CS 5436
INFO 5303

Web Tracking and Fingerprinting

Vitaly Shmatikov

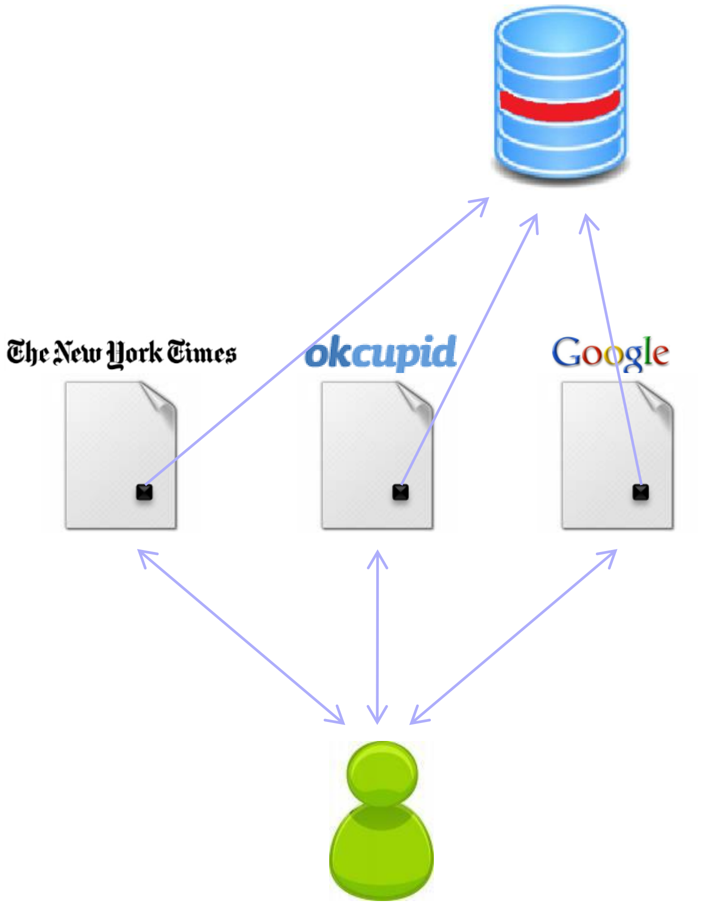
[redacted]

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!

Tracking via Cookies

- Cookie: value set by Web server, automatically sent by the browser on subsequent requests to same(ish) origin
- Link two sessions at same site
- Link sessions between different sites (third-party cookies)
- Can be combined with user-identifying information

