network delay they experienced to avoid any influence on their further responses.

Two cooperative levels (Coop World by Lenicolas59 and COOP by I-Lex) with approximately same difficulty level and duration were chosen. During the experiment, participants often encountered situations that required synchronizing their actions (e.g. carrying each other while shooting, and lifting and moving the same objects).

In every pair, one of the players was impaired by the network delay. By impairment of the player we mean that his PlayStation 3 was connected through the local area network by means of the impairment node (with NetEm installed). To initiate a gaming session in Little Big Planet 2, it is necessary for one player to invite the other one. The PlayStation which sends the invitation is called game leader and acts as 'server'. The other player connects to this server and is referred to as the follower. The player using the server console is at an advantage (because actions are directly undertaken) and is therefore referred to as 'unimpaired', while the others are 'impaired'. It is important to state that the unimpaired player also experiences detrimental performance due to the fact that the actions of the other players take a while to arrive at the server, but not in the order of magnitude of the impaired players.

During the test, level completion time and game score were measured. After completion of each level, the participants were asked to fill in a questionnaire enabling them to evaluate the influence of the network conditions on their gaming experience (enjoyment, frustration, difficulty to coordinate cooperative activities with the partner, performance, etc.).

2.2 Study 2: Influence of Jitter

For both parts of our second study we involved groups of three people playing a custom level of Little Big Planet 2 (BasketBall usertest 2 by Bezna). Three PS3 consoles were connected through a switch over the LAN. In order to simulate different network conditions for all players, two impairment nodes with NetEm were placed between the central switch and the consoles as shown in figure 1. To bring the setup closer to the real playing conditions and to avoid interactions through vocal communication, every participant was located in a different room.

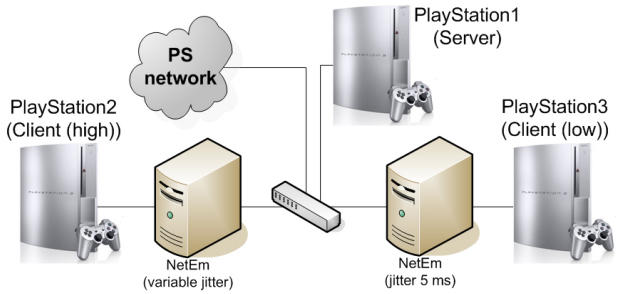

Figure 1: *Network layout in the second study.*

During the first part of the study, we fixed the amount of delay for each group and varied jitter to see whether it had any influence on players' performance. There were four groups participating in this test: the first two were exposed to 100 ms delay, and the other two to 200 ms delay. We varied the jitter values between PlayStation1 and PlayStation2 by assigning it to 20% and 50% of the fixed delay (simulating a cable access connection). These values were given in a different order to every group. At the same time, the jitter of the connection between PlayStation1 and PlayStation3 was fixed to 5 ms (which is typical for DSL connections). Every time the level was completed participants switched between the consoles. In such a way every player tried both unimpaired (PlayStation1) and impaired (PlayStation2 or PlayStation3) environments.

The second part of this study was designed similarly to the previous one and an identical setup was used. Twenty four people were recruited and randomly put together into eight groups. This time, a single fixed delay value was used (100 ms) and four levels of jitter were introduced: 10, 20, 40 and 50 ms. Each group of participants tested all four levels of jitter, whose order was randomized.

In both tests we captured the completion time. After completion of each level, the participants were asked to fill in a questionnaire similar to the one in the first study.

3 Results

3.1 Study 1: Influence of network delay

First of all we determine objectively whether or not the network delay influences player performance. Completion time analysis has shown that with a delay higher than 100 ms the game lasted noticeably longer. A significant positive correlation between completion time and the level of delay (R^2 = 0.82, p = 0.013) has been also found. Further analysis has shown the correlation between the delay and the game score (R^2 = -0.78, p = 0.024). There is a noticeable drop in the game score once the network delay exceeds 60 ms.

Furthermore, we find it interesting to see whether or not players have perceived this degradation. In the questionnaire, participants

were asked to rate the influence of the network delay on their score and task completion time. Players seemingly do not perceive a delay up to 200 ms as disturbing (a low impact on the experience level). A positive correlation has been found between delay and both completion time (R^2 = 0.81, p = 0.016) and game score (R^2 = 0.85, p = 0.008).

For each delay level players were asked to rate the gaming environment to define when it became annoying and/or unacceptable. Results show that up to 200 ms (one way delay), players considered the gaming environment to be acceptable without major impairment. Only when the delay exceeded 200 ms did they indicate this to be very annoying.

