

March 2016

# Understanding Ad Blockers

Doruk Can Uzunoglu  
*Worcester Polytechnic Institute*

Follow this and additional works at: <https://digitalcommons.wpi.edu/mqp-all>

---

## Repository Citation

Uzunoglu, D. C. (2016). *Understanding Ad Blockers*. Retrieved from <https://digitalcommons.wpi.edu/mqp-all/3269>

This Unrestricted is brought to you for free and open access by the Major Qualifying Projects at Digital WPI. It has been accepted for inclusion in Major Qualifying Projects (All Years) by an authorized administrator of Digital WPI. For more information, please contact [digitalwpi@wpi.edu](mailto:digitalwpi@wpi.edu).

# Understanding Ad Blockers

A Major Qualifying Project

Submitted to the Faculty of

Worcester Polytechnic Institute

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

In

Computer Science

By

---

Doruk Uzunoglu

March 21, 2016

---

Professor Craig E. Wills, Project Advisor

Professor and Department Head

Department of Computer Science

## **ABSTRACT**

This project aims to provide useful information for users and researchers who would like to learn more about ad blocking. Three main research areas are explored in this project. The first research area provides general information about ad blocking tools and aims to explore ad blockers from a user's perspective. The second research area provides analyses regarding third-party sites that appear on popular first-party sites in order to explore the behavior of third-parties. Finally, the third research area provides analyses regarding filter lists, which are sets of ad filtering rules used by ad blocking tools. The third research area aims to convey the differences and similarities between individual filter lists as well as sets of filter lists that form the defaults of ad blocking tools.

## **ACKNOWLEDGEMENTS**

I would like to thank Professor Craig Wills for advising my project, providing insight, and gathering the popular third-party domains data which I analyzed as part of this project. In addition, I would like to thank Jinyan Zang for sharing the third-party data regarding mobile apps, which they have gathered as part of their 2015 paper named “Who Knows What About Me? A Survey of Behind the Scenes Personal Data Sharing to Third Parties by Mobile Apps.” The data provided by Jinyan Zang was also analyzed as part of this project.

# TABLE OF CONTENTS

ABSTRACT.....	1
ACKNOWLEDGEMENTS.....	2
TABLE OF CONTENTS.....	3
LIST OF FIGURES.....	6
LIST OF TABLES.....	8
1. INTRODUCTION.....	9
2. BACKGROUND.....	10
2.1 Traditional Browser-Based Ad Blocking Methods.....	10
2.1.1 Browser Extension.....	10
2.1.2 Built-in Browser Feature.....	11
2.1.3 Hosts File.....	11
2.1.4 Local Content-Filtering HTTP(S) Proxy Server.....	11
2.2 Ad Blocking Methods For Mobile Devices.....	12
2.2.1 Browser Extension for Safari (iOS only).....	12
2.2.2 Proxy Apps.....	12
2.2.3 Browser Apps.....	12
2.4 Filter Rule Syntaxes.....	12
2.4.1 Adblock Plus Syntax.....	13
2.4.2 Hosts File Syntax.....	15
2.4.3 Internet Explorer Tracking Protection Syntax.....	15
2.5 Third-Party Categorizations.....	17
2.5.1 Ghostery.....	17
2.5.2 Abine.....	17
2.5.3 Trend Micro.....	18
2.5.4 Understanding What is Happening Regarding Internet Privacy.....	20
2.6 Related Work.....	20
2.6.1 Annoyed Users: Ads and Ad-Block Usage in the Wild.....	20

2.6.2	Generating a Privacy Footprint on the Internet.....	21
2.6.3	Measuring the Impact and Perception of Acceptable Advertisements.....	21
2.6.4	Third-Party Web Tracking: Policy and Technology.....	21
2.6.5	Who Knows What About Me? A Survey of Behind the Scenes Personal Data Sharing to Third Parties by Mobile Apps.....	22
2.7	Summary.....	22
3.	METHODOLOGY.....	23
3.1	Research Areas.....	23
3.1.1	General Information About Ad Blocking Tools And Filter Lists.....	23
3.1.2	Analyzing Popular Third-Party Domains.....	23
3.1.3	Analyzing Filter lists.....	24
3.2	General Information About Ad Blocking Tools And Filter Lists.....	24
3.2.1	Important Properties Of Ad Blocking Tools.....	24
3.2.2	Information Summary For Filter Lists.....	24
3.2.3	Ad Blocking Apps Available For Mobile Devices.....	24
3.3	Analyzing Popular Third-Party Domains.....	25
3.3.1	Creating Categories.....	25
3.3.2	Categorizing Third-Party Domains.....	25
3.3.3	Termination Step Analysis.....	28
3.4	Analyzing Filter Lists.....	29
3.4.1	Live Testing With Filter Lists.....	29
3.4.2	Parsing Filter Lists To Determine Blocked and Allowed Third-Party Domains.....	30
3.4.3	Effectiveness of Default Filter Lists.....	33
4.	RESULTS AND EVALUATIONS.....	34
4.1	General Information About Ad Blocking Tools and Filter Lists.....	34
4.1.1	Important Properties Of Ad Blocking Tools.....	34
4.1.2	Information Summary For Filter Lists.....	37
4.1.3	Ad Blocking Apps Available For Mobile Devices.....	40

4.2	Analyzing Popular Third-Party Domains.....	40
4.2.1	Creating Categories.....	40
4.2.2	Categorizing Third-Party Domains.....	41
4.2.3	Termination Step Analysis.....	43
4.3	Analyzing Filter Lists.....	45
4.3.1	Live Testing With Filter Lists.....	45
4.3.2	Parsing Filter Lists To Determine Blocked and Allowed Third-Party Domains.....	46
4.3.3	Effectiveness of Default Filter Lists.....	64
4.4	Summary.....	87
5.	CONCLUSION AND FUTURE WORK.....	89
	CITATIONS.....	90
	APPENDIX A: Popular domains.....	96
	APPENDIX B: Mobile popular domains.....	108
	APPENDIX C: Attachments.....	112

## LIST OF FIGURES

Figure 1: Categorization Algorithm.....	26
Figure 2: Open blockable items feature of Adblock Plus.....	30
Figure 3: Categorization results summary.....	41
Figure 4: Termination step summary.....	43
Figure 5: Categorization algorithm with summarized termination step results.....	44
Figure 6: Most popular domains analysis with filter lists.....	47
Figure 7: Most popular AdTrackers analysis with filter lists.....	50
Figure 8: Most popular Analytics domains analysis with filter lists.....	51
Figure 9: Most popular Beacons analysis with filter lists.....	52
Figure 10: Most popular Other Third-Parties analysis with filter lists.....	53
Figure 11: Most popular Social domains analysis with filter lists.....	54
Figure 12: Most popular Widgets analysis with filter lists.....	55
Figure 13: Popular domains analysis with filter lists.....	56
Figure 14: Popular AdTrackers analysis with filter lists.....	58
Figure 15: Popular Analytics domains analysis with filter lists.....	59
Figure 16: Popular Beacons analysis with filter lists.....	60
Figure 17: Popular Other Third-Parties analysis with filter lists.....	61
Figure 18: Popular Social domains analysis with filter lists.....	62
Figure 19: Popular Widgets analysis with filter lists.....	63
Figure 20: Most popular domains analysis with ad blocker defaults.....	65
Figure 21: Most popular AdTrackers analysis with ad blocker defaults.....	66
Figure 22: Most popular Analytics domains analysis with ad blocker defaults.....	67
Figure 23: Most popular Beacons analysis with ad blocker defaults.....	68
Figure 24: Most popular Other domains analysis with ad blocker defaults.....	69
Figure 25: Most popular Social domains analysis with ad blocker defaults.....	70
Figure 26: Most popular Widgets analysis with ad blocker defaults.....	71
Figure 27: Popular domains analysis with ad blocker defaults.....	72



Figure 28: Popular AdTrackers analysis with ad blocker defaults.....	73
Figure 29: Popular Analytics domains analysis with ad blocker defaults.....	74
Figure 30: Popular Beacons analysis with ad blocker defaults.....	75
Figure 31: Popular Other domains analysis with ad blocker defaults.....	76
Figure 32: Popular Social domains analysis with ad blocker defaults.....	77
Figure 33: Popular Widgets analysis with ad blocker defaults.....	78
Figure 34: Top 20 popular domains and their percentage of appearance in the popular first-party sites.....	79
Figure 35: Top 20 domains analysis with uBlock.....	80
Figure 36: Top 20 domains analysis with hpHosts.....	80
Figure 37: Top 20 domains analysis with AdFender.....	81
Figure 38: Top 20 domains analysis with Ghostery.....	81
Figure 39 Top 20 domains analysis with MVPS Hosts.....	82
Figure 40: Top 20 domains analysis with uBlock Origin.....	82
Figure 41: Top 20 domains analysis with Disconnect.....	83
Figure 42: Top 20 domains analysis with Adblock Edge, NoAds, NoAds Advanced and Bluehell Firewall.....	83
Figure 43: Top 20 domains analysis with Dan Pollock's Hosts.....	84
Figure 44: Top 20 domains analysis with Adblock.....	84
Figure 45: Top 20 domains analysis with Adblock Plus and Adguard.....	85
Figure 46: Top 20 domains analysis with GT-Soft Ad Blocker and Peter Lowe's List.....	85
Figure 47: Top 20 domains analysis with Malware Domain List.....	86

## **LIST OF TABLES**

Table 1: Ad blocker characteristics.....	35
Table 2: Filter list characteristics.....	37
Table 3: Analyzed sets of default filter lists.....	64

# 1. INTRODUCTION

The theme of this paper is “understanding ad blockers”. There are many ad blocking tools available for use, and this paper aims to provide useful information to users and researchers who would like to get more insight into ad blockers. In order to convey the theme of “understanding ad blockers,” three main research areas based on ad blockers, filter lists, and third-party domains are identified and explored.

The first research area involves researching general information about ad blocking tools and filter lists in order to identify important properties of ad blocking tools and filter lists. The main motive of this research area is to explore ad blockers from a user’s perspective, and to have a better idea of the variety of ad blocking options available to the users.

The second research area involves researching and analyzing popular third-party domains in order to categorize the popular third-party domains based on behavior, and to produce a clear picture that shows the portions of third-parties that fall under different categories. The main motive of this research area is to learn the functionalities of third-parties that appear in popular first-party sites. In addition, the third-party categorization results from this section are used to fulfill the goals of the third research area.

The third research area involves researching and analyzing filter lists in order to identify the popular third-party domains blocked by each filter list, and to summarize the results based on each third-party category. The main motive of this research area is to clearly see the differences and similarities between the effectiveness of individual filter lists as well as sets of filter lists that form the defaults of ad blocking tools.

The remainder of the paper is organized as follows. In Chapter 2, background information and related work for the project are described. Chapter 3 describes the research areas and the methodologies used to fulfill the goals of the research areas in detail. Chapter 4 describes the results and evaluations of the research, and Chapter 5 concludes with a summary of the paper and description of suggested future work.

## **2. BACKGROUND**

In order to understand ad blocking thoroughly, background research was done in several topics. Different methods of ad blocking and ad blocking tools available for traditional web browsers and mobile devices were investigated in order to better understand the variety of options available to users. Filter lists and behavior of third-parties were investigated as well. A filter list is a set of third-party blocking rules, and a third-party is a website that provides content and/or services including but not limited to advertising, analytics and tracking to an unrelated first-party website (e.g. the website browsed by the user) [1]. More specifically, filter rule syntaxes of different ad blocking tools were studied in order to do analyses on filter lists regarding third-parties that they block, the extent of blocking of different third-parties, and the conditions under which the third-parties are blocked. Moreover, categorization of third-parties by Ghostery [2], Abine [3], Trend Micro [4], and “Understanding What is Happening Regarding Internet Privacy” [5] presentation by Prof. Craig Wills were investigated to learn about the behavior of third-parties. Finally, research work related to the goals of this project was explored.

### **2.1 Traditional Browser-Based Ad Blocking Methods**

In this section, different methods of ad blocking for traditional browsers are discussed. For this project, a traditional browser-based ad blocking method is defined as an ad blocking method that is available for desktop and laptop computers. It is important to note that while hosts files and proxy servers are not browser-based, they are still valid under the “traditional browser-based ad blocking method” term as they can be used with desktop and laptop computers.

#### **2.1.1 Browser Extension**

Many ad blocking tools can be downloaded and installed from browsers’ official add-on/extension stores and externally from third-party sites. Functionalities of this type of ad blocking tools are managed through the browsers themselves. Most of the tools examined by this

project are of this type. Prominent examples include Adblock [6], Adblock Plus [7], and uBlock [8].

### **2.1.2 Built-in Browser Feature**

Internet Explorer 9 and above versions, and Mozilla Firefox 38 and above versions have a built-in tracking protection feature. For Internet Explorer, Tracking Protection Lists (TPLs) can be downloaded from the Internet Explorer Gallery to block third-party content based on the filter rules in the downloaded TPLs [9][10]. Firefox's Tracking Protection feature utilized only one filter list based on Disconnect.me's basic protection list, but starting with Firefox version 43, users are enabled to select Disconnect.me's strict protection list if they desire [11][12].

### **2.1.3 Hosts File**

Before a device can connect to a given domain name, the domain name must be translated into its mapped IP address. This process is called Domain Name Resolution, and the standard service used to carry out this process is called Domain Name System (DNS). A device can resolve a domain name to an IP address by querying a local DNS server for the IP address of the given domain name. After the request, the local DNS server would query other DNS servers such as root DNS servers or top-level domain DNS servers as necessary to return the requested IP address to the device. The device can open a connection to the IP address and communicate with the server/device located at that IP address.

An alternative way to resolve domain names without using DNS is by using a hosts file. A hosts file is a text file which contains entries of IP addresses and domain names separated by at least one space. Each line in a hosts file should contain only one entry. If there is a mapping for a requested domain name in the hosts file, most operating systems would use that mapping instead of DNS by default. By adding known third-party domains to the hosts file and mapping the domains to 127.0.0.1 (localhost), one can block content from these domains since 127.0.0.1 is the loopback address that points back to one's own machine [13]. Prominent examples of hosts files include hpHosts [14] and MVPS Hosts [15].

#### **2.1.4 Local Content-Filtering HTTP(S) Proxy Server**

Some ad blocking tools act as local content-filtering HTTP(S) proxy servers to block content from third-parties. An ad blocking tool of this type receives requests to retrieve content from a browser, contacts the web servers that contain the requested content, and passes the data from the web servers to the browser. Each request is checked to see whether if the request matches a rule in the filter lists of the ad blocking tool. If there is a match, the request is blocked, otherwise the ad blocking tool passes the data from the web servers to the browser [16]. Examples include AdFender [17] and Privoxy [18].

### **2.2 Ad Blocking Methods For Mobile Devices**

In this section, ad blocking for iOS and Android devices are discussed.

#### **2.2.1 Browser Extension for Safari (iOS only)**

With the release of iOS 9, Apple has added support for ad blocker extensions in Safari. This type of ad blocking tools can be downloaded and installed as apps from the App Store. Users can enable/disable the extensions through device settings and edit ad blocking preferences through the apps themselves [19]. Examples include Crystal [20] and Purify [21].

#### **2.2.2 Proxy Apps**

This type of ad blocking apps can be downloaded and installed normally by the users the same way as other apps. After installing, the users have to re-direct their traffic through the Proxy Hostname and Proxy Port provided by the app from the device's proxy settings [22]. Examples include Adblock Plus for Android [7] and SpeedMeUp [23].

#### **2.2.3 Browser Apps**

This type of ad blocking apps can be downloaded, installed and used the same way as other mobile web browser apps. Ad blocking preferences can be edited within the apps themselves. Examples include Adblock Browser [24] and Ghostery Privacy Browser [25].

## 2.4 Filter Rule Syntaxes

This section explores the syntax rules of Adblock Plus, Hosts files, and Internet Explorer Tracking Protection. Each filter list examined by this project uses at least one of the mentioned syntax rules. Some filter lists have multiple formats with each format using a different syntax.

### 2.4.1 Adblock Plus Syntax

Adblock Plus provides extensive address blocking/allowing options through its syntax. This section highlights the important elements of Adblock Plus syntax, Each subsection introduces new operators that provide different functions.

#### 2.4.1.1 Blocking By Address Parts

Example rule: `/banner/*/img^`

The filter rule above utilizes ‘\*’ which is the wildcard character and represents any number of characters. The separator character, ‘^’, indicates that the address should either end at that point or a separator character such as ‘?’ or ‘/’ has to follow. An example subset of the addresses that can be blocked by this rule is provided below:

```
http://example.com/banner/foo/img  
http://example.com/banner/foo/bar/img?param  
http://example.com/banner//img/foo
```

#### 2.4.1.2 Blocking By Domain Name

Example rule: `||ads.example.com^`

The filter rule above utilizes ‘||’, which is the domain name anchor. The text following the domain name anchor should be the domain name of the address. An example subset of the addresses that can be blocked by this rule is provided below:

http://ads.example.com/foo.gif  
http://server1.ads.example.com/foo.gif  
https://ads.example.com:8000/

### 2.4.1.3 Blocking exact address

Example rule: |http://example.com/|

The filter rule above utilizes ‘|’, which is the start/end anchor. This rule only blocks the address present between the anchors, which is “http://example.com/”.

### 2.4.1.4 Options In Blocking Rules

Example rule: ||ads.example.com^\$script,image,domain=example.com

The filter rule above utilizes ‘\$’, which is the option separator. The text following the option separator has to define filter type options. In the above rule, the defined options are ‘script’, ‘image’, and ‘domain’. The options ‘script’ and ‘image’ indicate that the rule above only blocks content from ads.example.com if the content is loaded as a script or image. In addition, the option ‘domain=example.com’ restricts this rule to the example.com domain. To summarize with an example, the above rule blocks http://ads.example.com/foo.gif if and only if the address is loaded as a script or an image, and the visited first-party site comes from example.com domain.

### 2.4.1.5 Exception Rules

Example rules: @@||example.com^\$document  
                  @@||example.com^\$~script

The filter rules above utilize ‘@@’ which is the exception operator. Rules that start with the exception operator override blocking rules. In the first rule, the special ‘document’ type option indicates that Adblock Plus should be completely disabled in the example.com domain.



In the second rule, the option ‘~script’ indicates that this filter should not be applied to scripts, but should be applied to everything else from example.com domain.

#### **2.4.1.6 Element Hiding**

Example rules: `##table[height="100"][width="100"]`  
`##a[href="http://example.com/"]`

Rules that begin with ‘##’ are element hiding rules and do not prevent content from loading. These rules only make the matching elements invisible on the page. The first rule matches a table with a height of 100 and a width of 100, and the second rule matches links to `http://example.com/`.

#### **2.4.1.6 Notes**

Example rule: `! This is a comment`

Lines that start with ‘!’ are comments, and are ignored. There are other types of operators for Adblock Plus as well, but it is not necessary to highlight those since the syntax rules described in the above subsections are adequate for the scope of this project.

### **2.4.2 Hosts File Syntax**

A hosts file entry consists of an IP address and a domain name separated by a space or tab. Lines that start with ‘#’ are comments and are ignored. Here are a few example entries:

```
# This is a comment
127.0.0.1    -ads.avast.dwnldfr.com
127.0.0.1    0.gvt0.com
```

### **2.4.3 Internet Explorer Tracking Protection Syntax**

This section highlights the important elements of Internet Explorer Tracking Protection syntax [26]. Each subsection introduces new operators that provide different functions.

### **2.4.3.1 Domain Block Rules**

Example rule: -d contoso.com

The filter rule above utilizes ‘-d’, which is the domain block operator. The rule above blocks all content from domain contoso.com.

### **2.4.3.2 Domain Allow Rules**

Example rule: +d contoso.com

The filter rule above utilizes ‘+d’, which is the domain allow operator. The rule above allows all content from domain contoso.com. Domain allow rules override domain block and substring block rules.

### **2.4.3.3 Substring Rules**

Example rules: -contoso

-contoso

-test.html

The filter rules above utilize ‘-’, which is the block operator. Substring rules specify a portion or substring of a URL, and blocks the URL if the URL contains the substring indicated in the rule. Substring allow rules are not permitted.

### **2.4.3.4 Notes**

Example rule: # this is a comment

Lines that start with ‘#’ are comments, and are ignored. There are other types of operators for Internet Explorer Tracking Protection as well, but it is not necessary to highlight those since the syntax rules described in the above subsections are adequate for the scope of this project.

## 2.5 Third-Party Categorizations

In this section, third-party categorizations by Ghostery [2], Abine [3], Trend Micro [27], and Wills' "Understanding What is Happening Regarding Internet Privacy" [5] presentation are examined.

### 2.5.1 Ghostery

Ghostery is a tracking protection tool available as an add-on for Chrome, Firefox, Opera, and Safari. Ghostery maintains a routinely updated database of approximately 2000 companies that provide third-party services which are grouped under 5 different categories. Information about the aforementioned companies can be found from Ghostery's user interface. Below are the 5 categories and their descriptions quoted from Ghostery's user interface:

- 1) **Advertising:** A tracker that delivers advertisements falls into the Advertising category.
- 2) **Analytics:** A tracker that provides research or analytics for website publishers falls into the Analytics category.
- 3) **Beacons:** Trackers that serve no purpose other than tracking (beacons, conversion pixels, audience segmentation pixels, etc.) fall into the Beacons category.
- 4) **Privacy:** Privacy notices as well as some other privacy related elements fall into the Privacy category.
- 5) **Widgets:** A tracker that provides page functionality (social network button, comment form, etc.) falls into the Widgets category.

### 2.5.2 Abine

Abine is a company that provides privacy protection tools such as Blur [28] and DeleteMe [29]. Abine used to offer a privacy protection tool called DoNotTrackMe (replaced by Blur) [30], which maintained a database that contains categorizations and information about third-party domains. Even though there are no pointers to the database from Abine's website, pointers to DoNotTrackMe's categorizations are reachable through a search engine. The categorizations provided by DoNotTrackMe's database were explored as part of this project. For example, categorization result of doubleclick.net is reachable through:

<http://www.donottrackplus.com/trackers/doubleclick.net.php>

If a third-party domain is categorized by Abine, the categorization result can be reached by using the following URL structure:

[http://www.donottrackplus.com/trackers/\[third-party domain\].php](http://www.donottrackplus.com/trackers/[third-party domain].php)

If the third-party domain is not categorized, a 404 Not Found response is received. Descriptions of DoNotTrackMe's categories are not reachable. Here are the categories used by DoNotTrackMe, which are compiled by checking different third-party domains' categorizations using the URL structure described above: Advertising, Analytics, Other, Widget.

### **2.5.3 Trend Micro**

Trend Micro is a content security software company, which provides categorizations to website domains through its Site Safety Center. Here are the categories with descriptions used by Trend Micro, which are compiled by checking different third-party domains' categorizations:

- 1) **Adult/Mature Content:** Sites with profane or vulgar content generally considered inappropriate for minors
- 2) **Blogs/Web Communications:** Blog sites or forums on varying topics or topics not covered by other categories; sites that offer multiple types of Web-based communication, such as email or instant messaging
- 3) **Brokerages/Trading:** Sites about investments in stocks or bonds, including online trading sites; includes sites about vehicle insurance
- 4) **Business/Economy:** Sites about business and the economy, including entrepreneurship and marketing; includes corporate sites that do not fall under other categories
- 5) **Computers/Internet:** Sites about computers, the Internet, or related technology, including sites that sell or provide reviews of electronic devices

- 6) **Entertainment:** Sites that promote or provide information about movies, music, non-news radio and television, books, or magazines
- 7) **Financial Services:** Sites that provide information about or offer basic financial services, including sites owned by businesses in the financial industry
- 8) **Government/Legal:** Sites about the government, including laws or policies; excludes government military or health sites
- 9) **Internet Infrastructure:** Content servers, image servers, or sites used to gather, process, and present data and data analysis, including Web analytics tools and network monitors
- 10) **Internet Radio and TV:** Sites that primarily provide streaming radio or TV programming; excludes sites that provide other kinds of streaming content
- 11) **News/Media:** Sites about the news, current events, contemporary issues, or the weather; includes online magazines whose topics do not fall under other categories
- 12) **Newsgroups/Forum:** Sites that offer access to Usenet or provide other newsgroup, forum, or bulletin board services
- 13) **Pay to Surf:** Sites that compensate users who view certain Web sites, email messages, or advertisements or users who click links or respond to surveys
- 14) **Photo Searches:** Sites that primarily host images, allowing users to share, organize, store, or search for photos or other images
- 15) **Search Engines/Portals:** Search engine sites or portals that provide directories, indexes, or other retrieval systems for the Web
- 16) **Social Networking:** Sites devoted to personal expression or communication, linking people with similar interests
- 17) **Streaming Media/MP3:** Sites that offer streaming video or audio content without radio or TV programming; sites that provide music or video downloads, such as MP3 or AVI files
- 18) **Travel:** Sites about travelling or travel destinations; includes travel booking and planning sites
- 19) **Web Advertisements:** Sites dedicated to displaying advertisements, including sites used to display banner or popup ads

20) **Web Hosting:** Sites of organizations that provide top-level domains or Web hosting services

If Trend Micro does not have a categorization for a given domain, “Untested” is returned as the categorization result by Trend Micro.

#### **2.5.4 Understanding What is Happening Regarding Internet Privacy**

Below are third-party categories and their descriptions defined by Wills in the “Understanding What is Happening Regarding Internet Privacy” [5] presentation:

- 1) **Analytics:** Provide data aggregation for first-party sites.
- 2) **AdTracker:** Serve ads and track user activity across third-party sites.
- 3) **Tracker:** Do not directly serve ads, but track and aggregate user activity.
- 4) **Social:** Icons/links to connect user activity with social media sites.

### **2.6 Related Work**

Five research papers that explore the topics of third-party tracking, internet privacy, and ad blocking were identified and examined. Key points from each paper are highlighted in the subsections below.

#### **2.6.1 Annoyed Users: Ads and Ad-Block Usage in the Wild**

The main research area of this paper is user interaction with ads [32]. The authors discuss that services which are offered free on the Internet are funded through ads which means that the cost of free content is viewing ads. The authors indicate that this situation has given rise to ad blocker usage since this situation is not viewed as acceptable by some users. They also note that increasing ad blocker usage may disrupt this widely used business model to offer free content.

The authors describe how they identified ad traffic, ad-blocker users, and the impact of ad-blockers in the “wild”. In the paper, “wild” is defined as the traffic seen in a residential broadband network of a major European ISP. Moreover, the authors describe how they characterized ad-traffic in the network. After briefly discussing the advertisement infrastructure on the Internet, the authors conclude by stating that based on the data they have gathered, 22% of

the most active users in the Web use Adblock Plus (ABP), which is one of the most popular ad blockers. The authors state that most ABP users do not enable additional filter lists or opt out from Acceptable Ads [31], which suggest that most ABP users do not change ABP's default configurations.

### **2.6.2 Generating a Privacy Footprint on the Internet**

The main goals of this paper are to examine how information related to individual users is aggregated as a result of browsing unrelated websites and to assess and compare the diffusion of privacy information across a wide variety of sites [33]. In addition, the authors examine the effectiveness of techniques such as ad blocking to reduce this privacy diffusion. The authors found that for a set of popular first-party sites, the mean number of associated third-party sites has increased by 50% within a six month interval, and methods such as ad blocking are partially effective for defeating tracking.

### **2.6.3 Measuring the Impact and Perception of Acceptable Advertisements**

The main goal of this paper is to examine Acceptable Ads [31] in detail [34]. More specifically, the authors characterize the allowed advertisements and how the whitelisting has changed since its introduction in 2011. The authors found that the Acceptable Ads filter list has been updated on average every 1.5 days and grew from 9 filters in 2011 to 5,900 in the Spring of 2015. In addition, the authors show that Acceptable Ads triggers filters on 59% of the top 5,000 websites.

### **2.6.4 Third-Party Web Tracking: Policy and Technology**

The main goal of this paper is to explore third-party web tracking and related technology, and inform researchers with background and tools for contributing to public understanding and policy debates about web tracking [1]. The authors explain privacy problems, regulations, and business models regarding third-party web tracking. In addition, the authors explain tracking technologies, privacy-preserving third-party services and user choice mechanisms regarding third-party tracking technologies. The authors report that the field of third-party web tracking is rapidly changing, and encourage researchers to contribute to this field.

### **2.6.5 Who Knows What About Me? A Survey of Behind the Scenes Personal Data Sharing to Third Parties by Mobile Apps**

The main goal of this research paper is to find out the types of user data sent by mobile apps to third-parties [35]. The authors tested 110 popular, free Android and iOS identify the apps that shared personal, behavioral, and location data with third-parties. The authors report that 73% of Android apps shared personal information such as email address with third-parties, and 47% of iOS apps shared location data with third-parties. In addition, the authors show that a significant proportion of apps share personal information or search terms with third-parties without Android or iOS requiring a notification to the user.

## **2.7 Summary**

The chapter highlights different ad blocking methods available for traditional browser-based ad blocking and ad blocking in Android and iOS devices. Operators of Adblock Plus, Hosts file, and Internet Explorer Tracking Protection filter rule syntaxes are explored afterwards. In addition, third-party categorizations by Ghostery, Abine and Trend Micro are explored. Lastly, the background section explores research work related to the goals of this project. The highlighted results from the related work show that there is a significant amount of Internet users that use ad blocking tools, and the field of third-party tracking in traditional browsers and mobile devices are growing rapidly.



### **3. METHODOLOGY**

In this section, research areas and motives are defined, and the methods used to investigate the identified research areas are explained.

#### **3.1 Research Areas**

Three main research areas were identified in order to thoroughly capture the theme of understanding ad blockers. The research areas are explained in the following subsections with their corresponding motives. Results and evaluations of all research is presented in Chapter 4.

##### **3.1.1 General Information About Ad Blocking Tools And Filter Lists**

The main motive to research general information about ad blocking tools and filter lists is to explore ad blockers from a user's perspective, and to have a better idea of the variety of ad blocking options available to the users. This main goal of this research area is to identify important properties of ad blocking tools and filter lists, and to explore as much ad blocking tools and filter lists as possible based on the identified important properties. This research area involves researching information about traditional browser-based ad blocking tools and filter lists as well as ad blocking tools for mobile devices. Filter lists for ad blocking tools for mobile devices were not explored due to time constraints.

##### **3.1.2 Analyzing Popular Third-Party Domains**

The main motive to research and analyze popular third-party domains is to learn the functionalities of third-parties that appear in popular first-party sites. The main goal of this research area is to categorize popular third-party domains under different categories based on the third-parties' functionality and behavior, and to produce a clear picture that shows the portions of popular third-parties that fall under each category. This research area involves analyzing popular third-parties that appear in popular first-party sites for traditional browsers as well as mobile devices.

### **3.1.3 Analyzing Filter lists**

The main motive to research and analyze filter lists is to clearly see the differences and similarities between the effectiveness of filter lists. The main goal of this research area is to identify the popular third-party domains blocked by each filter list, and to summarize the results based on each third-party category (third-party categories are defined by the previous research area). This research area involves analyzing filter lists for traditional browser-based ad blocking tools only. Filter lists for mobile ad blocking tools were not analyzed due to time constraints.

## **3.2 General Information About Ad Blocking Tools And Filter Lists**

In this section, the methods used to fulfill the goals of the first research area, “General Information About Ad Blocking Tools And Filter Lists”, are explained.

### **3.2.1 Important Properties Of Ad Blocking Tools**

Six important properties were identified in order to clearly convey the similarities and differences between ad blocking tools. The six properties are as follows: list of browsers that support the given tool, list of default filter lists, whether if there is a feature to add custom filter rules or not, whether if the tool is open-source or not, whether if the tool is free or not, and whether if the tool is discontinued or not.

### **3.2.2 Information Summary For Filter Lists**

Two important properties were identified in order to clearly convey the general similarities and differences between filter lists. The two properties are as follows: the syntax type used by the filter list and the update frequency of the filter list.

### **3.2.3 Ad Blocking Apps Available For Mobile Devices**

For this subsection of the research area, ad blocking apps available for Android and iOS devices were researched.

### **3.3 Analyzing Popular Third-Party Domains**

In this section, methods used to fulfill the goals of the second research area, “Analyzing Popular Third-Party Domains”, are explained.

#### **3.3.1 Creating Categories**

In order to categorize third-party domains based on their behavior, third-party categories of Ghostery [2] and third-party categories defined by Prof. Craig Wills in the “Understanding What is Happening Regarding Internet Privacy” [5] were examined. Categories were determined in such a way to extensively encompass the behavior of a significant portion of popular third-parties.

#### **3.3.2 Categorizing Third-Party Domains**

Third-party domains that appear in at least 1% of ~1200 most popular traditional browser-based first-party sites (rankings by Alexa [36]) were gathered by Prof. Craig Wills in December 2015 using a similar methodology explained in the paper “Privacy Diffusion on the Web: A Longitudinal Perspective” [37]. These domains were categorized by following the algorithm shown by the flowchart in Figure 1. In addition, third-party domains that received data from at least 1% of 110 mobile apps investigated by the paper “Who Knows What About Me? A Survey of Behind the Scenes Personal Data Sharing to Third Parties by Mobile Apps” [35] were categorized using the same algorithm in Figure 1.

