The Price of Free Illegal Live Streaming Services

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Abstract

As Internet streaming of live content has gained on traditional cable TV viewership, we have also seen significant growth of free live streaming services which illegally provide free access to copyrighted content over the Internet. Some of these services draw millions of viewers each month. Moreover, this viewership has continued to increase, despite the consistent coupling of this free content with deceptive advertisements and user-hostile tracking.

In this paper, we explore the ecosystem of free illegal live streaming services by collecting and examining the behavior of a large corpus of illegal sports streaming websites. We explore and quantify evidence of user tracking via third-party HTTP requests, cookies, and fingerprinting techniques on more than 27,303 unique video streams provided by 467 unique illegal live streaming domains. We compare the behavior of illegal live streaming services with legitimate services and find that the illegal services go to much greater lengths to track users than most legitimate services, and use more obscure tracking services. Similarly, we find that moderated sites that aggregate links to illegal live streaming content fail to moderate out sites that go to significant lengths to track users. In addition, we perform several case studies which highlight deceptive behavior and modern techniques used by some domains to avoid detection, monetize traffic, or otherwise exploit their viewers.

Overall, we find that despite recent improvements in mechanisms for detecting malicious browser extensions, ad-blocking, and browser warnings, users of free illegal live streaming services are still exposed to deceptive ads, malicious browser extensions, scams, and extensive tracking. We conclude with insights into the ecosystem and recommendations for addressing the challenges highlighted by this study.

1 Introduction

Countless studies in the past decade have examined misbehaving websites which attempt to exploit users. Traffic to these websites is often considered as driven by exploiting innocent users, whether via phishing/spam, URL misdirection, or other social engineering techniques. As a result, many security efforts towards protecting users from these websites has focused on a) preventing users from ending up on these sites at all and b) on making it difficult for sites to exploit users without the users’ noticing, giving them the chance to navigate away. However, such efforts fail to protect one group of Internet users—those who are willing to tolerate abnormal or undesirable web behavior because the service they seek would otherwise cost money. As a result, websites which illegally provide copyrighted content for free are able to present user-hostile, even blatantly malicious interfaces without fear of losing users as a result. Combine the behavior of these websites with the large number of users that visit them, and you have a phenomenon worth studying.

Of course, illegal live video streaming is not the only instance which meets the aforementioned criteria. While online piracy takes many forms, it has been traditionally dominated by peer-to-peer platforms like BitTorrent. Despite this, streaming presents an interesting use case—the attack vector for BitTorrent platforms is obvious, as users are required to download untrusted files outside the browser, and there is little expectation of safety. Video streaming, on the other hand, is often considered by users as a lower-risk alternative, where the browser is assumed to provide protection from harm. This perceived lower-risk has likely been a significant factor in the meteoric rise of illegal video streaming, and is an assumption worth investigating.

Like legitimate live video streaming services, illegal live streaming services exist to profit their operators. Hundreds of illegal live media streaming services and thousands of link-aggregating websites have emerged to lure viewers with free content and consequently attempt to monetize their ill-gained traffic through deceptive ads, malware, tracking, and other malicious behavior [23]. Users willingly to expose themselves to these risks by clicking through warnings and intrusive overlay ads in order to received paid content for free—even though this intrusive and malicious behavior would discourage them from visiting legitimate websites. Many of these sites receive millions of visits each month, which likely places them among the most visited sites that deliberately exploit their users. The surfeit of users that willingly expose themselves to malicious behavior on these websites puts these sites in a uniquely abusable position.

Previous research has focused on understanding and classifying the sites which aggregate links to these illegal streams [23], illegal on-demand streaming cyberlockers [12], or the security and privacy of legitimate streaming sites [18]. In this study, we explore the ecosystem of free illegal streaming services with a specific focus on services which host streams to live broadcasts. These websites are highly transient in nature: they may change domains frequently, inten-
tionally avoid being indexed by search engines, and only host paths to live streams for the duration the event is live (redirecting to an innocuous page after an event is over). Consequently, these sites often avoid the scrutiny of law enforcement and researchers. To study illegal live streams, we use live sports streams as a proxy. Sports media rights are estimated to be valued at $20.6B by 2019 [11]. Illegal live sports broadcasts are primarily viewed live by millions of viewers each month, making it a reasonable representative of the live streaming ecosystem. Further, given the quantity and diversity of these sites, we hypothesize that the malicious behaviors of these websites represent a decent survey of malicious tactics used on the Internet today by websites without fear of regulatory retribution.

