Spying the World from your Laptop

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Identifying and Profiling Content Providers and Big Downloaders in BitTorrent

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Abstract

This paper presents a set of exploits an adversary can use to continuously spy on most BitTorrent users of the Internet from a single machine and for a long period of time. Using these exploits for a period of 103 days, we collected 148 million IPs downloading 2 billion copies of contents.

We identify the IP address of the content providers for 70% of the BitTorrent contents we spied on. We show that a few content providers inject most contents into BitTorrent and that those content providers are located in foreign data centers. We also show that an adversary can compromise the privacy of any peer in BitTorrent and identify the big downloaders that we define as the peers who subscribe to a large number of contents. This infringement on users' privacy poses a significant impediment to the legal adoption of BitTorrent.

1 Introduction

BitTorrent is one of the most popular peer-to-peer (P2P) protocols used today for content replication. However, to this day, the privacy threats of the type explored in this paper have been largely overlooked. Specifically, we show that contrary to common wisdom [4,8,11], it is not impractical to monitor large collections of contents and peers over a continuous period of time. The ability to do so has obvious implications for the privacy of BitTorrent users, and so our goal in this work is to raise awareness of how easy it is to identify not only content provider that are peers who are the initial source of the content, but also big downloaders that are peers who subscribe to a large number of contents.

To provide empirical results that underscore our assertion that one can routinely collect the IP-to-content mapping on most BitTorrent users, we report on a study spanning 103 days that was conducted from a single machine. During the course of this study, we collected 148 million IP addresses downloading 2 billions copies of contents. We argue that this is a serious privacy threat for BitTorrent users. Our key contributions are the following.

i) We design an exploit that identify the IP address of the content providers for 70% of the new contents injected in BitTorrent.

ii) We profile content providers and show that a few of them inject most of the contents in BitTorrent. In particular, the most active injects more than 6 new contents every day and are located in hosting centers.

iii) We design an exploit to continuously retrieve with time the IP-to-content mapping for any peer.

iv) We show that a naive exploitation of the large amount of data generated by our exploit would lead to erroneous results. In particular, we design a methodology to filter out false positives when looking for big downloaders that can be due to NATs, HTTP and SOCKS proxies, Tor exit nodes, monitors, and VPNs.

Whereas piracy is the visible part of the lack of privacy in BitTorrent, privacy issues are not limited to piracy. Indeed, BitTorrent is provably a very efficient [6,9] and widely used P2P content replication protocol. Therefore, it is expected to see an increasing adoption of BitTorrent for legal use. However, a lack of privacy might be a major impediment to the legal adoption of BitTorrent. The goal of this paper is to raise attention on this overlooked issue, and to show how easy it would be for a knowledgeable adversary to compromise the privacy of most BitTorrent users of the Internet.

2 Exploiting the Sources of Public Information

In this section, we describe the BitTorrent infrastructure and the sources of public information that we exploit to identify and profile BitTorrent content providers and the big downloaders.

2.1 Infrastructure

At a high level, the BitTorrent infrastructure is composed of three components: the websites, the trackers, and the peers. The websites distribute the files containing the meta-data of the contents, i.e., .torrent file. The .torrent file contains, for instance, the hostname of the server, called tracker, that should be contacted to obtain a subset of the peers downloading that content.

The trackers are servers that maintain the content-to-peers-IP-address mapping for all the contents they are tracking. Once a peer has downloaded the .torrent file

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from a website, it contacts the tracker to subscribe for that content and the tracker returns a subset of peers that have previously subscribed for that content. Each peer typically requests 200 peers from the tracker every 10 minutes. Essentially all the large BitTorrent trackers run the OpenTracker software so designing an exploit for this software puts the whole BitTorrent community at risk.

Finally, the peers distribute the content, exchange control messages, and maintain the DHT that is a distributed implementation of the trackers.

