

# Stress Testing the Booters: Understanding and Undermining the Business of DDoS Services

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## ABSTRACT

DDoS-for-hire services, also known as *booters*, have commoditized DDoS attacks and enabled abusive subscribers of these services to cheaply extort, harass and intimidate businesses and people by knocking them offline. However, due to the underground nature of these booters, little is known about their underlying technical and business structure. In this paper we empirically measure many facets of their technical and payment infrastructure. We also perform an analysis of leaked and scraped data from three major booters—Asylum Stresser, Lizard Stresser and VDO—which provides us with an in-depth view of their customers and victims. Finally, we conduct a large-scale payment intervention in collaboration with PayPal and evaluate its effectiveness. Based on our analysis we show that these services are responsible for hundreds of thousands of DDoS attacks and identify potentially promising methods of increasing booters’ costs and undermining these services.

## 1. INTRODUCTION

Distributed Denial-of-Service (DDoS) attacks are becoming a growing threat with high profile DDoS attacks disrupting many large scale gaming services, such as Microsoft’s Xbox Live and Sony’s PlayStation networks at the end of 2014 [4]. These attacks were later claimed to be launched by the Lizard Squad as advertisements for their new DDoS-for-hire service called *Lizard Stresser* [3]. There is a long line of technical work exploring how to detect and mitigate these types of attacks [9, 10, 14, 20, 21, 23, 24, 33].

However, a large amount of DDoS attacks are being launched by relatively unsophisticated attackers that have purchased subscriptions to low-cost DDoS-for-hire (commonly called *booter*) services. These services are operated by profit-motivated adversaries that have scaled up their DDoS infrastructure to meet the increasing demand for DDoS attacks. Despite the threat they pose, little is known about the structures of these booter services and potential weaknesses in their operations that could be used to undermine them.

In this paper we undertake a large scale measurement study of these booter services to understand how

they are structured both technologically and economically with the focus of isolating potential weaknesses. We explore booters from three different angles including analysis of leaked and scraped data, measurements of their attack infrastructure and a payment intervention.

Our analysis of leaked and scraped data from three booters—Asylum Stresser, Lizard Stresser and VDO<sup>1</sup>—demonstrates that these services have attracted over 6,000 subscribers and have launched over 600,000 attacks. We also find that the majority of booter customers prefer paying via PayPal and that Lizard Stresser, which only accepted Bitcoin, had a minuscule 2% sign-up to paid subscriber conversion rate compared to 15% for Asylum Stresser and 23% for VDO, which both accepted PayPal. By analyzing attack traffic directed at our own servers we are able to characterize the set of amplifiers they use to direct large amounts of traffic at their victims. In order to measure the resilience of their payment infrastructure, we conduct a payment intervention in collaboration with PayPal. Our evaluation of the effectiveness of this approach suggests that it is a promising method for reducing the subscriber base of booters.

In this paper, we further our understanding of the booter ecosystem through our measurements. Based on this we identify potential improvements to ongoing efforts to disrupt their attack infrastructure and an alternative and possibly more effective method of undermining these services by targeting their payment infrastructure. Overall, we find a few places where costs might be marginally increased by more precisely mapping out and targeting parts of their attack infrastructure. We document how a large-scale payment intervention by PayPal impacts booters, including service closures. Finally, we detail some of their strategies for evading detection by PayPal and discuss how these increase the effort and costs associated with performing an ongoing payment intervention.

<sup>1</sup>We assign each booter service a unique three letter code based on their domain name to avoid unintentionally advertising their services. The two exceptions are Asylum Stresser, which ceased operation before our study and Lizard Stresser, which has already been highly publicized.

## 2. BACKGROUND

In this section we explain the high level business and technical structure of booter services as well as the underlying ethical framework for our measurements.

### 2.1 Booter Services

Thinly veiled booter services have existed since at least 2005 and primarily operate using a subscription-based business model. As part of this subscription model, customers or subscribers<sup>2</sup> can launch an unlimited number of attacks that have a duration typically ranging from 30 seconds to 1-3 hours and are limited to 1-4 concurrent attacks depending on the tier of subscription purchased. The price for a subscription normally ranges from \$10-\$300 USD per month depending on the duration and number of concurrent attacks provided. These services claim that they are only to be used by network operators to stress test their infrastructure. However, they have become synonymous with DDoS-for-hire and are a growing threat due to the fact that they have commoditized DDoS attacks that reach upwards of 2-3 Gbps. By offering a low-cost shared DDoS attack infrastructure, these criminal support services have attracted thousands of malicious customers and are responsible for hundreds of thousands of DDoS attacks a year as we will show in Section 4.

These services can be found by visiting underground forums where they advertise and by web searches for terms, such as “stresser” and “booter.” The services are all in English; we did not find any evidence of similar services that are focused on other markets, such as Asian or Russian. They maintain frontend sites that allow their customers to purchase subscriptions and launch attacks using simple web forms. Their backend infrastructure commonly consists of databases that maintain subscriber information, lists of misconfigured hosts that can be used for DDoS amplification and most rent high-bandwidth Virtual Private Servers (VPS) for attacks rather than using botnets. Ironically, booter services depend on DDoS-protection services, such as CloudFlare, to protect their frontend and attack infrastructure from attacks launched by rival competing booter services.

Figure 4 provides a detailed illustration of the infrastructure and process of using a booter service. (1) The customer first locates a booter site and visits their frontend webserver, which is normally protected by CloudFlare. (2) The customer must next purchase a subscription using a payment method, such as Bitcoin or PayPal. (3) The customer then uses the frontend interface to request a DDoS attack against a victim. (4) This request is forwarded from the frontend server to one of the backend attack servers. (5) The back-

<sup>2</sup>We use these two terms interchangeably in this paper.