Contributions Our methodology for studying the free illegal live streaming ecosystem consists of three main phases: (1) collecting links to illegal live streams, (2) storing the source and recording the behavior of these websites, and (3) analyzing this data for evidence of malicious behaviors. To summarize our contributions, in this study, we present:

- A contemporary snapshot of the free illegal live streaming ecosystem, showing that the number of channel providers has increased since [23] and that mainstream sites are used as aggregators (Section 3).
- A system for automatically detecting new links to illegal live streaming sites as they appear, and for subsequently crawling these sites to collect information on them (Section 4).
- Evidence that illegal streaming sites seek to track and identify users, suggesting that these entities may have profiles for their viewers (Section 6.1).
- A comparison of illegal and legal live streaming sites illustrating how illegal sites are more interested in tracking users (Section 6.2).
- Evidence that moderation and crowd-source voting are likely less effective than users expect at protecting them from malicious sites (Section 6.3).
- A collection of case studies for illegal live streaming websites which serve as a lens into how modern cyber-criminals attempt to exploit naïve users. (Section 7).

The remainder of the paper is structured as follows. Section 2 highlights related work and frames our study in the context of previous literature. Section 3 presents the ecosystem of illegal live streaming services. Sections 4 and 5 describe our methodology for gathering and analyzing our dataset. Section 6 presents our results. Section 7 dives into illustrative examples of illegal streaming sites. We discuss the implications of our observations in Section 8, provide recommendations in Section 9, and conclude in Section 10.

2 Related Work

Web Security. Many developments in web security have worked to minimize the risk that malicious websites can present to unsuspecting users. Here, we discuss three of these. First, tools like ad-blockers work to hide advertisements on a site, which may reduce a user’s exposure to deceptive advertisements that link to scams or malware. Some deceptive ads can be detected automatically [6]. However, this is an arms race, as anti-ad-blocking techniques have also improved [20, 13]. Second, work on designing user experiences and warnings that clearly alert users when their privacy may be at risk, such as security warnings, have been shown to be effective in practice [2, 9]. Third, browser sandboxing has been employed to ensure that access by websites to vulnerable aspects of the system is limited by specific browser UI, such as directing all downloads to a specific directory, limiting read access to files to certain OS-provided contexts, and presenting JavaScript alerts outside of the rendering engine [3]. However, online piracy presents a unique scenario in which users are often willing to ignore and bypass these security warnings in order to obtain paid content for free.

Measuring Online Tracking. [7] presents extensive measurements of online tracking across the Alexa top million websites and presents OpenWPM, the tool we utilize in our work to collect data on illegal stream URLs. Similarly, [4] studies third-party tracking on websites and mobile applications while [10] examines the differences in tracking activity between geographic locations. While these studies measure tracking on the web generally, they do not differentiate between sites, and none focuses specifically on sites for which visiting these sites could be considered criminal activity.

Illegal Media Streaming. [18] studies security and privacy concerns related to on-demand media streaming services and targets platforms that are known to host illegal content. Specifically, they study over 20 media streaming platforms (e.g., Kodi, Enigma 2, MediaTomb, etc.) and their attack surfaces, and find that there are over 100,000 devices using these platforms which are discoverable through simple search queries. Similarly, [12] explores the ecosystem of illegal streaming from the perspective of video piracy, where content is streamed on-demand, as opposed to our work, which will focus specifically on live-streamed content. [17] studies the architectures and protocols used to stream illegal content over the Internet and explores the value chain from content acquisition, preparation and distribution, web hosting, and content discovery. This study considers peer-to-peer streaming as well as web streaming, but does not study malicious behavior outside of breaking copyright law.

Illegal Live Media Streaming. [23] studies the ecosystem of free live streaming websites with an analysis of over 5600 live-streaming domains discovered from live-streaming
domains through aggregator websites. This study does not focus on user tracking, and instead highlights other aspects of their behavior such as trademark infringements, malware distribution, and anti-ad-block techniques, and uses these intuitions to build a classifier of these sites. Though this study is over two years old, it notably does not include Reddit as one of their aggregators, despite our finding that Reddit is now one of the most popular aggregators (see Section 4).

