Analysis of Gameplay in MOBA Games under Different Network Conditions

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***Abstract*— This work aims to analyze the influence that different network conditions can have on the performance of a player in a multiplayer game of the MOBA genre, according to scenarios where transmission rate, latency and packet loss are used as factors. The scoring data of the players is collected at the end of each scenario and a quantitative analysis is performed. For this purpose, the DOTA 2 game was chosen and the evaluation metrics were KDA (Kills, Deaths and Assists), along with the farm and the gold collected. This allowed the analysis of how the factors influenced the defined metrics. To create the scenarios, the Clumsy 0.2 network condition emulation tool was used, thus controlling how the network would behave in each scenario. Finally, it can be concluded that for games of the MOBA genre the players have a significant decrease in their performance when submitted to networks of lower quality. The latency has the greatest influence on the player's performance, whereas packet losses of up 5% are almost insignificant if not associated with high latency and the transmission rate is insignificant for the DOTA 2 game since it uses a very low transmission rate, which is typical of this game genre.**

Keywords – MOBA; games; network; Multplayer; DOTA2;

I. Introduction

Currently, the eSports are gradually expanding their audience. To Tassi [1], the internet has united all nerds of the world to turn the eSports from a simple time killer to a hugely popular phenomenon. Viewership has gone from the hundreds of simultaneous viewers to hundreds of thousands and prize pools have gone from insignificance to millions of dollars. Among eSports, a genre that has underscored in the world is the Multiplayer Online Battle Arena (MOBA). “In recent years, Multi-Player Online Battle Arena games (MOBAs), a variant of the RTS genre, have evolved to comprise a significant fraction of the esports environment” [2]. This genre consists of two teams facing each other for a specific purpose, usually the destruction of the enemy base or the accomplishment of missions.

Since it is a sub-genre of ARTS (Action Real-Time Strategy) games, in which all actions affect all players in the match simultaneously, network conditions become an important aspect of gameplay, with individual consequences for players. The massive multiplayer online (MMO) games need more and more network resources, and face problems such as delays and packet loss that restrict its efficiency and can harm its players [3]. Factors such as throughput, latency and packet loss can drastically affect a user's gameplay in an online match. This problem was addressed in [4], testing games of the Real-Time Strategy (RTS) genre and in [3], testing games of the First Person Shooter (FPS) genre.

Real-time multiplayer games try to get players to interact with other players and with the environment simultaneously. For this to happen, a high level of synchronism is required in the actions performed by all the players within the match [4]. Synchronism is a critical aspect and consists of getting all players to perceive an event at the same time. Synchronism is important at various moments in the match, from the connection establishment to the start of the match, and also for player actions such as collisions, sounds and also at the end of the match [3]. This synchronism is directly affected by the network conditions and user hardware capacity. The main problems that arise when synchronization is not properly managed in a game are: warping, lead targeting and dead reckoning.

Warping is characterized by the loss of packets referring to the position of a player during the match. Its movement will not be continuous, making other players see the player as if “teleporting” himself from one position to another in the virtual world of the game.

Lead targeting is the “technique” used by some players to aim and hit their opponents in First Person Shooter games when they are not accessible. This happens because the state of the world presented to the player is delayed according to its network connection. This way, the player does not see what’s happening to the world at that moment, but what happened a little before. The enemy is not where the player sees it, but a little dislocated from that position [3].

Dead reckoning comes from the necessity of establishing a common perception of major information in the game, such as start time, end time, winner(s), who died, etc. [3]. When a player knows that another player has already died but a third players does not know yet, it may affect user behavior, resulting in a poor experience for the players with the slower connections.

All the problems that network conditions can cause in the game negatively affect the player's performance, therefore it's important to quantify how much each network problem affects a player’s performance.

This work aims to analyze the impact of different network conditions between client and server on user playability through different network scenarios by collecting data on matches played in each of these scenarios. The analysis the data from each scenario can help define the minimum network conditions for good in-game performance and quantify how much each variation affects a player. The results obtained can generate data to be used by the companies that maintain the games to improve the balance of matches in servers and also serve for ordinary users to understand how their performance is affected by their network service.

II. RELATED WORKS

Callado et al. [3] performed a qualitative and quantitative analysis of game Counter-Strike, an online FPS game, under different network conditions. The factors used were latency and packet loss. The study was carried out by performing a qualitative analysis through a questionnaire applied to the players for each game, in which the players should inform how was the perception of the events in the game and the responses of their commands, assigning the options: awful, bad, reasonable, good and excellent (each option worth a number from 1 to 5 for the average calculation). The result of this analysis revealed that the tests performed with a packet loss rate of up to 5% did not negatively affect the players. It also revealed that packet delays affect gameplay in response to commands, that is, some commands generate delayed response and others are ignored due to the delay.

