



The Hitchhiker's Guide to Facebook Web Tracking with Invisible Pixels and Click IDs

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ABSTRACT

Over the past years, advertisement companies have used various tracking methods to persistently track users across the web. Such tracking methods usually include first and third-party cookies, cookie synchronization, as well as a variety of fingerprinting mechanisms. Facebook (FB) (now Meta) recently introduced a new *tagging* mechanism that attaches a one-time tag as a URL parameter (namely FBCLID) on outgoing links to other websites. Although such a tag does not seem to have enough information to persistently track users, we demonstrate that despite its ephemeral nature, when combined with FB Pixel, it can aid in persistently monitoring user browsing behavior across i) different websites, ii) different actions on each website, iii) time, i.e., both in the past as well as in the future. We refer to this online monitoring of users as FB web tracking.

We find that FB Pixel tracks a wide range of user activities on websites with alarming detail, especially on websites classified as sensitive categories under GDPR. Also, we show how the FBCLID tag can be used to match, and thus de-anonymize, activities of online users performed in the distant past (even before those users had a FB account) tracked by FB Pixel. In fact, by combining this tag with cookies that have rolling expiration dates, FB can also *keep track of* users' browsing activities in the future as well. Our experimental results suggest that 23% of the 10k most popular websites have adopted this technology, and can contribute to this *activity tracking* on the web. Furthermore, our longitudinal study shows that this type of user activity tracking can go as far back as 2015.). Simply said, if a user creates for the first time a FB account today, FB could, under some conditions, match their anonymously collected past web browsing activity to their newly created FB profile, from as far back as 2015 and continue tracking their activity in the future.

CCS CONCEPTS

- **Information systems** → Online advertising; Traffic analysis;
- **Networks** → Online social networks.

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KEYWORDS

User Web Tracking, Facebook Click ID, Web Pixels

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1 INTRODUCTION

Undoubtedly, advertising is the primary source of revenue for Facebook (FB, now Meta)[11]. Recent reports suggest that Meta had 117.9 billion revenue in 2021 [49], 97.5% of which was generated from advertising of third parties on FB and Instagram [65]. This revenue was achieved due to millions of ad campaigns whose success relied, in part, on key behavioral data and FB user tracking.

Indeed, FB uses cookies produced by its FB Pixel for user activity tracking purposes. This *third-party*, JavaScript-based FB code sets a *first-party* cookie (`_fbp`) on a website and transmits it back to FB to track the visitor. However, it cannot actually point to the *real* identity of the user: it is a cookie unique per browser and website, but it is not the *real* identity of the user¹. Potentially to amend this issue, FB recently (2018) introduced the FB Click ID (FBCLID): a *one-time* tag that FB appends to outbound links (e.g., ads, websites, etc.) that are shared on its platform. When a user clicks on an ad (or other external article) on FB, the outbound request includes a FBCLID query parameter that is transmitted to the landing page of the third party. This parameter is a long string that looks random and changes each time a user clicks on an outbound link. Even if the same user clicks twice on exactly the same link (after page reload), the two FBCLID values generated are different from each other². Since the FBCLID seems to have a temporary one-time value, one might assume that *it cannot be used to persistently track users* across the web and time. On the contrary, in this work, we show that FBCLID, despite its ephemeral nature, can aid FB in de-anonymizing users, whose activities on websites (that support FB Pixel) have been persistently tracked. In fact, as we show later, FBCLID can be used in conjunction with FB Pixel to reveal the *real* identity of a user and attribute all the previously captured browsing activity of an unknown `_fbp`, to a real FB account.

¹ *Real identity*: The user identity as is known to FB: i.e., the FB account of the user.

² Example of actual link with FBCLID: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5678212/?fbclid=IwAR0J2ueFwGP2ZSLznw04QEFAbkMDue3T9YSg6>

With this work, we are the first to shed light on the `_fbp` and FBCLID tagging mechanisms, assess their functionalities and how they collaborate, and the implications on users' privacy and persistent activity tracking on the web from FB. To understand the extent of this tracking by FB Pixel and the opportunity of FB to de-anonymize users' activity with FBCLID, we analyze a total of 17K websites of a wide range of categories and ranking in the top 1M websites, and the website behavior when the FBCLID tag and `_fbp` are present. We showcase the importance of the FBCLID tag which could eventually reveal the real identity of users and link them to past anonymous activities on various categories of websites. In fact, we find significant presence of FB Pixel on sensitive category websites under GDPR. In addition, our longitudinal study shows that this type of behavioral tracking on websites with FB Pixel dates as back as 2015, or even as 2013 (when the precursor of this technology was first introduced by FB). This means that FB could eventually have built customer profiles for its users with browsing activity, on websites utilizing FB Pixel, captured as far back as 2013. We show that those tags and cookies presented as first-party cookies can be used to persistently track users with rolling expiration dates, providing an adequate replacement of the third-party cookies blocked by privacy browsers or plugins.

2 BACKGROUND

2.1 What is the Facebook Pixel?

Tracking users who visit a website has been traditionally done with third-party cookies. Thus, FB Pixel (FB Pixel) [29] was first introduced in 2013 as an analytics tool for FB to help advertisers (websites external to FB) measure and increase the effectiveness of their advertising campaigns. FB also uses FB Pixel to track users' browsing activity anonymously while outside the platform. Given recent regulations, restrictions and blockade of third-party cookies, advertisers rely on other mechanisms such as *first-party* cookies to continue tracking user activities and provide better insights on ad campaigns. Those cookies are placed by third-party JavaScript code on the website [34, 72], and allow tracking the activity of a user under a pseudonym but not their real identity. This is a major drawback on tracking as it renders the attribution of history of activities to a real user (not a pseudonym) almost impossible. FB replaced the FB Pixel mechanism by a second version in 2015 and further updated it in Oct. 2018 to better leverage first-party cookies that FB Pixel can inject per website. Then, FB introduced FBCLID to enable FB to track, not just browsers, but FB user accounts.

FB Pixel is a piece of JavaScript code added to a website as a graphic element with dimension 1×1 pixel that is loaded when a user lands on the website hosting it. When FB Pixel is included in a website, it also has embedded a URL pointing to FB servers, with a specific ID reflecting the specific FB Pixel account holder, and can be used by FB to track relevant audiences for brand ads ([58]). When a user visits a FB Pixel-enabled website, an instance of the pixel loads in the HTML code of the page on the browser. According to FB Pixel documentation [30], if a corresponding first-party `_fbp` cookie does not exist on the browser, one is created and a unique ID is saved for this domain. FB Pixel is responsible for reporting to FB the user activity for the duration of the visit.

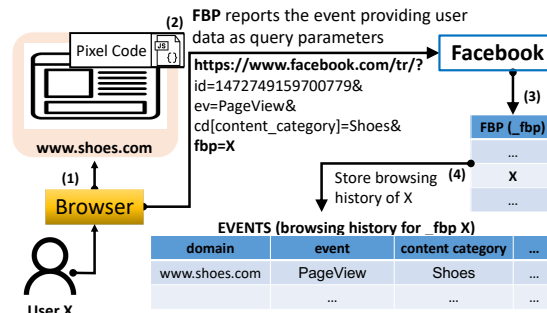


Figure 1: How FB can record the browsing activity of user X into an anonymous FB profile using reporting from FB Pixel.

