

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 a variety of 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. To complement these tracking approaches, Facebook (FB) (now Meta) recently introduced a new *tagging* mechanism that attaches a one-time tag as a URL parameter (namely FBCLID) on outgoing to 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 FB web tracking.

We show how this 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 addition, 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 more than 20% of the popular websites have adopted this technology, and thus can contribute to this kind of *activity tracking* on the web. Our longitudinal study shows that this type of user activity tracking can go as back as 2015, or even as 2013 (when the precursor of this technology was first introduced by FB). To put it simply, if a user creates for the first time a FB account today, the platform could match the user’s past web browsing activity, collected in anonymous form, to their newly created FB profile, from as far back as 2015 and continue tracking their activity in the future.

I. INTRODUCTION

Undoubtedly, advertising is the primary source of revenue for Facebook (now Meta). Recent reports suggest that Meta had 117.9 billion revenue in 2021 [1], 97.5% out of which was generated from advertising of third parties on FB and Instagram [2]. This revenue was achieved due to millions of ad campaigns whose success lied, in part, on key behavioral data and FB user tracking.

In addition to its traditional tracking mechanisms, such as cookies, FB recently launched 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 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 a page reload), the two FBCLID values that

will be generated will be different from each other¹. Given that the FBCLID value appears to be 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 Facebook Pixel² (FB Pixel)) have been persistently tracked. FB Pixel, operated by a third-party, sets a *first-party* cookie, namely `_fbp`, and thus it can be used to track a user, but it can not 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 user³. This is exactly where FBCLID comes into play. 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.

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 ranking in the top 1M websites, and their behavior when the FBCLID tag and `_fbp` (thus FB Pixel is utilized by the website) are present. With our present work, we make the following contributions:

- We 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.
- We show that FBCLID in conjunction with `_fbp` facilitate persistent user IDs, and can be used to track users’ activities on websites, not only with a cookie-based pseudonym, but eventually with their real identity.
- 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). To put it simply, if a user creates, for the first time, a FB account today, the platform could attribute their browsing activity and actions on websites operating FB Pixel, as far back as 2015.

¹The URL of an actual link with a FBCLID looks like this: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5678212/?fbclid=IwAR0J2ueFwGP2ZSlznw04PQEFAbkMDue3T9YSg6>

²a FB script that creates a first-party cookie, set by websites and transmitted back to FB via JavaScript

³When we say *real identity* we mean the identity of the user as it is known to FB: i.e., the FB account of the user.

- Although FB-related cookies appear to have a 3-month-long lifespan, we show that due to *rolling cookie expiration dates*, this dual mechanism enables FB tracking to go on for years in the future as well.
- Our experiments with cookie-consent managers suggest that even when users choose to reject all cookies, 63% of the websites propagate the `_fbp` cookie to FB.

II. BACKGROUND

In this section, we provide background on FB Pixel, a FB-specific ad-related analytics mechanism, and shed light on how it enables FB to track users on the Web.

A. What is the Facebook Pixel?

Facebook Pixel (FB Pixel) [3] 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. In particular, these entities can visit their FB Ads Manager and Events Manager, which with the help of FB Pixel, can provide analytics and insights on the conversions tracked, and thus, allow measuring the effectiveness of their ads. At the same time, FB can use the FB Pixel to keep track of its users' browsing activity while outside the platform. This mechanism was later updated to a second version in 2015 to better leverage the first-party cookies that FB can inject per website.

Tracking users who visit a website has been traditionally done with third-party cookies. Such cookies allow FB (and other advertisers) to track users all over the web. Third-party cookies allow FB, especially, to track users using their *real identity* - their FB name - not a pseudonym or a browser id (for a specific website). This is very important as FB is able to attribute browsing histories to *real people* - not to web browsers or to anonymous IDs. Although third-party cookies are widely used among advertisers, they also have several drawbacks as well. For example, third-party cookies are usually blocked by ad blockers. Even further, some browsers, such as Chrome, have announced that they are going to stop supporting third-party cookies. As a result, tracking users with third-party cookies seems to have an uncertain future. Maybe this is why FB has started using *first-party* cookies (which are placed by FB Pixel) to track the activities of users on websites utilizing FB Pixel across the web. In this case, first-party cookies work as follows: let us assume that a website **W** has adopted FB Pixel. Let us assume that the user **Z** visits a website **W**. Website **W** gives user **Z** a *first-party* cookie which can be used by **W** to track **Z**'s activities while on **W**. This cookie (using JavaScript which is part of FB Pixel) is also sent to FB as well. In this way, FB can also track **Z**'s behavior on **W** using the first-party cookie of **W**.

Using first-party cookies for tracking has clear advantages: they are supported by Chrome and they cannot be trivially blocked by ad blockers. However, and especially for FB, using first-party cookies for tracking has a major disadvantage as well: first-party tracking cookies do not allow FB to track activities of users with their *real identity* anymore. FB can keep track of users' website activities with a cookie, with a browser unique id, but not with the user's *real identity*. This can be a major gap in the *behavioral* information collected

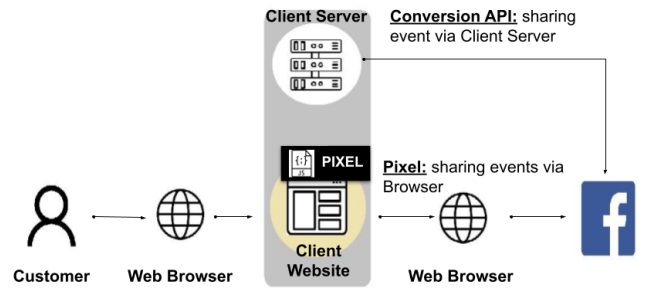


Fig. 1: Reporting a web browser event to FB via FB Pixel vs. Conversion API.

by FB. Indeed, although third-party cookies enabled FB to track *real users*, these first-party cookies enable FB to track only anonymous web browsers - but not real users. This is a significant issue that needs somehow to be addressed. Later in this paper, we demonstrate how FBCLID can be used to address this gap and enable FB to track (not browsers) but users with their *real identity*.

Furthermore, FB Pixel shares web events from an end-user web browser to the corresponding FB servers. In contrast, and recently introduced, FB Conversion API [4] allows server-to-server information exchange regarding ad-campaigns being executed on FB (Figure 1).

FB Pixel is a tracking pixel, typically a piece of JavaScript code added to a website to *track the user's activities on that website*. It is a graphic element with dimension 1×1 pixel that is loaded when a user lands on the website hosting it. Such pixels are designed to be transparent and not visible by the user. 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 [5]. When an event is fired on the website, e.g., a user visit, an instance of the FB Pixel loads in the HTML code of the page on the user's browser, and is responsible for reporting to FB the user activity for the duration of the visit.

Upon loading, FB Pixel creates `_fbp`, a corresponding cookie on the user's browser, if one is not already present. According to FB Pixel documentation [6], when a website uses FB Pixel and leverages first-party cookies, FB Pixel automatically saves a unique ID to this cookie for this domain (if there is no such cookie already stored). The value of `_fbp` cookie has the following format:

`version.subdomainIndex.creationTime.RandomNumber`

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

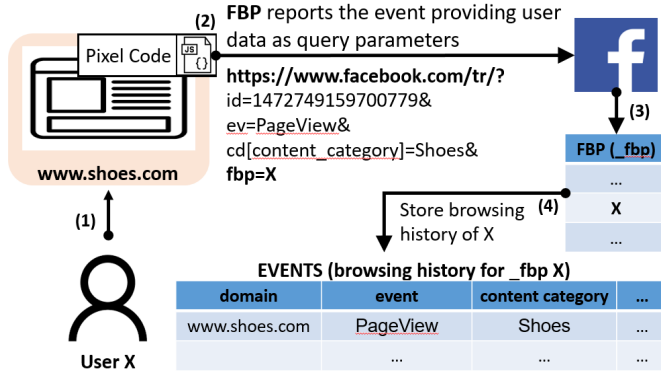


Fig. 2: How FB can record the browsing activity of user X into an anonymous FB profile using reporting from FB Pixel.

