

# Looking Into Online Gaming From Measurement Perspective

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**Abstract**—Owing to the development of computing hardware and networking related technologies, online gaming has become an important entertainment format for people of all ages. Understanding the system architecture and game players' behavior can benefit the users' Quality of Experience (QoE) optimization, the game competitiveness enhancement, and even a new game deployment. To this end, many attentions have been paid to the online game measurements. In this paper, we investigate the development of online games and look into the online gaming from the perspective of measurements, including the system architecture, users' QoE, and the user behaviour. We hope the work can benefit the game system design and optimization in the future.

**Index Terms**—online game, network measurement, measuring methods

## I. INTRODUCTION

Ever since SpaceWar was wrote in 1969, online games have evolved and become more and more popular. According to Sandvine, the amount of game traffic represents up to 7.78% of the current Internet traffic, 2.68% increase over last year [1]. Online gaming has a large market with 40 billion dollars [2]. What's more, due to the competitiveness brought to players and the taking up of time fragmentation feature, the number of active game users is growing quickly over the last few years. As illustrated in Fig.1, the number of monthly active users for *League of Legends (LoL)* reached 100 million in the year 2016, and keeps growing rapidly [3].

With the development of online gaming, there are several other significant landmarks. In 2004, a famous Massively Multiplayer Online Role-Playing Game (MMORPG) *World of Warcraft (WoW)* [4] brought millions of players simultaneously into the fantasy game world. And the version 8.1 of the WoW was released by Blizzard Entertainment Incorporation 14 years later. In year 2017, a Massive Multiplayer Online First Person Shooting (MMOFPS) game *PLAYERUNKNOWN'S BATTLEGROUNDS (PUBG)* [5] made the shortest record of early access to the steam platform with sales of one million units in 16 days. In 2018, the MOBA (Multiplayer Online Battle Arena) game *LoL* [6] takes up 51.53% of gaming connections among the top 100 online games [1].

However, we've also witnessed the boom and recession of many online games. A game often fails if its architecture is designed unreasonably or it ignores users' behaviors. To achieve a great success, lots of work focus on the measurement of online games, including the game structure and users' behaviors. These measurements can benefit the users' Quality

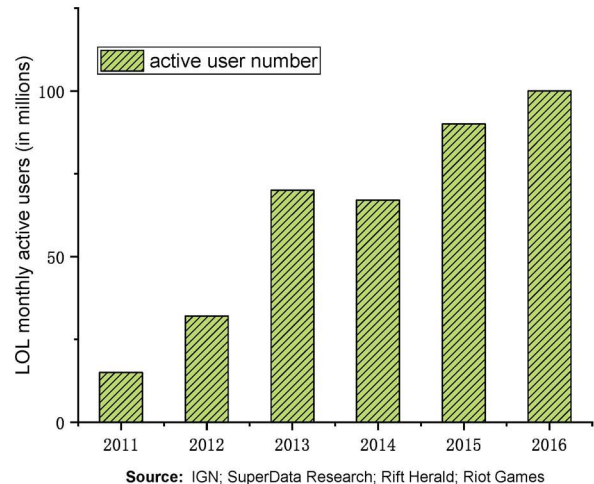


Fig. 1: The average number of monthly active users in the past decade for LoL. [3]

of Experience (QoE) optimization, the game competitiveness enhancement, and even a new game deployment. In detail, these works dug deeper into the game operation mechanisms or collected game data for simulation.

In this paper, we look into the online games from the perspective of measurement. From the development history of online games, it can be concluded that online games are moving towards high image quality and high frame rate, or supporting more players at the same time. And a potential direction for online game is towards to cloud gaming, which can free game players from expensive end-devices. To understand key principles of online gaming system, such as the architecture and user behaviors, many efforts have been devoted to the online game measurements. These works can be classified into white-box measurements and black-box measurements. With the success in mobile and cloud technologies, the gaming system will be more robust, fair, extensible, attracting and inevitably more intricacy.