3 The Illegal Live Streaming Ecosystem

In the ecosystem of free live streaming services, there are five main parties involved. The relationships between these parties are illustrated in Figure 1 and described below.

Media Providers acquire and stream media content. A media provider may be a single individual streamer sending a video stream using software like OBS\(^1\), or a large entity such as a broadcasting station. In the context of illegal live streams, an example of a media provider is an individual who has a subscription to a paid service, and rebroadcasts this content for free in real time.

Channel Providers (CPs) provide the infrastructure for live-streaming media through a media server, which receives live video streams from media providers and serves the streams to users. These entities host the webpages on which streams can be viewed. As such, the webpages of channel providers are where users ultimately land when searching for and viewing illegal live streams. In the context of legitimate websites, Twitch and YouTube are examples of channel providers. Examples of illegal services include sites like buffstreamz.com or watchsport.fun\(^2\).

Aggregators collect links to a variety of channel providers to allow users to discover and browse streams that are available to view. Some aggregators may offer search functionality (e.g., Reddit) while others simply offer a list of streams which are available for viewing at the current point in time (e.g., firstrowonly.eu). Some aggregators use crowdsourcing to gather URLs, while others may be run by a single individual or automated service. In some cases, aggregators themselves may also serve as channel providers, such that when a user clicks on a link to a live event, they do not leave the aggregator domain.

Advertisers allow media providers, channel providers, and aggregators to monetize their services through ads and overlays. Advertisers may be individuals or ad networks, and play a key role in this ecosystem. Typically, aggregators and channel providers will run JavaScript code which fetches advertisements from an ad network. These ads may be banner ads, or more intrusive overlay ads that a user is compelled to click in order to view a live stream, and typically open a new tab that is redirected for tracking before ending on an advertisement page. These advertisement pages are often deceptive or blatantly malicious, with many offering benefits in exchange for the user installing a browser extension.

Users are the individuals watching these free illegal live streams on these potentially malicious websites.

4 Methodology

Our investigation is organized into three phases.

Phase 1: Collection. In Phase 1, we identify a list of popular aggregators. Because we are most interested in understanding the behavior of channel providers (who host the video pages users ultimately land on when watching a live stream), we select eight popular aggregators (based on their Alexa rankings) found in search engines, along with Reddit.

Notably, adding Reddit represents a departure from prior research on this topic. Reddit is a top 20 website globally and

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\(^1\)Open Broadcaster Software (https://obsproject.com/)

\(^2\)Author’s note: The ads displayed on websites analyzed in this study vary frequently and widely, and any of the sites referenced in this paper may at times display ads for adult content. Please take appropriate caution if you choose to visit them.
is hosted in the United States, making it substantially different from the aggregators described in [23]. Further, Reddit is different from other social media platforms such as Facebook and Twitter in that the subreddits via which these links are available are public, where sharing is not dependent on friend networks, and where viewing links does not require users be a member of the Reddit platform. We manually identify 14 subreddits which focus exclusively on aggregating links to illegal sports streams. A comprehensive analysis of Alexa and SimilarWeb data on Reddit indicates that Reddit receives between 16 million and 85 million visits a month just from users looking for sports streams.

We monitor these aggregators for five weeks (11/2018 to 12/2018), to build a database of channel providers linked to by these aggregators\(^3\). Our collection code scraped each of these aggregators every 15 minutes for this five week period.

**Phase 2: Crawling.** In Phase 2, we automatically crawl these websites using our own fork of OpenWPM v0.8.0 [7], which is built upon Firefox and Selenium. OpenWPM allows us to collect data about a webpage such as cookies, HTTP requests, and JavaScript calls. By default, OpenWPM simply visits a webpage and collects information about the content that is immediately available. In our experience, however, we find that many of these websites redirect to what appear to be more malicious pages only when a user attempts to click on the “play” button of the video. As a result, we extend OpenWPM with commands for clicking the webpage and collecting data about the resulting behavior. Due to time constraints, we do not crawl all of the URL we harvested in Phase 1. Instead, we take a sample of the most recently harvested URLs from each channel provider in order to ensure each is represented.

