



# Online Gaming Lag:

Definition and Causes with Case Studies

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### **Definition and Causes with Case Studies**

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Online Gaming has evolved from the simple days of the dial-up modem (a major bottleneck), to the new world of cable and DSL modems and even Ethernet to the home. As broadband internet access becomes more and more prolific, we must look again at what is causing the dreaded 'Lag monster' to interfere with the online gaming experience.

This paper will first explore what is Lag in today's gaming world; what is a fair definition? Lag will be defined as one or more of the following in-game events:

- Game Freezing and Stuttering
- Warping and Rubber-banding
- Ghosting and Vanishing
- Slash-Slash-Pause
- Delayed Responses
- Frames-per-Second Loss

After Lag and the above terms are defined clearly, this white paper will discuss what the causes of Lag are in today's internet system using broadband connections of the above phenomenon. The causes will be clearly shown as:

- Server Slowness/Congestion
- Internet Packet Loss/Spikes
- Client Slowness
- Network Latency

Several case studies and research will be used to illustrate the concepts explored here. The case studies will include:

- Sony Everquest Client Test
- Sony Star Wars Galaxies Client Test
- Star Wars Battlefront Client+Server Test
- Battlefield: Vietnam Client+Server Test
- Counterstrike Source Client+Server Test

Finally, the obvious question would be what can be done about Lag? Bigfoot Networks, Inc., founded in Nov. 2004, is hard at work on the products and services that will solve the Lag problems of today.

It would be remiss not to mention some of the contributors to this paper and case studies, and the references section below gives credit to contributors.

### **Defining Lag**

Lag has no definition. It is a slang term that online gamers have been using since the early days of online gaming to represent anything 'funky' going on in an online game. Today, anything bad that happens in an online game is called Lag.

***Lag could be loosely defined today as everything bad that happens in an online game. It's become like an online curse word.***

Webster's defines Lag as "v. to fail to keep up a pace; straggle," but this definition does not explain the phenomenon previously

described. Lag could be loosely defined today as everything bad that happens in an online game. It's become like an online curse word.

The only way then, to define Lag, is by looking at those perceived events which gamers attribute to Lag. Those events vary in type and cause, but they are collectively called Lag.

First among these perceived events are the movement or action related events. Game Freezing, Game Stuttering, Warping, and Rubber-banding are terms commonly associated with movement or action based Lag events. Game Freezing occurs when the game appears to suddenly pause for no reason, then after some perceivable time, resume. Game Stuttering is the same as Game Freezing, but happens in rapid succession one right after another. Warping is a movement action whether 3<sup>rd</sup> person or 1<sup>st</sup> person perspective, where the character or persona is suddenly in a new position on the screen/in the game world than was expected. When the warping is back to a location that the gamer believed he just left, it is called Rubber-banding.

The next category of Lag is those events where other users or computer controlled characters exhibit strange perceived behaviour. Ghosting, Vanishing, and Slash-Slash-Pause fall into this category. Ghosting is when the user or computer character is experiencing warping in front of your own eyes, appearing to ghost walk or jump from place to place. Vanishing is the extreme form of Ghosting where the user or character simply vanishes before your eyes. The user or character moved out of your field of view in one big ghosting jump. Slash-Slash-Pause is that effect where an action has occurred on a screen towards another user or computer controlled character, but the results of that action are still waiting to be seen. It is so-called Slash-Slash-Pause because many online games

are 'fantasy' based, and fantasy games use a sword for combat saw this often, your sword would strike repeatedly, but did your attack succeed was not known for some perceivable delay. This term is still used, but applies to all sorts of game types, including firing bullets, driving a race-car, or flying a space-cruiser: a more general term would be delayed response. It is important to note here that this category of Lag has become much less frequent in the broadband world. However, when it occurs, it is much more obvious and out of the ordinary, and therefore, undesirable.

always the Slash-Slash-Pause type, because network Latency dominated the problem. Information simply

The last category of perceivable events is those events which are simply artefacts of low frames-per-second (FPS). Gamers call it Lag when they enter a new Game Zone with new textures that have to load. Gamers call it Lag when there are many users in view and as a result many custom textures to display simultaneously. Gamers call it Lag when they move their mouse faster than their PC can keep up with the experience in the game. It is Lag when new players enter the game view and the screen has to display the animation. In general, when the game is running slower frames-per-second than the gamer is used to; it is called Lag. Lag and frames-per-second have become inexorably linked.

Throughout this definition of Lag, the concept of perception has been at the forefront. If the user does not perceive the Lag, then it does not exist. It is this fundamental realization that allows for not only the definition of Lag, but also the measurement.

Bigfoot Networks, Inc. has defined a new metric, Lags-per-Minute, which is the number of perceived Lag events per minute that a user is experiencing. This number will vary by user, but focusing on those events we have described thus far, enables the possibility of measurement. For some games where Lag is hardest to see, this metric is measured hourly and then divided by 60, giving a fraction of a Lag-per-Minute. Other games and configurations, however, can yield as many as 10 Lags-per-Minute, as perceived some very discerning (hardcore) gamers.

### ***he Causes of Lag***

In the days of dial-up modems, everybody knew what Lag was caused by: it was caused by Latency. A Dial-Up modem had to convert packets into bits, which were slowly transmitted across phone lines, converted back into packets, and finally let loose onto the Internet. During the dial-up days, Lag was almost

When playing 'online' (rather than in a LAN environment), the bandwidth available to your broadband connection can easily become saturated as users connect to your server. So, while in a twitch game, the server is one of the causes of Lag. It's actually the bandwidth to the server rather than the processing like in an MMOG that causes the Lag.