The remaining contents of this paper are organized as follows: In section II, we summarize the development history. In section III, the methods used to measure the online gaming system will be elaborated. In section IV, we will survey the measurements done from several aspects, architectures, quality of experience and user behaviors. In section V, attention was

paid to the remaining problems and the future. In section VI, we finally conclude this paper.

## II. DEVELOPMENT OF ONLINE GAMING

In the past four decades, online games have evolved into a variety of forms across different platforms. On one hand, the computational capacity of computer hardware has been greatly improved, making it possible for online games with more delicate pictures and complex settings. On the other hand, the Internet has achieved great success, making it possible to reach real-time interacting experience.

The earliest online game dated back to the 1970s. At that time, the online games were based on the multi-user dungeon (MUD) system, which is transmitted in the packet-based computer networking and usually text-based. Then the commercial graphical games began growing in 1980s, such as Air Warrior and online Go game. Due to the limitations of hardware and the Internet availability, most of these online games could only support simple scenarios. By the 1990s, with the prevalence of TCP/IP protocol, online games were beginning to grow rapidly. During this time the home computers gained more attention of users, but they were too expensive to popularize. Video game consoles are still the most common choices for users. At the same time, more and more video game consoles gain the ability to access to online networking, such as PlayStation and Xbox.

Computer online games became more and more popular since 2000s. With the prevalence of mobile phones, some mobile online games emerged. And there appeared some new formats such as social games. Then, computer online games have made great progress driven by the continuous improvement of processors and graphic cards. Meanwhile, with the rapid popularization of home broadband network, more and more people can get high-speed network access. The advent of smartphones has increased the diversity of online games. Online games on smart terminals increase dramatically over recent years due to the portability and the availability of WLAN network and high-speed Cellular Mobile Network.

In addition, cloud computing gets a dramatic increase since Microsoft released Microsoft Azure in 2010. Encouraged by the improvements in connection speed and the development of 4G/5G technologies, some works proposed cloud gaming systems [7], [8] to fill the gap between weakly computational terminals and high performance cloud servers. Cloud gaming moves the computation and rendering tasks to the cloud servers and leverages high-speed connection to stream game videos from cloud servers to end users.

Nowadays, computer games are moving towards high image quality and high frame rate, or supporting more players at the same time. Mobile online games will continuously grow because of the 5G technologies and the widely use of smart terminals. Cloud gaming is a new way to enjoy high quality games with low computational capacity devices, which requires reasonable server deployment and high-bandwidth and low-latency network support. To get better performance when designing online games, there have been a lot of works

focusing on measuring online games, including the system architecture inference and user behaviors measurement.

## III. MEASUREMENT METHODS

When researchers look into the inner system, measurements are often performed for the reason that developing a new online game is expensive and time-consuming. What's worse, obtaining a large user base is even more difficult since it requires a robust implementation of an interesting game. We summarize the main motivations of Measurement:

- Survey the principle of the inner game structure. (inner-Measurement)
- Learn about the user playing behaviors. (outer-Measurement)
- Gather the data produced in the running system for simulation purposes.

Different methods are proposed according to the system kind and the measurement objects. Generally, inner-Measurement methods can be defined into two types: black-box measurement and white-box measurement, while outer-measurement usually pay more attention to game data analysis other than the measurement itself. The white-box measurement measures the game system with pre-known internal structures and modification to the system. On the contrary, black-box measurement examines the functionality of a game system without peering into the internal structures or workings [9].

### A. White-box Measurement

1) *Software code available*: For a game whose software code is available, internal researches can be done by reading and modifying the source code [10]–[13]. The transport protocol, the architecture information, and even whatever you want to know is known. The early open-source games, such as Quake (a First-Person Shooter Game) and Minecraft (a sandbox construction game), have been investigated thoroughly by senior players and subsequent game companies.

