

# Gaming Network Delays Investigation and Collection of Very Large-Scale Data Sets

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**Abstract**—The WTFast’s Gamers Private Network (GPN<sup>®</sup>) is a client/server solution that makes online games faster. GPN<sup>®</sup> connects online video-game players with a common game service across a wide-area network. Online games are interactive competitions by individual players who compete in a virtual environment. Response time, latency and its predictability are keys to GPN<sup>®</sup> success and runs against the vast complexity of internet-wide systems.

We have built an experimental network of virtualized GPN<sup>®</sup> components so as to carefully measure the statistics of latency for distributed Minecraft games and to do so in a controlled laboratory environment. This has led to a better understanding of the coupling between parameters such as: the number of players, the subset of players that are idle or active, the volume of packets exchanged, the size of packets, latency to and from the game servers, and time-series for most of those parameters.

In this paper we investigate specific game traffic connection types and show how we could collect very large-scale data sets of gaming metadata to control gaming network performance in real time. Such investigation and conducted experimentations will improve quality of service for GPN<sup>®</sup> systems and their reliability.

## I. INTRODUCTION

The “GPNPerf” (2014-2015) project has built a laboratory version of a Games Private Network<sup>®</sup> that is used for extensive and controlled-environment experiments to investigate the conditions of low and stable latency in online games. Experiments conducted since 2014 with the Minecraft network game have produced an ever-increasing quantity, quality and variety of measurements.

Our key objective is to understand the evolution of network traffic volume, latency of network + game server responses and game server CPU loads. Those target variables are measured against a mixture of:

- Time (as time series in minutes or seconds)
- Number of server VMs
- Number of physical cores/CPU’s to run the servers
- Number of human game players
- Number of artificial (bot) game players
- Game-idleness or action of the players

Initial analysis published in 2015 led to the explanation of most measurement’s average and standard-deviation values. Precisely because our experiments are controlled, the measured time-series are constant or almost flat lines with a degree of noise that accounts for standard deviations of a few percent to 10% or 20%. The possible variation in game environment and server configuration are not mixed within those

measurements but rather explored with multiple experiments, each one having a fixed environment and server configuration. This allows mapping the multi-dimensional space of game evolutions in a rational manner.

We are now building a better understanding of this space with a mathematical model of all the experiment variables and will continue to enrich it so as to cover the full variety of game situations for realistic network optimization. One experimental dimension that cannot be covered by our laboratory network is internet-scale measurements. To compensate for that lack of scale, the “GPNPerf2” project (2016-2019) will design, implement and use a mathematical simulation of very-large-scale game networks. To this end we introduce in this paper the model elements that will allow us to simulate hundreds of thousands of players, served by hundreds of thousands of game servers in realistic game simulations. Parallel computing, numerical modelling and symbolic computation will all be applied towards this end.

Once the model is completely implemented it will lead to the exploration of specific scenarios and in particular those that lead to server crashes or network overload (unlikely with games but important for general applications). The model and its simulations will thus become an experimental bench for characterizing DoS-prone situations and allow internet applications to have a database of “situation signatures” to enable alert capabilities and better reaction times. This project objective is thus to have game networks serve the general benefit of internet reliability.

## II. SPECIFIC GAME TRAFFIC CONNECTION TYPES

A core concern of GPNPerf2 is the analysis of GPN traffic to characterize the statistical- and time variation of message latency. This parameter is both the hearth of WTFast's business model and the key qualify feature of games networks. Indeed Saldana and Suznjevic [Saldana2015] *QoE and Latency Issues in Networked Games* have summarized existing litterature that, among other things, hilights the insensitivity of most online games to bandwidth while confirming that latency is critical to most games except perhaps games of strategy.

In the rest of this section we summarize those concepts and results of [Saldana2015] that define precise measurement and modeling objectives for GPNPerf2.

