The Afterglow effect and Peer 2 Peer networks

Peer to Peer networks (P2P) are heavily used for media sharing and distribution of files. Very few studies have looked at the effects and behaviors of these types of networks specifically during the period of time after the P2P connection has been terminated. This study will look specifically at this Afterglow period to look at the statistics related to the traffic seen during that period. Additionally qualitative methods will be used to look at this data for anomalies and malicious traffic.

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Abstract

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1.1. Introduction

The history of peer-to-peer (P2P) networking can be traced back to the late 1990's when computer technology had progressed to the point of easy viewing and storage of music and video files. This progression precipitated the desire for users to exchange, distribute and share these files amongst each other. The available technology, at that time, was cumbersome. It required an individual who wished to share or distribute files to set up a server and run a program that was dedicated to hosting those files. Setting up such a server, however, was beyond the skill of the typical computer user. In addition, there were other hurdles that prevented easy access, including setting up user accounts, letting users know where to locate the server, and what files were available to access. This desire for users to share their files in a less cumbersome format eventually prompted the development of software and services that allowed users to access and distribute files amongst themselves, which came to be known as P2P networking (Johnson, McGuire, & Willey, 2008).

BitTorrent is a protocol that is used to distribute a file or files between multiple clients (Cohen, 2008). The advantage that it has over traditional server/client methods is the fact that there may be multiple hosts on different networks that can provide the files simultaneously. This allows a host to download the file faster and more efficiently then directly from one server. This efficiency increases with the number of hosts that participate in the torrent. The process for distributing a file or files starts with the creation of a torrent file. This file contains two important things: the location of a "tracker" and information about the makeup of the file or files. The "tracker" is a URL to a server that keeps track of all of the peers that are

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participating in the torrent. It is important to note that the tracker does not have any pieces of the file that are inside of the torrent, it only keeps track of the participating peers (Cohen, 2008). To keep track of the makeup of the files contained in the torrent, the files are broken up into smaller pieces and an MD5 hash is created. The files are broken down into smaller pieces to increase the efficiency of transferring pieces from peer to peer. This allows a peer to grab pieces of the torrent from multiple peers simultaneously while assuring the continuity of the files as a whole.

One of the concepts that this study will focus on is "Afterglow". This is the period of time after the P2P session has terminated but there still may be incoming requests for searches or downloads to what was previously available while the P2P session was still active. These connection attempts are rejected by the system after the termination of the listening P2P program. There are several reasons that these connections are relevant. First, it is a way to evaluate the efficiency of the P2P program and its ability to keep an accurate record of systems that are still participating. Inefficiencies in this methodology of keeping track of participants would greatly increase the time needed to find and acquire participating systems and subsequently acquiring those files. Second, there are some security implications that need to be considered with these afterglow connection attempts. There can be difficulty in separating these connection attempts, which are legitimate and harmless, from traffic that could be malicious. Studying the decay rate of this afterglow period might provide a better idea of which connections are malicious and which are harmless and expected. An additional security consideration is the use of the P2P systems to identify systems that are potential victims for an attacker. An attacker might connect to a P2P system and utilize that information in reconnaissance to identify a system and a method to connect to that system via the port that the P2P program uses. These attacks could start or continue long after the P2P participation is over.

1.2. Purpose and Hypotheses

The purpose of this study is to measure the "Afterglow" period after a P2P session is terminated. In order to accomplish this goal, a P2P session will be established and the number of incoming connections will be tracked. After a predetermined period of time, the P2P program will be turned off and participation in the P2P will stop. Tracking of inbound connections after the termination of the program will continue for a period of time. As previously noted, this period of time after the P2P session is terminated is called the "Afterglow" period.

In order to measure the afterglow period, we need to count the number of connection attempts that are made once the program is turned off. This can be done by monitoring the traffic coming to and from the computer running the P2P software. On the monitoring computer a program called Snort is installed, this program will track the number of connection requests on any network port (Beale, Poor, & Foster, 2004). For each trial, a new set of Snort rules were created specific to the port settings designated in the uTorrent program. There are two types of connections that were tracked, TCP and UDP. All inbound TCP connections to the P2P computer will only have the SYN flag set and be made from the outside to the P2P computer (Stevens, 1994). As UDP is a connectionless protocol, there are no unique flags to key on (Stevens, 1994). A rule is created to look just for UDP packets whose destination is the P2P computer on the port number specified (Beale, Poor, & Foster, 2004).

Once collected, the data was broken down into number of connections in a ten minute period. An example: for the time period of 00:00 to 00:10, or the first ten minutes after the connection was terminated, there were XX TCP connection attempts and YY UDP connection attempts. In order to determine what the “Afterglow” looks like, the mean decay time, along with the standard deviation, will be determined. Any connection attempt beyond one and a half standard deviations will be considered atypical. For each trial, the atypical connection attempts will be looked at in detail in order to determine more information about atypical “Afterglow” attempts. Additionally, information about X and Y are of interest.

