Show Me Your Cookie And I Will Tell You Who You Are

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ABSTRACT
With the success of Web applications, most of our data is now stored on various third-party servers where they are processed to deliver personalized services. Naturally we must be authenticated to access this personal information, but the use of personalized services only restricted by identification could indirectly and silently leak sensitive data. We analyzed Google Web Search access mechanisms and found that the current policy applied to session cookies could be used to retrieve users’ personal data. We describe an attack scheme leveraging the search personalization (based on the same sid cookie) to retrieve a part of the victim’s click history and even some of her contacts. We implemented a proof of concept of this attack on Firefox and Chrome Web browsers and conducted an experiment with ten volunteers. Thanks to this prototype we were able to recover up to 80% of the user’s search click history.

1. INTRODUCTION
Over the last few years, Google’s core service “Search” was enhanced through feature deployments, new UI and display optimization. One major improvement regarding the quality of search results was the personalization of the ranking algorithms. Personalized search results are ranked according to the user’s context (i.e. localization and language), profile (search history), social networks and other characteristics extracted from the use of Google’s services. Via the Google Dashboard, users can view and possibly edit data that was collected by their use of Google services. These data may be very sensitive, so access to this interface naturally requires an authentication.

However, while the direct access to users’ data is subject to a strict security policy, using personalized services (which may leak this same personal information) is not. Indeed, some Web applications like Google Search only verify the (unsecured) user’s session to render personalization features. Such a session can be hijacked by simply capturing the corresponding “sid cookie”. Unlike cookies used to authenticate the user, the sid cookie may be sent cleartext, i.e. unprotected. Furthermore, this cookie is sent whenever the user accesses to a service hosted on google.com, increasing attack opportunities. In this paper we show how the sid cookie could be misused by an attacker, providing ungranted access to Google Search personalized results and history.

We study an information leakage attack that exploits the current Google’s access policy regarding personalized services (i.e. unauthenticated access). More specifically, we hijack a sid cookie to circumvent Google protection and access a user’s personal data who — possibly forced by the attacker — transmitted her cookie in clear text. We emphasize the risk of using unauthenticated personalized services over a shared network with the following contributions.

1. The description of an information leakage attack that uses the unprotected sid cookie to retrieve the victim’s visited search results and a list of her contacts.
2. A proof of concept, based on the browser extension “Firesheep”, and the tool we used to evaluate the impact of the information leakage.

The remaining of this paper is organized as follows. Section 2 describes Google’s architecture and services relevant to the understanding of the proposed attacks. Section 3 presents the information leakage attack using the sid cookie to retrieves user’s click history and contacts. An implementation of this attack is proposed in Section 4 along with statistics showing how seriously a Google account’s click history could be compromised. Finally section 5 discusses measures that should be deployed to counter this attack and section 6 concludes this paper.

2. GOOGLE SERVICES AND COOKIES
Google provides more than twenty different services, covering most of people needs over the Web. With a single Google account, a user can access to all these applications even those hosted on different domains (e.g. YouTube or Blogger). A couple of cookies are used to help users navigating smoothly between the Google services.

2.1 Google.com cookies
At least three cookies are systematically sent by the user’s browser to Google servers when accessing a service under the google.com domain.
• PREF: this cookie carries the preferences for the browser currently accessing the service. These preferences refer to the interface, the language, the number of results returned by a search, etc. The PREF cookie is attached to a browser and not bound to a specific user account.

• SID: this non-secured session cookie is transmitted to Google servers to identify the user and personalize the provided services. In the particular case of Search, this identification will trigger result personalization. Even if the user is not logged, best effort personalization of search results can be performed based on the recent browser activity.

• SSID: this secured session cookie provides access to services that contains user data and personal information like Gmail, Google Calendar, Google Contacts, etc.

It is our understanding that unlike the SSID cookie, the SID cookie just has an identification purpose and can not be used to authenticate a user. On the other hand, the SSID cookie is sent only over encrypted connections and is required for services providing access to users’ data and personal information. Google is thus implementing a two-level cookie based access policy; the first level only requires user identification while accessing to the second level assumes user authentication.

In our study, we focus on the SID cookie and the information leakage that results of subsequent service personalization.

