Comparative Study and Evaluation of Online Ad-blockers

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Abstract— **In the face of online advertising growing exponentially, numerous technologies have been developed to thwart the display of advertisements. This report is a comparative study of leading online software and hardware ad-blockers. In particular our research is on AdBlock, AdBlock Plus, and AdTrap. This report describes how they work, what types of advertisements they do and do not block, device compatibility, and if advertisers can detect and prevent ad-blockers. Our research shows that AdBlock leads the others in terms of ad blocking ability. Our research also shows AdTrap has significant benefits for implementing across an entire network. We also present ways for web developers to detect as well as counter ad-blockers.**

Index Terms— **Electronic Commerce, Internet Technologies, Comparative study, Advertising, Ad-blockers, Case-Studies, Online Advertising.**

I. INTRODUCTION

ADVERTISING on the web is a massive market, accounting for nearly US$50 billion in advertising revenue in the US alone [1]. Many websites provide free content in exchange for showing contextual advertisements. These advertisements cover many of the website costs and often are a strong profit model for both websites and advertising agencies. In 2014, Google collected over US$59 billion in advertising revenue worldwide, an 881,391% increase in advertising revenue since public financial records start in 2001. Although online advertising has grown exponentially, numerous systems have been devised to thwart the display of advertisements. These systems have been developed for various devices ranging from mobile phones to desktop computers, and come in a variety of install options. Hereinafter, we will call these *ad-blocking technologies,* or more generally, *ad-blockers*.

We analyzed the two most popular browser-extension ad-blockers, *AdBlock* and *AdBlock Plus,* and a well-known hardware solution called *AdTrap*. Our research sheds answers to important issues on how they work, how effective are they, and can they be prevented and/or detected.

We tested these ad-blockers using Safari, Chrome, Firefox,

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and Internet Explorer on OS X, Windows 8, and Ubuntu 14.04. We also tested AdTrap on various devices on a wireless network ranging from a Blackberry Playbook (Tablet) to Google's Nexus 5.

Our research goals were to answer the following questions:
1) *What is the scope of an online advertisement and how do you define it?*
2) *How do AdTrap, AdBlock, and AdBlock Plus work?*
3) *What do they block and fail to block?*
4) *Which ad-blocker is most efficient at blocking ads?*
5) *How do page load times differ with and without the ad-blockers?*
6) *Can one create advertisements which are unaffected by ad-blockers?*
7) *Are there bandwidth limits to block advertisements?*
8) *Do advertisers know that their ads are being blocked?*

II. WHAT IS AN ONLINE ADVERTISEMENT?

In order to address the important questions above, we crafted a definition of what an online advertisement is. Existing literature on online marketing shows two extremes for the definition of an online advertisement. One extreme comes from *Online Advertising Research in Advertising Journals: A Review* by Louisa Ha [2]. Ha details the definition of an advertisement that is very narrow in scope. Conversely, Wikipedia lists 20 different types of advertisements one may find online. Our definition of an online advertisement is designed to create a balance between these two extremes by giving explicit criteria an advertisement must meet. In the interest of brevity, our advertisement definition is simply something which is injected into the page that is not content and is usually sponsored; however, the full definition is available at csekharan.com. Furthermore, we have categorized four unique and specific classes of advertisements.

A. Classes of Advertisements

As mentioned, there exist many types of online advertisements. These have been categorized into four distinct classes:
1) Text Link Advertisements
2) Picture/Graphic Advertisements
3) Video Advertisements
4) Pop-up Advertisements, including internal and external

B. Text Link Advertisements

A Text Link Ad is any advertisement which is displayed on the same instance of the website or application that uses text as the primary mode for advertising. By "same instance", we mean that these would not count as a Pop-up Ad. We will use this definition of "same instance" throughout this paper.

C. Picture/Graphic Advertisements

Picture/Graphic Ads are similar to a Text Link Ad, and they may contain text. The primary difference is that the majority of the ad is an image. Text may be superimposed on this image; however, the parent element of the advertisement is usually an image.

D. Video Advertisements

Video Advertisements are ads that meet one or both of the following criteria, and are again in the same instance of the website or application:
1) An advertisement in video format, whether playing or not.
2) An advertisement that interrupts the video, either by interjecting between video segments or overlaid on top the content (non-advertisement) video.