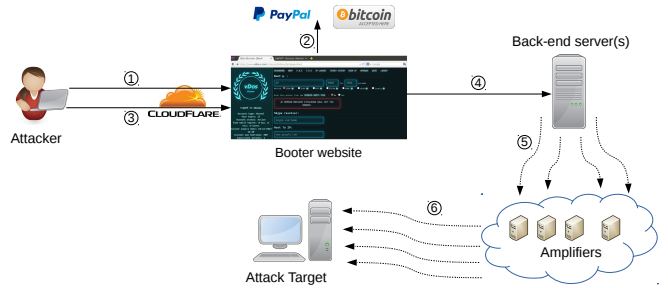


Figure 1: Structure of booter services.

end server then sends spoofed request packets to a set of previously identified vulnerable amplification servers. (6) Finally, DDoS traffic in the form of replies is sent to the victim from the abused amplification servers.

### 2.2 Ethical Framework

As part of the ethical framework for our study, we placed a number of restrictions on the types of booter services we actively interacted with and what we included in this paper. First, we did not engage with any DDoS service that advertised using botnets. For example, in the case of Lizard Stresser, when we became aware that a botnet was being used, we immediately abandoned plans to collect active attack measurements from this service and restricted ourselves to passive measurements. Our victim server was connected by a dedicated 1 Gbs network connection that was not shared with any other servers. We also obtained consent from our network operators before conducting any DDoS attack experiments. When services used reflectors, we minimized the attack durations.

When purchasing a subscription for a Booter service, we selected the cheapest option to minimize the amount of money given to these services. In total, we spent less than \$140 and no individual booter service received more than \$19 in payments as part of the measurements in this paper. Payments were made primarily using PayPal and we assumed that proper controls were put in place at PayPal to mitigate the risk of money flowing to criminal groups. Also, the 9 booters that overlapped with our payment intervention study likely lost larger sums of money due to our reporting of their PayPal accounts than we paid to them.

We received an exemption from our Institutional Review Board (IRB), since our study did not include any personally identifiable information and was based on publicly leaked data and measurements of services that are publicly accessible. Finally, we did not disclose the identity of customers or operators of these services even when we became aware of their identities and we did not reveal the identities of any victims unless they had been previously publicly disclosed.

Booter	Period	All Users	Subscribers	Revenue	Attacks	Targets
Asylum Stresser	10/2011-3/2013	26,075	3,963	\$35,381.54	483,373	142,473
Lizard Stresser	12/2014-01/2015	12,935	176	\$3,368 <sup>†</sup>	15,998	3,907
VDO <sup>‡</sup>	12/2014-2/2015	11,975	2,779	\$52,773*	138,010	38,539
Total	-	50,985	6,918	\$91,522.54	637,381	184,919

**Table 1:** Summary of Asylum Stresser and Lizard Stresser leaked databases and scraped VDO reported data. <sup>†</sup> Revenue was converted from bitcoin to USD. \*Revenue is estimated based on subscription cost and number of paying subscribers. <sup>‡</sup> Domain name is abbreviated to the first three characters.

### 3. RELATED WORK

DDoS attack and defense techniques have been studied for close to two decades [9, 10, 14, 20, 21, 23, 24, 33]. There have also been several empirical studies of DDoS attacks in the wild using backscatter analysis [18] which were revisited by Wustrow *et al.* [32]. More recent studies have measured Network Time Protocol (NTP) based DDoS attacks [7] and conducted broader measurements of UDP amplifiers along with introducing methods to identify spoofing-enabled networks [13].

Other studies have explored the structure of botnet based DDoS attacks [5] and malware [6, 28]. However, the closest related work to ours in this vein is by Kühner *et al.* which monitored the impact of DDoS attacks on victims [31] and an analysis of a leaked database from a single booter service done by Karami and McCoy [12]. Our work differs from this previous work in that we are focused on holistically understanding the stakeholders and infrastructure these booter services rely on to operate across a larger set of booter services.

Our study is in the same vein as prior work that views security problems through an economic lens [19]. We set out to understand the stakeholders and infrastructure of criminal DDoS-for-hire enterprises as has been done in other domains, such as abusive advertising [15, 17, 30] and fake anti-virus [25]. Since booters are a criminal support service rather than the previously studied domain of abusive advertising, they operate under a different set of constraints. In this respect our work is more along the lines of studies focused on criminal support services, such as email spam delivery [11, 26], fake social links [27] and fake account creation [29]. While this same *follow-the-money* and payment intervention approach has been explored in previous studies [16] our study is the first, to our knowledge, that explores the effectiveness of this method against more robust criminal-to-criminal payment methods rather than consumer-to-criminal payments.

The largest contribution of our study is in characterizing the ecosystem of subscription-based booter services, which has not been studied in much depth. We show that these booters are structured differently than traditional botnet based DDoS services that are rented for a fixed time period in terms of the underlying attack infrastructure, customer base, business model and payment methods. We believe that our findings enable

Operator		Subscriber	
CC	%	CC	%
US	44.06%	US	47.58%
PK	15.03%	DE	10.45%
CA	13.99%	GB	5.60%
GB	6.29%	NL	4.87%
AU	3.15%	RU	4.81%

**Table 2:** Top country IP geolocations of logins for booter operator’s and subscriber’s PayPal accounts.

a better understanding of the effectiveness of ongoing efforts to disrupt their attack infrastructure at the amplifier and hosting level, a preliminary evaluation of the potential effectiveness of a payment intervention along with a detailed analysis of the nature of these services and how they are structured.

### 4. INSIDE VIEW OF BOOTERS

In this section, we analyze publicly leaked backend booter databases, scraped data and aggregated PayPal account data. From this analysis we present some numbers to better understand the dynamics and scale of booter services. This includes, the amount of revenue generated, the number of users and their probable geolocation, the number of victims and the number of attacks initiated by the subscribers of these services.

#### 4.1 Data Sets

Our datasets for this section are comprised of aggregated PayPal account geolocation data provided by PayPal, two leaked backend databases for Asylum and Lizard Stresser and scraped data from VDO. A summary of these data sets is included in Table 1 and Table 2. Before presenting our analysis we will first describe each of these data sets in more detail.

**VDO Scraped Data.** At the time we started monitoring VDO to measure the scale of its operation in early December 2014, it was one the top booter services on underground forums with a high rate of positive reviews. During an eight weeks period ending in early February 2015, we crawled this booter every 10-minutes to collect data on users of the service and details of attacks launched by them. We found VDO to be unique in reporting a wealth of public information on their users and attack details. This data includes all users that logged into the services in the past 15 minutes and distinguishes paying subscribers from unpaid users.