SDK to ensure every `_fbp` cookie is unique” [6]. Therefore, if the developers modify it they threaten to compromise that uniqueness.

Example of the `_fbp` cookie:

```
fb.1.1596403881668.1116446470
```

B. 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 FB Pixel-enabled website. Events can be general such as ‘Page-View’, or more specific such as ‘Time-On-Page’. The actions that the website has configured to be tracked are defined as *conversions*. In Table I, we list the set of actions that are provided by FB Pixel as trackable events. Triggering any of those actions (if is set to be tracked) informs FB about the activity occurred, thus allowing FB to build an elaborate *history of activities* for the specific 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` is loaded (the older version was called `fb.js`, but both versions originate from the same domain [7] and previous version [8]), in the website. This library is the core mechanism of the FB Pixel.

In Figure 2, we illustrate the reporting process of the Page-View (visitation of the website) event. When an event is fired on a web-page because a user X loaded the website (step (1)), FB Pixel reports to FB some information about the event and the 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.

Given any modifications on FB Pixel’s code by the website developer (developers can declare what events they wish to be tracked meaning what events will fire-up FB Pixel’s reporting process), FB receives different types of data such as IDs and events (more details on these IDs in Section IV). However, the baseline information that is received is the event (e.g., PageView in Figure 2) and some IDs that help FB keep a history of activities and potentially match this history to a FB user.

III. FB PIXEL PRESENCE ON THE WEB

FB Pixel has been around for quite some time now. Before we dive deeper into understanding the impact it may have, we would like to understand the extent to which it has been adopted. Indeed, high adoption rates indicate that the extent and impact of tracking may be profound.

A. FB Pixel Adoption in Top 10K

1) *Experimental Setup*: To find the adoption of FB Pixel, we crawl top websites and analyzed any FB-related scripts embedded in them, along with the network traffic produced. For this crawling, we use the *Tranco* List [9]. To make experiments computationally feasible, we use the top 10K from the top 1M websites ranked for the date November the 2nd 2021 (ID:L394) [10]. Also, to explore the FB Pixel adoption from websites ranking lower than the top 10K, and down to 1M, we perform a sampling of 1000 websites for each of the following rank ranges: 10K-20K, 20K-50K, 50K-100K, 100K-200K, 200K-500K, 500K-1M, for a total of 6,000 extra websites.

For this crawling, we follow state-of-the-art practices and use Chromium browser [11], [12], [13], [14] and Puppeteer [15] on several parallel VM crawling instances, to automate, and speed-up the crawling process. 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.

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 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. We add a small delay of five seconds between website crawls, in order to prevent automatic bot detection that could block the next website visit. This crawl was completed on the 17th of January 2022.

2) *Top websites with FB Pixel in 2022*: Our results indicate that 2,308 websites of the top 10K websites (23.08%) used the FB Pixel. It is interesting to note that this percentage (23.08%)

TABLE I: Webpage events that can be monitored by FB Pixel for reporting to FB.

Event Name	Description	Code
AddPaymentInfo	The customer adding information upon the checkout process	fbq('track', 'AddPaymentInfo');
AddToCart	Adding an item to cart	fbq('track', 'AddToCart')
AddToWishlist	Adding an item to a wish list on the website	fbq('track', 'AddToWishlist')
CompleteRegistration	Submission of the user's information for a service by the website (e.g., subscription to a newsletter via the user's email)	fbq('track', 'CompleteRegistration')
Contact	Any type of contact between the client and the website (e.g., chat)	fbq('track', 'Contact')
CustomizeProduct	Customizing a product through a tool or a service provided by the website	fbq('track', 'CustomizeProduct')
Donate	A fund donation of the user (e.g., the website is a charity foundation)	fbq('track', 'Donate')
FindLocation	Searching for the location of a service provided by the website (e.g., finding a store that has availability in a specific product)	fbq('track', 'FindLocation')
InitiateCheckout	The initiation of the checkout process (e.g., pressing the button checkout). Not the completion of the process	fbq('track', 'InitiateCheckout')
Lead	Submission of the user's information with intent to be conducted later by the website (e.g., subscription for a trial season)	fbq('track', 'Lead')
Purchase	The completion of purchase of a product (e.g., after successful buy the user is redirected to a "thank you" page)	fbq('track', 'Purchase', value: 0.00, currency: 'USD')
Schedule	Scheduling an appointment for visitation to an actual location of one of the website services (e.g., a physical store)	fbq('track', 'Schedule')
Search	The search action on the web page (e.g., searching for a product)	fbq('track', 'Search')
StartTrial	The start of a free trial for a product (e.g., a free subscription)	fbq('track', 'StartTrial', value: '0.00', currency: 'USD', predicted_ltv: '0.00')
SubmitApplication	Submission of an application provided by the website (e.g., job position)	fbq('track', 'SubmitApplication')
Subscribe	The start of a paid subscription for a service provided by the website	fbq('track', 'Subscribe', value: '0.00', currency: 'USD', predicted_ltv: '0.00')
ViewContent	A visit to a web page you care about (e.g., a product page or landing page)	fbq('track', 'ViewContent')
PageView	PageView event is fired by the FB JS Pixel code on each URL change. This is the default behaviour	fbq('track', 'PageView')

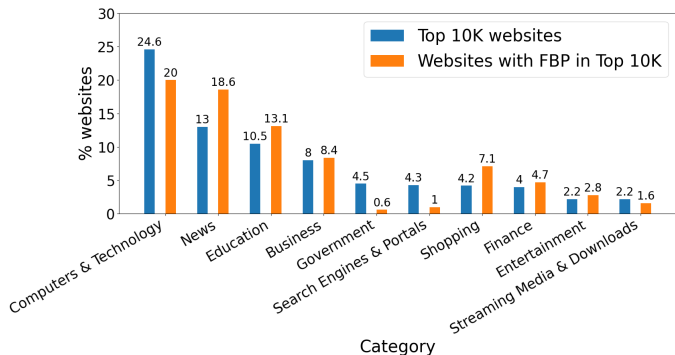


Fig. 3: Top 10 categories of the general web, depicting the proportional rate of FB Pixel adoption in the top 10K websites of the 1M Tranco list.



Fig. 4: Top 10 categories of the general web, depicting the proportional rate of FB Pixel adoption in websites the range between 10K and 1M websites of the Tranco list.

is compatible with previously reported results. For example Chen et al. found that 23.77% of the top 10K Alexa websites store `_fbp` cookies (see [13] table 3). We also look into the sampled set of 6K websites for rankings 10K-1M, and find that 990 (or 16.5%) of them adopt FB Pixel. It seems that higher-ranking websites are more eager to adopt FB Pixel. Note, however, that should not be surprising because higher-ranking websites are expected to be more active in ads and, therefore, in collaborations with FB. Overall, we conclude that *one in five to six websites employ the FB Pixel and its first-party cookies, enabling FB to monitor and track users' activities on websites, and across a large portion of the Web.*

3) *Website categories with FB Pixel:* Next we would like to know what types of websites are more eager to adopt FB Pixel and its associated tracking. In order to classify the top 2,308 websites found to operate FB Pixel, we use Cyren's URL category check gate [16].

Figure 3 shows the 10 most popular categories in the top 10K websites. For each category we plot two bars: the blue bar is the percentage of websites in the top 10K list that belong to this category - the orange bar is the percentage of sites that are using FB Pixel and belong to this category. Figure 3 suggests that 20% of the FB Pixel-adopting websites are categorized as "Computers and Technology" and the next 18.6% of the conversion tracking sites 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 advertisements.

