Character Customization in Fortnite Battle Royale as a Channel for Covert Communication

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ABSTRACT

Covert channels enable their users to transfer information without others being able to detect that communication has occurred. Such channels exist in both analog and digital formats, and have been utilized for millennia. Online multiplayer video games are a burgeoning medium ripe with potential for covert communication, but this potential has yet to be studied in extensive detail. We explore a novel channel, the presence of which is becoming increasingly common in such games; that of character customization. Examining the utility of this channel within one highly popular game, Fortnite Battle Royale, we find that while effectively undetectable communication is possible it is also highly inefficient.

KEYWORDS

Steganography, Covert Channels, Online Gaming

1 INTRODUCTION

Steaganography, the practice of concealing a piece of information within other information (be it text, audio, image, video, etc.), dates back to at least the year 440BC.[8] The objective is not to conceal the content of the transmitted information as in an encryption scheme, but rather to conceal the fact that communication is taking place. Practical applications are numerous, and range from the benign (e.g. invisible watermarks in videos) to the malicious (e.g. exfiltrating sensitive information from a computer with restricted Internet access). Research in the field therefore serves a dual purpose of enabling new technologies and detecting/preventing malicious behavior. The mechanism presented in this paper is more likely to fall into the latter category.

The surge in popularity of online gaming has created massive potential for covert communication through side-channels in games. Traffic to game servers generally looks inconspicuous, and playing an online game often requires transmitting large amounts of information. We consider one possible side-channel in the popular "Battle Royale" mode of the game Fortnite (hereafter simply "Fortnite"). Our primary contributions are to establish that covert communication over this channel is possible, and to estimate the average encoding density[1] possible on the channel as well as the amount of time and money required to carry out such communication. While the encoding scheme itself is quite simple, the circumstances under which a message may be passed without raising suspicion are rare and complex.

1.1 Paper Structure

The remainder of this paper proceeds as follows. We give a brief overview of Fortnite's gameplay in section 2 and discuss related work in section 3. Section 4 outlines the basic encoding mechanism , and section 5 details the scenarios under which message passing can take place and their probability of occurring. In section 6 we present the scheme's encoding density as well as the time and money requirements for carrying it out. We discuss some potential optimizations for the scheme in section 7, and future work for this research area in section 8. Finally, we conclude in section 9.

2 FORTNITE OVERVIEW

Fortnite is a free-to-play online multiplayer game created by Epic Games.[3] In each match, up to 100 players are airdropped onto an island together from a "Battle Bus" which traverses a random linear path over the island at the start of each game, as shown in Figure 1. Once on the ground, players scavenge for weapons, shields, and other items with which to harm other players or help themselves survive. They may also gather building materials with which they can construct (for example) walls to provide cover from enemy fire or stairs to obtain high ground over other players.

Throughout the course of a match, "the storm" gradually closes in on a randomized point on the island, as shown in Figure 2. Players will gradually lose health while outside "the eye of the storm", an ever-shrinking circular safe-zone. This mechanism prevents games from lasting too long, as the map is quite large and players would otherwise find it difficult to locate one another as the number of remaining players dwindles. Once a player's health reaches zero, as a result of damage taken either from the storm or from another player, they are eliminated from the game and begin spectating the

[1]Encoding density is a measurement of efficiency for steganographic communication. It is generally represented as a number between 0 and 1, indicating the ratio between the amount of covert traffic transmitted and the amount of cover traffic needed to disguise it.

Figure 1: The game map, as seen at the beginning of a match. The current position of the Battle Bus is shown in the upper left-hand corner, while its trajectory for the match is indicated by the line of yellow arrows.

Figure 2: The game map as seen partway through a match. The purple region indicates the area already encompassed by the storm, with a dark blue line outlining the eye of the storm. The white circle indicates where the eye of the storm will close in to next, and the white line extending from the left side of that circle indicates the most direct route the player can take to remain safely inside the eye of the storm.

player who eliminated them (or a random player if they are eliminated by the storm). The game ends when all players except one have been eliminated.

Players may choose from one of three game modes for each match: Solo, in which all players compete individually; Duo, in which players compete in teams of two; or Squad, in which players compete in teams of four. Other modes with differing rulesets are occasionally offered on a limited time basis. For example, a recent Blitz mode (with both Solo and Squad sub-modes) featured a faster-moving storm as well as a higher quantity of weapons and other items.