The final cause of Lag that this paper will explore is client slowness. While there are a few other minor causes, these three causes of Lag constitute the majority of the problem causes of Lag today. Client slowness is a large cause of Lag because it entails anything that is happening in your PC to cause a slower than expected experience. Today's PC systems are typically CPU limited, BUS limited, or HARD DRIVE limited. CPU limited is the most common today, because of the massive amounts of processing and 'data-moving' required in modern games. All that data has to get to the graphics processing unit (GPU) somehow, and all too often, the CPU is busy moving data from one place to another. This cause of Lag is usually associated with a loss in frames-per-second, but where more GPU horse-power would not really help.

In summary, Lag has four main causes, one of which is becoming less and less of an issue. Network delay (or latency) is the one cause that has shrunk to an imperceptible level. But latency spikes due to packet loss and other causes remains a significant cause of Lag. The biggest cause of Lag is server congestion/slowness whether by CPU limit or bandwidth limit. And finally, client slowness due to non-GPU related system limitations also contribute to Lag.

## **C se St dies Me s re ent nd C se**

Bigfoot Networks, Inc.'s new metric (Lags-per-Minute) has been tested against some of today's biggest game titles. The test setups included the use of three tools: a visual task manager, a popular networking tracing tool, and a human gamer. The client system used was a Dell XPS4 gamer desktop machine configured with a 256MB Geforce 6800 16x PCI-E graphics card and sporting a 3.4Ghz Pentium 4 HT, 1 GB of RAM, and 160GB of Raid 0 SATA 10,000RPM hard drives. A cable modem broadband connection was also used at the client.

The first game tested was the Everquest Client. In this test, there was obvious Game Stuttering during a shopping spree in a city environment. During the 1-hour of play, about 6 Freezes also occurred. The Freezing was clearly attributable to packet-loss events.

It is clear because the time of the apparent game freeze was the same time that a packet-loss event occurred in the internet trace. The stuttering, which only seemed to occur in the city, was not attributable to the client CPU trace or the internet trace; and without a trace on the Everquest server CPU, we can only infer that the server was the bottleneck. Some ghosting was also evident, but not attributable to client CPU or network tracing. Everquest scored a very respectable 3 Lags-per-Minute, mostly the result of being in the city.

During the Star Wars Galaxies test, we were again required to measure only at the game client. The results were similar to Everquest, but with much more obvious warping and rubber-banding. In fact, the game froze for over 1 second at one point where the 'dancer' character was searching for a trainer. This freezing was not client or packet-loss related, so the server cause is inferred.

Other 'in-city' experiences where there were many users in the field of view, correlated to both FPS and (presumably) server lag. The FPS (which was displayed) dipped low when drawing the custom clothing and objects for the many users in the field of view. This most likely is the result of hard drive limitations and/or CPU limitations trying to load too many custom objects. The CPU meter was near 100% during these scenes. When standing still, the CPU utilization dropped dramatically, but there was still obvious ghosting and vanishing with the users in the field of view. This can only be ascribed to the server in some way (either server bandwidth or server CPU load).

Star Wars Galaxies also suffered from some Slash-Slash-Pause effects. While fighting one rat-like creature in open plains, the blaster fired and appeared to score a hit, but there was noticeable delay before the 'death' animation was played. This animation delay was attributed to packet-loss in the network trace. Star Wars Galaxies scored 9 Lags-per-Minute, and suffered worst when in the city, but did also have some problems with death-animation lag.

Star Wars Battlefront and Battlefield: Vietnam use the same game engine, but Battlefront ran slightly smoother than Vietnam. The results were very similar for the two games, and for these games, the server was actually hosted on a DSL modem where the CPU utilization could be measured. With access to the game server, we were able to finally measure server CPU utilization and bandwidth as well as client CPU utilization and bandwidth. These games suffered from FPS loss several times when there was the most activity on the screen. It was clearly client CPU utilization hitting its maximum while rendering many

***The Freezing [in Everquest] was clearly attributable to packet-loss events by correlating the time of the apparent game freeze with the internet trace.***

different users and NPC graphics and animations simultaneously. Interestingly, there was no evidence of ghosting or vanishing during the testing of these games. This could be attributable to some very fine programming where extrapolation techniques were being employed in the game engine. Battlefield and Battlefield: Vietnam each scored about 0.6 Las-per-Minute.

Finally, while playing Half-Life 2's CounterStrike Source Mod, the most obvious effects of Lag were delayed responses, warping, and FPS. Warping was most evident when there were many users displayed at the same time. The warping, when correlated, was the result of a bandwidth limitation on

playing an online game. “Most non-gamers don't realize how big a problem Lag is to online gamers,” says Harlan, “However, the gamers know it, the game developers know it, and our investors know it.”

When not working or playing with son Christopher, you are likely to find Harlan at his ranch tending to his horses, playing online games, or tinkering with his multimedia room.

### **More nfor tion**

Harlan Beverly is the President and CEO of Bigfoot Networks, Inc. Bigfoot Networks is working to develop products that address today's lag problems in innovative new ways. He can be contacted as follows:

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### **References**

Below are the references used throughout the paper and also as background research. Special thanks to the members of the Mud-Dev developer lists<sup>6</sup> and Gamedev.com<sup>7</sup> forum.

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