The following are the purpose and goals for these trials:

1. To determine what a normative afterglow for P2P sessions might look like. This could be qualitative in the form of graphical analysis or quantitative in the form of statistics.

2. To determine if the normative afterglow is consistent for the two connection types or multiple methods of P2P sessions.

3. To determine if there is any consistent pattern to the connection attempts made during the afterglow period that would distinguish them as malicious or suspicious. This would include looking at the country of origin and repetition of connection attempts.

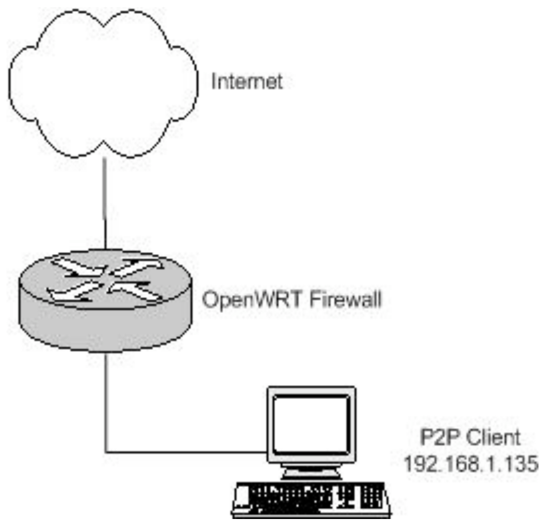
2. Design

A series of experiments were designed to explore the topic of P2P afterglow. Each trial collected data related to the number of connections in response to an open P2P session. The data collection was broken down into three categories. The first category is the "pre-session" connections; every test was verified to be zero connections for a minimum of 2 hours before the test. This assures that the connections recorded were unique to the session that was going to be used for the test. The second category is "active session" connections, or connections that occurred while the P2P session was active and the test server was participating in data transfer. The third category is the "post-session" connections. Post-session connections are categorized as those that took place after the P2P session was terminated and the test server was not participating in data transfer.

2.1. Network

One problem with most modern home networks is the monitoring of inbound and outbound traffic is difficult, as most networking equipment segregates the data that is being transmitted to increase efficiency and security. To accomplish this goal, a device called a hub is placed in the network that allows the monitoring of all the traffic flowing to all the computers. A hub is a network device that distributes all the traffic it sees on one port to all other ports on the hub. Diagram 1 depicts the network as it normally works without a hub installed where Diagram 2 depicts the network with the hub installed. As you can see, the installation of a hub will allow for the monitoring of all traffic that flows into and out of the network (Spurgeon, 2000).