Consider the case of streaming a video on YouTube and an advertisement plays before the video starts. Or, one may imagine watching TV online and every 15 minutes the episode pauses to present with ads pictures, or videos, or interactive video ads before the episode you were watching resumes. Any of these are defined to be Video Advertisements.

E. Pop-up Advertisements

Pop-up Ads are defined to be any advertisement which appears inside a pop-up window. We denote two sub-categories of pop-up window, *internal* and *external*.

In the early history of online browsing of a website one would suddenly encounter a swarm of new windows with various forms of advertising. These *external* pop-ups would happen frequently and involuntarily. Because usage of pop-ups were heavily abused, most modern browsers automatically block these types of advertisements by default. Now, special conditions must be met for a browser to allow a website to open up a new tab or window without the user expressly clicking on a link to do so.

However, as one technology is blocked, oftentimes another emerges. Internal ads take advantage of CSS, HTML and sometimes JavaScript to use a *modal box*. Modal boxes are mostly used for helping users and are intended to be not annoying— examples include help tips, log-in forms, etc. They are *internal* pop-ups because they appear inside the same tab or window of the website or application that one is using. They work by setting a higher z-index to the new pop-up element and sometimes creating a blanket around everything else to focus your attention on the new element.

The challenge of defining what an online advertisement is, is not different from the challenge of defining what spam email is. What may be considered an ad to a group of users may not be so for another group. However, we have proposed an acceptable and comprehensive definition of an online advertisement that we will use as a frame of reference for our research described in subsequent sections.

III. STATISTICS ON AD-BLOCKERS

Ad-blockers are extremely popular, and we tested the top two software options and the top hardware option: *AdBlock Pus*, *AdBlock*, and *AdTrap* (respectively). AdBlock Plus boasts 20.5 million users, it has four times the amount of users than the second-leading browser extension for Mozilla Firefox. AdBlock (not AdBlock Plus) claims to be "The #1 most downloaded extension for Google Chrome and Safari." It also claims to have over 40 million users, while AdBlock Plus claims over 50 million. The top extension for Safari is AdBlock with AdBlock Plus in second place. For Internet Explorer, AdBlock Plus was the second most downloaded extension with 300,000 downloads. Lastly, regarding the hardware solution AdTrap, it has sold over 10,000 units [3]. Besides the three Ad-blockers we tested, we found many other similar—but less popular—solutions, including *BluHell Firewall, HTTPS Everywhere, NoScript, ScriptSafe, Flashblock, Disconnect, DoNotTrackMe, Ghostery*, and so many more. Additionally, there are other solutions to blocking ads such as using proxies. One in particular is *Privoxy* which is a proxy used for privacy, and it is a fundamental component of AdTrap. In summary, Ad-blockers account for a considerable portion of browser extensions in both extensions available and download/user count. A report from September 2014 by Adobe and Pagefair shows 144 million users worldwide are blocking ads.

IV. OUR TESTING METHODOLOGY

We tested the Ad-blockers in combination with a variety of operating systems, browsers, and various devices. We tested each combination across 14 sites ranging from retailers to news outlets to fashion blogs to search engine. Additionally, we created custom web pages to test a range of modifications to HTML, CSS and JavaScript advertisement generation code. Visit csekharan.com for full research data and a more comprehensive report.

We tested all the sites first with a control (no Ad-blockers enabled), counted all the advertisements and categorized them into the four classes mentioned earlier, and then enabled each Ad-blocker one-at-a-time, individually at first, and then together, and counted the amount of ads showing each attempt. We also performed all the testing on a single day which allowed us to have uniform base of comparison across all the controls and all the subsequent tests. Lastly, we used default settings across all the Ad-blockers we tested. It is important to note that for AdBlock Plus, this includes *allowing* certain "acceptable ads" to be displayed on the web. Acceptable ads are, according to AdBlock Plus, "unobtrusive [ads] that don't need to be blocked" [4]. Note: AdBlock does not exist for Internet Explorer.

V. OUR FINDINGS

Through our research we were able to answer many of the questions we original set out to. Despite a few difficulties that are discussed in a following section, we were able to answer all the questions we originally set out to, and went further in depth in specific areas to compensate for lack of data in other questions.

A. Summary of Advertisements Blocked

In our tests, AdBlock was the lead ad-blocker in all four advertisement classes and had the fewest number of false positives. Refer to TABLE I for the summary.