In most cases, commercial computer games need to be modified to meet the requirements of experimental research. Independent variables (IVs) have to be manipulated depending on the research question, and specific dependent variables (DVs) have to be recorded. Fortunately, the manufacturers of some commercial computer games explicitly allow for modifications of their software by making the source code at least partially available to the public. For instance, games like Counter-strike, Half-Life, Unreal Tournament or Quake III published parts of the game's source codes [13].

Minecraft is a popular networked game that allows players to build with a variety of different blocks in a 3D procedurally generated world, and allows players a large amount of freedom [9]. Additionally, it allows for modification and thus many details of Minecraft have been presented by many researches, such as the communication protocols and client-server architecture. Because Minecraft's architecture is well documented and its community is rich with developer support, Minecraft has become a research platforms for researchers to build Massively Multi-user Virtual Environments (MMVEs),

in which topics like networking, communication, distributed data management, consistency and persistence are studied [10], [12].

2) *Log files available*: For those commercial successful games, software code may be difficult to get. Some works have been done by analyzing log files got from game company.

Finkel et al. [14] built a simulator for OnLive's service and modeled their game distribution strategy. In order to explore distribution methodologies, they examined actual OnLive server logs that provide details on player title requests with accompanying request times and durations. Using the data collected from the logs representing approximately 1.6 million player sessions, a discrete event simulator was constructed to model the OnLive games distribution, select and launch system.

### B. Black-box Measurement

In most occasions, researchers have only access to the client side without knowledge about the whole structure. Researchers are in the face of a black box, and measurement methods are greatly constrained. These approaches can be categorized as follows:

1) *Information provided in game*: In some game, there can be inherent commands for users to use, which might be installed for some other purpose. The round trip time (RTT) between clients and servers, and the workload of servers, are usually provided, which can be used to proof the running state of the game servers. In Tarng et al.'s paper [15], the inherent *who* command is used to collect their traces of players' online time.

2) *Packets probing*: Packet probing experiments capture relatively simple targets, such as delay, loss, reordering and topology that yield surprising insights into the structure and behaviors of the Internet. While on account of protecting the transmission from being intercepted and doing harm to the security, the important data is always encrypted. By analyzing the unencrypted information in packets, [16]–[18] present their works.

It is a key stage for players to locate a playable game server and the networking packets are usually readable. When multi players connect to the game server, the rules are influenced by the number of players already on the game server, the particular gaming map, the specific matching rules, and the round trip time (RTT) between the clients and servers. In the work [16], an artificial game client was created to communicate with the master game server in order to track the ranking of game servers.

Scamper [18] provides a powerful packet-prober designed to support large-scale Internet measurement. Included in the contribution to the measurement community are feature-rich implementations of traceroute, ping, MDA traceroute, four alias resolution techniques, Sting, and parts of TBIT. Operating system difference, accurate timing information, and more easily readable outputs are provided in Scamper.

## IV. MEASURING PRACTICES

In the former section, we summarize the motivations and methods of measurements. In this section, we mainly introduce the measurements based on the methods according to the three specific targets: the architecture measurement, the quality of experience (QoE) measurement, and the user playing behavior measurement. Most measurements can be classified into these three types, as illustrated in Tab.I.

### A. Architecture Measurement

The online game system is composed of different types of servers that only some of them are directly connected to clients. The architecture measurement is in other words, studying the topology, geographical and interconnection of these servers. The following two subsections respectively present the measurements on interconnection and server-side.

1) *Interconnecting Measurement*: According to whether clients transport packets to other clients directly, interconnecting architectures are generally divided into client-server (CS) architecture and peer-to-peer (PP) architecture described as follows.

- C/S - Players exchange periodic updates through a central server. The server uses received information to advance the states, and sends the resulting states back to players, who then display the updated game scene.
- PP - Each player communicates with every other player.

Pellegrino et al. [11] elaborates the CS and PP architecture by conducting analyze and experimentation on an open-source game. The CS architecture is not scalable with the number of players due to a large bandwidth requirement at the server. On the other hand, the PP architecture introduces significant overhead for the players. A combination of two architectures is proposed on this open-source game.

