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Bachelor of Science in Computer Systems (Computer Games Programming)

Comparing and Handling the Network Complexities in Massively Multiplayer Online Games (MMOGs)

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Declaration of Authorship

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Signed: 

Date: 21st November 2021

Abstract

Heriot-Watt University

Department of Mathematics and Computer Science

Bachelor of Science in Computer Systems (Computer Games Programming)

Comparing and Handling the many Connections in Massively Multiplayer Online Games

By Ross Davidson

This project seeks to evaluate the way that various Massively Multiple Online Games (MMOGs) handle the many connections that are required for the game to operate. MMOGs require constant, stable connections to allow the flow of information from client to server and back to remain steady. This will be performed by analysing data gathered from a variety of these games, be that data personally obtained or through public information available from larger games, albeit with a grain of salt. This project seeks to evaluate the techniques used and the potential impact of these techniques on the user experience.

Abbreviations

MMO – Massively Multiplayer Online Game

RPG – Role-playing Game

FPS – First-person Shooter

WoW – World of Warcraft

FFXIV – Final Fantasy XIV

GCD – Global Cooldown

oGCD – Off Global Cooldown

PvP – Player vs Player

PvE – Player vs Environment

MS – Milliseconds

NAT – Network Address Translation

DDoS – Distributed Denial of Service

Contents

1. Introduction

This chapter will provide a brief insight into Massively Multiplayer Online games, their history and describe the objectives of this project.

Video Games have existed for decades now. Of them, MMOs were of fairly limited success for many years. Many of them are known franchises, such as Everquest of Ultima Online, both from the late nineties, but it wasn't until World of Warcraft that the genre became a breakout success. With its rise came many attempts to get a large share of the market, some successful, such as Final Fantasy XIV, while others less so. As such, MMOs such as Warhammer Online: Age of Reckoning or Wildstar no longer exist in their original form, instead having to rely on 3rd party, private servers should players wish to play them anymore. As such, understanding what brings in and allows players to continue to experience these titles is very important. Of these there are many facets, Gameplay, Story, Music, Economy and more, but one thing that every MMO has in common is the need for a stable network. It doesn't matter what genre it is, what quality of story or music it has, whether it focus on Player vs Player or Player versus environment, or something else entirely. For an MMO to function, it needs a network. As such, this paper will investigate these networks and their complexities, and what MMO developers can do to provide a smooth, stable experience for their players.

The first known networked game was Mazewar in 1974, a simple first-person game in which players roam around a maze and shoot each other. At first, it required a serial cable, but then was expanded to use ARPAnet, which is what ultimately has become the internet of today.[1]

The University of Essex went on to develop MUD – Multi-user Dungeon in 1979.[2] It is the oldest known virtual world in existence. It was inspired by text-adventure games such as "Zork" and the aptly named "Adventure." These ran on an internal network at the University until 1983, when they began to allow remote access, which in turn allowed players from around the world to connect. MUD was ultimately retired in 1999, alongside other software, during the Y2K cleanup.[3]

Over the years, been able to connect to the internet to play with others was mostly limited to PC games. Of the three major console manufacturers today, Nintendo tried repeatedly to enter online gaming, using

peripherals such as the Nintendo 64DD, which ultimately was only released in Japan and sold only around 15000 units.[4] Sega, back when they were a console manufacturer also attempted to implement online gaming, through their Sega Saturn console. They released a NET link peripheral in America, although not many adopted it on the already not very successful console. They tried again with the Dreamcast, their final device before exiting the market and becoming a third-party publisher.[5]

Xbox Live, now known as Xbox network, was launched in 2002. Microsoft wished to make online gaming one of the key pillars of the Xbox strategy. Within 6 years, it had managed to gather 10 million subscribers, and ultimately set the foundation for what would be expected of console online gaming, no longer the purview of PC alone.[6] This in turn led to the modern day, where online gaming has grown to become huge in a variety of genres, from MMORPGs such as World of Warcraft and Final Fantasy XIV, to Battle Royales such as Fortnite, to First Person shooters such as Call of Duty and Halo. A multiplayer game launching today without an online component can no longer be considered the norm, with games limited to local online multiplayer been far less numerous than ever before.

All of these games, dating back to MUD, to the more recently released, at time of writing, New World, rely on the user's ability to connect to others. This can be down as peer-to-peer, directly connecting from one game client to another, but for larger scale is typically done on servers. And these servers must be able to properly communicate with the clients for the users to be able to experience them correctly. These large-scale operations need to be able to host thousands of concurrent users while remaining stable, while also contending with malicious actors using the likes of Distributed Denial of Service attacks to try and cause the server to go down.

1.1 Aims & Objectives

The aim of this project is study how many MMOGs handle their network complexities. How they established the client/server relationship, handle the constant flow of data back and forth between the two and provide potential solutions to common issues experienced throughout the market. Many MMOGs rely upon different methods to handle this data, with the likes of a First-Person Shooter and a

Role-Playing Game having very different requirements. Identifying these, while finding commonalities that could then benefit the other will be a key part of this project.

The objectives of this project are:

- Examine various MMOs, commercial and otherwise, and their approach to client-server communication.
- Gather relevant data of how these games perform, such as latency and bandwidth.
- Show how the techniques used interact with this data, and how the games are structured to take advantage of it and work around potential shortcomings.
- Compile a list of both common and more specialised techniques used by these games.
- Review the techniques and examine how some of the less common ones could benefit the market as a whole.

While they may just be “games” to some people, they are undeniably a huge business in this day and age, and thus is behoves companies to make sure that their servers are reliable, their netcode is stable and they optimise the flow of information to allow people on all levels of connection to play their games. As such, this research will help to show how this can be achieved.

2. Literature Review

There is curiously little public literature and information on this subject with regards to MMOs. This could be due to a variety of reasons, from a lack of investigation into the subject matter, to the ever changing situation as technologies advance. The complexities of a Network today are very different to how they were even 10 years ago, let alone 20 and more.