2.2 Setting up the Attack
The SID cookie is valid over the entire (*.google.com) domain, so it is sent to every Web application hosted on Google (*.google.com). Some services, such as Gmail, are only available via a secured HTTPS connection, whereas others can be accessed through clear connection (HTTP) that is the case of Google Search and other services listed in Table 1. The SID cookie is sent every time a request to a service under the (google.com) domain is sent, even when the queried page cannot be personalized (e.g. privacy policy, terms of services). Because this cookie is sent to many URLs, it is enough for one of these URLs not to be accessible through HTTPS to be able to compromise it.

2.2.1 Bypassing HTTPS enforcement policy
HTTPS-Everywhere [3] is a browser extension that, when available, redirects a user to the secured version of the requested service to prevent traffic interception. Unfortunately, this approach suffers from several drawbacks:

• First, not every service is yet available through HTTPS. For instance, Google Alerts remains only accessible through HTTP.

• Second, the list of services available through HTTPS has to be maintained. Some services are already available in HTTPS but not yet redirected. A list of such services is reported in Table 1.

• Finally, some services are redirected while not yet available. As a result, these services can not be reached by HTTPS-Everywhere users.

Due to these flaws, even HTTPS-Everywhere users could be redirected to a URL where they would have to send their SID cookies in cleartext.

2.2.2 Intercepting the SID cookie
Whenever a user accesses to one of the listed URL, her vulnerable SID cookie is exposed and so is her personal information. The objective of the attacker is to force the victim to exchange this cookie with unsecured services over a shared network, and so easily capture the cookie. Here are some examples:

• The attacker can setup an open access point with a name (SSID) corresponding to a local hot-spot (e.g. fast-food restaurant name) and include in the welcome page an hidden iframe pointing to an unsecured Google service. When connected, the browser will send to the rogue access point the valid SID cookie in clear text.

• In an open wireless network, the attacker could also spoof the access point’s physical address (MAC) and respond to a victim’s HTTP GET request by any Web page including the hidden iframe just like in the previous case.

2.2.3 Googling for Cookies
The simpler solution to find SID cookies is to search them. Typing the query “pref=uid= sid= google” in Google provides a list of pages where people published captured HTTP traffic, including SID cookies. Using the “Past Month” search filter increases the chances of retrieving valid SID cookies. Not all these results contain full SID cookies and some of the listed SID cookies may have already expired, but this simple search should already provide many valid cookies.

3. PERSONALIZED SEARCH ATTACK
The search results provided to users who enabled Google Web Search History are personalized and colored based on their previous interactions. One advantage of this feature is the ability to see the websites a user previously visited in the Google’s search results. Furthermore, frequently visited pages are more likely to be high ranked. In 2009, Google also started to consider social network indicators as part of the inputs used to improve the search algorithm. “Social Search” now up-ranks results that user’s contacts shared publicly via Google Buzz, Twitter and other social networks.

The personalized search algorithm is based on private data held in the user’s account. As such, it can be considered as a controlled information leakage. In [2], authors suggest that this information leakage can be used to know some of the results a user clicked on. This flaw has not yet been fixed as considered hard to exploit: an attacker must know what the victim searched for and then compare the personalized and un-personalized results. Similarly, the visited-link coloration feature/vulnerability [2] was not addressed as considered innocuous regarding the benefits it offered.

However, since these flaws have been reported, Google introduced new features that could improve the efficiency of attacks based on this information leakage. This section shows how these features could be misused to compromise users’ click history.
3.1 Google Search filters

In this section we list the features that made the information leakage attack more critical. These features – available when clicking on “Show search tools” – could be misused to significantly reduce the number of queries one has to issue to retrieve the previously clicked search results (and so harder to detect).

3.1.1 Visited Results

Collecting a user’s visited links via random regular searches may take a very long time as the result pages mix visited and unvisited hyperlinks. However, an update of the Google Search interface introduced new filters. For instance, the “Visited” filter removes unvisited results. By enabling this filter, the information leakage becomes critical: only visited links remain listed as search results, partly disclosing the user’s click history.

3.1.2 Social

With the “Social” filter, pages commented, twitted or shared via a social platform are displayed. The user’s social network is built up according to his Gmail contacts and possibly other social applications such as Twitter, Livejournal, etc (once linked to his Google account). This filter does not only provide the list of shared links, but also the connections that exist between the user and his social peers. Moreover, the user’s Gmail contacts that should be treated as strictly private data is exposed and could be used for blackmailing, phishing or spamming attacks. While we did not investigated how many contacts this attack may compromise, it appears that people who share a lot of information or belong to a large social network, are very likely to be listed in the “Social” search result page.

