

User Experience while playing Halo with network delay or loss

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Abstract-We report the results of several experiments that were performed to evaluate the impact that the network path characteristics have on multi-player Xbox games. We did not focus on the technical issues but on the user experience when trying to play under high delay or high packet loss conditions. Both, the subjective impression of the players and the objective performance (number of kills per game) were investigated. We found that for a Round Trip Time of 150 ms the performance decreased by about 50% while the perceived quality was still quite high. For packet loss the results were the opposite the perceived quality of the game play reduced much faster with increased loss than the actual kill rate. Games with over 500 ms delay and 4% packet loss were considered as un-playable.

I. INTRODUCTION

In recent years interactive network games have become more popular with Internet users and constitute an increasingly important component of the traffic seen on the Internet. Interactive game traffic has different characteristics to the WWW and e-mail traffic prevailing on the Internet today and therefore imposes different requirements on the underlying network.

Providing premium service to the increasing on-line gaming community could be a promising source of revenue for ISPs. To provide this service an ISP must have a knowledge of the traffic load offered by game traffic to the network as well as the upper bounds on network delay and packet loss that game players can tolerate to provision their networks accordingly.

Research has already started in both areas. [1] - [3] characterize traffic of different popular on-line games to provide a suitable traffic model to test existing or planned network designs for their ability to support game traffic. The effect of network delay on game play has been studied in [4] and [5].

Our work addresses both traffic characteristics [6][7] and user perception. We chose to investigate Halo, a very popular Xbox System Link game. Even though the system link feature has been designed to work only over LANs, several Ethernet-over-IP tunneling solutions are available to connect Xboxes over the Internet [8]-[10]. In addition the launch of Xbox Live allows Xboxes to be directly connected to the Internet without the use of tunneling [11]. This variety of different solution and the reported success of Xbox Live [12], give an indication that ISPs might observe a substantial amount of Xbox traffic over their networks and having a characterization

of this traffic as well as delay and loss bounds for player satisfaction will help them to provide better service to their customers.

II. EXPERIMENT SET-UP

A FreeBSD PC is used as an Ethernet bridge, with FreeBSD's kernel-resident "dumynet" functionality providing controllable network delay and packet loss. The server Xbox is connected to one interface of the bridge with a cross-connect cable. A hub is connected to the other bridge interface. The 3 Xbox clients are connected to the hub.

One-way delay is introduced by delaying the forwarding of bridged packets through the bridge for a specified amount of time. Different delay values can be used on the forward and the return link. Loss is introduced by dropping the received packets according to a set packet loss probability. A uniform distribution is used to determine if a packet is lost. Neither fixed delays nor uniform packet drop probabilities are very realistic models for the behavior of the Internet. However, they are sufficient for the purpose of studying the impact the delay and loss have on the gaming experience of users.

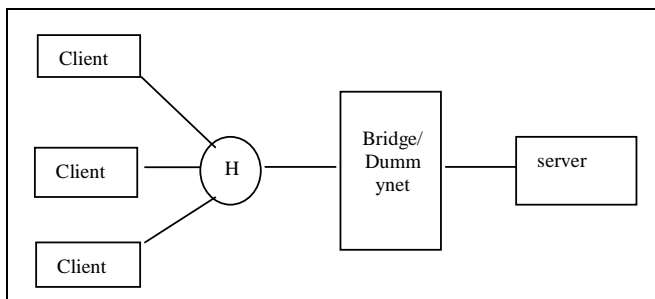


Figure 1: Experimental setup

III. DETERMINING PLAYABLE VALUE

Before setting up a test with multiple users we determined the delay and loss values up to which the game was still playable. The following observations were made during this trial:

- If the one way delay is above 230 ms a connection is never established
- Delays larger than 200 ms causes very noticeable lag

- If the delay is increased to more than 300 ms after a game begins, the game terminates within a short time
- If the packet loss rate is greater 10% a connection is never established
- Connection set-up can fail at a lower loss rate. Client Xboxes seem to send only one set-up packet to the server
- If the loss rate is greater 5% the game terminates after a short time
- Loss greater 1% causes the game to freeze for short periods

All actions are transmitted to the server before rendered on the screen (even if you shoot at a stone it will take one round trip time before the result is visible).