Figure 3 also shows whether a category of websites is more aggressive at adopting FB Pixel or not. Indeed, if the orange bar is higher than the blue bar, the category is more aggressive in adopting FB Pixel. We see that "News", "Education", and "Shopping" are clearly disproportionately more eager to adopt FB Pixel. We also see that "Government" and "Search Engines & Portals" are much less eager to adopt FB Pixel. This seems perfectly reasonable: these sites probably are not interested in advertisement.

Figure 4 plots the top 10 categories of websites adopting FB Pixel from the sampled population of 6K sites from the Tranco list for the range (10K-1M). Some of the observations made for the popular top-10K sites (in Figure 3) still hold. For example, shopping sites seem to be over-eager in adopting FB Pixel. On the other hand, some other trends are just not there. For example, we do not see any "Government" or "Search Engine & Portal" sites to make it to the popular categories. This is probably because the few sites of this type that exist are too few to make themselves visible in a population of almost one million websites.

B. Historical FB Pixel Adoption

In our next experiment, we would like to know when websites started to adopt the FB Pixel code. To answer this question, we proceed as follows:

- We find the top websites detected in January 2022 which adopted the FB Pixel (from the top 5K Tranco

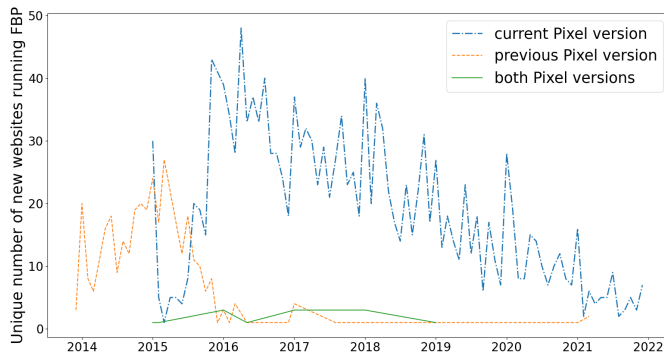


Fig. 5: New websites with FB Pixel, through time, for the top 5K websites. We see that the previous Pixel version was adopted around 2014 while the current Pixel version was introduced around 2015.

list).

- We visit older versions of these websites using the *Wayback Machine* (WM) [17] to find out when it was the first time these sites embedded the FB Pixel code in their HTML.

Data Cleanup: During the experimentation, we found occurrences of FB Pixel’s version 2 code in snapshots dating before its official launch in 2015. We explored further if those findings were caused by our crawling mechanism, a WM utility, or we could attribute them to some websites where version 2 was beta-tested earlier than the official release date. As already mentioned, FB Pixel’s base code injects a FB third-party JavaScript library into the HTML code of the website. Thus, by revisiting such outlier cases, while monitoring their outgoing traffic, we were able to capture the requests sent for retrieving this library from snapshots for that given period. Therefore, if the date of the requesting snapshot (e.g., 2014) did not match the date of the requested library snapshot (in a year-month basis) (e.g., 2015), we identified this case as a false positive, and excluded it. This was done for both FB Pixel versions, each time capturing the request to the corresponding library with respect to the version on the website visited.

1) *A decade of tracking!:* Figure 5 shows the distribution of unique new websites adopting FB Pixel through time, for the top 5K websites. Also, Figure 6 plots the same distribution for the 1K set of websites from the publicwww service.

First, we note that FB Pixel has been around since December 2013 with the first version, while its adoption (per new website) peaked around early 2015. At the same time, on 2015, we also had the release of the second version, which peaked in adoption in early 2016, while the first version lost momentum. In fact, FB faced-out the “Conversion Tracking Pixel” (first version) in February 2017. Second, the careful reader may notice a small number of websites that used both versions in parallel, as evident from the third line. This is probably due to websites that adopted the code for the new version of FB Pixel without removing the previous version from their code. Third, as noted by the spikes per month, FB Pixel adoption was not smooth, but probably came in waves due to marketing campaigns by FB, usually happening at the beginning of each year and quarter.

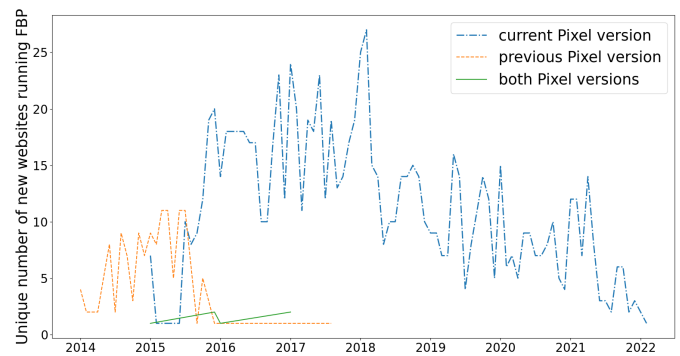


Fig. 6: New websites with FB Pixel, through time, for 1K websites of general Web. The previous Pixel version was adopted around 2014 while the current Pixel version was introduced around 2015.

C. Key Takeaways

From these findings, we draw the following key takeaways:

- About 23% of top 10K websites facilitated FB tracking activities, using FB Pixel for their ad conversion analytics.
- We found FB Pixel in 40+ categories of websites, with top 3 categories being Computers & Technology (~20%), News (~18.6%), and Education (~13%). This wide coverage shows that conversion tracking through FB Pixel can capture activity of different types of users.
- FB has been tracking users’ browsing activities since at least 2013 using FB Pixel on websites. 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.

IV. FB PIXEL TRACKING MECHANICS

The analysis on historical adoption of FB Pixel demonstrates that FB has been collecting browsing activity of users since at least 2013, for a vast range of different types of websites, giving it an opportunity to build user profiles for the last decade, while helping its customers (advertisers) to perform effective ad-targeting campaigns. In this Section, we focus on the next key question: *How can FB use its newly 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.

A. Case 1: matching visitor of website W 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 the landing website runs FB Pixel, the pixel saves the appended FBCLID under a cookie named `_fbc`, with the following format:

version.subdomainIndex.creationTime.fbclid

where:

- *version*: always the prefix *fb*
- *subdomainIndex*: the domain where the cookie was defined ('com':0, 'example.com':1, 'www.example.com':2)
- *creationTime*: UNIX time in milliseconds when the *_fbp* cookie was created
- *fbclid*: the value (ID) of the FBCLID query parameter in the landing page URL (see next for generation details)

FB is assigning the FBCLID to the user, since it knows who performed the click, and also has a browsing history of the user for the website *W* under the unique *_fbp* value. Therefore, the combination of the two cookies (i.e., *_fbp* and *_fbc*) enables FB to uniquely track users and their visits through time and inside or outside FB.