In addition, it displays a list of all currently running attacks that includes the type of the attack, the target of the attack, duration and the time remaining for the attack to be finished. Users can optionally choose to remain anonymous and hide attacks, but the default is for all information to be public. Less than 30% of login records scraped were anonymous and 39% of all attacks seen were hidden.

While we cannot fully vet this self-reported data, we did verify that the data representing our actions were reported accurately. We also validated that all NTP attacks reported for a day were accurate by sending mon-list requests in 10-minute intervals to a set of 12 NTP amplifiers known to be abused by *VDO* and recorded the received responses. A total of 44 distinct victims were the target of NTP attacks as reported by *VDO* during that 24 hour time period and we were able to find matching records for all 44 targets in the mon-list responses collected from the set of monitored NTP servers. This gives us some increased level of confidence that the details of reported attacks and users are accurate.

**Asylum Stresser Backend Database.** Asylum Stresser was an established booter that was in operation for over two years before their backend database was publicly leaked, which covered 18 months of operational data that included user registrations, payments and attack logs. It ceased operation shortly after the leak and has not resumed operation. This leaked database has been vetted by many members of the anti-DDoS community that located their own test accounts in the user registration data and is believed to be authentic.

**Lizard Stresser Backend Database.** Lizard Stresser was launched in late December of 2014 by individuals calling themselves the *Lizard Squad*. This same group was responsible for DDoS attacks on Sony PlayStation and Microsoft Xbox networks on December 25, 2014. Later, the group announced that the attacks were meant to demonstrate the power of Lizard Stresser, a booter service they started to offer to users on a subscription basis. As the attack infrastructure used by this service was backed by hacked home Internet routers, we did not directly interact with this service. However, their backend database covering their first two weeks of operation that included user registrations, payments and attack logs was publicly leaked. For this database, since all payments were in bitcoin and the wallet addresses are included, we have validated that this part of the database is accurate. We have also checked for internal consistency within these leaked databases. While we cannot rule out that some of the data has been fabricated, it would take a fair amount of resources to create this high fidelity of a forgery.

**Aggregated PayPal Data.** In order to understand where booter operators and subscribers are potentially

located, we use aggregated data provided to us by PayPal that was computed from all the accounts identified by PayPal as belonging to booter operators and subscribers. This data did not include any scale on the number of booter and subscriber accounts included in the dataset. It was computed by assigning the location for each account to the country from which the majority of their logins occurred and computing the percentage of accounts assigned to each country. In the case that an account did not have a majority of their logins occurring in a single country it was removed from the dataset. This accounted for 3% of subscriber accounts and none of operator accounts. Also, IP addresses for proxies, VPN services, hosting service and Tor were removed using a database from IP2Location<sup>3</sup>

## 4.2 Subscribers

We find that 15% of Asylum users and 23% of all VDO users purchased a subscription, however less than 2% of all Lizard Stresser users purchased a subscription. This might be attributed to the fact that Asylum and VDO both accepted PayPal payments at least sporadically while Lizard Stresser only accepted Bitcoin as a payment method. It is difficult to attribute why the conversion rate of registered users to subscribers is much less for Lizard Stresser, since other factors, such as the media coverage, might have also driven many users to sign up out of curiosity. However, anecdotally 42 of the 225 support tickets mention that the user wants to purchase a subscription using PayPal. As one potential attacker wrote, “I want to pay via paypal real bad I’m a huge fan of and want to buy this ASAP but I don’t have bitcoins.”

Based on the aggregated geolocation information provided by PayPal in Table 2, over 44% of the customer and merchant PayPal accounts associated with Booters are potentially owned by someone in the United States. There are many inherent limitations of this data which we cannot correct or quantify due to the highly aggregated nature of the data. These include the fact that booter services create multiple accounts to replace ones that are limited by PayPal. Thus it might be the case that a few booter services control a large number of the total accounts and are biasing the location and the same might hold for customers as well. Assuming it is accurate, this might support the notion that these services are to some extent limited in their ability to accept payments using virtual currencies, such as Webmoney, which block residents in the United States from creating accounts.

## 4.3 Revenue

Asylum earned an average of \$2,079/month. How-

<sup>3</sup>IP2Proxy IP-Country Database—<http://www.ip2location.com/databases/ip2proxy>

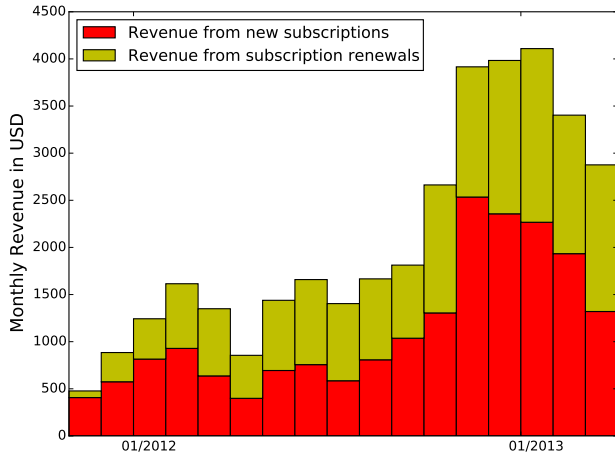


Figure 2: *Asylum Stresser* monthly revenue.

ever, as Figure 2 shows their revenue started at a modest \$500/month and grew to over \$3,000/month towards the end of the leaked data period. Also, it is interesting to note that their revenue from subscription renewals was \$16,025.12 and almost equal to the \$19,356.42 earned from new subscriptions. The Lizard Stresser leak only covers 2 weeks in which time they earned \$3,368 and VDO earned an estimated \$24,737/month confirming that VDO was operating at a far larger scale. Asylum collect 99.4% (\$35,180.14) of their revenue through PayPal payments and only 0.6% (\$201.40) of their revenue was collected using their secondary payment method of MoneyBookers. Lizard Stresser collected all their revenue through their only supported payment method of Bitcoin and VDO accepted both PayPal and Bitcoin. All of this underscores the fact that revenue from paid subscriptions and renewals is the driving factor for operating these services and expanding them to grow customer bases. They are presumably profitable, but these individual booters do not generate the profits required to pay the upfront capital, fees and potential fines for dedicated credit card merchant processing accounts, which amounted to around \$25-\$50K per an account, as was the case with illicit pharmaceutical and fake anti-virus groups that had revenues on the order of millions of USD dollars a month [17, 25].