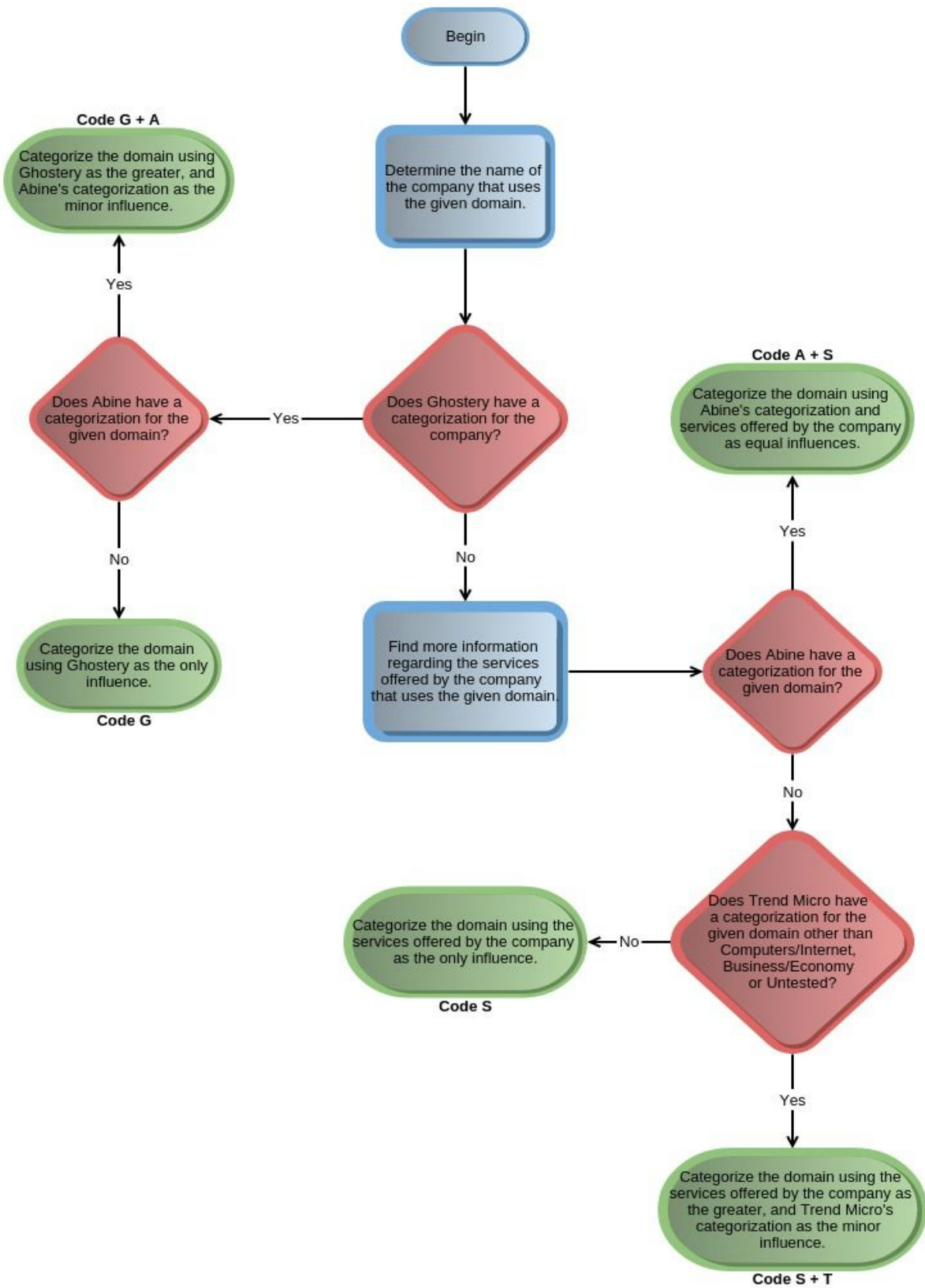


Figure 1: Categorization Algorithm

As part of the algorithm, it is required to find the name of the company that owns the given third-party domain. In order to find the name of the company, the following algorithm was followed:

- 1) If the domain name matches a company name in Ghostery's database, use the matching company name. For example: google-analytics.com with Google Analytics, addthis.com with AddThis, dynamicyield.com with Dynamic Yield, etc..
- 2) If the domain name does not match a company name from Ghostery's database, open the domain from a browser. If the domain opens or redirects to a company website, and use the name of the company from the opened website. Optionally, perform a WHOIS lookup to solidify the result.
- 3) If the domain does open or get redirected to a company website, do a Google search and perform a WHOIS lookup with the domain to find out the company that owns the domain by either an external source or by WHOIS lookup results (registrant organization). Use the company name found from the results of external search and/or WHOIS lookup.

If Ghostery does not have a categorization, it is required to find more information regarding the services offered by the company that uses the given third-party domain as a step of the algorithm. Information provided on company websites were used as references for this step.

As seen from Figure 1, each termination step of the categorization algorithm has a code. Here are the descriptions for each termination step code that appear in the algorithm:

- 1) **G**: Ghostery was the only influence for categorization.
- 2) **G + A**: Ghostery was the greater influence and Abine was the minor influence for categorization.
- 3) **A + S**: Abine and services offered by the company were equal influences for categorization.
- 4) **S + T**: Services offered by the company was the greater influence and Trend Micro was the minor influence for categorization.
- 5) **S**: Services offered by the company was the only influence for categorization.

The main reason for using Ghostery as the primary source of influence is that Ghostery's database gets updated regularly, and its third-party categories are privacy-related. The main reason for using Abine as the secondary source of influence is that Abine's DoNotTrackMe service is discontinued and its third-party database no longer gets updated, but its categories are privacy-related. Finally, the main reason for using Trend Micro as the tertiary source of influence is that the categories used by Trend Micro convey a broad spectrum of purposes, but are not privacy-oriented.

After categorizing all third-parties, categorization analyses were done under three main groups:

- 1) **Popular domains:** This group contains the third-party domains that appear in at least 1% of ~1200 most popular traditional browser-based first-party sites.
- 2) **Most popular domains:** This group contains the third-party domains that appear in at least 5% of ~1200 most popular traditional browser-based first-party sites. Most popular domains is a subset of popular domains.
- 3) **Mobile popular domains:** This group contains third-party domains that received data from at least 1% of 110 mobile apps investigated by the paper "Who Knows What About Me? A Survey of Behind the Scenes Personal Data Sharing to Third Parties by Mobile Apps".

For each group above, a bar chart figure that shows the percentages of third-party domains that fall under each third-party category were created to summarize the categorization results.

### 3.3.3 Termination Step Analysis

The codes of the termination steps that resolve third-party domains into categories were noted and bar chart figures for popular domains, most popular domains, and mobile popular domains were created to summarize the percentage of third-party domains that resolved under each termination step.

## 3.4 Analyzing Filter Lists

In this section, methods used to fulfill the goals of the third research area, “Analyzing Filter Lists”, are explained.

### 3.4.1 Live Testing With Filter Lists

The main goals for doing live tests with filter lists are to gather more third-parties that do not appear in the set of popular third-parties and to observe any interesting behavior regarding the blocked third-parties.

Two live testing trials were done using Adblock [6] and Fiddler [38] on “cnn.com”. First, the GET requests done on cnn.com were recorded using Fiddler without any filter lists enabled on Adblock. The GET requests done on cnn.com were recorded again with only EasyList enabled on Adblock. This procedure was repeated once and a total of two sets of data were gathered. The differences in the sets of requested domains were analyzed afterwards.

In addition, live tests were conducted using Adblock Plus [7] and Selenium WebDriver [39] library for Python on cnn.com, yahoo.com, imdb.com, msn.com, stackoverflow.com, reddit.com, ask.com, bbc.com, nytimes.com, and ebay.com using different filter lists. A Python script that does the following was written in order to semi-automate the live testing process:

- 1) Open Firefox with a Firefox profile that has Adblock Plus enabled.
- 2) Send the keyboard shortcut to open up the “open blockable items” feature of Adblock Plus. (“Open blockable items” feature is shown in Figure 2)
- 3) Browse to each one of the websites mentioned above in new tabs.

A different filter list is enabled each time the script is run. Only one filter list was enabled at a time. The GET requests and the activated filter rules are recorded for each website and for each enabled filter list.





- **ABP Syntax:** ||g.doubleclick.net  
||doubleclick.net/ads
  - **Hosts file:** 127.0.0.1 g.doubleclick.net
  - **IETP Syntax:** -d g.doubleclick.net  
-d doubleclick.net /ads
- \*: If there is at least one rule that blocks everything from a given third-party domain only in a set of first-party sites, the filter list blocks the given third-party domain with \* level. This blocking level can only be found in filter lists that use ABP syntax.
    - **ABP Syntax:** ||doubleclick.net^\$domain=example.com
  - \*B-: If there is at least one rule that blocks the given third-party domain with a B- level and if there is at least one rule that blocks the given third-party domain with a \* level, the filter list blocks the given third-party domain with a \*B- level. Since \* is only found in ABP Syntax lists, this blocking level is also only found in ABP Syntax lists.:
    - **ABP Syntax:** ||g.doubleclick.net/ads AND  
||doubleclick.net^\$domain=example.com
  - A: If there is at least one rule that allows everything from a given third-party domain, the filter list allows the given third-party domain with an A level. Not present in hosts files.
    - **ABP Syntax:** @@||doubleclick.net
    - **IETP Syntax:** +d doubleclick.net
  - A-: If there is at least one rule that allows at least one server and/or path from the given third-party domain, the filter list allows the given third-party domain with an A- level Not present in hosts files.
    - **ABP Syntax:** @@||doubleclick.net/ads  
@@||g.doubleclick.net  
@@doubleclick.net^\$domain=example.com
    - **IETP Syntax:** +d g.doubleclick.net  
+d doubleclick.net /ads

It is important to note that each a filter list can only have one blocking level associated with a given third-party domain. More extensive blocking levels override the less extensive blocking levels, and all blocking levels override all the allowing levels. The extensiveness of the blocking levels are as follows:

**B** > **\*B-** > **B-** > **\*** > **A** > **A-**

For example, if there is a rule that blocks a domain with a B level and another rule that blocks the domain with a B- level, the third-party will be associated with a blocking level of B instead of B- in the given filter list since B is more extensive than B-. For example, if there is a rule that blocks the domain with a B- level and another rule that allows the domain with a A- level, the third-party will be associated with a blocking level of B-, since blocking levels override allowing levels. Finally, allowing level A overrides A- since A is a more extensive allowing level. As mentioned in Section 2.4, only Adblock Plus (ABP) and Internet Explorer Tracking Protection (IETP) syntaxes have allowing rules, and none of the filter lists that use ABP or IETP syntaxes have a rule that corresponds to allowing level A and another rule that corresponds to one of the blocking levels at the same time. This ensures the validity of the extensiveness levels mentioned above since allowing rules override blocking rules in the filter lists, and the presence of an overarching allow rule would overrides all blocking rules.

Python scripts are written to parse the gathered filter lists to check for the blocking levels described above. Different versions of the script are written and each version is tailored for a different filter rule syntax. A table that contains the popular third-parties and the gathered filter lists is created, and the blocking level of each third-party domain is indicated on the table. If there is no mention of a given third-party in a filter list, the corresponding cell in the table is left blank. A table of the same format that only contains the most popular domains is also created.

The results are summarized based on the third-party categories, and explained with bar chart figures in Chapter 4. Instead of the individual blocking and allowing levels described above, the summarized analyses are based on the “primary behavior” of the blocking and allowing levels. That is, if a third-party is associated with one of the blocking levels, the

third-party falls under the “Blocked” group. If a third-party is associated with one of the allowing levels, the third-party falls under the “Allowed” group. If there is no mention of the third-party in the given filter list, the third party would fall under the “No Action” group. Conducting the analyses by putting third-parties under three groups, “Blocked”, “No Action”, and “Allowed”, provides a simple and effective way of summarizing the findings and conveying the big picture shown by the data with bar chart figures. In addition, contextual information about some filter lists are provided as part of the summarized results in order to enhance analysis results with online research findings.

### **3.4.3 Effectiveness of Default Filter Lists**

Parsing results of ad blocker tools’ default filter lists are analyzed together to show the effectiveness of defaults of ad blocking tools. The results are summarized based on the third-party categories, and explained with bar chart figures in Chapter 4. Again, the analyses are based on the “primary behavior” of blocking and allowing levels, but this time, there are four groups instead of three: “Blocked”, “Mixed Blocking”, “No Action”, and “Allowed”. Some ad blocking tools have more than one default filter list. and the “Mixed Blocking” group represents the portion of third-parties that are blocked by some and allowed by some of the default filter lists of ad blocking tools.

In addition, the default filter lists are analyzed based on the top 20 popular third-party domains that appear on traditional browsers. The top 20 popular domains are the 20 third-party domains that have the highest portion of presence in the top 1200 first-party sites. These analyses are also done based on the “primary behavior” of blocking and allowing levels, and there are three groups: “Blocked By % of Filter Lists”, “No Action By % of Filter Lists” and “Allowed By % of Lists”. The first group represents the portion of default filter lists of the given ad blocking tool that block the given third-party domain. The second group represents the portion of default filter lists that do not contain any references to the given third-party, and the third group represent the portion of default filter lists that allow the given third-party domain. The summarized results are explained with bar chart figures in Chapter 4.

## **4. RESULTS AND EVALUATIONS**

In this chapter, results of each research area are presented, explained, and evaluated.

### **4.1 General Information About Ad Blocking Tools and Filter Lists**

In this section, results and evaluations of the first research area, “General Information About Ad Blocking Tools and Filter Lists”, are explained.

#### **4.1.1 Important Properties Of Ad Blocking Tools**

A total of 23 different ad blocking tools were investigated by using them and through online research to see whether if they possess the six important properties identified in Section 3.2.1. The results are presented in Table 1. Abbreviations in the “Supported Browser” column of Table 1 stand for the following:

- **C:** Google Chrome [40]
- **I:** Internet Explorer [41]
- **M:** Mozilla Firefox [42]
- **O:** Opera [43]
- **P:** Standalone program
- **S:** Safari [44]

**Table 1: Ad blocker characteristics**

Tool	Supported Browsers	Default Filter Lists	Custom Filter Rules Allowed?	Open-source?	Free?	Currently Available?
AdBlock [6]	C, O, S	Acceptable Ads, AdBlock custom filters, EasyList, Malware protection	✓	✓	✓	✓
Adblock Edge [45] [46]	M	EasyList	✓	✓	✓	x
AdBlock Fast [47] [48]	C, O	Adblock Fast List	x	✓	✓	✓
Adblock Plus [7]	C, M, O, S	EasyList, Acceptable Ads	✓	✓	✓	✓
AdFender [49]	P	EasyList, EasyPrivacy	✓	x	✓	✓
Adguard [50]	C, I, M, O, S	Acceptable Ads, Adguard English filter (based on EasyList)	✓	x	Free trial	✓
Bluhell Firewall [51]	M	Bluhell Firewall list (EasyList based)	x	x	✓	✓
Disconnect [52]	C, M, O, S	Disconnect Tracking Protection	✓*	x	✓	✓
Emma Ad Blocker [53]	P	Emma Ad Blocker list	x	x	✓	?
Ghostery [54]	C, M, O, S	Ghostery list	✓*	x	✓	✓
Google Ad Blocker [55]	P	Google Ad Blocker list	x	x	✓	✓
GT-Soft Ad Blocker [56] [57]	P	Peter Lowe's List	x	x	✓	?
Internet Explorer Tracking Protection [9]	I	N/A	✓	x	✓	✓
Karma Blocker [58]	M	Karma Blocker list	✓	✓	✓	✓
Kill Evil [59] [60]	C	N/A	x	✓	✓	?
Mozilla Firefox Tracking Protection [61]	M	Mozilla Firefox Tracking Protection list (based on a subset of Disconnect Blocklist)	x	✓	✓	✓
NoAds [62]	O	EasyList	✓	x	✓	?
NoAds Advanced [63] [64]	O	EasyList	✓	✓	✓	?
Privacy Badger [65]	C, M	No initial list. List builds up as user browses	✓*	✓	✓	✓
PrivacyFix [66]	C, M	PrivacyFix list	x	x	✓	✓
Privoxy [67]	P	Privoxy list	✓	x	✓	✓
uBlock [68]	C, M, O, S	uBlock filters, uBlock filters - Privacy, EasyList, Peter Lowe's list, EasyPrivacy, Malware Domain list, Malware Domains	✓	✓	✓	✓
uBlock Origin [69]	C, M, S	uBlock filters, uBlock filters - Badware risks, uBlock filters - Privacy, uBlock filters - Unbreak, EasyList, Peter Lowe's list, EasyPrivacy, Malware Domain list, Malware Domains	✓	✓	✓	✓

Key points from Table 1 are highlighted below:

**Highlights from “Supported Browsers”:** Twelve ad blocking tools are supported on Mozilla Firefox, eleven are supported on Google Chrome, nine are supported on Opera, seven are supported on Safari, and five tools are standalone programs.

**Highlights from “Default Filter Lists”:** Eight ad blocking tools have EasyList as a default filter list and two ad blocking tools have EasyList-based default filter lists. In addition, three ad blocking tools have Peter Lowe’s list as a default, and three ad blocking tools have Acceptable Ads as a default.

**Highlights from “Custom Filter Rules Allowed?”:** A “check mark asterisk” (✓\*) in the “Custom Filter Rules Allowed?” column indicate that the tool does not allow for adding custom filter rules, but allows customization to some extent in terms of blocking third-parties. Disconnect and Privacy Badger have a “check mark asterisk” on this column because the user has the ability to manually select trackers to block from the tools’ user interfaces. Ghostery has a “check mark asterisk” on this column since Ghostery does not block any third-parties by default and the user has to manually select the third-parties and/or third-party categories they wish to block. Twelve ad blocking tools allow custom filter rules, three tools allow customization to some extent (e.g. “check mark asterisks”), and eight tools do not allow custom filter rules.

**Highlights from “Open Source?”:** Eleven ad blocking tools are open-source whereas twelve ad blocking tools are not.

**Highlights from “Free?”:** 22 ad blocking tools are free to use whereas one tool offers a free trial but requires payment afterwards.

**Highlights from “Currently Available?:** Question marks in the “Currently Available?” column indicate that the latest version of the tool was released a long time ago and there is no information about whether if the tool is discontinued or not. Emma Ad Blocker’s latest version 1.1.0.1 was released in 2013, GT-Soft Ad Blocker’s latest version 1.5 was released in 2012, Kill Evil’s latest version 2.3 was released in 2011, NoAds’s latest version 1.0.8 was released in 2010, and NoAds Advanced’s latest version 1.3.7 was released in 2013. 17 ad blocking tools are currently available, one tool is discontinued, and it is not certain whether if four tools are discontinued or not.

### 4.1.2 Information Summary For Filter Lists

A total of 36 filter lists were investigated by downloading and observing them, and through research to find out the filter lists' syntax type(s) and update frequencies. The results are presented in Table 2.

**Table 2:** Filter list characteristics

Filter List	Adblock Plus Syntax	Hosts File Syntax	Internet Explorer Tracking Protection Syntax	Other	Update Frequency Notes
Acceptable Ads [31] [70]	✓	✗	✗	✗	Update check every day
Adblock custom filters [71]	✓	✗	✗	✗	No regular update interval specified
Adblock warning removal [72], [73]	✓	✗	✗	✗	Update check every day
Adware filters [74]	✓	✗	✗	✗	Update check every day
EasyList [73] [75] [10]	✓	✗	✓	✗	Update check every 4 days
EasyList without element hiding [73] [76]	✓	✗	✗	✗	Update check every 4 days
EasyList without rules for adult sites [73] [77]	✓	✗	✗	✗	Update check every 4 days
EasyPrivacy [73] [78] [10]	✓	✗	✓	✗	Update check every 4 days
EasyPrivacy without international filters [73] [79]	✓	✗	✗	✗	Update check every 4 days
Fanboy's Annoyance List [73] [80]	✓	✗	✗	✗	Update check every 4 days
Fanboy's anti-Facebook list [81] [82]	✓	✗	✗	✗	Update check every 4 days
Fanboy's anti-third-party fonts list [81] [83]	✓	✗	✗	✗	Update check every 2 days
Fanboy's Social Blocking List [73] [84]	✓	✗	✗	✗	Update check every 4 days
Malware Domains [85] [86]	✓	✗	✗	✗	Update check every day
Peter Lowe's List [87]	✓	✓	✓	✗	No regular update interval specified
Spam404 [88] [89]	✓	✗	✗	✗	Update check every 2 days
uBlock filters [8]	✓	✗	✗	✗	No regular update interval specified
uBlock filters badware risks [69]	✓	✗	✗	✗	No regular update interval specified
uBlock filters privacy [8]	✓	✗	✗	✗	No regular update interval specified
uBlock filters unbreak	✓	✗	✗	✗	No regular update interval specified
Dan Pollock's hosts [90]	✗	✓	✗	✗	No regular update interval specified
hpHosts [91]	✗	✓	✗	✗	No regular update interval specified
Malware domain list [92] [93]	✗	✓	✗	✗	No regular update interval specified
MVPS hosts [15]	✗	✓	✗	✗	No regular update interval specified

Abine List [94] [95]	x	x	✓	x	No regular update interval specified
PrivacyChoice All Companies [10] [96]	x	x	✓	x	Update check every 3 days
PrivacyChoice Block Companies Without Network Advertising Initiative Oversight [10] [97]	x	x	✓	x	Update check every 3 days
Stop Google Tracking [10] [98]	x	x	✓	x	Update check every day
TRUSTe [10] [99]	x	x	✓	x	Update check every 2 days
Ad filter list by Disconnect [100]	x	x	x	✓	No regular update interval specified
Basic tracking list by Disconnect [101]	x	x	x	✓	No regular update interval specified
Disconnect Tracking Protection [102] [103]	x	x	x	✓	No regular update interval specified
Ghostery List	x	x	x	?	No regular update interval specified
Malvertising list by Disconnect [104]	x	x	x	✓	No regular update interval specified
Malware list by Disconnect [105]	x	x	x	✓	No regular update interval specified
Malware protection [106]	x	x	x	✓	No regular update interval specified

Key points from Table 2 are highlighted below:

**Highlights regarding filter rule syntaxes:** 20 filter lists have versions that use Adblock Plus (ABP) syntax, five lists have versions that use hosts file syntax, eight lists have versions that use Internet Explorer Tracking Protection (IETP) syntax, and seven lists use another form of filter rule syntax. There are three filter lists that have multiple versions. EasyList and EasyPrivacy have two versions which use ABP and IETP syntax. Peter Lowe’s list have three versions which use ABP, hosts file and IETP syntax. Ghostery’s list could not be located and was not investigated in file form, therefore, the type of syntax used by Ghostery’s list was not found. However, since Ghostery’s third-party database is available through Ghostery’s user interface, making observations was possible and the observation results are presented in Section 4.3 along with other filter lists. Disconnect Tracking Protection and Malware Protection use JSON [107] syntax. Ad filter list by Disconnect, Basic tracking list by Disconnect, Malvertising list by Disconnect, and Malware list by Disconnect does not use any syntax rules but instead exist as text files which contain a domain name on each new line. This type of syntax will be referred to as “lists by Disconnect” syntax. Excerpts from Ad filter list by Disconnect and Disconnect Tracking Protection are provided below to demonstrate “list by Disconnect” syntax and JSON syntax respectively:



**Excerpt from Ad filter list by Disconnect:**

101com.com  
101order.com  
123found.com

**Excerpt from Disconnect Tracking Protection:**

```
{"Facebook": {"http://www.facebook.com/": [  
    "facebook.com",  
    "facebook.de",  
    "facebook.fr",  
    "facebook.net",  
    "fb.com",  
    "atlassolutions.com",  
    "friendfeed.com"  
]}}
```

**Highlights regarding update frequencies:** 18 of the filter lists do not specify a regular update check interval. eight lists require update checks every four days, five lists require checks everyday, three lists require checks every two days, and two lists require update checks every three days. It should be noted that the update check intervals do not mean that the lists always get a new update in the specified time interval. The update check intervals are instructions that make ad blocking tools check for an update for the given filter list once in every specified time interval. These instructions only exist in ABP and IETP syntax based filter lists and are denoted by special comments. Below are example update interval comments for ABP and IETP syntaxes:

**ABP Syntax:**

! Expires: 5 days

**IETP Syntax:**

: Expires=3

### **4.1.3 Ad Blocking Apps Available For Mobile Devices**

Ad blocking apps available for Android and iOS devices were researched online. Below are results of the research:

**For Android:** AdAway [108], Adblock Browser [109], Adblock Plus for Android [7], AppBrain Ad Detector [110], Ghostery Privacy Browser [25]

**For iOS:** 1block [111], Ad Block Multi [112], Ad Control [113], Ad-Blocker [114], Adamant [115], Adblock Browser [101], Adblock Fast [47], AdBlockX [116], AdMop [117], BlockBear [118], Blockr [119], Chop [120], Clear [121], Clearly [122], Crystal [20], Distilled [123], F-Secure [124], Flare: Block Tracking and Ads [125], Freedom - Ad Blocker [126], Ghostery [127], Just Content [128], Magic AdBlock [129], Oasis Blocker [130], Privacy Content Blocker [131], Purify [21], Refine [132], Rocket [133], Silentium [134], SpeedMeUp [23], Swab [135], Vivio AdBlocker [136], Wipr [137]

Through online research, a total of 5 ad blocking apps for Android devices and 32 ad blocking apps for iOS devices were identified. The only common app for both Android and iOS was Adblock Browser.

## **4.2 Analyzing Popular Third-Party Domains**

In this section, results and evaluations of the second research area, “Analyzing Popular Third-Party Domains”, are explained.

### **4.2.1 Creating Categories**

Six third-party categories are defined after evaluating categories defined by Ghostery and by Wills in his “Understanding What is Happening Regarding Internet Privacy” [5] presentation. Categories are determined in such a way to extensively encompass the behavior of a significant portion of popular third-parties by focusing on privacy-related behavior. Some examples of privacy related-behavior are tracking user activity, analyzing user audiences, gathering personal

information, serving personalized content/ads, and modifying page functionality based on personalized content. Below are the defined categories:

- **AdTrackers:** Third-parties that serve ads and track user activity across third-party sites.
- **Analytics:** Third-parties that provide research or analytics for website publishers.
- **Beacons:** Third-parties that serve no other purpose than tracking.
- **Other:** Third-parties that do not fall under the other 5 categories.
- **Social:** Third-parties that provide social networking services as well as services such as advertising, analytics, and tracking.
- **Widgets:** Third-parties that provide page functionality.

#### 4.2.2 Categorizing Third-Party Domains

Categorization results of popular domains, most popular domains, and mobile popular domains are summarized in Figure 3. Most popular domains consists of 97 third-parties, popular domains consists of 316, and mobile popular domains consists of 94 third-parties. As mentioned in Section 3.3.2, most popular domains is a complete subset of popular domains. In addition, there are 25 common domains between popular domains and mobile popular domains.

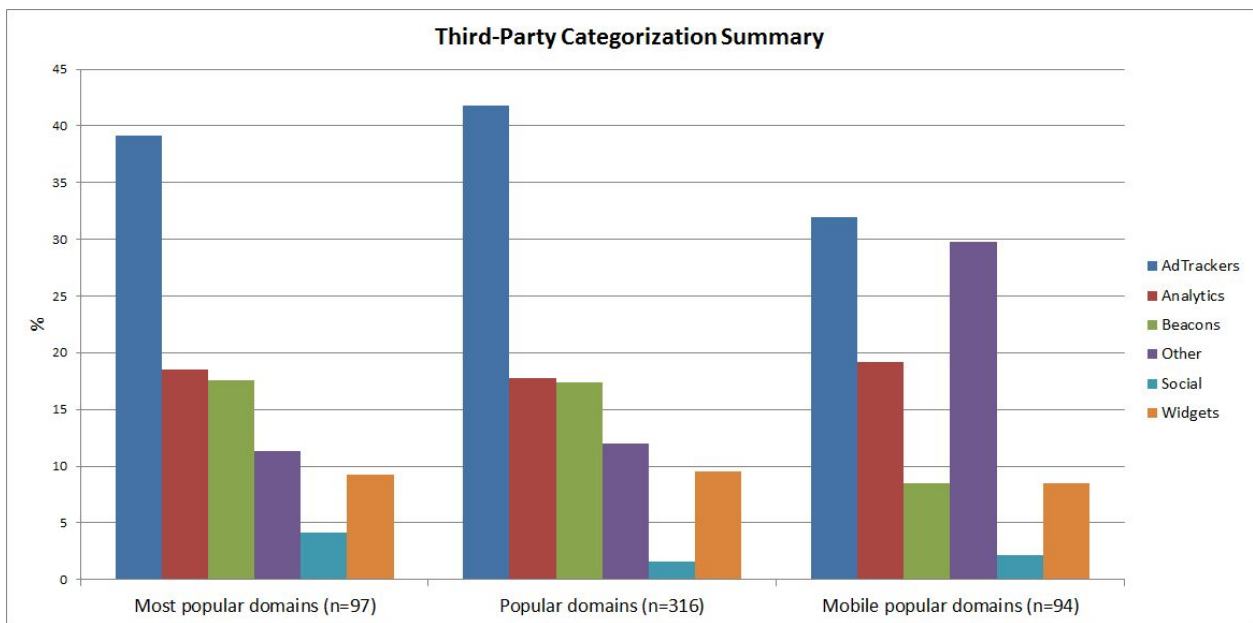
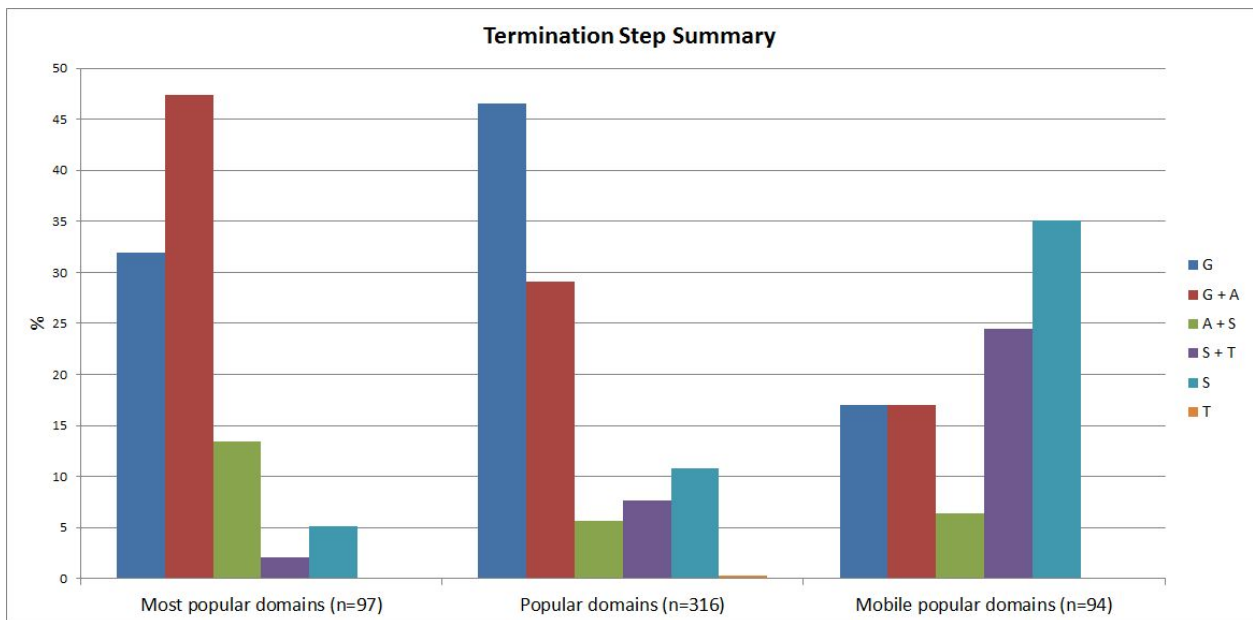


Figure 3: Categorization results summary

There are a few points to highlight from Figure 3. First of all, the highest portion of third-party domains are AdTrackers for all three groups. More precisely, 39% of most popular domains, 42% of popular domains, and 31.9% of mobile popular domains were AdTrackers. In addition, the Social category contains the smallest portion of third-parties in all three groups: 4%, 1%, and 2% in most popular domains, popular domains, and mobile popular domains respectively. Moreover, the Analytics category consists of ~18% of domains and the widgets category consists of ~9% of domains in all three groups. Finally, 30% of mobile popular domains are categorized under the Other category, whereas ~12% of domains in most popular domains and popular domains are categorized under the Other category, which is a significant difference. The list of popular domains can be found in Appendix A, and list of mobile popular domains can be found in Appendix B. The attached Excel sheet called “Categorization.xlsx” contains detailed categorization information such as notes, citations, and categorizations by Ghostery, Abine, and Trend Micro. Information about attached files can be found in Appendix C.

### 4.2.3 Termination Step Analysis

Termination step results are summarized in Figure 4. The same results are also incorporated into the categorization algorithm flowchart in Figure 5.

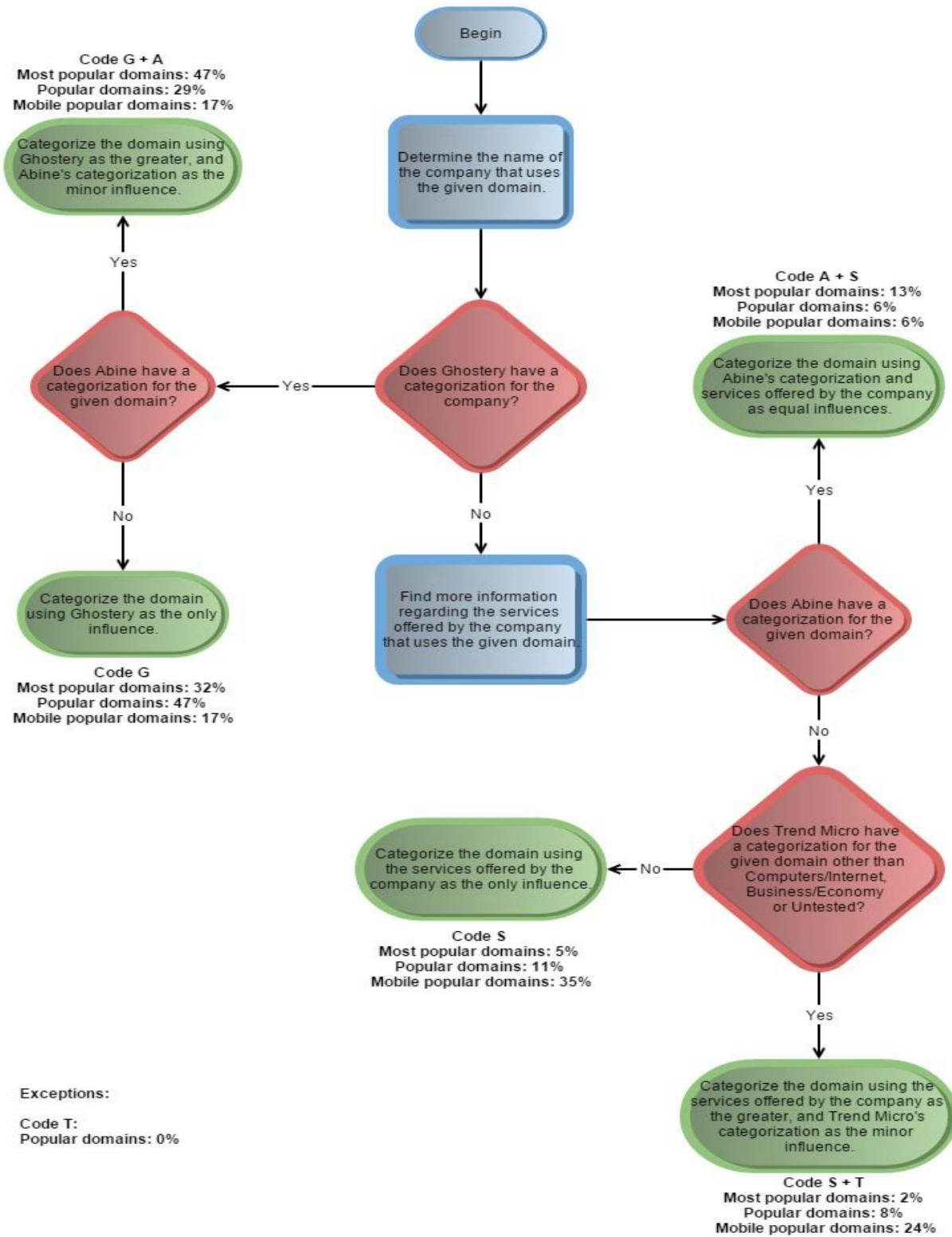


**Figure 4:** Termination step summary

There is one domain, “declaredthoughtfulness.co” that resolved under “T”, which is an exception, and means that Trend Micro was the only influence for categorization.