2.2 The Content Providers

BitTorrent content providers are the peers who insert first a content in BitTorrent. They have a central role because without a content provide no distribution is possible. We consider that we identify a content provider when we retrieve its IP address. One approach for identifying a content provider would be to quickly join a newly created torrent and to mark the only one peer with an entire copy of the content as the content provider for this torrent. However, most BitTorrent clients support the superseeding algorithm in which a content provider announces to have only a partial copy of the content. Hence, this naive approach cannot be used. In what follows, we show how we exploit two public sources of information to aide in identifying the content providers.

2.2.1 Newly Injected Contents

The first source of public information that we exploit to identify the IP address of the content providers are the websites that list the content that have just been injected into BitTorrent. Popular websites such as ThePirateBay and IsoHunt have a webpage dedicated to the newly injected contents.

A peculiarity of the content provider in a P2P content distribution network is that he has to be the first one to subscribe to the tracker in order to distribute a first copy of the content. The webpage of the newly injected contents may betray that peculiarity because it signals an adversary that a new content has been injected. *An adversary can exploit the newly injected contents to contact the tracker at the very beginning of the content distribution and if he is alone with a peer, conclude that this peer is the content provider.*

To exploit this information, every minute, we download the webpage of newly injected contents from ThePirateBay website, determine the contents that have been added since the last minute, contact the tracker, and monitor the distribution of each content for 24 hours. If there is a single peer when we join the torrent, we conclude that this peer is the content provider. We repeated this procedure for $39,298$ contents for a period of 48 days from July 8 to August 24, 2009.

2.2.2 The Logins

Sometimes, a content is distributed first among a private community of users. Therefore, when the content appears in the public community there will be more than one peer subscribed to the tracker within its first minute of injection on the website. In that case, exploiting the newly injected contents is useless and an adversary needs another source of public information to identify the content provider. The second source that we exploit are the *logins* of the content providers on the website. Indeed, content providers need to log into web sites using a personal login to announce new contents. Those logins are public information.

Moreover, a content provider will often be the only one peer distributing all the contents uploaded by his login. The login of a content provider betrays which contents have been injected by that peer because it is possible to group all the contents uploaded by the same login on the website. *An adversary can exploit the login of a content provider to see whether a given IP address is distributing most of the contents injected by that login.*

To exploit this information, every minute, we store the login of the content provider that has uploaded the .torrent file on the webpage of the newly injected contents. We then group the contents per login and keep those logins that have uploaded at least 10 new contents. Finally, we consider the IP address that is distributing the largest number of contents uploaded by a given login as the content provider of those contents. We collected the logins of $6,210$ content providers who have injected $39,298$ contents for a period of 48 days from July 8 to August 24, 2009.

We verified that we did not identify the same IP address for many logins which would indicate that we mistakenly identify an adversary as content provider. In particular, on $2,206$ such IP addresses, we identified only 77 as the content provider for more than 1 login, and only 8 for more than 3 logins. We performed additional checks that we extensively describe in Le Blond et al. [2].

We validate the accuracy of those two exploits in Section 3.1.1 and present their efficiency to identify the content providers in Section 3.1.2.

2.3 The Big Downloaders

For now, we define the big downloaders as the IP addresses that subscribe to the tracker for the largest number of unique contents. It is believed to be impractical to identify them because it requires to spy on a considerable number of BitTorrent users. We now describe the two sources of public information that we exploit to compromise the privacy of any peer and to identify the big downloaders.