**Phase 3: Analysis.** Finally, in Phase 3, we analyze the behavior of the visited webpages in the context of tracking. To understand the tracking behavior of these websites, we leverage EasyPrivacy\(^4\)—a filter list which seeks to block web tracking. We compare the domains of third party HTTP requests and cookies against EasyPrivacy to determine which of the requests and cookies set by a webpage are associated with web tracking. Importantly, this metric likely underestimates the amount of tracking, since EasyPrivacy is not exhaustive and may fail to flag some resources as tracking [27].

Next, to understand the fingerprinting behavior of these sites, we implement checks for canvas, font, and WebRTC fingerprinting using the techniques described in [8]. Canvas fingerprinting is detected by a series of checks: (1) the canvas element must be greater than 16px in height and width, (2) the JavaScript on the page must not call save, restore, or addEventListener, (3) the JavaScript must attempt to save an image with toDataURL or getImageData with a size greater than 16px × 16px. Font fingerprinting is flagged when a site calls measureText 50 or more times. WebRTC fingerprinting is detected by whether or not the page accesses the localDescription property of a RTCPeerConnection, as this property covers all possible IP address retrievals. We then use the same techniques for quantifying user tracking on legitimate sites in order to compare the behavior of illegal and legitimate streaming sites\(^5\).

### 4.1 Tracking Score

We present a general metric for how malicious a particular channel provider is based on the tracking techniques they utilize. This metric follows:

\[
\text{score} = 0.5 \times r + 3 \times c + 5 \times f
\]

where:

\[ r = \text{Ave.} \# \text{ of HTTP requests to tracking domains for each visited channel provider URL}. \]
\[ c = \text{Ave.} \# \text{ of cookies set by tracking domains for each visited channel provider URL}. \]
\[ f = \# \text{ of unique of fingerprinting methods used by the channel Provider}. \text{ (Ranges from 0 to 3, i.e. a site using both canvas fingerprinting and font fingerprinting would have } c = 2) \]

We evaluate this metric for each channel provider. The higher the score, the more invasive a site is. We acknowledge that these constants are relatively arbitrary. Our basic reasoning is as follows: fingerprinting is the hardest tracking mechanism to evade [1], and thus is given the highest multiplier. For tracking cookies and requests, we observe that cookies are set less frequently, and scale them accordingly.

### 4.2 Limitations

First, many channel providers are protected by Cloudflare. Although there are techniques to discover the true IP addresses through information leakage [21], we did not implement these checks. Consequently, our study does not include detailed analysis about the true geolocation of the parties involved in the illegal live streaming ecosystem.

Second, due to time constraints, we do not perform a measurement of malware distributed by these websites. OpenWPM does not include mechanisms for collecting malicious downloads or browser extensions. We believe this is an interesting area of future work and highlight some of the malicious extensions served by these websites in Section 7. Future work could also seek to detect drive-by-downloads [16].

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\(^3\)Our collection code is available at https://github.com/hudson-ayers/safe-sports-streams.

\(^4\)https://easylist.to/

\(^5\)Our crawling and analysis code is available at https://github.com/lukehshiao/price-of-free-illegal-streams.
4.3 Ethical Considerations

The purveyors of the illegal sites we study are breaking U.S. copyright law, and this paper discourages illegal streaming. We aim to observe a set of websites which large numbers of users willingly and regularly visit despite circumstantial evidence of malware and deceptive practices. Our methodology benefits these illegal sites very little—while we may slightly increase ad revenue in the process of our study, our visit numbers are insignificant compared to the number of users these sites attract daily. We are not personally taking revenue from the copyright holders of this content, as the majority of our crawls occurred through headless browsers that do not display any video. Finally, any added views to these websites from our study is likely offset by any increased awareness of the hostile behavior that this study highlights.

5 Collection Results

As discussed in Section 4, we scrape stream URLs from several manually selected popular aggregator sites. The aggregators that we target are listed in Table 1.