The value of `_fbp` cookie has the following format:

`version.subdomainIndex.creationTime.RandomNumber`

Example of the `_fbp` cookie: `fb.1.1596403881668.1116446470`, where:

- *version*: always the prefix `fb`
- *subdomainIndex*: domain where the cookie was defined. e.g., 'com':0, 'shoes.com':1, 'www.shoes.com':2
- *creationTime*: UNIX time in milliseconds when the `_fbp` cookie was created
- *RandomNumber*: a number generated from FB Pixel's SDK ensures that every `_fbp` cookie is unique. As stated by FB, it is "generated by the Meta Pixel SDK to ensure every `_fbp` cookie is unique" [30].

2.2 How does FB Pixel track users?

FB Pixel performs *event-driven* tracking of user activities on websites. That is, the webpage administrator has to define to FB Pixel the behavior they wish to track and report to FB, by defining *events*, i.e., actions, that a user takes on the website. Events can be general such as 'Page-View', or specific such as 'Time-On-Page'. Actions the website has configured to be tracked are defined as *conversions*. FB provides a set of 18 trackable events named **Standard Events** (listed in Appendix A.2). FB is informed about actions being tracked by FB Pixel and triggered by the user, allowing FB to build a *history of activities* for said user.

The *Base Pixel code* is a small segment of JavaScript code which acts as an 'initiator' for the overall FB Pixel behavior. The base function `fbq()` is initialized and a library of functions currently called `fbevents.js` [24] is loaded on the website (the older version was called `fb.js` [23]; both versions have been also found in [67]). This library is the core mechanism of the FB Pixel.

In Figure 1, we illustrate the reporting process of the Page-View (visitation of the website) event. When an event is fired on a webpage because a user X loaded the website (step 1), FB Pixel reports to FB information about the event and user that caused it, which initially is the `_fbp` value (for an unknown user, step 2). On the other hand, FB can record the reported information in appropriate tables (steps 3 and 4) for future use in ad-conversion and further user profiling and tracking, thus building a history of activities for a (yet) unknown user on this website. Based on the uniqueness of the `_fbp` cookie, the browsing activities tracked by FB Pixel will be attributed to this (yet) unknown `_fbp` value.

Developers of the website can also declare **Custom Events** (apart from the 18 standard events) they wish to track, as well as

Table 1: FB Pixel adoption in websites of sensitive categories.

	health	politics	sexual orientation	ethnicity	religion
Pixel adoption	16.9%	14%	10.5%	5.3%	4.6%
Total websites	7679	5663	1140	2509	9119

additional user information they wish to share with FB through FB Pixel (see Appendix A.2, Table 2 for the additional ids). However, the baseline information that is received is the event (e.g., PageView in Figure 1) and some IDs that help FB keep a history of activities and potentially match this history to a FB user, as shown later.

3 FB PIXEL PRESENCE ON THE WEB

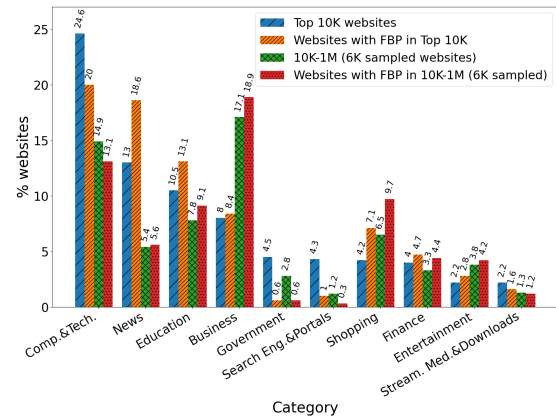
First, we measure the extent to which FB Pixel has been adopted across the web, before analyzing further its impact to users’ privacy. We also quantify FB’s ability to build elaborate histories of user activities on sites, by tracking a variety of events users perform.

3.1 FB Pixel Adoption in Top 1M

3.1.1 Experimental Setup. To find the adoption of FB Pixel, we crawl top websites and analyzed any FB Pixel-related cookies, along with the network traffic produced. For this crawling, we use the *Tranco* List [36] of top 1M websites, ranked for 2.11.21 (ID:L394) [37]. To make experiments computationally feasible, we use the top 10K websites (T10), as well as a sample of 1000 websites for each of the following 6 rank ranges: 10K-20K, 20K-50K, 50K-100K, 100K-200K, 200K-500K, 500K-1M, for a total of 6K extra websites (6S). For this crawling, we follow state-of-the-art practices and use Chromium browser [12, 52, 53, 63] and Puppeteer [22] on several parallel VM instances. Moreover, given that automated crawling can face network errors, disconnections, unavailability of web servers, etc., we visit each website three times. Each visit is performed with a clean browser instance. In order to emulate a real user more closely, we do not perform headless crawling. Instead, we launch a 1600x1200 pixel instance of Chromium. All crawlings performed, followed the ethical guidelines described in Appendix A.5.

Finally, we consider the navigation to each page completed by monitoring two main indicators from Puppeteer: 1) *networkidle0*: No more than 0 network connections for at least 500 ms; 2) *domcontentloaded*: The DOMContentLoaded event is fired (in order not to wait for style-sheets, images, etc., to load, that would slow down our crawling process). If both indicators are true, we assume that the navigation for the specific website has been completed. After that, we check all cookies stored from this domain for any whose name matches the pattern *_fbp*. If such a cookie exists, we store the whole array of cookies for that website. Each visit to a new website is done with a new instance of browser in order to avoid cross-domain contamination. This crawl was completed on 17.01.22.

3.1.2 Top websites with FB Pixel in 2022. Our results indicate that 2,308 (2.3K FBP) of the top 10K websites (23.08%) used the FB Pixel. It is interesting to note that this percentage (23.08%) is in line with previously reported results: Chen et al. (see [12], Table 3) found 23.77% of the top 10K Alexa websites store *_fbp* cookies. We also look into the 6S set, and find that 990 (or 16.5%) of websites adopt FB Pixel (990 FBP), indicating that higher-ranking websites are more eager to adopt FB Pixel. This is not surprising since such websites are expected to be more active in ads and, therefore, in

**Figure 2: Top 10 categories depicting the proportional rate of FB Pixel adoption in T10 and 6S sets.**

collaborations with FB. We conclude that 1 in 5-6 top websites employ FB Pixel and its first-party cookie, enabling FB to track users’ activities on websites, across a large portion of the Web.