Most networked games share the similar CS architecture. There are several reasons for the popularity of client-server architecture.

- It is simpler to implement because only one connection is established for each client.
- It is simpler to maintain the centralized servers.
- It is easier to detect and handle game cheating.

For the sake of being closer to clients, server centers are distributed geographically worldwide. Gargolinski's paper [17] describes the game server's selection principle for single player at that time.

PP architecture has no worry about the bandwidth but open the game to additional cheating, while fairness is the most important factor to be considered. Since there is no server to detect and resolve the inconsistencies, distributed agreement protocol should be implemented by players to detect inconsistencies.

2) *Server-side Measurement*: Due to the limited computing resources and bandwidth of game servers, the server performance is often measured.

Kim et al. design and evaluate a game server [19]. Generally, a game server would be connected to hundreds of thousands

TABLE I: The overview of measuring practices

Classifications	Detailed Discription	Motion	Related Works
Architecture Measurement	The architecture refers to the system structure of an online game, including the topology structure, geographical distribution of the servers and the way how they are interconnected.	inner-measurement	server design details [19] server selecting principle [17] three architectures [11] stress testing [12] load balancing [20]
QoE Measurement	The quality of experience is a measure of the delight or annoyance of a customer's experiences with a service.	outer-measurement	cloud gaming QoE [21] online gaming QoE [22]
Playing Behavior Measurement	The user playing behavior is the study of online gamers associated in the gaming. User behavior is an inter-disciplinary social science, including psychology, sociology, marketing, and economics.	outer-measurement	<i>who</i> command in <i>WOW</i> [15] Steam game playing time [23]

of users, a large number of packets would traverse between the server and clients in real time. IOCP (Input/Output Completion Port) and multi-threads are implemented in a system to evaluate its performance. Also, IOCP packet design and processing method are presented.

Due to the large user base and long time measurement required for measuring online games, game bots are often deployed. Using game bots, server's capability can be tested. Cocar et al. [12] utilize open software libraries to create automated bots for Minecraft. In this way, the goal of emulating the real-world stress that players create on hosting servers can be achieved.

Denault *et al.*'s work [20] discusses the huge load caused by thousands of players. A dynamic load balancing mechanism is presented that considers both the load associated with performing game actions as well as the load incurred through interest management.

### B. QoE Measurement

Whether price-sensitive players will be willing to pay for QoE may depend on whether they are sensitive enough to detect the effects of higher or lower levels of QoE. A player who cannot tell the difference between a best-effort and a priority service will be unlikely to pay for the QoE-based service.

In the work [22], QoE of online games is surveyed. An interesting phenomenon comes into sight that there is no significant difference in the number of players who leave the game as a result of increased delay. One possible explanation for this phenomenon is that because of the lack of option to acquire higher levels of QoE, they would rather play games over a lossy and high-delay network, than not play games at all.

QoE is based on the human feeling that is not well quantized. We summarize four parameters affecting QoE that are typically applied to define the QoE in Tab.II related to the network and server (regardless of the client device hardware performance):

Different types of games will have different requirements for each of these parameters. Throughput is typically not an issue for current online games, but delay is treated as the most important parameter of all.

TABLE II: QoE parameters of Online Games

QoE parameter	Discription
throughput	the data rate transported between client and server, during the game, it is mostly stable
operation delay	the time needed for the client scenes to change, when clients send input commands
delay jitter	unstable operation delay gives bad playing experience
server tickrate	the frequency with which the game server computes and sends to clients

Henderson et al. [22] explored the QoE of online games. The delay bound for online games is discussed, which is measured by many former works. The measurement of quality in this paper was performed by running public game servers for the FPS game Half-Life. By degrading the QoE through adding extra delay to one of two servers, the number of game players will change. Latency between servers and clients, considered as the most important parameter for performance, is measured by comparing client numbers of two contrast servers.

As the fast developing gaming format, cloud gaming puts forward higher requirement on the QoE. The article [21] conducts a systematic analysis of state-of-the-art cloud gaming platforms, and highlight the uniqueness of their framework design.