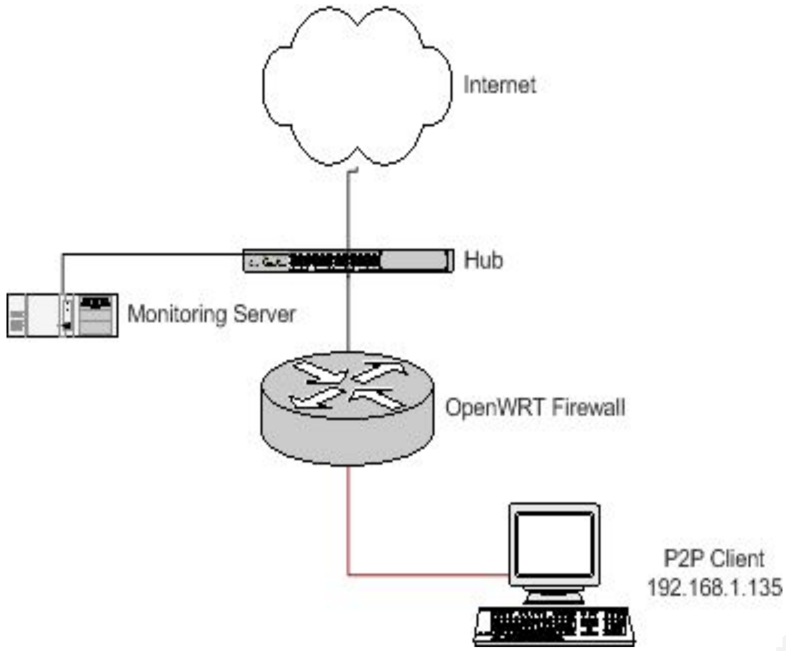
Diagram 1- Network with no hub



2.2. Hardware

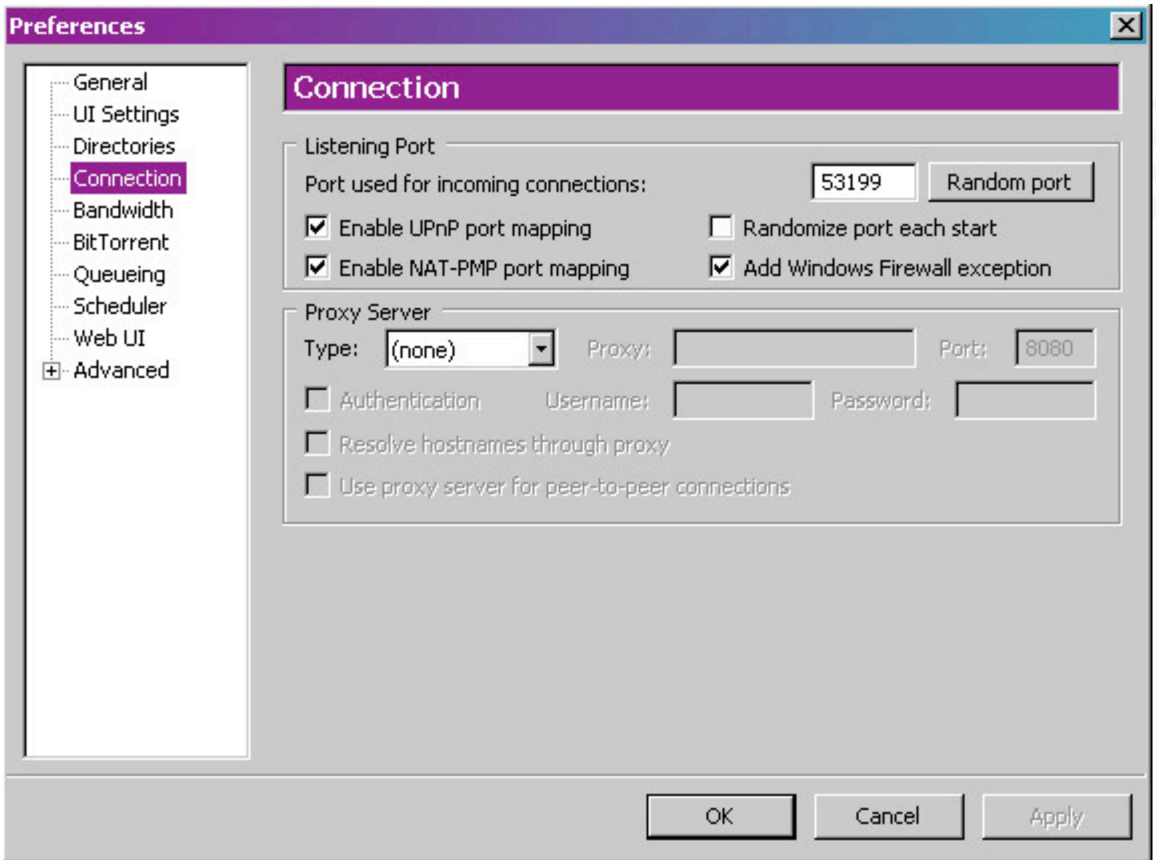
In addition to the network, other equipment is needed to accomplish the goals of this project. A Dell Inspiron 530 was used in this experiment to do the monitoring. Ubuntu 9.0 Server and an additional Network Interface Card (NIC) were both used on this computer. The NIC on the mainboard was set up to talk on the network with SSH installed and enabled, which allows for management remotely in a secure fashion. The additional network card was setup with no IP address information and physically hooked up to the hub installed at the perimeter of the network (as shown in Diagram 2). This configuration will best allow programs to interface with the network traffic the hub allows us to see.

Diagram 2 – Network with hub



2.3. Software and Setup

In addition to the hardware and network, several software packages are necessary to monitor network flow. First, a client is needed to run the P2P software as a stimulus to generate the network traffic to and from the computer. The client will be a standard computer running Windows XP Professional. For the first experiment, uTorrent (http://www.utorrent.com/) , a free package that allows for communication on BitTorrent networks, was installed. After the installation of this software is complete, one adjustment needs to be made to the default installation. Specifically, the network port number that the BitTorrent software will use for communication needs to be specified. This adjustment can be made in the uTorrent program by going to the Preferences and setting the port number to something other than the default. For each trial in this experiment, the port was changed. These actions are to decrease the chance that some other program or traffic will skew the data collection.



To allow for traffic from the outside to enter the network, port changes were made in the uTorrent software including adjustments to the perimeter firewall. Before each trial was performed, the firewall rules were matched up with the adjustments made to the firewall device. In this case, it was a Linksys WRT54G running OpenWRT (http://openwrt.org/). These adjustments can be located on the NAT Tab in the setup configuration.