However, some papers have been written, but little that covers the extent or intricacies of how an MMOGs network connections vary and work. One paper, written by M. Suznjevic, O. Dobrijevic, and M. Matijasevic for the University of Zagreb goes into some detail about how the users' actions in the game affect the network performance, and how the latency of the game influences the players behaviour. By breaking the players actions down into various categories and analysing what actions are important to those categories, they provided some very useful data and graphs to represent it, as shown in Fig 2.1.[7]

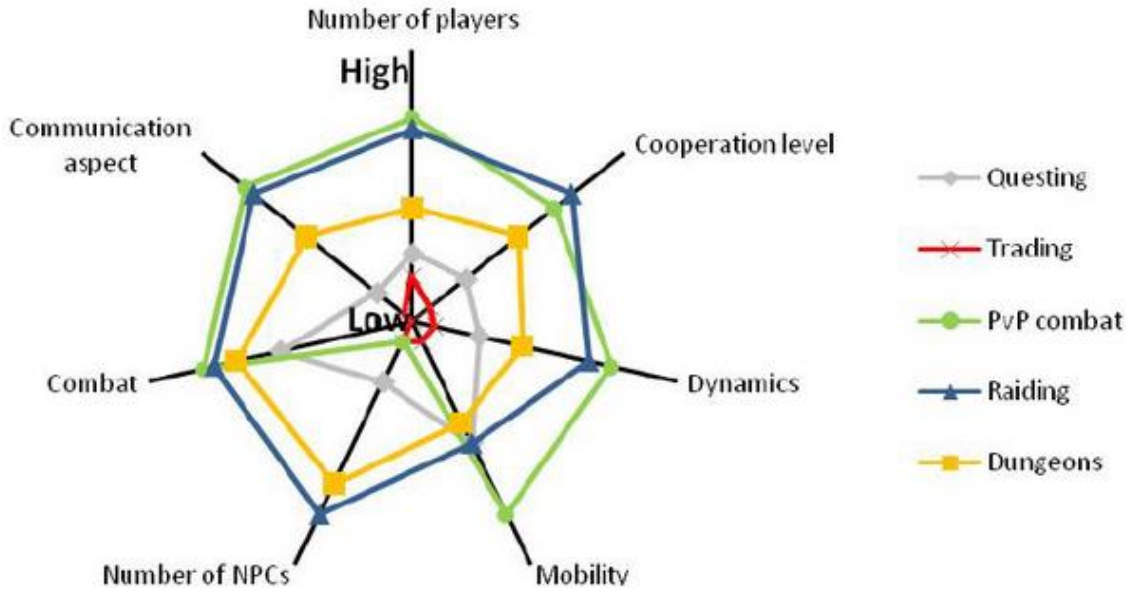

Fig 2.1: Player actions categories (P. 8, MMORPG Player Actions: Network performance, session patterns and latency requirements analysis)

Each of these categories has different requirements, such as PvP requiring little to no NPCs, compared to raiding that requires a significant amount of them. Curiously, trading barely requires anything at all in their data. This paper is from 2009 and as such may not be accurate for today, as technologies have

changed. As we continue to move towards Fibre internet, the flow of data can be improved more and more. Games today do not generally support less than broadband internet, with Dial-up no longer supported as it was when the above article was written. This can be seen by going to online games on steam or other platforms and checking their requirements. Even older MMOs, such as Final Fantasy XI, which did run on dial up when it first released, now lists broadband as required. [8]

This data is very important, as MMOs continue to rise. In Fig 2.2, we can see the most recently reported Monthly Active Users for a variety of popular MMOs. From just these 6 games alone, we have nearly 300 million players playing these games every month.[9][10][11][12][13][14] While there is likely some crossover, with players playing multiple games from those provided, this is still a significant amount of people logging into these games every month, and an awful lot of network traffic to be handled.

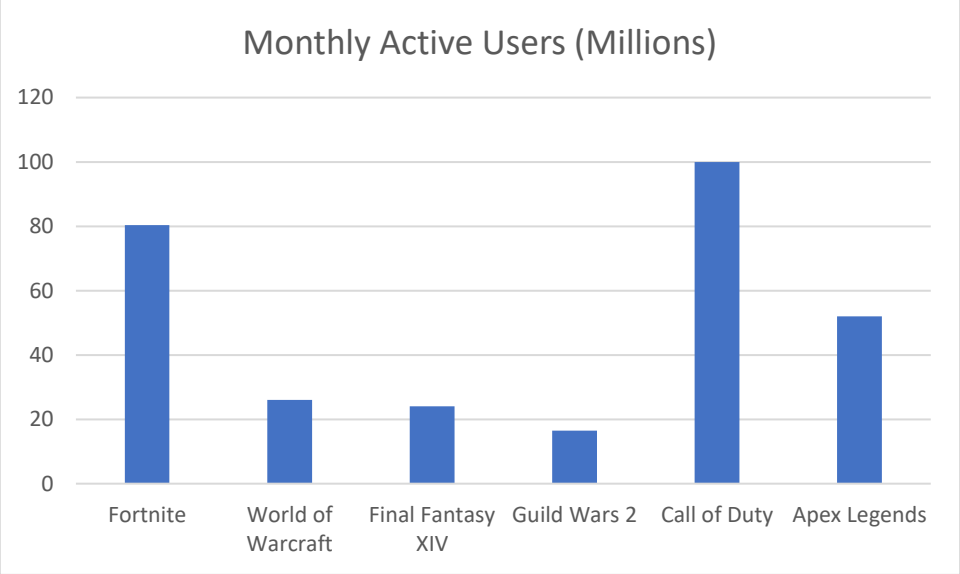

Fig 2.2: Reported Monthly Active Users (2020/2021).

For this review, I have broken down the literature into various areas to research.