The quantitative analysis was done through the collection of data during the games. Statistical analysis is done by collecting data as the number of times the player killed in the same match, maximum number of players killed by all players, minimum number of deaths of all players and number of player death. Through this analysis it was possible to conclude that package losses do not affect the players while the delay of packages has a greater influence on the gameplay of the same ones. The difference from our analysis in this work was that the game genre, the selected network conditions and the metrics gathered are different.

Alexandre [4] performs an analysis of the impact caused by the change of factors in the network between client and server in a strategy game, and the influence on the gameplay of the user is verified through data collected in different created network scenarios. It was used the multiplayer game Apocalypse of the Dead, a strategy game of the RTS genre.

The analysis is based on data provided by the game during the match, evaluating resources, units, exploration and using the four scores defined by the game, which are: Economic Score, Military Score, Exploration Score and Total Score. The tests also make a division of experienced and inexperienced players.

The work proposes five scenarios with variations of the following factors that players are submitted: throughput, packet delay and packet loss. The first scenario is the representation of an ADSL connection, the second the representation of a radio connection, the third the representation of a dial-up connection, the fourth represents the ADSL and radio junction where there is a group of players in a network condition playing against another group in other network condition and the fifth is the inversion of the network condition of the fourth scenario with the same players. Also in that work the game genre and the metrics collected differ from our work.

Sapienza et. al [5] perform an analysis of the individual and collective performance of players in MOBA games and how a player changes his performance according to how he interacts with different teams. The game used was the League of Legends [6]. In their work, Sapienza et al. propose four questions: "Do players improve over time because they acquire skills and experience through teamwork? Are there notable changes in individual performance during the course of a single team play session? If performance changes in a session, does the experience decrease its variation? What factors predict a player's choice to continue playing or ending a particular session?"

The data analyzed by Sapienza et. al [5] were collected from about 242,000 matches played by a sample of 16,665 players. The performance analysis of the players is performed through some metrics defined by the author, among them the KDA Ratio (Kills, Deaths and Assists):

$$R = (K + A) / \max (1, D). \quad (1)$$

In (1), K is the number of kills a player made, A the number of assists a player performed and D the number of deaths a player suffered. R is the KDA Ratio. Other metrics used in the performance analysis of each player are the winning rate, the achievement of specific goals in each match, the average duration of matches and the amount of gold collected.

III. METODOLOGY

A. *Factors*

In order to define the factors used in this work, we searched for works that test networks in multi-user games, as well as those mentioned in section 2 of this work. Callado et al. [3] use latency and packet loss in their tests, while Alexandre [4] uses latency, packet loss and throughput and Cecin and Trinta [7] emphasizes the importance of bandwidth and latency for a multiuser game. After this analysis, the factors defined to modify the performance of the network in the creation of the different evaluation scenarios were latency, ratio packet loss and throughput.

Latency or packet delay is described as "the measure of time between a packet being sent from the origin and being received by the final recipient". Transmission rate is described as "the transmission capacity in a communication line" [7]. Packet loss "is the disposal of packets by a router that has its packet queue overloaded" [8].

B. *The Game*

The MOBA game genre was chosen because it is one of the most popular online multiplayer games [1], and also due to the fact that in the bibliographic research there were no other works that performed these experiments in this style of game. For this work, the game needed to be free and provide an installation that allows the use of a local server, thus enabling the construction of a 100% controlled game environment. One of the games observed was the League of Legends [6], but it did not have the option to install a local server. Another game observed was the DOTA 2 [9], available on the Steam games platform [10]. This game is free and allows a client to become a local server of a match, thus fulfilling the requirements necessary for this work.

C. Player Performance

At the end of each match in DOTA 2, the game presents data about the match and about each player individually. Data such as match duration, KDA (Kills, Deaths e Assists), farm (number of minions the player slaughtered during the match) and gold collected, along with each player's level.

Sapienza et al. [5] define a KDA Ratio that assigns a player score rating based on their killings, deaths, and assists – see (1). This formula is also used in this work as one of the evaluation points of the player's performance. Another metric defined was based on the player's farm during the game. Since the matches have different duration times, we defined the metric farm/second, to compare different matches. The last metric evaluated was the quantity of gold that the player was able to accumulate during the match. We used the gold/second analysis to evaluate this metric in order to properly compare matches with different durations. This prevents artificially increasing a metric when a match has a longer duration.