### a) Game genres i.e. types of online games:

- First Person shooters (FPS). Games such as *Call of Duty* where the user sees himself as an armed warrior evolving alone or among a team of a few dozen members to eliminate virtual enemies. Average time between firing and death of the enemy is about 161ms for the most popular FPS games. Studies have confirmed that such games require very low latencies.
- Massively Multiplayer Online Role Playing Games (MMORPG) are games where thousands of players, merge with artificial entities into a complex virtual world. They cooperate or fight each other so that, (simulated) firearm exchanges happen and put a constraint on latency as in FPS games but at a lesser frequency by the nature of the game. The element of tactics is also important in such games so virtual-world coherence is critical.
- Real Time Strategy (RTS) games where a dozen players share a virtual worlds where they build "civilizations" i.e. geometric and slowly-dynamic structures.
- Multiplayer Online Battle Arena (MOBA) games, a special-case of RTS where two teams try to conquer a battlefield.
- Sports games that simulate car racing or team sports. In vehicle racing it is possible that latency can be critical while team- or other realistic sports involve the simulation of balls, running humans and other objects that are very slow relative to the "firearms" and "bullets" of FPS games.

[Saldana2015] quote existing surveys that for FPS games, a one-way delay of 80ms can be acceptable for most game users. Low latency convinces users to join the game, which confirms its importance for game-related business that is aimed at latency-reduction or latency-stabilization.

For MMORPG games, players started rating the game quality from "excellent" to "good" when one-way latency raised above 120ms. When it rose further above 150ms up to 200ms, players started leaving their game sessions. The same phenomenon has been observed when latency in RTS games rose from 200ms to 500ms.

Studies have also shown that experienced players are more sensitive to those factors than ordinary players.

b) *Connection Types*: Network games are implemented with a variety of network connection types. Known connection types are the following.

c) *Geographical location*: Geographical location of servers is correlated with latency for obvious reasons of transmission delays. Many games report the geographical location of their servers so players connect to the closest ones.

Open questions for GPNPerf2 and for WTFast:

- How does player-server geographical distance correlate with message latency and its variance ?
- Is the length of traceroutes between client and server and additional element of message latency/variance ? In other words: does it matter if a given geographical distance is covered by a single transmission or by a multiple-forwarding transmission ? If so, how much ?
- Are the time-series of latency measurements dependent on geographical location ?

Mapping IP addresses to geographical location is necessary for experimental and mathematical investigation of the above questions.

d) *Latency reduction*: Once empirical and mathematical tools are built to analyze and predict message latency and its variance, the results will be used to predict human- and business-effects in various games. For example player QoE in specific situations defined by combinations of the above factors (game genres, connection types, etc). In turn, the effect of this perceived or real QoE can be correlated to game session durations, popularity of the game service etc, and in the end of business objectives and economic factors for game players and GPN providers.

Once this analysis is put in place it will be natural to apply latency-reduction techniques such as *zoning* and *mirroring*. Zoning partitions the virtual world into geographical areas called zones, handled independently by separate machines. Mirroring, targets parallelization of game sessions with a large density of players located and interacting within each others geographical vicinity.

### e) *Quality of Enhancements (QoE)*:

- Table ??: Scalability

### Methods to enhance QoE

#### Scalability:

Logical Sharding: A virtual world spans over multiple servers.

Sharding: Multiple instances of seperate but identical virtual servers.

Zoning: Seperable locations in a virtual world are handled by different servers.

Mirroring: Distributes a zone load by replicating the zone on multiple servers. The state of a subset of active entities is calculated by each participating server and communicated between servers.

Instancing: Sharding on a smaller(zone) level.

## III. EXISTING WORKS

Predictable and sub-second response time has long been a key concern for interactive computer systems [1]. For a

TABLE I  
ONLINE GAME SYSTEM ARCHITECTURES [?]