Third-Party Tracking

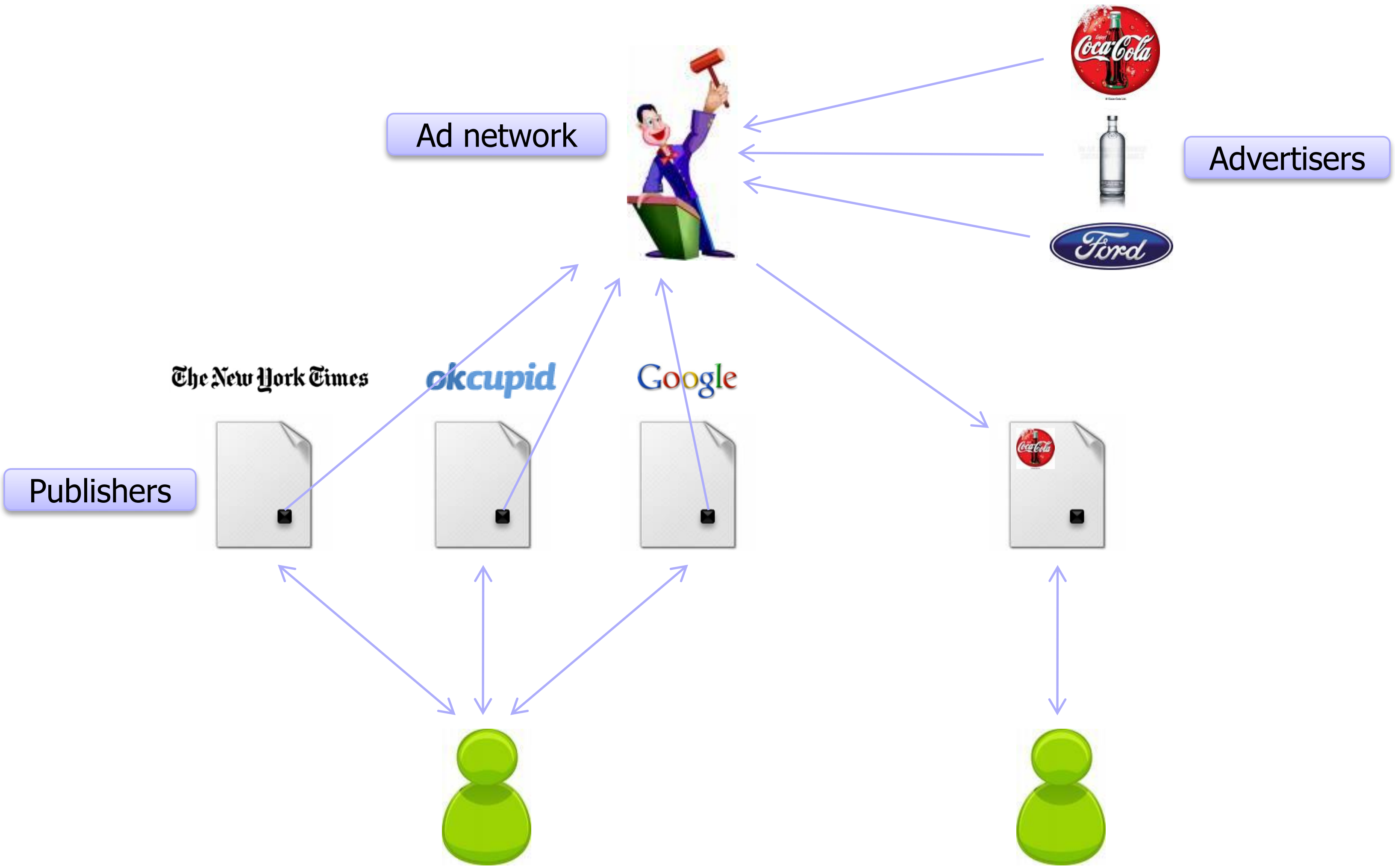


Third-party cookies:

- Disabled by default (Safari)
- Can be disabled by user (many browsers)
- Cannot be disabled (Android)