2.3.1 Scrape-all: Give Me All the Content Identifiers

Most trackers support *scrape-all* requests for which they return the identifiers of all the content they track and for each content, the number of peers that have downloaded a full copy of the content, the number of peers currently subscribed to the tracker with a full copy of the content, i.e., seeds, and with a partial copy of the content, i.e., leechers. A content identifier is a cryptographic hash derived from .torrent file of a content. Whereas they are not strictly necessary to the operation of the BitTorrent protocol, scrape-all requests are used to provide high level statistics on torrents. *By exploiting the scrape-all requests, an adversary can learn the identifiers of all the contents for which he can then collect the peers using the announce requests described in Section 2.3.2.*

To exploit this information, every 24 hours, we send a scrape-all request to all 8 ThePirateBay trackers and download about 2 million identifiers, which represents 120MB of data per tracker. We then filter out the contents with less than one leecher and one seed which leaves us with between 500 and 750K contents depending on the day. We repeated this procedure for 103 days from May 13 to August 23, 2009. ThePirateBay tracker is by far the largest tracker with an order of magnitude more peers and contents than the second biggest tracker [11], and it runs the OpenTracker software therefore we limited ourselves to that tracker.

2.3.2 Announce: Give Me Some IP Addresses

The *announce started/stopped* requests are sent when a peer starts/stops distributing a content. Upon receiving an announce started request, the tracker records the peer as distributing the content, returns a subset of peers, and the number of seeds and leechers distributing that content. When a peer stops distributing a content, he sends an announce stopped requests and the tracker decrements a counter telling how many contents that peer is distributing. We have observed that trackers generally blacklist a peer when he distributes around 100 contents. So an adversary should send an announce stopped request after each announce started requests not to get blacklisted. *By exploiting announce started/stopped requests for all the identifiers he has collected, an adversary can spy on a considerable number of users.*

To exploit this information, every 2 hours, we repeatedly send announce started and stopped requests for all the contents of ThePirateBay trackers so that we collect the IP address for at least 90% of the peers distributing each content. We do this by sending announce started and stopped requests until we have collected a number of unique IP addresses equal to 90% of the number of seeds and leechers returned by the tracker. This procedure takes around 30 minutes for between 500K and 750K contents. By repeating this procedure for 103 days from May 13 to August 23, 2009, we collected 148 million IP addresses downloading 2 billion copies of contents.

We will see in Section 4.1 that once an adversary has collected the IP-to-content mappings for a considerable number of BitTorrent users, it is still complex to identify the big downloaders because it requires to filter out the false positives due to middleboxes such as NATs, IPv6 gateways, proxies, etc. We will also discuss how an adversary could possibly reduce the number of false negatives by identifying the big downloaders with dynamic IP addresses. Finally, we will see that an adversary can also exploit the DHT to collect the IP-to-content mappings in Section 6.

2.4 The Torrent Files

Once we have identified the IP address for the content providers and big downloaders, we use the .torrent files to profile them. A .torrent file contains the hostname of the tracker, the content name, its size, the hash of the pieces, etc. Without .torrent file, a content identifier is an opaque hash therefore, an adversary must collect as many .torrent files as possible to profile BitTorrent users. For instance, an adversary can use the .torrent files, to determine if the content is likely to be copyrighted, the volume of unique contents distributed by a content provider, or the type of content he is distributing. Clearly, .torrent files must be public for the peers to distribute contents however, it is surprisingly easy to collect millions of .torrent files within hours and from a single machine. *By exploiting the .torrent files, an adversary can focus his spying on specific keywords and profile BitTorrent users.*

To exploit this information, we collected all the .torrent files available on Mininova and ThePirateBay websites on May 13, 2009. We discovered $1,411,940$ unique .torrent files on Mininova and $974,980$ on ThePirateBay. The overlap between both website was only $227,620$ files. Then, from May 13, to August 24, 2009, we collected the new .torrent files uploaded on the Mininova, ThePirateBay, and Isohunt websites. Those three websites are the most popular and as there is generally a lot of redundancy among the .torrent files hosted by different websites [11], we limit ourselves to those three.

We will discuss the reasons why our measurement was previously thought as impractical by the related work in Section 5.