Peer-to-Peer	Peer-to-Peer (P2P) systems where game players interact directly with each other. They have not been very popular in recent systems.
ClientServer	Client-Server systems where a set of logically central servers store the game state and provide most operations except player interaction and complex view rendering (in a local client). This architecture has been very popular recently.
P2PClientServerHybrid	Peer-to-peer\Client-Server hybrid (lockstep) Hybrid types of implementations.
CloudGaming	Cloud Gaming where the client is a very thin piece of software are almost all functions are realized by the server. Like all cloud platforms, services or software, its advantages are in easy deployment, no installation for the players etc. But its disadvantages lie in heavier computation and communication. [Saldana2015] quote bandwidth requirements multiplied by 10 to 1000 for cloud games by comparion with traditional client-server games.

TABLE II  
NETWORK GAME SCALING

Peer-to-Peer	Connection Type: TCP or UDP QoE considerations: No server authority (cheating/hacking). No hardware considerations for game developer. Game Example(s): StarCraft 1 (1998) Game Genre(s): RTS
Client-Server	Connection Type: TCP or UDP Description: Clients synchronize to a single source which propogates the synchronization outwards. QoE considerations: Central server authority for anti-cheating, pay-gate, etc. Ability to deploy dedicated servers if included with game (LAN parties w/ low latency). Individual players game-client may also act as server (Game interruption if player leaves). Game Example(s): Counter Strike, Warcr aft 3, Call of duty, Minecraft Game Genre(s): FPS, MMORPG, Sandbox
Cloud Gaming	Description: Game logic and virtual world rendering occure server-side and a video stream is sent to the client. The client only sends commands to the server. Game Example(s): Playstation Now Game Genre(s): Game Streaming service

majority of video games this is an obvious requirement that modern hardware has satisfied, despite a continuous rise in graphics and interaction quality. A *video game network* is a distributed set of “apparatus which are capable of exhibiting an interactive single identity game”, as defined in a patent dated 1986 [2]. The requirements for response time are even more stringent in this context and in addition to inevitable network latencies, “the on-line service’s computers themselves introduce latencies, typically increasing as the number of active users increases” [3]. The work described here is an experimental analysis of the conditions for satisfying this key requirement, namely low and predictable response time for a game network faced with a scalable number of players.

The last decade had seen a growing interest in tackling this problem. Some researchers like Iimura, Jardine and co-authors have proposed peer-to-peer architectures for multiplayer online video games [4], [5], this with the intention of reducing the bandwidth and processing requirements on servers. This can in theory provide better scaling but “opens the game to additional cheating, since players are responsible for distributing events and storing state”. Pellegrino et al. [6] have then proposed a hybrid architecture called P2P with central arbiter. The bandwidth requirements on the arbiter are lower than the server of a

centralized architecture. Like many non-functional properties of online services (security, scalability, reliability etc.) the choice between centralization and distribution is not one that can be given a definitive answer. Our work concentrates on a logically centralized architecture, its potential for predictability and scalability of the server and router (“arbiter”) performance. Other work [7] has studied the same performance problems in the presence of mobile player nodes. Despite its clear importance for the future, this line of study appears even less mature than the P2P approach.

Zhou, Miller, and Bassilious [8] have made the obvious but central observation that “Internet delay is important for FPS games because it can determine who wins or loses a game.” Many game mechanics are time sensitive, but it is the time the information reaches the server that matters, not the time the player actually pushes the button. Our experiments measure packet size and inter-packet times or traffic volume as they have in their statistical model. Those authors’ investigation also took into account the effects of other Internet traffic. But our study will exclude those effects precisely because we wish to isolate the scalability and load-resistance of the server and routing modules.

Claypool and Claypool [9] have observed that Internet latency’s effect is strongest for games with a first-person

perspective and a changing model. The work we describe here takes this into account by experimenting with the game Minecraft, which is first-person and has changing game environments.

More recent studies [10], [11] of first-person shooter games have modeled time series behaviour of game traffic and tested the model on up to eight different games. According to our previous comment, such a comparative study would not have allowed us to get very stable load measurements, hence our choice of a single first-person game. Indeed the study of Wu, Huang and Zhang [12] shows that “the server-generated traffic has a tight relationship with specific game design”, again from our point of view confirming the need for precise measurements of a given architecture on a single game. Hariri et al. go even further in this line of thought by designing a model of the player’s activity to extract traffic patterns [13]. Such a representation is beyond the scope of this paper but is certainly relevant and its combination with our conclusions should be the object of future work.