The analysis of the aforementioned characteristics has been performed based on the data collected from the players who were directly influenced by the network conditions. However, cooperative games involve simultaneous interaction between several players, both those affected and those that are not. Therefore, players who are not directly influenced by the network delay can also be affected by an inadequate performance of their game partners. To investigate whether an impaired player impacted his/her collaborator we have asked both of them to evaluate their gaming experience (figure 2). By comparing these responses we aim to define a threshold that provides all players with an enjoyable gaming experience.

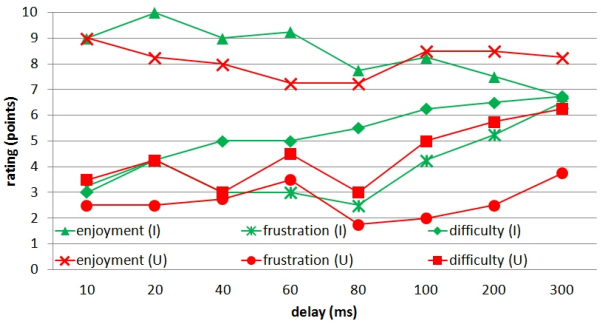

Figure 2: *Influence of the delay on the impaired (I) and unimpaired (U) players.*

To define the threshold of acceptable delay, values should be chosen that keep the difficulty and frustration level for both players at a relatively low level, while the level of enjoyment remains high. Based on the coordination difficulty scores, there is an indication that a one-way delay below 60 ms does not significantly decrease the user experience for both parties involved. The rating of enjoyment given by the affected players has a negative trend, indicating that there is reduced enjoyment when faced with higher delays (R^2 = -0.88, p = 0.004). However, ratings given by unimpaired players do not have such a strongly pronounced regularity. Therefore, the threshold of acceptable delay is defined here based on the evaluations by the class of impaired players. With delays higher than 100 ms, there are indications that user enjoyment decreases constantly. Finally, we observe that after a delay of 100 ms the level of frustration of impaired players is increased dramatically. At the same time for non-affected players the level of frustration remains quite low with a slight increase when the maximal delay is reached.

Taking into account these findings delays between 60 and 100 ms (and below) are considered as those that provide the most enjoyable experience and adequate performance in the cooperative game being used. 100 ms delay is defined as a threshold above which players perceive network degradation as disturbing with a significant decrease in their performance.

3.2 Study 2: Influence of jitter

3.2.1 Part 1: Existence of jitter impact

During this first study we want to see whether jitter has any negative influence on the cooperative play. In order to perform this we have opted for certain delay values (100 and 200 ms) and compared the performance and experience of players under conditions of low (5%) and high (20%, 50%) levels of jitter.

As in the previous study, we have evaluated the impact of the network quality both objectively and subjectively. As an objective characteristic of the gaming experience we have analyzed the level completion time. We have observed that players who were exposed to lower jitter values completed the level quicker (figure 3).

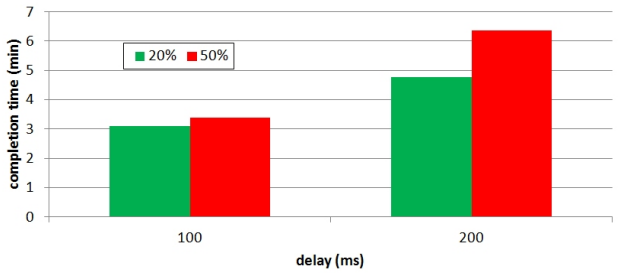

Figure 3: *Influence of jitter on the completion time.*

Although we have found a negative effect of jitter on player performance (objective measurement), it is still necessary to analyze whether players consider it degrading their experience (subjective). Participants played the game in groups of three, where everyone was exposed to a different condition. We will refer to them as server, client (high) and client (low) (as shown in figure 1). We reiterate the fact that NetEm uses a normal distribution to determine the delay values; the values in the following paragraphs therefore indicate the standard deviation.

All three players found the conditions acceptable without noticeable impairment for any level of jitter when delay was fixed to 100 ms. When players were subjected to 200 ms delay different levels of jitter were not perceived equally. Jitter up to 20% (or 40 ms) was considered as an acceptable environment with minor impairments. Yet, high level of jitter (50% or 100 ms) significantly decreases the perceived quality of the network. The server player has not experienced negative influence, but both other players have indicated these conditions to be very annoying with many noticeable impairments. Note that this is probably due to the fact that the latency compensation techniques in LBP2 cannot efficiently cope with the variations in delay.