3 The Content Providers

In this section, we run the exploits from Section 2.2 in the wild, quantify the content providers that we identify, and present the results of their profiling.

|Alone|	|Login|	|Alone ∩Login|	Accuracy
$21,544$	$15,308$	$9,243$	99.99%

Table 1: Cross-validation of the two exploits. This table shows the accuracy of the two exploits to identify the same content provider for the same content. *Alone* ∩ *Login* is the number of contents for which both sources identified a content provider. *Accuracy* is the percentage of such contents for which both sources identified the same content provider.

3.1 Identifying the Content Providers

We start by validating the exploits we use to identify the IP address of the content providers.

3.1.1 Validating the Exploits

In Section 2.2, we described two exploits to identify the IP address of a content provider. The first exploit is to connect to the tracker as soon as a new content gets injected and to check whether we are alone with the content provider (*Alone*). The second exploit is to find the IP address that has injected the largest number of contents uploaded by a single login (Login). Whereas it makes sense to use those exploits to identify content providers, it is necessary to validate how accurate they are.

We validate the accuracy of these exploits in Table 1. This table shows that for $9,243$ contents, both exploits identified a content provider. Moreover, for 99.99% of those contents both exploits identified the same IP address as the content provider. Thus, with a high probability the same content providers are identified by two independent exploits.

3.1.2 Quantifying the Identified Content Providers

In Fig. 1, we identify the IP address for 70% of the content providers injecting $39,298$ new contents over a period of 48 days. The fraction of content providers that we identify using *Alone* only decreases with the number of peers distributing the content. This is because the more popular the content, the lower the chances to be alone with the content provider, i.e., from 60% for contents with 10 peers or less to 17% for contents with more than $1,000$ peers. However, *Login* compensates for contents with up to $1,000$ peers. In essence, for contents with more than $1,000$ peers, we identify close to half of the content providers.

3.2 Profiling the Content Providers

We now use the IP address of the content providers that we have identified for 48 days to profile their contribution in number of contents and their location.

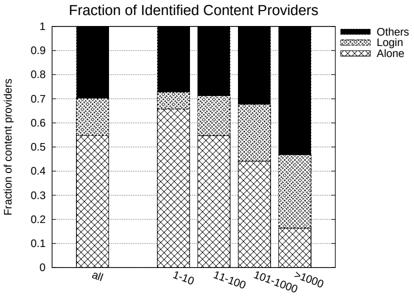

Figure 1: Fraction of content providers that we identify. On the x-axis, *all* is for all contents, *a-b* is for content with between a and b peers distributing the content after 24 hours, and > 1000 for contents with more than $1,000$ peers distributing the content after 24 hours. *Others* is the fraction of content providers that we do not identify.

Figure 2: Tag cloud of contents injected by the content providers that we have identified. We extract the two most significant keywords from each content name contained in the .torrent files and vary their police size to reflect the number of contents whose name matches those keywords, the largest the keywords, the more frequent those keywords appear in the content names.

3.2.1 Semantic of the Injected Contents

Fig. 2 shows a tag cloud of the names of the contents injected into BitTorrent. This tag cloud suggests that many contents refer to copyrighted material and that BitTorrent closely follow events. Indeed, two weeks before we started to identify the content providers, Michael Jackson died and the latest Happy Potter movie got released one week after.

3.2.2 Contribution of the Content Providers

We see in Fig. 3 (top) that some content providers inject much more contents than others with the most active in-

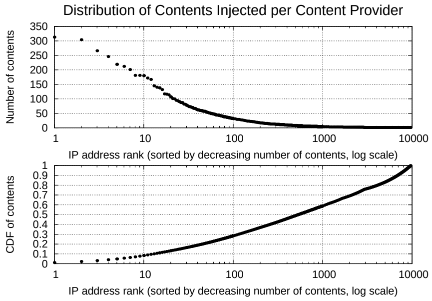

Figure 3: Distribution of the number of contents injected by each content provider. The top plot shows the number of contents per content provider and the bottom plot shows the CDF of contents.