In addition to the list of Gmail contact, Google+ users will also receive links that have been shared by people in their Circles whether or not these contacts belong to exposed Circles. Consequently, information about the victim private Circles could also be leaked and retrieved through the “Social” filter.

3.2 Capturing the victim’s data

The sole prerequisite to run this attack is to capture the SID cookie of a user with Web Search History enabled. SID cookies are not marked “secured” and so are usually sent cleartext. If the victim uses a secure connection (HTTPS), the attacker could use the iframe injection described in Section 2 to force her to send the SID cookie cleartext. Once the cookie has been intercepted, the attack is launched by opening a window on Google Search with the “Visited” filter enabled.

To start the attack, we use a list of 15 terms composed of domain extension (.com, .net, .org, .us, .edu, .fr, .co.), words and acronyms likely to appear in URLs (.jsp, .asp, .php, .html, .index, .wuw) and popular websites (google, facebook). To maximize the chance of finding all the visited links, the program should not only parse the first page of results, but browse all of them. We implemented a prototype that parses the result page and then clicks on “Next” to display and parse the following and so on until the last page. With Google Instant disabled – the attacker can set his Google PREF cookie to display 100 results per page instead of 10. Because the PREF cookie is browser specific – and not linked to the currently used Google Account – the attacker search preferences won’t be mirrored on the victim browser. The list of retrievable clicked URLs can therefore be browsed very quickly. However, this attack is destructive; as the program interacts with the result pages, queries entered during the attack will appear in the victim’s Web Search History.

We conducted an experiment we analyze in section 4 and which shows that on average, 40% of the click history can be retrieved. For Google users who search only occasionally from their account, up to 80% of the click history could be retrieved using this method.

4. IMPLEMENTATION AND EVALUATION

In order to validate the applicability of our attack and to illustrate its easy deployment, we implemented a proof of concept as a Firefox extension and another extension to measure the number of visited links that were retrievable. Both tools are available online (see http://unsearcher.org/sid-test) and we describe them in this section. We then detail and analyze our experiment results.

A chrome extension has also been developed to quickly set the SID cookie for the google.com domain (this extension is also available online http://unsearcher.org)

4.1 Extending Firesheep

In October 2010, the Firefox extension Firesheep [1] was released and emphasized the simplicity of session hijacking. This extension monitors network interfaces to capture cook-

Table 1: List of URLs that require the victim to send cleartext her cookie

| URL not available in HTTPS | URL not redirected to HTTPS |
|---------------------------|---------------------------|
| google.com/bidsearch      | google.com/sitesearch      |
| google.com/dirhp          | google.com/insights/search |
| google.com/alerts         | google.com/sitemap        |
| google.com/mobile         | google.com/adsense/support|
| google.com/nexus          | google.com/insights/search|
| google.com/analytics      | google.com/prdhp           |
| google.com/postini        | google.com/appsstatus      |
| google.com/chrome         | google.com/chromebook      |
| google.com/wallet         | google.com/googlebooks     |
| google.com/ads/preference | google.com/patents         |
| google.com/baraza         |                          |
| google.com/imghp          |                          |

1To visit the result page containing only visited links, one can directly go to http://www.google.com/search?q=&com&tb=1&ctb=whv:1
ies corresponding to sessions established on popular Web Service websites like Facebook, Google and Twitter. Once a cookie is captured, the extension provides an access to the account related to the hijacked session.

We extended Firesheep to implement our information leakage attack. Thanks to the Firehseep modularity, we easily added a module that performs the attack on the session hijacked by the original code.

As a result, when a Google SID cookie is captured, the account name appears in the Firesheep sidebar. Double clicking on it starts the attack; double clicking again displays the retrieved list of visited links.

4.2 Measurement methodology

We asked ten users to run the experiment on their Google accounts, we provided them with an extension that extracts from a user Web Search History the clicks recorded since 1st January 2011 and then issues some queries from the user’s account with the “Visited” filter activated. The extension — developed for this experiment — and the corresponding instructions have been publicly released to let users evaluate which portion of their click history can be exposed. Notice that, in order to preserve privacy of our testers, we asked them to send us only the ratio of clicks the attack was able to retrieve.