Before each match, players have the option to customize the appearance of their in-game character with one or more "skins". These skins are purely cosmetic, providing no gameplay advantage other than potentially camouflaging their wearer. In reality though, most skins are much more visible than the default character models (as shown in Figure 3), so if anything their use may put players at a disadvantage.

3 RELATED WORK

Information Hiding and the study thereof have a long history. Petitcolas et al. provide a good overview of the field in [8]. There has also been a fair amount of prior work done in the realm of information hiding within games specifically. Hernandez-Castro et al. provide a general methodology for game-based steganography and detail an application to the game of Go in [5]. Murdoch and Zieliński explore potential covert channels in online versions of the games Bridge and Connect-4 in [7].

The most closely related[2] work we were able to find is Zander et al.'s 2008 scheme for embedding information within subtle character movement patterns in the game Quake III Arena.[10] They achieve a messaging rate for their covert traffic of 14-18 bits/second, which is several orders of magnitude more efficient than our scheme. However, Quake III Arena no longer has very active multiplayer servers, and even the most subtle movement-based schemes are inherently more detectable than our method. To our knowledge, no prior work has examined the potential utility of character customization for information hiding, perhaps because technical limitations have prevented extensive customization options from appearing in many games until recently.

[2]Related in the sense that it considers a similar type of game.

Figure 3: Two potential outfits a player may equip for their character. The outfit on the left is one of several default character models which are randomly assigned to players for free (though it can also occasionally be purchased for $800 V-Bucks, or approximately $8 USD if players don't want to rely on randomness), while the outfit on the right was briefly available for 2000 V-Bucks, or approximately $20 USD.

4 ENCODING MECHANISM

Fortnite offers players four categories of character customization, which currently have the following numbers of available skin options[1]:

- Outfit: 86
- Back Bling: 12
- Harvesting Tool: 31
- Glider/Umbrella: 29

A player may equip up to one item from each category prior to each match. However, a player's glider/umbrella is only visible at the start of a match or with the use of an item which can only be found in-game on rare occasion. Thus, it is not a reliable way to encode information as there is a low likelihood of it being visible in one of the scenarios described in section 5.2. A player who has unlocked every skin in each of the three remaining categories is thus able to select one of 31,992 (just under 2^{15}) unique combinations when customizing their character.

Players wishing to communicate covertly may use some scheme to assign (out of band) an integer to each of these combinations. Thus, in a single match a player may encode approximately 15 bits of information within their selection of character skins. As new skins are frequently added to the game, we will generously round up to 16 bits[3] in order to simplify the math for our efficiency calculations in section 6.

5 MESSAGE PASSING

Consider a scenario in which Alice wishes to pass a message to Bob. For this to occur Bob must be able to see Alice's character in game, and must also be able to link Alice's username to that character. For the first condition to be met, Alice and Bob must be playing on the same server at the same time. The likelihood of this happening is explored in further detail in section 5.1 below. Section 5.2 details the scenarios under which the second condition may occur and their likelihood.

5.1 Matchmaking

In order for Alice and Bob to communicate, they must be able to join the same game. Cross-platfrom play is now partially supported, but is implemented in such a way that if they play on the same platform as each other (either Windows/macOS (collecvitely "PC"), PS4/Xbox One (collectively "console", or Android[4]/iOS (collectively "mobile"), they will be placed in a server dedicated[5] to that platform. [9] For simplicity's sake, we will assume Alice and Bob both play in the Solo game mode, in which there is no cross-platform play.

They must also select the same matchmaking region. By default, regions are assigned automatically based on network latency, but players may choose a region with a slower ping speed if they desire. However, doing so would likely degrade gameplay and may therefore arouse suspicion. If Alice and Bob are geographically distant from one another, it may be beneficial for one of them to use a VPN near the other so that they will be placed in the same matchmaking region automatically.

There are currently six region options available: Asia, Brazil, Europe, NA-East, NA-West, and Oceania. If Alice and Bob both have access to VPN services which could automatically place them in the region of their choice, or if they determine that manually selecting a region with a higher ping is worth the potential risk of detection, they may choose

[3]Enough to transmit two characters, e.g. "gg"

[4]Pending release.

[5]The actual[6] cross-platform matchmaking scheme is slightly more complex, as there are no servers dedicated to multi-platform parties. Instead there is a hierarchy of platforms, ostensibly based on the difficulty of using each platform's input device. PC players are considered to have an advantage over both console and mobile players, and console players are considered to have an advantage over mobile players. Thus if a team has any PC players they will play on a PC server, regardless of the other players' platforms. If a team contains a mixture of console and mobile players, it will be placed on a console server.