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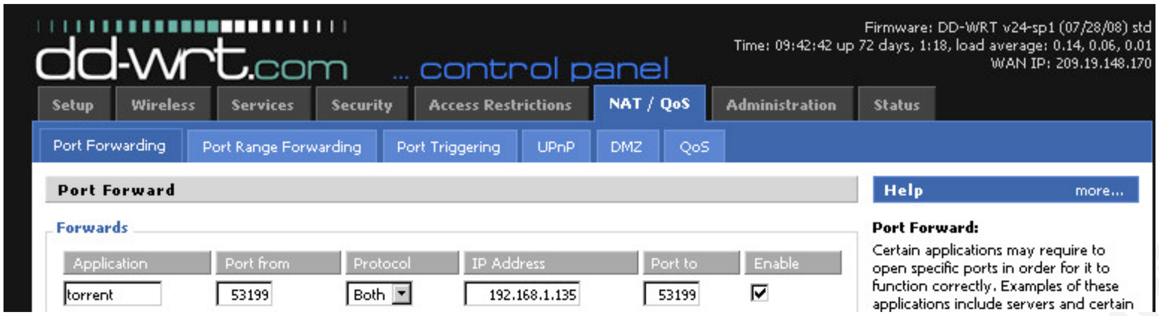

3. Results

The first step in analyzing the data was to determine the basic pattern of connections for each of the four trial types, this included both an analysis of "pre" and "post" sessions connections. The basic description of data for each of the four trials can be seen in Table 1. The decay rate, or the rate at which connection attempts decrease over time, will be the first set of analyses. This will be completed using primarily qualitative analysis, although some quantitative statistics were used. Second, the possibilities of variations between the trials were examined. Finally, we looked at the source of the connections that were determined to be beyond the typical connections responding.

Table 1

	Trial 1		Trial 2		Trial 3	
	Pre	Post	Pre	Post	Pre	Post
N	132	170	156	312	336	526
Mean (SD)	165.22 (143.19)	1.54 (3.41)	311.58 (165.79)	9.99 (17.05)	52.50 (828.41)	15.31 (60.66)
Skew	0.86	3.38	0.31	5.51	3.55	54.92
Kurtosis	-0.54	13.72	-0.31	0.28	-5.13	176.60

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As can be seen in the table, some of the data violated the assumption of a normal distribution, which one would expect of a decay rate as many of the post values should approximate zero. Keeping in mind a skew or kurtosis value of + or – 2 is considered abnormal, you can see the rates for almost every trial are outside the normal range. This makes it difficult to run most typical tests (such as an ANOVA or t-test) when comparing the data or attempting to describe a measure of central tendency (i.e., mean, medium, mode) (Myers & Well, 1995). Whenever possible, however, parametric statistics were used. In situations where data violated the parametric assumptions of normal distribution, such as highly skewed or kurtotic data, non-parametric statics were used and the data will also be considered qualitatively, such as through the graphs below. All data will be analyzed using SPSS Version 17 unless otherwise stated.

3.1 Decay Rates Analysis

The first analysis examined the decay rate, or the rate at which connection attempts decrease over time as measured from the time the P2P session is terminated on the client side. Graph 1 shows the number of attempts made while the connection was on, and Graph 2 displays the connection attempts after the connection was terminated for the third trial, which used BitTorrent.