“Declaredthoughtfulness.co” resolved under “T”, because neither Ghosrtery nor Abine had a categorization for “declaredthoughtfulness.co”, online research did not yield results, and Trend Micro’s categorization was the only source of information on the domain.

There are a two points to highlight from Figure 4 and Figure 5. Firstly, highest portion of domains in most popular domains, popular domains and mobile popular domains resolved under “G + A” with 47.2%, “G” with 46.5%, and “S” with 35.1% respectively. Lastly, excluding “T”, lowest portion of domains in most popular domains, popular domains and mobile popular domains resolved under “S + T” with 2.1%, “A + S” with 5.7%, and “A + S” with 6.4% respectively.



**Figure 5:** Categorization algorithm with summarized termination step results

## 4.3 Analyzing Filter Lists

In this section, results and evaluations of the third research area, “Analyzing Filter Lists”, are explained.

### 4.3.1 Live Testing With Filter Lists

The two trials on “cnn.com” with Adblock and Fiddler [38] yielded some noteworthy observations. The observations are explained below.

In the first trial, a total of ten domains that were requested when EasyList was disabled were not requested when EasyList was enabled. According to AdBlock, six ads were blocked in this trial. However, the GET request analyses indicate that eight domains were blocked out of the ten that did not appear when EasyList was enabled.

In the second trial, a total of twelve domains that were requested when EasyList was disabled were not requested when EasyList was enabled. According to AdBlock, seven ads were blocked but the GET request analyses indicate that 8 domains were blocked out of the twelve.

It should also be noted that In each trial, there was some variation in requested domains by “cnn.com”.

The difference between the number of blocked ads shown by AdBlock and the GET requests analyses may be caused because there may be some ads which make GET requests to multiple different domains.

The observations of live tests on cnn.com, yahoo.com, imdb.com, msn.com, reddit.com, stackoverflow.com, ask.com, bbc.com, nytimes.com, and ebay.com with Adblock Plus and Selenium WebDriver [39] are explained below.

Throughout the trials, a total of 21 first and second-party domains are requested. Out of 27 requested third-party domains, 15 of them are also present in the popular domains list. Only 12 of the requested third-parties were not present in the popular domains list.

In addition, some of the requested domains were blocked by “non-domain specific” filter rules. For example, in one of the trials, a URL from “betrad.com” which contained the substring “/pixel.gif?” was blocked by the filter rule “/pixel.gif?”. Some other domains were also blocked

by rules such as “/.com/ads\$image, object, subdocument” and “.com/c.gif?”. Since Adblock Plus (ABP) and Internet Explorer Tracking Protection (IETP) syntaxes allow substring rules, it can be stated that the domains blocked by ABP or IETP syntax-based filter lists are not limited by the filter rules that state domain names. Results from live testing can be found in the “live\_testing\_results” directory of the attached “MQP\_Attachments.zip” file. Information about attached files can be found in Appendix C.

#### **4.3.2 Parsing Filter Lists To Determine Blocked and Allowed Third-Party Domains**

A total of 36 filter lists are investigated in this section. The parsing results are presented for most popular domains in Section 4.3.2.1, and for popular domains in Section 4.3.2.2. Contextual information about filter lists are also provided in Section 4.3.2.1 in order to enhance analysis results with online research findings. The contextual information presented in Section 4.3.2.1 applies to all filter list analyses in Section 4.3.2.

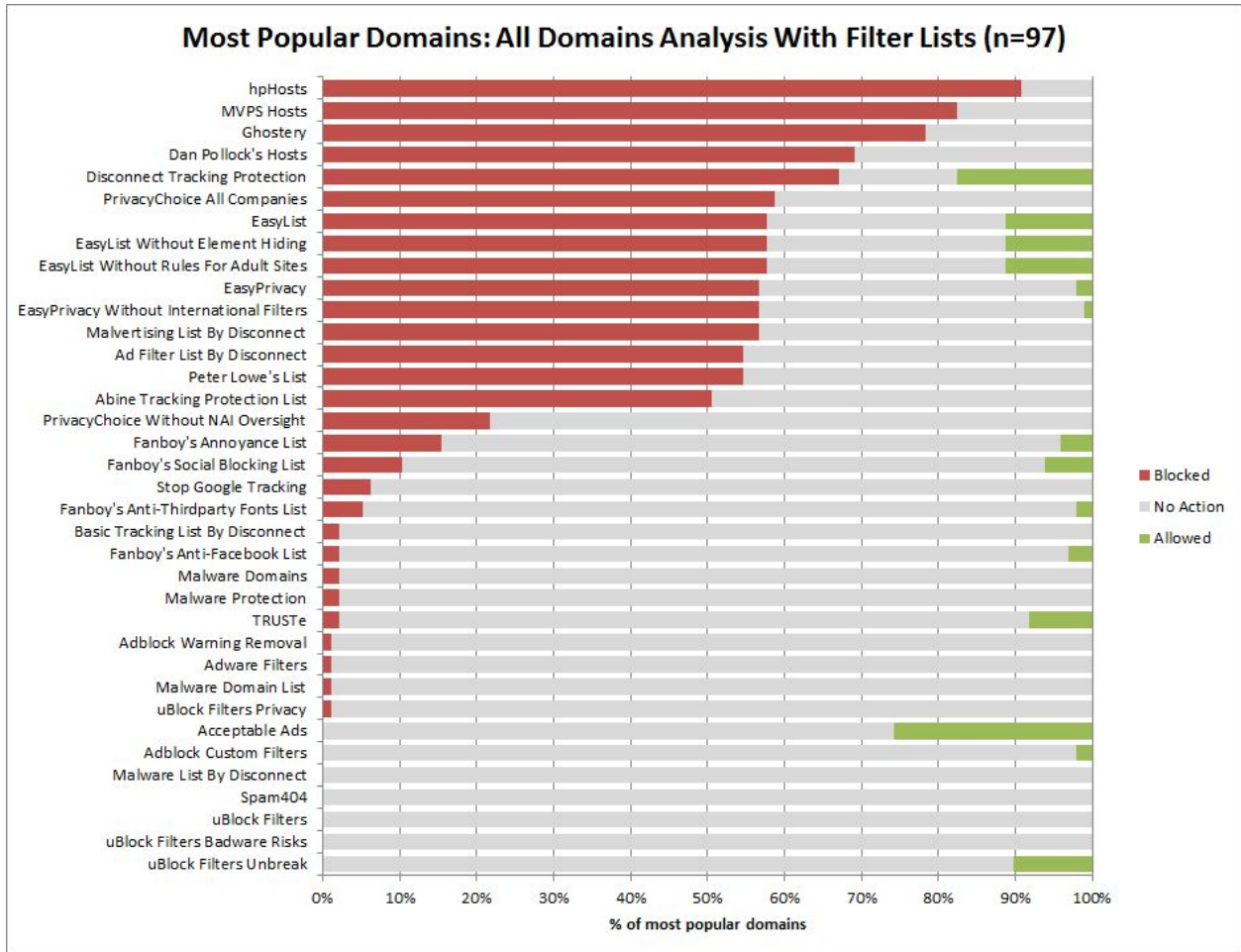
Online research did not yield useful results regarding whether if the investigated filter lists are also used in ad blocking tools for mobile devices. Therefore, analyses are not done for mobile popular domains. If the investigated filter lists are not used with ad blocking tools for mobile devices, analyses with mobile popular domains would bear no significance. Filter lists for mobile devices can be researched and analyzed as part of future work.

Abine Tracking Protection List, PrivacyChoice All Companies, PrivacyChoice Without NAI Oversight, Stop Google Tracking, and TRUSTe were gathered on January 27, 2016. All other filter lists were gathered on November 26, 2015. The analyzed filter lists can be found in the “filter\_lists” directory and the scripts used to parse the filter lists can be found in the “parsing\_scripts” directory of the attached “MQP\_Attachments.zip” file. In addition, parsing results of the filter lists can be found in the attached “Categorization.xlsx” Excel sheet. Information about attached files can be found in Appendix C.

##### **4.3.2.1 Most Popular Domains And Contextual Information About Filter Lists**

Figure 6 shows the percentage of blocked and allowed most popular domains by the parsed filter lists. The filter lists are sorted in descending order regarding the percentage of blocked third-party domains.





**Figure 6: Most popular domains analysis with filter lists**

Key points from Figure 6 are highlighted below. Contextual information about some filter lists are also provided while highlighting the key points,

Five filter lists have blocking rates higher than 70%. In this set of five lists, hpHosts has the highest blocking rate with 91%. As of March 12, 2016, there are 359,196 hosts listed in hpHosts [14]. This list is followed by a 83% blocking rate by MVPS Hosts [15], and a 78% blocking rate by Ghostery [54]. As mentioned in Section 4.1.1, no third-parties are blocked by Ghostery by default, and the user has to manually select the third-parties and/or categories to block. For all analyses that involve Ghostery in Section 4.3.2, all third-parties in Ghostery's database were selected for blocking. Ghostery is followed by Dan Pollock's Hosts [90] with 69% and Disconnect Tracking Protection [103] with 67%.

Ten filter lists have blocking rates ranging from 50% to 60%. In this set of ten lists, EasyList [75] has the highest blocking rate with 58%. Other filter lists from the “EasyList subscriptions”, namely, EasyList Without Element Hiding [76], EasyList Without Rules For Adult Sites [77], EasyPrivacy [78], and EasyPrivacy Without International Filters [79] are also in this set. The EasyList subscriptions are filter lists designed for Adblock Plus, and are maintained by four authors, “Fanboy”, “MontzA”, “Famlam”, and “Khrin”, who are assisted by in maintaining the lists by a forum community [73]. As shown in Table 1, many ad blocking tools have at least one of the “EasyList subscriptions” as part of their default filter lists. Finally, Abine Tracking Protection List [95] is the filter list with the lowest blocking rate in this set with 51%.

Abine Tracking Protection List is followed by 14 lists which have blocking rates ranging from 1% to 28%, which is a drastic decrease on the blocking rates. This set of 14 lists are followed by seven lists which do not have any blocking rules regarding the most popular domains. Out of this seven, Malware List By Disconnect [105], Spam404 [88], uBlock Filters , and uBlock Filters Badware Risks do not have any allowing rules either and are not included in the analysis other analysis figures in this section.

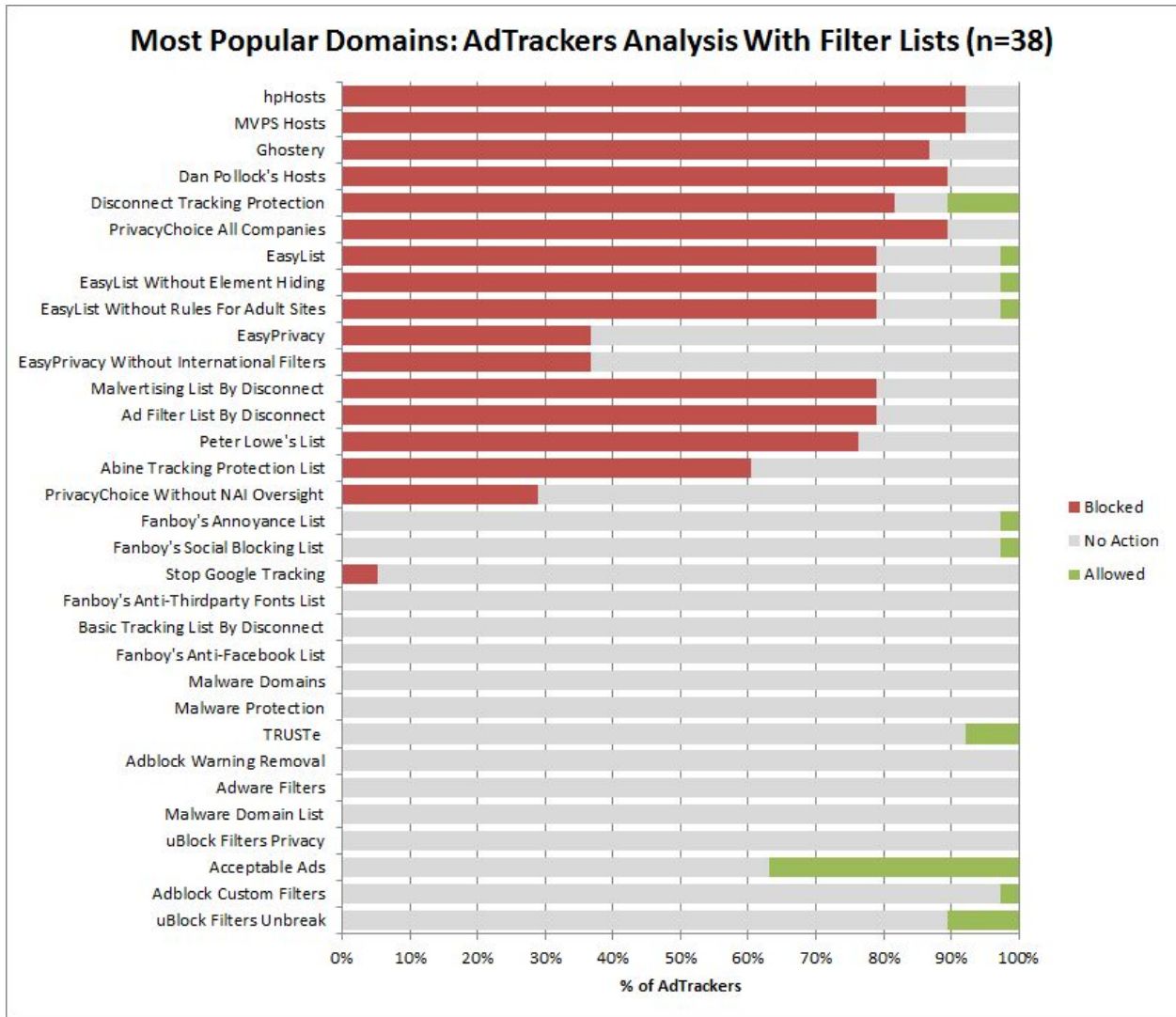
Moreover, there are a total of 14 filter lists that allow a portion of the most popular domains. A noteworthy example from this set is the Disconnect Tracking Protection list, which is Disconnect’s [52] default filter list. Disconnect Tracking Protection blocks 67% and allows 18% of most popular domains. According to Disconnect, tracking sites that commit respect to users’ Do Not Track (DNT) preferences and agree to comply with DNT as defined by the Electronic Frontier Foundation [138] are “unblocked” (e.g. allowed). In addition, Disconnect generally allows tracking sites that require users to explicitly opt in to data collection and retention. Moreover, Disconnect allows trackers to provide a “better user experience” based on error reports, internal testing, and user experiments with the trackers [102].

Another noteworthy example from the set of filter lists with allowing rules is Acceptable Ads [70], which blocks none and allows 29% of the most popular domains. Acceptable Ads list is maintained by the Acceptable Ads Initiative [31], which was started by Adblock Plus. Other companies such as DuckDuckGo [139], PageFair [140], and Developer Media [141] participate in this initiative as well. The Acceptable Ads Initiative maintains an “Acceptable Ads Manifesto”

which determines the requirements for acceptable ads. Companies can get their ads “whitelisted” by the Acceptable Ads filter list by sending a whitelisting application to the Initiative, which reviews the application to check whether if the ad complies with the Acceptable Ads Manifesto [142].

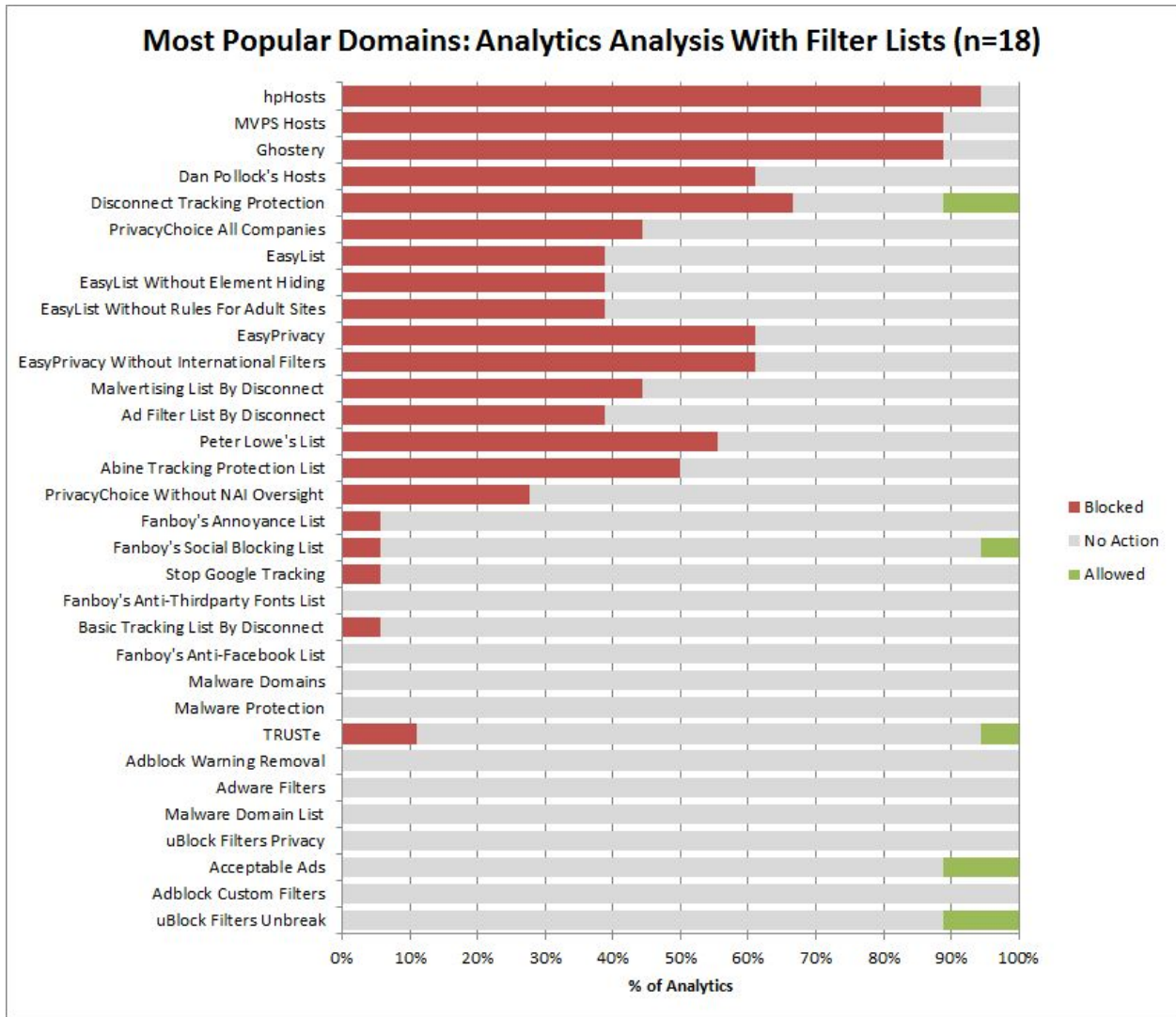
The final highlights from the set of filter lists with allowing rules involve EasyList, EasyList Without Element Hiding, EasyList Without Rules For Adult Sites, EasyPrivacy, EasyPrivacy Without International Filters, Adblock Custom Filters [71], and uBlock Filters Unbreak. Based on the comments in these lists, it can be concluded that these filter lists allow some domains in order to fix some sites whose functionality are distorted by blocking rules.

It should also be noted that Fanboy’s Social Blocking List [84] is included in Fanboy’s Annoyance List [73], [80]. In other words, Fanboy’s Social Blocking List is a subset of Fanboy’s Annoyance List.



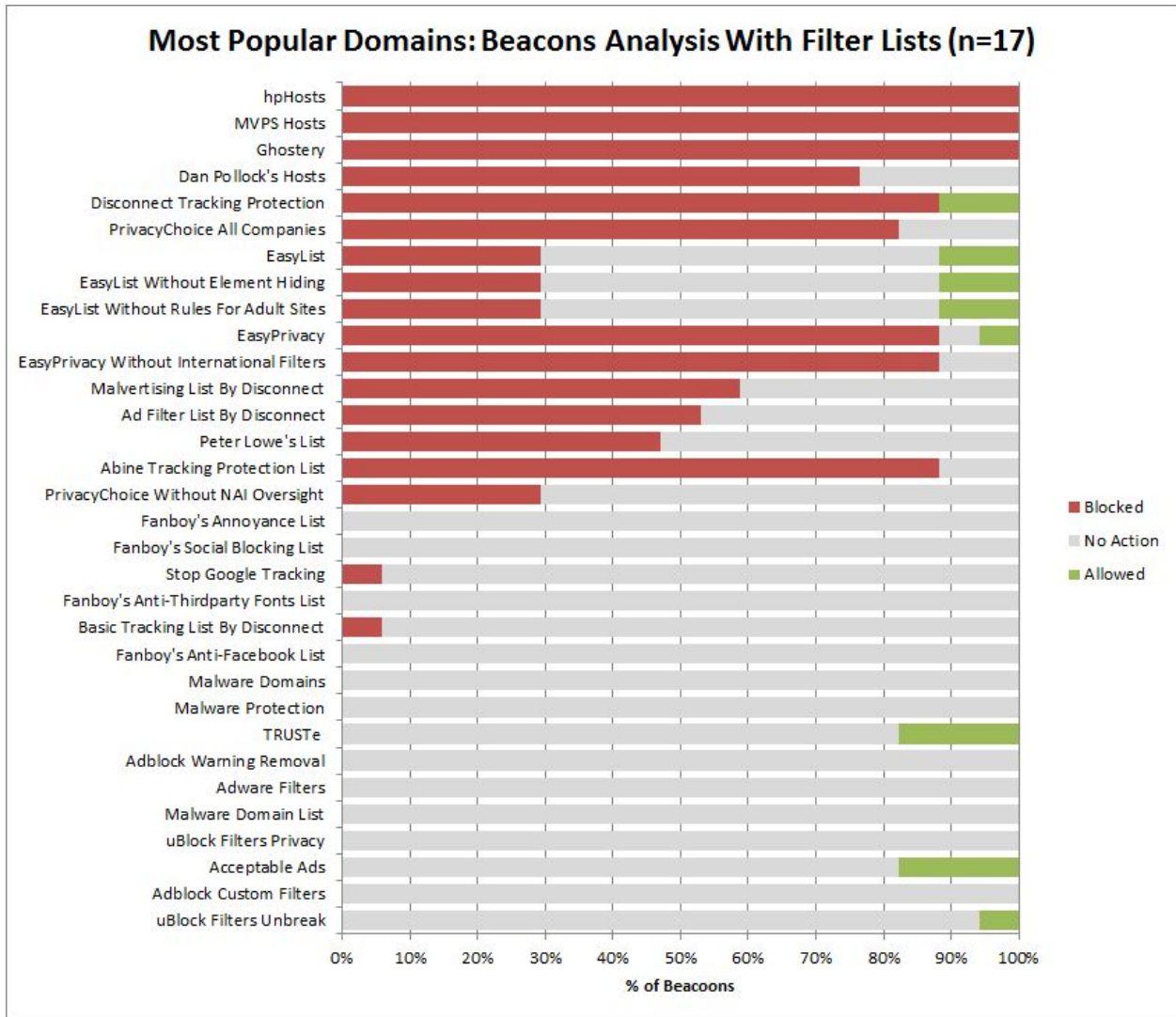
**Figure 7: Most Popular AdTrackers analysis with filter lists**

Figure 7 shows the percentage of blocked and allowed most popular AdTrackers by the parsed filter lists. MVPS Hosts and hpHosts have the highest AdTracker blocking rate with 92%. These two lists are followed by Dan Pollock’s Hosts and PrivacyChoice All Companies with a blocking rate of 90%. Ghostery has the fifth highest AdTracker blocking rate with 87%. Seven filter lists have an AdTracker blocking rate between 61% and 82%. Four lists have a and AdTracker blocking rate between 5% and 37%, and 15 lists do not block any of the most popular AdTrackers. Finally, there are ten filter lists that allow a portion of the most popular AdTrackers. In this set of ten, Acceptable Ads have the highest allowing rate with 37%.



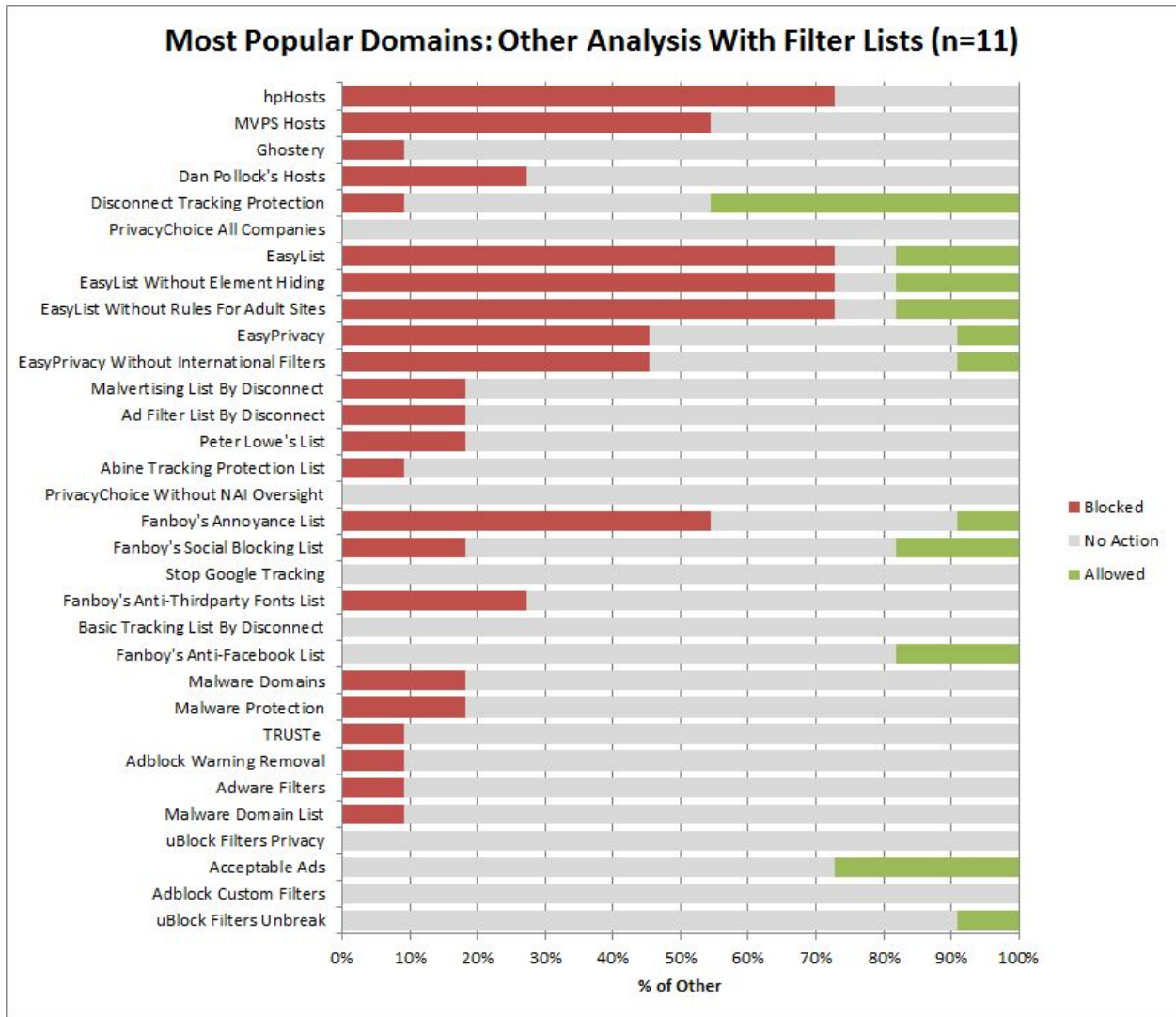
**Figure 8: Most Popular Analytics domains analysis with filter lists**

Figure 8 shows the percentage of blocked and allowed most popular Analytics domains by the parsed filter lists. hpHosts have the highest Analytics domains blocking rate with 94%. This list is followed by MVPS Hosts and Ghostery which have a blocking rate of 89%, and Disconnect Tracking Protection with a blocking rate of 67%. Dan Pollock's Hosts, EasyPrivacy, and EasyPrivacy Without International Filters share the fifth highest highest blocking rate with 61%. 14 lists have an Analytics blocking rate between 6% and 56%, and eleven lists do not block any of the most popular Analytics domains. Finally, there are five filter lists that allow a portion of the most popular Analytics. In this set of five, Disconnect Tracking Protection, Acceptable Ads, and uBlock Filters Unbreak share the highest allowing rate with 11%.



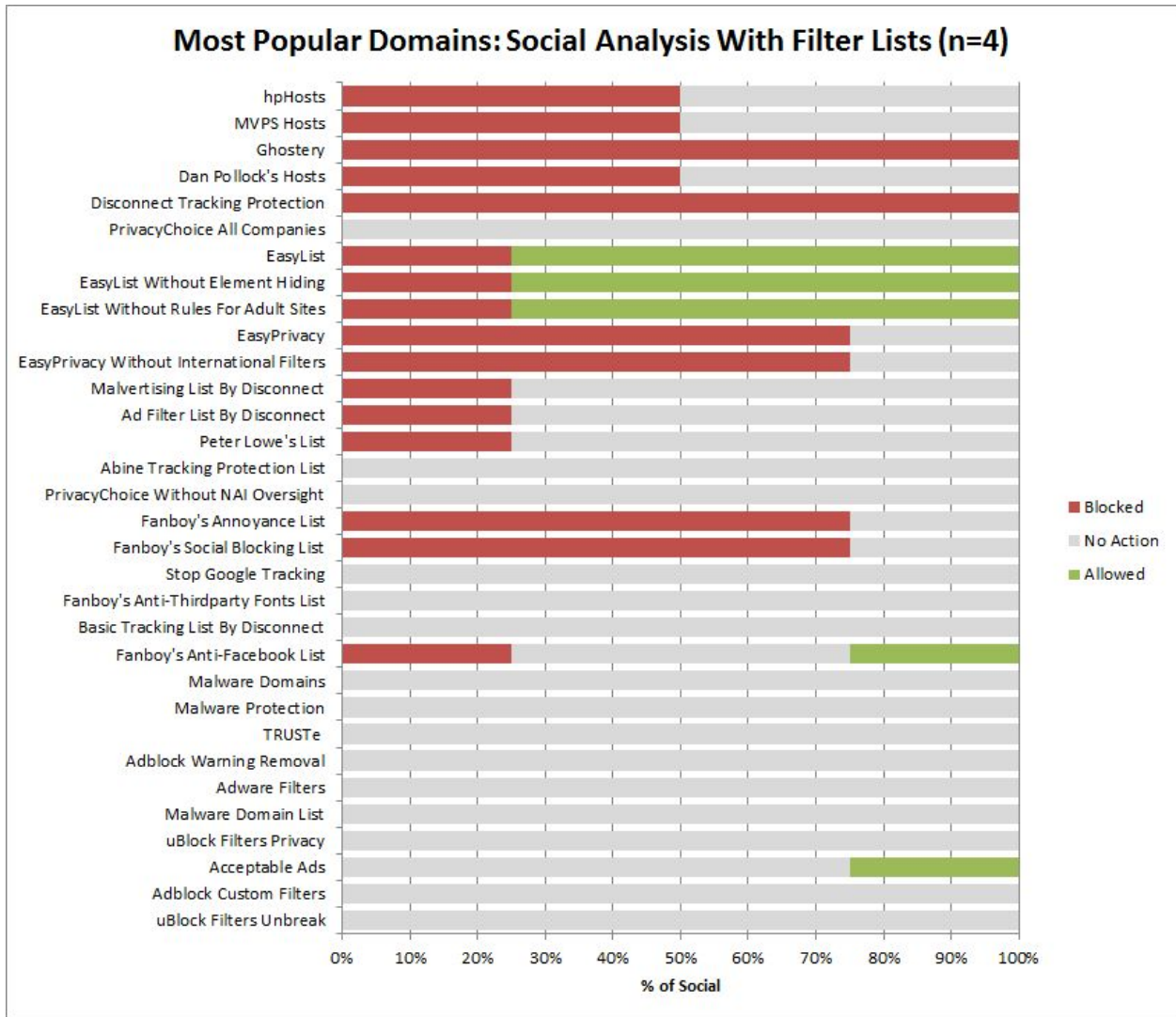
**Figure 9:** Most Popular Beacons analysis with filter lists

Figure 9 shows the percentage of blocked and allowed most popular Beacons by the parsed filter lists. MVPS Hosts and hpHosts have the highest most popular Beacons blocking rate with 100%. They are followed by Disconnect Tracking Protection EasyPrivacy, EasyPrivacy Without International Filters, and Abine Tracking Protection List which have a blocking rate of 88%. Five filter lists have a Beacons blocking rate between 47% and 82%. In addition, there are six filter lists that have a blocking rate between 6% and 29%, and there are 14 filter lists that do not block any of the most popular Beacons. Finally, there are eight lists that allow a portion of the most popular Beacons. In this set of eight, TRUSTe and Acceptable Ads have the highest allowing rate with 18%.