### C. Playing Behavior Measurement

User playing behavior is a set of good reference values for game company, social researchers, and even Internet service providers. That is why games today are able to collect behavioral telemetry data from entire populations of players, and using cloud based storage technologies, it is possible to collect and process every single user event from games.

Sifa et al. [23] carries out four experiments targeting at uncovering high-level patterns in the behavior of players focusing on playtime, using frequent itemset mining on game ownership, cluster analysis to develop playtime-dependent player profiles, correlation between user game rankings and, review scores, playtime and game ownership, as well as cluster

analysis on Steam (online game distribution platform [24]) games.

Tang et al. [15] use a command, which is publicly available to every player in the game, to collect their traces. After logging in the game, players can ask the game server to reply with a list of players who are currently online. During 2-year's gathering, they analyzed the length of gamer's stay and predicted the game hours, which is important for understanding the players' behavior and improving gaming quality. They presented the predictability of online gamers' subscription time, in other words, users' gaming hours can be predicted, which will take profits to game companies.

## V. REMAINING PROBLEMS AND FUTURE

### A. Game Security

Online games are attracting hackers' attention because there are opportunities to profit illegally. Game developers have the need to protect information assets related to online game services, such as game server systems, network devices, databases, and applications. In the game world, game bots should be detected to provide well-balanced virtual economic environment in MMORPGs.

While from the point of researchers who measure online games through black box testing, it is not a good message. The security countermeasures greatly increase the difficulty measuring the system.

Woo et al. [25] survey academic research efforts and practices related to the security issues. The main security issues that significantly affect game users originate from game bot, in-game hack, gold farming, and identity theft. Game bots and in-game hack can make users feel unfair. In addition, actual illegal activities are examined to look at countermeasures being adopted.

Huguenin et al. [26] propose several techniques to detect and prevent cheating on a distributed version of Quake III. The approach is based on mutual verification, indirect communication, and vision-based information filtering.

### B. Game Optimization

Users of real-time online games often assume that their game performance and match or game outcome is determined by network conditions. Optimizing the game experience is an endless work due to the increasing requirement of players. As we can see, what we measure is what we care about. The architecture, QoE, and strategies based on user behavior all can be optimized.

### C. Future of Online Gaming

With the explosion of cloud resources nowadays, third-party cloud providers enable organizations to focus on their core businesses instead of expending resources on device maintenance. Game companies are able to deploy and optimize their systems with low costs. When it comes to game measurements, game developers are able to experiment their architectures with low cost, at the same time, measurements can be performed widely around the world.

Quality of experience (QoE) is not paid much attention to since the network infrastructure is not good enough for providing low latency and high bandwidth. Game server distribution is also a limitation for every players worldwide to reach. Some famous and successful games are providing good enough service after investing much in infrastructure.

Because of the gaming industry profiting pattern, many online games are not charging by time, QoE based service may be ignored at this time. The network is only providing doing-best service for users. The QoE of gaming should be standardized in the future.

Cloud gaming are attracting players' attention since 2010, especially for those whose computer or game box is not good enough for the newest games. It also presents harder requirement for the networking infrastructure and game design. Cloud gaming nowadays just provides the games that have been developed. We can put the game server together with cloud server as a new architecture, so that the latency can be decreased by adopting this new architecture.

Online gaming measurement will face more difficulty due to the adoption of cloud resources. The system architecture will be more complex for the purpose of increasing security, fairness and extensibility.

## VI. CONCLUSION

Online gaming is now an important form of entertainment. With the development of mobile devices, more and more people of all ages join in online gaming. For the motion of learning about the game system, measuring is the best way with lowest cost. We review the measurements that mainly targeting at architectures, QoE, user behaviors. Different methods are also presented. Then the most concerned problems remaining to be optimized are presented and we look to the future of online games.

We believe this paper will be helpful for researchers to have a general comprehension on online games.

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