FBCLID generation: Interestingly, although the FB Pixel has been in use in its latest version since 2015, the FBCLID parameters started being appended to outgoing URLs around mid-October 2018 with no official documentation from FB [18]. Although there is no clear documentation of how these hashed-like FBCLID strings are created or what information is stored inside those values, 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., '-'). Unfortunately, there is little documentation on what this ID encodes. An educated guess based on observations on the generation of these click ids is that the hash source is some combination of user's account, click action, etc.:

$$\text{hash_function}(\text{time} + \text{username} + \text{website} + \dots) = \text{IwAR0} \dots$$

Facebook for Developers documentation also states [6]:

If the *_fbc* browser cookie is not available, either because there is no FB Pixel on the website, or because first-party cookies are turned off, *it is still possible to send the fbc event parameter if a FBCLID query parameter is in the URL of the current page request.*

Therefore, 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 observe changes and 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 the HTML elements, meaning these values are not created "on the fly", but rather they are assigned once the document is loaded. But are these IDs statically appended on the links? The answer is no. If a user visits the page of a business on FB (e.g., IKEA) and clicks on the first outgoing link to IKEA's website, the user can notice the FBCLID

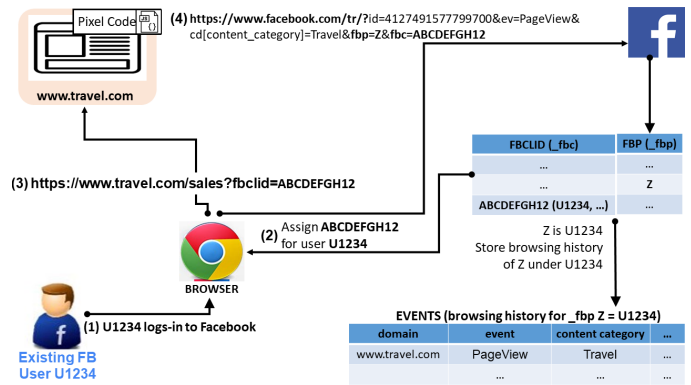


Fig. 7: How FB can match the browsing of the anonymous profile of user *Z*, using FBCLIDs, with the existing FB user *U1234*. When user *U* accesses the website *www.travel.com*, FB adds the FBCLID value of *ABCDEFGH12* as an argument to the URL. The HTML code of website (i.e., *www.travel.com*) eventually makes an invocation to Facebook sending (i) the first party cookie (*fbp=Z*) and (ii) the FBCLID value of *ABCDEFGH12*. When Facebook receives (i) the *_fbp* cookie (*fbp=Z*) and (ii) the value of *ABCDEFGH12*, it is able to associate the Facebook user *U1234* who received the FBCLID value of *ABCDEFGH12* with all browsing history of the user who has cookie *fbp=Z*.

appended in the URL. Then, if the user reloads or revisits their FB home page, a different FBCLID value is assigned to that same URL. Upon further examination of the FB webpage JavaScript source code, we find that when loading a page inside FB, there is an array called *click_ids*, whose values are updated upon every request that is landing on the specific page (e.g., reload). This array hosts 50 FBCLID values, and each FBCLID has a fixed length of 61 characters. Therefore, these FBCLIDs cannot be uniquely distributed amongst the different URLs that could exceed 50 in total. Also, there can be the same FBCLID assigned to different URLs. But, the same FBCLID could only be assigned to elements that had the same class name, thus concluding that FBCLID seems to be 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*. Let us also assume that the website *www.travel.com* uses the FB Pixel code. This means FB will be able to collect some browsing history information about this user, but will not know the *real identity* of the user. Let us call this user *Z* - this is not the user's *real identity*. But since we have no other information, the name *Z* would be enough for the time being. In the absence of a *real* name, all the browsing history for this user (for *www.travel.com*) can be registered in FB under the name *Z*, which is a corresponding pseudonym for the *_fbp* value stored for this yet unknown user). 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 7 shows what happens from this point on and how FB could match the browsing history of user *Z*, inside *travel.com*, with the *real identity* of FB user *U1234*. Indeed, let us assume that *U1234* browses through their news-feed in FB (step (1)). Their news-feed, possibly as the result of advertising, contains an external link to website *www.travel.com*. When user 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). Assuming that **www.travel.com** operates FB Pixel on its web-page, a `_fbp` cookie is created with the FBCLID **ABCDEFGH12** stored locally. This visit also triggers an event such as the “PageView” on the web-page 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 `_fbclid` cookie values, all reported to FB (step (4)). Given that the reported FBCLID **ABCDEFGH12** was given to user **U1234**, and given that this value (i.e., **ABCDEFGH12**) arrived to FB along with the `_fbp` cookie for user **Z**, FB can now know that user **Z** and user **U1234** are the same person. As a result, all the previously performed browsing activity of user **Z** captured on **www.travel.com**, can now be attributed to user **U1234**.

B. Case 2: matching visitor of website *W* with new FB user

This is the most interesting case: a user (say **Z**) who does not have a Facebook account browses the network for quite some time. Let us assume that in all this time (some of) the websites they visit have the FB Pixel. This means that FB can track this user using first-party cookies of these websites and probably has created a history record of **Z** for all the FB Pixel-enabled websites the user visited, under different pseudonyms: each website created a unique `_fbp` value for the user (e.g., **Z1**, **Z2**, ..., etc.). For the sake of the argument, we will proceed to explain how de-anonymization can be achieved through FBCLID for one such website (the same process is applicable for the rest of the entries in the FB stored browsing history record of user **Z**).

Let us assume that the browsing activity for **Z** in **www.travel.com** is stored under the name **Z** (corresponding to the `_fbp` cookie value for this user). However, although FB has a history for user **Z**, it probably does not have information about the *real identity* of the user: name, surname, email, friends, education, etc. After all, **Z** does not have a FB account. Let us now assume that at some point in time, **Z** decides to create a FB account and from that point on is known to FB with the name **U1234**. We show that using FBCLID, FB can match this new user **U1234** with the browsing history that user **Z** performed on **www.travel.com** over the years.

To demonstrate this case, we envision a *4-day* hypothetical scenario, in which user **Z**, without a FB account associated with them *yet*, performs the following process with the same computer and browser.

- **First Day:** User **Z** visits a website (say **www.travel.com**) which has Facebook Pixel. As a result, FB Pixel informs FB of this visit. As we have said, FB may store information regarding the user behavior on the website, under user **Z**.
- **Second Day:** Same activity is performed in order to enhance FB’s profiling of anonymous user **Z**.
- **Third Day:** The user decides to create a FB account. From now on the user is known to FB as user **U1234**. Note that at this point, FB still does not have enough information to associate user **U1234** with the browsing history of user **Z**.

- **Fourth Day:** While user **U1234** browses through their news-feed on FB (step (1) in Figure 7), they click on an external link to website **www.travel.com**. This link (step (3)) takes as argument the FBCLID value of **ABCDEFGH12**. 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 query parameter (step (4)). The event that triggered this request is appended in the URL, along with both the `_fbp` and `_fbclid` cookie values, all reported to FB (step (4)). Given that the reported FBCLID **ABCDEFGH12** is associated with user **U1234**, Facebook can now know that user **Z**’s and user **U1234** are the same user.

Therefore: FB Pixel tracks the browsing history of an anonymous user and associates multiple websites’ activities (of the same user) with multiple pseudonyms, e.g., $Z = \{Z_1, Z_2, \dots, Z_n\}$, corresponding to the each website’s `_fbp` value for that user. Although a visitation through FB to one of those websites does not reveal the real identity of all pseudonyms **Z**, it only takes one visit through FB to one of such websites, to reveal the real identity of the browsing history for each value in **Z**.

V. FB PIXEL USER ACTIVE PROFILING

Having seen the mechanics for user profiling and matching, in our next experiments, we would like to 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.*

A. Experimental Setup

We generalize the process outlined in Section IV-B into 4 steps, in order to collect data on multiple websites, and show how this matching can be done at scale.

Step S1: Similar crawling executed as in Section III, but focused on the 2,308 of the top 10K websites loading FB Pixel.

Step S2: Similar to S1, but with 2 main differences:

- Before the 2,308 websites are revisited, their previously stored `_fbp` cookie is loaded. We only store and then load the `_fbp` cookie and not other cookies, since the rest of cookies may be session cookies that have expired and restoring them could cause unknown behavior on the website’s functionality.
- While waiting for the navigation to complete, we monitor the network traffic and capture all outgoing GET requests to FB that include the `_fbp` as a query parameter. Thus, we establish when FB is being informed for the activity of the visitor upon each visit in each of the 2,308 websites, and thus being able to build a browsing history for each website under a “pseudonym”.