TABLE I
ADVERTISEMENTS BLOCKED BY AD-BLOCKER

	Text-Link	Picture	Video	Popup	False Positive
Control	25	85	3	1	N/A
AdBlock	10	28	0	0	7
AB Plus	18	36	0	0	7
AdTrap	13	39	0	0	8

B. Methods for Embedding Ads

In our research we encountered several ways of embedding advertisements into a website. Most advertisements are dynamically generated, and the majority of these were done through JavaScript. The website hosting the advertisement would place a few lines of JavaScript on each page ads should be displayed, and this script would load an external script from the ad-server, returning the advertisements. In many cases, to get around the same-origin policy enforced by JavaScript, the script would embed an iframe which then called the ad-server.

There are other methods for dynamically generating advertisements, and this is likely what you see in Google's search results. These would likely be done through some form of server-side scripting rather than client-side. One may also see this in many websites running a Content Management System (CMS) like WordPress that use a plugin installed on the CMS to act as an ad-server.

Lastly, ads can be hardcoded into the site. This is the most effective way of creating Ad-blocker proof advertisements, but is also the least effective advertising revenue generation model and has many other inherent flaws associated with it.

C. Major Questions

1) How do AdTrap, AdBlock, and AdBlock Plus work?

AdTrap uses a proxy software named *Privoxy* to filter out advertisements. This does not modify the website or application's request to download/embed third-party scripts, etc.; however, it does prevent them from ever actually loading by denying the request.

AdBlock and AdBlock Plus both work using filter lists. These lists are publicly available and crowd-sourced. AdBlock and AdBlock Plus are very similar, and this is likely because they are both forks from an original Ad-blocker called AdBlock (A different AdBlock than the AdBlock we are testing). Hence forth, all AdBlock references are regarding the modern AdBlock we used during testing. Most ads are loaded into the page via JavaScript. A few lines of JavaScript are placed on the site to query an ad-server such as DoubleClick.net and this query injects the site with contextual advertisements (reference previous sub-section for advertising embedding methods). Both AdBlock and AdBlock Plus attempt to prevent the JavaScript file from ever loading, whereas AdTrap allows the JavaScript file to load but blocks the request the script sends. If AdBlock or AdBlock plus fail to block the JavaScript, or if the ad is embedded through a different manner (such as hard coded onto the site), they attempt to use CSS to hide the advertisement, rather than actually block it.

2) What do ad-blockers block or fail to block?

AdBlock and AdBlock Plus attempt to block the JavaScript file from ever loading, and AdTrap allows it to load but blocks the request it sends from returning an advertisement. AdBlock and AdBlock Plus both generally block most Video Ads, all Pop-up Ads, and the majority of Picture and Text-Link Ads. Our testing has revealed they are most efficient at blocking ads injected with JavaScript (or otherwise dynamically generated) and least efficient at blocking hard-coded ads, especially Text-Link Ads.

AdTrap was successful in blocking about half the advertisements seen in browsers. Unfortunately AdTrap caused visible problems loading these webpages as seen in Chrome's web inspector. Although AdTrap failed to block many advertisements that the browser extension based Ad-blockers did, AdTrap has a powerful feature the others lack: it is available for any device on the network, as it acts a proxy between the modem and router, rather than helping the browser parse data. This allowed us to test other devices such as tablets and mobile phones. Running AdTrap disabled all advertisements on all tested mobile and tablet games.

3) Which Ad-blocker is most efficient at blocking ads?

In all our testing, AdBlock repeatedly came out as the most successful: more ads were blocked and it had the fewest false positives in comparison to the other Ad-blockers. If we limit the scope to browsers, AdBlock is the most efficient at blocking ads. It is likely this is related to AdBlock Plus allowing "acceptable ads," but we, again, ran all tests with default settings enabled. Therefore, out of the box, AdBlock is the most reliable in preventing ads from being displayed.

However, if we do not limit scope to web pages on a non-mobile browser (because many mobile devices do not support browser extensions), then AdTrap is the most efficient. In this scope, AdTrap stands alone as an effective blocker of ads.

4) How do page load times differ with and without the Ad-blockers?

No documentable changes in page load time were observed when using on AdBlock or AdBlock Plus. Using Chrome's Web Inspector we were able to detect a few hundred millisecond of delay in page loads.