Rank	# contents	Volume	CC	AS name
1	313	136	NZ	Vodafone
2	304	79	FR	OVH
3	266	152	DE	Keyweb
4	246	34	FR	OVH
5	219	186	FR	OVH
6	212	247	DE	Keyweb
7	201	535	FR	OVH
8	181	73	US	HV
9	181	17	CA	Wightman
10	180	7	SK	Energotel
11	172	161	FR	OVH
12	167	23	RU	Corgina
13	145	197	DE	Keyweb
14	140	11	FR	OVH
15	138	109	US	Aaron
16	132	12	US	Charter
17	117	119	FR	OVH
18	116	109	FR	OVH
19	114	79	NL	Telfort
20	107	225	RU	Matrix

Table 2: Rank, number of contents, volume of contents (GB), country code, and AS name for the top 20 content providers.

jecting more than 300 contents in 48 days. The most active content providers inject more than 6 contents every day, e.g., *eztv* [1], the top content provider, daily injects 6.5 TV shows of 430MB in average. Given the time to capture and encode a TV show, it suggests that a small community of users injects contents from the same IP address.

We now look at the contribution of the biggest content providers in comparison to the total number of injected contents. We see in Fig. 3 (bottom), that the top 100 content providers inject 30% of all the contents injected into BitTorrent and the top $1,000$ content providers inject 60% of all the contents.

Conclusions These results show that few content providers insert most of the contents. We do not claim that it is easy to stop those content providers from injecting content into BitTorrent however, it is striking that such a small number of content providers triggers billions of downloads. Therefore, it is surprising that the anti-piracy groups try to stop millions of downloaders instead of a handful of content providers.

3.2.3 Location of the Content Providers

Focusing on the top 20 content providers in Table 2, we observe that half of them are using a machine whose IP address is located in a French and a German hosting center, i.e., OVH and Keyweb. Those hosting centers provide cheap offers of dedicated servers with unlimited traffic and a 100MB/s connection.

However, we observed that the users injecting contents from those servers are unlikely to be be French or German. Indeed, on $1,515$ contents injected by the content providers from OVH, only 13 contained the keyword *fr* (French) in their name whereas 552 contained the keyword *spanish*. Similarly, on 623 contents injected from Keyweb, we found 228 contents with the keyword *spanish* in their name and none contained the keywords *fr*, *ge* (German), or *de* (Deutsche). In conclusion, one cannot easily guess the nationality of a content provider based on the geolocalization of the IP address of the machine he is using to inject contents.

4 The Big Downloaders

In this section, we focus on the identification and the profiling of the big downloaders, i.e., the IP addresses that subscribed in the largest number of contents. Once we have collected the information described in Section 2.3, it is challenging to identify and profile the big downloaders because of the volume of information. Indeed, we collected 148M IP addresses and more than 510M endpoints (IP:port) during a period of 103 days.

Ordering the IP addresses according to the total number of unique contents for which they subscribed, we observe a long tail distribution. In particular, the top $10,000$ IP addresses subscribed for at least $1,636$ contents and the top $100,000$ IP addresses subscribed for at least 309 contents. In the remaining of this section, we focus on the top $10,000$ IP addresses.

In the following, we show that for many IP addresses, there is a linear relation between their number of contents and their number of ports suggesting that those IPs are middleboxes with multiple peers behind them. However, we will also see that some IP addresses significantly deviate from this middlebox behavior and we will identify some of those players with deviant behavior. Finally, we will profile those players.

4.1 The Middlebox Behavior

It is sometimes complex to identify a user based on its IP address or its endpoint, because the meaning of this information is different depending on his Internet connectivity. A user can connect through a large variety of middleboxes such as NATs, IPv6 gateways, proxies, etc. In all those cases, many users can use the same IP address and the same user can use a different IP address or endpoints. So an adversary using the IP addresses or endpoints to identify big downloaders may erroneously