The latency, packet loss and throughput are not metrics; they are characteristics imposed by the network emulation tool in the scenarios selected, in different levels (therefore, they are called *factors*), which are explained as follows.

D. Scenarios

As reported in section III.A, the factors that this work used in the scenarios were latency, packet loss and throughput. However, preliminary tests performing packet capture with the Wireshark [11] application demonstrated that the throughput that the game uses only exceeded 25000 Bytes/s in the beginning of the match. There were a few short peaks of the 50000 Bytes/s in the first seconds of the match and none thereafter, as the throughput never exceeded theses values again. Based on these data, it was considered unnecessary to carry out the tests using the throughput as a factor. While such data were obtained with DOTA 2 game, different throughput rates can be found in other MOBA games.

Alexandre [4] used a pragmatic approach to define the network conditions, matching each condition to a specific access network that the game player might have. Cecin and Trinta [7] go further and say that in real time multiplayer games a latency of 100ms is acceptable for first person games and 350ms is acceptable for strategy games. Based on this information and on our preliminary tests, a latency variation was defined around the value of 100ms. The levels used were: 50ms, 100ms and 180ms. Callado et al. [3] defined in their experiments a variation of packet loss with the values 0.5% and 5% and found it not to be significantly impacting on the perception of the player in FPS games. In this work, the same values were used to evaluate the MOBA game. Combining the presented factors we defined the following scenarios listed in table I. The scenario representing network condition 1 is used for player adaptation to the game. In scenarios C2 to C7, all human players share the same network conditions. Finally, in scenarios C8 and C9 players face each other in different network conditions.

TABLE I. SCENARIOS

Scenarios Configuration		
Scenario	***Latency***	***Packet Loss***
C1	0	0
C2	50ms	0,5%
C3	50ms	5%
C4	100ms	0,5%
C5	100ms	5%
C6	180ms	0,5%
C7	180ms	5%
C8	scenario C2 versus scenario C6	
C9	scenario C4 versus scenario C5	

To create the test scenarios for this work, a tool was needed to simulate network conditions affecting latency and packet loss in the Windows 10 operating system. The tool chosen was Clumsy 0.2 [12]. This tool allows the simulation of various factors in the network, such as latency, packet loss and packet duplication. The tool was installed on the server and the filter was applied to each player’s IPs in order to impost the required network condition to the scenario.

E. Application of tests

The scenarios presented were performed as follows: in the first seven scenarios the matches were played with team versus team, three versus three, among players and artificial intelligence. Three humans play together against groups of AI (Artificial Intelligence) players in the same scenario. In these scenarios, each player chose a character to play the seven scenarios and the teams were mirrored, so there was no character selection advantage of one champion over another. The first seven scenarios were also used to level the players for scenarios eight and nine. In scenarios eight and nine, players faced each other in matches, one versus one, based on their levels of experience in gameplay. These scenarios were also mirrored. In these scenarios, each player was submitted to two network configurations as seen in section III.D of this work. At each match change, the network configurations of the players were reversed. As in the previous scenarios, a match was also carried out without influence on the conditions of the network. In the player versus player scenario (known as “1x1”), the KDA relationship metric has been removed because the rules of victory are different. The objective of the game is to eliminate the opponent twice or knock down the middle tower. The first player to complete one of the two objectives wins the game. In the table II, the configurations of each scenario and the metrics evaluated in each one are presented.

TABLE II. NETWORK CONDITIONS AND EVALUATION METRICS

Scenario	*Network Configuration*	*Evaluation Metrics*
C1	Without influence of Network.	KDA Ratio Farm/second Gold/second
C2	Latency: 50ms Packet Loss: 0,5%	KDA Ratio Farm/second Gold/second

Scenario	*Network Configuration*	*Evaluation Metrics*
C3	Latency: 50ms Packet Loss: 5%	KDA Ratio Farm/second Gold/second
C4	Latency: 100ms Packet Loss: 0,5%	KDA Ratio Farm/second Gold/second
C5	Latency: 100ms Packet Loss: 5%	KDA Ratio Farm/second Gold/second
C6	Latency: 180ms Packet Loss: 0,5%	KDA Ratio Farm/second Gold/second
C7	Latency: 180ms Packet Loss: 5%	KDA Ratio Farm/second Gold/second
C8	scenario C2 versus scenario C6	Farm/second Gold/second
C9	scenario C2 versus scenario C6	Farm/second Gold/second

F. Network Topology

The tests of this work were carried out in a controlled network environment. The computers were interconnected with a network switch to perform communication. Fig. 1 shows the network topology of the player versus artificial intelligence (AI) group, in this group three players face three AIs running on the server, and is not affected by network conditions. Fig. 2 presents the network topology of the player versus player scenarios (C8 and C9). In these scenarios two players face each other in several matches hosted on the server. Both Fig. 1 and Fig. 2 present the Clumsy [12] network condition emulation tool installed on the server. It is important to notice that since the Clumsy configuration is IP-based, it is possible to configure each player with a different network condition, despite the fact that all players are connected to the server through the same network switch.