3.1.3 Website categories with FB Pixel. Next, we quantify what types of websites are more eager to adopt FB Pixel and its associated tracking. In order to classify the websites found to operate FB Pixel, we use Cyren’s URL category check gate [21]. Figure 2 shows the 10 most popular categories across websites for T10 and 6S, as well as for websites adopting FB Pixel for each set (2.3K FBP and 990 FBP, respectively). The results suggest that 20% of the FB Pixel-adopting websites are categorized as “Computers and Technology” and 18.6% of them are “News” websites. This should not be surprising as these kinds of websites are very frequent on the web and offer lots of opportunities for ad sales. Figure 2 also shows whether websites of a specific category are more aggressively adopting FB Pixel than the average site. Indeed, websites in “News”, “Education”, and “Shopping” are disproportionately more eager to adopt FB Pixel. In contrast, and perhaps expected, websites under “Government” and “Search Engines & Portals” are less eager to adopt FB Pixel, as they may be less dependent on ads. We also observe some deviations from the lower ranking websites, which employ FB Pixel more than expected in additional categories of “Business”, “Finance”, and “Entertainment”. Alternatively, if we examine how many websites in a given category are adopting FB Pixel, the top 3 categories are “Shopping”, “News” and “Education” (more details in Appendix A.1).

3.1.4 Pixel adoption in sensitive categories. Next, we focus on specific categories deemed sensitive under GDPR [44], and study the adoption of FB Pixel in each. For this, we crawl Curlie’s Internet directory [13] and fetch various websites for the following 5 *sensitive* categories: ethnicity, health, politics, religion, sexual orientation, thus constructing 5 lists with unique domains for each category. We visit each website utilizing the same method as earlier to identify the use of FB Pixel (we focus on this script compared to other FB-related scripts studied in [32]). Table 1 shows per sensitive category the size of each list, and portion of websites using FB Pixel. Interestingly, websites on health, politics and sexual orientation are quite eager to adopt FB Pixel and track users’ activities.

3.1.5 Tracking with Standard & Custom Events. FB provides 18 standard events that trigger the FB Pixel reporting process. Each

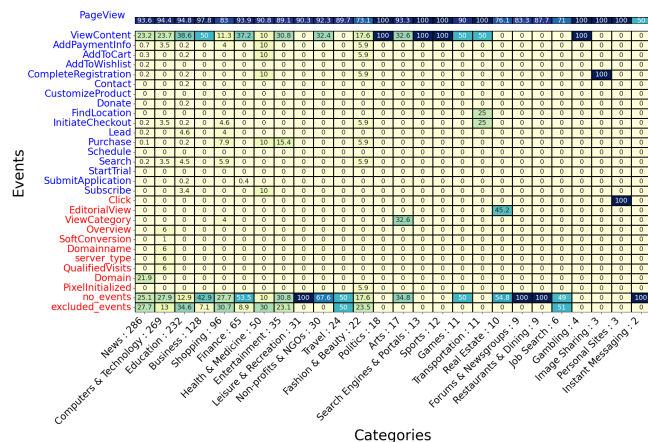


Figure 3: Events tracked by FB Pixel on subpages of top 10K websites, analyzed per category. Blue-colored events are the 18 standard from FB. Red-colored events are newly discovered and studied. Cells show portion of websites per category (x-axis) tracking said event (y-axis).

website can also define its own events to be reported through FB Pixel, by modifying the call to the *fbq()* base function. The tracking of an event is achieved by modifying the 1st argument of the function with possible modifications: ‘track’, ‘trackCustom’, ‘trackSingle’, ‘trackSingleCustom’ and the order of the next arguments, as described by FB [25, 26]. To understand the intensity of user tracking via different events across websites, we perform automatic static analysis of the pages that use FB Pixel, and identify the aforementioned function and the tracked events included therein. This methodology allows us to go beyond recent work which collected FB Pixel events by observing the traffic of real users but on a handful of websites [43], and instead scale the crawling to thousands of websites. In fact, and inspired by recent work on under-study of subpages [8], we go beyond the homepage of each website and study its subpages as well: For each homepage, we extract all links pointing to the same domain, and keep all that are one level below the top-level domain. Then, on 27/09/2022 we crawl all identified homepages and its subpages to detect (statically) the events tracked.

From the 2.3K FBP websites, we find 1473 that load FB Pixel statically on their HTML. In total, we crawled 1473 homepages and 18683 subpages (out of which only 932 did not track any event). We extract the *fbq()* calls and identify the events set to be tracked by FB Pixel. From our analysis, beyond the 18 FB standard events, we discover 10 new events, excluding website-specific events encountered only in one website, or variables. From the standard events, we did not encounter: *CustomizeProduct*, *StartTrial* and *Schedule*. We normalize the events captured in the websites per category. Figure 3 shows the portion of events (per category) found in subpages (due to space limits, results on homepages in Appendix A.2, Figure 8b).

Unsurprisingly, in both homepages and subpages, the great majority of websites track the *PageView* event. Beyond that, there is a wide variety of events tracked and reported by different categories of websites. For example, ‘Fashion & Beauty’ and ‘Shopping’ websites, beyond the actual content viewed by their visitor, also track and report to FB financial transactions on their site related to payment, shopping cart, etc. Other interesting outliers are ‘Personal sites’ that track the ‘click’ event, ‘Imagesharing’ websites that track ‘completeregistration’, ‘Education’ websites that track ‘lead’,

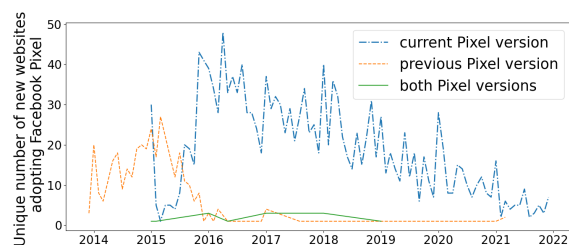


Figure 4: New websites with FB Pixel, through time, for the top 5K websites. We see that the previous Pixel version was adopted around 2014 while the current Pixel version was introduced around 2015.

‘search’, ‘subscribe’, and ‘Non-profits&NGOs’ websites that track ‘addtocart’, ‘lead’, ‘purchase’, ‘completeregistration’. Alarmingly, and in addition to Sec. 3.1.4 findings, ‘Health and Medicine’ websites track events such as ‘add payment info’, ‘addtocart’, ‘purchase’, ‘completeregistration’, and ‘subscribe’, all reported to FB. Overall, the variety of events reported to FB by its pixel, enables it to build a detailed history of activity per user, and finally profile the users more effectively for better ad-targeting.

3.2 Historical FB Pixel Adoption

Next, we want to know when websites started adopting FB Pixel. For this, we proceed as follows: We visit all top 5K (from Tranco) websites using the *Wayback Machine* (WM) [69] to find if they had FB Pixel code embedded in their HTML, and when this was done for the first time, starting from 01.2022 and going back to 2013.

3.2.1 A decade of tracking through FB Pixel. Figure 4 shows the distribution of unique new websites adopting FB Pixel through time, for the top 5K websites (similar results were found for the general top 1M websites and are omitted due to space). First, we note that FB Pixel has been around since 12.2013 with the 1st version, while its adoption (per new website) peaked around early 2015. At the same time, in 2015, we also had the release of the 2nd version, whose adoption peaked in early 2016, while the 1st version lost momentum. In fact, FB faced-out the 1st version in 02.2017. Second, we notice a few websites using both versions in parallel, as evident from the third line. This is probably due to websites that adopted the code for the new FB Pixel version without removing the previous version. Forth, as noted by the spikes per month, FB Pixel adoption was not smooth, but in waves due to FB marketing campaigns and website updates, happening at the beginning of each year and quarter.