#### 4.4 Attacks

From the leaked data we find that these three booters were responsible for over half a million separate attacks against over 100,000 distinct IP addresses. While the average attack from VDO only lasted 27 minutes this data demonstrates the large-scale abuse problems and unwanted traffic generated by these services. Our analysis of victims finds that they are predominantly residential links and gaming-related servers, with a small number of higher profile victims, such as government,

journalist and law enforcement sites. This matches previous analysis of victims from leaked databases [12]. For VDO our scraped data included the type of DDoS attack launched and our analysis of this data shows that amplified attacks where the adversary attempts to exhaust the bandwidth capacity of the victim’s connection accounted for 72% of all attacks launch from VDO. The next most popular class of attacks were SYN flooding attacks, which made up only 16% of all attacks.

## 5. ATTACK INFRASTRUCTURE

Our measurements of booters’ attack infrastructure are based on engaging with these services to understand what techniques and hosts are being actively used for attacks. Using this information we provide a better understanding of cost structure and trade-offs of different attack techniques. It also informs defenders as to which ISPs and hosts to focus on for blacklisting, remediation and notification efforts. Our analysis of frontend servers finds a reliance on CloudFlare to protect this infrastructure from takedown and DDoS. In addition, we find that booters gravitate to using more stable amplifier infrastructure when possible. This differs from previous studies that scan the Internet for the vulnerable populations of misconfigured amplification servers many of which might be highly transient and not be used for DDoS attacks. We also identify two hosting providers connected to the same ISP that are actively courting booter operators and providing stable high bandwidth attack servers that allow spoofing.

This set of measurements is based on data gathered from a combination of sources including subscribing to booters and launching attacks against our server, active probing measurements and analysis of two hosting providers that rent attack servers.

### 5.1 Dataset

Our first task was to identify booter services for this part of our study. Absent a centralized location for finding booters, we found services via search engines and advertisements on hacker forums such as *hackedforums.net*. We selected 15 booter services that received the most positive feedback on underground forums for our attack infrastructure characterization. The number of booters was kept relatively small in order to minimize the amount of money we paid to these services, which totaled less than \$140 and no individual booter service received more than \$19. We make no claim about the coverage these booters provide of the entire ecosystem. Rather, we were looking to provide a sample of stable services most of them ranked highly for search terms associated with booter services and they also garnered the most positive replies to their advertisements on underground forums.

We purchased a one month subscription from each

Booter	Attack Types	Cost
ANO	DNS	\$6.60
BOO	NTP,Chargen	\$2.50
CRA	DNS,SSDP	£10.99
GRI	NTP,SSDP	\$5.00
HOR	NTP,SSDP	\$6.99
INB	DNS,NTP,SSDP	\$11.99
IPS	NTP,SSDP,Chargen	\$5.00
K-S	SSDP,Chargen	\$3.00
POW	SSDP	\$14.99
QUA	DNS,SSDP	\$10.00
RES	DNS,NTP	\$10.00
SPE	DNS,NTP,SSDP,Chargen	\$12.00
STR	DNS,SSDP	\$3.00
VDO	DNS,NTP,SSDP	\$18.99
XR8	DNS	\$10.00

**Table 3:** List of booter services we measured, which of the four attack types included in our measurements each booter offered and cost of cheapest one month subscription.

of the services which ranged from \$2.50-18.99 and focused on measuring amplification attacks based on our measurements of VDO that showed this was the most common type of attack and the fact that amplification attacks were the default attack type for all 15 booters. More precisely, we chose to measure the most common amplification reflection attack types offered by the booters, which were SSDP, NTP, DNS and Chargen. Table 3 shows the set of booters, which of the four attack types that booter offered and the cost of a basic month subscription.

We conducted attacks directed at our target server from December 2014 - January 2015. The goal of these attacks was to map out the set of misconfigured hosts that were being used by each booter to amplify their reflection attacks. The configuration of our target system used for measuring the attacks was an Intel Xeon 3.3GHz server running Ubuntu with 32 GB of RAM and an isolated 1 Gbps dedicated network connection.

We used `gulp` [22], which is a lossless Gigabit packet capture tool to capture attack traffic. Each attack lasted for one hour total and was comprised of many shorter attack instances of 10 minutes each, which is the standard time limit for basic subscriptions. The reasoning behind the longer attack times was to increase our probability of identifying all the misconfigured reflection hosts used by a booter for each attack type. However, we found almost all of the amplification servers were identified after the first attack. Therefore we limited our attacks to shorter durations for the rest of our experiments that required launching attacks.

## 5.2 Frontend Servers

Booter services maintain a frontend website that allows customers to purchase subscriptions and launch DDoS attacks using convenient drop-down menus to

specify the attack type and victim’s IP or domain name. These frontend websites commonly come under DDoS attack by rival booters and are subject to abuse complaints from anti-DDoS working groups. All 15 booters in our study use CloudFlare’s DDoS protection services to cloak the ISP hosting their frontend servers and to protect them from abuse complaints and DDoS attacks.

As part of this study we contacted CloudFlare’s abuse email on June 21st 2014 to notify them of the abusive nature of these services. As of the time of writing this paper, we have not received any response to our complaints and they continue to use CloudFlare. This supports the notion that at least for our set of booters CloudFlare is a robust solution to protect their frontend servers. In addition, *crimeflare.com* has a list of over 100 booters that are using CloudFlare’s services to protect their frontend servers.