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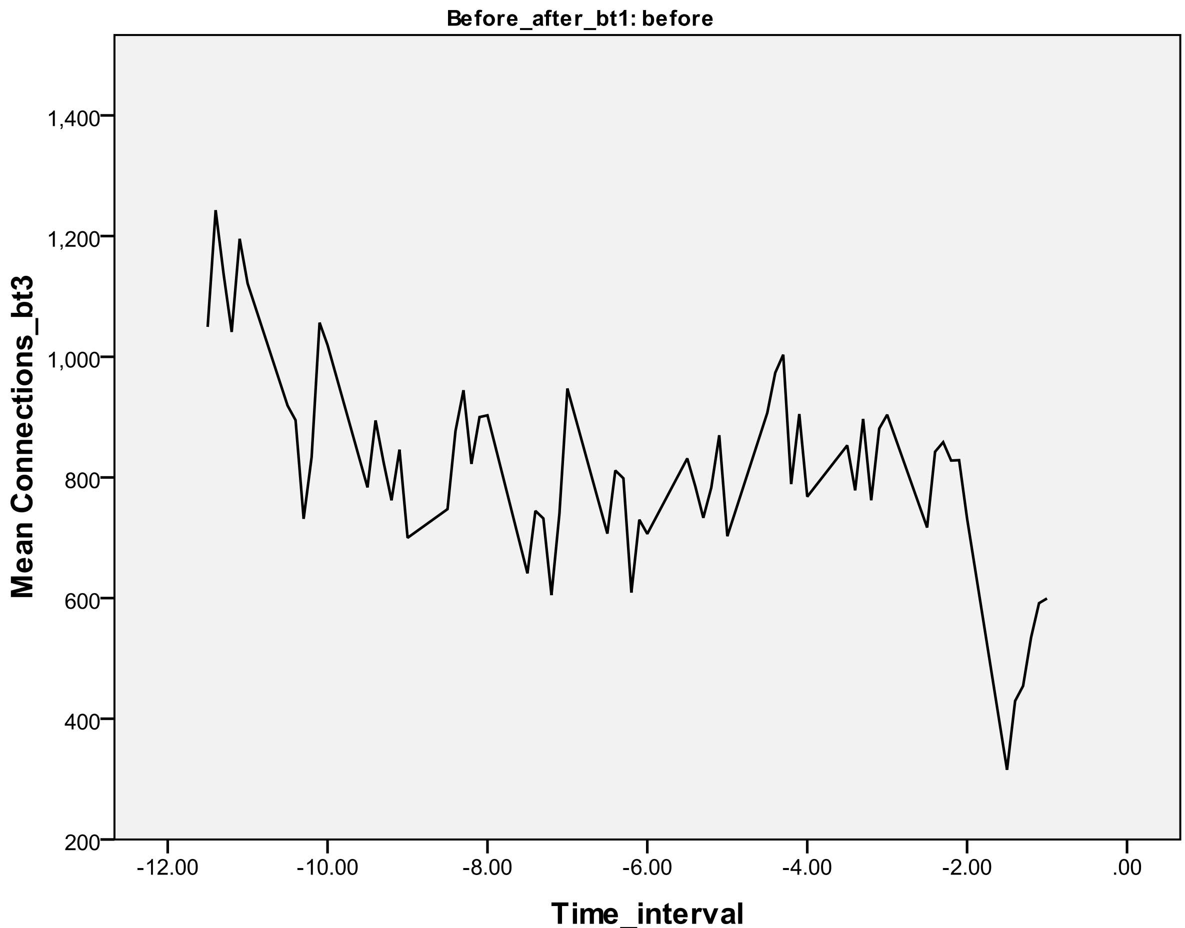
Graph 1 – Connection Attempts With Active Connection, Trial 3, BitTorrent



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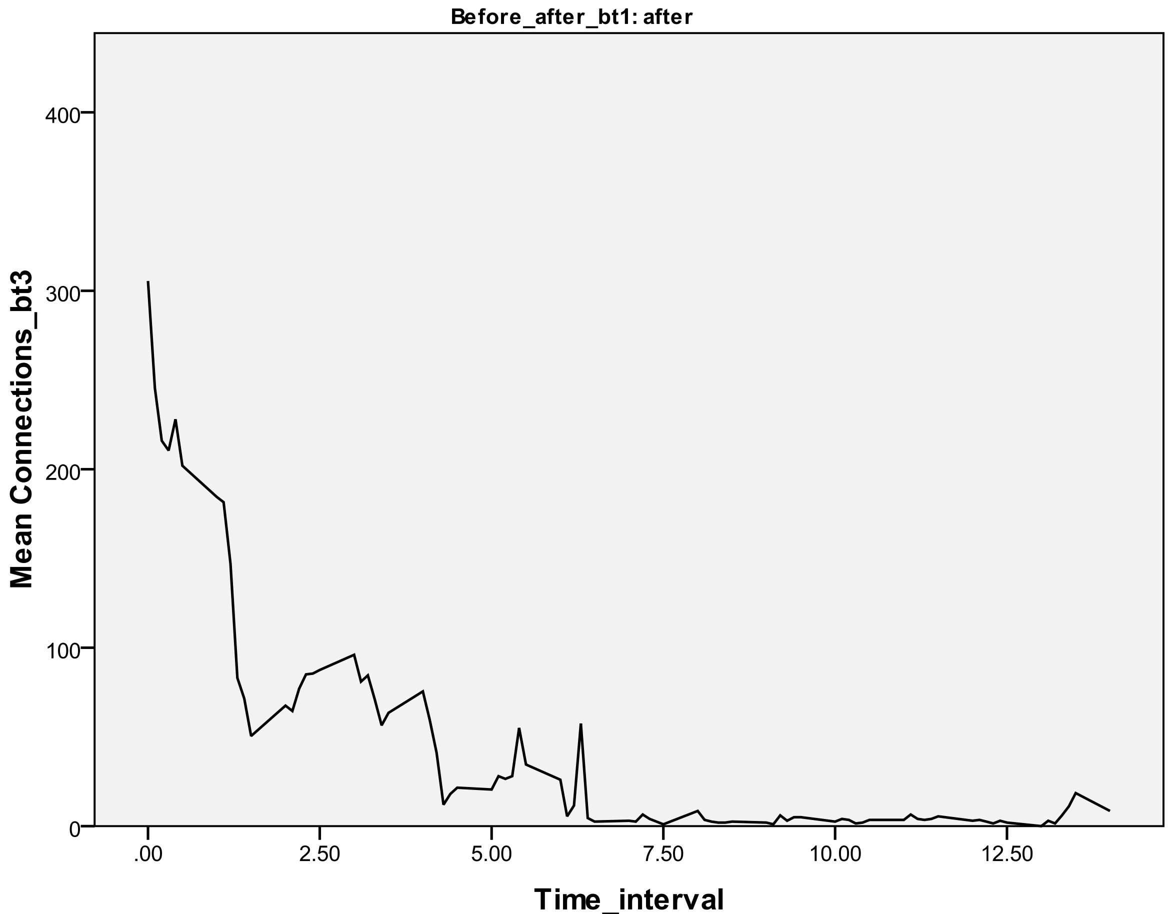
Graph 2 – Connection Attempts With Deactivated Connection, Trial 3, BitTorrent