3.3 Key Takeaways

About 23% of T10 websites facilitate FB tracking activities, using FB Pixel for their ad conversion analytics. We find FB Pixel in 40+ categories of websites, with the top 3 being Computers & Technology, News, and Education. This wide coverage shows that conversion tracking through FB Pixel can capture activity of different profiles of users. We also find at least 28 different web events tracked and reported by FB Pixel (10 more than the Standard events of FB). Of special interest are GDPR-declared *sensitive* categories such as health, politics and sexual orientation that track user activity via various events. FB has been tracking users’ browsing activities since at least 2013 using FB Pixel on websites, building elaborate profiles with a wide range of captured actions. Thus, the opportunity for

tracking and de-anonymizing a user's browsing history of activities for a website that utilizes FB Pixel goes back a decade or so.

4 FB PIXEL TRACKING MECHANICS

Next, we focus on the key question: *How can FB use its recently launched one-time-tag FBCLID with its `_fbp` cookie to match historical website visitors with FB user profiles?* In the following paragraphs, we explore the mechanics of these cases.

4.1 Matching website visitor coming from FB

This is the base scenario, which involves a user with a FB profile, who arrives at website W after they clicked on a post or ad of W while browsing within FB. In most such cases, there is a *fbclid* (FBCLID) query parameter with an ID appended in the URL of the landing website. If W runs FB Pixel, the pixel saves the appended FBCLID under a cookie named `_fbc`, with the following format:

version.subdomainIndex.creationTime.fbclid

where the fields are similar to the `_fbp` cookie apart from the last, which holds the FBCLID value. An example of such a FBCLID is:

`IwAR0X0CXJ2hZB_CNGJbMjHYZqZiS9-MJ9QrFxJBRkacHhJMMjnQLsEjvXYZ`

Since FB knows who performed the click, we assume that FB assigns the FBCLID to the user. Thus, with a browsing history of the user for website W under the unique `_fbp` value, the combination of the two cookies (i.e., `_fbp` and `_fbc`) enables FB to uniquely track FB users and their visits through time, inside or outside FB.

FBCLID generation: Interestingly, although the FB Pixel has been in use in its latest version since 2015, FBCLID has been appended to outgoing URLs only since mid-October 2018, with no official documentation from FB [40]. Since FB does not reveal how these hashed-like strings are generated or what information is stored inside them, we provide some empirical analysis on their usage and possible values. A FBCLID parameter has 61 alphanumeric characters which can consist of upper/lower case letters, numbers and symbols (e.g., '-'); thus, it is not base64 encoding. FB for Developers documentation also states [30] that regardless of the existence of said cookies, if the FBCLID parameter exists in a URL, the ID can be sent to FB to provide browsing insights for the FB user.

FBCLID assignment: Given the lack of documentation on how these IDs are being generated and assigned to users, ads, links, etc., from within FB, we conduct a few experiments to acquire better understanding. We perform these experiments using two different user accounts on FB, and three different browsers (Google Chrome, Mozilla Firefox and Microsoft Edge). We inspect the HTML code of FB's home page (for those accounts) and in the FB pages of some businesses. We observe that FBCLID is assigned inside the *href* value of HTML elements, meaning these values are not created "on the fly", but rather they are assigned once the document is loaded.

Upon further examination of the FB webpage JavaScript source code, we find that when loading a page inside FB, there is a *static* array called *click_ids*, loaded as part of a JSON object inside a `<script>` tag, whose values are updated upon every request that is landing on the specific page (e.g., reload). This array hosts 50 FBCLID values, each with a fixed length of 61 characters. Therefore, these FBCLIDs cannot be uniquely distributed amongst the different URLs that

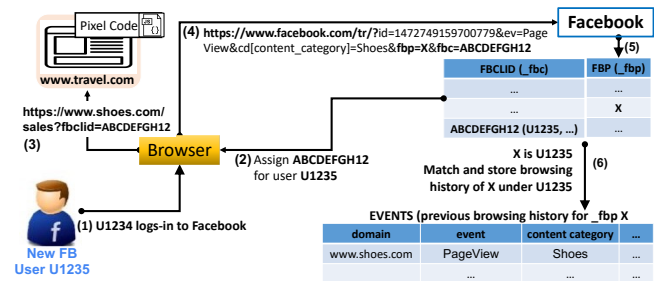


Figure 5: How FB can match the browsing of the anonymous profile of user Z, using FBCLIDs, with the existing FB user U1234.

could exceed 50 in total. Also, there can be the same FBCLID assigned to different URLs. But, the same FBCLID seems to only be assigned to elements of same class name, thus concluding FBCLID is probably element dependent.

FB User to Visitor Matching: Let us assume that a user starts with a clean browser (no cookies) and visits the website *www.travel.com*. Also assume this website uses FB Pixel, i.e., FB can collect some browsing history information about this user, but under a pseudonym Z (not the real identity) corresponding to the `_fbp` value.

Let us now assume that this user actually has a FB account and is known to FB as user U1234. Let us also assume that this user will now login into FB - into their account. Figure 5 shows what happens from this point on and how FB could match the browsing history of Z, inside *travel.com*, with the *real identity* of FB U1234. U1234 browses through their newsfeed on FB (step 1) which contains an external link to website *www.travel.com*, possibly as the result of ad-targeting. When U1234 clicks on this URL (step 3), a FBCLID value of ABCDEFGH12 is also appended on the outgoing URL (step 3). This value (i.e., ABCDEFGH12) was set by FB on step 2, and then FB Pixel on *www.travel.com* creates a `_fbc` cookie storing the FBCLID locally. This visit also triggers an event such as the "PageView" on the webpage that FB Pixel picks up. Then, FB Pixel performs a GET request to a FB server providing the URL information about this event as a query parameter (step 4). The event that triggered this request is appended in the URL, along with both the `_fbp` and `_fbc` cookie values, all reported to FB (step 4). Given that the reported FBCLID ABCDEFGH12 was given to U1234, and given that this value (i.e., ABCDEFGH12) arrived to FB along with the `_fbp` cookie for Z, FB can now infer that user Z and user U1234 are the same person. As a result, all the previously performed browsing activity of Z captured on *www.travel.com*, can now be attributed to user U1234.

4.2 Matching website visitor with new FB user

Given that FB Pixel reports the browsing activity of a user regardless of the existence of a FB account, the same build-up of history of activities can be achieved for non FB users. If such a user later on creates a FB account and browses websites with FB Pixel, then the same matching process can occur and connect the previous browsing history of the new FB user to a specific website W. To depict the overall matching process, we envision a 3-day scenario: **1st day:** Z visits a website (say *www.travel.com*) with FB Pixel, which informs FB of the visit. FB may store information regarding the user behavior on the website, under anonymous user Z.

2nd day: The user creates a FB account. From now on the user is known to FB as **U1234**. At this point, FB still does not have enough information to associate *U1234* with the browsing history of *Z*.

3rd day: While *U1234* browses their FB newsfeed (step (1), Figure 5), they click on a link pointing to *www.travel.com*. This link (step 3) takes as argument the FBCLID value **ABCDEFGH12**. The visit also triggers a “PageView” event on the page that FB Pixel reports to FB, thus enabling the aforementioned the matching process.