… but there are many other tracking technologies

Behavioral Targeting

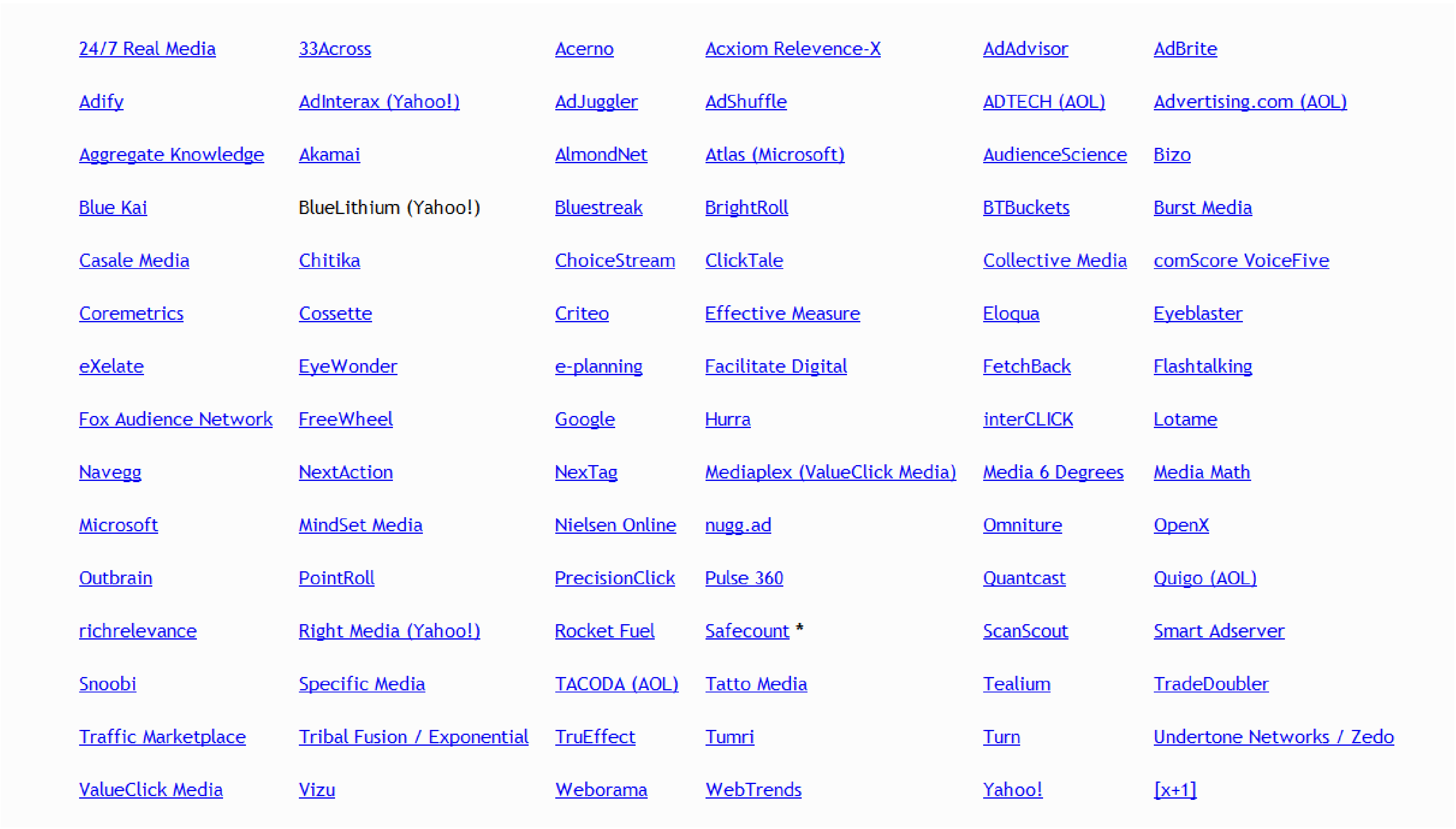


Ad network

Advertisers

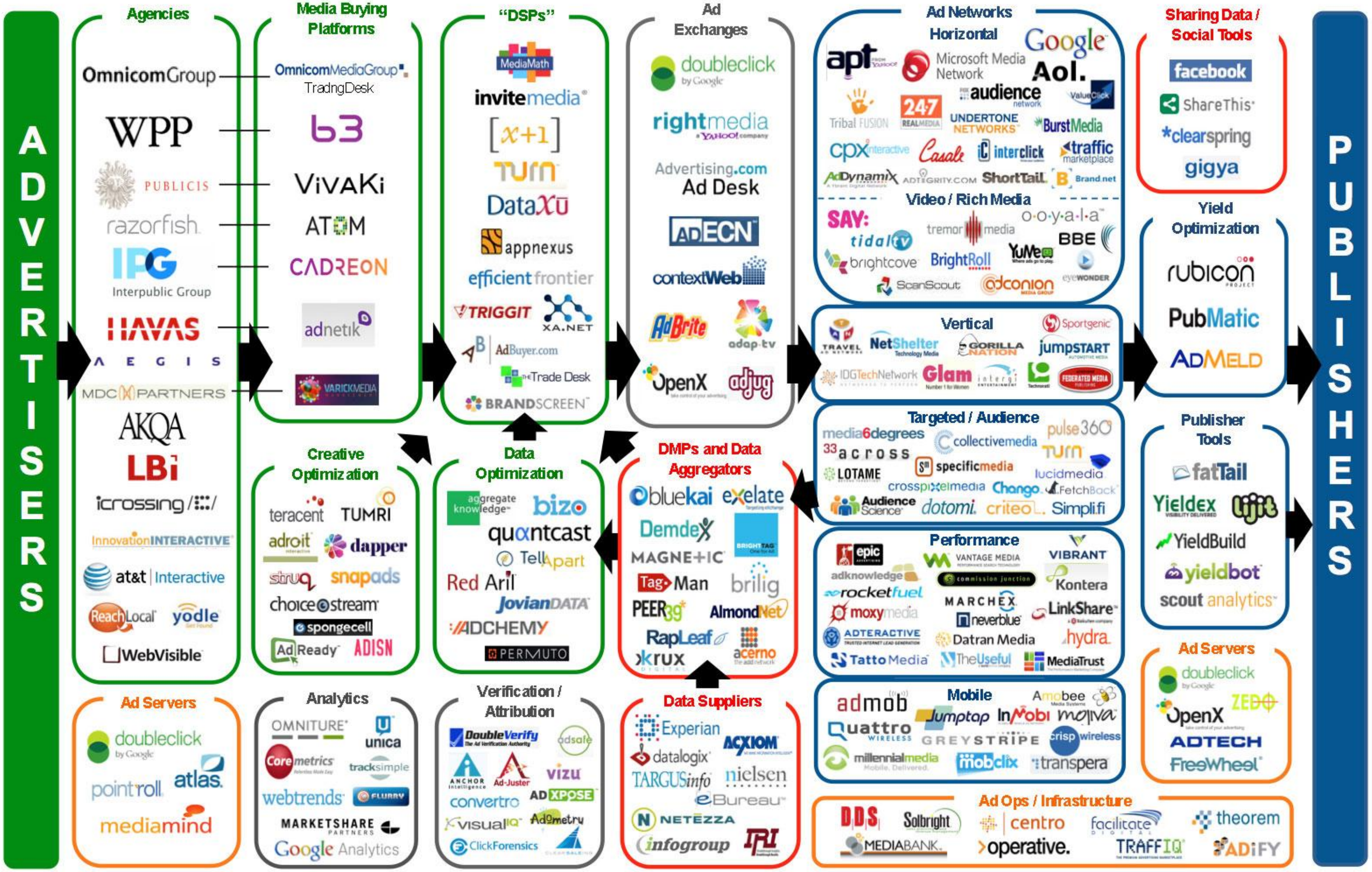
Publishers

Partial List of Ad Networks



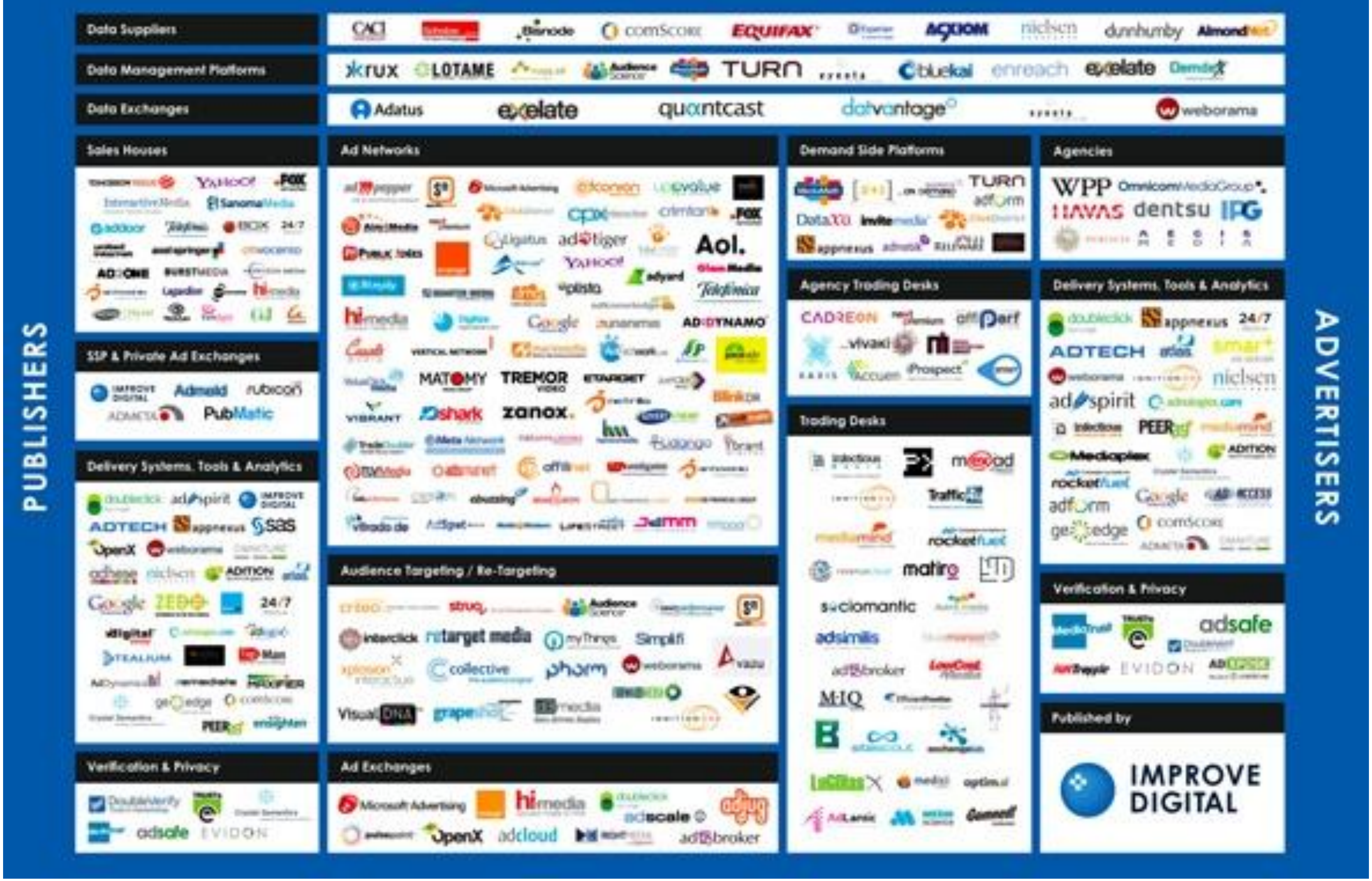
- 24/7 Real Media
- 33Across
- Acerno
- Acxiom Relevence-X
- AdAdvisor
- AdBrite
- Adify
- AdInterax (Yahoo!)
- AdJuggler
- AdShuffle
- ADTECH (AOL)
- Advertising.com (AOL)
- Aggregate Knowledge
- Akamai
- AlmondNet
- Atlas (Microsoft)
- AudienceScience
- Bizo
- Blue Kai
- BlueLithium (Yahoo!)
- Bluestreak
- BrightRoll
- BTBuckets
- Burst Media