AdTrap is different in the sense that it allows the dynamically generated advertising scripts to run initially, this caused clearly visible changes in loading times while the page was waiting for assets to load. In most cases, these assets were attempted to load asynchronously and would not prevent us from interacting with the website while these requests were pending; however, this was not always the case. In several situations where the advertising scripts were placed at the top of the document (standard practice is to place it at the bottom so the web document can load before loading external resources) it rendered the webpage simply unresponsive until the request timed out. In these cases, the webpage had other issues present after the original timeouts including failure to load other external documents such as images and stylesheets.

Combining Ad-blockers did not differ results. For instance, when using AdTrap in combination with other AdBlock, AdTrap would run first (because it filters the network traffic

before data is sent to the browser) and then whatever AdTrap missed, AdBlock would catch, provided it was something AdBlock would have caught normally. These results were consistent between all permutations of Ad-blockers.

5) Can one create advertisements which are unaffected by Ad-blockers?

We found that by hardcoding advertisements it is relatively easy to fool Ad-blockers, but this is an impractical approach for most websites that use advertising as this prevents contextual advertising. Alternatively, we discovered that changing all the identifying attributes of an advertisement would cause the Ad-blocker to miss it. This includes changing the ID, class, alternate text, etc. for the image and hyperlink tags. Additionally, any text surrounding the advertisement should be intentionally misleading to trick an ad-blocker. Dynamically generated advertising scripts should be saved locally and avoid common keywords of advertising (such as "ads.js"). Lastly, the hyperlink should be routed through a different, local page before being sent as a request to the ad-server.

Much labor would be required to effect these tricks. Furthermore, the result would be intentionally misleading advertising code. It is likely only a temporary solution, too, as if it were to become prevalent the lists that most Ad-blockers use would be updated to detect for these workarounds.

Although it is essentially non-viable to circumvent the Ad-blockers, it is possible to detect them. We documented numerous examples of this in our research, most notably on audio and video streaming websites such as Pandora.com, YouTube.com, and Hulu.com. The detection is rather simple and can be done with a few lines of JavaScript. The page hosting the advertisements runs a script at page load that checks the height and width of the advertisements. If they are not visible or not present, then the assumption is an Ad-blocker is enabled and they should present the user an error message. An interesting point to note is that AdBlock Plus gives an option to hide these messages; however, we did not test this as it is not a default setting.

6) Are there bandwidth limits to block advertisements?

The short answer to this question is no for all browser-extension based Ad-blockers. In fact, these actually *save* on bandwidth because they prevent scripts from being loaded entirely, rather than just hiding the elements (when possible). For AdTrap, this is a different situation. It is conceivable that this device could potentially slow down a large network.

7) Do advertisers know that their ads are being blocked?

We have already shown that the website hosting the advertisements can detect that advertisement s are being blocked, and hence it is possible to send statistical results to the advertisers on ad-blocking data. We can say that because AdBlock and AdBlock Plus prevent the JavaScript-powered, dynamically generated ad scripts from ever loading, any data sharing would have to be done by the host website to the advertiser.

VI. Impact of Ad-blockers for Advertisers and Web Search Companies

Many advertisement-sponsored websites have begun implementing code to detect Ad-blockers. Some websites will deny the user access to content if they detect an ad-blocker, while others act more like Hulu, YouTube, Pandora and other media streaming websites in prompting the users to remove the ad-blockers.

Google has attacked the issue of Ad-blockers on multiple fronts. As noted earlier, it is paying an undisclosed premium to have certain advertisements whitelisted as "acceptable ads." In addition to this, Google has teamed up with Microsoft and a French newspaper, threatening legal action against the companies which develop Ad-blockers [5]. Late in 2014 Google announced *Google Contributor*, which is an alternative to advertisement based revenue streams that allow the end-user to pay Google a fee of $1-$3 which Google will forward to websites that are part of the contributor program.

As for advertisers and websites sponsored by advertising, there are mixed reports. Some reports state Ad-blockers are destroying online businesses by cutting into their revenue, while others say business owners are not afraid of the loss of advertising because the users who block ads would not normally interact with them anyway.

VII. Conclusion

There is no doubt that online advertising is a huge source of revenue, and reports show that Ad-blockers are on the rise, nearly doubling in usage each year. A more comprehensive research report and full research data is available at csekharan.com. There are philosophical angles to be explored and discussed. This report provides information on how they work, strengths and weaknesses of the main options, and insight into options for detecting and possibly deterring them.

VIII. References

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