It is worth noticing that, among the 10 volunteers who all had Web Search History enabled, 6 were not aware that the service existed and never used it (on purpose). It has been estimated that 50% of Google accounts have Web Search History enabled, but many may not be aware that the service is enabled, as the opt-out option has not always been obvious.

4.3 Result Analysis

We summarize the results of our experiments in Table 2. We simulated the attack on a set of ten volunteers who visited between 88 and 3059 search results between January and July 2011. For these users, between 72 and 467 links were retrieved counting for 82% to 11% of the links recorded in their Web Search History over the considered period. We also recorded the total number of links that the attack retrieved independently of the date they were visited.

The attack provides similar results for the three users with the more visited links in their search history. For these three users who visited more links (Users 8, 9, and 10), a similar number of visited links were retrieved (between 628 and 644) although the number of clicks in the Web Search History varies from 1340 to 3059.

Figure 1 depicts the ratio of retrieved query as a function of the number of query submitted. We decided to use suffix and file extensions in our query list as they are very likely to appear in the URL of visited links and should return many search results. For instance, the query “.com” will return the list of visited links with the “.com” suffix.

The objective is to recover a large portion of the victim’s visited search results with the smallest set of search queries. Limiting the number of queries that will appear in the Web Search History reduces the risk that the victim detects the attack. A detected attack is likely to result in the purge of the victim’s Web Search History and would prevent any further exploitation of the SID cookie by the attacker.

Four queries — with no associated visited search results — are likely to remain unnoticed in victims’ Web Search History and are enough to retrieve a large part of the clicked results. For all users, the attack submitted the 15 queries in less than 5 minutes.

![Figure 1: Destructive Approach: Result for the 10 users](http://unsearcher.org/

5. COUNTERMEASURE

The information leakage attack we described just require to read victims’ SID cookies. If a user is not logged on her Google account when she accesses to Google services from a shared network, her SID cookie can not be compromised. A solution is therefore to sign out from Google accounts when connecting from a shared network or to use a VPN to encrypt the traffic and prevent cookie interception.

From a user perspective a solution to prevent this second attack is to purge the Web Search History and to disable temporarily this feature. Such radical solution would definitely prevent the leakage of information about the user’s search history but would not prevent a list of Gmail and Google+ contacts to be exposing by “Social Search”.

Another solution is to disable the “visited” and “social” search filters when a user is not visiting the secured version of Google. While this – most likely –temporary solution does not fist the information leakage, it makes its exploitation more complicated and detectable.

6. CONCLUSION

We presented an information leakage attack that leverages Google two-level cookie based access policy. We described an information leakage attack, implemented a proof of concept and evaluated the number of links visited over the last six months that could be exposed. Both issues should soon be fixed and we describe measures users could take to protect their search history from this kind of attack.

Nevertheless, some issues can not be addressed by users and require a modification of Google’s cookie policy. As Google is taking steps to include social indicators in result personalization, user’s social network could soon be exposed.

7. REFERENCES

[1] Eric Butler. Firesheep, 2010.

[http://codebutler.com/firesheep](http://codebutler.com/firesheep)
| USER | U1 | U2 | U3 | U4 | U5 | U6 | U7 | U8 | U9 | U10 | Avg |
|------|----|----|----|----|----|----|----|----|----|-----|-----|
| Links (since January 2011) | 88 | 111 | 211 | 426 | 625 | 812 | 1148 | 1340 | 2521 | 3059 | 1034 |
| Found (since January 2011) | 72 | 69 | 145 | 133 | 199 | 320 | 372 | 429 | 467 | 351 | 256 |
| Query 1 | 66% | 15% | 41% | 4% | 16% | 12% | 23% | 21% | 12% | 7% | 22% |
| Query 2 | 68% | 50% | 60% | 26% | 19% | 23% | 28% | 26% | 16% | 9% | 33% |
| Query 4 | 72% | 62% | 66% | 29% | 24% | 34% | 31% | 29% | 17% | 10% | 37% |
| Query 15 | 82% | 62% | 69% | 31% | 32% | 39% | 32% | 32% | 19% | 11% | 41% |
| Found | 338 | 69 | 359 | 137 | 315 | 541 | 425 | 628 | 644 | 640 | 410 |

Table 2: Summary of the experiment results

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[6] Alma Whitten. The freedom to be who you want to be…, February 2011. http://googlepublicpolicy.blogspot.com/2011/02/freedom-to-be-who-you-want-to-be.html.