- Casale Media
- Chitika
- ChoiceStream
- ClickTale
- Collective Media
- comScore VoiceFive
- Coremetrics
- Cossette
- Criteo
- Effective Measure
- Eloqua
- Eyeblaster
- eXelate
- EyeWonder
- e-planning
- Facilitate Digital
- FetchBack
- Flashtalking
- Fox Audience Network
- FreeWheel
- Google
- Hurra
- interCLICK
- Lotame
- Navegg
- NextAction
- NexTag
- Mediaplex (ValueClick Media)
- Media 6 Degrees
- Media Math
- Microsoft
- MindSet Media
- Nielsen Online
- nugg.ad
- Omniture
- OpenX
- Outbrain
- PointRoll
- PrecisionClick
- Pulse 360
- Quantcast
- Quigo (AOL)
- richrelevance
- Right Media (Yahoo!)
- Rocket Fuel
- Safecount *
- ScanScout
- Smart Adserver
- Snoobi
- Specific Media
- TACODA (AOL)
- Tatto Media
- Tealium
- TradeDoubler
- Traffic Marketplace
- Tribal Fusion / Exponential
- TruEffect
- Tumri
- Turn
- Undertone Networks / Zedo
- ValueClick Media
- Vizu
- Weborama
- WebTrends
- Yahoo!
- [x+1]

Display Advertising Technology Landscape



tkawaja@lumapartners.com

2012 DISPLAY ADVERTISING ECOSYSTEM EUROPE



Tracking Is Pervasive

64

independent tracking mechanisms in an average top-50 website

Sticky Tracking

Subverting same origin policy
(publisher also runs an ad network)