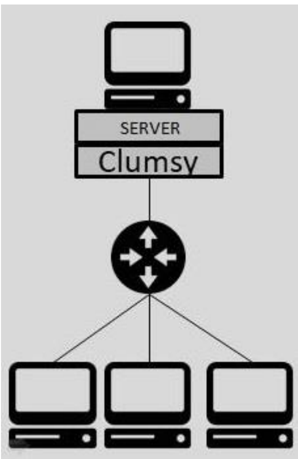

Figure 1. Player versus AI network topology.

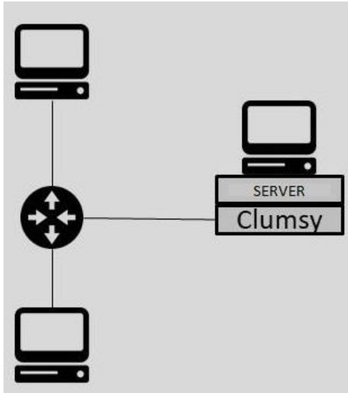

Figure 2. Player versus player network topology.

G. Data Collection and Evaluation

At the end of each match, KDA, farm and gold data are collected for each player. After performing all scenarios, a comparison of the performance of each player was made based on the metrics mentioned to evaluate the influence of the factors on the player's performance.

IV. RESULTS

In this section the results collected are presented.

A. Player versus AI Scenarios

In these scenarios, the experiments were based on four teams of human players, with three players in each team, a total of twelve players. The data was collected based on the defined metrics are presented in the following subsections.

1) KDA Ratio:

The data collected for the farm/s metric are shown in table III.

TABLE III. KDA RATIO, PLAYER VERSUS AI

Player	**Scenario**						
	C1	***C2***	***C3***	***C4***	***C5***	***C6***	***C7***
1	3,50	4,75	2,36	2,20	8	2,12	3,16
2	4	10	3,75	2,87	5,6	4,4	4,6
3	1,16	3,22	2,37	1,22	0,92	2,08	0,92
4	26	14	20	8,3	20	9,5	5,75
5	5,33	19	6	3	21	6,5	6,66
6	2,5	6	11	8,5	4	8	5
7	1,16	9	11	16	2,33	1,66	2,6
8	4	3,5	3,4	1,66	1,33	2,5	2,8
9	3,4	7	21	2,42	2,33	2,28	4,5
10	15	19	18	17	14	18	13
11	13	9,5	7	4	2,33	4,2	1,71
12	6	15	4,5	4,33	2,5	25	5

In table III it is possible to notice that some players (1, 2, 3, 8) maintain varying indexes, but these are always low, while other players vary a lot their indexes (5, 6, 7, 9, 11, 12) and the rest always maintain high rates (4, 10). This is because of the player's experience, which allows him/her to better adapt to varying network conditions.

Fig. 3 presents the graph of the KDA ratio calculation of means and confidence intervals based on a 90% confidence level for each scenario.

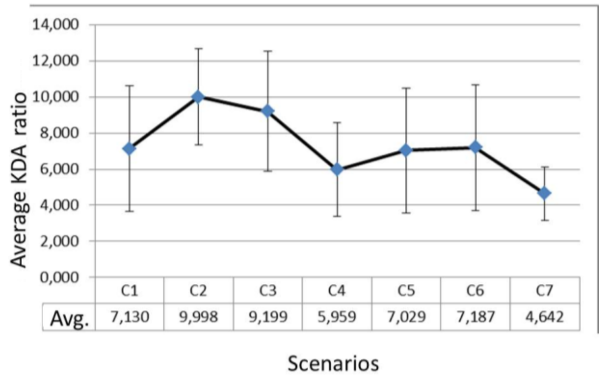

Figure 3. Confidence intervals, KDA Ratio, player versus AI scenarios.

The Fig. 3 shows the influence of each scenario on the players' KDA, listing from best to worst case scenario. As scenario 01 is a preparation scenario for the players, the data collected in it can be disregarded, because as the match is against AI the tendency is for the player to improve each match's performance. In graph 2 it is possible to see that in the second scenario the players perform better and according to the change of scenario their performances fall.