IV. IMPACT OF DELAY AND LOSS ON GAME PLAYING

To improve the statistical validity of our results we held 4 game playing sessions with the same 8 players. During each session 13 games with different loss or delay settings were played. The loss and delay settings were chosen randomly for each game from the following range of values:

Delay [ms]: 0, 50, 75, 100, 150, 200, 250

Loss [%]: 0, 1, 2, 3, 4

For each game a player recorded his/her number of kills and deaths (to evaluate the objective performance of the players), a quality indicator from 5 to 1 (5 representing excellent, 1 representing very poor) and if he/she would stay on or leave the game if he/she were actually participating in an Internet game session. During each game two players played on the Xbox acting as the server, and were not affected by the network loss and delay (as can be seen in the next section). After each game a different pair of players were moved onto the game server. The presented results are averages over all client player and all server players for the 4 game sessions.

A. Delay

The results for the games with varied delay are presented from Figure 2 to Figure 3 for players on the server as well as players on the clients. As expected the number of kills for the client players (Figure 2) decreases as soon as the delay increases. When a delay of 75 ms is reached, the average number of kills by a client player is reduced by about 50% (from an average of 8 kills per player to an average of 4 kills). After this initial sharp decrease, the average number of kills only decreased moderately with additional delay. The average kills per player connected to the server increases as the delay increases because the increasing lag that the client players suffer increases the server player's advantage over them.

Figure 3 presents the average number of deaths per player. The average number of deaths decreases for both server and client players as the delay increases. The decrease in deaths for the players connected to the server is sharper than the one for client players. For a delay of

75 ms the deaths per server player has decreased by 50% (from 8 to 4 deaths per player). This decrease is caused by the fact that client player will have a much harder time killing the server players, therefore the server players will mostly kill one another, decreasing the number of adversaries from 7 to 1. The number of deaths per client players also decreases as the delay increases. Client players will have a harder time killing other client players therefore client players will also mostly be killed by players connected to the server Xbox.

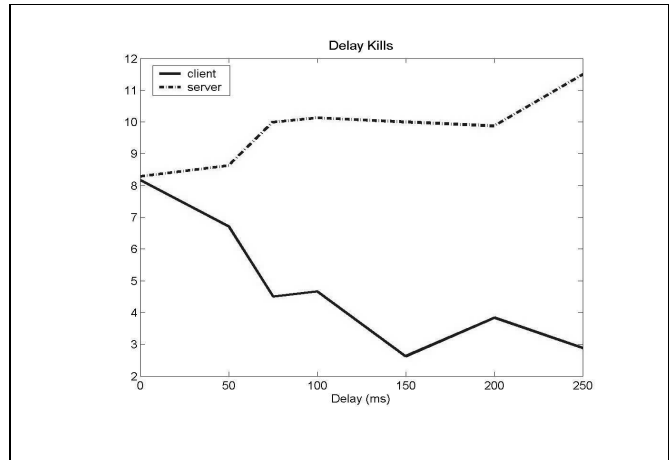


Figure 2: average kills per player for different delays

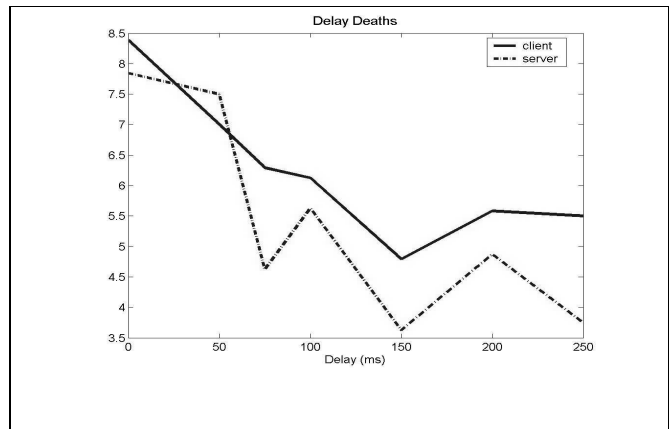


Figure 3: average deaths per player for different delays

Figure 4 and Figure 5 show the quality with which the player rated the game and the desire of the players to continue the game at the perceived quality level. Since server player are not affected by the delay their quality if always close to 5 and they never want to leave the game. The perceived quality (and desire to stay) for client players decreases quite clearly with the increase in delay.