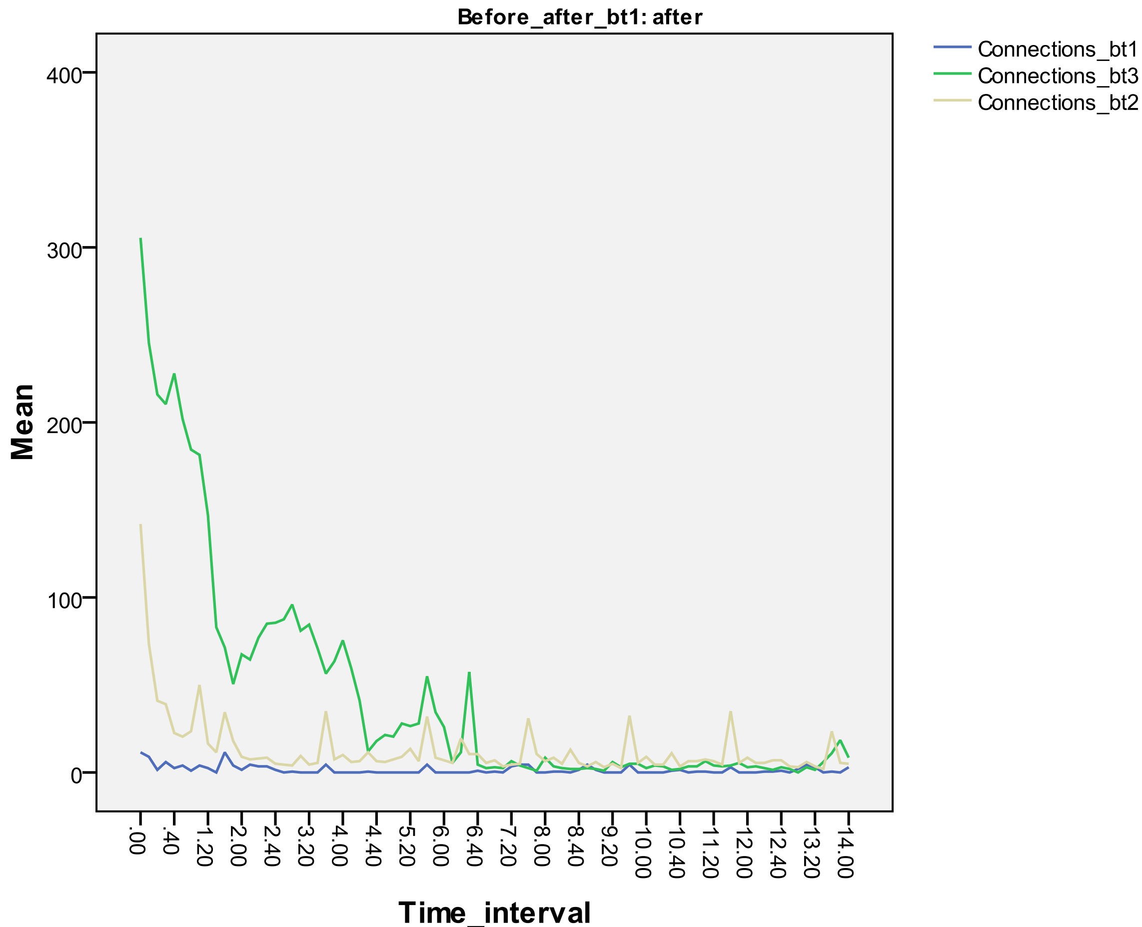


In the first graph, the zero time, or time before connections were established, is shown in addition to the increases and peaks of connections during the "active" phase. In this trial, the average attempts were roughly 2500 connections per 10 minute interval. The second graph shows the afterglow time starting from the time that the P2P session is terminated. A dramatic drop in number of connections during the first 5 hours can be seen, followed by a level approaching zero after that. Due to the nature of a decay, the mean and standard deviation are meaningless, as the results violate the laws of a normal distribution (one which approximates a bell curve). Instead, a qualitative analsysis was completed looking at trial variance in order to determine the typical rate of decay, or a time point at which the connection rate should aproximate zero.