[6]The actual actual cross-platform matchmaking scheme is even more complex, as cross-platform play between PS4 and Xbox One is not yet supported.

to use a region with less traffic in order to increase their odds of being placed in the same game. Some regions are consistently more utilized than others due to higher populations of players, and the traffic in each region also varies by time of day – the most beneficial strategy would be to select a server located in a timezone that is currently in an off-peak hour. Similarly, if they are restricted to using a single region they may choose to attempt communication at off-peak hours only.

Within each region and platform there are many concurrent games, hosted on AWS servers which total in the thousands [4]. We can approximate the odds of Alice and Bob being placed in the same game based on the number of concurrent players. In February, 2018 it was reported that the game reached 3.4 million concurrent players.[4] It has almost certainly peaked higher than that since, but average concurrent user counts are likely still lower, so we'll assume a typical number is 3 million.

It's unclear how these players were or are distributed between platforms and regions, but when that number was announced, the mobile version had not yet been released. That means those players were split across three platforms and six regions. Assuming they were uniformly distributed, that equates to 166,667 simultaneous players in each of the 18 platform-region combinations. As a single game contains at most 100 players, that gives us 1,666 simultaneous games per platform-region. However, there are also three separate game modes to choose from. Assuming that players are evenly distributed between those game modes as well, and that Alice and Bob agree in advance on which mode to play, they are left with 555 concurrent games into which each of them may be placed. Thus, the odds of Alice and Bob being placed in the same game are $\frac{1}{555}$.

5.2 Player Identification

There are only a few scenarios in which Bob may be able to see Alice's username in-game:

(1) Bob and Alice are playing together on the same squad
(2) Alice eliminates Bob
(3) Bob eliminates Alice
(4) Bob witnesses Alice eliminate someone else
(5) Bob witnesses Alice be eliminated by someone else
(6) Bob is eliminated and eventually spectates Alice

We must discount the possibility of scenario 1, as it requires an overt admission of a connection between Alice and Bob, negating any plausible deniability for their communication. If Alice and Bob determine that this observable association does not violate their threat model however, it would remove the requirement for them to actually play the game in order to communicate. They could pass messages rapidly by changing their character skins in the lobby instead, perhaps using an emote[7] or some other signal to indicate when a skin combination has been selected and is ready for interpretation by the other player. Or they could use a more standard steganographic technique to encode information within messages sent through the in-game voice or text chat.

Scenarios 3, 4, and 5 are all unreliable. Once a player is eliminated, their character disappears from the game. Thus, if Bob eliminates Alice before he is able to determine which skins she has selected, he fails to receive her message. Whenever any player eliminates another, all players in the game see a brief message announcing the fact, which includes both players' usernames as well as the weapon used. Thus, if Bob witnesses one character eliminate another using a rifle and then sees the message "Alice eliminated Eve with a Rifle", he may assume that the victorious character was Alice. Conversely, if he sees the message "Eve eliminated Alice with a Rifle", he may assume that the defeated character was Alice. However, it is often the case that multiple characters are eliminated in a very short period of time, so Bob may actually see two or more similar messages simultaneously after witnessing such an event, and would therefore be unable to discern whether the character he just observed was in fact Alice.

Scenarios 2 and 6 are reliable, though both require either a great deal of chance or a great deal of skill on Alice's part. When Alice eliminates Bob, he will see her username and have ample time[8] to view her character's skins in order to decipher her message while spectating her. Additionally, Alice will be notified that the she has eliminated Bob, so she can safely assume that her message was received (a property which scenarios 3-5 do not possess, even if Bob is able to receive the message). If we assume that Bob is equally likely to be eliminated by Alice as he is by any other player, then she has a $\frac{1}{99}$ chance of passing her message in a given game.

However, if Bob is eliminated by Eve, he will begin to spectate her – being able to see both her username and her character's skins. If Frank then eliminates Eve, Bob will begin spectating Frank instead, again with the ability to see both his username and his character's skins. This continues until the game ends with just one player standing, at which point Bob will be spectating that player. Thus, if Alice wins the game or otherwise eliminates someone Bob is spectating, Bob will be able to receive her message (and, as above Alice will be able to see that Bob is spectating her, confirming that he has received her message). However, this requires

[7] The omission of emotes from the list of skin categories in section 4 above is intentional. Players may equip multiple emotes per match and may use each one arbitrarily many times per match. This would potentially allow players to transmit a much higher number of bits per match, but excessive use of emotes in-game may arouse suspicions that a player is attempting to communicate.