## 5.3 Attack Servers

Provider	VPS IP	Uplink speed	Bandwidth	Monthly cost
CaVPS Host	192.210.234.203	3.5 Gbps	Unmetered	\$35
Spark Servers	96.8.114.146	949 Mbps	10 TB	\$60

**Table 4:** Spoofing enabled VPS services.

Renting back-end servers to generate attack traffic is the primary source of cost for the operators of booter services. We did some research to get a broad sense of the market availability and cost of back-end servers that allow the source IP address to be spoofed. Being spoof friendly, fast uplink speed and high caps or unmetered bandwidth usage are the key requirements of a server appropriate for supporting the operation of a booter service.

In order to understand if these services delivered on their claims of allowing spoofing and providing the bandwidth they advertised we rented Virtual Private Servers (VPS) from two hosting providers that advertised on underground forums. Table 4 summarizes the services that we purchased. Both of the VPSs we purchased were connected to the same ISP (ColoCrossing) in the US. We also verified that both VPSs allowed spoofing and measured their actual link speeds. One VPS provided around 1Gbps uplink bandwidth and the other one interestingly provided up to 3.5Gbps. The servers we purchased were virtual and therefore running on shared hardware. A busy booter service would need to use dedicated servers with more resources to support its operation. The price range for a dedicated servers with a link speed of 1Gbps and unlimited bandwidth usage was around \$300-\$500. Due to budget limitations we could only rent these two VPSs and did not rent any higher end dedicated servers. However, our initial results show that this is a potentially effective method of mapping out abusive hosting and we plan to scale this part of our measurements as future work.

Booter	Chargen		DNS		NTP		SSDP	
	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)
ANO	-	-	1,827	73%	-	-	-	-
BOO	370	65%	-	-	1,764	86%	-	-
CRA	-	-	43,864	56%	-	-	64,874	46%
GRI	-	-	-	-	1,701	72%	10,121	60%
HOR	-	-	-	-	8,551	58%	242,397	30%
INB	-	-	38,872	55%	4,538	92%	170,764	54%
IPS	1,636	44%	-	-	1,669	85%	90,100	29%
K-S	1,422	30%	-	-	-	-	5,982	76%
POW	-	-	-	-	-	-	1,424,099	11%
QUA	-	-	10,105	85%	-	-	39,804	67%
RES	-	-	2,260	82%	27	100%	-	-
SPE	2,358	38%	26,851	61%	6,309	35%	258,648	24%
STR	-	-	93,362	53%	-	-	7,126	74%
VDO	-	-	16,133	82%	6,325	82%	150,756	62%
XR8	-	-	44,976	52%	-	-	-	-
Total	4,565	23.46%	181,298	35.30%	17,599	42.31%	2,145,015	11.84%

Table 5: Number of total amplification servers and percentage of overlap with amplifications servers used by other booters.

## 5.4 Attack Techniques

Due to their effectiveness, amplified volume-based attacks are the default attack technique offered by most booter services. We focused our analysis on SSDP (more commonly known as Universal Plug and Play (UPnP)), DNS, NTP and Chargen. These attacks depend on servers running misconfigured UPnP, DNS resolvers, NTP and Chargen services that enable attackers to amplify attack traffic by sending spoofed packets with the victim’s source address in the IP header and having these services respond with a larger amount of traffic directed to the victim.

We have also seen booter services offering reflection-based attacks by misusing popular web Content Management Systems (CMS) such as WordPress and Joomla to generate and direct HTTP requests to target web servers.

In addition, many booters offer direct attacks including TCP SYN, and UDP flood where the attack spoofs the source IP address and directly sends packets to the victim. Some booters also implement HTTP-based attacks including HTTP POST/GET/HEAD, RUDY (R-U-Dead-Yet) and Slowloris using proxies to conceal their attack server’s IP address.

## 5.5 Amplifiers

As part of our measurements we can map out the set of amplifiers that are being abused to magnify the traffic volume of attacks. This sheds light on the population of hosts that are not only vulnerable to amplification attacks, but are actively being abused. Table 5 shows that the set of abused Chargen and NTP servers are smaller and more highly shared between two or more services, whereas there is an ample supply of DNS and SSDP servers that are used as amplifiers. However, the overlap of DNS servers used by two or more booter services is still relatively high suggesting that these DNS resolvers might be more stable, have higher bandwidth

CC	%	AS	%
<b>Chargen</b>			
CN	48.78%	4134 (Chinanet)	14.46%
US	12.51%	37963 (Hangzhou Alibaba Advertising)	10.47%
KR	5.50%	4837 (CNCGROUP China169 Backbone)	6.88%
RU	4.58%	17964 (Beijing Dian-Xin-Tong Network)	2.61%
IN	2.56%	7922 (Comcast Cable Communications)	2.61%
<b>DNS</b>			
US	12.38%	4134 (Chinanet)	2.68%
RU	11.58%	3462 (Data Communication Business Group)	2.15%
BR	9.19%	18881 (Global Village Telecom)	1.46%
CN	6.84%	4837 (CNCGROUP China169 Backbone)	1.45%
JP	3.61%	7922 (Comcast Cable Communications)	1.27%
<b>NTP</b>			
US	31.47%	3462 (Data Communication Business Group)	14.01%
TW	15.29%	46690 (Southern New England Telephone)	12.35%
CN	10.68%	7018 (AT&T Services)	4.84%
KR	5.50%	4134 (Chinanet)	3.58%
RU	4.74%	4837 (CNCGROUP China169 Backbone)	2.18%
<b>SSDP</b>			
CN	36.26%	4837 (CNCGROUP China169 Backbone)	18.98%
US	19.37%	4134 (Chinanet)	11.16%
EG	6.83%	8452 (TE Data)	6.61%
AR	5.37%	22927 (Telefonica de Argentina)	5.13%
CA	5.36%	7922 (Comcast Cable Communications)	4.60%

Table 6: Top country locations and autonomous systems for amplifiers.

connections and be in more limited supply.

## 5.6 Amplifier Location

As demonstrated by Table 6 both the geolocation and AS of amplifiers used by booters are fairly diffuse. There are a few notable exceptions, such as the concentration of Chargen amplifiers in China with three Chinese ASs connecting 34% of these amplifiers. In addition, there is a slight concentration of abused NTP servers connected to one Taiwanese AS and two United States network operators. This might indicate a potential to focus notification and patching efforts on these networks, given the limited pool of hosts used for Chargen and NTP attacks from Table 5. Feeds of these actively abused servers could also be distributed to these network operators and to DDoS mitigation services.