5 FB PIXEL USER ACTIVE PROFILING

Next, we quantify *how many FB Pixel-enabled websites, in conjunction with `_fbp` and FBCLID, can enable FB to reconstruct a user’s browsing history, even before the user had created a FB account?*

5.1 Experimental Setup

We generalize the process outlined in Section 4.2 into 4 steps, to scale the data collection process on multiple websites:

Step S1: Similar crawling as in Sec. 3, but on 2.3K FBP websites.

Step S2: Similar to S1, but with 2 differences: (1) we load only `_fbp`, and no other to avoid loading session cookies; (2) while waiting for navigation to complete, we monitor all GET requests to FB that include `_fbp` as a query parameter with its value, allowing FB to build a browsing history for each site, under a user “pseudonym”.

Step S3: Extracting a real FBCLID value from a dummy FB account. We store this ID and use it in the next crawling, in S4.

Step S4: Similar to S2, but with a fundamental difference. Now we visit each of the 2.3K FBP websites with the FBCLID (extracted in S3) appended in the URL of each website. Each visit is done by loading the `_fbp` cookie corresponding to each website and monitoring network traffic, as in S2. Because of the FBCLID, a `_fbp` is created and sent to FB along with `_fbp` cookie. We capture the outgoing traffic that includes both `_fbp` and `_fbp` values. We store each URL with those values for further analysis.

5.2 Browsing history build-up & matching

Looking into the traffic collected from S2, we find that out of 2,308 websites storing the `_fbp` cookie when visited (S1 and S2), 2,223 (or 96%) websites report this event to FB. Thus, FB can create an anonymous profile for user *Z* with these websites included, along with any other useful data such as type of website, etc.

At the end of S4, FB has both the `_fbp` (unique browser ID) and `_fbp` containing the one-time FBCLID tag. Thus, by looking into the outgoing traffic of S4, we can find on how many websites FB can link to *Z*’s newly created FB profile. In fact, from the 2,308 websites, 2,165 (or 93%) send to FB both the original `_fbp` and the newly created `_fbp` values. In particular, 92.3% of the websites report both `_fbp` (S2) and `_fbp` (S4), meaning that for those websites the previous browsing activity was tracked based on the `_fbp` value and could be matched to a user based on the FBCLID value of S4. The remaining portion is due to cases where websites do not track the visitation event, or do not load FB Pixel due to network errors, or use URL shorteners that cut FBCLID.

5.3 Key Takeaways

The above results show how the great majority of top websites report user-related IDs facilitating persistent tracking of anonymous

users by FB, even *before* FB user profile creation. In fact, given this tracking on websites by FB Pixel is event driven, it only takes one click of the user on a given website, for FB to be able to attribute the user’s browsing history to an (existing) FB user: 96% of FB Pixel-enabled websites report “PageView” (visitation) event to FB and 93% of such websites report both `_fbp` and `_fbp` values, enabling FB to perform user matching with anonymous historical data.

6 FB PIXEL: IS ANYONE LISTENING?

Next, we look to answer the following question: *Do websites share FB-related IDs with other third parties, thus, facilitating or enhancing user behavioral tracking beyond the scope of FB?*

6.1 Shared `_fbp` with third parties

From S1 and S2 crawls of Sec. 5, we find 4 websites that report `_fbp` cookies to other third parties, beyond FB. Interestingly, 3 are sub-domains of the first party, but appear to be advertising or analytics APIs. Thus, we cannot know if they propagate these IDs to other vendors after receiving them. Repeating this analysis on the 990 FBP sites, we find 13 more third parties receiving `_fbp` cookies.

These results confirm our intuition that other third parties can perform the same level of profiling as FB, by recording the user browsing history through time and attempting to link anonymous user browsing with legit user profiles using external IDs. These results also confirm past work [12, 63] that similarly found third parties receiving `_fbp` cookies. For example, [12] found 76 third parties receiving the `_fbp` value. The core difference with our results is that [12] used dynamic taint analysis to capture data flows of third-party JavaScript at runtime, whereas we capture GET requests that include those cookie values in the request URL.

6.2 Shared FBCLID with third parties

Next, we measure the network activity that a FBCLID value yields when visiting a website, to study how websites handle this ID. In order to confirm if this functionality is affected depending on the FBCLID value, we craft 3 versions of this ID, as follows: *real* (a value extracted from a real FB user account), *random* (a FBCLID-looking value, following the proper format, but with randomly picked characters), *dummy* (a value that does not follow proper format, with string value: “Adummy_param”). These variations allow us to study if a website’s FB Pixel checks the value of FBCLID passed by FB, and performs some filtering, or if it blindly records it in the `_fbp` cookie, and then alerts FB of the user’s arrival. Furthermore, we study if the website performs any actions such as forwarding to other third parties, depending on the type of FBCLID.

We revisit each of the 2.3K FBP (and 990 FBP) websites, capturing every GET request encapsulating either the FBCLID value injected on the URL, or the `_fbp` cookie value recorded for each website. For each of the 3 versions of the ID, the crawler: 1) Visits the website with the appended FBCLID parameter and value on the URL. 2) *first_hop*: Gets all URLs from the HTML DOM that include this value and all URLs from the network that receive those values with a GET request (if any). These outgoing URLs, apart from FB properties, can be third parties informed of these FB IDs. 3) *second_hop*: Visits all such detected URLs and captures again all outgoing requests that include the FBCLID or `_fbp` values. Clearly, this is an artificial

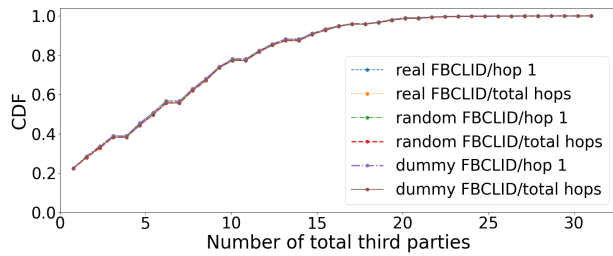


Figure 6: CDF of number of unique third-parties informed of FB-related IDs, per hop within 2.3K FBP websites.

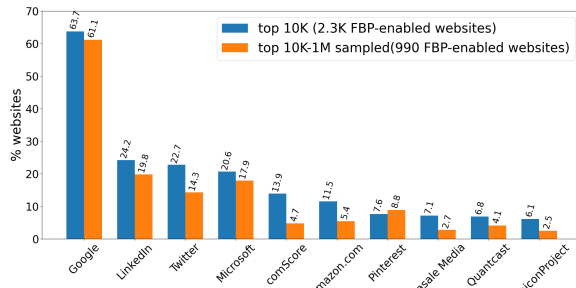


Figure 7: Top 10 third-party entities from each list of FB Pixel-enabled websites (2.3K FBP and 990 FBP).

invocation of said URLs, but we want to measure if these third parties pass the received IDs to further third parties.