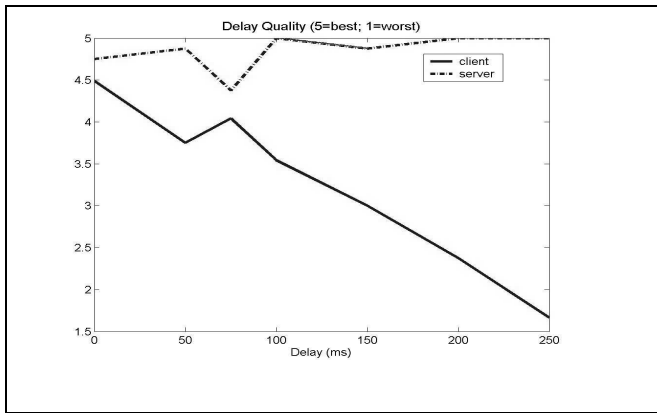


Figure 4: average quality perception per player for different delays

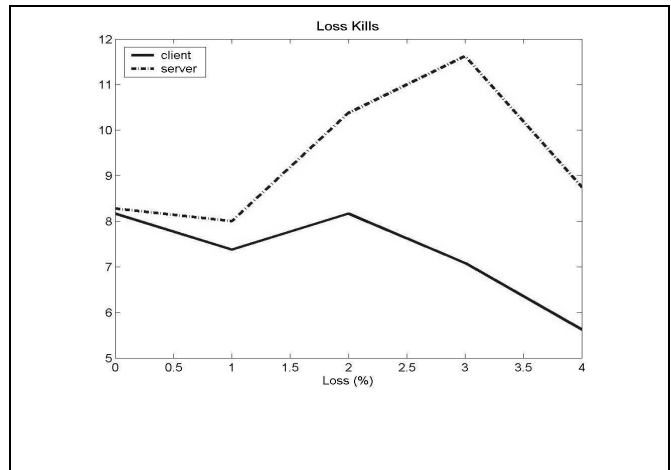


Figure 6: average kills per player for different loss probabilities

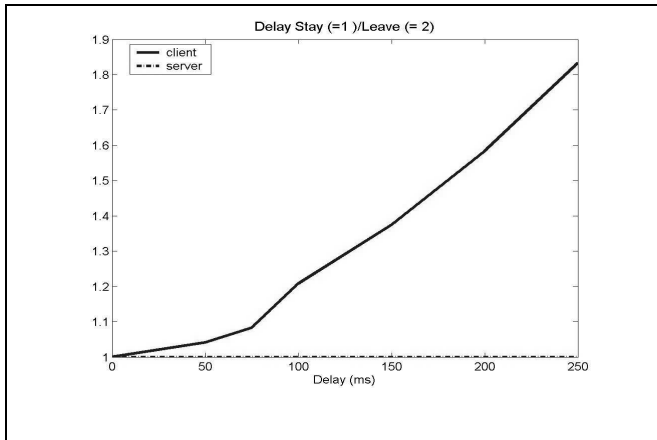


Figure 5: players wanting to stay in the game for different delays

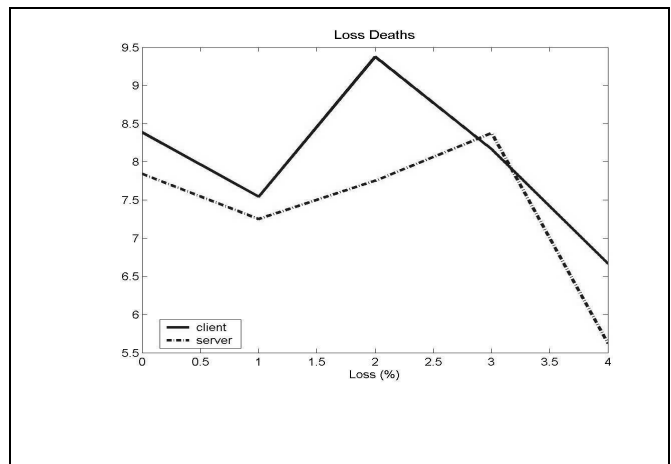


Figure 7: average deaths per player for different loss probabilities

B. Loss

The results for packet loss are quite different from those for increased delay. The average kills per server and client player are displayed in Figure 6. For packet loss rates from 0% to 2% the average kills per client player remains quite stable while the kills per server players increases moderately. From 2% to 3% packet loss, server player have a distinct advantage over players connected to the client Xboxes. Their average kills increases while the ones for client players decreases. Packet loss rates over 3% start to impact the game performance even on the server side because packets from the clients to the server get lost and the average kill per server player starts to decrease. This impact of packet losses greater than 3% on the server players is particularly visible in Figure 8 and Figure 9, which display the game quality and the desire to leave. From 3% there is a drop in the perceived quality for server players and they start to express a desire to leave the game.

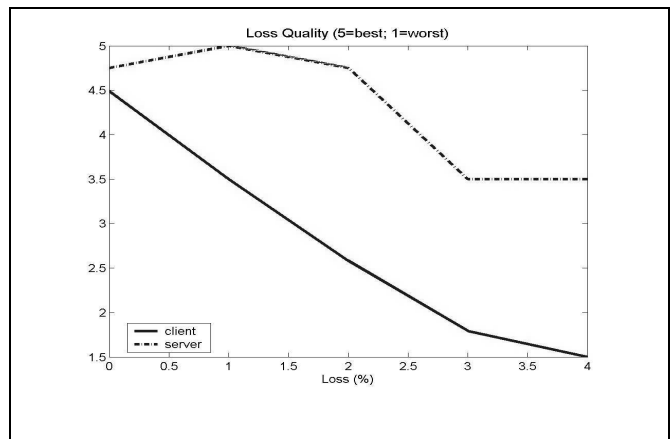


Figure 8: average quality perception per player for different loss probabilities