**Figure 10: Most Popular Other Third-Parties analysis with filter lists**

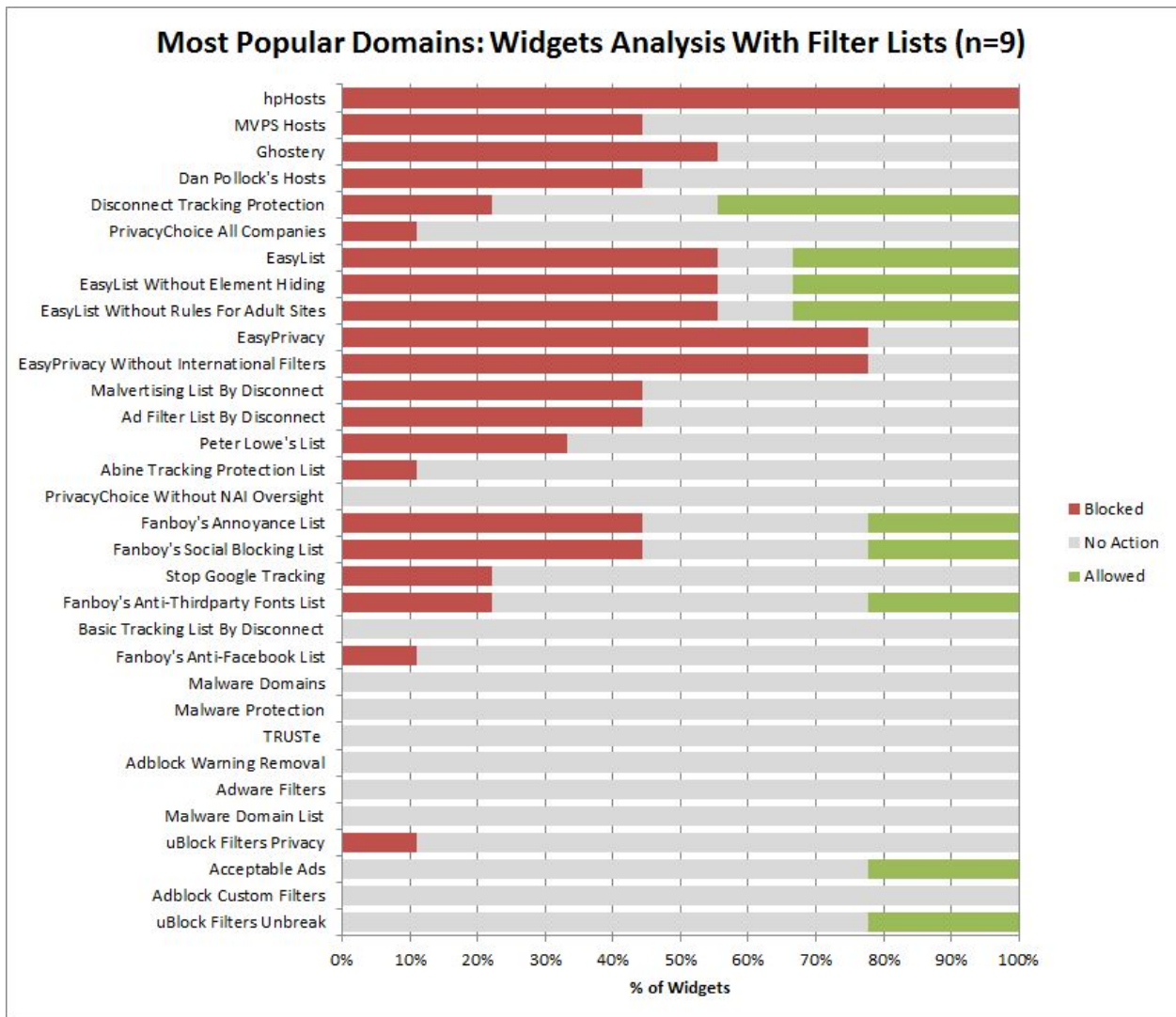
Figure 10 shows the percentage of blocked and allowed most popular Other Third-Parties by the parsed filter lists. EasyList, hpHosts, EasyList Without Element Hiding, and EasyList Without Rules For Adult Sites have the highest most popular Other Third-Party blocking rate with 73%. These lists are followed by MVPS Hosts and Fanboy's Annoyance List which have a blocking rate of 55%. EasyPrivacy and EasyPrivacy Without International filters share the third highest blocking rate with 46%. There are 14 filter lists that a blocking rate between 9% and 27%, and there are nine lists that do not have any block any of the most popular Other Third-Parties. Finally, there are eleven filter lists that allow a portion of the Other Third-Parties. In this set of eleven, Disconnect Tracking Protection has the highest allowing rate with 46%.



**Figure 11: Most Popular Social domains analysis with filter lists**

Figure 11 shows the percentage of blocked and allowed most popular Social domains by the parsed filter lists. Ghostery and Disconnect Tracking Protection have the highest most popular Social domains blocking rate with 100%. These lists are followed by EasyPrivacy, EasyPrivacy Without International Filters, Fanboy's Annoyance List, and Fanboy's Social Blocking List with a blocking rate of 75%. There are ten filter lists that have a blocking rate between 25% and 50%, and there are 15 filter lists that do not block any of the most popular Social domains. Finally, there are five filter lists that allow a portion of the most popular Social domains. EasyList, EasyList Without Element Hiding, and EasyList Without Rules For Adult Sites have the highest allowing rate with 75%.





**Figure 12: Most Popular Widgets analysis with filter lists**

Figure 12 shows the percentage of blocked and allowed most popular Widgets by the parsed filter lists. hpHosts has the highest most popular Widgets blocking rate with 100%. This list is followed by EasyPrivacy and EasyPrivacy Without International Filters with a blocking rate of 78%. Dan Pollock’s Hosts, EasyList, EasyList Without Element Hiding, and EasyList Without Rules For Adult sites have the third highest blocking rate with 56%. There are 14 filter lists that have a blocking rate between 11% and 44%, there are eleven filter lists that do not block any of the most popular Widgets. Finally, there are nine filter lists that allow a portion of

the most popular Widgets. Disconnect Tracking Protection has the highest allowing rate with 44%.

### 4.3.2.2 Popular Domains

Figure 13 shows the percentage of blocked and allowed popular domains by the parsed filter lists. The filter lists are sorted in descending order regarding the percentage of blocked third-party domains. Key points from Figure 13 are highlighted below.

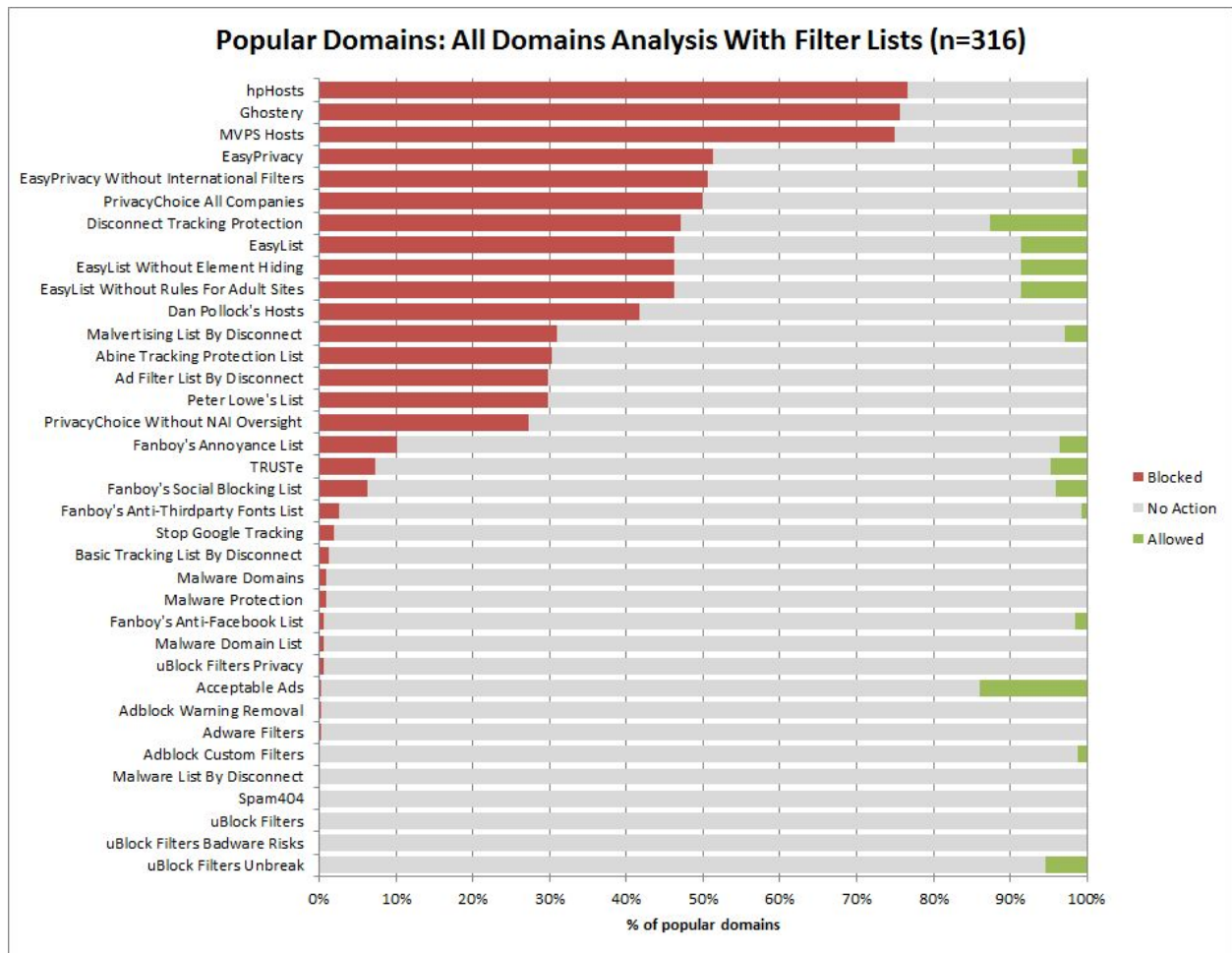
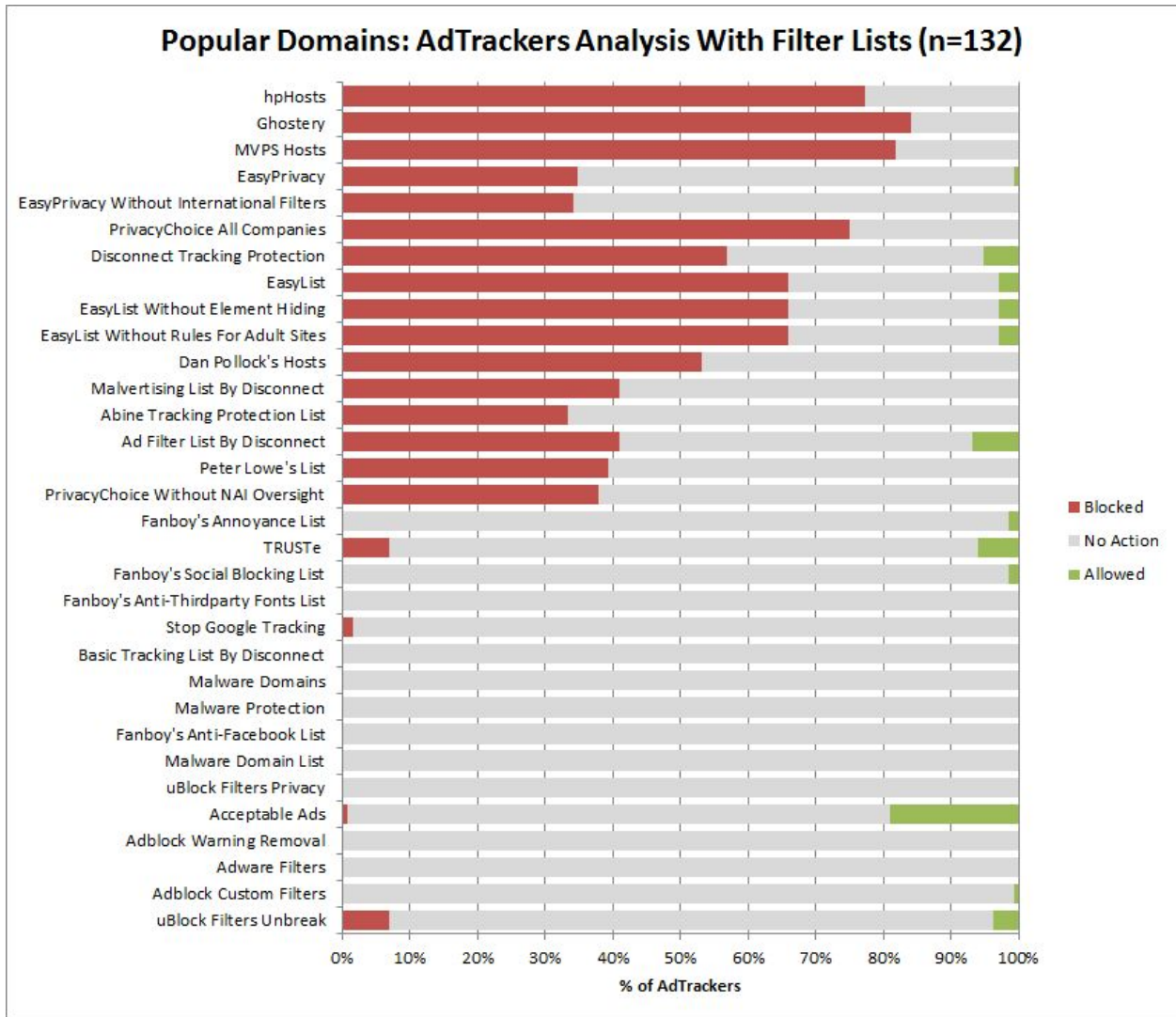


Figure 13: Popular domains analysis with filter lists

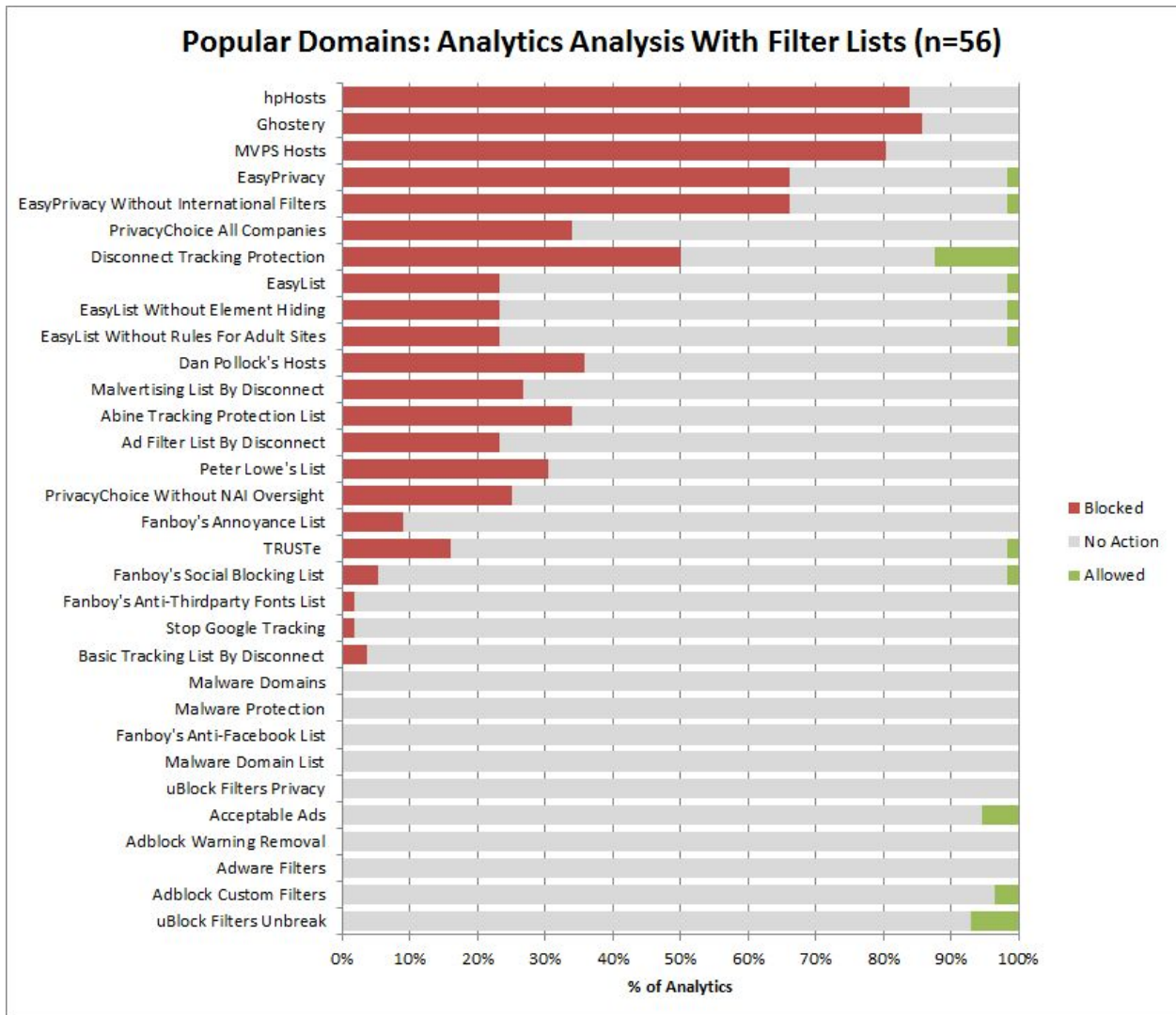
Three filter lists have a blocking rate higher than 70%. In this set of three, hpHosts have the highest popular domains blocking rate with 77%. hpHosts is followed by Ghostery which has a blocking rate of 76%, and Ghostery is followed by MVPS Hosts which has a blocking rate of

75%. MVPS Hosts is followed by EasyPrivacy which has a blocking rate of 51%, which is a drastic decrease from 75%. There are eight filter lists that have a blocking rate between 42% and 51%. This set of eight lists is followed by a set of five lists that have blocking rates between 27% and 31%. Moreover, there are 14 lists that have a blocking rate between 0.3% and 10%, which is a drastic decrease from 27%. Finally, there are 15 filter lists that allow a portion of the popular domains. In this set of 15, Acceptable Ads has the highest allowing rate with 14%. Malware List By Disconnect, Spam404, uBlock Filters, and uBlock Filters Badware filters neither have blocking nor allowing rules regarding popular domains and therefore are not included in the rest of the analysis figures in this section.



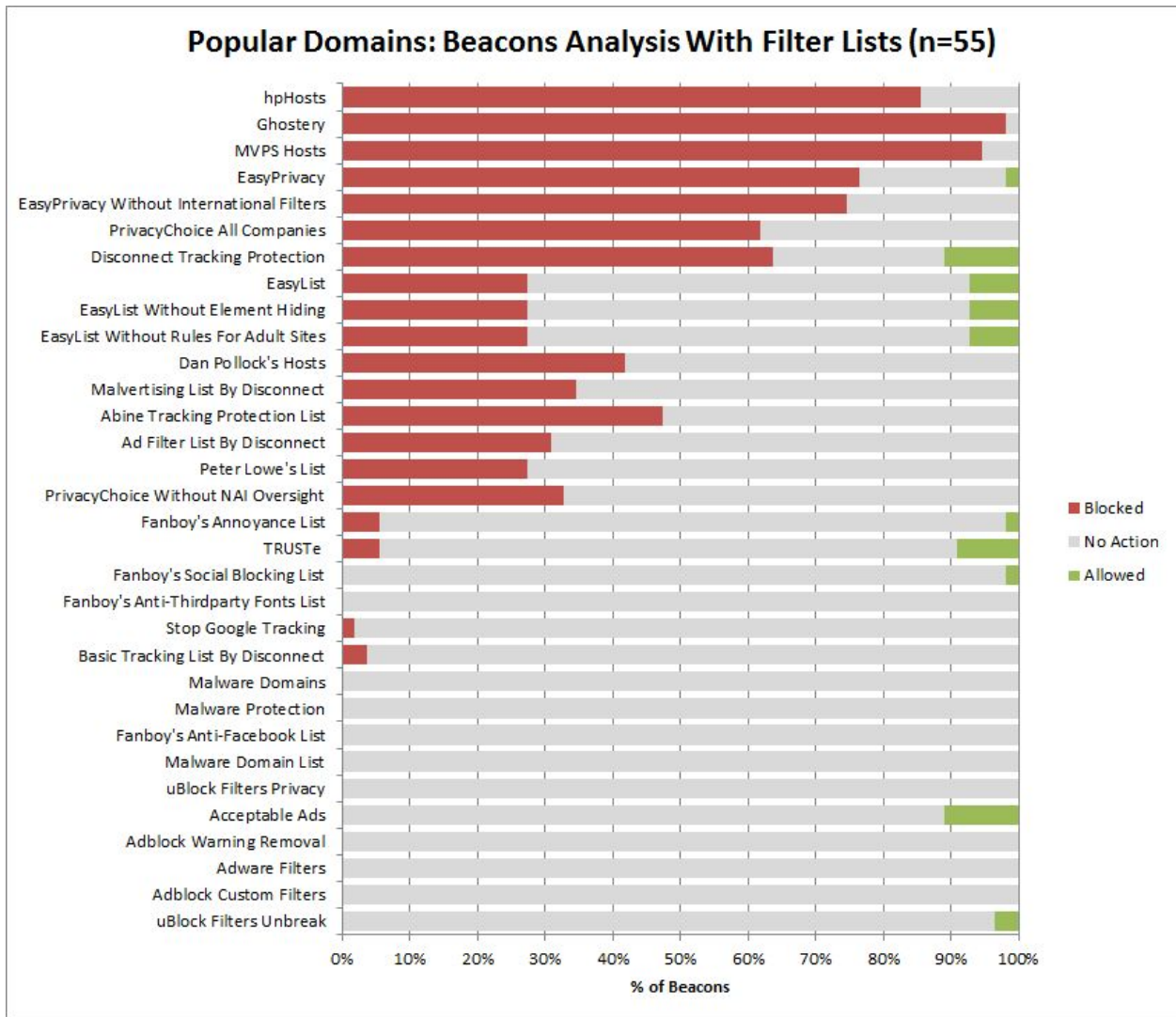
**Figure 14:** Popular AdTrackers analysis with filter lists

Figure 14 shows the percentage of blocked and allowed popular AdTrackers by the parsed filter lists. Ghostery has the highest popular AdTracker blocking rate with 84%. Ghostery is followed by MVPS Hosts 82%, and MVPS Hosts is followed by hpHosts 77%. PrivacyChoice All Companies has the fourth highest blocking rate with 75%, and EasyList, EasyList Without Element Hiding, and EasyList Without Rules For Adult Sites share the fifth highest blocking rate with 66%. There are nine filter lists that have a blocking rate between 33% and 57%, and there are four filter lists that have a blocking rate between 1% and 7%. Twelve filter lists do not block any of the popular AdTrackers. Finally, twelve lists allow a portion of the popular AdTrackers. In this set of twelve, Acceptable Ads has the highest allowing rate with 19%.



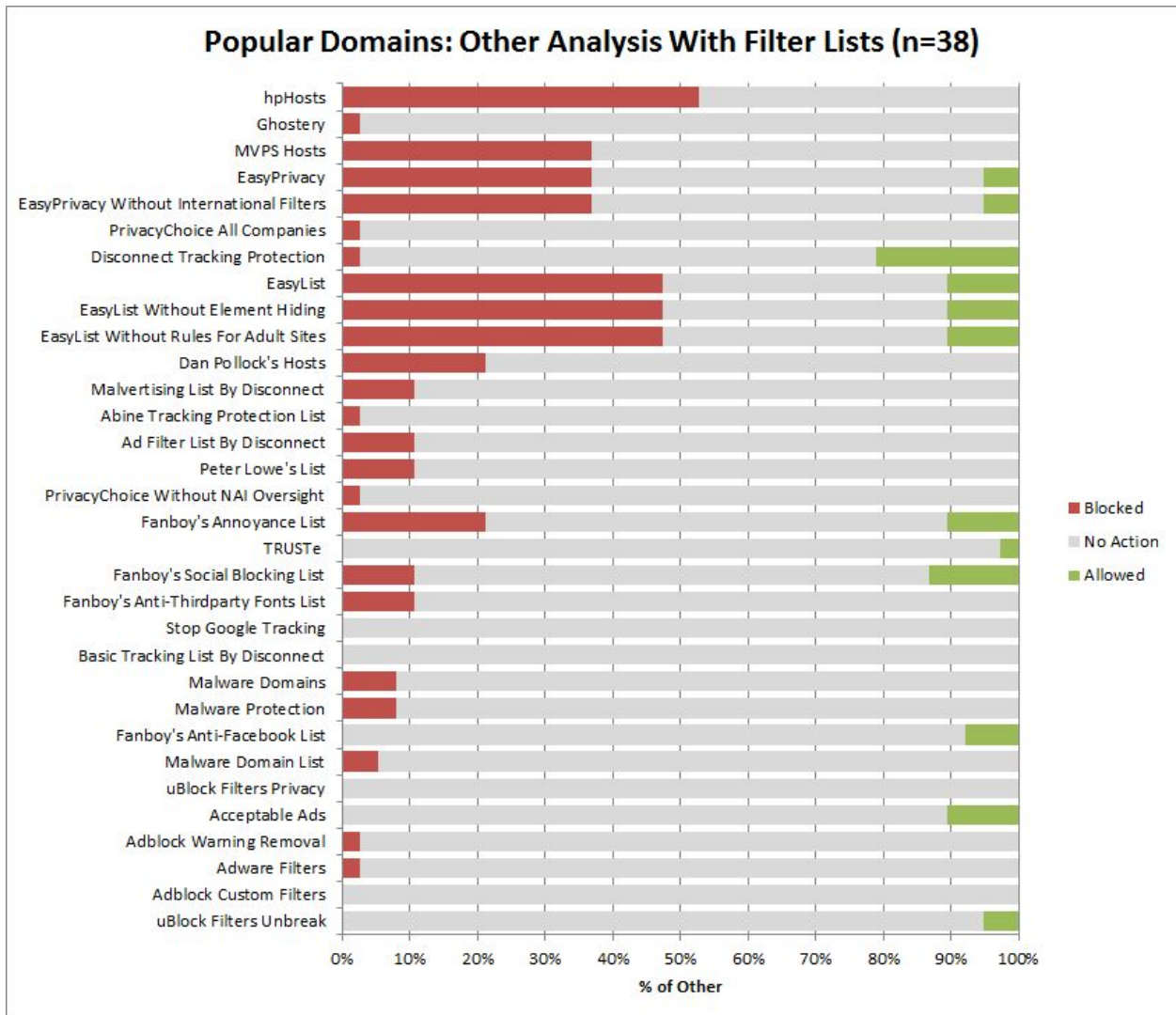
**Figure 15:** Popular Analytics domains analysis with filter lists

Figure 15 shows the percentage of blocked and allowed popular Analytics domains. Ghostery has the highest popular Analytics blocking rate with 86%. Ghostery is followed by hpHosts with a blocking rate of 84% and MVPS Hosts, with a rate of 80%. EasyPrivacy and EasyPrivacy Without International Filters share the fourth highest blocking rate with 66%, and Disconnect Tracking Protection has the fifth highest blocking rate with 50%. Ten lists have a blocking rate between 23% and 36%, and six lists have a blocking rate between 2% and 16%. Ten lists do not block any of the popular Analytics. Eleven lists allow a portion of the popular Analytics, and Disconnect Tracking Protection has the highest allowing rate with 13%.



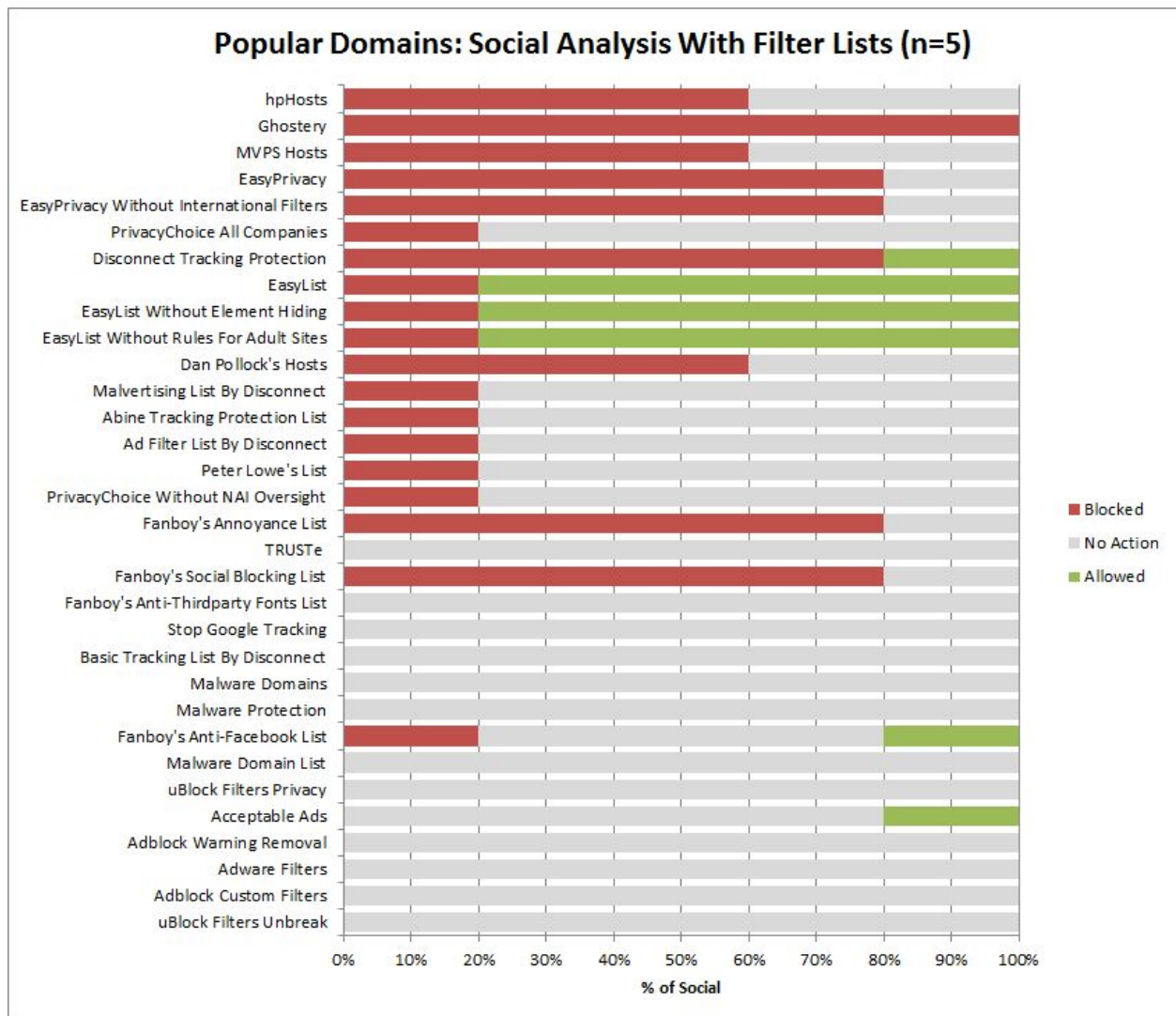
**Figure 16:** Popular Beacons analysis with filter lists

Figure 16 shows the percentage of blocked and allowed popular Beacons. Ghostery has the highest popular Beacons blocking rate with 98%. Ghostery is followed by MVPS Hosts with a rate of 95% and hpHosts with a rate of 86%. EasyPrivacy has the fourth highest blocking rate with 76% and EasyPrivacy Without International Filters has the fifth highest blocking rate with 75%. There are four lists that have a blocking rate between 42% and 64%, and there are eleven lists that have a blocking rate between 2% and 35%. Moreover, twelve filter lists do not block any of the popular Beacons. Finally, ten lists allow a portion of the popular Beacons. In this set of ten, Disconnect Tracking Protection and Acceptable Ads have the highest allowing rate with 11%.



**Figure 17:** Popular Other Third-Parties analysis with filter lists

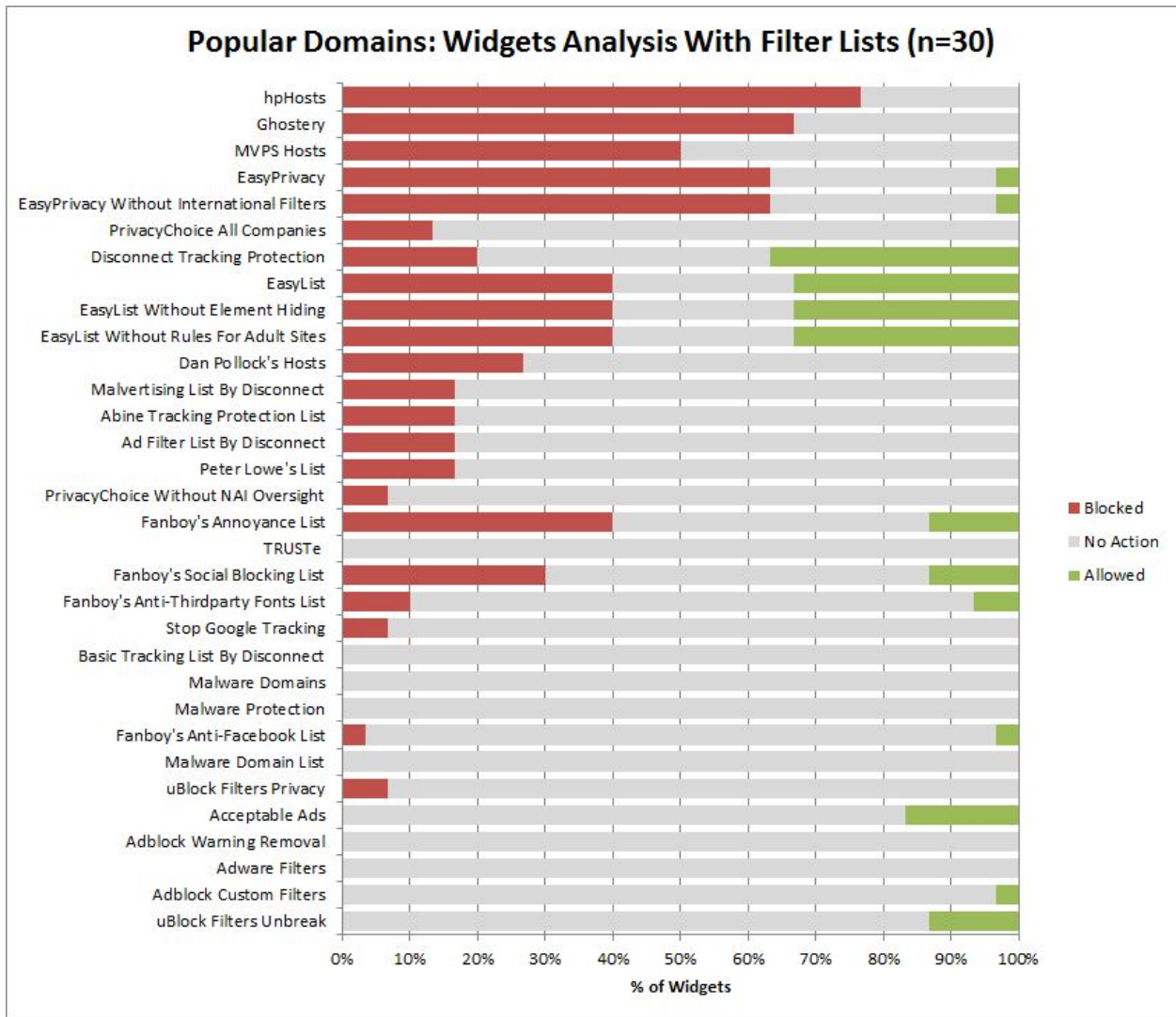
Figure 17 shows the percentage of blocked and allowed popular Other Third-Parties. hpHosts has the highest Other Third-Party blocking rate with 53%. EasyList, EasyList Without Element Hiding, and EasyList Without Rules For Adult Sites share the second highest blocking rate with 47%, and MVPS Hosts, EasyPrivacy, and EasyPrivacy Without International Filters share the third highest blocking rate with 37%. There are 17 filter lists that have a blocking rate between 3% and 21%, and eight lists do not block any of the popular Other Third-Parties. Finally, twelve lists allow a portion of the popular Other Third-Parties. In this set of twelve, Disconnect Tracking Protection has the highest allowing rate with 21%.