## 5.7 Amplifiers Churn

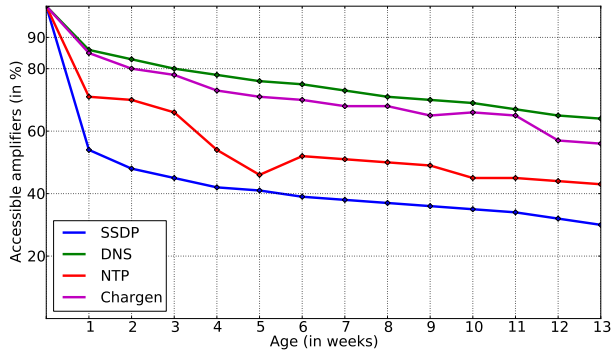


Figure 3: IP churn of amplifiers.

In order to measure the stability of these amplifiers we probed them periodically for 13 weeks to understand how many were still located at the same IP and vulnerable to abuse. As shown in Figure 3, the set of DNS resolvers were the most stable with nearly 80% still vulnerable and located at the same IP after one month and over 60% were still misconfigured after 13 weeks. This result is counter to the previous results of churn based on Internet wide scanning that found a 50-60% churn rate for DNS servers after one week [13]. It indicates that booters have gravitated to using a more stable set of DNS resolvers and that focusing mitigation efforts on these might cause these DNS attacks to be less efficient and require additional bandwidth and cost. From our measurements, SSDP servers were the least stable with a 50% churn rate after only a single week. This result agrees with the previous Internet wide scanning result and indicates that either booters have not found or there might not exist a set of more stable SSDP servers.

## 5.8 Amplification Factor

One of the few direct costs incurred for every attack a booter service launches is the bandwidth sent from their rented attack servers. In order to reduce this cost amplification attacks are used for volume-based flooding attacks. Some attack methods can potentially produce a larger amplification factor than others, but there are many factors that effect the amplification factor. Our measurements largely agree with the lower-end bandwidth amplification factor numbers reported in a previous study [13], with NTP attacks resulting in an average amplification factor of 603 times, Chargen being the next largest at 63 times, DNS resulting in an average of 30 times amplification and SSDP generating the smallest average amplification factor of 26 times. This and the limited number of NTP amplifiers confirms that the communities focus on prioritizing notification and patching of misconfigured NTP servers is the correct approach. We also suggest that some effort be placed into efforts to notify operators of servers with misconfigured

and abused Chargen services, since these are the next largest threat and there is also a potentially constrained supply.

## 6. PAYMENT INTERVENTION

As part of our study we sought out opportunities to understand and also measure the effectiveness of undermining DDoS Services. In this section, we present our measurements of a payment intervention that was conducted in collaboration with PayPal.

We find that reporting accounts to responsive payment service providers, such as PayPal, can have the desired effect of limiting their ability and increasing the risk of accepting payments using these payment services. Although, this technique requires constant monitoring of the booters and drives them to move to more robust payment methods, such as Bitcoin.

### 6.1 Payment Ecosystem

At the onset of our study the majority of booter services accepted credit card payments via PayPal as their primary mechanism for receiving funds from their customers. In addition to PayPal, some booters accepted bitcoin payments and a limited number of booters also accepted credit card payments using Google Wallet<sup>4</sup> and virtual currencies, such as WebMoney and Perfect Money—these last two prohibit customers from the United States from opening an account and using their platform.

We identified a larger set of 60 booter services<sup>5</sup> that accepted PayPal and created custom crawlers to monitor their payment methods and merchant accounts for about 6 weeks from April 22, 2014 through June 07, 2014. These booters were located from underground forum advertisements and web searches for terms commonly associated with booter services. Again we make no claim about the coverage these booters provide of the entire ecosystem. To minimize the effect of unstable booters on our study, the final set of booters included in our analysis was limited to the 23 stable booter services that were able to successfully use PayPal to receive funds for at least half of the time before the PayPal intervention and used at least one PayPal account after the intervention. Nine of these 23 booter services overlapped with the set of 15 booters measured in section 5, among the reasons that six booters were not included in this measurement is that some did not accept PayPal and others did not accept PayPal over half the time in the first 6 week period.

<sup>4</sup>Google phased out their digital goods payment processing at the start of March 2015 — <https://support.google.com/wallet/business/answer/6107573>.

<sup>5</sup>This set is larger than the previous set, since we did not have to pay for a subscription in order to monitor their payment accounts.



Booter	accounts before	accounts after	Status
ANO *	6 (8.2)	7 (2.9)	✓
AUR	6 (7.2)	6 (2.7)	✗
BOO •	6 (8.3)	11 (2.7)	✓
CRI †	4 (9.0)	1 (2.0)	✗
DAR ◊	4 (6.0)	5 (4.8)	✓
DIA †	3 (15.7)	0 (-)	✗
GET	2 (14.0)	1 (4.0)	✓
GRI *	4 (10.5)	1 (6.0)	✓
HAZ ◊	4 (12.2)	5 (5.6)	✓
IDD ◊	3 (7.7)	2 (9.0)	✓
IPS ◊	3 (7.3)	5 (5.4)	✓
POW	5 (4.5)	9 (5.0)	✓
PRI	6 (8.8)	2 (1.0)	✗
QUA •	11 (4.3)	22 (1.8)	✓
RAG •	13 (3.9)	4 (2.0)	✓
REB	2 (11.5)	9 (2.3)	✗
RES *	6 (8.2)	7 (2.9)	✓
SNO	1 (-)	0 (-)	✗
STA	5 (13.0)	3 (5.3)	✓
STR	1 (47.0)	1 (4.0)	✓
TIT ◊	12 (5.3)	17 (2.9)	✓
XR8	4 (10.5)	11 (1.6)	✓
XRS •	8 (5.2)	4 (2.5)	✗
	119 (7.84)	133 (3.07)	