`ad.hi5.com = ad.yieldmanager.com`

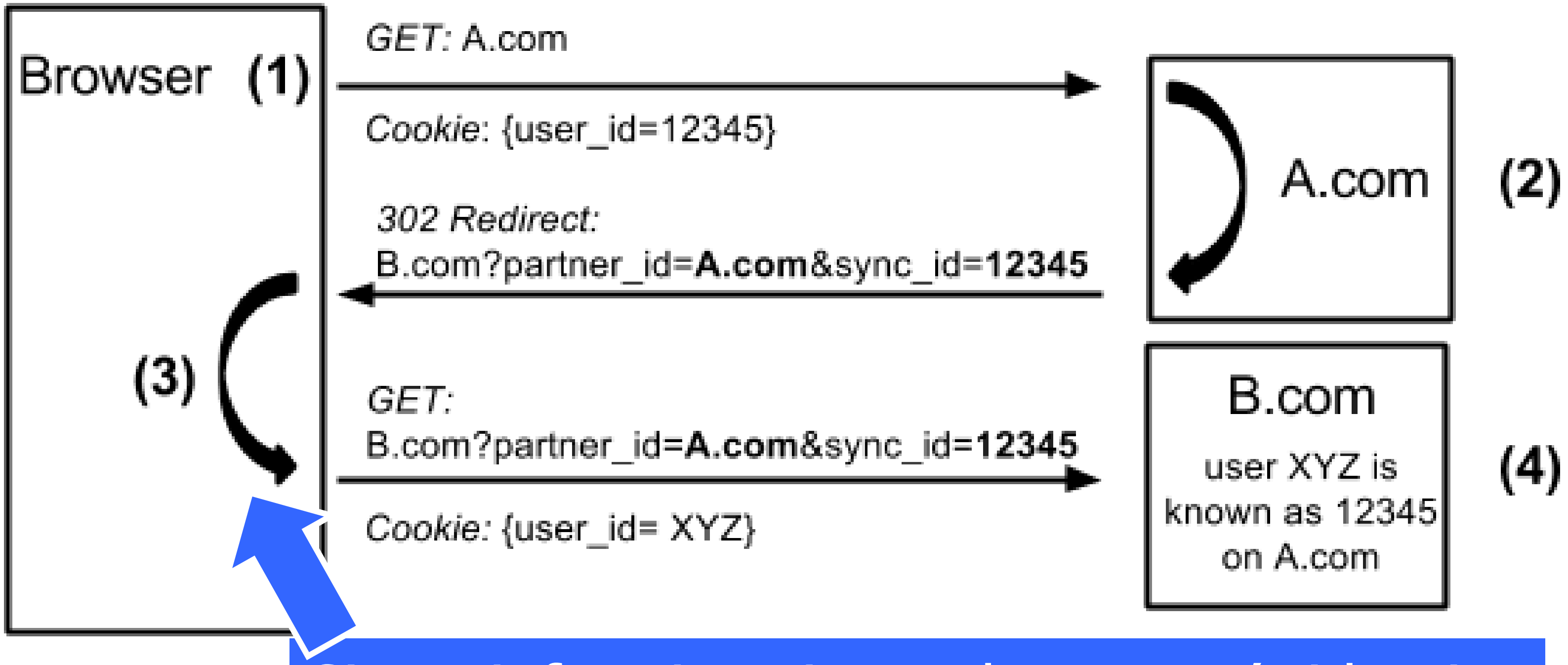
Flash cookies

Browser fingerprinting

Panopticlick
How Unique — and Trackable — Is Your Browser?

History sniffing

Cookie Syncing


Browser (1)
GET: A.com
Cookie: {user_id=12345}
A.com
(2)
302 Redirect:
B.com?partner_id=A.com&sync_id=12345
(3)
GET:
B.com?partner_id=A.com&sync_id=12345
Cookie: {user_id= XYZ}
B.com
user XYZ is known as 12345 on A.com
(4)

Site A informing site B about user’s identity (via user’s browser)

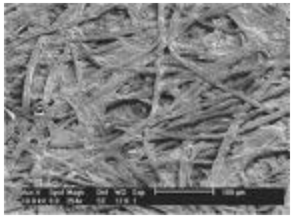
Allows aggregation across multiple trackers

Tracking Technologies

- HTTP Cookies
- HTTP Auth
- HTTP Etags
- Content cache
- IE userData
- HTML5 protocol and content handlers
- HTML5 storage

- Flash cookies
- Silverlight storage
- TLS session ID & resume
- Browsing history
- window.name
- HTTP STS
- DNS cache