2.1 Latency

A key aspect will of course be Latency. The players ping when connecting to the server, representing in milliseconds typically. This is an extremely important aspect that can directly affect how a game plays and is even structured. An example of this would be World of Warcraft (WoW) vs Final Fantasy XIV (FFXIV). Both games use a similar structure of having a set of Global Cooldown inputs (GCD)

and Off Global Cooldown (oGCD) inputs. In WoW, the GCD is 1.5 seconds, and player inputs are very snappy and thus rely on a low ping, to allow the player to quickly hit inputs one after the other to maximise their ability usage.

FFXIV however is slower, with a 2.5 second base GCD. This leads to a slower rotation, but also suffers less for high ping as a result. It also uses animation locks which comes into play with the oGCDs and the act of "weaving" them between GCDs, unlike WoW where you prefer to hit them asap. That isn't to say Ping has no impact in FFXIV, it very much does, with players on a lower ping capable of doing a technique known as "double weaving" to use two oGCD abilities between GCDs, which players on higher ping simply cannot without clipping into the next GCD usage. The slower ping has resulted in a different gameplay structure. This can be corroborated by the changes to the battle system recently outlined (at time of writing) in the upcoming expansion for the game, Endwalker, where certain abilities that previously required hitting an input an ability as fast as possible are being changed to a charge-based system, to avoid people with a higher ping being unable to get as many abilities off in the short window as those on a lower ping.

In the early days of Final Fantasy XIV A Realm Reborn, the servers for Europe where stored in Montreal, Canada. This caused immense issues for players in Europe would suffer from increased latency, leading to certain aspects of the game been significantly more difficult, such as the Titan (Extreme) battle that was one of the early endgame activities. This boss has an ability called Landslide that, if it hits a character, hurls them backwards off the platform and removes them from the fight until rather the group wins or all die. Due to this, European players had to start to react to the ability often before he even began to charge it, as due to its short cast-time, it would often hit them even if they were outside of its actual visible area due to their location not been properly updated on the server at the time the ability triggers. As of September 2015, the servers for Europe are hosted in Germany and avoiding this ability is now much, much simpler for players. [15]

A paper, "The Effect of Latency and Network Limitations on MMORPGS" written by T. Fritsch, H. Ritter, and J. Schiller, covered a field study into the MMORPG Everquest 2. Their analysis focused on Movement and Combat, the two things they believed were most dependant on latency and set specific

speeds for their two test subjects to play out. For movement and combat alone, they believed 500ms would be the breaking point, but their findings in the end supported 1250 as this breakpoint for combat in the MMO in question, due to its queueing system rendering even 500-1000ms as completely playable, if not quite as responsive. For movement, they found it responded well up to 2000ms. The duration it took for each test subject to complete the given task at each test is recorded in Fig 2.3, showing the time increasing by more than 40 seconds to complete the given task. Fig 2.4 also shows the players remaining Health and Mana after completing the task, showing a dramatic decrease in how much they have left as latency grows. [16] This alone can show just how important latency is to the gameplay experience, as the higher it is, the longer and more difficult to becomes to defeat enemies.

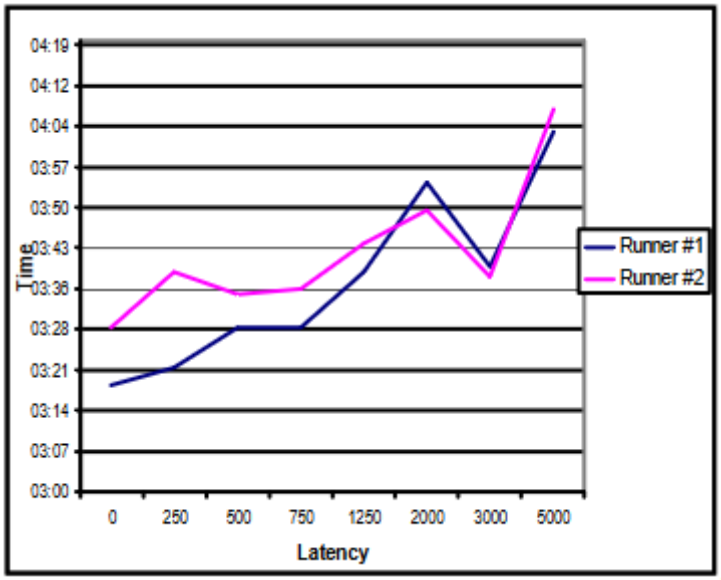

Fig 2.3: Overall time in relation to growing latency (P. 5, The Effect of Latency and Network Limitations on MMORPGS)

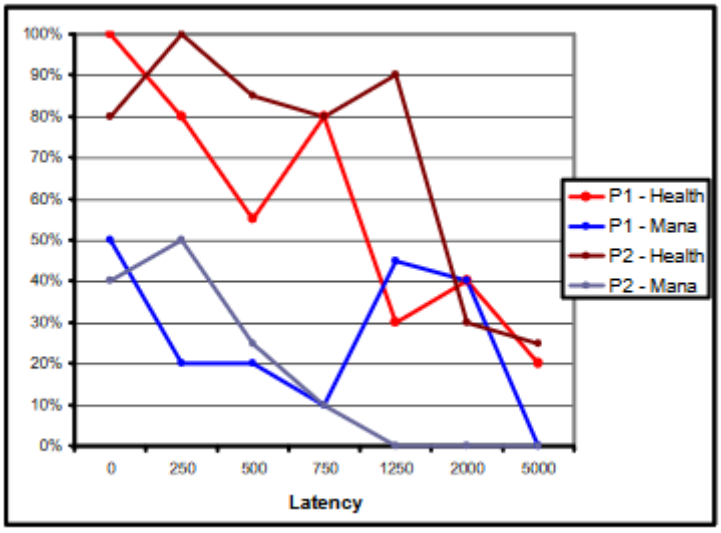

Fig 2.4: Remaining health and mana after each fight (P. 5, The Effect of Latency and Network Limitations on MMORPGS)

Ping is a complicated issue that is not easily solved, as it is affected by a variety of variables, from your internet speed, its reliability and even the physical distance from the server you are connecting to. If you live in Edinburgh and connect to a server in Edinburgh, your ping will be lower than if you connected to one in London, which in turn would be lower than connecting to one in New York City.