Step S3: This experiment does not include any crawling. Instead, we create a “dummy” account on Facebook and browse around their wall for different sponsored or suggested

content to appear. Then, by clicking on any of these items, a unique FBCLID associated with the specific user is generated and attached to each outgoing URL. Thus, FB can alert its associate website that this user is coming from FB. To perform this activity at scale, we store this ID and use it in the crawling of the next step, S4.

Step S4: Similar to S2, but with a fundamental difference. Now we visit each of the 2,308 websites with the FBCLID extracted in S3, appended in the URL of each website, to imitate FB mechanics. 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 `_fbc` is created and sent to FB along with `_fbp` cookie. We capture the outgoing traffic that includes both `_fbp` and `_fbc` values. We store each URL with those values for further analysis.

B. 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 X 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 `_fbc` which contains the one-time tag Facebook Click ID. Thus, by looking into the outgoing traffic of S4, we can find how many websites FB can link to user U’s newly created FB profile using these values received. In fact, from the 2,308 websites, 2,165 (or 93%) send to FB both the original `_fbp` and the newly created `_fbc` values. In particular, 92.3% of the websites report both `_fbp` (S2) and `_fbc` (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. Also, 1.5% of websites report the `_fbp` value on S4 only when FBCLID exists. This could be due to the websites having their own triggering mechanisms invoking FB Pixel, or network errors on S2 (e.g., FB Pixel not loaded or captured correctly on S2). So, for these few websites, the tracking begins when the customer comes from FB (S4). There is also a 3.9% of websites that share only the `_fbp` value (S2). This could be due to the website implementing some URL shortener that strips the URL from any additional parameters (FBCLID), or network errors (e.g., FB Pixel not loaded on S4). Finally, 2.3% of websites do not share any information upon visitation. This can be due to network errors as in other cases, or due to the fact that they do not have “PageView” event in their FB Pixel configuration to be tracked: they may report to FB upon additional events such as “Add-To-Cart”, which our crawler did not perform.

C. 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 that the user tracking on websites by FB Pixel is event driven, it only takes one click of the user on a given website, for FB to attribute the user’s browsing history to an (existing) FB user:

- 96% of FB Pixel-enabled websites report the “PageView” (visitation) event to FB.
- 93% of FB Pixel-enabled websites report both `_fbp` and `_fbc` values, giving the ability to FB to perform user matching with anonymous historical data.

VI. FB PIXEL: IS ANYONE LISTENING?

We demonstrated how FB can track a user’s browsing activity and link it to a FB profile. In this section, we take this tracking study a step further 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?*

A. Shared `_fbp` with third-parties

From the crawling of S1 and S2 of Section V, we find a small set of 4 websites that report `_fbp` cookies to other third-parties, beyond FB. Interestingly, three of them are sub-domains of the first party, but they appear to be advertising or analytics APIs. Therefore, we cannot know if they propagate these IDs to other vendors after they received them. Repeating the same analysis on a sampled top 10K-1M websites (which had 990 websites with FB Pixel), we find an additional 13 third-parties receiving the `_fbp` cookie value.

These results come as a confirmation of 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 the anonymous user browsing with legit user profiles using external IDs. These results are also confirming past work [13], [14] that in a similar fashion, found third-parties being informed of the `_fbp` cookies from FB. For example, [13] found 76 third-parties receiving the `_fbp` value. The core difference with our results is that [13] used dynamic taint analysis to capture the data flows of third-party JavaScript at runtime, whereas we only capture the GET requests that include the first-party cookie values in the request URL. In addition, our work goes a step further and identifies that some websites are notified of the `_fbc` cookies as well, which are cookies generated due to the FBCLID.

B. Shared FBCLID with third-parties

Next, we implement an experiment that measures 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:

- 1) *real* FBCLID: A value extracted from FB while browsing with a real user account.
- 2) *random* FBCLID: A FBCLID-looking value, following the proper format, but with randomly picked characters.
- 3) *dummy* FBCLID: A value that does not follow proper format, but has the string value: “Adummy_param”.

These variations allow us to study if a website’s FB Pixel checks the value of the FBCLID passed by FB, and performs some fundamental filtering, or if it just blindly records it in the FBC cookie, and then alerts FB of the user’s arrival.

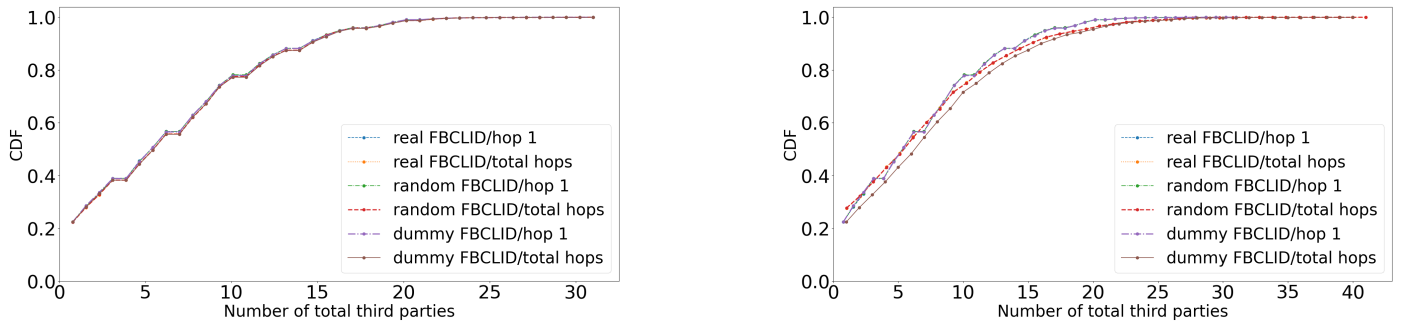


Fig. 8: (left) CDF of number of unique third-parties informed of FB-related IDs, per hop within top 10K websites; (right) CDF of number of third-parties informed of FB-related IDs, per hop, disregarding if they appeared in earlier hop within top 10K websites.

Furthermore, we study if the website performs any actions such as forwarding to other third-parties in a different way, depending on the type of FBCLID passed.

We revisited each of the 2.3K (990) websites with FB Pixel, from the top 10K (top 10K-1M) list, and for each one, we captured every GET request that encapsulated either the FBCLID value we injected on the URL, or the `_fbp` cookie value recorded for each website. The experiment is:

- Visit the website with each of the 3 values appended in the URL.
- *first_hop*: Get all URLs from the HTML DOM that include this value and all the URLs from the network that receive those values with a GET request (if any). These outgoing URLs, apart from FB-related properties, are third-parties informed of these FB-related IDs.
- *second_hop*: Visit all such captured URLs from the aforementioned set, and capture again all outgoing requests that include the FBCLID or the `_fbp` value. Clearly, this is an artificial invocation of said URLs, but we want to find out if these third-parties are passing on the received IDs to even more third-parties.
- On each step, we perform a reload after landing on the page to refresh connections.

General Remarks: The total number of third-parties informed from the `_fbp` value, per case is: 1931 for real, 1920 for random, and 1920 for dummy FBCLID. Therefore, we can first conclude that websites do not handle the type of FBCLID differently, regardless if it has an actual FBCLID or not. Instead, they seem to pass the ID to third-parties indiscriminately of the value it holds, its structure, etc., as long as it is passed into a query parameter named “fbclid”.

Unique vs. total third-parties: Figure 8 shows for the 3 cases, the distribution of unique (left) and total (right) third-parties for ‘first hop’ and ‘total hops’ (as explained earlier), excluding FB-related domains, in the top 10K websites (for results on top 10K-1M sampled websites check Appendix A, Figure 10 and 11). We find that 22.4% (24.4%) of websites from the 2.3K list (10K-1M sampled list) 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. Looking into the Figure 8 (right), the main difference from the left plot is the lines for “total” hops. In fact, we find that the median website passes FBCLIDs to 6.7 (7.9) and max up to 41 (50) third-parties within the 2nd hop. Therefore, and in contrast to unique third-parties, the lower ranked websites pass FBCLIDs to more entities within 2 hops.