[8] Unless she is eliminated very quickly thereafter.

Alice to be skilled at the game, as she must eliminate at least one player other than Bob. In fact, the more players she eliminates the more likely it is that Bob will be able to spectate her.

We determine the probability that Bob will come to spectate Alice, either through a direct or indirect elimination, by modeling each game as a sequence of one-on-one matches between two players drawn at random from the pool of all remaining players. We assume all players are equally skilled, and therefore have a 50% chance of winning each one-on-one fight. This model is more realistic than a conventional tournament-style bracket, as it allows players to win the game after eliminating anywhere from 1 to 99 other players, rather than a fixed quantity. Note that this model does not account for players being eliminated by the storm – this is a rare occurrence even for players with below average skill, so we assume that Alice and Bob are consistently careful enough not to let it happen.

Instead of figuring out how to compute this probability, we simulated a million matches with "players" numbered 0-99 and measured the number of times that player 1 (Bob) came to spectate player 0 (Alice). In our simulations, this scenario occurred 42,180 times, indicating that for any given game in which Alice and Bob both participate, he will have approximately a 4.218% chance of spectating her. Combining this figure with our results from section 5.1, we find that Bob and Alice should expect to play a little over 13,000 games each in order to receive a single two-byte message.

Note that utilizing this spectating scheme requires Bob to wait until the very end of a game to attempt his receipt of a message. However, while it will roughly quadruple the average duration of his matches (as discussed in section 6.1), the odds of passing a message in a given match are more than quadrupled. As the majority of network traffic transmission occurs towards the beginning of a game (as discussed in section 6.2), this scheme will not impose a significant reduction in encoding density.

Additionally, if Bob always waits until the end of a match to start a new one while Alice begins a new match as soon as she wins or is eliminated, they are less likely to enter into a detrimental synchronization which could prevent them from ever being placed in the same match. For instance, if they both always waited until the end of a match but started their first matches ten minutes apart, they would most likely continue to start each new matche roughly ten minutes apart. Considering all of these factors, Bob would be wise to spectate until the end of every match.

6 EFFICIENCY

6.1 Time

The amount of time required to complete a game depends largely on one's skill level. Measuring from the moment a player indicates they are ready to join a game until the moment they are eliminated, we find that the fastest games last approximately two minutes, while a full match generally lasts about twenty. The mean length of a match is likely about 5 minutes for a player of average skill. Thus, in the best case scenario (in which Alice and Bob are placed in the same server on their first attempt and Alice eliminates Bob immediately after they reach the ground) it will take Alice and Bob just two minutes to pass a single two-byte message, while in the average case it will take them 180.556 days of continuous gameplay, for a messaging rate of 1.0256×10^{-6} bits/second.

6.2 Bandwidth

With any information hiding scheme, it is important to determine how much cover traffic is needed to pass a message. More specifically, for each bit of traffic sent on the covert channel, how many total bits must Alice and Bob transmit? Over the course of a typical game[9], we find that each player must transmit (combined sending and receiving) approximately 5MB of data with a lower bound of ~4MB for very short games. [10] Playing (or spectating) a game until it ends takes approximately 8MB. Thus, in the best case scenario (as described above in section 6.1), Alice and Bob must collectively transmit 4MB of cover traffic for every one byte sent on their covert channel.

The average case is significantly worse. As detailed in section 5.2, we assume that Bob spectates until the end of each match while Alice begins a new match as soon as she is eliminated. Bob should thus expect to play 13,000 20-minute games to receive each two-byte message, transmitting 104GB of data in the process. Alice should expect to play 13,000 matches averaging 5-minutes each in order to send each message, transmitting upwards[11] of 65GB in the process.

[9]Measurements were taken over the course of five matches. We played the macOS version of the game, in the NA-East region, in the Solo game mode. Graphics settings were configured to Low. The hardware used was a 2016 MacBook Pro with a 2.7GHz Intel Core i7 CPU, 16 GB 2133 MHz LPDDR3 RAM, and an Intel HD Graphics 530 1536 MB graphics card. The device was running macOS 10.12.6 and Fortnite version 3.3.

[10]Data transfer appears to be heavily front-loaded, such that longer games require fewer bits/second to be transmitted.