Through these aggregators, we collect 151,661 unique URLs, spread across 467 unique channel providers. Of these, we could not identify a host for 2. Of the remaining 465 channel providers, we found that 160 (34%) were protected by Cloudflare, which hides their true IP addresses. This data is summarized in Table 2 where 74% of our channel providers are hosted by just 10 hosts. Figure 2 shows the global ranking distribution of the channel providers—111 channel providers did not make the top million. The top two Alexa-ranked channel providers were youtube.com and twitch.tv—some streamers manage to sneak live sports content past the filtering on these websites using misleading names. Sites such as buffstreamz.com and streamlabs.com were ranked about 2000 globally, with buffstreamz.com ranked 344 in the U.S., ahead of nlh.com and close to nba.com (the primary domains for legally streaming NHL and NBA games).

6 Crawling & Analysis Results

We perform three analyses to illustrate the behavior of illegal live streaming sites. We first measure user tracking with respect to HTTP requests and cookies from known-tracking domains as well as common fingerprinting techniques. Next, we perform the same measurement on popular, legitimate sports streaming websites in order to compare their behavior with illegal streaming sites. Finally, we use the tracking score introduced in Section 4 to generally compare user tracking across sites and to assess the efficacy of heavily moderated aggregators in protecting users from tracking.

6.1 Evidence of User Tracking

As discussed in Section 4 we break user tracking down into three categories: third-party HTTP requests, cookies, and fingerprinting. We measured channel providers by the prevalence of each of these tracking techniques, and for each technique we ranked all of the channel providers we found by using the tracking score for each channel provider, as described in Section 4. These illegal streaming websites expose users to a significant number of requests and cookies of unknown trackers. For each channel provider, we measure the total number of third-party HTTP requests that are made on each page we visit, the number of requests which are flagged a tracking request by EasyPrivacy, and compute an average over all pages for a particular channel provider. We do the same for tracking cookies.

Next, we analyzed each webpage’s JavaScript behavior to detect whether or not they were trying to perform device fingerprinting based on a series of heuristics (see Section 4).
We summarize the number of channel providers suspected of engaging in illegal websites. We see that Google Analytics and significantly fewer requests to known tracking domains than the responsible parties. We find that the legitimate sites make a significant percentage of total tracking requests that each tracker was frequently detected trackers exists in Table 5, alongside the viewing page accessible to non-logged-in users. Because these are widely used services, and because they exist on other websites. To provide this context, we repeated our measurement process for a small corpus of legitimate websites.

### 6.2 Comparison to Legitimate Sites

Observing the frequency of tracking on these sites is only useful within the context of the frequency of such tracking on other websites. To provide this context, we repeated our measurement process for a small corpus of legitimate websites via which users can pay to watch sports. Specifically, we selected the services WatchESPN, NHLTV, CBS Sports, WatchTNT, NBATV, Fox Sports Go, and Willow TV, because these are widely used services, and because they expose a viewing page accessible to non-logged-in users.

The results can be found in Table 4. A list of the most frequently detected trackers exists in Table 5, alongside the percentage of total tracking requests that each tracker was responsible for. We find that the legitimate sites make significantly fewer requests to known tracking domains than the worst illegal websites. We see that Google Analytics and DoubleClick are the only top 10 trackers shared between illegal and legitimate streaming services. We also observe that all of the trackers used by legitimate sites are either .com or .net domains (the .t.co domain is owned by Twitter). On the illegal sites we find a much more diverse set of trackers, often with obscure names, and with some domains corresponding to countries outside the US (Russia and Tuvalu).

The biggest difference between the legal and illegal sites shows up when looking at cookies and fingerprinting. For all legal streaming sites analyzed, only 2 total instances of fingerprinting behavior was observed, and none of the cookies set by these sites were detected as tracking cookies according toEasyPrivacy.

### 6.3 Efficacy of Moderation

It is interesting to analyze trends across streaming providers and aggregators, to answer questions such as “Do moderated streaming aggregators do a better job of filtering out the most malicious websites?”. Specifically, we focus on the use of Reddit as a moderated aggregator of illegal streams. Reddit as an aggregator has exploded in recent years, likely taking customers away from many of the other unmoderated aggregators discussed in this paper. One reason for this may be that viewers feel safer accessing streams linked to on subreddits with moderators that promise to remove links which violate subreddit rules. In fact, some subreddits go so far as to mark certain streamers as “verified”, meaning that they have been sharing their streams for an extended period of time, have communicated personally with the moderators, and have not been outed as abusing their users. As discussed in Section 4, we rely on our tracking score metric to evaluate the effectiveness of moderation by averaging the score of each channel provider across the aggregators that link them.