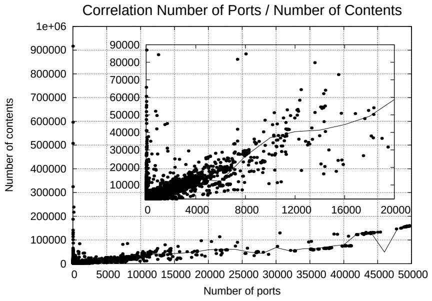

Figure 4: Correlation of the number of ports per IP address and of the number of contents for the top $10,000$ IP addresses. Each dot represents an IP address. The solid line is the average number of contents on the 148M IP addresses computed per interval of $2,000$ ports.

identify a middlebox as a big downloader. In the following, we aim to filter out those false positives to identify the big downloaders.

We do not consider false negatives due, for instance, to a big downloader with a dynamic IP address. It may be possible to identify big downloaders with a dynamic IP address but it would require a complex methodology using the port number as the identifier of a user within an AS; most BitTorrent clients pick a random port number when they are first executed and then use that port number statically. The validation of such a methodology is beyond the scope of this paper and we leave this improvement for future work. However, we will see that we already find a large variety of big downloaders using public IP addresses as identifiers.

We confirm the complexity of using an IP address or endpoint to identify a user in Fig. 4. Indeed, we see that for most of the IP addresses the number of contents increases linearly with the number of ports. Moreover, the slope of this increase corresponds to the slope of the average number of contents per IP over all 148M IP addresses (solid line). Each new port corresponds to between 2 and 3 additional contents per IP address. Therefore, it is likely that those IP addresses correspond to middleboxes with a large number of users behind them. There are also many IP addresses that significantly deviate from this middlebox behavior.

Conclusions A large number of IP addresses that a naive adversary would classify as big downloaders actually corresponds to middleboxes such as NATs, IPv6 gateways, or proxies. However, we also observe many IP addresses whose behavior significantly deviates from a typical middlebox behavior.

4.2 Identifying the Big Players

To understand the role of the IP addresses that deviate from middlebox behavior, we identify 6 categories of big players.

HTTP and SOCKS public proxies The two first categories are HTTP and SOCKS public proxies that can be used by BitTorrent users to hide their IP address from anti-piracy groups. We retrieved a list of IP addresses of such proxies from the sites *hidemyass.com* and *proxy.org*. We found 81 HTTP proxies and 62 SOCKS proxies within the top $10,000$ IP addresses.

Tor exit nodes The third category is composed of Tor exit nodes that are the outgoing public interfaces of the Tor anonymity network. To find, the IP address of the Tor exit nodes, we performed a reverse DNS lookup for the top $10,000$ IP addresses and extracted all names containing the *tor* keyword and manually filtered the results to make sure they are indeed Tor exit nodes. We also retrieved a list of nodes on the Web site *proxy.org*. We found 174 Tor exit nodes within the top $10,000$ IP addresses.

Monitors The fourth category is composed of monitors that are peers spying on a large number of contents without participating in the content distribution. We identified two ASes, corresponding to hosting centers located in the US and UK, containing a large number of IP addresses within the top $10,000$ with the same behavior. Indeed, these IP addresses always used a single port and we were never able to download content from them. Therefore, they look like a dedicated monitoring infrastructure instead of regular peers. We found $1,052$ such IP addresses within only two ASes in the top $10,000$ IP addresses

VPNs The fifth category is composed of VPNs that are SOCKS proxies requiring authentication and whose communication with BitTorrent users is encrypted. To find VPNs, we performed a reverse DNS lookup for the top $10,000$ IP addresses and extracted all names containing the *itshidden*, *cyberghostvpn*, *peer2me*, *ipredate*, *mullvad*, and *perfect-privacy* keywords and manually filtered the results to make sure they are indeed the corresponding VPNs. Those keywords correspond to well-known VPN services. We found 30 VPNs within the top $10,000$ IP addresses.