2) Farm/second

The data collected for the farm/second metric are shown in Table IV.

TABLE IV. FARM/SECOND, PLAYER VERSUS AI

Player	Scenario						
	C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*
1	0,032	0,023	0,041	0,047	0,048	0,039	0,039
2	0,075	0,066	0,055	0,067	0,04	0,061	0,05
3	0,049	0,047	0,05	0,049	0,04	0,033	0,02
4	0,066	0,051	0,056	0,061	0,05	0,049	0,06
5	0,048	0,044	0,075	0,049	0,07	0,09	0,066
6	0,078	0,05	0,063	0,07	0,053	0,07	0,085
7	0,055	0,044	0,072	0,083	0,07	0,05	0,04
8	0,057	0,064	0,036	0,026	0,028	0,05	0,03
9	0,046	0,039	0,047	0,037	0,04	0,04	0,03
10	0,103	0,088	0,137	0,106	0,101	0,182	0,12
11	0,086	0,077	0,069	0,054	0,072	0,046	0,049
12	0,098	0,157	0,085	0,066	0,08	0,09	0,09

In this table (Table IV), it is interesting to notice some players with low farm indexes (1, 2, 4, 7,) and always varying near the same level, while others (4, 5, 10, 12) vary much more and get better in scenarios with worse network conditions. This fact is due to the player's experience, which makes it adaptable to varying network conditions, especially when other players do not adapt well and the best players take advantage of the other players' poorer performance.

Fig. 4 shows the graph of the farm/second calculation of means and confidence intervals with a confidence level of 90% for each scenario.

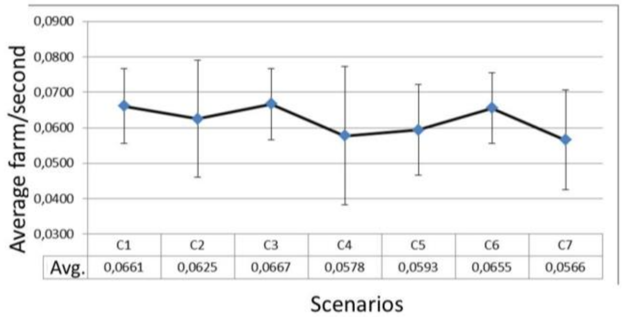

Figure 4. Confidence intervals, farm/second, player versus AI scenarios.

Fig. 4 shows the influence of the scenarios on the players' farm. In Fig. 4 one can see that packet loss is not a mitigating factor in the farm/s. Only scenarios C4 and C7 present poorer performance, when latency is high.

3) Gold/second

The data collected for the gold/s metric are shown in table V.

TABLE V. GOLD/SECOND, PLAYER VERSUS AI

Player	Scenario						
	C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*
1	6,001	5,547	6,773	6,5	8,11	6,4	7,257
2	8,914	8,108	7,79	7,699	8,13	8,017	7,77
3	7,475	8,529	7,985	7,554	6,63	8,015	5,382
4	10,87	10,87	11,15	10,61	10,76	9,083	8,648
5	8,248	9,123	8,813	8,63	12,23	10,31	9,824
6	9,35	7,482	9	10,01	8,592	9,834	10
7	6,712	7,873	7,59	9,316	7,5	6,84	6,49
8	6,994	8,03	7,037	5,995	5,824	7,503	5,784
9	7,643	7,553	7,712	8,027	7,219	7,337	6,696
10	12	11,83	16,39	11,55	13,77	12,59	12,02
11	10,45	12,89	10,03	9,53	9,576	9,03	8,607
12	10,37	12,67	9,962	9,445	9,87	12,60	10,07

Indexes also vary for different players with different levels of experience in the game. It is possible to observe players with higher indexes even in scenarios with worse network conditions.

Fig. 5 shows the graph of the gold/second calculation of averages and confidence intervals with a confidence level of 90% for each scenario.

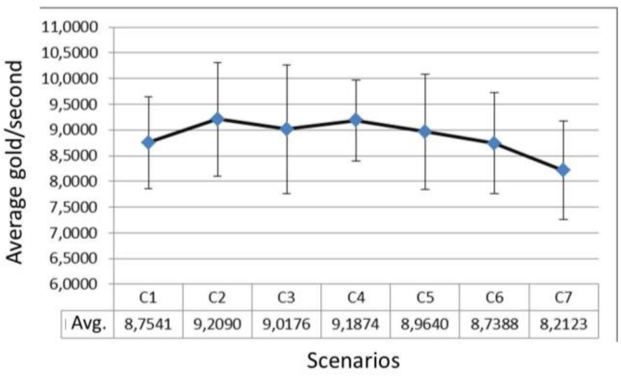

Figure 5. Confidence intervals, gold/second, player versus AI scenarios.