### Table 3: Channel Providers using Fingerprinting

| Technique             | # CPs | % CPs |
|-----------------------|-------|-------|
| Canvas Fingerprinting  | 23    | 4.93  |
| WebRTC Fingerprinting | 164   | 35.12 |
| Font Fingerprinting   | 23    | 4.93  |

### Table 4: Tracking Behavior of Top CPs by Tracking Score

| Illegal Channel Providers | Ave. # Requests | Ave. # Cookies | Canvas Fingerprinting | WebRTC Fingerprinting | Font Fingerprinting | Tracking Score |
|---------------------------|-----------------|----------------|-----------------------|-----------------------|---------------------|----------------|
| www.totalsportek.com      | 152.33          | 4.00           | ●                     | ●                     | ●                   | 93.17           |
| ko.rivosport.co           | 93.60           | 0.00           | ●                     | ●                     | ●                   | 56.80           |
| nowwatchtvlive.ws         | 108.23          | 0.00           | ●                     | ●                     | ●                   | 54.12           |
| in.xrivonet.info          | 81.71           | 0.00           | ●                     | ●                     | ●                   | 50.85           |
| rv0z.blogspot.com         | 72.00           | 0.00           | ●                     | ●                     | ●                   | 46.00           |
| www.gatehd.com            | 67.70           | 0.13           | ●                     | ●                     | ●                   | 44.25           |
| www.lineports.club        | 56.87           | 0.00           | ●                     | ●                     | ●                   | 43.43           |
| streamhd247.com           | 63.30           | 0.03           | ●                     | ●                     | ●                   | 41.75           |
| www.timetv.net            | 70.20           | 0.10           | ●                     | ●                     | ●                   | 40.40           |

| Legitimate Channel Providers | Ave. # Requests | Ave. # Cookies | Canvas Fingerprinting | WebRTC Fingerprinting | Font Fingerprinting | Tracking Score |
|------------------------------|-----------------|----------------|-----------------------|-----------------------|---------------------|----------------|
| www.nbs.com/nbatv           | 42.00           | 0.00           | ●                     | ●                     | ●                   | 26.00           |
| www.chppersports.com/live/  | 38.67           | 0.00           | ●                     | ●                     | ●                   | 19.33           |
| www.eepn.com/watch/         | 32.00           | 0.00           | ●                     | ●                     | ●                   | 16.00           |
| wtv.totdrama.com/watchtnt/  | 14.67           | 0.00           | ●                     | ●                     | ●                   | 12.33           |
| wtv.nhl.com/tv/            | 20.33           | 0.00           | ●                     | ●                     | ●                   | 10.17           |
| wtv.willow.tv/             | 7.33            | 0.00           | ●                     | ●                     | ●                   | 5.67            |
| wtv.foxportsogo.com/       | 7.00            | 0.00           | ●                     | ●                     | ●                   | 3.50            |

### Table 5: Top Trackers

| Trackers on Illegal Sites | % All Tracking |
|---------------------------|----------------|
| www.google-analytics.com  | 27.84          |
| cm.g.doubleclick.net      | 7.89           |
| trk.vibible.tv            | 7.63           |
| stats.g.doubleclick.net   | 4.14           |
| px.noatads.com            | 3.79           |
| counter.yadro.ru          | 2.92           |
| c.ngid.com                | 2.56           |
| d3.c3.bl.ail.top.mail.ru | 2.43           |
| k.streamrail.com          | 2.30           |
| mc.yandex.ru              | 2.17           |