2.2 Version control

Version Control is immensely important for modern video games. In the past, a video game once it was released very rarely had any form of updates, with the majority of the variance happening for localisations between nations, Japan > North America > Europe all varying for example, with some under the hood changes or languages, plus of course Europe used 50hz TVs and monitors as opposed to the 60hz used by Japan and America. An example of these changes could be seen in Streets of Rage 3, known as Bare Knuckle 3 in Japan, which had big changes to the plot, difficulty and even altered the colour palette of characters, as well as removed or added additional clothes or to some they viewed as problematic. [17]

Nowadays, games can get updated at almost any time. The game at release does not need to be the final product. This is immensely true for MMOGs, given their ever-expanding nature. World of Warcraft today is very different to the World of Warcraft of 2004, to the point they released a Classic version to try and revisit that original product. More serious examples of this can be seen with No Mans Sky,

which is a drastically different game that disappointed at launch that is now doing very well,[18] or more related to the MMOG focus, Final Fantasy XIVs 1.0 version that damaged Square-Enix to the point they reduced their projected income for that year by 90%, as reported by news outlets such as Gamasutra. [19]

As such, regular updates and new versions are important. However, they need to be controlled, to ensure players are accessing the server with the right version of the product, and that files have been delivered to the client correctly to avoid corruption or errors. As explained by Perforce, various studios have their own ways of performing this, for example Epic with their flagship title Fortnite and Unreal Engine. They run their development through various sub-teams' branches, each that have their own Quality Assurance, long before the code ever even approaches the main development product. This allows for a stable release and allows individual branches to remain stable due to any changes having already gone through the QA process.

The Chinese Room however, use a more Agile approach, designing features, collaborating then returning to the development once they are refreshed. They don't worry about the management of the assets, but instead will go back after the fact to find and correct any issues with the product. They focus less on stability and more on designing the actual game.[20]

Other tools used for this are of course GitHub as well as Subversion. As explained by UnknownWorlds Entertainment, GitHub allows you to create branches of a repository to work on without affecting the base one until you are ready to merge them into one. Subversion is also open source, with a variety of clients, including Tortoise which works as Windows Shell Extension. UnknownWorlds claims that Subversion is very easy to set up but falls behind when it comes to more complex coding, requiring good practise code to be made, which might not always be possible in specific situations, such as Game James.[21]

2.3 Cross-platform players

These days, many games have cross-platform play. Mobile and console, console and PC, or a mixture of all three. Sometimes even within PC itself you have cross-platform multiplayer between various

outlets, such as Borderlands 3 having Cross-platform between Epic Games and Steam. Other examples include Fortnite, which has cross-play between Mac, PC, Mobile, Xbox, Playstation and Switch, or Final Fantasy XIV which has cross-play between PC and Playstation.

Cross-platform play is a growing desire amongst player bases, as it breaks down barriers and allows people to play together regardless of their choice of platform. For younger audiences that might get a Playstation or an Xbox, it allows them to still play together with their friends online without having to leave someone out. This has faced difficulties in the past however, as often the console manufacturers have resisted efforts by developers to integrate such features. Sony allowed many cross-platform titles between PC and Playstation 4 but resisted efforts for cross-console platy specifically. Some companies, such as Bethesda prior to their acquisition by Microsoft. According to the publication Cnet, which in turn cited a german website, Gamestar, Bethesda's Todd Howard described Playstation cross-play as difficult because "Sony is not as helpful as everyone would like." [22] This has changed more recently, with Sony easing up the restrictions since September 2018 when a beta-test for Fortnite cross-platform play began.[23]

Two of the earliest cross-platform titles are Quake 3 Arena and Final Fantasy XI, as written about by OurCulture. Final Fantasy XI was on the Playstation 2 and PC, and later the Xbox 360. Furthermore, it won a Guinness World Record for being the first game to provide a cross-platform for an online role-playing game.[24] The PS2 allowed users to connect a USB keyboard and mouse, but Square also introduced a robust, simplified, controller layout to ensure all players could play and communicate without issue. Given its audience would cover many countries and languages, they also introduced a system that allowed users to select phrases from a list that would auto-translate into the language set by other users' clients.

Quake 3 was less successful with its cross-play between the Dreamcast and PC, and to some extent highlights issues some games have to this day, where PC gamers enjoy a more precise control method, through mouse aiming, as well as higher, more consistent framerates leading to faster response times.[25] While improvements to controllers and more advanced aim assist options now exist, Keyboard and mouse remains the more precise method for games involving shooting mechanics.[26]

2.4 Game Genres

Each genre of gaming has its own requirements for what it needs to deliver the intended experience. A game such as Final Fantasy XIV can rely on a slower response due tits nature as a primarily Player vs Environment game, while Call of Duty, Fortnite and other Player vs Player games are heavily dependent on a hitscan delivering the correct data on where the player and their target are located, requiring much faster response times. As written by Tristan Jung in an article on Medium, Hitscan is a simple but modifiable way to detect when a bullet hits its target, using a technique known as raycasting, which is used by games as old as Doom and more recently by modern games such as Overwatch.[27]

This is especially important if the game has a competitive mode, as ensuring all players are on an even playing field is essential. This is confounded by issues such as using an aimbot to always hit targets in their weakpoints, usually the head, or lag switches. A lagswitch, as explained by Lifewire, can temporarily stall the traffic been sent and received through the network, often causing the player to appear unresponsive to others. Despite this, they can continue to play locally, which is then sent to the server when the connection resumes, causing a burst of activity.[28]

For MMORPGs with their dungeons and raiding scene, you can't have a situation where one player sees a fireball going left and one sees it going right due to a desync, nor can you allow a situation where a player's attacks are not been registered properly due to a bad connection, leading to their damage been discarded by the server, or occurring in short bursts. From personal experience, it can be immensely frustrating to have the game stall mid-combat, only for it to resume some moments later with you suddenly dying to a huge onslaught of damage you could not avoid due to the connection issue.