“A study of different first-person games shows that the client traffic is characterized by an almost constant packet and data rate” [14]. The study found that “the average interpacket time for client to server traffic to be 51ms for the game being studied”. Our new bot can send the action packets at 50ms intervals [15].

Our research mostly concentrates on the servers’ performance optimization, additionally to the network traffic analysis [16] and design and implementation of the custom bot for Minecraft [15]. As it was shown in [17] the “bottleneck in the server is both game-related as well as network-related processing (about 50%-50%)”. In our research we investigated the highest possible workload for the CentOS 6.5 virtual server by utilizing our custom based bot for Minecraft.

Some authors discuss interactive online games, especially ones related to the “first person shooter (FPS)” [10], [11] and network traffic for such games [8]. They investigate network impact on the games and realistic traffic generators. In our infrastructure our aim was not just to emulate 2 or 3 players, but 100 and even 1000 and more players. This is important for gaming companies, because as it is shown in [13] online games become major contributors to Internet traffic. Latency is the another challenge for online games, as it’s reported in [9], [6] and [18] and it’s an important factor of an online gaming experience. We built our infrastructure to emulate artificial latencies in the emulated traffic [16]. In [5] “massively multiplayer online games with a client-server architectures and peer-to-peer game architectures” are investigated. The authors developed a hybrid game architecture to reduce game server bandwidth. In [4] authors even proposed to implement a zoned federation model for the multi-player online games trying to reduce workloads of the centralized authoritative game servers. A US 5956485 patent [3] describes how to link multiple remote players of real-time games on a conferenced telephone line, which could reduce latency for the game players.

In the technical report from IBM [1] it was demonstrated

that “rapid system response time, ultimately reaching subsecond values and implemented with adequate system support, offers the promise of substantial improvements in user productivity” and it’s even better to “implement subsecond system response for their own online systems”. They mentioned that not so many online computer systems are well balanced. They divided system response time for two large groups: computer response time and communication time, which are both critical for the game players user experience as well.

In [7] the authors discuss online multiplayer gaming issues in wireless networks, which is an additional problem related to the game players experience on the Internet. These issues are not covered in the current paper. On the other hand, we experienced packet loss in our infrastructure too. In paper [12] the authors investigated a multiplayer on-line game traffic including modelling traffic in mobile networks.

#### IV. COLLECTOR

The GPERF2 project requires collecting a large scale of data from upwards of 400,000 client’s gaming sessions in order to statistically analyze their network performance. Using the open source programming language golang, a data collection web application (named Collector), was constructed that is able to accept a vast number of rapid incoming connections. The collector will then transmit some amount of data to a data store before disconnecting. This operational information from clients, would first be authenticated by the Collector and then at some point bulk transmitted to some form of data store as was possible. Experiments were conducted as to the best way to create and tear down connections to achieve the optimal cross between the greatest number of connections and the greatest volume of data processed in the future. The goal is for the collector to be able to handle at least one million connections per second.

The Collector server generates a number of workers which listen for incoming TLS connections. When a worker receives a request it uses a multiplexed handler function to authenticate the data packet, extracts the information, generates a job object using the extracted information, and adds the new job object to the job channel. The job channel is a queue from which objects are processed and inserted into a bulk Elasticsearch processor which finally sends a bulk packet of data to a data store. The server also regularly prints updates on the screen with the number of connections processed, the incoming connection’s host and IP address as well as the target Elasticsearch index.

The server has a configuration file that contains general server operations, profiling options, and Elasticsearch options. The general server operations involve opening a specific port, maximum packet size and connection keep alive options. The profiling options determine the type of profiling the application will record which include memory, cpu and blocking. Elasticsearch options regard functionality of the Elasticsearch processor and the IP address of the Elasticsearch server location. Other configuration variables determine the number of workers and jobs the server will be able to handle.