| Trackers on Legitimate Sites | % All Tracking |
|-----------------------------|----------------|
| cm.g.doubleclick.net        | 18.60          |
| analytics.twitter.com       | 4.32           |
| ma61.r.analytics.edgekey.net| 3.99           |
| ib.adnxs.com                | 3.65           |
| px.noatads.com              | 3.65           |
| www.facebook.com            | 2.99           |
| stats.g.doubleclick.net     | 2.99           |
| ping.chartbest.net          | 2.99           |
| www.google-analytics.com    | 2.99           |
| t.co/i/adsct               | 2.66           |
This figure reveals that the distribution of tracking scores reflects the nature of the aggregator site. For example, Reddit is crowd-sourced and manually moderated. Despite a high number of submissions of highly variable quality (reflected in the large number of outliers), Reddit’s moderation appears to help it maintain an average tracking score that is lower than many of the other aggregators. In contrast, firstrowonly.eu is not crowd sourced and acts as both an aggregator and channel provider. It exhibits much less variance in tracking scores, along with a higher average score, indicating more tracking activity. Ultimately, this figure shows that Reddit does not successfully moderate away the worst websites by this metric, suggesting that moderation is more helpful for filtering out non-functioning streams than it is at removing sites that exhibit malicious behavior.

One other interesting aspect of Reddit is that users are able to vote on the streams posted to this site. We were curious as to whether this voting would punish sites which track users, as we suspected that sites which track users might also be more likely to display deceptive ads or other features which annoy users. To do so, we plotted the average number of upvotes on each post which linked to a channel provider from a streaming subreddit against the tracking score of that channel provider. In order to disregard posts which had not been voted on much, we did not count posts with 0, 1, or 2 upvotes. The results of this can be seen in figure 4. As this figure shows, there is minimal correlation between upvotes and tracking score. This suggests that user opinions are not a good method for distinguishing malicious sites in this ecosystem.

7 Case Studies

We manually investigated several channel providers and aggregators and noticed a wide variety of interesting techniques and strategies which could be studied in future work. We highlight several of the techniques we observed below.

Malicious Extensions As discussed in Section 4, limitations with OpenWPM made it infeasible for us to conduct a widespread study of malware on these sites. Despite this, we did manually visit dozens of these sites and clicked on “download now” and other similar links which we thought were most likely to lead to malware (these links were typically accompanied by some promise of helpful software or free media). Almost always, these links would open a new webpage in another tab, and this new webpage would provide instructions on how to install a specific Chrome extension, alongside some claim that the extension was necessary to use whatever product the original link promised. These extensions were accompanied by vague descriptions and few or no reviews, and most were uploaded to the Chrome Web-store within the last couple of months. These extensions often had the ability to read users entire browsing history, and to read and modify data on all websites users might visit. Some even had the ability to replace the page users see when opening a new tab and manage users downloads folder. Notably, some of these extensions had tens or hundreds of thousands of users. Limited existing reviews largely corroborated our suspicion that these extensions were adware or spyware. A description of these extensions can be found in Table 6.

We did not go so far as to install these Chrome extensions, but we have little doubt that their sole purpose is to record and sell data to advertisers, or to steal users informa-
Figure 5: Embedded live stream amid innocuous content on mokoshalb.com. On some sites, when a stream is over, the video element is removed, leaving only innocuous content.

Obfuscation Another common theme we found when visiting these websites was that they would go to varying levels of effort to disguise their habits from a casual investigator. For example, We observed that watchkobe.info/espn.php modified its behavior if the Chrome Developer Tools tab was opened, immediately hiding all ads as well as some overlay iframes that redirect to external pages. Additionally, we often encountered URLs that were hidden from any casual scans through URI encoding or Base64 encoding the URLs in the page source, and then having onClick methods decode these URLs before navigating to them.

Browser Alerts A particularly nasty technique which we frequently encountered involved sites tricking users into believing they could only play video, or only close the window, if they first accepted a browser notification, via arrows on the page that pointed at where the browser notification would appear. An example of this is shown in Figure 6.