C. Top Third Parties and Entities

Having the traffic of each FBCLID value for the two lists (2.3K and 990), 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 a total of 1,398 third-party domains. Focusing on their Top Level Domain (TLD) using the `tld Library` [19], we find 755 unique TLDs. Figure 9 (left) 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.

Next, we categorize these TLDs to third-party entities. We use the `Disconnect.me` list of entities and services [20] to match these domains with entities. We successfully matched 210 out of 755 (27.8%) third-party domains to various services of those entities. Figure 9 (right) shows the top 10 third-party entities informed with FBCLIDs for the two lists. Again, Google is the top entity with more than 61% of websites reporting to its services the FBCLIDs of users. 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 lists of ranked websites (top 10K vs. 10K-1M). 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.

VII. ROLLING EXPIRATION DATES OF FB PIXEL

FB Pixel cookies (`_fbp` & `_fbp`) seem to have a lifespan of three months [21]. With such a short lifespan, one would expect that any form of tracking would be limited to three

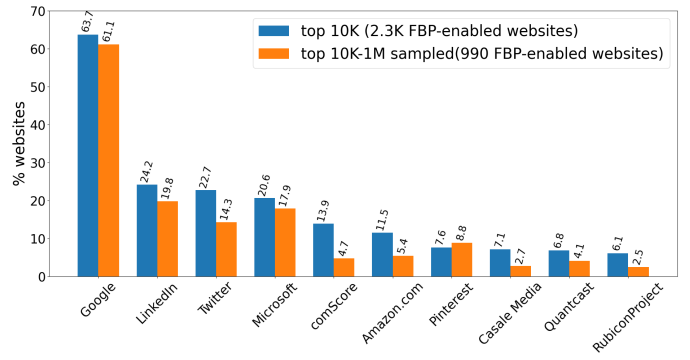
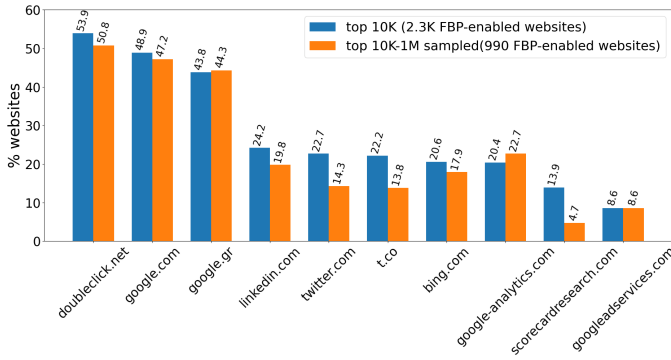


Fig. 9: (left) Top 10 third parties (right) Top 10 third-party entities from each list of FB Pixel-enabled websites (2.3K and 990).

months. Indeed, one would expect any linking of real users and browsing activities to be limited to the most recent (or to the upcoming) three-month-long period. Unfortunately, this is not the case. Our experiments suggest that the persistent ID of `_fbp` which acts as the user identifier of an unknown user, seems to have a rolling expiration date. Upon different events in the website (e.g., reload, revisit, etc.) the expiration date of this cookie is updated, thus increasing the interval of potential tracking, and making it a persistent ID which last long after the original 90 days. Moreover, the value of `_fbp` cookie is generated and updated with every new FBCLID. This means that if a user clicks on different ads or articles of the same website (from inside FB), multiple FBCLIDs will be generated, and the FBC cookie will be updated multiple times: once per visit - once per click. In this section, we demonstrate that these cookies **update their expiration dates** to keep the tracking rolling into the future well beyond the seemingly three-month-long time period.

A. Experimental Setup

We perform an experiment to measure how often the `_fbp` cookies update their expiration date, and thus, how long can FB track the same user under the same (anonymous or not) profile. We focus on showing that this persistent ID (`_fbp`) stays alive far more than 90 days. Please note that `_fbp` cookie updates its **value** on every new FBCLID and FB Pixel updates its **expiration date** on every event (e.g., reload). Indeed, `_fbp` also updates its expiration date but given that it is not persistent like the `_fbp` cookie, we did not conduct any experiment to showcase that.

This experiment follows the next steps:

Step S1: Same crawling as Section III (navigation settings, etc.). We store the FB Pixel cookie and record its expiration date.

Step S2: Reload all FB Pixel-enabled websites, and thus fetch the FB Pixel cookie again.

Step S3: Reload all such websites, but with the FBCLID appended in each URL, forcing each website to generate a FBC cookie. We store the produced FB Pixel cookie, but not the FBC 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. Furthermore, we check that the difference between expiration dates that were updated is equal to the difference in days between the crawls of each step. For example, if website `W` is crawled on day i and then re-crawled on day j , and its FB Pixel cookie expiration date is updated, this update would be $90+j-i$ days from day i .

B. Rolling tracking: cookies that never die

The great majority of top websites (1,942 of 2,308, or 84.1%) update the FB Pixel cookie expiration date on every event (reload or with FBCLID). On the other hand, there are 115 (or 5.0%) websites that do not update the expiration date of the FB Pixel cookie, regardless of the event or action done on the website.

There are also some interesting outlying cases:

- 57 (or 2.5%) websites hold the same FB Pixel value during all steps, but update the expiration date only upon visitation with FBCLID in the URL (S3).
- 17 (or 0.7%) websites hold the same FB Pixel value on all steps, but update the expiration date of FB Pixel cookie upon reload of the website (S2), and not with FBCLID (S3).
- 5 (or 0.2%) websites update the FB Pixel cookie entirely, including value and expiration date.

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 Section III. Moreover, 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, or simply redirection to human authentication mechanisms (e.g., CAPTCHA) for the current site, or even blocking the crawler from further action if it was flagged as a potential bot.

Key Takeaways: Overall, the great majority of top websites with FB Pixel (87.5%) update the expiration date of the

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

VIII. FB PIXEL TRACKING WITH EXTERNAL IDS

In this Section, we push the investigation further and ask the question: *What if the user deletes the FB Pixel cookie before it expires? Will this stop the matching?*

Unfortunately, the answer is no: Beyond FB Pixel-related data sent to FB, there are several other, external to FB unique IDs, or *user_data* as referred to by FB’s documentation, that can be shared along with FB Pixel reporting. They can enable FB to perform a more accurate matching of FB users to browsing activity registered under anonymous user profiles. A typical data point shared is the *external_id*, a unique ID assigned to the user when visiting the website, generated via different means such as registration with the website or even a standard cookie for consistent user experience. In fact, as explained in FB documentation [22], *if the first-party system is set to include such IDs, those should be shared with FB and if not, the _fbp will act as a replacement for those unique IDs*. In particular, FB assumes that the presence of an *external_id*, along with FB Pixel can offer improved performance, compared to just FB Pixel, since these external ids do not expire as FB Pixel cookies do. Also, even without FB Pixel cookie delivered, FB can handle an *external_id* delivered in place of FB Pixel.

A. Experimental Setup

In this Section, we experimentally explore how often such *external* IDs are transmitted to FB, and how persistent they are, in order to help FB match the browsing activity in a given website with a FB user, even if the _fbp cookie happens to expire and a new one is loaded (as demonstrated in Section VII). To motivate this experiment, we assume the following user scenario:

Step S1: User X visits website W. A FB Pixel cookie is stored for that user. Also, *external_ID* (hash) of website W for that user is created. Thus, FB Pixel sends both FB Pixel cookie and FBCLID to FB.

Step S2: The same user revisits W, and the above data are again shared with FB to perform better matching of user X.