**Figure 18:** Popular Social domains analysis with filter lists

Figure 18 shows the percentage of blocked and allowed popular domains that fall under the Social category. Ghostery has the highest popular Social blocking rate with 100%. EasyPrivacy, EasyPrivacy Without International Filters, Disconnect Tracking Protection, Fanboy’s Annoyance List, and Fanboy’s Social Blocking List share the second highest blocking rate with 80%. MVPS Hosts, hpHosts, and Dan Pollock’s Hosts share the third highest blocking rate with 60%. Moreover, seven lists block 20% of the popular domains that fall under the Social category, and 13 lists do not block any of the domains under this category. Finally, six lists allow a portion of the popular domains in this category, and EasyList, EasyList Without Element Hiding, and EasyList Without Rules For Adult sites have the highest allowing rate with 80%.





**Figure 19:** Popular Widgets analysis with filter lists

Figure 19 shows the percentage of blocked and allowed popular Widgets. hpHosts has the highest popular Widgets blocking rate with 77%. Ghostery has the second highest blocking rate with 67%, and EasyPrivacy and EasyPrivacy Without International Filters share the third highest blocking rate with 63%. There are six lists that have a blocking rate between 30% and 50%, and there are twelve lists that have a blocking rate between 3% and 27%. Moreover, ten lists do not block any of the popular Widgets. Finally, 13 filter lists allow a portion of the popular Widgets, and Disconnect Tracking Protection has the highest allowing rate with 37%.

### 4.3.3 Effectiveness of Default Filter Lists

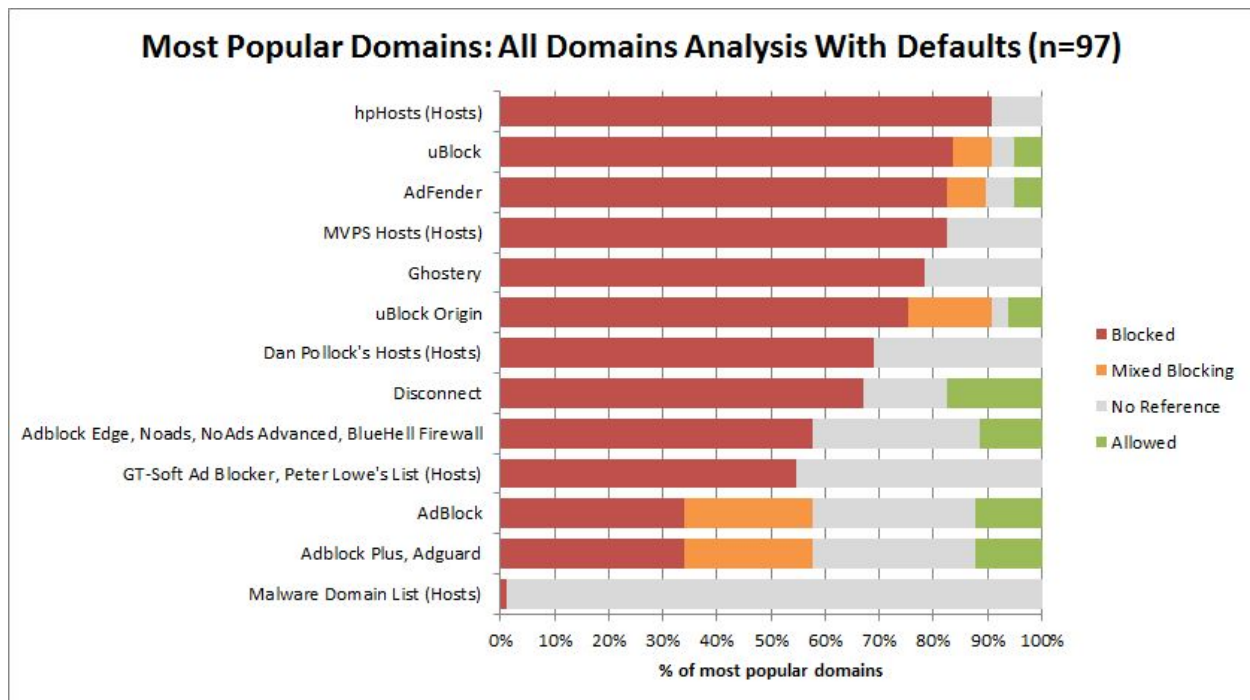
In this section, the effectiveness of ad blocker tools' default filter lists are analyzed by grouping the results from Section 4.3.2 to form the default configurations of ad blocking tools. The results are presented for most popular domains in Section 4.3.3.1, for popular domains in Section 4.3.3.2, and for the top 20 domains in Section 4.3.3.3. Since hosts files can be used independently to block ads, they are counted as ad blocking tools and are included in the analyses. Table 3 shows the 13 different sets of default filter lists that are analyzed in this section. It should be noted that a few of the tools, including the hosts files, only have one default list. Therefore, the analysis results of ad blocking tools that have one default filter list are the same as the analysis results of the given individual filter lists, which are presented in Section 4.3.2.

**Table 3:** Analyzed sets of default filter lists

Tools	Default filter lists
AdBlock [6]	Acceptable Ads [70], Adblock custom filters [71], EasyList [75], Malware protection [106]
Adblock Edge [45], Noads [62], NoAds Advanced [63], Bluhell Firewall [51]	EasyList
Adblock Plus [7], Adguard [50]	EasyList, Acceptable Ads
AdFender [17]	EasyList, EasyPrivacy [78]
Dan Pollock's Hosts (Hosts) [90]	Dan Pollock's Hosts
Disconnect [52]	Disconnect Tracking Protection [103]
Ghostery [54]	Ghostery list
GT-Soft Ad Blocker [56], Peter Lowe's List (Hosts) [87]	Peter Lowe's List
hpHosts (Hosts) [91]	hpHosts
Malware Domain List (Hosts) [92]	Malware Domain List
MVPS Hosts (Hosts) [15]	MVPS Hosts
uBlock [68]	uBlock filters, uBlock filters - Privacy, EasyList, Peter Lowe's list, EasyPrivacy, Malware Domain list, Malware Domains [86]

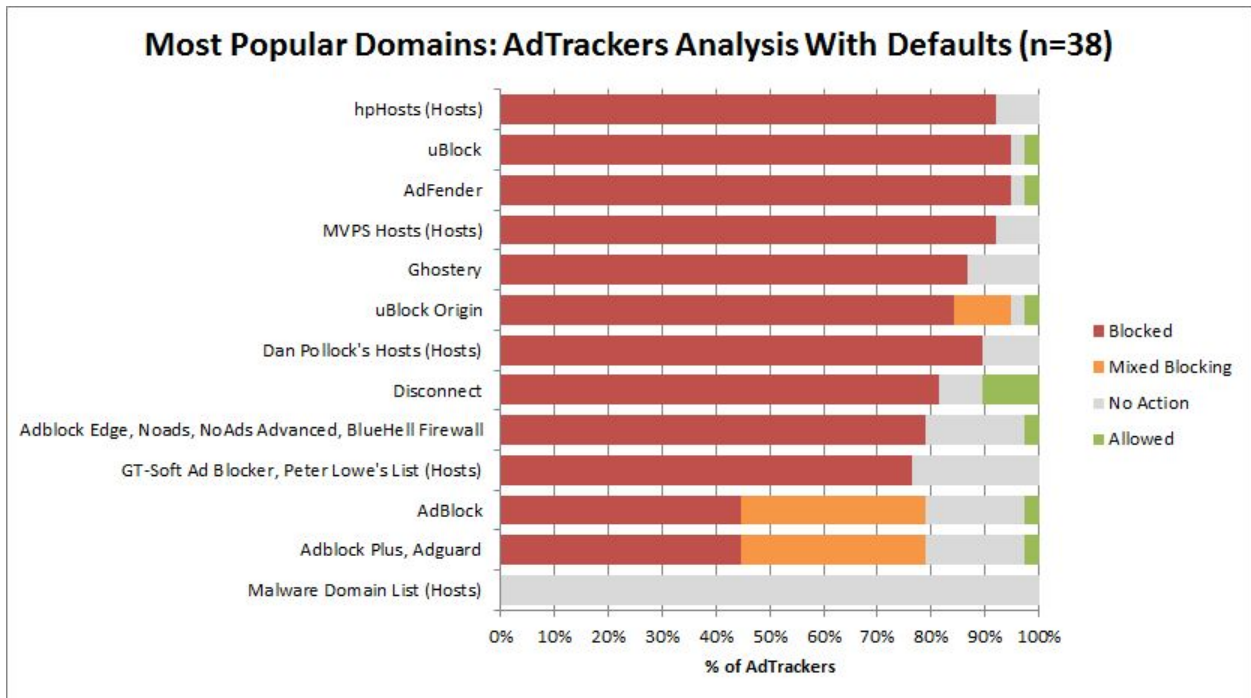
### 4.3.3.1 Most Popular Domains

Figure 20 shows the percentage of blocked and allowed most popular domains by the ad blocker defaults. The ad blocker tools are sorted in descending order regarding the percentage of blocked third-party domains.



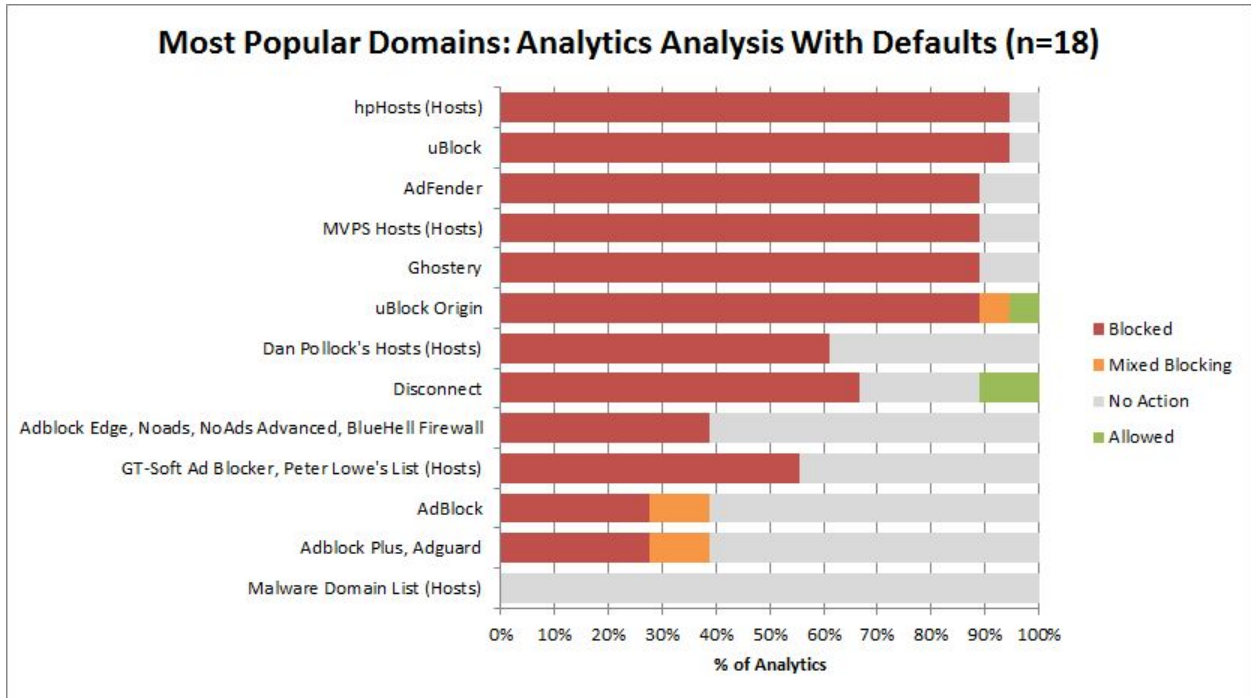
**Figure 20:** Most popular domains analysis with ad blocker defaults

Six sets of defaults have a blocking rate higher than 70%. In this sets of six, hpHosts has the highest blocking rate with 91%. uBlock has the second highest blocking rate with 84% and AdFender and MVPS Hosts share the third highest blocking rate with 83%. Ghostery has the fourth highest rate with 78% and it is followed by uBlock Origin which has a blocking rate of 75%. Four sets of defaults have a blocking rate between 55% and 69%, and three sets of defaults have a blocking rate between 1% and 34%. In addition to blocking, AdFender, uBlock, uBlock Origin, AdBlock, Ablock Plus, and Adguard also do mixed blocking for a portion of the most popular domains. Finally, seven sets of defaults allow a portion of the most popular domains. In this set of seven, Disconnect's defaults have the highest allowing rate with 18%.



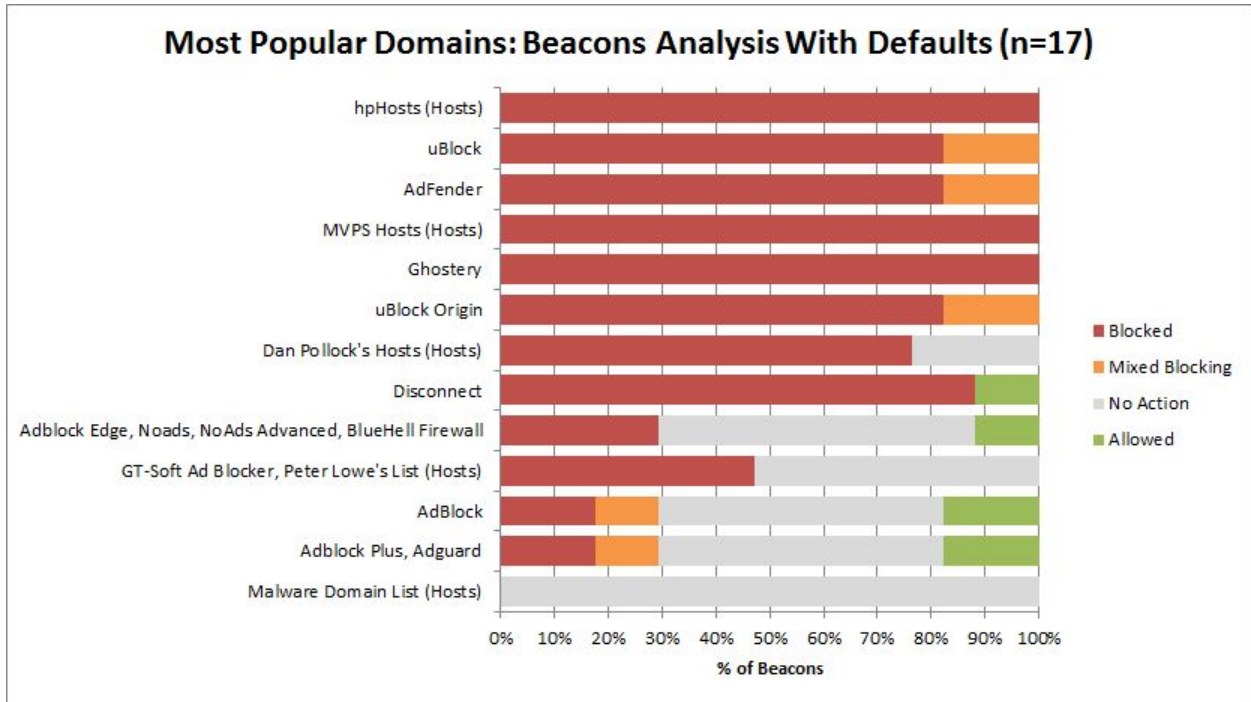
**Figure 21:** Most popular AdTrackers analysis with ad blocker defaults

Figure 21 shows the percentage of blocked and allowed most popular AdTrackers. Ten sets of defaults block more than 70% of the most popular AdTrackers. AdFender and uBlock share the highest blocking rate with 95%, and hpHosts and MVPS Hosts share the second highest rate with 92%. Dan Pollock's Hosts has the third highest blocking rate with 90%. Two sets of defaults have a blocking rate of 45%, and one set does not block any of the most popular AdTrackers. In addition to blocking, AdBlock, Adblock Plus, Adguard, and uBlock Origin also do mixed blocking regarding most popular AdTrackers. Finally, seven defaults allow a portion of the most popular AdTrackers, and Disconnect has the highest allowing rate with 11%.



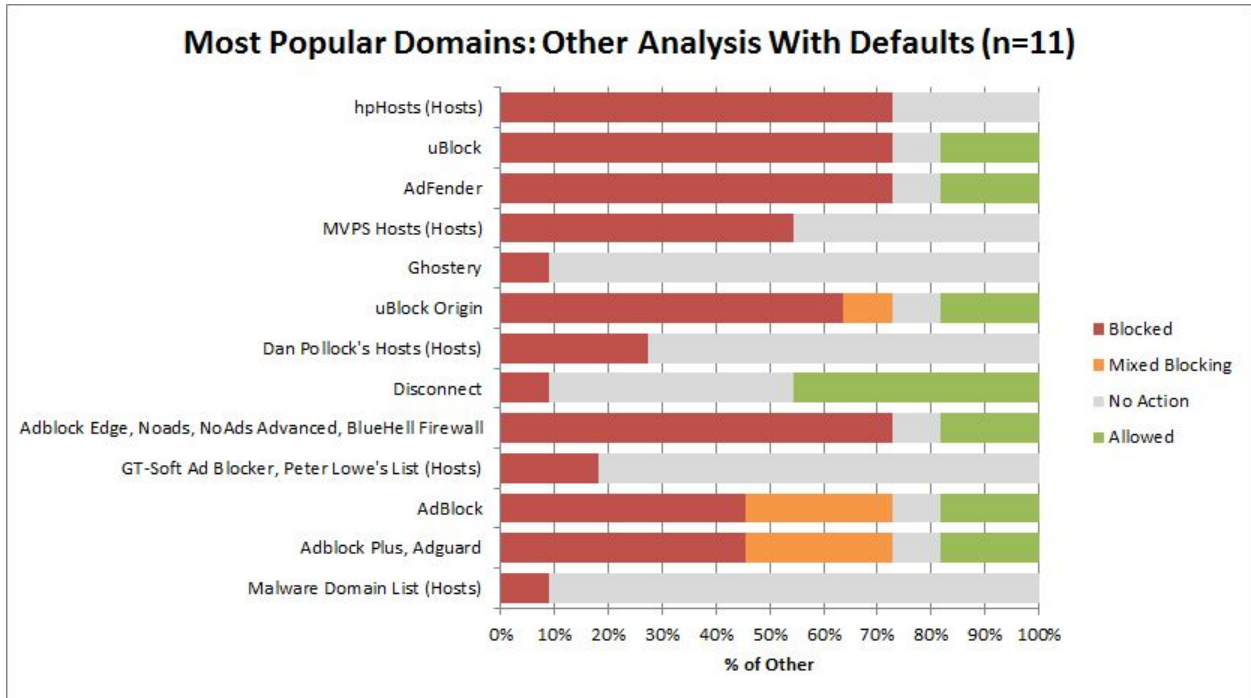
**Figure 22:** Most popular Analytics domains analysis with ad blocker defaults

Figure 22 shows the percentage of blocked and allowed most popular Analytics domains. Seven sets of defaults block more than 70% of the most popular Analytics domains. uBlock and hpHosts have the highest blocking rate with 94%, and AdFender, MVPS Hosts, Ghostery, and uBlock Origin share the second highest blocking rate with 89%. Disconnect has the third highest most popular Analytics blocking rate with 67%. Five sets of defaults have a blocking rate between 28% and 61%, and one set does not block any of the most popular Analytics domains. In addition to blocking, AdBlock, Adblock Plus, Adguard, and uBlock Origin also do mixed blocking regarding most popular Analytics domains. Finally, uBlock Origin and Disconnect allow a portion of the most popular Analytics domains, and Disconnect has the highest allowing rate with 11%.



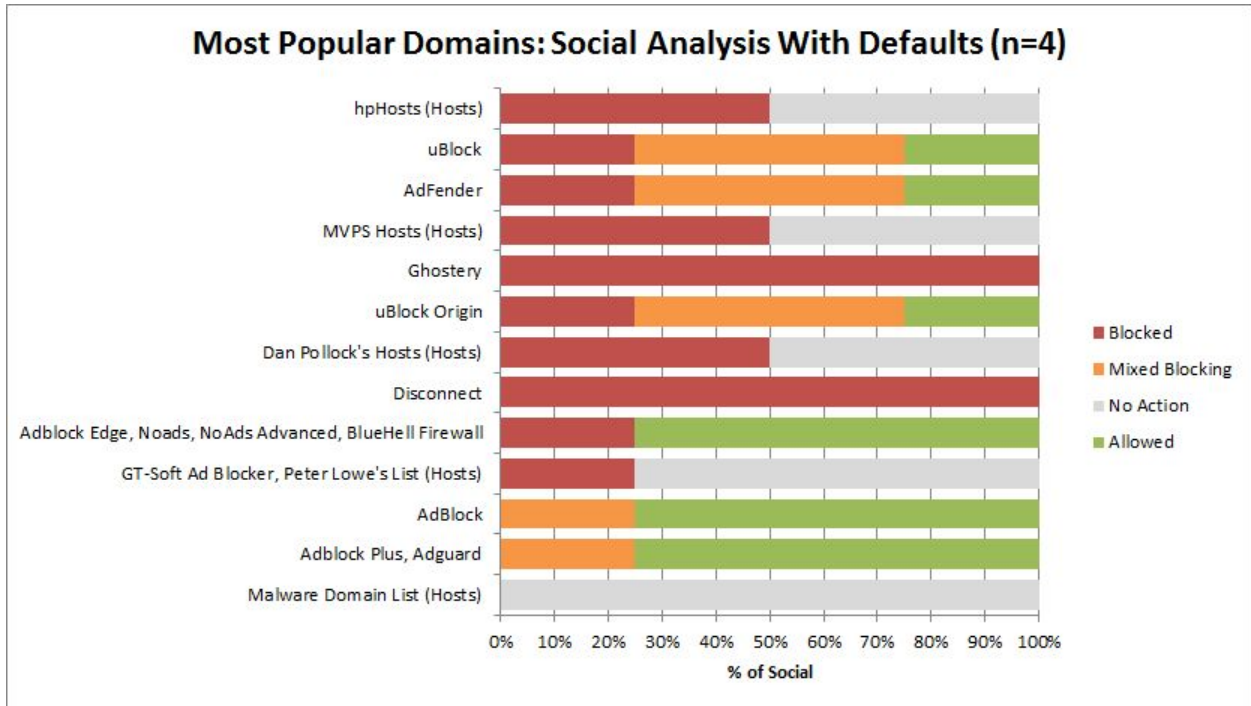
**Figure 23:** Most popular Beacons analysis with ad blocker defaults

Figure 23 shows the percentage of blocked and allowed most popular Beacons. Eight sets of defaults have a blocking rate higher than 70%. MVPS Hosts, Ghostery, and hpHosts share the highest most popular Beacons blocking rate with 100%. Disconnect has the second highest blocking rate with 88%, and uBlock Origin has the third highest blocking rate with 82%. Four sets of defaults have a blocking rate between 18% and 47%, and one default set does not block any of the most popular Beacons. In addition to blocking, AdFender, uBlock, uBlock Origin, AdBlock, Adblock Plus, and Adguard also do mixed blocking regarding most popular Beacons. Finally, four sets of defaults allow a portion of the most popular Beacons and Adblock Plus, Adguard, and AdBlock share the highest allowing rate with 18%.



**Figure 24:** Most popular Other domains analysis with ad blocker defaults

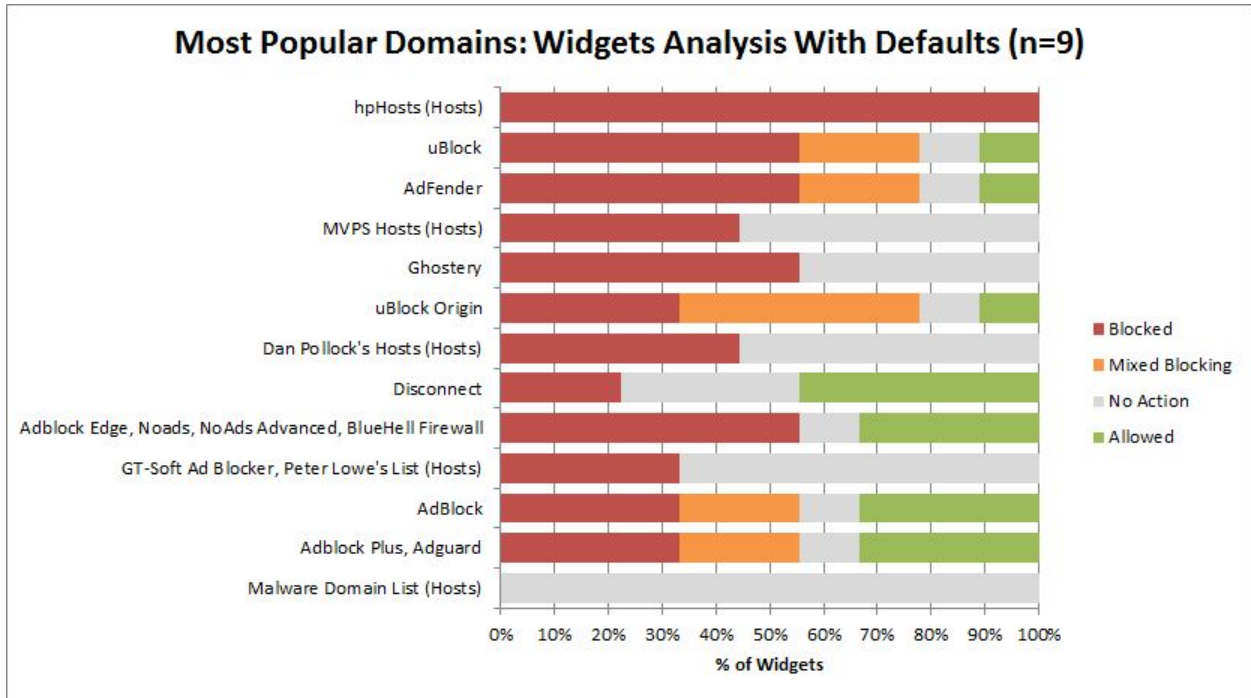
Figure 24 shows the percentage of blocked and allowed most popular Other domains. Four sets of defaults have a blocking rate higher than 70%. AdFender, uBlock, hpHosts, Adblock Edge, Noads, NoAds Advanced, and Bluehell Firewall share highest rate of blocking with 73%. uBlock Origin has the second highest blocking rate with 64%, and MVPS Hosts has the third highest blocking rate with 55%. Seven sets of defaults have a blocking rate between 9% and 46%. In addition to blocking, uBlock Origin, AdBlock, Adblock Plus, and Adguard also do mixed blocking regarding most popular Other domains. Finally, seven sets of defaults allow a portion of the most popular Other domains, and Disconnect has the highest allowing rate with 46%.



**Figure 25:** Most popular Social domains analysis with ad blocker defaults

Figure 25 shows the percentage of blocked and allowed most popular Social domains. Ghostery and Disconnect share the highest blocking rate with 100%. MVPS Hosts, hpHosts, Dan and Pollock’s Hosts share the second highest blocking rate with 50%. Five sets of defaults share the third highest blocking rate with 25%. In addition to blocking, AdFender, uBlock, uBlock Origin, AdBlock, Adblock Plus, and Adguard do mixed blocking regarding most popular Social domains. Finally, six sets of defaults allow a portion of the most popular Social domains, and three sets of defaults share highest allowing rate with 75%.



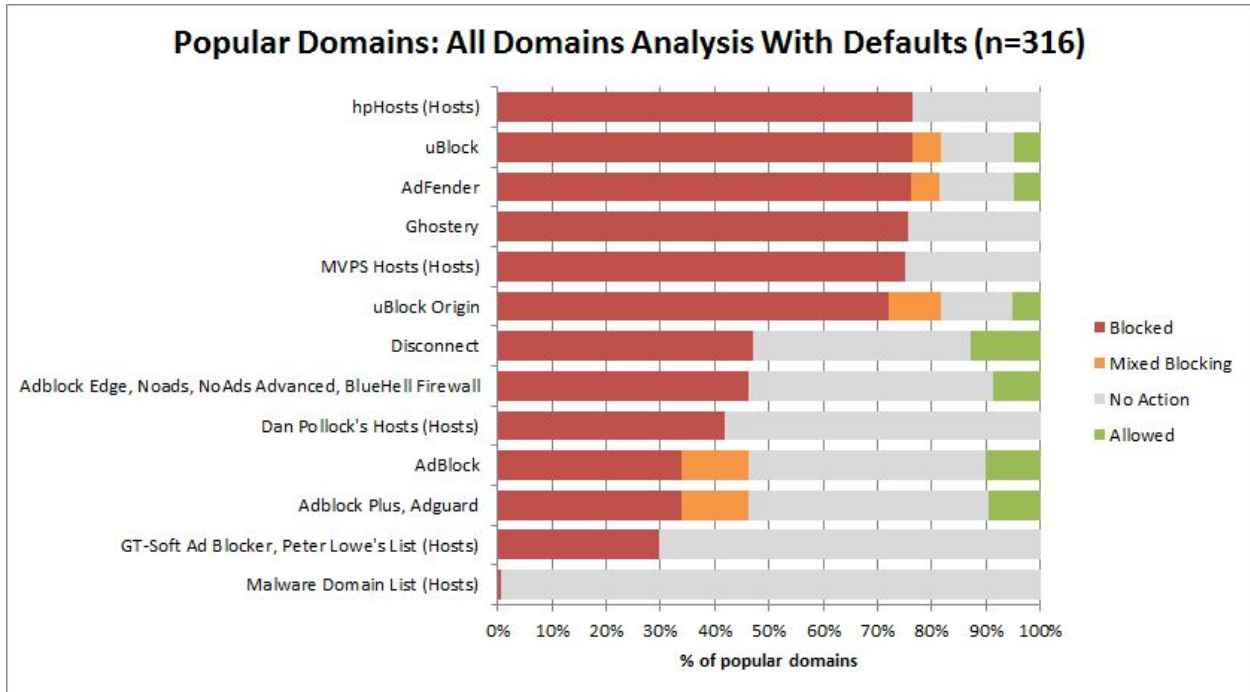


**Figure 26:** Most popular Widgets analysis with ad blocker defaults

Figure 26 shows the percentage of blocked and allowed most popular Widgets. hpHosts has the highest most popular Widgets blocking rate with 100%. AdFender, uBlock, Ghostery, Adblock Edge, Noads, NoAds Advanced, and Bluehell Firewall share the second highest rate of blocking with 56%. MVPS Hosts and Dan Pollock’s Hosts share the third highest blocking rate with 44%. Five sets of defaults have blocking rates between 22% and 33%, and one set does not block any of the most popular Widgets. In addition to blocking, AdFender, uBlock. uBlock Origin, AdBlock, Adblock Plus, and Adguard also do mixed blocking regarding the most popular Widgets. Finally, seven sets of defaults allow a portion of the most popular Widgets, and Disconnect has the highest allowing rate with 44%.

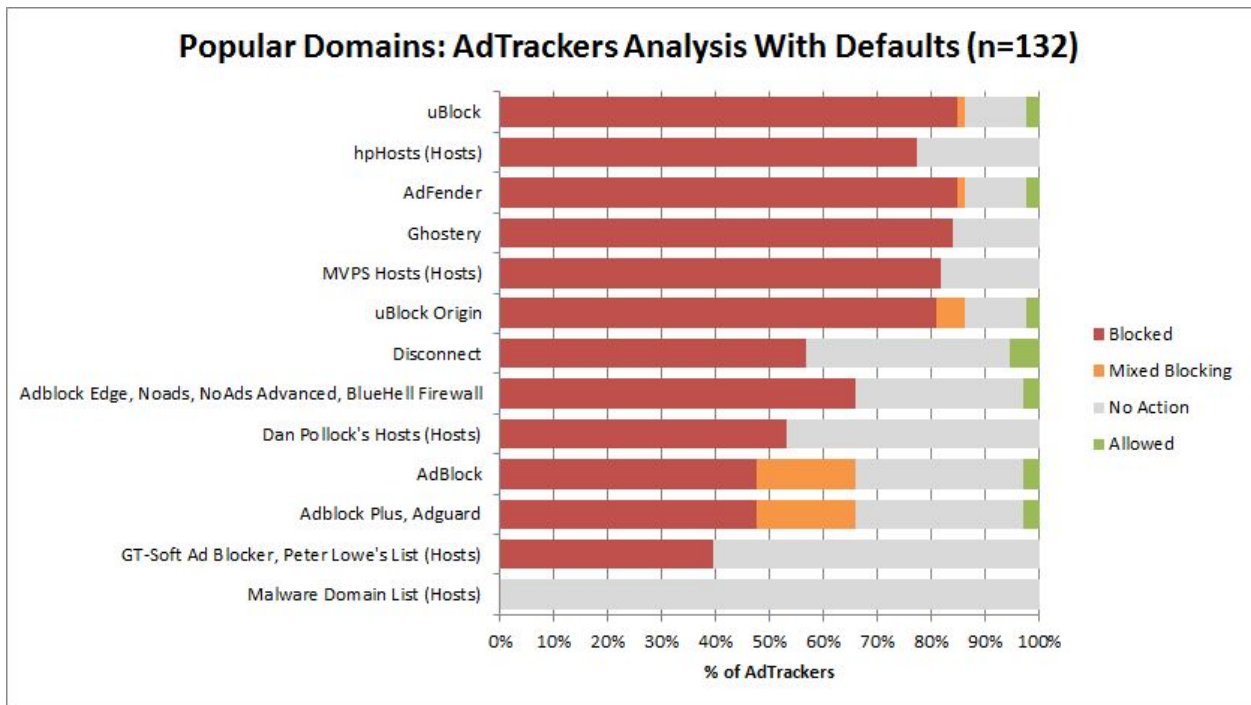
### 4.3.3.2 Popular Domains

Figure 27 shows the percentage of blocked and allowed popular domains by the ad blocker defaults. The ad blocker tools are sorted in descending order regarding the percentage of blocked third-party domains.