We find the total number of third parties receiving the FBCLID value, per case is: 1931 for real, 1920 for random, and 1920 for dummy FBCLID. Thus, websites do not check FBCLID values: they pass IDs to third parties indiscriminately of its value, its structure, etc., as long as it is passed into a URL parameter named “fbclid”.

Unique vs. Total third parties: Figure 6 shows for the 3 cases, the distribution of unique third parties for ‘first hop’ and ‘total hops’ (as explained earlier), excluding FB-related domains, in the 2.3K FBP websites (results for the 990 FBP can be found in Appendix A.3, Figures 9a and 9b). We find that 22.4% (24.4%) of websites from 2.3K FBP list (990 FBP) do not send FBCLIDs to any third party. However, a median website passes these IDs to 6.2 (4.9) third parties. In the extreme scenario, there are websites that pass FBCLIDs to a maximum of 31 (26) third parties. Thus, lower ranked websites seem to share FBCLIDs with fewer entities than popular websites, at the median and maximum case.

6.3 Top Third Parties and Entities

Having the traffic of each FBCLID value for the two lists (2.3K FBP and 990 FBP), we merge every third party encountered from each list, excluding every subdomain of the websites visited (e.g., metrics.shoes.com is excluded as a first-party subdomain of shoes.com), ending with 1398 third-party domains. Focusing on their Top Level Domain (TLD) using the tld Library [2], we find 755 unique TLDs, many of which are typical such as doubleclick.net (Appendix A.3, Fig. 11 plots the top 10 third parties receiving FBCLID).

Next, we use the Disconnect.me list [1] to match these domains with third-party entities. We match 210 out of 755 (27.8%) third-party domains to various services of those entities, and Figure 7 shows the top 10 of them. Google is the top, with more than 61% of websites reporting to its services user FBCLIDs. Interestingly,

Microsoft can be considered second, since it also owns LinkedIn, with Twitter and ComScore following. Finally, the breakdown of third parties and their entities is very similar between the two sets of websites (2.3K FBP vs 990 FBP). This means that such trackers and other Web entities well embedded across all ranks of websites get informed of FB IDs and thus FB user activity.

6.4 Key Takeaways

FB Pixel does not have a mechanism to distinguish real vs. artificial values of FBCLIDs: if there is a URL parameter *fbclid*, its value is reported to FB. Also, a median website passes such IDs to 4.9–6.2 third parties beyond FB, who can persistently record the user browsing activities using the *_fbp*, and attempt to link anonymous user browsing with legit user profiles using external IDs, thus allowing a more elaborate analysis of a user behavior.

7 ROLLING EXPIRATION DATES OF FB PIXEL

Next we investigate: *How long does this behavioral tracking by FB last on websites?* Intuitively it should be for the 3-months lifespan of the FB Pixel cookies (*_fbclid* and *_fbp*) [28]. But is it true?

7.1 Experimental Setup

To answer this question, we measure how often *_fbp* cookies update their expiration date, and thus, how long FB can track the same user under the same (anonymous or not) profile. Thus, we study if this persistent ID (*_fbp*) stays alive beyond 90 days, by:

Step S1: Crawling as Sec. 3 (navigation settings, etc.). We store *_fbp* cookie and record its expiration date.

Step S2: Reloading all 2.3K FBP websites to fetch *_fbp* again.

Step S3: Reloading all such websites, but with the FBCLID appended in each URL, forcing each website to generate a *_fbclid* cookie. We store the produced *_fbp* cookie, but not the *_fbclid* cookie since it is not persistent (i.e., the value changes per FBCLID).

This experiment aims to establish when websites update the expiration date of their *_fbp*, depending on the actions performed on the website: reload vs. reload with a FBCLID included, i.e., the visit originated from within FB. As a sanity check, in all steps and websites that a cookie is created and stored, we confirm that the expiration date is 90 days after the creation date.

7.2 Rolling tracking: cookies that never die

The great majority of 2.3K FBP (1942 or 84.1%) update the *_fbp* expiration date on every event (reload or with FBCLID). Also, there are 115 (or 5.0%) websites that do not update the expiration date of *_fbp*, regardless of event or action on the website. Also, ~3.2% outlying cases have the expiration date of the *_fbp* cookie updated upon *only* one specific event. While FB Pixel handles these cookies, they still remain first party cookies, thus websites have access to modify them. Thus, a small deviation between their behavior on different websites can be expected.

Interestingly, there are 172 (7.5%) websites that blocked our access after a specific event, or stored duplicate results for an event. Not generating a *_fbp* value could be due to network errors (unable to load FB Pixel), or the specific website stopped supporting FB Pixel since our first crawl in Sec. 3. Given that for this experiment

we did not use any mechanism to disguise our crawler from bot detection, duplicate cookies could be due to network errors, redirection to human authentication mechanisms (e.g., CAPTCHA), or even blocking the crawler from further action if it was flagged as a potential bot.

7.3 Key Takeaways

Overall, 87.3% of 2.3K FBP websites update the expiration date of `_fbp` cookie, under some visiting condition (e.g., reloading website, visiting with FBCLID, etc.). This continuous updating of `_fbp` expiration enables FB to perform persistent and consistent tracking of users across visits on the same website, browser and device, beyond the initial 90-day expiration date of `_fbp` cookies.

8 RELATED WORK

User tracking on websites by first and third parties, primarily done for ad-conversion attribution and user profiling purposes, has been extensively studied in the last decade [4, 5, 10, 12, 15, 18, 19, 35, 46, 48, 50, 54–57, 63, 66]. Research also detected changes in user web tracking due to enforcement of EU regulation such GDPR and e-Privacy on EU-based websites, by measuring changes in cookies and other fingerprinting technologies employed by websites and third parties [45, 47, 52, 64, 66, 70]. In such studies, FB is identified as a key player in the third-party Web tracking ecosystem. Previous FB-related works [6, 60–62] focused on how FB track a user's online activities across the Web through social widgets (the 'like' button) and third-party cookies.

Studies on trackers' historical presence on the web [38, 39, 71] looked at the prevalence of various third-party tracking techniques over a period of time up to 2016. As a complement to those studies, we showcase the expansion of Analytical Tracking (FB Pixel) up to 2022. Recent studies on cookies that are injected by third parties (such as FB) into a browser, but stored as first-party cookies [12, 14, 15, 63] identified the entities and their relationships in the current post-third-party ecosystem.

Moreover, studies [7, 14, 20] focused on the analysis of such pixels and identifying such tracking techniques and their prevalence in the web. The Markup [43] recently conducted the first large-scale study to measure the presence of FB Pixel and the data it collects from real users. They analyze FB Pixel-reported IDs and how FB can extract personal information from the hashed values. Also [41, 42] raised issues regarding FB tracking of 4M college students applying for federal financial aid, by sharing personal data with FB through FB Pixel. Lastly, [17] studies how cancer-related health companies use third-party tools to track patients' behavior between their websites and FB, capturing the FBCLID as data shared with FB.