Step S3: The user revisits W but 90+ days after their last visit. Thus, FB Pixel cookie has expired. The cookie is renewed and sent back to FB along with the same, persistent *external_ID* as with S1 and S2. Now FB can re-link user X with their previous browsing activity, thanks to the external ID of W.

We perform an experiment that involves similar crawls as in S1 and S2 of Section V on the 2.3K websites, while monitoring the outgoing traffic of each website. In particular, we search all outgoing-to-FB URLs for any parameters named “*ud[external_ID]*”. Indeed, we cannot be sure how these IDs are created per website. We only observe the SHA256 hash outcome of such values, which in some cases could be created by a subscription to a mailing list which we did not perform.

TABLE II: Number of websites per category sharing external IDs with FB during FB Pixel reporting.

Category	#	Category	#
Computers & Technology	21	Health & Medicine	3
Education	8	Travel	3
Entertainment	5	Leisure & Recreation	2
Business	5	Transportation	1
Finance	5	Fashion & Beauty	1
News	4	Restaurants & Dining	1
Shopping	4	Arts	1
Sports	4		

The format of such parameter is the following, included as a query parameter in the URL directed to FB:

`ud[external_id]: [8d16a0dcb109e26121cacb648c5f40e7]`

In order not to wait 90 days for the expiration of the FB Pixel cookie, we force the FB Pixel cookie to have a new expiration date by dropping it before S3, thus forcing FB Pixel to create a new cookie. While studying external IDs shared from websites through these steps, we also drop any that had an expiration date smaller than the difference in days between S2 and S3. In this way, we guarantee that any external IDs shared with FB when S3 was executed (with the new FB Pixel cookie), were valid in S2.

B. Sharing is caring

We find a small, but non-zero set of 68 (2.9%) websites that, besides _fbp cookie, share at least an additional, external ID with FB. Table II shows the list of all categories of websites that share external_IDs with FB for better user matching in the back-end. Interestingly, almost one third of these websites (22/68) are of the “Computers & Technology” category, followed by 8 websites of the category “Education”.

Interestingly, the great majority of these websites (55/68 or 80.1%) share the same external ID on S2 and S3, making their visitor re-identifiable by FB, even if the FB Pixel cookie has changed. In addition, we find 4 websites that share the same external ID for two different user agents we tested, and for two modes of visiting: regular and *incognito*. These websites are: *mubi.com*, *hellofresh.com*, *navyfederal.org*, and *webstaurantstore.com*. Although the set of websites that allow this tracking across incognito browsing is rather small, it is non-zero. Upon manual investigation on those websites and their embedded JavaScript code, we find that the sent *external_ids* are assigned a default value when the user is unknown (e.g., not a logged-in user). Moreover, according to FB documentation [23], the data retention period for those IDs is 90 days.

Key Takeaways: Overall, the above results show how external IDs can be used to match a user to previous browsing history even if the user deleted the cookies. Moreover, the *external_id* can be used to match two different _fbp cookie values, and thus enhance the persistent tracking of the user activities on this website. It also points to future research needed to define precisely the parameters these IDs are depended on, as well as possible reverse-engineering of them (e.g., SHA256-hashed emails could be de-anonymized [24]).

IX. FB PIXEL COOKIE CONSENT COMPLIANCE

Past research has identified discrepancies between what the users select in the cookie consent banner offered by a website, and what is actually registered by the website. For example, users may provide a negative response (i.e., “reject all cookies”), but the cookie banner may record a positive response (i.e., “accept all cookies”). Similarly, the cookie banner may register a positive response, even before the user had the opportunity to provide any choice [25], [12].

Motivated by this research, lastly, we look at the compliance of privacy regulations such as GDPR and e-Privacy [26] by websites running FB Pixel, and if they respect a user’s cookie settings, while they perform the aforementioned tracking on behalf of FB. For this analysis, we use the well-known Consent-o-Matic (CoM) tool [27] that has been used in such studies [12], and perform three experiments to measure website cookie compliance. CoM operates at the browser level, and allows the user to automatically handle cookie consent forms that websites have in place and present to the user.

Experimental Setup: We install CoM on the Puppeteer browser of the crawler, and run the crawler on the 2.3K top websites operating FB Pixel, with three options on cookie consent:

- 1) “accept-all”: CoM configured to accept all cookies
- 2) “reject-all”: CoM configured to reject all cookies
- 3) “no-action”: Visitation without the CoM plugin

Results: First, we measure on how many websites CoM actually works and how many of those store the FB Pixel cookie in each case examined. From the 2.3K websites that we initially found as operating FB Pixel, CoM worked correctly on 480 of them (i.e., 20.8%). From those websites:

- 480 stored a `_fbp` cookie when “accept-all” was tested.
- 310 stored a `_fbp` cookie when “reject-all” was tested.
- 306 stored a `_fbp` cookie when “no action” was taken.

X. RELATED WORK

User Web Tracking: 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 (e.g., [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [13], [14], [38]). Research has been also done to detect 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 (e.g., [39], [40], [37], [25], [12]). In many of these studies, FB is identified as a key player in the third-party Web tracking ecosystem. Our work, inspired by this prevalence of FB tracking, is primarily focused on the mechanics used by FB to track users’ activities in the post third-party cookie era, and the potential privacy implication of such mechanics, regardless if the users have a FB profile or not.

User Tracking Through Time: The work in [41] focused on requests of websites to third parties to assess their prevalence in 2014, on Top 1M websites, finding FB amongst the top

entities across the general Web. Also, various studies used WM for historical analysis of websites, such as [42] which studied third-party presence on websites between 2009-2016. FB presence was calculated using all requests to FB servers, from a WM archived website. Instead, we focus on years 2013-2022 and study the adoption of FB pixel across the Web. One more work [43] contacted a longitudinal measurement of web tracking for the years 1996-2016. Indeed, the authors refer to third-party JavaScript in first party websites as *Analytics Tracking*, but did not explore further the core of such mechanism, but only measured its prevalence on the Web. Moreover when it comes to methods utilized by FB to track users, in [43] they mention the “Like” button and tracking through social widgets, which FB Pixel is not part of.

First-party Cookies Served by Third parties: There have also been some recent studies on cookies that are injected by third parties (such as FB in our case) into a browser, but stored as first-party cookies [13], [14], [38], [44], perhaps in order to evade ad-blocking filters. First, [13] studied the way that third-party JavaScript code is deployed on websites, especially to store first-party cookies that can be used as trackers. The authors measured the prevalence of such techniques across top 10K websites. Furthermore, two more works [14], [38] explored the first-party field to measure the existence of this new tracking technique, and define the roles and actors for the entities taking part in this “ecosystem”. Also, [12] found first-party identifiers shared with FB as third party in 18.3-19.5% of the top 850K websites, ratios that resemble our findings in FB Pixel presence. Lastly, [45] takes a look at how cancer-related health companies use third-party tools to track patients’ behavior between their websites and FB, as they capture the FBCLID as data shared with FB.

Tracking Through Pixels: Works that relate to ours also focus on analysis of pixels embedded on websites [46], [47], [44]. In [46], the authors propose a way to detect invisible web pixels, and block them based on fine-grained behavior-based tracking detection methods. Furthermore, [47] describes the overall functionality of tracking pixels on the Web, how they rely on Javascript code, and how this, usually third-party, JavaScript aids tracking. However, the study does not go into details about the mechanics of these pixels. Finally, [44] focuses on how fast a user can encounter trackers online and estimate the fraction of a user’s browsing history known by trackers. They analyze third-party scripts loaded on websites and identify trackers by comparing the scripts’ request destination domain with third-party lists such as Mozilla Firefox[48] and EasyPrivacy [49].