**Figure 27:** Popular domains analysis with ad blocker defaults

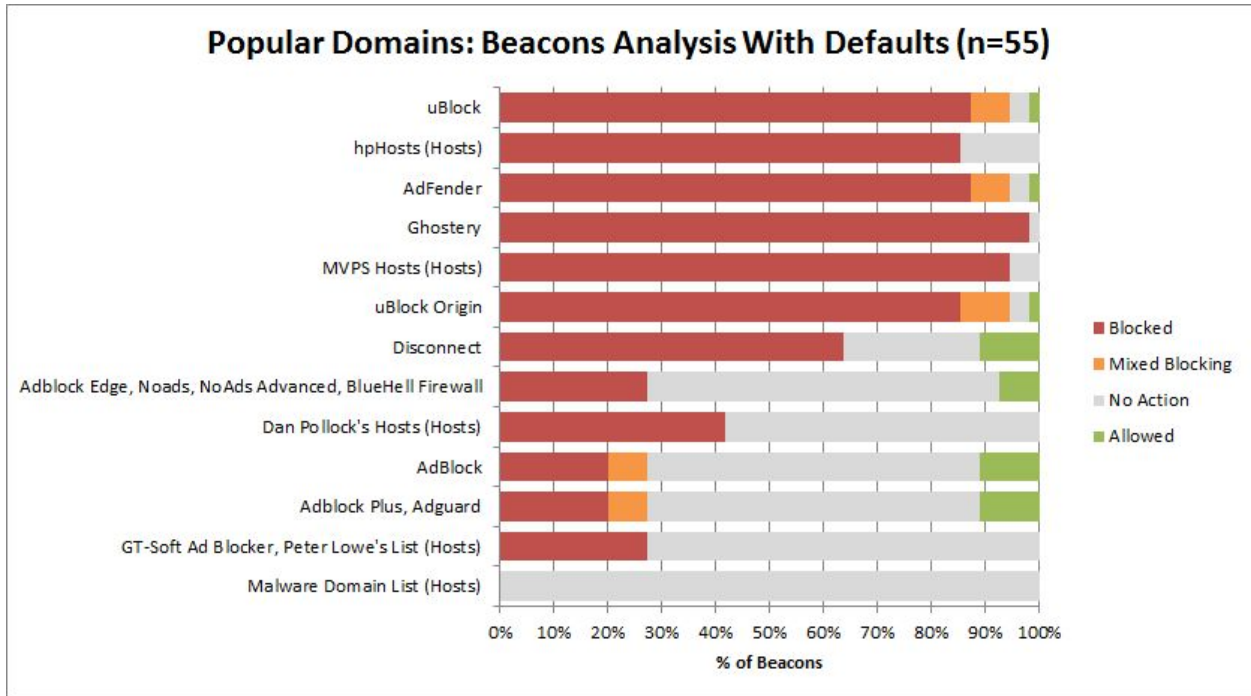
Six sets of defaults block more than 70% of the popular domains. uBlock and hpHosts share the highest blocking rate with 77%. AdFender has the second highest blocking rate with 76%, and Ghostery has the third highest blocking rate with 76%. Six sets of defaults have a blocking rate between 30% and 47%, and Malware Domain List has a blocking rate of 1%. In addition to blocking, AdFender, uBlock, uBlock Origin, AdBlock, Adblock Plus, and Adguard also do mixed blocking regarding popular domains. Finally, seven sets of defaults allow a portion of popular domains, and Disconnect has the highest allowing rate with 13%.



**Figure 28:** Popular AdTrackers analysis with ad blocker defaults

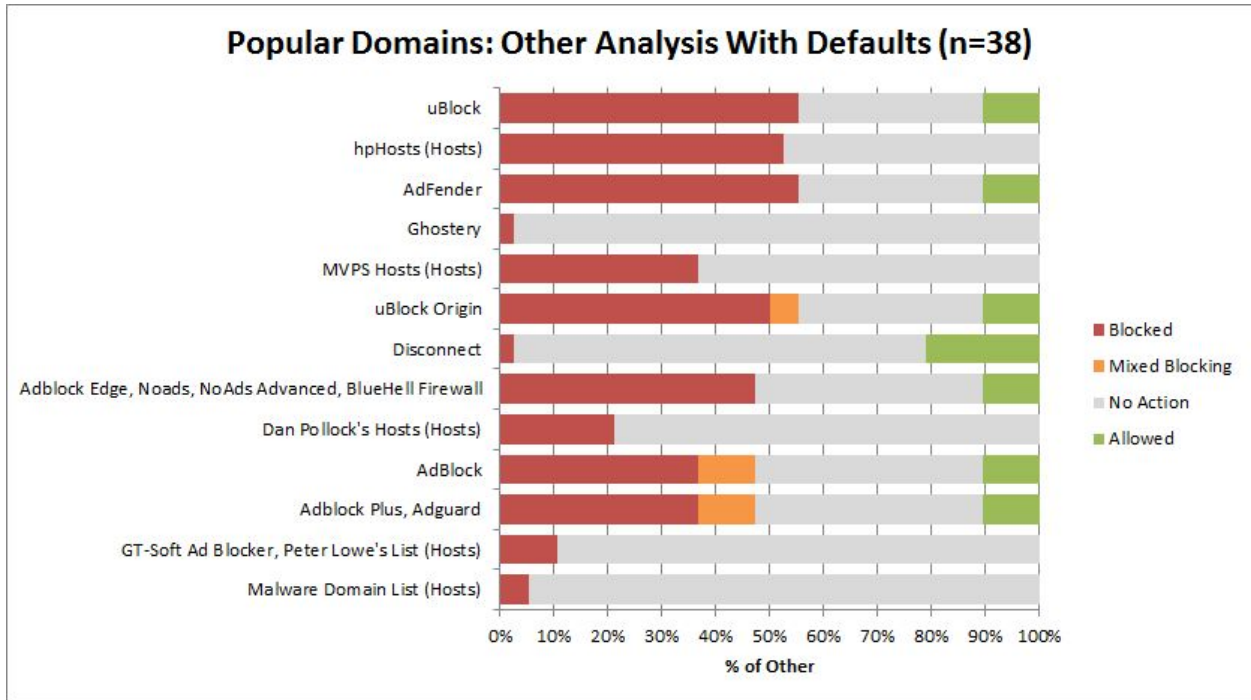
Figure 28 shows the percentage of blocked and allowed popular AdTrackers. Six sets of defaults have a popular AdTrackers blocking rate higher than 70%. AdFender and uBlock share the highest blocking rate with 85%. Ghostery has the second highest blocking rate with 84%, and MVPS Hosts has the third highest blocking rate with 82%. Six sets of defaults have blocking rates between 39% and 66%, and Malware Domain List does not block any of the popular AdTrackers. In addition to blocking, uBlock, AdFender, uBlock Origin, AdBlock, Adblock Plus, and Adguard also do mixed blocking regarding popular AdTrackers. Finally, seven sets of defaults allow a portion of the popular AdTrackers, and Disconnect has the highest allowing rate with 5%.





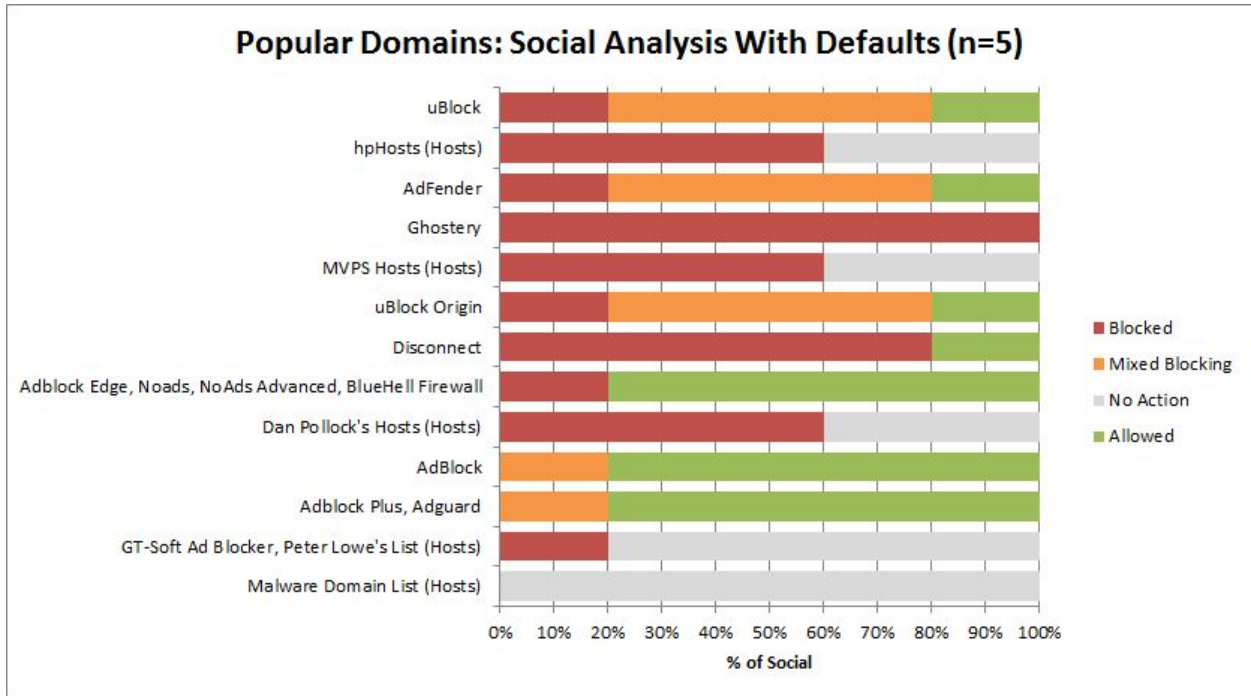
**Figure 30: Popular Beacons analysis with ad blocker defaults**

Figure 30 shows the percentage of blocked and allowed popular Beacons. Six sets of defaults block more than 70% of the popular Beacons. Ghostery has the highest blocking rate with 98%, MVPS Hosts has the second highest blocking rate with 95%, and AdFender and uBlock share the third highest blocking rate with 87%. Six sets of defaults have blocking rates between 20% and 65%, and Malware Domain List does not block any of the popular Beacons. In addition to blocking, uBlock, AdFender, uBlock Origin, AdBlock, Adblock Plus, and Adguard also do mixed blocking regarding popular Beacons. Finally, seven sets of defaults allow a portion of the popular Beacons, and Disconnect has the highest allowing rate with 11%.



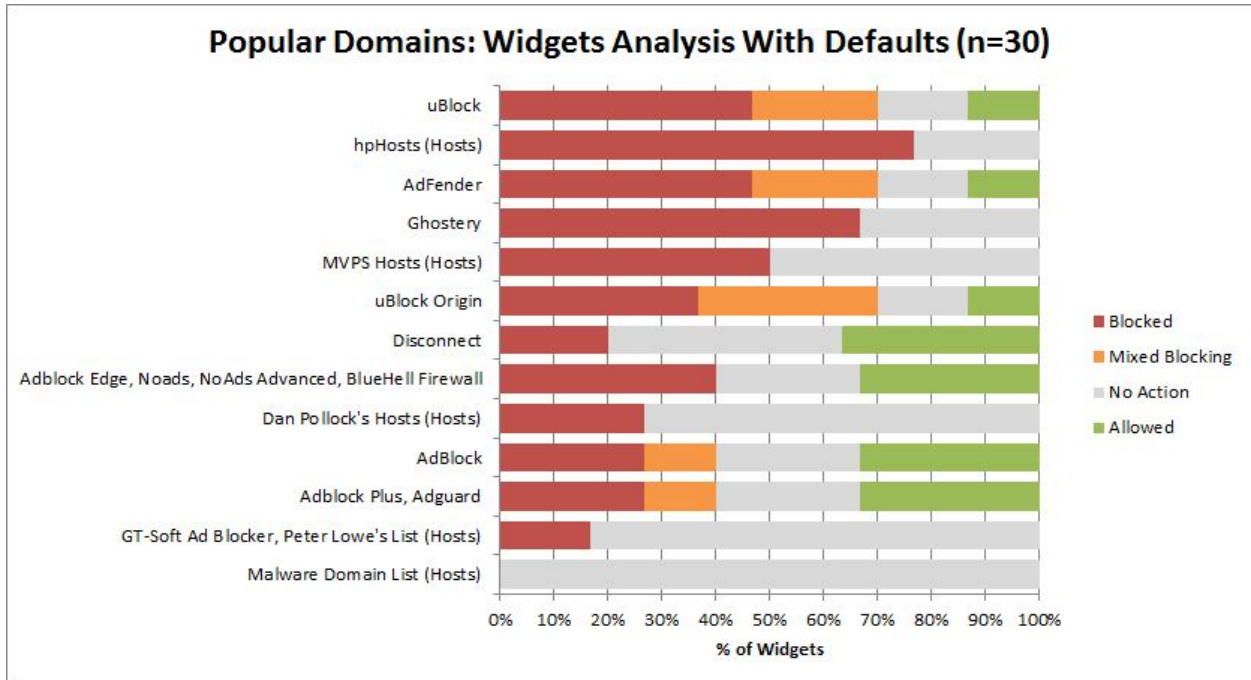
**Figure 31:** Popular Other domains analysis with ad blocker defaults

Figure 31 shows the percentage of blocked and allowed popular Other domains. AdFender and uBlock share the highest popular Other domains blocking rate with 55%. hpHosts share has the second highest blocking rate with 53%, and uBlock Origin has the third highest blocking rate with 50%. Five sets of defaults have blocking rates between 22% and 47%, and four sets of defaults have blocking rates between 3% and 11%. In addition to blocking, uBlock Origin, AdBlock, Adblock Plus, and Adguard also do mixed blocking regarding popular Other domains. Finally, seven sets of defaults allow a portion of the popular Other domains, and Disconnect has the highest allowing rate with 22%.



**Figure 32: Popular Social domains analysis with ad blocker defaults**

Figure 32 shows the percentage of blocked and allowed popular Social domains. Ghostery has the highest popular Social domains blocking rate with 100%, and Disconnect has the second highest blocking rate with 80%. MVPS Hosts, hpHosts, and Dan Pollock’s Hosts share the third highest blocking rate with 60%. Five sets of domains have a blocking rate of 20%. In addition, Adblock, AdBlock Plus, and Aduard only do mixed blocking and allowing. Moreover, in addition to blocking, uBlock, AdFender, and uBlock Origin also do mixed blocking regarding popular Social domains. Finally, seven sets of defaults allow a portion of the popular Social domains, and Adblock Edge, Noads, NoAds Advanced, Bluhell Firewall, Adblock Plus, Aduard, and AdBlock share the highest allowing rate with 80%.



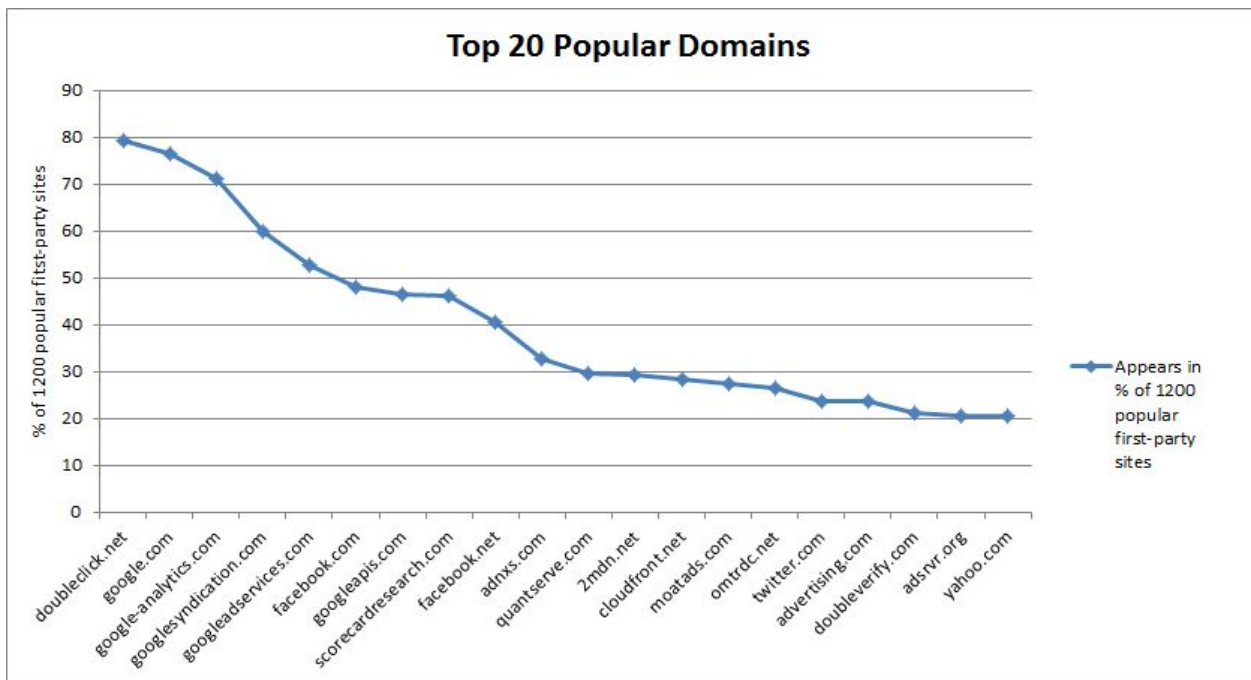
**Figure 33:** Popular Widgets analysis with ad blocker defaults

Figure 33 shows the percentage of blocked and allowed popular Widgets. hpHosts has the highest popular Widgets blocking rate with 77%. Ghostery has the second highest blocking rate with 67%, and MVPS Hosts has the third highest blocking rate with 50%. nine sets of defaults have blocking rates between 17% and 47%, and Malware Domain List does not block any of the popular Widgets. In addition to blocking, uBlock, AdFender, uBlock Origin, ADBlock, Adblock Plus, and Adguard also do mixed blocking regarding popular Widgets. Finally, seven sets of defaults allow a portion of the popular Widgets, and Disconnect has the highest allowing rate with 37%.

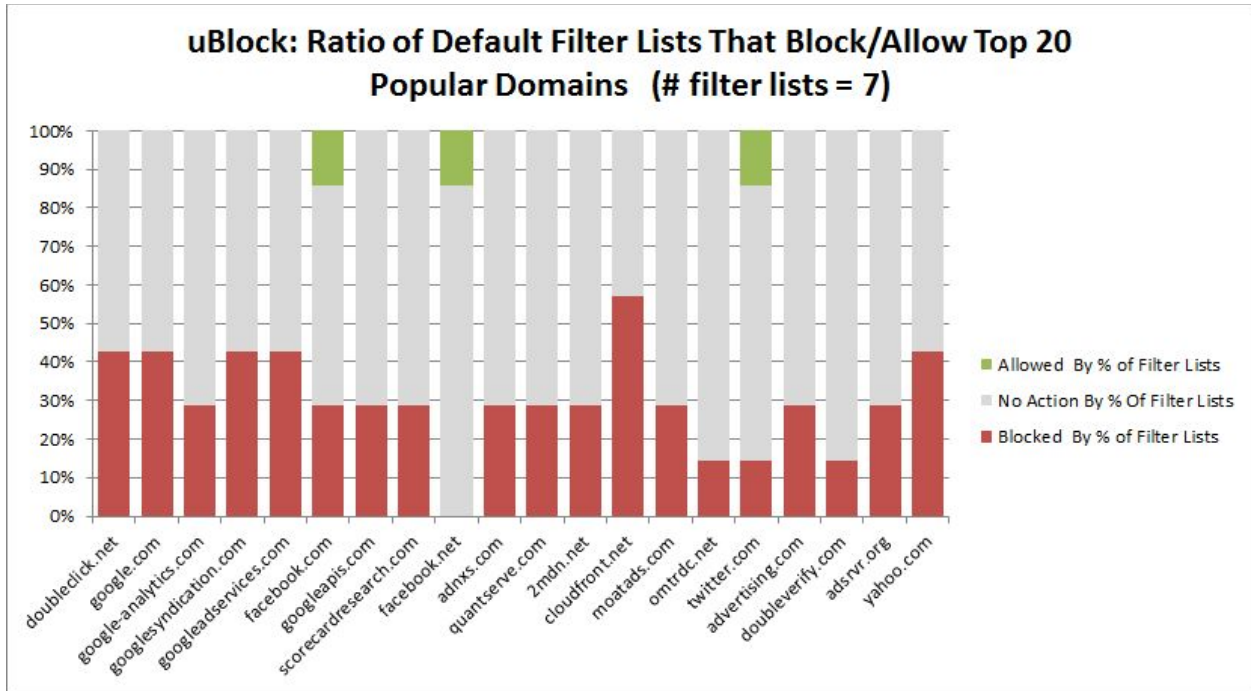


### 4.3.3.3 Top 20 Third-Party Domains

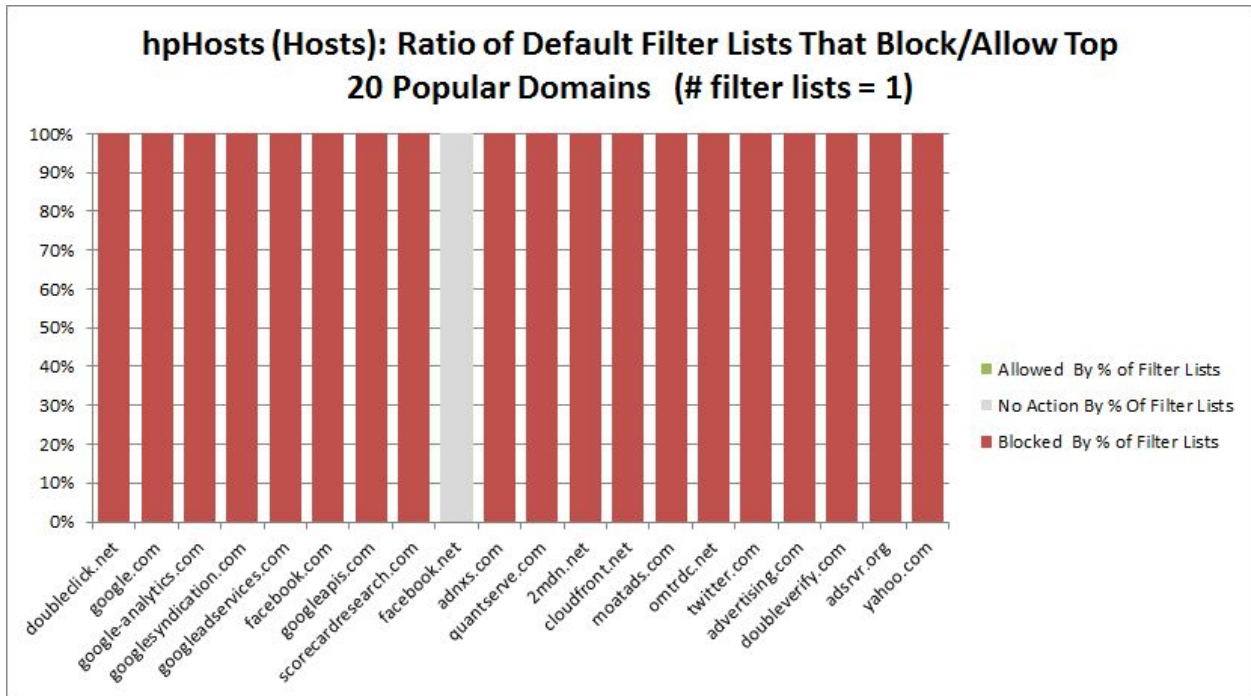
In this section, default filter lists analyses based on the top 20 popular third-party domains are presented. The names of default filter lists of the ad blocking tools can be found in Table 3. The order of presented analyses of ad blocking tools in this section are the same as the order seen on figures in Section 4.3.3.2. Figure 34 shows the top 20 popular third-party domains and the percentage of the popular ~1200 first-party sites that the third-party domains appear in. With 79%, doubleclick.net has the highest appearance rate, and it is followed by google.com with a 77% appearance rate. In addition, google-analytics.com has an appearance rate of 71%. The domain with the lowest appearance rate in the top 20 domains is yahoo.com with 20%. Key points from Figure 35 through 47 are highlighted on page 86.



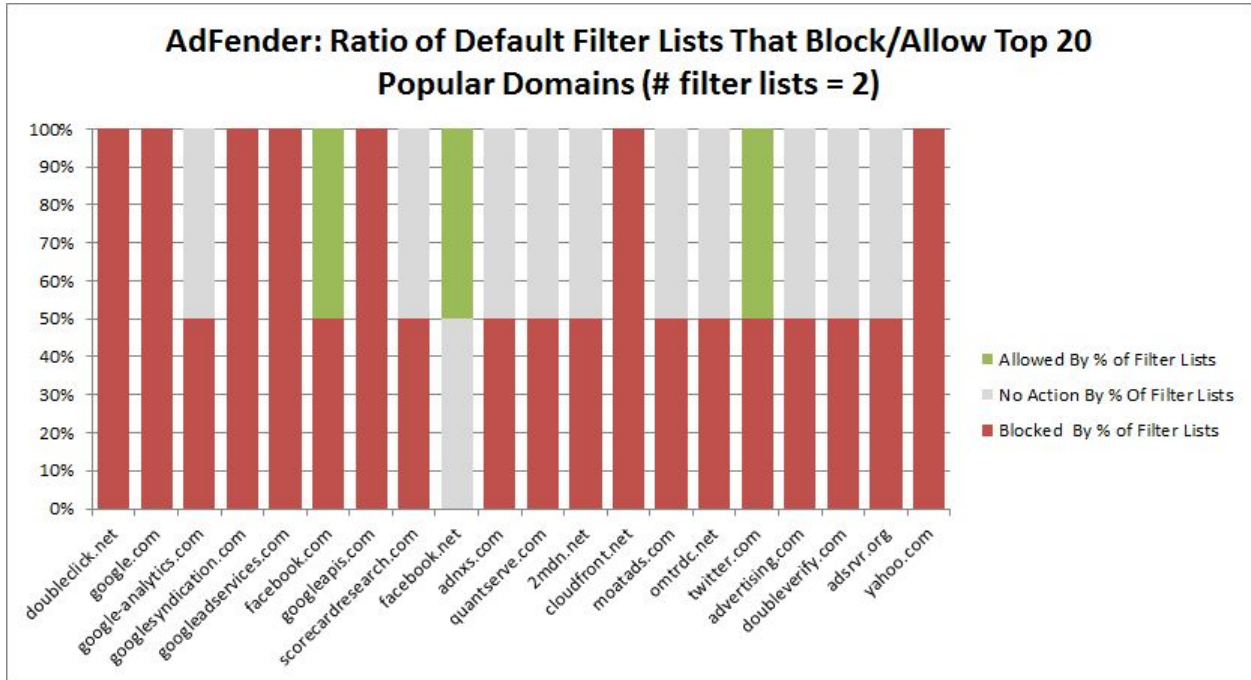
**Figure 34:** Top 20 popular domains and their percentage of appearance in the popular first-party sites



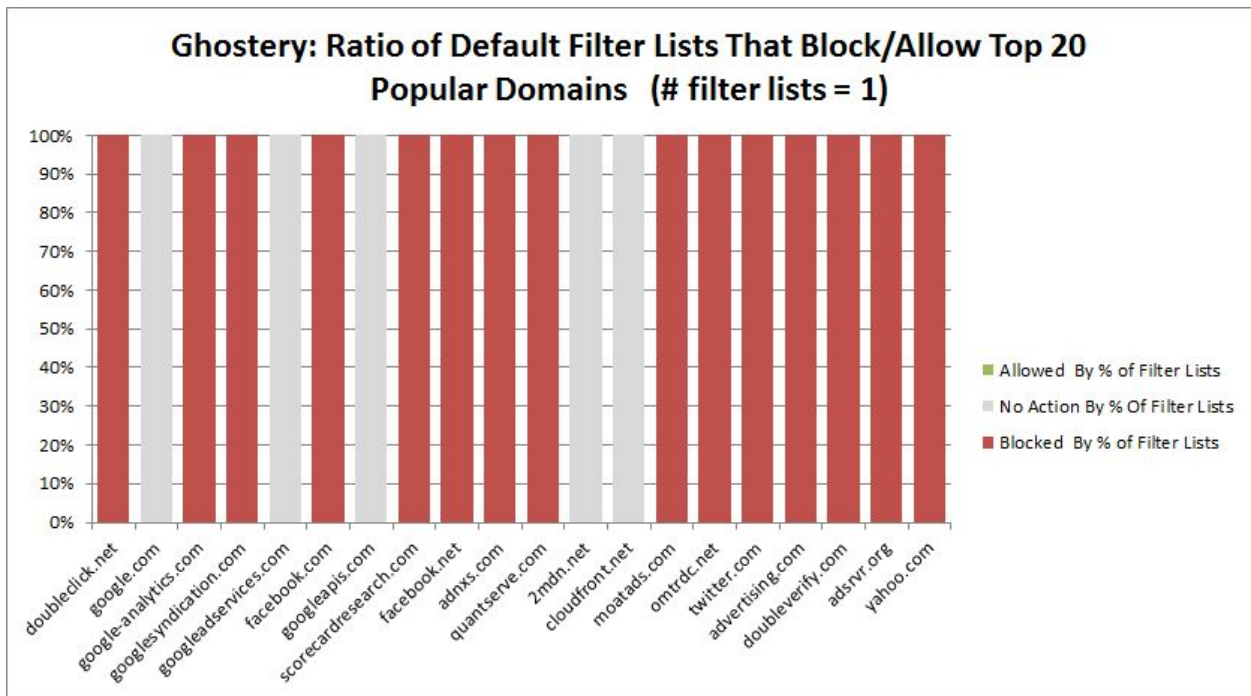
**Figure 35:** Top 20 domains analysis with uBlock



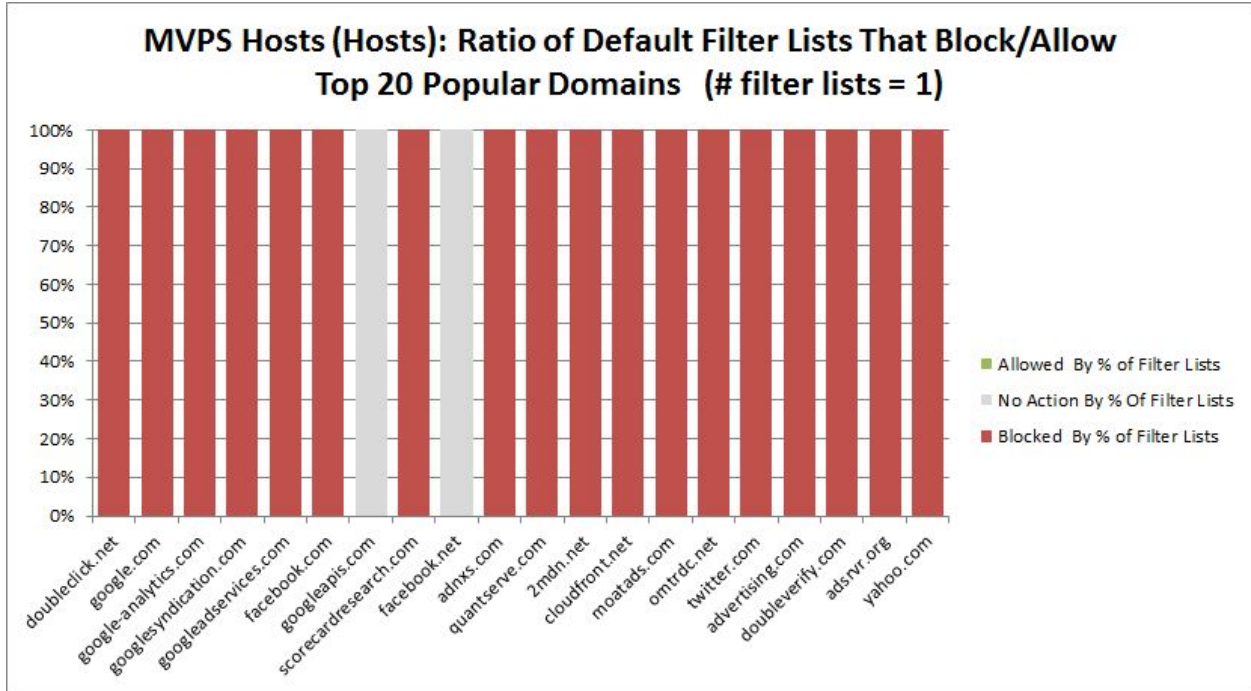
**Figure 36:** Top 20 domains analysis with hpHosts



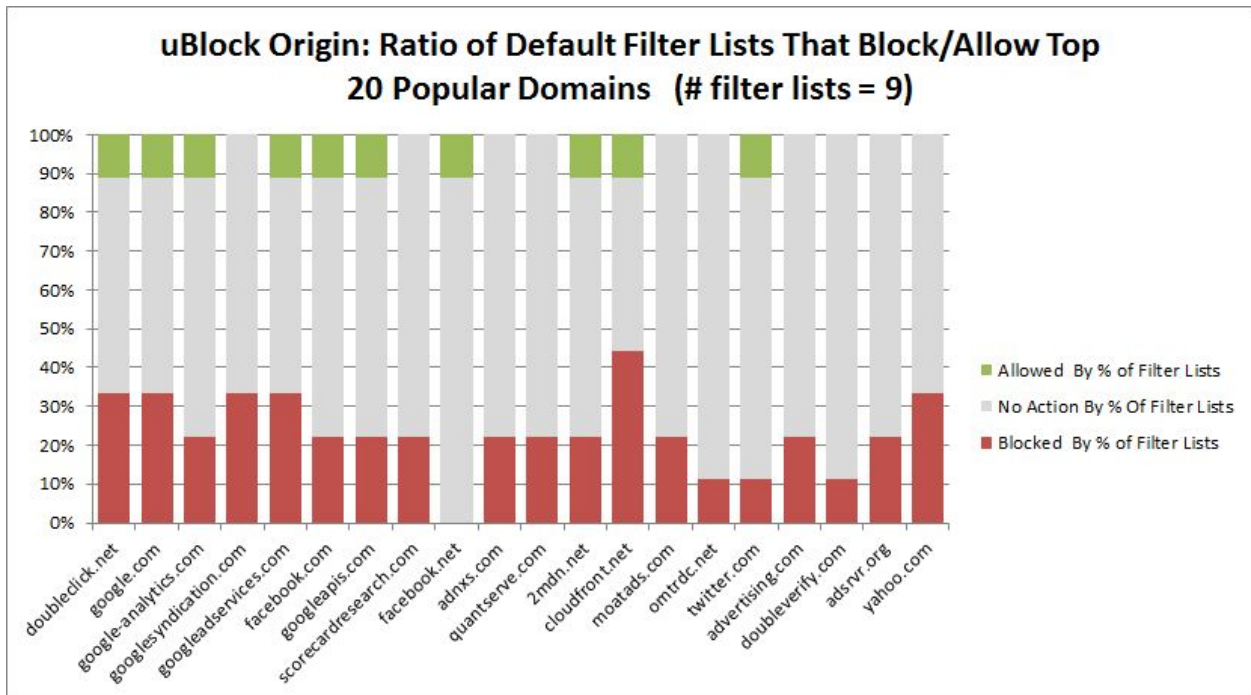
**Figure 37:** Top 20 domains analysis with AdFender