Outside of MMOs, this is still a concern. Fighting games, such as Street Fighter or BlazBlue, or even Smash Bros, requires the game to correctly transmit the attacks over the network, using delay-based and rollback netcode. Netcode allows multiple computers to communicate via the internet and tries to get as close to local play as possible. Local play will generally always have players inputs process identically, outside of minor differences such as a wired vs wireless controller, but over the internet this is not the case. As explained by ArsTechnica, Delay-based simply delays the processing of a player's

inputs for the same amount of time it takes the opponents inputs to arrive over the network, compared to Rollback which does not wait for the opponents' input, processing the local users first, then "rolling back" to correct itself when the opponents' inputs arrive.[29]

Other genres, such as turn based games, such as Hearthstone, a card-based strategy game, can be much more lenient. A single user goes at once, playing what cards they can, then ends their turn. While their actions need to be properly portrayed to their opponents, this does not matter until the opponents turn as they cannot perform any inputs outside of that window. If one player is lagging somewhat so that their opponent does not see the card they played for a few seconds, it ultimately will not have a huge impact on the game, provided it is displayed correctly by the end of the turn.

2.5 Packet Size and Load

A study by K. Chen, P. Huang, and C. Lei, "Game Traffic Analysis: An MMORPG Perspective" of an MMO by the name of ShenZhou Online investigated the games traffic, by way of server traces. They found that packets have a drastically different size when sent from the client than when sent from the server. They found that this made sense, as a client's packet need only contain data relative to that users' inputs, while the servers needed to carry the data from all of the nearby users' inputs as well as the environments in response.[30] This lines up with my own expectations.

More surprising, their data found that most MMOs of the time could easily run on a dial-up modem, of 56 Kbps, as the clients' packets would only use 3 Kbps for the game in question.[30] This data comes from 2006, and as such may not reflect accurately on the packet size of today. Information on the packet size of more recent games is rather difficult to find. One article, "Online Gaming Traffic Generator for Reproducing Gamer Behavior" found that World of Warcrafts packets ranged from below 60Kb to just below 140Kb depending on the situation but did not specify if this was client to server or server to client (See Fig 2.5).[31]

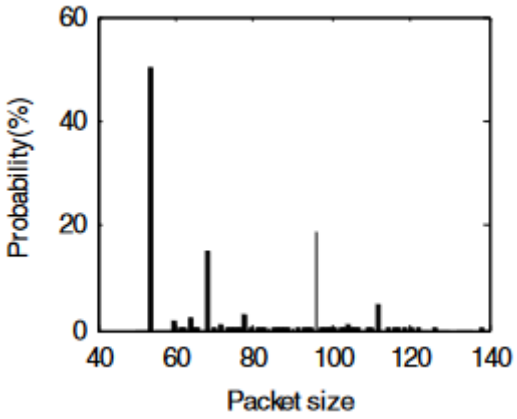

Fig 2.5: World of Warcraft packet size (P 163, Online Gaming Traffic Generator for Reproducing Gamer Behavior)

The first article also investigated the packet load and its bandwidth usage. They found the requirements to be rather low, with their target of study, ShenZhou Online, with 99% of the connections having less than 15 packets per second in both directions. They found comparable usage between the Real-time Strategy genre and the MMORPG genre. However, they found that First person shooters needed is much higher.[30]

2.6 Network Topology

MMOGs nearly always use a central server. There is a variety of reasons for this, from been fairly easy to implement, easier to avoid cheating and improved security as a whole, and if one user has a problem with their internet, it does not directly affect the other players.[32] As explained by the University of Dayton, Peer to Peer, by comparison, has much lower security, may require extra work on the users' part to forward ports, and will have much more variable latency. That is not to say that peer to peer does not have its uses. World of Warcraft, for example, has a peer-to-peer option for patching the game files, akin to a torrent system, where other users, or "peers" can send their downloaded files to you, allowing multiple people to "seed" the file to a variety of clients, who in turn can then seed it to even more clients. This can lead to reduced bandwidth for the provider as well as decrease network load.[33]

Peer-to-peer was used by some large AAA studios in recent times. Ubisofts "For Honor" game utilised this method for a time after it launched, before switching to a cloud-based system.[34] During its period as a peer-to-peer game, For Honor had to utilise session migration, should the current host leave, and NAT, which could lead to slower matchmaking. Many news articles during this period highlighted

many issues with this system. One outlet, Eurogamer, found that many of the issues experienced by users were “game-breaking” as well as their personal experience of frequent disconnections leading to them been forced back to the main menu.[35] Another outlet, VG247, reported similar problems, referencing “countless videos and forum posts online complaining about the state of online play.” [36]

The more users there are, the more chances for peer-to-peer to encounter issues, while a central server will scale far more efficiently and is not subject to an individual user that could encounter a network issue that disrupts everyone else currently connected.

2.7 Security

Security in online games is a never-ending battle, with hackers constantly trying to find new ways to break and manipulate the game and developers patching these exploits, causing the hackers to search for new avenues in an endless cycle. In his thesis, “Security in online gaming” by R. Summeren, the author broke it down into three major issues: exploits, hacks, and attacks. He went further, to have exploits and hacks considered “cheats” while attacks were something separate. He classified an attack as something used at the game, while a cheat is something used in game.[37]

Cheats in single player games are largely harmless, self-inflicted and do little to cause issues, but when online with other players, it can cause severe issues for others. An example of this would be back in 2010, when World of Warcraft had recently released a new raid - a large scale piece of group content for groups of 10 or 25 players – called Icecrown Citadel. The World First completion of this raid was achieved by a group called Ensidia. However, it came to light that they had used an exploit to trivialise part of the final encounter. The group in question received a 72-hour ban for abuse of this exploit, and had the achievements awarded to them removed, and ultimately the World First was awarded to another group.[38]