Big downloaders The last category is composed of big downloaders that we redefine as the IP addresses that *distribute* the largest number of contents and that are used by a few users. We selected the IP addresses we could download content from and that used fewer than 10 ports. Hence, those IP addresses cannot be a monitors as we downloaded content from them and they cannot be large middleboxes due to the small number of ports. We found 77 such big downloaders.

Conclusions We have identified 6 categories of big players including the big downloaders. We do not claim that we have identified all categories of players nor found all the IP addresses that belong to one of those 6 categories. Instead, we have identified few IP addresses

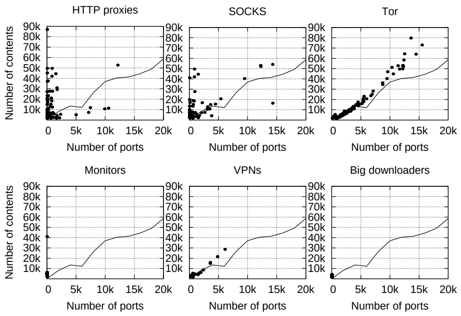

Figure 5: Correlation of the number of ports per IP address and of the number of contents of the big players. Each dot represents an IP address. The solid line represents the middlebox behavior.

in each category within the top $10,000$ peers that we use in the following to profile the big players.

4.3 Profiling the Big Players

We see in Fig. 5 that for HTTP and SOCKS proxies the number of contents per IP address is much larger than for middleboxes (solid line). Considering the huge number of contents these IP addresses subscribed to, it is likely that the proxies are used by anti-piracy groups. Indeed, we see in Fig. 6 that our measurement system suddenly stops seeing the IP addresses of monitors after day 50. In fact, by that date, ThePirateBay tracker changed its blacklisting strategy to reject IP addresses that are subscribed to a large number of contents. Whereas it was not a problem for our measurement system because it uses announce stopped requests as described in Section 2.3.2, monitors got blacklisted. However, we observe on day 80 that the number of HTTP and SOCKS proxies suddenly increased, probably corresponding to anti-piracy groups migrating their monitoring infrastructure from dedicated hosting centers to proxies. Considering, the synchronization we observe in Fig. 6 in the activity of the HTTP and SOCKS proxies, it is likely that those proxies were used in a coordinated effort.

The correlation for monitors and big downloaders in Fig. 5 does not show any striking result, therefore we do not discuss it further. However, we observe in Fig. 5 that for Tor exit nodes and VPNs the number of contents per IP address is close to the IP addresses of the middleboxes (solid line). For large number of ports, Tor exit nodes deviate from the standard middlebox behavior. In fact, we found that just a few IP addresses are responsible of this deviation, all other Tor exit nodes following the trend of the solid line. We believe that those few IP addresses responsible for the deviation are used by either big downloaders or anti-piracy groups.

Conclusions We have shown that many peers do not correspond to a BitTorrent user but to monitors or to middleboxes with multiple users behind them. These peers introduce a lot of noise for an adversary who would like to spy on BitTorrent users and in particular on the big downloaders. However, we have shown that it is possible to filter out that noise to identify the IP address and profile the big downloaders.

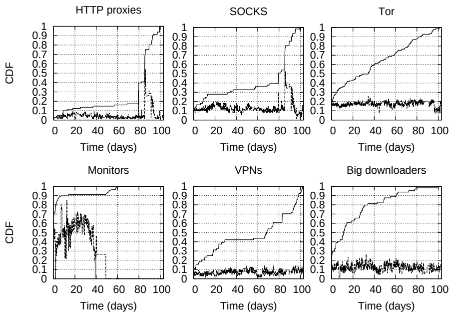

Figure 6: Activity of the big players in time. For each category, the dashed line represents the fraction of the top $10,000$ IP addresses of a given snapshot that belongs to the top $10,000$ IP addresses on all snapshots. The solid line represents, for each category, the fraction of the top $10,000$ IP addresses on all previous snapshots that belongs to the top $10,000$ IP addresses on all snapshots.