[11]Since more data transfer happens at the start of each match, Alice's shorter matches require her to transmit more bits/second than her longer ones, so the real amount she needs to transfer is higher. As we are lacking good data on exactly how the data transfer is temporally distributed throughout a match and we are attempting to establish an upper bound on our mechanism's efficiency, we ignore this complexity.

	\$5	\$8	\$12	\$15	\$20	Bundled	Free Pass	Battle Pass	Promotion
Outfit	0	19	24	24	8	0	0	10	2
Back Bling	0	0	0	0	0	8	1	2	1
Harvesting Tool	4	13	1	10	0	0	0	3	0
Glider/Umbrella	14	6	1	1	1	0	0	3	4

Figure 4: The number of cosmetic items per category available at each pricing tier.

Thus, they will have to transmit a collective average of 169GB of cover traffic per byte of hidden traffic, an encoding density of 5.9172×10^{-12}.

6.3 Money

While Fortnite's Battle Royale mode is free-to-play, the vast majority of its character skins are not free to use. The intent is to provide players with a sense of pride and accomplishment for unlocking different skins. As for cost, cosmetic items are priced in multiple tiers. Prices are listed in "V-Bucks", 1000 of which can be purchased for $9.99 USD. Certain items are not available for direct purchase – some of these can be unlocked through extensive play after purchasing a Battle Pass (950 V-Bucks per season, currently on season 3), a select few can be unlocked by playing for free, some have been offered through promotional deals with Twitch Prime ($12.99/month)[2], and some Back Bling items come bundled with paid Outfits.

The table in Figure 4 shows the number of skins that have been available to-date at each tier and in each category. The total minimum cost to obtain all cosmetic items to date is $1,452. Note that this is a one-time cost, and that obtaining skins is only necessary to send messages, not to receive them. If Alice is financially constrained, she may opt to purchase only a subset of the available character skins, beginning with those at lower price tiers. Naturally, this would allow her to send fewer bits of information per game.

7 POTENTIAL OPTIMIZATIONS

There are several tactics that Alice and Bob may employ to increase the odds of finding themselves in one of the limited scenarios under which they would be able to communicate. Unfortunately, most of them require somewhat unusual gameplay behavior which may arouse suspicions about a potential attempt to communicate. For instance, they may choose to land in the same part of the island each time in order to increase the odds of seeing each other early in a game (or at least to determine whether they have actually been placed into the same game), but the set of optimal landing areas changes from game to game, and certain areas are effectively unreachable in some games.

Perhaps the best optimization would be for Alice and Bob to get good at playing Fortnite. The more skilled Alice is, the easier it will be for her to stay alive long enough to eliminate Bob (or someone Bob is spectating), and similarly the more skilled Bob is, the more likely he will be to stay alive long enough to be eliminated. However, as the scheme is *not* reliable when Bob eliminates Alice, he must pursue an unconventional strategy of attempting to stay alive while eliminating as few other players as possible – ideally remaining hidden until only one other player is left, hoping that player is Alice.

Note that as their skill levels increase, so will their average game times, though assuming Bob makes use of the spectating method discussed in section 5.2, this factor will be irrelevant for him. If Alice gets extremely good, she may be able to reduce the amount of time required to finish her matches as they simply end when all other players have been eliminated and therefore in theory they have no minimum duration.

An additional benefit of getting good is that it may help Alice and Bob overcome the financial barriers to message passing outlined in section 6.3 above. Playing Fortnite can be an extremely lucrative profession. One streamer by the name of Tyler "Ninja" Blevins reportedly makes $500,000 USD per month playing the game, and the bulk of his popularity can likely be attributed to his skill and the high frequency with which he plays the game.[6] Such an income should be sufficient to purchase all forthcoming cosmetic items in the game.

8 FUTURE WORK

There is a great deal more research to be done in this area. The efficiency of our method should be considered for other similar games, such as PlayerUnknown's Battlegrounds which offers extensive character customization options along with very similar matchmaking and player identification mechanisms. There are also likely additional optimizations to our methodology which we have not considered. There are almost certainly more efficient covert channels one could take advantage of within Fortnite and similar games, though most are unlikely to offer the same degree of imperceptibility. Finally, as new cosmetic items are added to the game it will be important to update this paper's efficiency measurements accordingly.

9 CONCLUSION

We have established that character customization in Fortnite is a viable, if highly inefficient, mechanism for covert communication. If players have both the requisite patience and financial resources, they may be able to pass messages with almost zero fear of detection. Network operators aiming to prevent users from exfiltrating sensitive data should be wary of any users playing Fortnite.

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