Fig. 5 shows the influence of the different scenarios on the players' gold collecting. In Fig. 5 it is possible to see that packet losses cause a decline in players' gold collection. It is possible to perceive a decrease between scenarios C2 and C3, between scenarios C4 and C5 and between scenarios C6 and C7, when only packet loss is varied. In scenario C4 onwards, players' gold/second performance also worsens according to the increase in latency.

B. *Player versus Player Scenarios*

In the player versus player scenarios, the experiments were based on 1 versus 1 clashes, which means a match where a single player goes against another single player. In scenario C8, players are submitted to scenarios C2 and C6 alternately, which means there is always a player with low network latency against a player with high network latency. Scenario C2 has 50ms latency and a packet loss of 0.5% and scenario C6 has a latency of 180ms and also has packet loss of 0.5%. Thus, in scenario C8 only the latency is changed. In scenario C9, players were submitted to scenarios 4 and 5 alternately. Scenario C4 has latency of 100ms and packet loss of 0.5% and scenario C5 also has latency of 100ms but with packet loss ratio of 5%. Thus, in scenario C9 only the packet loss rate is changed. Prior to the scenarios, the players made a match without influence of the network, to check the baseline result of the match if there was no difference in the network conditions.

1) *Scenario C8*

In scenario C8, a total of 10 players faced successively the first versus the second, the third versus the fourth and so on. After performing the tests, it was observed that 6 of the 10 players who faced each other, won the match when they had the best network conditions and lost when in the worst network conditions, while 4 of them won or lost regardless of the network conditions to which they were submitted.

a) *Farm/second*

Table VI shows the farm/second data for each player.

TABLE VI. FARM/SECOND, SCENARIO C8

Player	Sub scenario		
	C1	***C2***	***C6***
1	0,048	0,028	0,03
2	0,064	0,082	0,064
3	0,085	0,064	0,07
4	0,063	0,062	0,048
5	0,097	0,099	0,108
6	0,091	0,092	0,048
7	0,048	0,036	0,03
8	0,056	0,059	0,047
9	0,076	0,068	0,07
10	0,049	0,069	0,073

Table VI shows that most players present a decline in performance following the scenarios, but some show improvement. This is probably because the player learns how his opponent behaves, learning to predict his actions. It is also expected that most players perform best in scenario two because his opponent is in scenario C6, which is a scenario with worse network conditions.

Fig. 6 shows the graph of the farm/second calculation of averages and confidence intervals with a confidence level of 90% of each scenario.

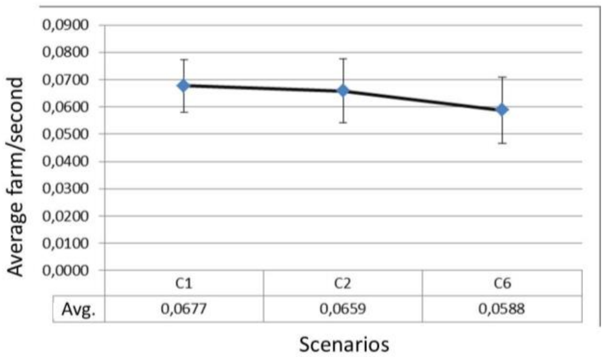

Figure 6. Confidence intervals, farm/second, scenario C8.

In Fig. 6 a decline in the farm of the players can be noticed. This decline occurs according to the change of scenario, being of the scenario one for the two do not very expressive, but from scenario C2 to scenario C6 with a larger decline.

b) *Gold/second*

Table VII shows the gold/second data of each player.

TABLE VII. GOLD/SECOND, SCENARIO C8

Player	Sub scenario		
	C1	***C2***	***C6***
1	5,044	3,555	3,248
2	4,341	5,867	5,3
3	5,541	5,086	5,04
4	4,053	3,96	3,921
5	4,97	4,575	4,535
6	4,887	4,604	2,853

Player	Sub scenario		
	C1	*C2*	*C6*
7	5,167	2,944	3,44
8	2,808	5,22	2,228
9	6,84	3,147	3,304
10	2,89	5,51	5,59

In Table VII an improvement can be seen in the performance of some players even in a worse scenario. The variation that occurs from scenario one to scenario two happens because the opponent is in a scenario with worse network conditions. The players' improvement from scenario two to scenario six is due to the player's learning curve over their opponent.