FB-related Tracking Studies: There are some works [50], [51], [52] that study how FB uses the “like” button to place a third-party cookie on a website to track a user’s online activities across the Web with social widgets. In contrast to those social widgets and third-party cookies, FB Pixel tracks the browsing activity per site, and especially actions that users perform on them. Similarly, [53] quantifies the extent to which FB can track Web behavior outside of their platform using a network of engagement buttons, placed on websites. Also related to ours, the Markup [54] 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 [55], [56] raised issues regarding FB tracking of 4M college students applying for federal financial aid, by sharing personal data with FB through FB Pixel.

Going beyond state of art: The main difference of this work with past studies is that while they captured a broader view of the first-party tracking ecosystem (and key participation of FB in it), they do not explore the connection between FB first-party cookie (`_fbp`) and the FBCLID URL parameter, also crucially used as value to a first-party cookie (`_fbc`). In fact, we study how this pair of cookies can aid FB to perform persistent building of a history of activities for users, and matching the anonymous web users (via their activities outside the platform) to FB users. In particular, we are the first to focus on a set of targeted questions such as: (a) How FB can keep track of activities for a user that has no FB account yet and how it can match previous browsing history and activity on a given website (utilizing FB Pixel) to a new or existing FB user, (b) How long this behavioral tracking of an online (FB or not) user lasts, (c) How the FBCLID parameter can 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 outside FB.

XI. DISCUSSION & CONCLUSION

Summary: FB has recently introduced Facebook Click ID (FBCLID): a one-time tag that is passed as an argument to all outgoing URLs for users who browse through FB. Although this one-time tag is ephemeral and can seemingly not be used for tracking, we show that when combined with Facebook Pixel, a conversion tracking tool embedded via JavaScript on websites, it can be used to track the users' activities both in space (i.e., in domains all over the web that utilize FB Pixel), and in time (i.e., in the past and future). To make matters worse, although the FB Pixel advertises a three-month-long lifespan, and can seemingly limit any tracking to at most three months, unfortunately, it uses rolling expiration dates for the first party cookies it places in websites (`_fbp`), which can postpone its lifespan (and its associated tracking) indefinitely. We have experimentally verified this behavior in more than 20% of the top 10K websites.

Contributions: Our present study makes the following key contributions and findings:

- 1) FBCLID is being depicted as an ephemeral (one time) parameter that could not be used to persistently track users' activities. In this work, we showcase how FB Pixel can utilize these ephemeral tags alongside with other parameters to continually track users' online activities across websites utilizing FB Pixel.
- 2) The great majority of top websites with FB Pixel (87.5%) update the expiration date of the `_fbp` cookie, under some visiting conditions (e.g., reloading website, visiting with FBCLID, etc.). This continuous updating of `_fbp` cookie expiration enables FB to perform persistent and consistent tracking of users across visits on the same websites (with the same browser and device), beyond the initial 90-day expiration date of `_fbp` cookies. This mechanism allows FB to build a

longer running profile for each user and their behavior on the given website.

- 3) FB has been tracking users' browsing activities since at least 2013 using FB Pixel on websites. Thus, the opportunity for tracking and de-anonymizing a user's browsing history on websites utilizing FB Pixel goes back a decade, even before a user had a FB account.

It seems that FBCLID combined with FB Pixel could provide enough information to track users for a very long time, building individual history of activities per website. We are afraid that combating this tracking may turn out to be difficult: this tracking (i) is being implemented with first-party cookies that are difficult to block, (ii) seems to ignore user's preferences to "reject all cookies", and (iii) seems to be able to track users in the distant past.

Discussion on Countermeasures: To this day, preserving the privacy of online users still remains an open topic. While steps have been taken towards that by regulations (GDPR, e-Privacy) and efforts to limit the tracking have been performed by third parties (e.g., Chrome and Safari browsers blocking third-party (cross-session) cookies), companies whose revenue heavily relies on advertising come up with novel ideas to preserve their advertising reach and profits. As we have shown, tracking through the FB Pixel that utilizes first-party cookies and URL tags evades the blockade of third-party cookies, while still serving the same tracking purposes for FB.

Another solution employed by privacy browsers such as Brave and Firefox ([57], [58]) to the tagging of URLs is URL stripping. These browsers strip the URLs from known tracking parameters such as the one we studied here: `fbclid`. Although this is a step forward, it does not provide a concrete solution to the problem. In fact, and more recently, it was observed [59] that FB started utilizing a different URL scheme for outgoing links, by encrypting the existence of click ids in the URL. FB stated that the modification of the URLs with respect to the IDs was done as "a privacy measure intended to deter scrapers from collecting and potentially misusing people's Facebook IDs". Even if that is the case, this presents another obstacle on combating tracking through URL parameters.

Finally, ad-blockers could be a potential solution as well to this problem. Ad-blockers such as Adblock Plus, block the requests that fetch third-party libraries and embed them into a website. This means that the call of the FB Pixel to the core library of FB `fbevents.js` is being blocked, thus forbidding client-side communication with FB for sharing of user-performed website events and IDs. But once again, as previously mentioned, FB has recently introduced the FB Conversion API, which allows server-to-server communication between the website and FB, potentially rendering the ad-blocking countermeasure ineffective.

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 while capturing browsing activity per site and user is becoming more expensive and difficult than in the past, large advertisers have both the capacity and utilities to continue doing so. Therefore, the question of how we can preserve the user's privacy under this type of behavioral tracking remains open.

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APPENDIX

A. FBCLID Sharing With Third Parties

In addition to the 2.3K from the top 10K websites, we also crawled 6K websites from the ranges 10K-1M identifying 990 websites that utilize FB Pixel. While visiting and monitoring the traffic on those websites, the third party invocations of unique and total numbers are found in Figures 10 and Figure 11, respectively.

B. 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 [60], [61]. 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. Therefore, we crawl only the landing page of each website and visit it only a few times. These visits are spread over a period of a few days to not overload the website server. 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.

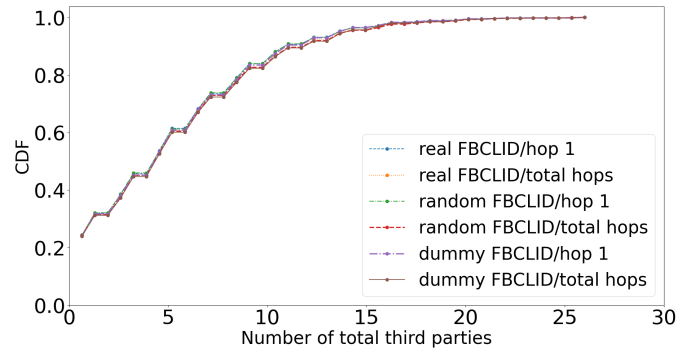


Fig. 10: CDF of number of unique third-parties informed of FB-related IDs, per hop top 10K-1M websites (sampled).

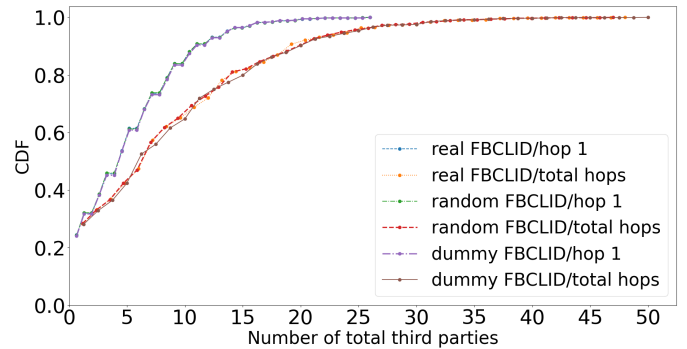


Fig. 11: CDF of number of third-parties informed of FB-related IDs, per hop, disregarding if they appeared in earlier hop within top 10K-1M websites (sampled).

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.