The server has three changeable variables which vary the server's capacity that can be found at the top of the main function. `MaxQueueSize` sets the number of jobs that the job channel can hold. `MaxWorkers` dictates the number of workers that are generated to listen for connections. The more workers there are the more connections that can be handled in a shorter period of time; however, adding more workers will quickly consume more resources.

## V. FRAMEWORK BENCHMARKING

The Collector uses Aliaksandr Valialkin's `fasthttp`, an implementation of a `http` platform/framework. In determining the framework we'd utilize, we investigated different technologies and their current real world benchmark results. The initial performance comparison comes from TechEmpower (needs citation), an online organization that performs a standard benchmark test on web frameworks. Their round 12 tests, which occurred February 25th of 2016, were hosted on a static environment that was created according to best practices and community input. Each instance of the framework is implemented and goes through standard tests which are then compared to each other.

The tests we are directly interested in are related to data updates to a database. TechEmpower's benchmark tests use `wrk`, a load simulator, to send a request packet containing 20 updates at a rate limited only by the infrastructure and framework. `Fasthttp` connecting to `postgresql` was able to handle 3,959 requests over a 15 seconds. The requests had an average latency of 62.9 ms, standard deviation of 62.3 ms and a maximum of 893.7 ms.

## VI. CONCLUSION

In this work we have built the elements and general structure of a mathematical performance model of GPN latency time-series in the presence of a variety of hardware-player configurations. Human vs artificial players are covered, scalability with the number of players, virtualization of game servers is also modelled with its (limited) scalability and effect on latency. Elementary aspects of the game-state have begun to be explored for their effect on latency: the presence of animals, idleness of players etc. Finally, the computational cost of numerically computing the model has been estimated. This provides an initial estimate of its application to very-large scale simulations.

The GPNPerf project aims at a deep understanding of game network latency. It appears natural not to consider bandwidth saturation effects for online games are not as heavy in traffic consumption as video streaming, data streaming for example. In all our experiments the amount of traffic was very low compared with the overall bandwidth of the network equipment. The only overload that could be measured is the computational load (CPU monitoring levels) on the game servers. That is being measured precisely and modeled mathematically. But currently game traffic never overloads the experimental network bandwidth and in practice never overloads internet bandwidth. Any configuration where bandwidth becomes a

bottleneck is likely to correspond to a very degraded state of services. This is either beyond the scope of our research, or will be precisely estimated once our large-scale simulations are operational.

Our ultimate goal of a lab simulator for internet-scale GPN is now a little closer. Remaining work on the way contains at least the following elements:

- Extensive statistical testing of the time-series and of all aspects of the model.
- More realistic bots with game-state models and their lightweight simulation.
- Design of various game scenarios and system configurations to be simulated in the very-large internet scale.
- Choice of pseudo-random number generators with very long periods: to avoid simulation bias that is invisible at small scale but important for very-large simulations.
- Choice of the resulting trace, visualization or statistics to be produced out of each simulation for interpreting its result.

A general long-term question to investigate: is large-scale GPN simulation similar to weather prediction or more like the stock exchange? The former is chaotic but follows general laws while the latter is unpredictable beyond the near future or global tendencies.

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TABLE III  
TECHEMPOWER TEST ENVIRONMENT

Hardware	<b>Dell R720xd dual Xeon E5-2660 v2</b> (40 HT cores) with 32 GB memory; database servers equipped with SSDs in RAID; switched 10-gigabit Ethernet <b>i7: Sandy Bridge</b> Core i7-2600K workstations with 8 GB memory (early 2011 vintage); database server equipped with Samsung 840 Pro SSD; switched gigabit Ethernet <b>EC2: Amazon EC2 c3</b> large instances (2 vCPU each); switched gigabit Ethernet (m1.large was used through Round 9)
Operating System	Ubuntu Linux 12.04 64-bit Windows Server 2012 64-bit
Databases	MySQL MongoDB PostgreSQL
Load Simulator	Wrk
Tests	JSON serialization Single query Multiple queries Fortunes Data updates Plaintext

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