5 Related Work

As far as we know, no related work has explored the identification of the content providers in BitTorrent so both the data and the results concerning these players are entirely new.

Some related work has measured BitTorrent at a moderate scale but none at a large-enough scale to identify the big downloaders. This is because most of the measurements inherited two problems from using existing BitTorrent clients [7, 8, 10]. The first problem is that existing clients introduce a huge computational overhead on the measurement. For instance, each announce started request takes one fork and one exec. Therefore, the measurement is hard to efficiently parallelize.

The second problem is that regular BitTorrent clients do not exploit all the public sources of information that we have presented in Section 2.3 and 2.4. A content identifier is essentially the hash of a .torrent file. So not exploiting scrape-all requests limits the number of spied contents to the number of .torrent files an adversary has collected. In addition, clients may not be stopped properly and so not send the announce stopped request, making the measurement prone to blacklisting.

In the following, we describe how the scale of previous measurements differs from ours according to the sources of public information that they exploit.

5.1 No Exploitation of Scrape-all Requests

We split the related work not exploiting scrape-all requests into two families: A first family spying on few contents and a second one using a large infrastructure to spy on more contents. Siganos et al. measured the top 600 contents from The ThePirateBay [10] Web site during 45 days collecting 37 million IP addresses. Using only the top 600 contents does not allow an adversary to identify the big downloaders. The same remark holds for Choffnes et al. [4] who monitored $10,000$ peers and did not record information identifying contents therefore they cannot either identify the big downloaders.

The second family spied on more contents but using a large infrastructure. Piatek et al. used a cluster of workstations to collect 12 million IP addresses distributing $55,523$ contents in total [7, 8]. It is unclear how many simultaneous contents they spied as they reported being blacklisted when being too aggressive, suggesting that they did not properly send announce stopped requests.

Finally, Zhang et al. [11] is the work that is the closest to ours in scale however, they used an infrastructure of 35 machines to collect 5 million IP addresses within a 12 hours window. In comparison, our customized measurement system used 1 machine to collect around 7 million IP addresses within the same time window, making it about 50 times more efficient. In addition, that we performed our measurement from a single machine demonstrates that virtually *anyone* can spy on BitTorrent users, which is a serious privacy issue.

5.2 No Exploitation of Announce Requests

Dan et al. measured 2.4 million torrents with 37 million peers, but used a different terminology [5]. Indeed, they performed *only* scrape-all requests so they knew the number of peers per torrent but not the IP addresses of those peers. This data is much easier to get and completely different in focus.

6 Discussion and Conclusions

We have shown that enough information is available publicly in BitTorrent for an adversary to spy on most BitTorrent users of the Internet from a single machine. At any moment in time for 103 days, we were spying on the distribution of between 500 and 750K contents. In total, we collected 148M of IP addresses distributing 1.2M contents, which represents 2 billion copies of content.

Leveraging on this measurement, we were able to identify the IP address of the content providers for 70% of the new contents injected into BitTorrent and to profile them. In particular, we have shown that a few content providers inject most of the contents into BitTorrent making us wonder why anti-piracy groups targeted random users instead. We also showed that an adversary can compromise the privacy of any peer in BitTorrent and identify the IP address of the big downloaders. We have seen that it was complex to filter out false positives of big downloaders such as monitors and middleboxes and proposed a methodology to do so.

We argue that this privacy threat is a fundamental problem of open P2P infrastructures. Even though we did not present it in this paper, we have also exploited the DHT to collect IP-to-content mappings using a similar methodology as for the trackers. That we were also able to collect the IP-to-content mappings on a completely different infrastructure reinforces our claim that the problem of privacy is inherent to open P2P infrastructures.

A solution to protect the privacy of BitTorrent users might be to use proxies or anonymity networks such as Tor, however a recent work shows that it is even possible to collect the IP-to-content mappings of BitTorrent users on Tor [3]. Therefore, the degree to which it is possible to protect the IP-to-content mappings of P2P filesharing users remains an open question.

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