Our contributions: While previous studies captured a broad view of the first-party tracking ecosystem (and key participation of FB in it), they do not explore how de-anonymization can be achieved for those anonymous first-party trackers. Moreover, they do not explore how mechanisms such as FB Pixel could replace methods like social widgets, that leverage third-party cookies, effectively achieving user de-anonymization. We study how this pair of cookies can aid FB to persistently build an elaborate history of user activities, and match anonymous web users (via their activities outside FB) to FB

users. In particular, we are the first to study the following questions: (a) How FB can keep track of a variety of activities for a user that has no FB account yet? (b) How FB can match previous browsing history and activity on a given website (utilizing FB Pixel) to a new or existing FB user? (c) How long can this behavioral tracking of an online (FB or not) user last? (d) How can the FBCLID parameter help FB, through FB Pixel, and its persistent cookie `_fbp`, to match a user's specific online activity on a website (e.g., viewing, clicking, purchasing, etc.) to a certain FB profile, and even possibly expose FB activity of a user to other third parties?

9 CONCLUSION

FB has recently introduced FB Click ID (FBCLID): a one-time tag passed as argument to all outgoing URLs for users who browse through FB. Although this one-time tag is ephemeral and seemingly cannot be used for tracking, with our present study, we show for the first time how FBCLID can be combined with FB Pixel, a conversion tracking tool embedded via JavaScript on websites, and be used to track users' activities both in space (i.e., in websites utilizing FB Pixel), and in time (i.e., in the past and future). Although FB Pixel advertises a 3-month-long lifespan and can seemingly limit any tracking to at most 3 months, unfortunately, in a great majority of websites with FB Pixel, the pixel employs rolling expiration dates for the first-party cookies it places (`_fbp`), which can postpone its lifespan (and its associated tracking) indefinitely. We have experimentally verified this behavior on more than 20% of top 10K, and 6K samples of top 10K-1M websites. We also find that FB Pixel has been tracking user activity since 2013 and is present in many sensitive under GDPR categories of websites. Finally, these FB-related IDs are passed to several third parties beyond FB, aiding other entities to monitor and profile users' web activity.

Disclaimer: This work reports our findings on *what* data are been collected and how they *could be* used. Unfortunately, we do not know how, when and why they are used after been collected.

Countermeasures: Regardless of privacy regulations (GDPR, e-Privacy), and efforts to limit third-party tracking (e.g., Chrome and Safari browsers blocking cross-session cookies), companies heavily relying on ads come up with novel ideas to preserve their ad reach and profits. For example, as shown here, with tracking through the FB Pixel utilizing first-party cookies and URL tags that evade third-party cookie blockade. Privacy-focused browsers have been a subject of research [51], and recently Brave and Firefox [3, 68] adopted URL striping to avoid URL tagging such as with `fbclid` parameters. Still, websites can share other IDs such as hashed emails, etc., thus, enabling FB and other third parties of historical matching.

Ad-blockers which block requests fetching third-party libraries (in our case the FB Pixel core library) into a site could be a solution. But this can also be bypassed by redirecting the request that loads the library through proxy servers or similar techniques. Indeed, as previous studies showed (e.g., [9]), companies tend to find ways to evade ad-blockers. Due to space, we elaborate more on various countermeasures regarding readily available tools such as private browsers and ad-blockers in Appendix A.4. Alas, the question of how to preserve user privacy under behavioral tracking in the post-third-party cookie era, remains open.

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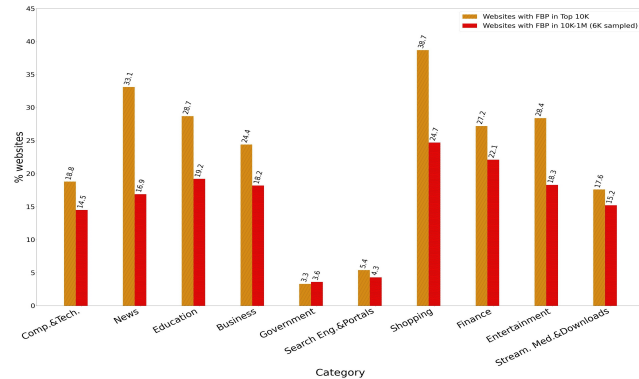
A APPENDIX: EXTENDED RESULTS

A.1 Categories adopting FB Pixel

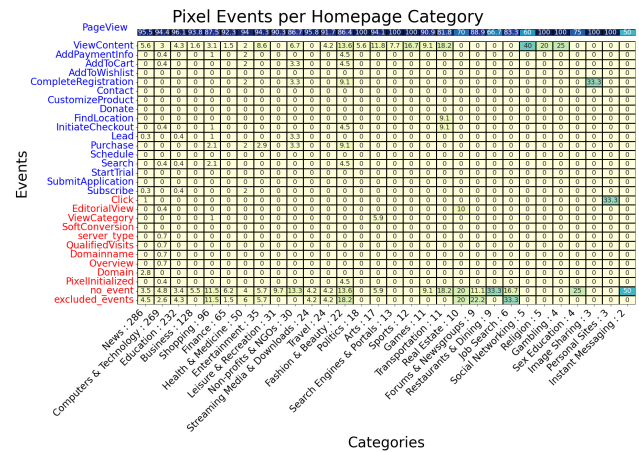
One question a careful reader might ask would be: *If a user, visits a website of category X (e.g. Shopping), what is the chance that the website will be utilizing Pixel?*

To answer this question we need to quantify the adoption rate per category, for each examined category. This differs from the results shown in Fig. 2 on the categorization of websites utilizing FB Pixel, and allows us to find what website categories are the most dominant across FB Pixel utilizing websites. For example, according to Fig. 8a, 38.7% of “Shopping” websites utilizes FB Pixel, but only 7.1% of the total 2.3K FBP websites are of the “Shopping” category. This means that, although FB Pixel is more widespread across “Shopping” websites, this category has a small population across websites found utilizing FB Pixel on the T10. (Note: Fig. 8a results per category are sorted based on the order of Fig. 2 for easy comparison).

As the results in Fig. 8a indicate, the most predominant category that utilizes FB Pixel is “Shopping” websites in both sets, T10 and 6S, with adoption rates 38.7% and 24.7% respectively. This category is followed by News (33.1%) and Education (28.7%) for the websites utilizing Pixel from T10. For the websites utilizing Pixel from the 6S, the next two most predominant categories are Shopping (24.7%) and Finance (22.1%).



(a) FB Pixel adoption rate for the 2.3K FBP and 990 FBP.



(b) Events tracked by FB Pixel on homepages of T10 websites, analyzed per category. Blue-colored events are the 18 standard from FB. Red-colored events are newly discovered and studied. Cells show portion of websites per category (x-axis) tracking said event (y-axis).

A.2 Facebook Pixel Events & User Data

In Fig. 8b, we see that although websites can track various events on their pages, the most common is the ‘PageView’. As mentioned, FB Pixel allows a website to define the events to be tracked, by specifying each event in the fbq(). For example, the submission of a registration form can be tracked by fbq(‘track’,CompleteRegistration). Standard Events (as defined by FB [31]) are listed below:

- PageView
- AddToCart
- Contact
- Donate
- AddToWishlist
- AddPaymentInfo
- FindLocation
- CustomizeProduct
- Lead
- Purchase
- Schedule
- Search
- CompleteRegistration
- InitiateCheckout
- SubmitApplication
- StartTrial
- Subscribe
- ViewContent

Alongside to the _fbp and FBCLID (_fbc) values, as previously mentioned, the FB Pixel shares a variety of additional information regarding the user that caused the event, in order to enhance FB attribution of activity to a real user. Table 2 lists some of the extra user data (complete list can be found at [27]) that can be reported by websites to FB for better user matching.