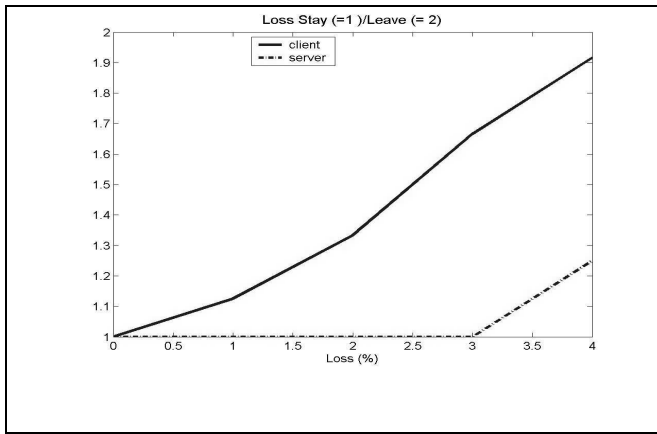


Figure 9: players wanting to stay in the game for different loss probabilities

V. CONCLUSIONS

We evaluated the impact of different network path characteristics (delay and packet loss) on the Xbox System Link game Halo. Even though this game was developed specifically for playing over LANs, different tunneling solutions enable the playing of System Link games over the Internet. The introduction of Xbox Live also opens up the possibility of similar games being played "natively" over the Internet.

During our investigation we found the delay and packet loss impact the game quite differently. Delay has no impact on players connecting on the server Xbox while the average kills as well as the subjective game quality per client players decreases almost linearly with increasing delay above 75 ms.

Packet loss impacts players on the server as well as players on the server however not as severely. Client players experience the negative impact of packet loss from about 2% in the objective performance measurements (average kills/deaths) while the subjective game quality decreases almost immediately with the introduction of packet loss. Server players are only impacted by packet losses higher than 3%.

As a next step we will repeat the same set of experiments with the Internet multi-player game Quake3 to determine if games specifically developed for the Internet give better performance over network paths with delay or loss characteristics.

VI. ACKNOWLEDGMENTS

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