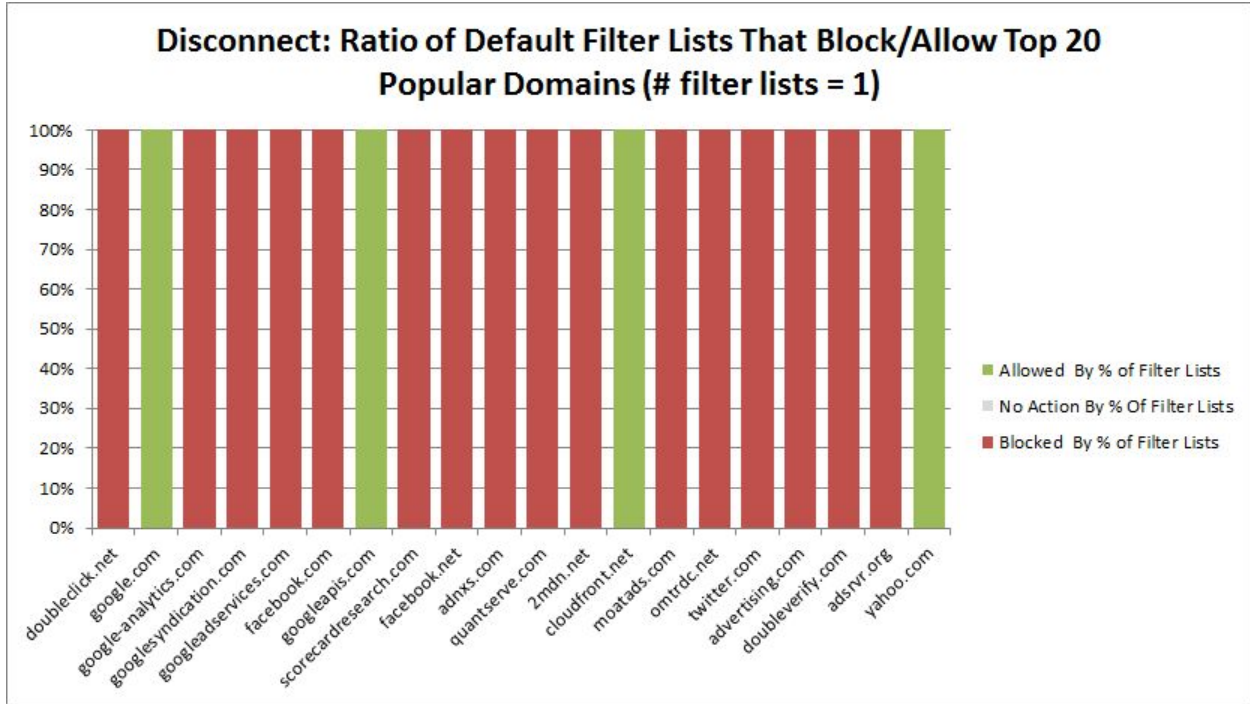
**Figure 38:** Top 20 domains analysis with Ghostery



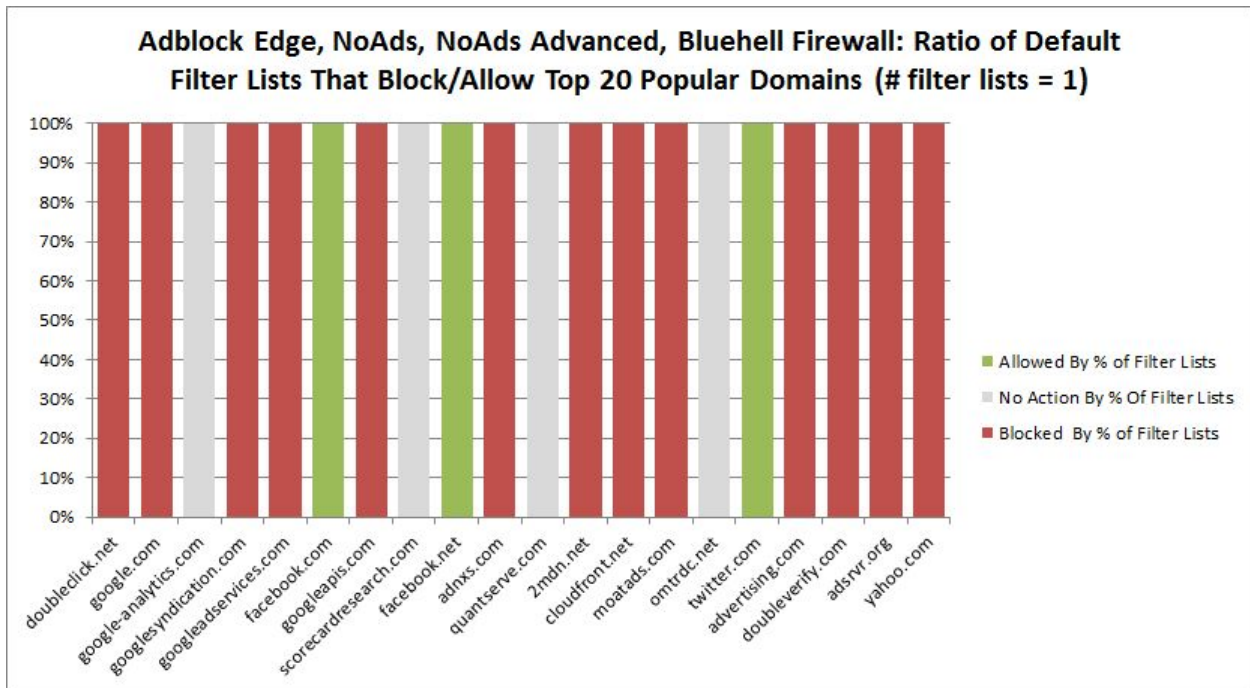
**Figure 39:** Top 20 domains analysis with MVPS Hosts



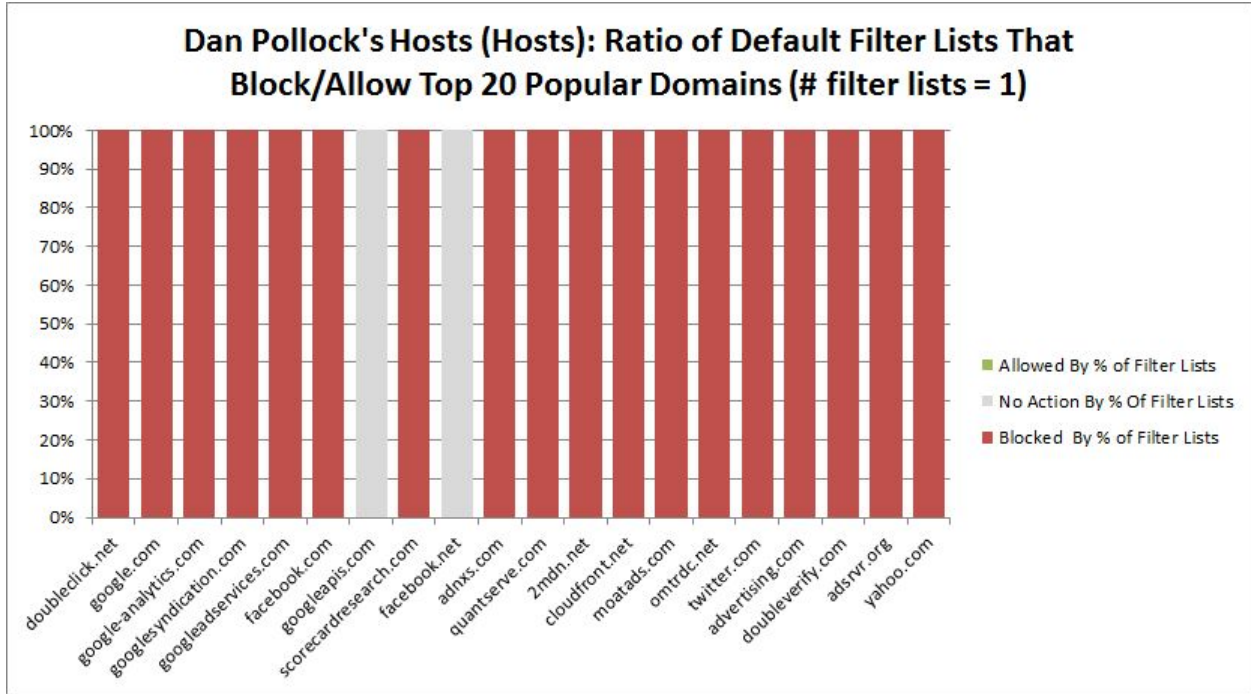
**Figure 40:** Top 20 domains analysis with uBlock Origin



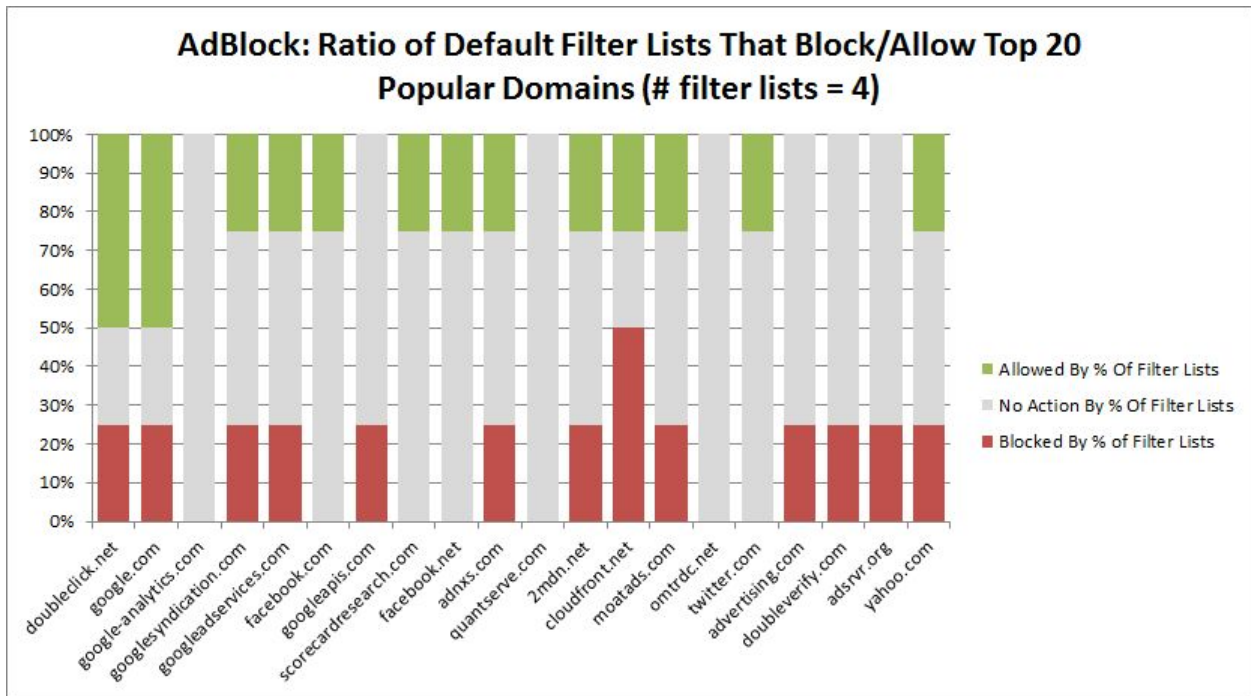
**Figure 41:** Top 20 domains analysis with Disconnect



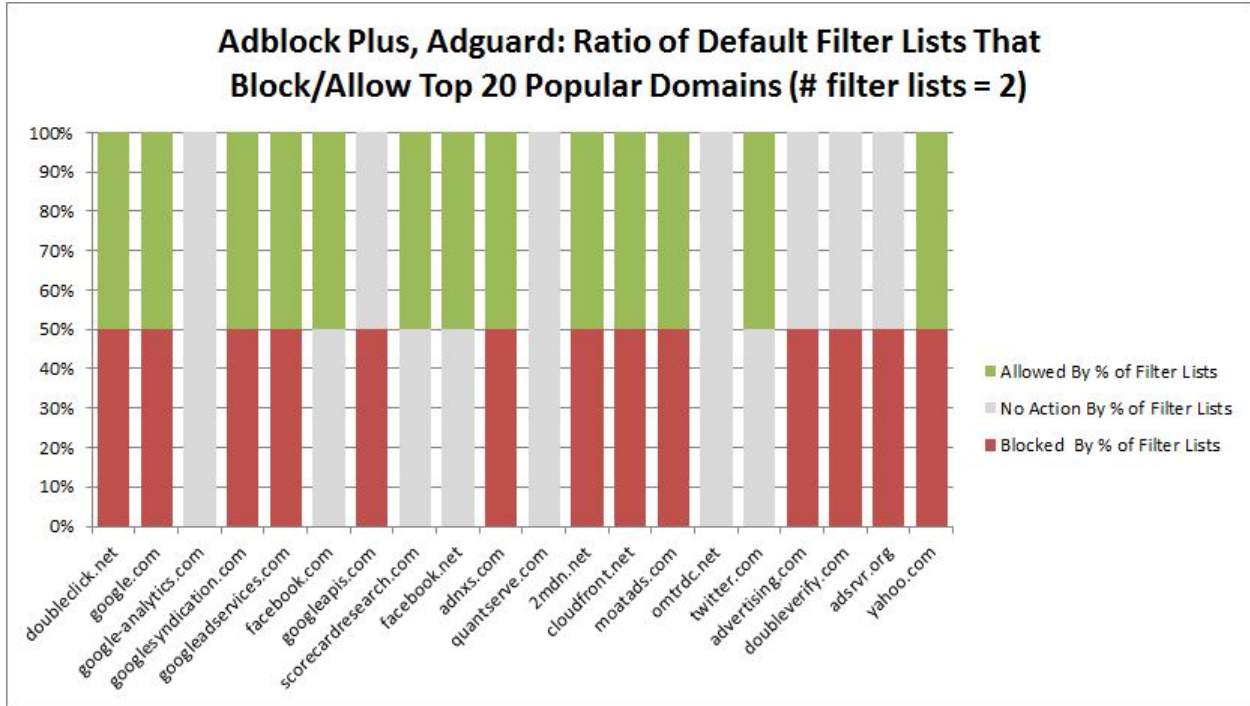
**Figure 42:** Top 20 domains analysis with Adblock Edge, NoAds, NoAds Advanced, and Bluehell Firewall



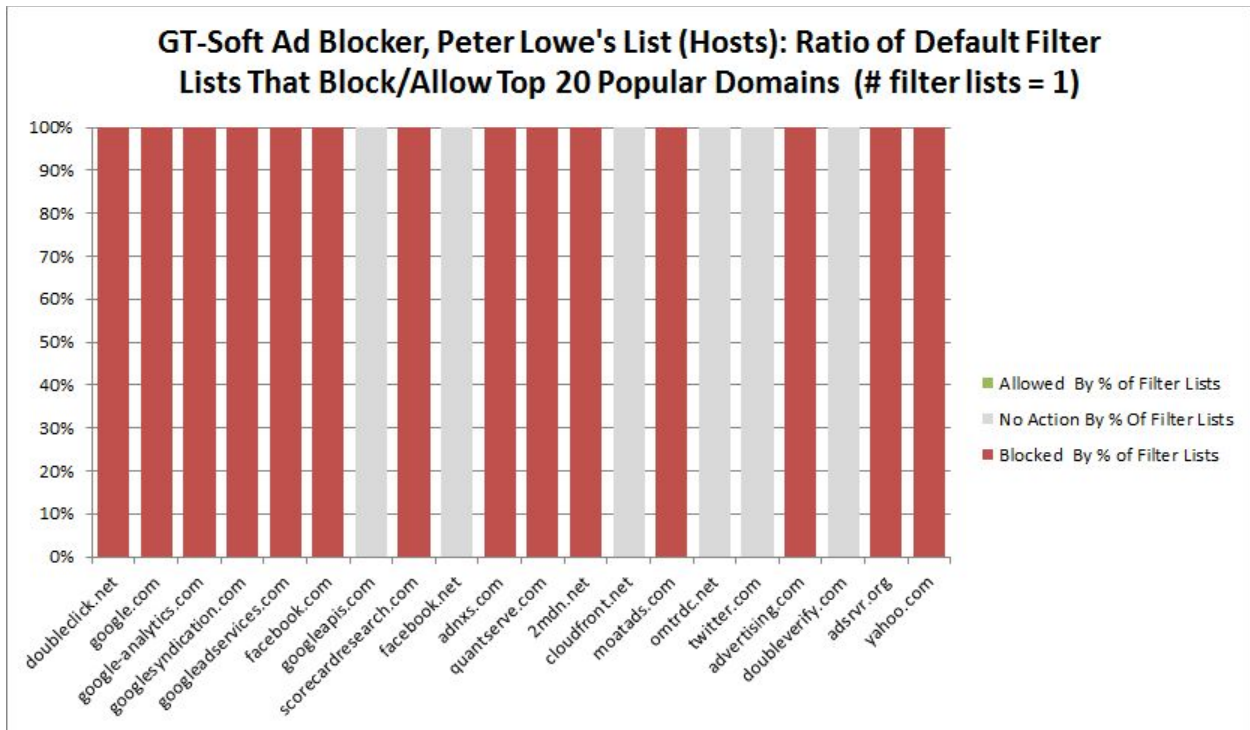
**Figure 43:** Top 20 domains analysis with Dan Pollock's Hosts



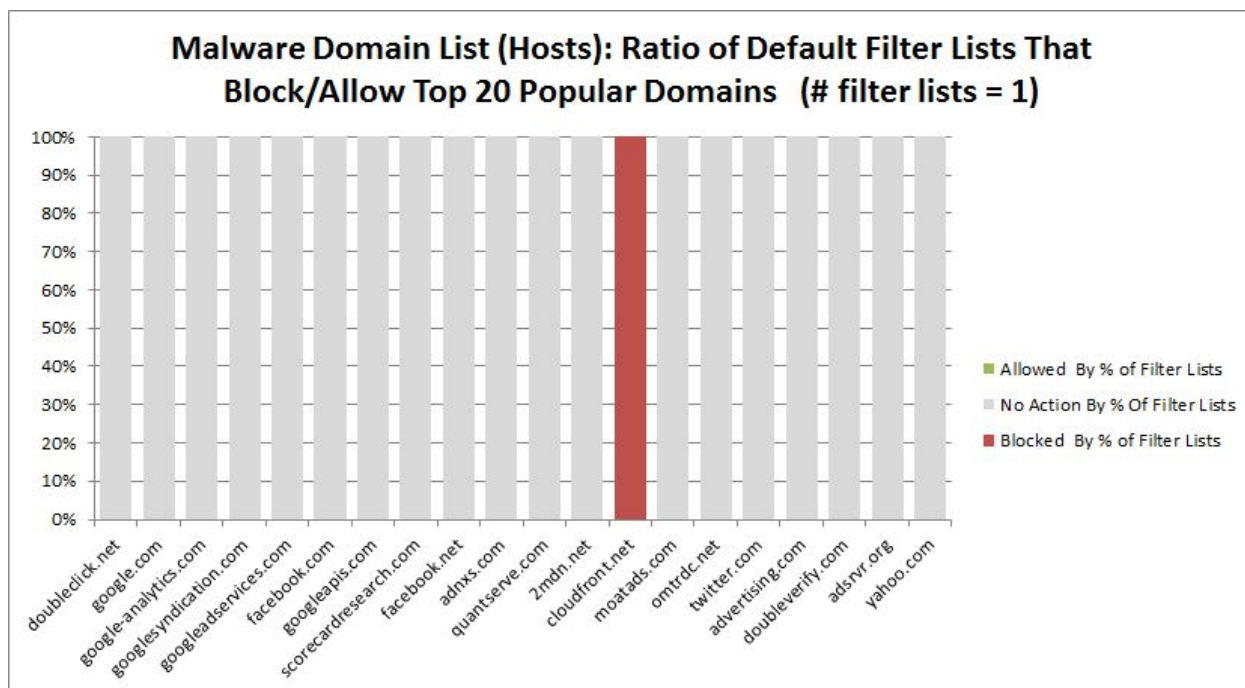
**Figure 44:** Top 20 domains analysis with Adblock



**Figure 45:** Top 20 domains analysis with Adblock Plus and Adguard



**Figure 46:** Top 20 domains analysis with GT-Soft Ad Blocker and Peter Lowe's List



**Figure 47:** Top 20 domains analysis with Malware Domain List

AdFender, uBlock, uBlock Origin, and hpHosts do blocking on 19 of the top 20 domains. MVPS Hosts and Dan Pollock’s Hosts do blocking 18, and Disconnect does blocking on 16, Ghostery does blocking on 15 of the top 20 domains. GT-Soft Ad Blocker and Peter Lowe’s List do blocking on 14, and Three sets of defaults do blocking on 13 domains. Moreover, Malware Domain List does blocking on only one domain.

None of the sets of defaults have corresponding blocking rules for each one of the top 20 domains. However, twelve out of 13 sets have blocking rules regarding doubleclick.net, googlesyndication.com, googleadservices.com, adnxs.com, moatads.com, advertising.com, and adsvr.org. In addition, only two sets of defaults have blocking rules regarding facebook.net. All other domains have corresponding blocking rules in at least 8 sets of defaults.

None of the sets of defaults have corresponding allowing rules for each one of the top 20 domains. A total of 15 domains have corresponding allowing rules in at least one set of defaults. Three domains, facebook.com, facebook.net, and twitter.com are have allowing rules in six out of 13 sets of defaults, which is the highest among the top 20 domains. Finally, five domains,



adsrvr.org, advertising.com, doubleverify.com, omtrdc.net, and quantserve.com do not have corresponding allowing rules in any of the sets of defaults.

## 4.4 Summary

The chapter presents the results and evaluations. In Section 4.1, general information about ad blocking tools and filter lists are presented with Table 1 and Table 2. Overall 23 ad blocking tools and 36 filter lists are investigated in Section 4.1. Key points from Table 1 and Table 2 are highlighted and explained.

In Section 4.2, 6 third-party categories are defined: AdTrackers, Analytics, Beacons, Other, Social, and Widgets. 316 popular domains that appear on first-party sites for traditional browsers, and 94 popular domains that appear on 110 different mobile apps for Android and iOS are categorized. Categorization results are grouped under most popular domains, popular domains, and mobile popular domains, and are presented on Figure 3. In most popular domains, 39% are AdTrackers, 19% are Analytics domains, 18% are Beacons, 11% are Other domains, 4% are Social domains, and 9% are Widgets. In popular domains, 42% are AdTrackers, 18% are Analytics domains, 17% are Beacons, 12% are Other domains, 2% are Social domains, and 10% are Widgets. In mobile popular domains, 32% are AdTrackers, 19% are Analytics domains, 9% are Beacons, 30% are Other domains, 2% are Social domains, and 9% are Widgets.

In Section 4.3, filter list analysis results are presented. Live testing results and observations are explained in Section 4.3.1. Filter list parsing results are presented in Section 4.3.2. In Section 4.3.2, the results are presented in two groups, most popular domains and popular domains, and summarized based on third-party categories. Overall, similar percentages are observed in both domain groups. Generally, most filter lists yielded higher blocking rates in most popular domains. Moreover, some filter lists yielded a significantly higher blocking rate in the most popular domains analyses, which indicates that a significant portion of the popular domains blocked by these lists were concentrated in the most popular domains subset. In each category analysis, approximately 50% to 75% of the filter lists blocked a portion of third-party domains in both most popular and popular domains. In addition, in each category analysis, approximately a third of the filter lists allowed a portion of third-party domains regarding all

categories in both groups. Finally, in each category analysis, approximately a third of the filter lists took no action regarding the domains.

Default filter list analyses are presented in Section 4.3.3. A total of 13 different sets of default filter lists are analyzed. Similar to Section 4.3.2, the results are presented in two groups, most popular domains and popular domains, and summarized based on third-party categories. Generally, most sets of default filter lists yielded higher blocking rates. In each category analysis, almost all sets of defaults blocked a portion of the third-party domains both in most popular and popular domains. In addition, approximately half of the sets of defaults also allowed a portion of the third-party domains in each category analysis regarding both most popular and popular domains. Moreover, default filter lists are analyzed based on top 20 popular domains. None of the sets of defaults have corresponding blocking rules for each one of the top 20 domains, but four sets of defaults have blocking rules regarding 19 out of the 20 domains.

## **5. CONCLUSION AND FUTURE WORK**

Many ad blocking tools, filter lists, and third-parties are investigated as part of this project. General information about ad blocking tools and filter lists are researched to explore ad blockers from a user's perspective and to understand the variety of ad blocking options available to the users. In addition, popular third-party domains that appear on first-party sites for traditional browsers and in mobile apps are investigated. The third-party domains are categorized based on their functionality and behavior in order to produce a clear picture that shows the portions of popular third-parties that show different behavior. Moreover, filter lists are analyzed to demonstrate the differences and similarities between the effectiveness of filter lists. Popular third-party domains that are blocked by filter lists are identified, and summarized based on each third-party category. Finally, the default filter lists of ad blocking tools are grouped together and analyzed in order to demonstrate the differences and similarities between the effectiveness of ad blocking tools' defaults.

Information presented in this project can be useful for Internet users and researchers who would like to gain an insight into understanding ad blockers, filter lists, and third-parties, and can provide significant background information for further research in the field of ad blocking.

Based on the work presented in this paper, future work can involve more detailed analyses of filter lists. For example, third-party URLs from the popular first-party sites and activated filter rules from filter lists can be recorded, and observations can be done regarding the frequency of activation of non-domain specific filter rules. In addition, default filter lists of ad blocking tools can be investigated in more detail in order to identify blocking rules that are nullified by allowing rules. After identifying nullified blocking rules, primary behavior of ad blockers regarding third-party domains can be more accurately presented. Moreover, future work can involve analyzing the changes in filter lists which occur over time via updates. The observed differences between versions of a filter list can be used to highlight the third-party domains that are affected by the updates and how the primary behavior of a filter list regarding the affected domains changes. Finally, filter lists for mobile devices can be researched and analyzed with popular third-party domains that appear in mobile apps.

## CITATIONS

- [1] Mayer and Mitchell, “Third-Party Web Tracking: Policy and Technology.” [Online]. Available: [https://jonathanmayer.org/papers\\_data/trackingsurvey12.pdf](https://jonathanmayer.org/papers_data/trackingsurvey12.pdf). [Accessed: 02-Mar-2016]
- [2] “Take Control of Your Digital Experience - Ghostery.” [Online]. Available: <https://www.ghostery.com/>. [Accessed: 02-Mar-2016]
- [3] “Protect your privacy with Blur from Abine.” [Online]. Available: <https://www.abine.com/index.html>. [Accessed: 02-Mar-2016]
- [4] “Trend Micro Site Safety Center.” [Online]. Available: <http://global.sitesafety.trendmicro.com/>. [Accessed: 02-Mar-2016]
- [5] Wills, “Understanding What Is Happening Regarding Internet Privacy.” [Online]. Available: [http://d32ogqmya1dw8.cloudfront.net/files/sencer/newsletters/understanding\\_what\\_happening\\_r.pdf](http://d32ogqmya1dw8.cloudfront.net/files/sencer/newsletters/understanding_what_happening_r.pdf). [Accessed: 08-Mar-2016]
- [6] AdBlock, “AdBlock.” [Online]. Available: <https://getadblock.com/>. [Accessed: 02-Mar-2016]
- [7] “Adblock Plus - Surf the web without annoying ads!” [Online]. Available: <https://adblockplus.org/>. [Accessed: 02-Mar-2016]
- [8] “uBlock - Home.” [Online]. Available: <https://www.ublock.org/>. [Accessed: 02-Mar-2016]
- [9] “Tracking Protection - Microsoft Windows,” *windows.microsoft.com*. [Online]. Available: <http://windows.microsoft.com/en-us/internet-explorer/products/ie-9/features/tracking-protection>. [Accessed: 14-Feb-2016]
- [10] “Internet Explorer Gallery.” [Online]. Available: <https://www.microsoft.com/en-us/IEGallery>. [Accessed: 14-Feb-2016]
- [11] Kontaxis and Chew, “Tracking Protection in Firefox For Privacy and Performance.” [Online]. Available: [http://iee-security.org/TC/SPW2015/W2SP/papers/W2SP\\_2015\\_submission\\_32.pdf](http://iee-security.org/TC/SPW2015/W2SP/papers/W2SP_2015_submission_32.pdf). [Accessed: 14-Feb-2016]
- [12] “Tracking Protection in Private Browsing | Firefox Help.” [Online]. Available: [https://support.mozilla.org/en-US/kb/tracking-protection-pbm#w\\_to-change-your-blocklist](https://support.mozilla.org/en-US/kb/tracking-protection-pbm#w_to-change-your-blocklist). [Accessed: 14-Feb-2016]
- [13] L. Abrams, “The Hosts File and what it can do for you,” *BleepingComputer*. [Online]. Available: <http://www.bleepingcomputer.com/tutorials/hosts-files-explained/>. [Accessed: 14-Feb-2016]
- [14] “hpHosts Online.” [Online]. Available: <http://www.hosts-file.net/>. [Accessed: 02-Mar-2016]
- [15] M. Burgess, “Blocking Unwanted Connections with a Hosts File.” [Online]. Available: <http://winhelp2002.mvps.org/hosts.htm>. [Accessed: 02-Mar-2016]
- [16] “AdFender Support - Frequently Asked Questions.” [Online]. Available: <http://www.adfender.com/support.html>. [Accessed: 14-Feb-2016]
- [17] “AdFender - The Ultimate Adblock and Privacy Protector.” [Online]. Available: <http://www.adfender.com/>. [Accessed: 02-Mar-2016]
- [18] “Privoxy - Home Page.” [Online]. Available: <http://www.privoxy.org/>. [Accessed: 02-Mar-2016]
- [19] “iOS 9 lets app developers make ad blockers for Safari,” *9to5Mac*, 10-Jun-2015. [Online]. Available: <http://9to5mac.com/2015/06/10/block-ads-ios-9-safari-iphone/>. [Accessed: 28-Feb-2016]
- [20] “Home,” *Crystal*. [Online]. Available: <http://crystalapp.co/>. [Accessed: 08-Mar-2016]
- [21] “Purify App.” [Online]. Available: <https://www.purify-app.com/>. [Accessed: 08-Mar-2016]
- [22] “Block Ads on Smartphone – Android and iOS,” *7labs*. [Online]. Available: <https://7labs.heypub.com/mobile/ad-blocker-android-ios.html>. [Accessed: 28-Feb-2016]
- [23] “SpeedMeUp » Adblock for iPad & iPhone.” [Online]. Available: <http://www.speedmeup.net/>.

- [Accessed: 09-Mar-2016]
- [24] “Adblock Browser.” [Online]. Available: <https://adblockbrowser.org/>. [Accessed: 08-Mar-2016]
- [25] “Ghostery Privacy Browser - Android Apps on Google Play.” [Online]. Available: <https://play.google.com/store/apps/details?id=com.ghostery.android.ghostery>. [Accessed: 08-Mar-2016]
- [26] “Create and Host Tracking Protection Lists (Windows).” [Online]. Available: [https://msdn.microsoft.com/en-us/library/hh273399\(v=vs.85\).aspx](https://msdn.microsoft.com/en-us/library/hh273399(v=vs.85).aspx). [Accessed: 28-Feb-2016]
- [27] “Trend Micro Site Safety Center.” [Online]. Available: <http://global.sitesafety.trendmicro.com/>. [Accessed: 02-Mar-2016]
- [28] I. Abine, “Blur: Keep your web activity and personal info private.” [Online]. Available: <https://dnt.abine.com/#register>. [Accessed: 02-Mar-2016]
- [29] “DeleteMe - Protect Your Personal Data And Reputation Online.” [Online]. Available: <https://www.abine.com/deleteme/landing.php>. [Accessed: 02-Mar-2016]
- [30] “Protect your privacy with DoNotTrackMe from Abine.” [Online]. Available: <https://www.abine.com/donottrackme.html>. [Accessed: 02-Mar-2016]
- [31] “Acceptable Ads Manifesto.” [Online]. Available: <https://acceptableads.org/>. [Accessed: 03-Mar-2016]
- [32] Feldmann, Pujol, and Hohlfeld, “Annoyed Users: Ads and Ad-Block Usage in the Wild,” 2015. [Online]. Available: <http://conferences.sigcomm.org/imc/2015/papers/p93.pdf>. [Accessed: 03-Mar-2016]
- [33] Krishnamurthy and Wills, “Generating a Privacy Footprint on the Internet,” 2006. [Online]. Available: <http://web.cs.wpi.edu/~cew/talks/imc06.pdf>. [Accessed: 03-Mar-2016]
- [34] Walls, Kilmer, Lageman, and McDaniel, “Measuring the Impact and Perception of Acceptable Advertisements,” 2015 [Online]. Available: <http://conferences2.sigcomm.org/imc/2015/papers/p107.pdf>
- [35] Zang, Dummit, Graves, Lisker, and Sweeney, “Who Knows What About Me? A Survey of Behind the Scenes Personal Data Sharing to Third Parties by Mobile Apps,” *Technology Science*, 2015 [Online]. Available: <http://techscience.org/a/2015103001/>
- [36] “Alexa Top 500 Global Sites.” [Online]. Available: <http://www.alexa.com/topsites>. [Accessed: 18-Mar-2016]
- [37] Krishnamurthy and Wills, “Privacy Diffusion on the Web: A Longitudinal Perspective,” 2009 [Online]. Available: <http://web.cs.wpi.edu/~cew/papers/www09.pdf>
- [38] “Fiddler free web debugging proxy,” *Telerik.com*. [Online]. Available: <http://www.telerik.com/fiddler>. [Accessed: 05-Mar-2016]
- [39] “Selenium Projects.” [Online]. Available: <http://www.seleniumhq.org/projects/>. [Accessed: 05-Mar-2016]
- [40] “Chrome Browser.” [Online]. Available: <https://www.google.com/chrome/browser/desktop/>. [Accessed: 06-Mar-2016]
- [41] “Download Web Browser - Internet Explorer,” *windows.microsoft.com*. [Online]. Available: <http://windows.microsoft.com/en-us/internet-explorer/download-ie>. [Accessed: 06-Mar-2016]
- [42] “Choose the independent browser,” *Mozilla*. [Online]. Available: <https://www.mozilla.org/en-US/firefox/new/>. [Accessed: 06-Mar-2016]
- [43] “Browser | Fast & Safe Web Browser | Download Free - Opera.” [Online]. Available: <http://www.opera.com>. [Accessed: 06-Mar-2016]
- [44] A. Inc, “OS X - Safari - Apple,” *Apple*. [Online]. Available: <http://www.apple.com/safari/>. [Accessed: 06-Mar-2016]
- [45] “Adblock Edge.” [Online]. Available: <http://adstomper.bitbucket.org/About.html>. [Accessed: 06-Mar-2016]