Further, we have analyzed users' responses regarding the influence of the network quality on their enjoyment, frustration, difficulty to coordinate joint activities, game completion time and wish to continue the game. When the delay was 100 ms players did not feel hampered by any of the jitter values (5, 20, 50 ms).

An opposite situation is observed for those players that are subjected to 200 ms delay. Firstly, there is a greater discrepancy in players' perception within the same group (between server player, client (high) and client (low)). Secondly, the analysis of results have shown the difference between responses of players that are subjected to 20% and 50% jitter, which do not occur for the 100 ms delay case. For all aspects of the interaction investigated in this study, client (high) has indicated the highest influence of the network quality on his gaming experience. Client (low) has evaluated

the influence of the network quality to be relatively high but not very different from the server player.

3.2.2 Part 2: Quantification of jitter impact

In the previous part we have shown that jitter negatively affects user performance in the cooperative game that is being used. Because we have checked this only for two different levels of jitter it is still necessary to confirm the findings with gradually increasing jitter. To quantify the impact of jitter on cooperation, in this part several levels of jitter are introduced. We aim to define the threshold of jitter below which players do not feel hampered in the game.

This time we have restricted delay to 100 ms only, as an acceptable threshold value. Although we have found no influence of this network condition on players' experience in earlier test (subjective), we have observed a negative impact on completion time of the cooperative game (objective). Therefore, we assume that the same network quality will be perceived differently if the goal of the task is time dependent.

First we have analyzed the influence of different levels of jitter on the task completion time. A positive significant correlation (R^2 = 0.44, p = 0.002) has been found between jitter and the completion time. Furthermore, we have analyzed how different players perceived this degradation subjectively. We asked players to evaluate whether or not they perceived any influence of the given network condition on the time to accomplish the task. The server player has not perceived an increase of jitter as a degradation of his experience. At the same time we have observed an increase of jitter influence on client (high). Client (low) felt more affected than the server player, but in reality remained at the same level with exception of the highest level of jitter. While the jitter remained under 50 ms we have not observed a major difference between players exposed to different conditions.

We have asked players to rate the overall quality of the network condition for each level of jitter. It has been found that jitter does not substantially decrease player perception of the network quality for the server player and client (low). At the same time client (high) experiences a gradual decrease of network quality, which drops to a relative low when jitter reaches 50 ms. Moreover, in cases of very high jitter the difference between player perception is more noticeable.

Other data gathered through the questionnaire reflects an influence of jitter on the ability to efficiently coordinate joint actions, player enjoyment and frustration. We have observed that the server player's experience has not been affected by the jitter increase. Ratings given by client (high) are somewhat different, indicating a low yet growing negative influence of jitter. For client (low) we observe a relatively similar evaluation among four conditions, with the exception of the highest level of jitter. Again we observe a greater difference between the server player and players that experience jitter. The existence of this difference between the server player and affected players confirms our assumption that there is a clear negative influence of jitter, as it unbalances the gaming experience between players.

The obtained findings have proved that higher levels of jitter have a negative influence on player experience in cooperative games (i.e. LBP2). Besides a negative impact on the performance, it also results in an unbalanced experience between players. While the discrepancy between players (caused by different access technologies) remains relatively small with low jitter level, it grows significantly when jitter reaches 50 ms.

4 Discussion and Conclusion

Our studies have shown that cooperative games (i.e. Little Big Planet 2) which actively require interaction with other players are sensitive to the network quality, in particular to network delay and jitter. In our first study we analyzed the impact of delay on different factors of the gameplay. Based on the analysis provided in section 3.1 we conclude that delays up to 100 ms can be considered as acceptable for the game being used.

During our second study we have found that jitter has a negative influence on user performance, in particular on the task completion time. At the same time players have not perceived this influence as a degradation of their experience. Most given ratings indicated a very low negative impact. Nevertheless, we have observed a difference between ratings given by players who were not directly affected by the network jitter and players who experienced low or high jitter. The differences between affected and non-affected players have confirmed our expectation of the negative influence of jitter on the gaming experience. Jitter higher than 50 ms introduces a great discrepancy between responses given by impaired and unimpaired players.

With our study we made the first attempt to evaluate the influence of network quality on the cooperative games, which we based on Little Big Planet 2. Although we realize that the results obtained in our study may be game-dependent, we believe that they are applicable to other games involving similar types of interaction between players. Of course further analysis is absolutely necessary. Other aspects of cooperation as well as other cooperative games need to be analyzed.

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