8 Implications

As seen in Section 6, tracking on illegal live streaming websites is widespread via third party HTTP requests, cookies, and device fingerprinting. We want to draw attention to the significance of such tracking. Though these free streaming websites are able to collect device fingerprints and cookies, these sites rarely request access to the actual identity of users, and thus, such tracking may seem inconsequential. Accord-
ingly, we direct readers to [19, 1], to remind them that linking fingerprints to identities is often possible post-collection. For example, these websites could sell these unique profiles to any online entity that does have access to user identity, such as an ISP, an email operator, or a social network. These entities would then be capable of comparing this known user identity and their own collection of fingerprints with the fingerprints obtained from these illicit sites, thus obtaining a list of people who view illegal streams. There are many scenarios in which a legitimate company could benefit from such a list—it could be useful for targeted ads about low-cost TV services or sports betting websites. A more salacious example involves an ISP/cable company desiring to throttle the Internet speed of any device suspected of violating the exclusive broadcast rights of certain sports content. Such a list could also be sold to more malicious actors and used as part of a ransomware scheme in which users have to pay some entity under threat of being exposed for viewing illegal content. These toy examples encompass only a fraction of the different ways in which such fingerprints could be used for harm, and highlight that the tracking mechanisms detected in this work are far from harmless.

9 Recommendations

Our experience studying free illegal live streaming sites has led us to notice several common patterns which are used to deceive users. Here, we make recommendations for addressing these issues. Our purpose in presenting these recommendations is to highlight them as potential areas for future work, and to encourage discussion around these issues. For the recommendations we present, we do not empirically evaluate their efficacy, nor do we claim that they are infallible.

The most obvious pattern we found was that it was common for aggregators and channel providers to leverage transparent iframes which covered the majority of the page, such that a user is essentially coerced to first click on the iframe before interacting with the page. This technique, which is similar to clickjacking, has been a longstanding problem with a variety of proposed solutions [22, 24, 25]. Building in more robust clickjacking protections into common browsers may help raise awareness and provide a baseline level of security for everyday users.

These deceptive overlays often prompt users to install malicious browser extensions which masquerade as legitimate, but instead inject advertisements or collect personal data. At the time of this writing, the Chrome Webstore does not show an extension’s version history and requested permissions up front on the homepage of the extension. Furthermore, we found that different versions of the same extension may display a different number of downloads and different reviews. Different version can be directly linked to, but are not discoverable via search or from the latest extension page. Chrome only shows the permission requested by an extension after a user has consciously decided to click the “Add to Chrome” button. In contrast, Firefox Add-ons show both the permissions an add-on requires, and allows a user to browse the version history before clicking “Add to Firefox”. With Chrome, a user decides to add an extension, and then is shown the permissions and given an opportunity to change her mind. With Firefox, the user has all the information up front before needing to make that initial decision, and is also given an opportunity to change her mind.

In our experience, malicious browser extensions represented the most user-hostile behavior we found on these websites. Notably, we were not prompted to download or install any binaries or desktop applications. All of the prompts we encountered for malicious software took the form of browser extensions. Although significant progress has been made in recent years to fight malicious extensions [14], it is clear that malicious extensions are still a prevalent attack vector, and further work in automatic detection of potentially malicious extensions would benefit users.

10 Conclusion

In this paper, we extend and update the body of work investigating illegal streams. We discover that the streaming ecosystem has continued to expand, with Reddit emerging as one of the largest aggregators of illegal streams. We collect links to hundreds of thousands of streams over the period of a month, and crawl these websites using OpenWPM, which leads us to discover that these websites go to significant lengths to track users—and that they do so in a much more comprehensive and unavoidable manner compared to legal sports streaming websites. Further, our personal observations of dozens of channel providers lead us to the conclusion that there is still a large range of options for monetizing page visits beyond traditional ads for criminals willing to exploit users. We find that deceptive ads and full-page overlay redirects are commonly used, and that techniques to deceive users into installing malicious extensions are commonplace. Further, the frequency with which we observe tracking and distribution of user specific information implies that these sites also monetarily benefit from from tracking users, in addition to serving advertisements. We caution that this might indicate at least some of these sites are able to sell this tracking data to third parties, where these third parties could be advertisers or more malicious entities.

We believe that this piece has shown that illegal streaming represents a uniquely accessible view into misbehaving websites on the Internet. These sites are by definition criminal enterprises, but require substantial audiences in order to profit—as a result, they are easy to locate, and make little attempt to hide from security researchers. These sites serve as an excellent case study of modern techniques used to profit off of users, whether that be via deceptive ads, abuse of affiliate programs, user tracking, or distributing malware. We
encourage future security research to take advantage of the illegal streaming ecosystem as a resource for studying how cybercriminals monetize page views, and a tool for measuring modern tracking techniques employed on the web.

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