- [46] “adstomper / adblockedge.” [Online]. Available: <https://bitbucket.org/adstomper/adblockedge>. [Accessed: 06-Mar-2016]
- [47] “Adblock Fast: The world’s fastest ad blocker.” [Online]. Available: <http://adblockfast.com/>. [Accessed: 06-Mar-2016]
- [48] rocketshipapps, “rocketshipapps/adblockfast,” *GitHub*. [Online]. Available: <https://github.com/rocketshipapps/adblockfast>. [Accessed: 06-Mar-2016]
- [49] “Download AdFender - Adblock for all leading web browsers.” [Online]. Available: <http://www.adfender.com/download.html>. [Accessed: 06-Mar-2016]
- [50] “Adguard is the world’s most advanced adblock program” [Online]. Available: <https://adguard.com/en/welcome.html>. [Accessed: 06-Mar-2016]
- [51] “Bluhell Firewall.” [Online]. Available: <https://addons.mozilla.org/en-US/firefox/addon/bluhell-firewall/>. [Accessed: 06-Mar-2016]
- [52] Disconnect, “Disconnect.” [Online]. Available: <http://disconnect.me>. [Accessed: 06-Mar-2016]
- [53] G. Norman, “Download Emma Ad Blocker Free,” *FindMySoft*. [Online]. Available: <http://emma-ad-blocker.findmysoft.com/>. [Accessed: 06-Mar-2016]
- [54] “Ghostery Tracker Browser Extension | GHOSTERY.” [Online]. Available: <https://www.ghostery.com/our-solutions/ghostery-browser-extention/>. [Accessed: 06-Mar-2016]
- [55] “Google Ad Blocker - Free Tool to Block or Unblock Google Ads on All Browsers.” [Online]. Available: <http://googleadblocker.com/>. [Accessed: 06-Mar-2016]
- [56] “GT-Soft Ad Blocker,” *Download.com*. [Online]. Available: [http://download.cnet.com/GT-Soft-Ad-Blocker/3000-2381\\_4-75820297.html](http://download.cnet.com/GT-Soft-Ad-Blocker/3000-2381_4-75820297.html). [Accessed: 06-Mar-2016]
- [57] S. Ghosh, “GT-Soft Ad Blocker Blocks Advertisements using Hosts File - Insights in Technology,” *Insights in Technology*, 25-Jul-2012. [Online]. Available: <http://www.insightsintechology.com/2012/07/gt-soft-ad-blocker-blocks.html>. [Accessed: 06-Mar-2016]
- [58] arantius, “arantius/karma-blocker,” *GitHub*. [Online]. Available: <https://github.com/arantius/karma-blocker>. [Accessed: 06-Mar-2016]
- [59] “Kill Evil.” [Online]. Available: <https://chrome.google.com/webstore/detail/kill-evil/epiehnpcpegfiildhdklacomihpoldk>. [Accessed: 06-Mar-2016]
- [60] decklin, “decklin/kill-evil,” *GitHub*. [Online]. Available: <https://github.com/decklin/kill-evil>. [Accessed: 06-Mar-2016]
- [61] “Firefox,” *Mozilla Developer Network*. [Online]. Available: <https://developer.mozilla.org/en-US/docs/Mozilla/Firefox>. [Accessed: 06-Mar-2016]
- [62] “NoAds,” *Opera add-ons*. [Online]. Available: <https://addons.opera.com/extensions/details/noads/>. [Accessed: 06-Mar-2016]
- [63] “NoAds Advanced,” *Opera add-ons*. [Online]. Available: <https://addons.opera.com/extensions/details/noads-advanced/>. [Accessed: 06-Mar-2016]
- [64] Gemorroj, “Gemorroj/noads-advanced,” *GitHub*. [Online]. Available: <https://github.com/Gemorroj/noads-advanced>. [Accessed: 06-Mar-2016]
- [65] “Privacy Badger,” *Electronic Frontier Foundation*, 24-Apr-2013. [Online]. Available: <https://www.eff.org/privacybadger>. [Accessed: 06-Mar-2016]
- [66] “PrivacyFix - Lock down your privacy.” [Online]. Available: <http://www.privacyfix.com/start>. [Accessed: 06-Mar-2016]
- [67] “Privoxy - Home Page.” [Online]. Available: <http://www.privoxy.org/>. [Accessed: 06-Mar-2016]
- [68] “uBlock - Home.” [Online]. Available: <https://www.ublock.org/>. [Accessed: 06-Mar-2016]
- [69] gorhill, “gorhill/uBlock,” *GitHub*. [Online]. Available: <https://github.com/gorhill/uBlock>. [Accessed:

06-Mar-2016]

- [70] “Acceptable Ads Filter List.” [Online]. Available: <https://easylist-downloads.adblockplus.org/exceptionrules.txt>
- [71] “Adblock Custom Filters Filter List.” [Online]. Available: [https://adblockcdn.com/filters/adblock\\_custom.txt](https://adblockcdn.com/filters/adblock_custom.txt)
- [72] “Adblock Warning Removal Filter List.” [Online]. Available: <https://easylist-downloads.adblockplus.org/antiadblockfilters.txt>
- [73] “The Official EasyList Website.” [Online]. Available: <https://easylist.adblockplus.org/en/>. [Accessed: 08-Mar-2016]
- [74] “Adware Filters Filter List.” [Online]. Available: <https://easylist-downloads.adblockplus.org/adwarefilters.txt>
- [75] “EasyList Filter List.” [Online]. Available: <https://easylist-downloads.adblockplus.org/easylist.txt>
- [76] “EasyList Without Element Hiding Filter List.” [Online]. Available: [https://easylist-downloads.adblockplus.org/easylist\\_noelemhide.txt](https://easylist-downloads.adblockplus.org/easylist_noelemhide.txt)
- [77] “EasyList Without Rules For Adult Sites.” [Online]. Available: [https://easylist-downloads.adblockplus.org/easylist\\_noadult.txt](https://easylist-downloads.adblockplus.org/easylist_noadult.txt)
- [78] “EasyPrivacy Filter List.” [Online]. Available: <https://easylist-msie.adblockplus.org/easyprivacy.tpl>
- [79] “EasyPrivacy Without International Filters Filter List.” [Online]. Available: [https://easylist-downloads.adblockplus.org/easyprivacy\\_nointernational.txt](https://easylist-downloads.adblockplus.org/easyprivacy_nointernational.txt)
- [80] “Fanboy’s Annoyance List Filter List.” [Online]. Available: <https://easylist-downloads.adblockplus.org/fanboy-annoyance.txt>
- [81] “Fanboy Adblock Homepage.” [Online]. Available: <https://www.fanboy.co.nz/filters.html>. [Accessed: 08-Mar-2016]
- [82] “Fanboy’s Anti-Facebook List Filter List.” [Online]. Available: <https://secure.fanboy.co.nz/fanboy-antifacebook.txt>
- [83] “Fanboy’s Anti Third-Party Fonts Filter List.” [Online]. Available: <https://secure.fanboy.co.nz/fanboy-antifonts.txt>
- [84] “Fanboy’s Social Blocking List Filter List.” [Online]. Available: <https://easylist-downloads.adblockplus.org/fanboy-social.txt>
- [85] “DNS-BH – Malware Domain Blocklist » About.” [Online]. Available: [http://www.malwaredomains.com/?page\\_id=2](http://www.malwaredomains.com/?page_id=2). [Accessed: 08-Mar-2016]
- [86] “Malware Domains Filter List.” [Online]. Available: [https://easylist-downloads.adblockplus.org/malwaredomains\\_full.txt](https://easylist-downloads.adblockplus.org/malwaredomains_full.txt)
- [87] P. Lowe, “Ad blocking with ad server hostnames and IP addresses.” [Online]. Available: <http://pgl.yoyo.org/adservers/>. [Accessed: 08-Mar-2016]
- [88] “Spam404,” *Spam404*. [Online]. Available: <http://www.spam404.com/>. [Accessed: 08-Mar-2016]
- [89] “Spam404 Filter List.” [Online]. Available: <https://raw.githubusercontent.com/Dawsey21/Lists/master/adblock-list.txt>
- [90] “Using a Hosts File To Make The Internet Not Suck (as much).” [Online]. Available: <http://someonewhocares.org/hosts/>. [Accessed: 08-Mar-2016]
- [91] “[No title].” [Online]. Available: <http://www.hosts-file.net/>. [Accessed: 08-Mar-2016]
- [92] “MDL.” [Online]. Available: <http://www.malwaredomainlist.com/>. [Accessed: 08-Mar-2016]
- [93] “Malware Domain List Filter List.” [Online]. Available: <http://www.malwaredomainlist.com/hostslist/hosts.txt>
- [94] “Internet Explorer Tracking Protection List.” [Online]. Available: <https://www.abine.com/tracker-protection-list/>. [Accessed: 08-Mar-2016]
- [95] “Abine Tracking Protection List Filter List.” [Online]. Available: <https://www.abine.com/tpl/abineielist.txt>

- [96] “PrivacyChoice All Companies Filter List.” [Online]. Available: [http://www.privacychoice.org/trackerblock/all\\_companies\\_tpl](http://www.privacychoice.org/trackerblock/all_companies_tpl)
- [97] “PrivacyChoice Block Companies Without NAI Oversight Filter List.” [Online]. Available: [http://www.privacychoice.org/trackerblock/no\\_oversight\\_companies\\_tpl](http://www.privacychoice.org/trackerblock/no_oversight_companies_tpl)
- [98] “Stop Google Tracking Filter List.” [Online]. Available: <https://modernievms.blob.core.windows.net/misc/google.txt>
- [99] “TRUSTe Filter List.” [Online]. Available: <http://easy-tracking-protection.truste.com/easy.tpl>
- [100] “Ad filter list by Disconnect Filter List.” [Online]. Available: [https://s3.amazonaws.com/lists.disconnect.me/simple\\_ad.txt](https://s3.amazonaws.com/lists.disconnect.me/simple_ad.txt)
- [101] “Basic tracking list by Disconnect Filter List.” [Online]. Available: [https://s3.amazonaws.com/lists.disconnect.me/simple\\_tracking.txt](https://s3.amazonaws.com/lists.disconnect.me/simple_tracking.txt)
- [102] Disconnect, “Online Privacy & Security.” [Online]. Available: <https://disconnect.me/trackerprotection>. [Accessed: 08-Mar-2016]
- [103] disconnectme, “disconnectme/disconnect-tracking-protection,” *GitHub*. [Online]. Available: <https://github.com/disconnectme/disconnect-tracking-protection>. [Accessed: 08-Mar-2016]
- [104] “Malvertising List By Disconnect Filter List.” [Online]. Available: <https://disconnect.me/lists/malvertising>
- [105] “Malware list by Disconnect Filter List.” [Online]. Available: <https://disconnect.me/lists/malwarefilter>
- [106] “Malware Protection Filter List.” [Online]. Available: <https://data.getadblock.com/filters/domains.json>
- [107] “JSON.” [Online]. Available: <http://www.json.org/>. [Accessed: 08-Mar-2016]
- [108] “F-Droid.” [Online]. Available: <https://f-droid.org/repository/browse/?fdid=org.adaway>. [Accessed: 08-Mar-2016]
- [109] “Adblock Browser.” [Online]. Available: <https://adblockbrowser.org/>. [Accessed: 08-Mar-2016]
- [110] “AppBrain Ad Detector - Android app on AppBrain,” 28-Mar-2012. [Online]. Available: <http://www.appbrain.com/app/appbrain-ad-detector/com.appspot.swisscodemonkeys.detector>. [Accessed: 08-Mar-2016]
- [111] S. Khanov, “1Blocker - Block ads, tracking scripts, anything,” *1Blocker*. [Online]. Available: <http://1blocker.com>. [Accessed: 08-Mar-2016]
- [112] R. Shevtsov, “Ad Block Multi - Content Blocking Extension on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/de/app/ad-block-multi-content-blocking/id1037619477?l=en&mt=8>. [Accessed: 08-Mar-2016]
- [113] A. Grigor, “Ad Control.” [Online]. Available: <http://www.adcontrolapp.com/>. [Accessed: 08-Mar-2016]
- [114] “Ad-Blocker | Blocking advertisements on Safari for the cleanest browsing experience.” [Online]. Available: <http://www.ad-blocker.co/>. [Accessed: 08-Mar-2016]
- [115] CocoaApp, “Adamant – Browse faster with the best content blocker for iOS 9,” *Adamant*. [Online]. Available: <http://cocoaapp.com/adamant/>. [Accessed: 08-Mar-2016]
- [116] M. Guta, “AdBlockX on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/us/app/adblockx/id1042803639?mt=8>. [Accessed: 08-Mar-2016]
- [117] “Surf without ads,” *AdMop*. [Online]. Available: <http://admop.iphonso.com>. [Accessed: 08-Mar-2016]
- [118] “BlockBear | Block ads and protect your privacy.” [Online]. Available: <https://blockbear.com>. [Accessed: 08-Mar-2016]
- [119] “Blockr App.” [Online]. Available: <http://blockr-app.com/>. [Accessed: 08-Mar-2016]
- [120] L. Talkabout Design, “Easily Block Ads and Trackers,” *Chop*. [Online]. Available:



- <http://www.talkaboutdesign.com/chopapp>. [Accessed: 08-Mar-2016]
- [121] “Download Clear Ad-Free Apps | browseclear.com.” [Online]. Available: <http://browseclear.com/download/>. [Accessed: 08-Mar-2016]
- [122] “Clearly.” [Online]. Available: <http://www.getclearly.com/>. [Accessed: 08-Mar-2016]
- [123] S. Murphy, “Distilled ~ The iOS Content Blocker with Taste.” [Online]. Available: <http://distilled-app.com/>. [Accessed: 08-Mar-2016]
- [124] F.-S. Corporation, “F-Secure ADBLOCKER on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/us/app/f-secure-adblocker/id1040899919?mt=8>. [Accessed: 08-Mar-2016]
- [125] B. Chester, “Flare: Block Tracking and Ads on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/us/app/flare-block-tracking-and-ads/id1041741862?mt=8>. [Accessed: 08-Mar-2016]
- [126] Z. Simone, “Freedom - Ad Blocker on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/us/app/freedom-ad-blocker/id1033791657?mt=8>. [Accessed: 08-Mar-2016]
- [127] I. Ghostery, “Ghostery on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/us/app/ghostery/id472789016?mt=8>. [Accessed: 09-Mar-2016]
- [128] “JUST THE CONTENT,” *Just The Content - Block Ads & Trackers*. [Online]. Available: <http://www.justthecontent.com/>. [Accessed: 08-Mar-2016]
- [129] S. Moghimi, “Magic Adblock - Best adblocker. Block Ads. Browse faster, ad & tracking free. dans l’App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/fr/app/magic-adblock-block-ads.-browse/id1044364938?mt=8>. [Accessed: 08-Mar-2016]
- [130] “Oasis Blocker | Squarevibe Inc.” [Online]. Available: <http://squarevibe.be/oasis-blocker/>. [Accessed: 08-Mar-2016]
- [131] “Welcome to Obsessive Software.” [Online]. Available: <https://obsessive.io/>. [Accessed: 08-Mar-2016]
- [132] L. Li, “Refine - Customizable Ad Blocker for Safari on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/us/app/refine-customizable-ad-blocker/id1011678834?mt=8>. [Accessed: 08-Mar-2016]
- [133] R. U. G. (haftungsbeschraenkt), “Rocket – AdBlocker on the App Store,” *App Store*. [Online]. Available: <https://itunes.apple.com/de/app/rocket-adblocker/id1028881662?l=en&mt=8>. [Accessed: 08-Mar-2016]
- [134] “Silentium.” [Online]. Available: <http://www.silentium.xyz/>. [Accessed: 08-Mar-2016]
- [135] “Swab | The Content Blocker of Creative, Web and Design Culture Ads.” [Online]. Available: <http://swabthe.com/>. [Accessed: 08-Mar-2016]
- [136] “Vivio AdBlocker – iOS 9 Safari Content Blocker.” [Online]. Available: <http://www.vivioapp.com/>. [Accessed: 08-Mar-2016]
- [137] “Giorgio’s Apps.” [Online]. Available: <http://giorgiocalderolla.com/index.html>. [Accessed: 08-Mar-2016]
- [138] “Website.” [Online]. Available: <https://www.eff.org/dnt-policy>. [Accessed: 11-Mar-2016]
- [139] “DuckDuckGo,” *DuckDuckGo*. [Online]. Available: <https://duckduckgo.com/>. [Accessed: 11-Mar-2016]
- [140] “PageFair - Reclaim Your Adblocked Revenue.” [Online]. Available: <https://pagefair.com/>. [Accessed: 11-Mar-2016]
- [141] “Developer Media | Tech Marketing Experts.” [Online]. Available: <http://developermedia.com/>. [Accessed: 11-Mar-2016]
- [142] “Acceptable Ads - Adblock Plus.” [Online]. Available: <https://adblockplus.org/acceptable-ads>. [Accessed: 11-Mar-2016]

## APPENDIX A: Popular domains

Domain	Appears in % of 1200 popular first-party sites	Categorization Termination Code	MQP Classification
doubleclick.net	79.3	G + A	AdTrackers
google.com	76.5	A + S	Widgets
google-analytics.com	71.2	G + A	Analytics
googlesyndication.com	59.9	G + A	Beacons
googleadservices.com	52.6	A + S	AdTrackers
facebook.com	48.1	G + A	Social
googleapis.com	46.3	A + S	Widgets
scorecardresearch.com	46.1	G + A	Beacons
facebook.net	40.4	G + A	Social
adnxs.com	32.8	G + A	AdTrackers
quantserve.com	29.7	G + A	AdTrackers
2mdn.net	29.3	A + S	AdTrackers
cloudfront.net	28.2	A + S	Other
moatads.com	27.5	G	AdTrackers
omtrdc.net	26.4	G + A	Beacons
twitter.com	23.7	G + A	Social
advertising.com	23.5	G + A	AdTrackers
doubleverify.com	21	G + A	Analytics
adsrvr.org	20.4	G	AdTrackers
yahoo.com	20.4	G + A	Analytics
demdex.net	20.2	A + S	Analytics
rubiconproject.com	19.5	G + A	AdTrackers
adsafeprotected.com	18.8	G	Analytics

mathtag.com	18.4	G + A	AdTrackers
bluekai.com	17.6	G + A	Beacons
turn.com	17.3	G + A	AdTrackers
betrad.com	17.2	G	Other
rlcdn.com	17	G + A	Beacons
criteo.com	16.6	G	AdTrackers
imrworldwide.com	16.5	G + A	Analytics
amazonaws.com	16.4	A + S	Other
adadvisor.net	16.2	A + S	AdTrackers
openx.net	15.8	G + A	AdTrackers
chartbeat.com	15.7	G + A	Analytics
pubmatic.com	15.6	G + A	AdTrackers
cloudflare.com	15.5	S	Other
crwdcntrl.net	15.4	G + A	Beacons
nexac.com	15.1	G + A	AdTrackers
dmtry.com	15	G	Analytics
akamaihd.net	14.8	S	Other
optimizely.com	14.7	G	Beacons
newrelic.com	14.6	G	Analytics
serving-sys.com	14.5	G + A	AdTrackers
casalemedia.com	14.3	G + A	AdTrackers
amazon-adsystem.com	13.9	G	AdTrackers
btrll.com	13.9	G	AdTrackers
agkn.com	13.7	G	Beacons
krxn.net	13.7	G	Beacons
truste.com	13.6	G + A	Other
addthis.com	13.3	G + A	Widgets

exelator.com	13.3	G + A	Beacons
spotxchange.com	12.9	G + A	AdTrackers
iasds01.com	12.7	G	Analytics
adtechus.com	12.4	G + A	AdTrackers
fbcdn.net	12	A + S	Other
flashtalking.com	11.9	G	AdTrackers
liverail.com	11.8	G + A	AdTrackers
revsci.net	11.8	G + A	Beacons
chartbeat.net	11.4	G	Analytics
dynect.net	11.4	S + T	Other
voicefive.com	10.9	G + A	Beacons
chango.com	10.7	G + A	Beacons
aol.com	9.9	G	Widgets
mxptint.net	9.9	G	AdTrackers
tiqcdn.com	9.7	G	Analytics
nr-data.net	9.5	G	Analytics
youtube.com	9.4	G + A	Widgets
tapad.com	9.1	G	AdTrackers
yting.com	9	A + S	Other
tubemogul.com	8.5	G	Analytics
tidaltv.com	8.4	G	Beacons
rfihub.com	8.2	G	Beacons
adap.tv	8.1	G	AdTrackers
mookie1.com	8	G + A	Analytics
spotxcdn.com	7.8	G	AdTrackers
bidswitch.net	7.7	G	AdTrackers
w55c.net	7.6	G + A	AdTrackers

adobedtm.com	7.4	G	Widgets
dotomi.com	7.1	G + A	Beacons
yimg.com	7	G + A	Analytics
akamai.net	6.9	A + S	Widgets
contextweb.com	6.9	G + A	AdTrackers
typekit.net	6.7	G	Widgets
insightexpressai.com	6.6	G + A	Analytics
ixiaa.com	6.4	S	AdTrackers
twimg.com	6.4	A + S	Widgets
ml314.com	6.2	S	Analytics
pointroll.com	6.2	G + A	AdTrackers
smartadserver.com	5.9	G	AdTrackers
bing.com	5.7	S + T	Other
servedbyopenx.com	5.7	G	AdTrackers
linkedin.com	5.5	G	Social
msn.com	5.3	A + S	AdTrackers
2o7.net	5.1	G + A	Beacons
bootstrapcdn.com	5.1	S	Other
lijit.com	5.1	G + A	AdTrackers
adroll.com	5	G + A	AdTrackers
atdmt.com	4.9	G + A	AdTrackers
ensighten.com	4.9	G	Analytics
adsymptotic.com	4.8	G	AdTrackers
bizographics.com	4.8	G + A	Beacons
gigya.com	4.8	G + A	Social
gwallet.com	4.8	G + A	Beacons
taboola.com	4.8	G	Widgets

univide.com	4.8	S	Other
createjs.com	4.7	S	Widgets
ru4.com	4.7	G + A	Beacons
tremorhub.com	4.6	G	AdTrackers
crazyegg.com	4.5	G	Analytics
criteo.net	4.5	G	AdTrackers
brightcove.com	4.2	G + A	Widgets
visible.tv	4.2	G	AdTrackers
bkrx.com	4	G	Beacons
media6degrees.com	4	G + A	AdTrackers
outbrain.com	4	G + A	Widgets
pinterest.com	4	G	Widgets
t.co	3.9	S + T	Widgets
tribalfusion.com	3.9	G + A	AdTrackers
yldbt.com	3.9	G	Beacons
amgdgt.com	3.8	G	AdTrackers
rhythmxchange.com	3.7	G	Beacons
adhigh.net	3.6	G	AdTrackers
dashbida.com	3.6	S	Other
semasio.net	3.6	G	Beacons
clickagy.com	3.5	S + T	Analytics
jquery.com	3.5	S	Other
realtime.co	3.5	G	Analytics
sharethrough.com	3.5	G	AdTrackers
skimresources.com	3.5	G + A	AdTrackers
vindicosuite.com	3.5	G	AdTrackers
altitude-arena.com	3.3	G	AdTrackers

appserver.tv	3.3	G	AdTrackers
pagefair.com	3.3	G	Beacons
postrelease.com	3.3	G + A	AdTrackers
sonobi.com	3.3	G	AdTrackers
247realmedia.com	3.2	G + A	AdTrackers
go-mpulse.net	3.2	G	Analytics
mediaplex.com	3.2	G + A	AdTrackers
qualtrics.com	3.2	G	Analytics
undertone.com	3.2	G + A	AdTrackers
adform.net	3.1	G	AdTrackers
stickyadstv.com	3.1	S + T	AdTrackers
thebrighttag.com	3.1	G	Beacons
audienceiq.com	2.9	G + A	Beacons
myspace.com	2.9	S + T	Widgets
eyeviewads.com	2.8	G	AdTrackers
btstatic.com	2.7	G	Beacons
fastclick.net	2.7	A + S	AdTrackers
monetate.net	2.7	G	Analytics
pagefair.net	2.7	G	Beacons
sekindo.com	2.7	G	AdTrackers
springserve.com	2.7	S	AdTrackers
vizu.com	2.7	G + A	Analytics
webspectator.com	2.7	S + T	AdTrackers
answerscloud.com	2.6	G	Analytics
bounceexchange.com	2.6	G	Beacons
gumgum.com	2.6	G + A	AdTrackers
mpstat.us	2.6	G	Analytics

pippio.com	2.6	S	Analytics
sascdn.com	2.6	G	AdTrackers
securedvisit.com	2.6	G	Beacons
yieldmanager.com	2.6	G + A	AdTrackers
collective-media.net	2.5	G + A	AdTrackers
edgesuite.net	2.5	A + S	Other
owneriq.net	2.5	G	Beacons
pingdom.net	2.5	G	Beacons
clicktale.net	2.4	G + A	Analytics
exponential.com	2.4	G + A	AdTrackers
parse.ly.com	2.4	G	Beacons
rackcdn.com	2.4	S	Other
rfihub.net	2.4	G	Beacons
yashi.com	2.4	G	AdTrackers
afy11.net	2.3	G + A	AdTrackers
declaredthoughtfulness.co	2.3	T	AdTrackers
disqus.com	2.3	G + A	Widgets
domdex.com	2.3	G + A	Beacons
mediavoice.com	2.3	G	AdTrackers
rundsp.com	2.3	G	AdTrackers
wp.com	2.3	G + A	Analytics
ntv.io	2.2	G	AdTrackers
optimatic.com	2.2	S + T	AdTrackers
sharethis.com	2.2	G + A	Widgets
simpli.fi	2.2	G + A	AdTrackers
specificmedia.com	2.2	G + A	AdTrackers
gssprt.jp	2.1	S	AdTrackers



maxymiser.net	2.1	G	Beacons
netdna-ssl.com	2.1	S	Other
netmng.com	2.1	G	Beacons
viglink.com	2.1	G + A	AdTrackers
visualrevenue.com	2.1	G	Analytics
adobe.com	2	G + A	Beacons
adtricity.com	2	G	AdTrackers
atlassbx.com	2	S	Other
dsply.com	2	S	Beacons
researchnow.com	2	G	Beacons
sitescout.com	2	G	AdTrackers
tagsrvcs.com	2	S	Other
tynt.com	2	G + A	Beacons
adrta.com	1.9	S + T	Analytics
sail-horizon.com	1.9	G	Beacons
verisigndns.com	1.9	S	Other
atwola.com	1.8	G + A	AdTrackers
coremetrics.com	1.8	G + A	Analytics
hotjar.com	1.8	G	Analytics
legolas-media.com	1.8	G	Beacons
navdmp.com	1.8	G	Analytics
polarmobile.com	1.8	G	AdTrackers
truoptik.com	1.8	S + T	Analytics
yieldoptimizer.com	1.8	G	Analytics
zedo.com	1.8	G + A	AdTrackers
livefyre.com	1.7	G	Widgets
marinsm.com	1.7	G	Beacons

zergnet.com	1.7	G	Widgets
aolcdn.com	1.6	A + S	Other
cdninstagram.com	1.6	S	Other
convertro.com	1.6	G	Beacons
dyntrk.com	1.6	S	AdTrackers
fonts.net	1.6	S + T	Widgets
liveperson.net	1.6	G + A	Widgets
qubitproducts.com	1.6	G	Beacons
ultradns.biz	1.6	G	Beacons
webtrends-live.com	1.6	G + A	Beacons
wordpress.com	1.6	G + A	Analytics
eyeota.net	1.5	G	Beacons
mxpnl.com	1.5	G	Analytics
richrelevance.com	1.5	G	AdTrackers
tealiumiq.com	1.5	G	Analytics
angsrvr.com	1.4	S + T	AdTrackers
basebanner.com	1.4	G	AdTrackers
dataxu.net	1.4	G	AdTrackers
de17a.com	1.4	G	AdTrackers
gravity.com	1.4	G	Analytics
indexww.com	1.4	G	AdTrackers
keywee.co	1.4	S	Analytics
mixpanel.com	1.4	G	Analytics
scanscout.com	1.4	G	AdTrackers
tru.am	1.4	G	Widgets
visualdna.com	1.4	G	Analytics
209.15.224.6	1.3	S	Other

3lift.com	1.3	G	AdTrackers
adtech.de	1.3	G + A	AdTrackers
cachefly.net	1.3	S	Other
cbsi.com	1.3	G	AdTrackers
gravatar.com	1.3	G + A	Widgets
grvcdn.com	1.3	G	Analytics
llnwd.net	1.3	A + S	Other
openxenterprise.com	1.3	G	AdTrackers
perfectmarket.com	1.3	G	AdTrackers
rlcll.com	1.3	S + T	AdTrackers
videe.tv	1.3	S + T	Widgets
visualwebsiteoptimizer.com	1.3	G	Beacons
yabidos.com	1.3	S	Other
abmr.net	1.2	G	AdTrackers
acuityplatform.com	1.2	G	AdTrackers
algovid.com	1.2	S	AdTrackers
bluecava.com	1.2	G	Beacons
effectivemeasure.net	1.2	G	Analytics
invitemedia.com	1.2	A + S	AdTrackers
microsoft.com	1.2	G	Analytics
po.st	1.2	G	Widgets
questionmarket.com	1.2	G + A	Beacons
rtbidder.net	1.2	G	AdTrackers
smaato.net	1.2	G	AdTrackers
wtp101.com	1.2	G	AdTrackers
yumenetworks.com	1.2	G	AdTrackers
33across.com	1.1	G + A	AdTrackers

360yield.com	1.1	G	AdTrackers
adgrx.com	1.1	G	AdTrackers
admathhd.com	1.1	S	Other
aspnetcdn.com	1.1	S	Other
bidr.io	1.1	S	Other
cbsima.com	1.1	S	Other
cbsimg.net	1.1	S + T	AdTrackers
cdn77.org	1.1	S	Other
cxense.com	1.1	G	AdTrackers
demandbase.com	1.1	G + A	Beacons
dl-rms.com	1.1	G + A	Beacons
dtmpub.com	1.1	S + T	AdTrackers
dvtps.com	1.1	S	Analytics
dynamicyield.com	1.1	G	AdTrackers
eloqua.com	1.1	G + A	Analytics
en25.com	1.1	G	Analytics
fwmrm.net	1.1	G	AdTrackers
go.com	1.1	S + T	Other
ic-live.com	1.1	G	Analytics
ifmnwi.club	1.1	S + T	Other
innovid.com	1.1	G	AdTrackers
instagram.com	1.1	S + T	Widgets
iperceptions.com	1.1	G + A	Analytics
nanigans.com	1.1	G	AdTrackers
provenpixel.com	1.1	G	AdTrackers
proximic.com	1.1	G	AdTrackers
r1-cdn.net	1.1	S	Other

sojern.com	1.1	G	AdTrackers
timeinc.com	1.1	S + T	Other
timeinc.net	1.1	S + T	Other
tinypass.com	1.1	G	Widgets
tlvmedia.com	1.1	G	AdTrackers
trk4rx.com	1.1	S + T	AdTrackers
usa.gov	1.1	S + T	Other
vdna-assets.com	1.1	G	Analytics
videoamp.com	1.1	S + T	AdTrackers
yume.com	1.1	G	AdTrackers
acxiom-online.com	1	G	AdTrackers
adotube.com	1	G	AdTrackers
adsnative.com	1	G	AdTrackers
cedexis.com	1	G	Analytics
celtra.com	1	G	AdTrackers
crowdsience.com	1	G + A	Analytics
intentiq.com	1	G	AdTrackers
janrain.com	1	G	Widgets
jwpcdn.com	1	S	AdTrackers
reson8.com	1	G	AdTrackers
rpxnow.com	1	G	Widgets
teads.tv	1	G	AdTrackers
vilpoint.com	1	S	Other

## APPENDIX B: Mobile popular domains

Domain (domains that are present in popular domains are green)	% of all apps (110 apps) sent data	Categorization Termination Code	MQP Classification
google.com	36%	A + S	Widgets
googleapis.com	18%	A + S	Widgets
apple.com	17%	S	Other
facebook.com	14%	G + A	Social
exacttargetapis.com	7%	S	AdTrackers
yahoopapis.com	7%	A + S	Other
ad-x.co.uk	5%	S	Beacons
google-analytics.com	5%	G + A	Analytics
scorecardresearch.com	5%	G + A	Beacons
2o7.net	4%	G + A	Beacons
doubleclick.net	4%	G + A	AdTrackers
fksu.com	4%	S	Analytics
instagram.com	4%	S + T	Widgets
appspot.com	3%	S	Other
crittercism.com	3%	S	Analytics
expedia.com	3%	S + T	Other
flurry.com	3%	G	Analytics
rubiconproject.com	3%	G + A	AdTrackers
aisle411.ws	2%	S	Other
amazonaws.com	2%	A + S	Other
appboy.com	2%	S	Analytics
nanigans.com	2%	G	AdTrackers

tapjoy.com	2%	S	Analytics
tapjoyads.com	2%	S + T	AdTrackers
twitter.com	2%	G + A	Social
2gis.ru	1%	S + T	Other
aa.com	1%	S + T	Other
adadvisor.net	1%	A + S	AdTrackers
adcolony.com	1%	S	AdTrackers
agkn.com	1%	G	Beacons
aimatch.com	1%	S + T	AdTrackers
akamaihd.net	1%	S	Other
amazon-adsystem.com	1%	G	AdTrackers
amazon.com	1%	A + S	Widgets
apigee.net	1%	S	Other
appclick.co	1%	S + T	AdTrackers
appsflyer.com	1%	S	Analytics
apsalar.com	1%	S	Analytics
bazaarvoice.com	1%	G	Widgets
beintoo.com	1%	S + T	Analytics
birdstep.com	1%	S	Analytics
bluekai.com	1%	G + A	Beacons
celtra.com	1%	G	AdTrackers
citygridmedia.com	1%	S + T	AdTrackers
cloudapp.net	1%	S	Other
crashlytics.com	1%	S	Other
factual.com	1%	S	AdTrackers
flickr.com	1%	G + A	Widgets
fluentmobile.com	1%	S	Analytics

foursquare.com	1%	G	Widgets
googlesyndication.com	1%	G + A	Beacons
healthcaresource.com	1%	S + T	Other
herokuapp.com	1%	S	Other
ihg.com	1%	S	Other
inmobi.com	1%	S	AdTrackers
inner-active.mobi	1%	S	AdTrackers
intellitxt.com	1%	G + A	AdTrackers
itriagehealth.com	1%	S + T	Other
jumptap.com	1%	G	AdTrackers
kik.com	1%	S + T	Other
kochava.com	1%	S	Analytics
manage.com	1%	S	AdTrackers
moceanads.com	1%	G	AdTrackers
mopub.com	1%	G	AdTrackers
mydas.mobi	1%	S + T	AdTrackers
optimizely.com	1%	G	Beacons
panoramio.com	1%	S + T	Other
parkme.com	1%	S	Other
paypal.com	1%	G + A	Beacons
pubnub.com	1%	S	Other
quantserve.com	1%	G + A	AdTrackers
runadtag.com	1%	G	AdTrackers
samsungapps.com	1%	S	Other
segment.io	1%	G	Analytics
sensis.com	1%	S	Analytics
shoplocal.com	1%	S + T	AdTrackers



skyhookwireless.com	1%	S	Analytics
smaato.net	1%	G	AdTrackers
snagajob.com	1%	S + T	Other
sponsorpay.com	1%	S + T	AdTrackers
undertone.com	1%	G + A	AdTrackers
urbanairship.com	1%	S + T	Analytics
vesselapp.com	1%	S	Other
vrvn.com	1%	G	AdTrackers
where.com	1%	G	AdTrackers
wikilocation.org	1%	S	Other
wikimapia.org	1%	S + T	Other
wp.com	1%	G + A	Analytics
wunderground.com	1%	S + T	Other
yelp.com	1%	S + T	Other
youtube.com	1%	G + A	Widgets
yozi.io	1%	S	Analytics
zigi.com	1%	S + T	AdTrackers
zomato.com	1%	S + T	Other

## **APPENDIX C: Attachments**

A zip file named “MQP\_Attachments” is included as an attachment. Below are the contents of the file:

- “Categorization.xlsx” contains detailed categorization and filter list parsing information and results.
- “filter\_lists” directory contains the filter lists that are analyzed as part of this project.
- “live\_testing\_results” directory contains the results gathered from live testing as part of this project.
- “parsing\_scripts” directory contains the Python scripts used to parse filter lists.