3.2 Trial Variance Analysis

The consistency in the decay rate between trial, or Trial Variance (Myers & Well, 1995), was the focus of the second analysis. Ideally, the results of the test would be similar as this would provide a basis for "normal" decay rates using P2P networks. Graph 3 indicates the rate of decline in connection rate for all three trials and provides a visual comparison.

Graph 3: Three BitTorrent Tests, Afterglow period



The above graph shows a significant drop-off in the first two hours for all three trials. There are a small amount of connection attempts for the following fourteen hours.

Using this visual we set the cut off rate at approximately two hours.

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3.3 Analysis of post-disconnection sources

Finally, the IP address of each of the incoming connections made after the determined period, in this case, the two hour mark, is of interest. This data, while not directly related to the afterglow statistics, might be useful in determining a pattern in the connections that are trying to be established after the P2P session is terminated.

The top ten countries with post-connection attempts are shown, by trial, in Tables 3.1 – 3.3.

Table 3.1 (BT1)

USA	26.77%
Brazil	24.80%
Poland	7.87%
Thailand	7.87%
Russia	7.48%
Austria	5.91%
Ukraine	5.91%
Germany	5.51%
Taiwan	1.97%
Qatar	1.18%

Table 3.2 (BT2)

USA	29.73%
China	7.68%
France	4.87%
Great Britain	4.55%
Netherlands	4.29%
Russia	3.84%
Canada	3.75%
Sweden	3.66%
Poland	3.26%
Japan	2.46%

Table 3.3 (BT3)

USA	20.36%
Brazil	6.41%
Russia	5.81%
Canada	5.23%
China	4.47%
United Kingdom	4.19%
Spain	3.76%
Japan	3.56%
Taiwan	3.15%
France	2.70%

After looking at the afterglow data, there were a couple trends that warranted further investigation. In the second BitTorrent test, there were consistent bumps at specific intervals in the post connection period. (See Graph 4)

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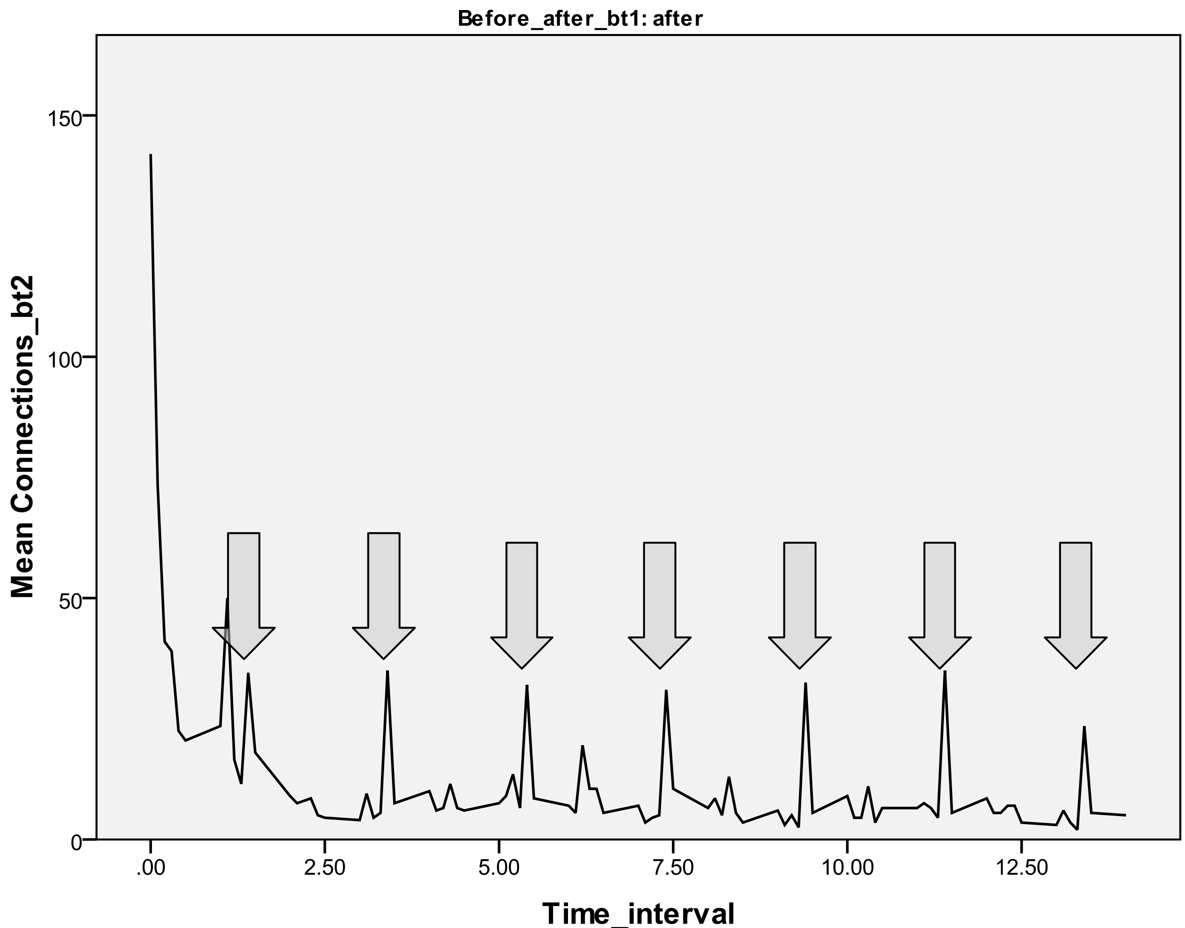
Graph 4 – BitTorrent test #2 – Afterglow