This is but one small example of players using in game mechanics, but security goes far further than that. A frequently used tactic to cause network issues is a Distributed Denial of Service attack. These attacks attempt to disrupt the traffic to a server by bombarding it with a flood of traffic. This can lead to the server hosting the target, be it a game server, website or even a specific person’s computer, to

struggle to keep up with the flow of data. This can lead to increased response times for users connecting to the server in question, or in some cases cause the server to go down entirely, preventing use of it until restored. These attacks can be difficult to manage, as separating the malicious traffic from the normal can be a difficult process. If a website goes live with a new product that is in very high demand, the surge of customers all trying to purchase it could simulate a DDoS attack simply due to the shear amount of people trying to get to the product page and purchase it.[39]

Some services, such as Cloudflare, claim to be able to combat these attacks, claiming that their network "blocks an average of 70 billion threats per day, including some of the largest DDoS attacks ever recorded." Despite this, in the context of MMOs, DDoS attacks are quite frequent.[40] A website by the name of Mazebolt tracks a worldwide list of DDoS attacks, and by going month by month, several games can be seen. In August of 2021, Final Fantasy XIV suffered an attack on its European data centre.[41] Two months prior, in June, Apex Legends was subject to an attack that managed to take the server down entirely. At the same time, Blizzard was hit by an attack on its World of Warcraft classic server which had recently launched the Burning Crusade expansion. [42] Blizzard had already been hit earlier in 2021, in January.[43] Reading through the reports by Mazebolt, there have been 10 DDoS attacks on big games alone this year, with dozens more attacks on online industries as a whole.

These attacks can cause severe issues for the games and companies in question. Riot Games, who was also attacked in January of 2021, had to cancel an event in the popular game League of Legends and refund players tickets that had been purchased. Despite their use of anti-DDoS technology, they claimed this was due to a new type of DDoS attack, which in turn shows that these malicious acts will continue to find new ways to attempt to disrupt servers.[44]

This is but one facet of security that needs to be considered when managing a network. Securing the users personal data is another matter, as is the integrity of the games databases and how it can filter packets that may have been altered to try and gain an advantage in game. Botting programs are another issue, and frequently seen in MMOs with a large economy, where the bots can be set to endlessly farm items and money.

2.8 Conclusion

While there is a lack of papers regarding the complexity of an MMO network itself, there is relevant papers and data available which can be used to facilitate this research. By exploring and finding the ways these papers apply to the work in question and can be built upon so that this project may provide answers and solutions.

3. Methodology

Primarily, quantitative data will be used for this paper. The data will be numerical in nature, allowing for clear information allowing counting and measuring of data to locate patterns. These will be gathered through three primary methods.

- Self-obtained. Data obtained through my own efforts, using network monitors to gather connection statistics. This data will allow me to directly compare various sets, albeit with the caveat that it will all be done from the point of view of my own connection.
- Publicly reported. This data is more transient and harder to judge, as what is revealed by the various companies who run MMOs is not consistent, and often with a twist to make the game in question appear to be doing incredibly well, even if it might be on the decline.
- Open sourced. Data obtained and reported but not by the companies themselves. This data also has to be handled carefully as the reporters' bias may come into play. Cold, hard numbers will be required to verify it.

The reason for this is simple: Connection data is subjective in the sense that everyone has a different experience based upon their internet connection and availability of high speeds in their area, but at the end of the day the numbers should be consistent. As such, the numbers should be on a similar scale regardless of where they come from, as the server should work to normalise the user inputs.

User surveys released online will be a useful source of data for this, allowing comparison of various experiences depending on the internet speed in question. Ideally, these surveys will cover a wide population, from those running slower internet connections on DSL, faster on Fibre, whether they have a data cap, and potentially even their distance from the data centres they are connecting to, which will affect ping.

As such, this paper will be looking at the Network Traffic of the MMOG, such as the packet size, its arrival and departure times, the load and how much bandwidth it will use to be sent. Each of these has a direct impact on the flow of data over the connection, as does its reliability. Packet loss is a potential risk, causing fragmentation of the data and potentially causing desync issues and rubberbanding.

Bandwidth is of course immensely important, directly influencing the networks capacity, while the packet load affects processing time. Details of many of the aspects and data that needs to be considered are as follows

3.1 Latency

Latency is very much a Quantitative data type, recorded in milliseconds and able to be understood quite easily in the sense that higher = slower response time. Recording is possible with a variety of tools, both located in game and out. If you know the servers address, it can be pinged through the command line while most MMOs allow the users to see their ping in game. For example, in WoW, hovering your mouse over the Main Menu button while logged in will tell you your latency speed, while also displaying as green/yellow/red, with green been low and red been high. FFXIV allows you to check by hovering your mouse over a typical Wi-Fi icon next to the minimap. Fortnite provides simpler tools for this, allowing you to enable options that allow you to see your Network stats at all times, covering ping, speed, number of packets and the percentage of packets that are lost.

This data will allow for a direct comparison between the various MMOs that will be researched. By comparing the games, their gameplay, and their genre, I will be able to provide insight into how these aspects are affected by the game's latency, and thus its importance on a per-game basis.

3.2 Version control

Gathering data here will be somewhat difficult, as MMOs often do not allow you to even attempt to connect without the correct version installed. If you attempt to load up Fortnite, or Call of Duty, World of Warcraft, or Final Fantasy XIV, the first thing they do is check for a new version, then download and install it before they allow you to try and connect, with no way to downgrade to a previous version officially available. That in itself speaks of strong version control however, with needing to resort to finding user-uploaded previous versions to test whether it can be bruteforced.

This data will be more vague, but still very useful to have. By analysing it and the ways each MMO maintain it, be it through Git, Perforce, Subversive, or other means entirely will allow for comparisons and insight, which can be used to consider improvements.