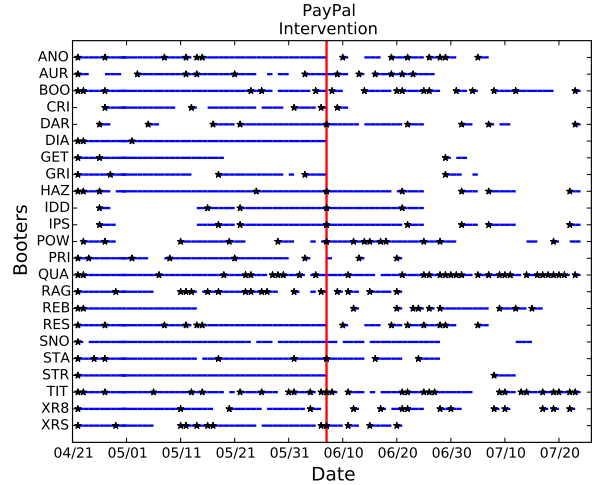
**Table 7:** Number of PayPal accounts used by monitored booters before and after the intervention. The numbers within the ( ) are the average lifespan of the accounts used by that booter. Accounts that are active both before and after are counted only in the before and not included when computing the average lifespan. Matching symbols indicate that this set of booters shared at least one PayPal account. These shared accounts might be instances of a third party agreeing to accept payments for these services.

After collecting our initial data on the stability of their PayPal merchant accounts, we reported these booters’ domains and accounts to PayPal and they began to monitor merchant accounts linked to these domains and suspending them after an investigation. Note that PayPal will initially limit reported merchant accounts that are found to violate their terms of service by accepting payments for abusive services and perform an investigation of the account. Once an account is limited the merchant cannot withdraw or spend any of the funds in their account. This will result in the loss of funds in these accounts at the time of freezing and potentially additional losses due to opportunity cost while establishing a new account. In addition, PayPal performed their own investigation to identify additional booter domains and limited accounts linked to these domains as well. This had the affect of a large-scale PayPal payment disruption for the majority of booter services.

In order to further understand the effectiveness of our payment intervention, we monitored underground forums where these booters advertise their services and news feeds from booters we joined to discover qualitative data on the effectiveness of PayPal’s payment intervention.

## 6.2 Usage Pattern of PayPal Accounts

Based on our observations, booter services for the



**Figure 4:** PayPal account usage over time. Black asterisks denote a new PayPal account and gaps in the blue line represent PayPal unavailability for that time period. The red vertical line indicates when the reporting of accounts started.

most part only use a single PayPal account at a time to receive payments and change their PayPal merchant account when a limit is put on their previous account or they proactively change accounts to reduce the risk of limits on their previous accounts. We used the dataset collected during the initial monitoring period to understand how frequently booter services were changing their PayPal accounts. Note that our age measures are both right and left-censored. For the booter’s initial account our data is left-censored and for the last account our data is right-censored. However, we believe our age measurements accurately represent the effects of the PayPal intervention based on our interactions with and postings from the booters themselves.

Table 7 provides an overview of the PayPal accounts observed by our crawler broken down by each service monitored. As Table 7 shows accounts had an average life time of slightly over a week before the intervention with STR and SNO each using a single account that remained active during the entire 47 day initial observation period and SNO’s account that remained active for 37 days after the intervention began. On the other end of the spectrum, QUA, RAG and TIT changed accounts every 4-5 days before the intervention. The impact of the intervention can be visually seen in Figure 4.

Once the target intervention begins the average lifespan of an account drops to around 3.5 days with many booter’s PayPal accounts only averaging around two days before they are no longer used again. Figure 4 visually shows the impact of the payment intervention on the lifespan of booter services PayPal accounts and provides some indication of the time period that elapsed between a new PayPal account being actively used to accept payments and when PayPal took action against

the account or it was proactively replaced. The length and number of PayPal outages increase after the intervention, with only QUA and TIT avoiding major PayPal outages by resorting to aggressively replacing accounts. Note that this replacement strategy was not fully effective, since our monitoring infrastructure detected and reported these accounts.

### 6.3 Booters’ Status

As part of our daily monitoring of the 23 booter services, we recorded if the service could accept PayPal payments and if the site was functional. This enabled us to better understand the impact of the payment intervention on the booter’s ability to accept PayPal payments and the operation of the service. For each booter, we placed it in one of the following statuses each day based on the results of our crawl.

**Active:** The booter is able to successfully use a PayPal account to receive payments from its customers.

**Unreachable/Broken:** Either the booter’s frontend website was not responding to HTTP requests, the booter service had closed or the frontend site was not functional.

**PayPal Disabled:** The booter’s frontend website is active, but the service has either removed PayPal as a payment option, or the PayPal account linked to the booter website is limited and therefore unable to receive payments.

Figure 5 shows the status of booter services over time. The vertical line represents the date on which we started sharing our data with PayPal and PayPal started to independently investigate the reported accounts and take action against them. As observed in Figure 5, the percentage of active booters quickly drops from 70-80% to around 50% within a day or two following the intervention date and continues to decrease to a low of around 10% and then fluctuating between 10-30%. This resulted in an increase in PayPal unavailability from 20% before the intervention to 63% during the intervention. In addition, we observed 7 booter services in our study shut down their business and most of the remaining services switch to alternative payment methods, such as Bitcoin.

### 6.4 Qualitative Assessments

In addition to our quantitative measurements, we also have qualitative evidence of PayPal’s payment interventions efficacy. By monitoring the underground forums where these services advertise we can witness the impact of these account limitations. Wrote one booter operator during the intervention, “So until now 5 time my 5 PayPal Accounts got Limited on My stresser is other stresser have same Problem with the fucking Paypal ? is there any solution what we should do about fucking Paypal ?” Similarly, customers vented their frustration

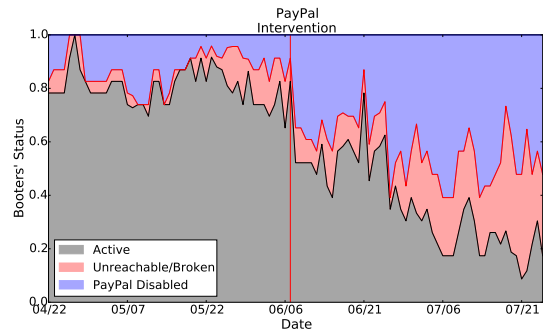


Figure 5: Status of booters over time.

at being unable to purchase a booter service using PayPal. Wrote one booter customer, “when i go to buy a booter it normally says i can’t buy because their PayPal has a problem.”