These data spikes are spaced at two hour intervals and are TCP SYN connections. The log files show these spikes are coming from the same group of clients making six connection attempts each. There were no commonalities in the group of repeating clients (different countries, different ISPs, etc). This could be a specific version or client program that has a unique retry mechanism or it could be a factor that has not been considered yet. This pattern was also unique to this specific test, and did not appear in either of the other two BitTorrent tests.

4. Discussion

This study found that the decay rates in BitTorrent P2P sessions are generally quite consistent with regards to the overall pattern of connection attempts. When looking at the afterglow periods of all three tests, there is a quick drop in connection attempts, followed by a trickle of connection attempts over the course of fourteen hours.

The post-connection source information can be used to identify a trend indicating who is trying to connect to a terminated P2P client. By looking for repetitive IP addresses, IP address ranges, or Whois data based on the IP addresses, a pattern might begin to emerge. In the future, this information could help distinguish suspicious connections from harmless connections and could provide useful tools for determining “atypical” or “dangerous” connection attempts.

4.1 Limitations of the study

There were some limitations to this study. First, there are many types of P2P clients that could be used in the BitTorrent protocol, and these might interact differently when compared with the one used in this study. Other client programs might interact differently with other peers – impacting the data. Second, this study only used a consistent file type in the P2P search, Fedora 9 Installation DVD. Different files types might be more “risky” and produce a different result. For example, files that are in violation of copyright could invoke more afterglow activity. Third, the number of test runs and only looking at the 14 hours after the P2P session was terminated could be seen as a limitation. More tests might provide a better total picture of what the afterglow looks like. Additionally, assessing more than the first 14 hours after the connection was terminated might also provide a clearer picture of what absolute zero looks like. Finally, one inconsistency in the data is that the third BitTorrent protocol was run on a different network. In between the second and third trial the test network changed from Comcast to a small local ISP named WestTel. The WestTel network connection had higher bandwidth which might have accounted for the higher number of connections in the third trial. Although the number of connections in the third trial was higher, the rate of decay in the afterglow was consistent with the other two trials.

4.2 Future considerations

The current study was a good place to start in terms of looking at decay rate analysis. There are, however, several prospective directions that could expand on this line of research. One future direction might look at the protocol and program associated with the P2P clients to see if there are inefficiencies in the way it keeps track of active or participating clients. The statistical information could also lead to more adaptive intrusion detection strategies which would use these types of statistics to flag connections that are outside the bounds of normal traffic rather than traffic that is expected.

A second area of possible future research would further expand on the anomaly seen in the second test case where there were multiple repeat clients attempting connections at consistent time intervals. Research could be done to identify further details on these clients to determine a commonality between them.

Another direction would be to do further analysis on the connection attempts being made in the afterglow period to try and identify additional markers that would distinguish them as being suspicious. This could be parts of the TCP/UDP packet structure and content.

Overall there is room to grow in the area of P2P connection research. This limited study only looked at a small area of P2P interactions. There are an ever-growing number of BitTorrent clients and all of them handle the protocol differently. These differences could greatly impact every area of P2P communications, all of which are areas that could be grounds for research. Further research of how P2P clients interact could provide additional ways to increase efficiency and provide enhanced security.

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