3.3 Cross-platform players

Finding the number of cross-platform players will require examining how many players there are per platform. This could end up rather difficult however, as some games will have the same player playing over multiple platforms, as that is part of the appeal of cross-play games. Another appeal is of course been able to play with friends regardless of platform. From preliminary searches, there is not a lot of data on how many players actually use this functionality provided online, so a survey may be required to try and get some form of data to analyse, although this would be a last resort to avoid potential ethical issues. There is a sizable growing list of games to consider, particularly between Xbox and PC with the more recent strategy by Microsoft to combine the two into one ecosystem, spurred on by Xbox GamePass and simultaneous releases of their first party titles on both platforms.[45]

Looking at what cross-platform games do to maintain their presence on each platform, without disadvantaging the others will be very useful. Given some are exclusive to one platform or another, I.E World of Warcraft is only on PC at time of writing, while Fortnite is on PC, Mobile and console, finding ways to expand to these other platforms without comprising the game will be key. Thus, thorough analysis of what is done right, and indeed wrong, will be important.

3.4 Game Genres

Research into the various genres, and what factors are more or less important for games within that genre, will require exploring reports by various game developers, potentially some surveys by users on what they think is important and personal testing. The surveys will be heavily subjective, as player bias and perception are not always accurate to what is actually needed vs what is just wanted. As mentioned in the literature review, response time is more important in an FPS game than it is in a turn-based game. Compiling a list of the genres and what is most important to each will be a sensible way forward.

By itself, theres little to compare here, but in conjunction with other data, such as latency or packet size, this particular aspect becomes more and more important, as it will influence the construction of the network in the first place. Taking the network created to maintain a first-person shooter and comparing to one for an RPG could provide some useful insights and improvements they can provide each other.

3.5 Packet Size and Load

Finding the size of packets and their load on the server should be possible with a scraping script. Some MMOs will also have this data publicly available for comparison's sake. It will be important to tie this point to Latency and Genre, to show how the packet size can vary between games and its impact on the response time.

Analysing this data will allow for some interesting comparisons. Does Game X use fewer larger packet, if so, why? Game Y uses smaller, but more frequent packets. Is this better? By looking into the whys and hows, it will allow construction of a solution that might provide benefits in a more general sense. Its very important to understand why a packet is built in such a way.

3.6 Network Topology

Exploring the topologies of MMOs will likely be fairly simple, as the majority of them use a central server setup for security and ease of roll out. While some games have and do still use Peer to peer, the example of For Honor can show just how major the issues for it can be, particularly when it is a game coming from a large publisher such as Ubisoft. Smaller games, those made by independent studios for example, might resort to peer to peer simply due to costs, as maintaining dedicated servers can ramp up costs that they simply cannot afford.

I fully expect to have very consistent data over the various MMOs for this section. The central server is consistently the most commonly used type of network for MMOs, for security, maintenance and consistency. While of limited use, this data will still be important to look at matters as a whole.

3.7 Security

Security in of itself could be a project. The sheer amount of different ways that a server can be secured, that hackers and malicious actors may try to break, the ways they can encrypt their data, verify the integrity of packets and more is immense. For this project, I will be looking more at the ways security is used to avoid disruption to network operations, such as traffic, bandwidth, and stability. The information written on DDoS attacks in the literature section will be especially relevant in this case. Analysing how companies attempt to prevent or mitigate these attacks will be key, but

likely very difficult to get a hold of. This is due to companies understandably been secretive of their security techniques as if they are found out, it could allow hackers ways to find new avenues to attack from.

3.8 Conclusion

Data will be gathered from each of the 7 categories written about and analysed. By exploring the techniques used to handle this data, I will be able to explore its complexities and see how they could potentially be applied to other games and potentially even other products entirely, although MMOs remain the target of this project. This data will need to be gathered in a variety of ways, from attempting to use scripts to scrape the network data as I connect to these servers, to publicly reported data by the companies themselves, albeit with a grain of salt, and open-source information already gathered by other papers and academics. My hope is that once properly analysed, methods to improve each aspect of the network will reveal themselves.

4. Project Management

Six MMOs will be selected for this project, from several genres. As information is gathered, it will be stored in a GitHub repository (https://github.com/Ross-Davidson-HW/HW-MMOG-research) for ease of access. Any findings of this project will be opensource and available to any who visit it. The tasks of this project are as follows:

- Compile a list of the six MMOs that will be studied
- Gather data from each MMO (latency, packet size, etc)
- Compile and compare this data
- Explore the techniques used in each MMO (security, packet construction, etc)
- Compile and compare these techniques
- Review the data and techniques and provide solutions.

The data will be analysed using the IBM SPSS Statistics software. The timeline of how these tasks will be carried out can be found in the Gantt chart, Fig 4.1.

4.1 Risk Analysis

All projects carry some potential risks. Identifying these and how they could negatively affect the project is highly important. By identifying them early, plans can be made on how to mitigate or work around them, to minimise the disruption to the project.

Risk	Probability	Impact	Comments
Loss of internet	Low	Severe	Would lead to difficulty in acquiring data and information. Due to my health and the ongoing pandemic, the internet is the most important tool I have for working.
Illness	Moderate/High	Moderate	Fairly high chance, as my immune system is very weak, and I have a history of illness. Will slow production if/when it occurs.
Covid-19	Low	High	Likely to cause severe issues with the workflow. I am double vaccinated however, and unlikely to catch it.
Loss of Power	Low	Severe	Unable to work on anything should this occur.

Equipment Malfunction	Varies	Varies	Depends largely on the item that breaks. A loss of a keyboard is not going to have huge impact and is easy to replace, but the loss of a harddrive or the computer would have severe impact
Deadlines	Moderate	Manageable	The project will be planned out in full, with deadlines listed. Should workload increase or exceed the expectation, that will have an impact.
Emergency	Low	High	Should an emergency happen, such as a family member getting sick, it could have a high impact on the workflow for a time.

4.2 Gantt Chart

This chart shows a basic project timeline, with week by week segments of what tasks will be carried out in that time period. Red tasks are the major tasks, while yellow are subtasks within those. While blue sections are marked as breaks, tasks may still be performed during them depending on the progress of the project.