Fig. 7 shows the graph of the gold/second calculation of averages and confidence intervals with a confidence level of 90% of each scenario.

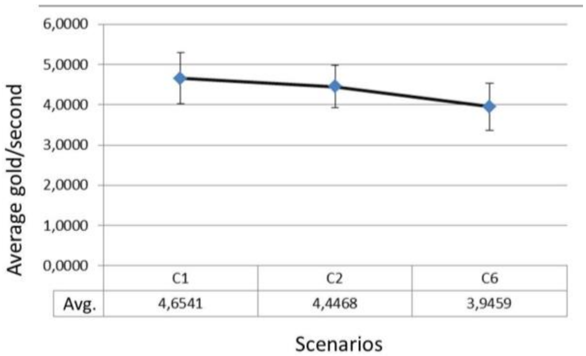

Figure 7. Confidence intervals, gold/second, scenario C8.

Fig. 7 shows a decline in the gold collected by the players according to the change in scenario, where from scenario one to scenario two there is a smaller variation. This is due to the fact that in scenario one, the two players are in equal network conditions, and when one player is in scenario two, the opponent accesses the game from a network with worse conditions. Since the variation from scenario two to scenario six is greater, the player in scenario six faces a player in scenario two, and a lower performance is expected.

2) Scenario C9

In this scenario, only the packet loss rate is changed. In total 8 players participated of the experiments in this scenario, successively the first versus the second, the third versus the fourth and so on. After the tests, it was observed that four of the eight players who faced each other won the match with better network conditions and lost in the worst conditions, while four of them always won or always lost, having the same result regardless of the network conditions to which they were submitted.

a) Farm/second

In Table VIII shows the farm/second data for each player.

TABLE VIII. FARM/SECOND, SCENARIO C9

Player	Sub scenario		
	C1	*C4*	*C5*
1	0,048	0,039	0,038
2	0,064	0,068	0,066
3	0,085	0,071	0,064
4	0,063	0,062	0,075
5	0,028	0,085	0,09
6	0,099	0,051	0,053
7	0,097	0,082	0,08
8	0,091	0,09	0,045

In Table VIII, it is possible to see that most players present a decrease in performance in the sequence of scenarios. However a player has won in all scenarios, which is probably due to his learning curve over his opponent. The variation that happens from scenario one to scenario four is expected because the opponent is in a scenario with worse network conditions. But the variation from scenario 04 to scenario 05 can be affected by the player's learning curve and also by the fact that the opponent was unable, due to lower game experience, to adapt to worse network conditions.

Fig. 8 shows the graph of the farm/second calculation of averages and confidence intervals with a confidence level of 90% of each scenario.

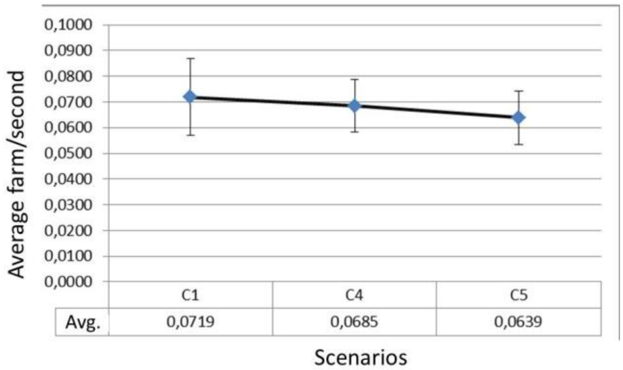

Figure 8. Confidence intervals, farm/second, scenario C9.

Fig. 8, it is possible to notice a decline in the players' farm according to the change of scenario for worse network conditions. However, this decline was not very expressive, which shows that the loss of packets does not have a great influence on the players' farm.

b) Gold/second

Table IX shows the gold/second data of each player.

TABLE IX. GOLD/SECOND, SCENARIO C9

Player	Sub scenario		
	C1	*C4*	*C5*
1	5,044	6,124	3,612
2	4,341	5,944	4,165
3	5,541	5,552	4,647
4	4,053	3,954	4,267
5	2,928	5,981	5,89

Player	Sub scenario		
	C1	***C4***	***C5***
6	6,77	3,118	3,874
7	4,97	4,001	3,835
8	4,887	4,104	2,853

Just as occurred in the previous metric, it is possible to notice two players (4, 6) with performance gains in the worse scenario. Of course, if this occurs on a player's gold collecting, it is expected to also occur in his/her farm, since one is greatly influenced by the other.