In a number of cases booters directly link their closers to loss of funds due to PayPal merchant account limitations. This message was posted on the front page of a defunct booter service, “It’s a shame PayPal had to shut us down several times causing us to take money out of our own pocket to purchase servers, hosting, and more.”

### 6.5 Booter Response

As with any intervention the adversary, booters, will respond by adapting to the pressure. In this case, we do not have enough quantitative measurements to access the effectiveness or the full range of responses to our attempt to undermine their payment infrastructure. However, we have identified several common classes of adaptations in response to the intervention.

**Alternate payment methods.** Most booters have added Bitcoin as an alternate payment methods and have posted links to services that allow customers to purchase bitcoins using credit cards or PayPal. In addition to bitcoins some switched to Google Wallet and others added the option to pay using virtual currencies, such as Webmoney and Perfect Money. By all accounts these have resulted in reduced customer bases if the booter cannot directly accept credit card payments. Evidenced by the fact that many booters continued to replace their PayPal accounts even when previous ones were limited and their funds were lost. Assuming that alternative payment methods did not result in reduced revenue or higher costs there would be little incentive to continue using risky payment methods, such as PayPal.

**Referrer anonymizing services.** We have noticed that some booters have stopped directly linking to PayPal and are now linking to an intermediary site and then redirecting the customer’s browser from this intermediary domain to PayPal’s site. This intermediary redirection site is used to hide the booter’s real domain name in the referrer field from PayPal. A subset of booters have

also started to replace this intermediary domain every time they replace a PayPal account. The effect of this is that it requires active crawling and measurements of booter sites to identify a booter’s new PayPal account bypasses passive methods PayPal could use to linking accounts, such as by using referrers. This has increased the difficulty of monitoring booter’s PayPal accounts and effort required to investigate these accounts.

**Offline payment.** Finally, in some cases booters have posted that customers must open a ticket to pay using PayPal. This method increases the effort to monitor the booter for new accounts, since instead of an automated crawler someone must now interact with the booter service manually. It also increases the difficulty of PayPal’s investigation into the nature of the merchant account. However, this method also requires the booter service to manually activate each account and drives away customers that are seeking automated subscription purchasing systems.

## 7. DISCUSSION AND FUTURE WORK

We have gathered a few key points from ours and the community’s efforts to understand and undermine these DDoS services. Most of these potential strategies involve driving up costs of operating booter services and reducing the convenience of subscribing. This might force these booters from operating largely unopposed in the open to more resilient hosting, attack and payment infrastructure for which they pay a premium due to the risk of support services being taken down or blacklisted for being associated with DDoS attackers.

**Reducing scale.** Limiting access to convenient payment methods, such as PayPal, had an impact on the scale of booter services based on our quantitative and qualitative analysis. However, criminal-to-criminal payment infrastructure is more resilient than consumer-to-criminal payment infrastructure. As future work, we plan to understand how to improve the effectiveness of these interventions and make them sustainable. This in part requires developing more robust monitoring tools that better mitigate countermeasures being deployed to make their payment methods more robust to interventions. To this end, we are working on building a generic crawler that can learn how to navigate a booter site and map out payment accounts. This would reduce the burden of having to create and maintain custom crawlers for each site.

**Reducing effectiveness of attacks.** We plan to continue our monitoring efforts of the amplification servers used by booters and begin sharing this information with existing patching efforts, such as the OpenResolverProject [2] and OpenNTPProject [1]. Along with this, we plan to experiment with active notifications sent to the ISP and abuse contact for the server. Our hope is that by focusing mitigation efforts on actively abused am-

plifiers, we can mitigate the pool of more stable amplifiers and thus reduce the effectiveness of booter attacks as they are forced to use less stable amplifiers and protocols with a lower bandwidth amplification factor. There is some indications that active notification improves patching rates in another context [8].

**Increasing costs.** This might be achieved with an increased effort to locate and blacklist or de-peer low-cost hosting services that cater to DDoS attacks by providing the ability to spoof and unlimited bandwidth. This might force these services to pay a premium for bullet-proof hosting attack servers, which would result in reduced profitability or be passed along to subscribers in the form of increased subscription costs. In addition, convincing CloudFlare and other free anti-DDoS services to prohibit these booter services would increase their costs by forcing them to build and pay for anti-DDoS services that cater to these abusive booters. Admittedly these suggestions will likely not result in large cost increases unless tremendous amounts of pressure were placed on these parts of their infrastructure.

## 8. CONCLUSION

Unfortunately, there is no silver bullet that will mitigate the threat posed by booter services overnight. These booters have grown in scale due to the perceived low-risk nature, their profitability and increasing demand for DDoS attacks as a method of knocking out the competition, harassment and censorship on the Internet.

In this paper we have mapped out a range of support infrastructure that booters depend on in terms of advertising, attack, hosting and payment. We have also measured the effectiveness of ongoing attack infrastructure interventions and demonstrated the potential effectiveness of a payment intervention. Our measurement techniques, including direct observations by interacting with these booters and support services, such as hosting providers, highlight potential improvements to ongoing efforts to undermine attack infrastructure by focus patching efforts on abused NTP and Chargen servers and exposing ISPs and hosting centers that enable these attacks. We also demonstrated that payment interventions, which undermine the accessibility of convenient payment methods, such as PayPal, can potentially have an impact on reducing the scale of these services. Our hope is that by continuing to explore new methods for understanding and undermining booters, we can identify increasingly effective methods of adding friction, cost and risk to these ventures that further erodes their attack potency, scale and profitability over time.

## 9. ACKNOWLEDGMENTS

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