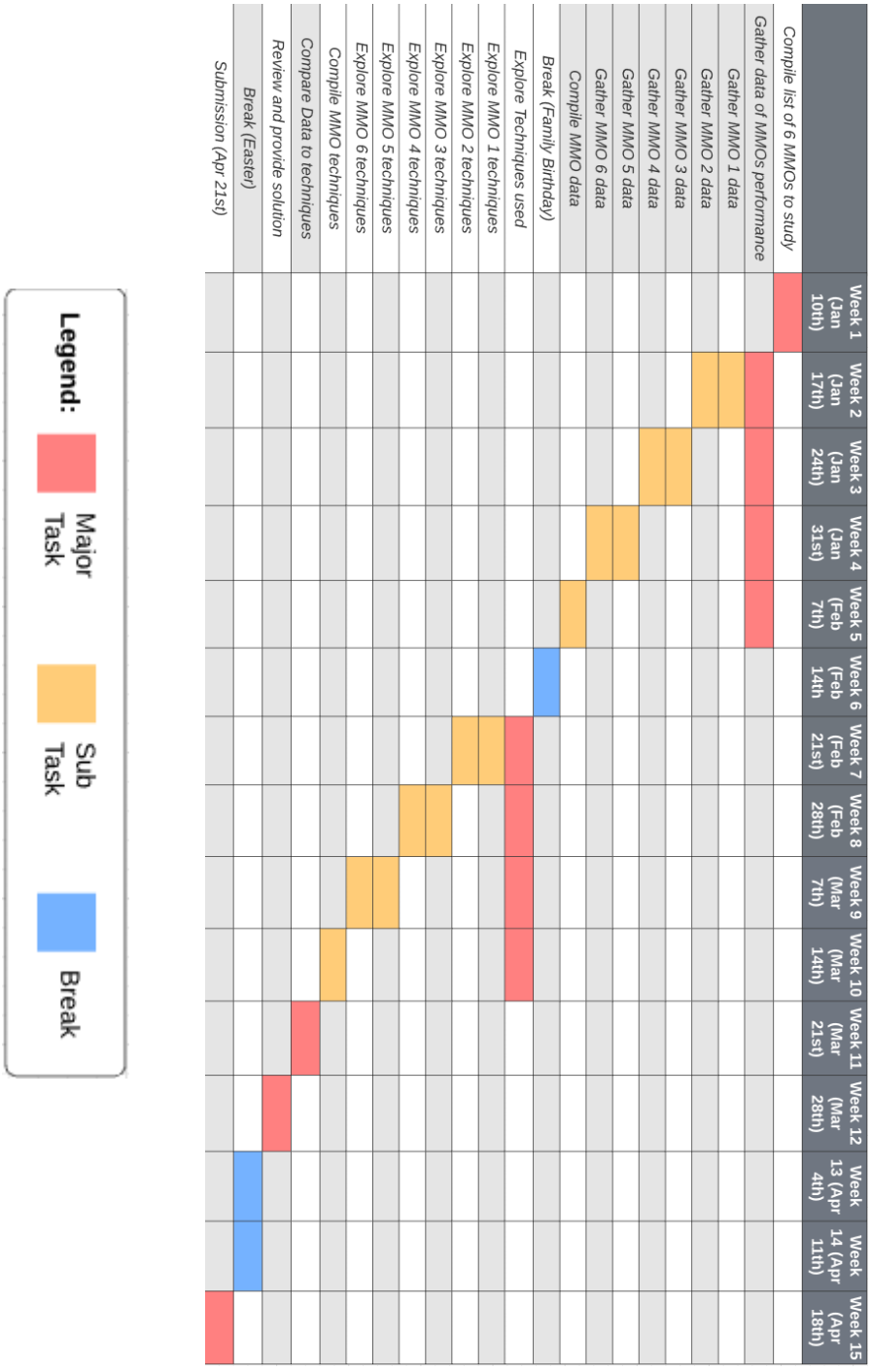

Fig 4.1: Gantt chart for project.

5. Professional, Legal and Ethics

5.1 Professional

Data will be collected personally or through data reported through other publications and the internet, that can be properly vetted and sourced. As per the British Computer Society's code of conduct, the work carried out will only be that within the capacity of the researcher.[46]

Heriot-watt supplies us with the ability to make use of the IBM SPSS statistics software which will be used to analyse the data gathered. The data will not be gathered from human participants but only from personal use and that reported online, and thus no concerns with GDPR, or personal data apply. This software can be obtained by visiting the Heriot-Watt website, navigating to the SPSS article in professional services > IT essentials and navigating to the SPSS statistics webpage from there, using a HWU login and password.[47]

5.2 Legal

No personal data will be gathered, and thus does not concern the Data Protection Act nor GDPR guidelines. No software will be created for this project, thus there will be no licenses, no trademarks, and no copyright. Third party software will be used to gather and process data, such as SPSS, which is licensed by the university and data will be stored in a GitHub repository.

5.3 Ethics

This project does not require human participants. All data will be of software and purely numbers, such as ping numbers or monthly connections to a particular piece of software. As of writing, the project has received ethical approval from the university, but should matters change so that a survey or other form of human data is required, the ethical form shall be resubmitted beforehand, and the project updated to reflect that.

5.4 Social

This project's purpose is to analyse data and evaluate techniques used to allow an MMO to navigate a complex network. Should this project prove fruitful and be used by any of these MMOs, the benefit would be for the game's communities, and if not, no impact will be had on society. No environmental impact should occur beyond the standard impact caused by running a computer. As there are no human participants, there will be no risks to anyone that might impact them emotionally or physically. As per the Ethics section (5.3) this will require updating should the projects demand a shift to require a human participant or participants.

6. Conclusion

This project will, with any luck, give insight and understanding into the complexities of an MMO network. From here, new ideas can grow, and techniques be shared between the various games, hopefully to their mutual benefit. Given the size of the MMO market, and its constant growth, this is an important subject for any developer looking to create and maintain software with an online presence. While focused on MMOs themselves, all online games require some level of network to be created, and thus, this project can benefit everything from an MMORPG to a one-on-one fighting game.

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