Fig. 9 shows the graph of the gold/second calculation of averages and confidence intervals with a confidence level of 90% in each scenario.

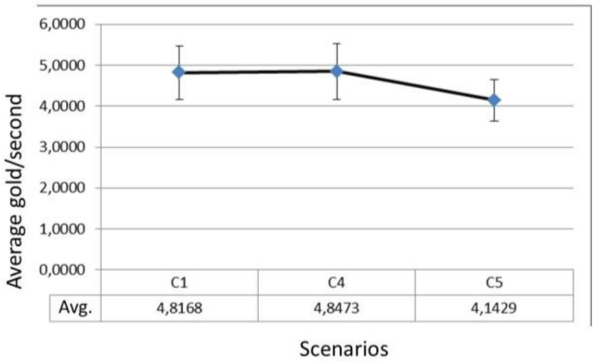

Figure 9. Confidence intervals, gold/second, scenario C9.

In Fig. 9, it can be noted that in scenarios one and four there was no decline in average gold collected by players. In scenario five, the packet loss is greater, the performance drop was considerable.

C. Discussion

An interesting fact that has been observed in the team versus team scenarios was that the different network conditions have a greater influence on the farm and the gold collected from more experienced players, that is, players with higher farm rates, KDA and gold. To evaluate this fact we used the calculation of the mean and the calculation of the variance on the scenarios of each player. These data are presented in Table X. We also found a correlation of 92% between higher average farming and higher farm variance, along with a correlation of 81% between higher average gold and higher gold variance. This suggests that better players risk more, resulting in better performance when the bet pays off and worse performance when it doesn’t. Best performances are highlighted in blue bold font and worst performance is shown in red bold font.

When comparing these results with other works [3, 4, 5, 7], it becomes common sense that network performance affects player performance. However, the influence of player expertise in the effects of the network performance varies according to game genre. Clearly, in strategy [4] and MOBA (this work) games, the higher player expertise allows the player to prevent some loss in performance due to poorer network conditions. In other game genres, such as FPS [3], the network performance effect on player performance is more straightforward.

TABLE X. AVERAGE AND VARIANCE – FARM AND GOLD/SECOND

Player	Average Farm/Second	Farm/Second Variance	Average Gold/Second	Gold/Second Variance
1	**0,038429**	**0,00006453**	**6,655428571**	**0,605397388**
2	0,058714	0,000113061	8,061142857	0,146525837
3	0,041143	0,000107265	7,367142857	0,954585551
4	0,056143	0,0000358	10,28628571	0,843875633
5	0,063143	0,000244694	9,597571429	1,584851673
6	0,067	0,000137714	9,181142857	0,725607837
7	0,059143	0,000221265	7,474428571	0,788164531
8	0,041714	0,000196776	6,738142857	0,672426694
9	0,039857	0,00002783	7,455285714	0,154840204
10	**0,119571**	**0,000857388**	**12,87957143**	**2,518698245**
11	0,064714	0,000198204	10,01771429	1,691704776
12	**0,095143**	**0,000724122**	**10,71457143**	**1,545860531**

V. CONCLUSION

The objective of this work was to evaluate the influence of different network conditions on the performance of a player in MOBA games, using network emulation to vary the network conditions to which the players are submitted.

Nine scenarios with different network conditions were defined in two groups of different scenarios. In the first seven scenarios, players played in team with each team of three human players faced three AI players (bots). In scenarios eight and nine players faced each other in one versus one matches (“1x1”).

The network factors chosen to evaluate the players' gameplay were throughput, latency, and packet loss. At the end of this work, we can conclude that the throughput for the DOTA 2 game does not exert an influence, since the throughput used by the game is always less than 53 KBytes/s and typically less than 25 KBytes/s. Latency has been shown to have an influence on player performance, having nearly equal influence on the 50ms and 100ms levels but having a greater influence when subjected to 180ms. The packet loss ratios used were 0.5% and 5%, where 0.5% did not present influence on the player and 5% presented insignificant influence alone, but a higher influence when associated with a high latency. In summary, network conditions affect a MOBA player's performance, independent of the player's experience level. Even though the more experienced player can adapt to network conditions, his performance is affected.

As a future work, the experiment may be reproduced introducing a new network factor, the jitter (the variation of latency during each game). Another point that can also be explored is to use different hardware configurations on each player's machines, ranging from robust machines to machines with weaker hardware, forcing the game to work in minimal and maximum video configuration conditions and measuring how FPS (number of Frames rendered per Second) influences player performance in a MOBA game.

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