Table 2: Sample of User data reported by websites to FB for better user matching. HR: Hashing Required; HRC: Hashing Recommended; DNH: Do Not Hash.

Query parameter name	Description	Hashing Guide
em	Email	(HR)
ph	Phone Number	(HR)
fn	First Name	(HR)
ln	Last Name	(HR)
db	Date of birth	(HR)
ge	Gender	(HR)
ct	City	(HR)
st	State	(HR)
zp	Zip Code	(HR)
country	Country	(HR)
fbp	The FB Pixel cookie value	(DNH)
fbc	The _fbc cookie value	(DNH)

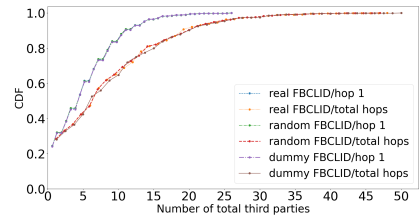
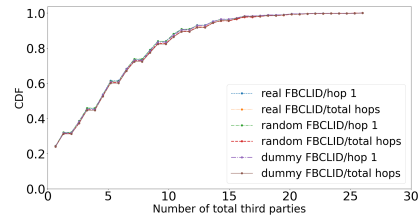


Figure 9:

Figure 8:

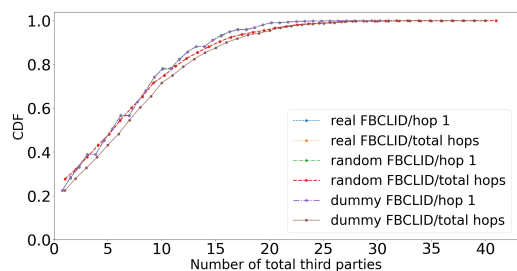


Figure 10: CDF of number of third parties informed of FB-related IDs, per hop, disregarding if they appeared in earlier hop (2.3K FBP).

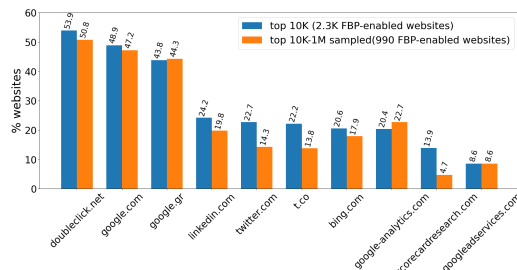


Figure 11: Top 10 third parties from each list of FB Pixel-enabled websites (2.3K FBP and 990 FBP).

A.3 FBCLID Sharing With Third Parties

While visiting and monitoring the traffic on 990 FBP websites coming from the top 10K-1M, the third-party invocations of unique and total numbers are found in Figures 9a and Figure 9b, respectively.

In Figure 10, we see the distribution of third parties per hop, disregarding if these third parties appeared again in earlier hop (excluding FB-related domains), for the 3 cases, and the two lists. “First hop” and “total hops” have similar meanings as described in 6. Looking into the Figure 10, the main difference from the plot in Figure 6 is the lines for “total” hops. In fact, we find that the median website passes FBCLIDs to 6.7 (7.9) and up to 41 (50) third parties within the 2nd hop. Therefore, and in contrast to unique third parties, lower ranked websites pass FBCLIDs to more entities within 2 hops.

Figure 11 shows the top 10 third parties informed with FBCLIDs, ranked based on the portion of websites emitting these IDs from each list. As no surprise, doubleclick.net and other top trackers are informed of a user’s FB activity from many websites.

A.4 Countermeasures

Privacy by design browsers such as Brave, have utilized mechanisms to block those click ids and prevent query parameter tracking. Specifically, Brave holds a list of known tracking parameters including the FBCLID. When a user visits a website with a tracking parameter, Brave removes the value from the URL before the browser makes the request. So even if the website the user lands on utilizes FB Pixel, it will not be able to create a _fbp cookie and report it alongside with the _fbp. One might assume that this would stop any potential matching of browsing activity (under the _fbp) to a real FB profile. But, as we mentioned, websites can declare other identifiers to be shared with FB Pixel such as the email, first & last name, etc. Although those identifiers are shared in a hashed form, they could still enable FB to perform the matching process.

Furthermore, sharing of other unique identifiers, such as the SHA-256 hash of the user’s email can be used to bypass mechanisms such as private/incognito browsing. FB Pixel performs its event tracking even when the user browses in private mode (incognito). By doing so, cookies and website data are recorded while the user is browsing in incognito, but deleted when they exit the browser’s private mode. This means that the persistent _fbp cookie will be created with a new value at each new visitation of a website and will be deleted after closing the browser. So for each browsing duration, every action will be collected under a different _fbp (a different pseudonym). Someone could assume that this effort and process would break the ability of FB Pixel and FB tracking and storing the history of activities of the same user under a unique pseudonym. But again, the website can decide to share other **persistent** and **unique** identifiers such as the user’s hashed email through FB Pixel, thus still enabling the correlation of multiple _fbp values with one (still) **anonymous** to FB user.

Ad-blockers such as Adblock Plus, UBlock, Disconnect, etc., can partially block the use of FB Pixel. Such tools contain a list of filters which determine what third-party requests (e.g., resources such as third-party JavaScript) will be blocked. Adblock Plus, for example, blocks the request that the base FB Pixel code makes to fetch the *fbevents* library. Without this library, the FB Pixel cannot create the first-party cookies to either track or report events. Although this action may restrain FB Pixel from performing the tracking correctly, it can still be bypassed. Websites can utilize a variety of methods such as request redirection through proxy servers or similar techniques explained in [33]. Moreover, the websites can utilize banners that require for the user to disable their ad-blocking extensions in order to continue browsing the website.

All these aforementioned efforts need to be investigated in the future in order to quantify how effective they can be, and if they are not, what other methods can be proposed by the security and privacy community. Indeed, it seems that even though capturing browsing activity per site and user is becoming more expensive and difficult than in the past, large advertisers have both the capacity and resources to continue doing so.

A.5 Ethical Considerations

The execution of this work has followed the principles and guidelines of how to perform ethical information research and the use of shared measurement data [16, 59]. In particular, this study paid attention to the following dimensions. We keep our crawling to a minimum to ensure that we do not slow down or deteriorate the performance of any web service in any way, by visiting the websites a few times spread over a long period of time. We do not interact with any component in the website visited, and only passively observe network traffic and cookies stored due to the visit. In addition to this, our crawler has been implemented to wait for both the website to fully load and an extra period of time before visiting another website. Consequently, we emulate the behavior of a normal user that stumbled upon a website, and arrives with potentially some cookies and or URL parameters in their browser. Therefore, we make a concerted effort not to perform any type of DoS attack on the visited websites. Also, and in accordance with GDPR and ePrivacy regulations, we did not engage in collection of data from real users.