Everything Has a Fingerprint

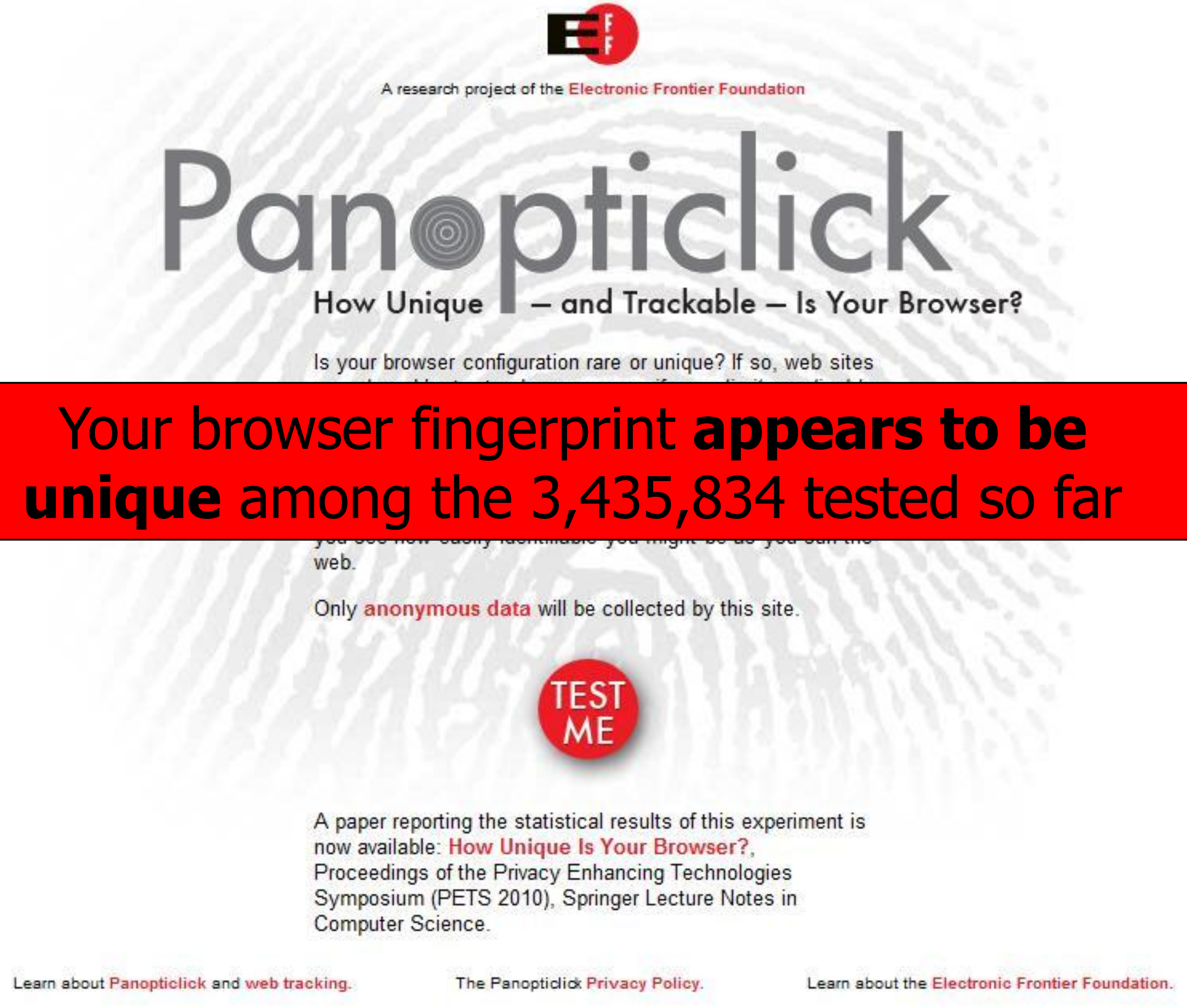


Fingerprinting Web Browsers

- User agent
- HTTP ACCEPT headers
- Browser plug-ins
- MIME support
- Clock skew

- Installed fonts
- Cookies enabled?
- Browser add-ons
- Screen resolution

Your browser fingerprint **appears to be unique** among the 3,435,834 tested so far



A research project of the Electronic Frontier Foundation

Panopticlick

How Unique – and Trackable – Is Your Browser?

Is your browser configuration rare or unique? If so, web sites

web.

Only anonymous data will be collected by this site.

A paper reporting the statistical results of this experiment is now available: How Unique Is Your Browser?, Proceedings of the Privacy Enhancing Technologies Symposium (PETS 2010), Springer Lecture Notes in Computer Science.

Learn about Panopticlick and web tracking. The Panopticlick Privacy Policy. Learn about the Electronic Frontier Foundation.

Panopticlick Example

Plugin 0: Adobe Acrobat; Adobe Acrobat Plug-In Version 7.00 for Netscape; nppdf32.dll; (Acrobat Portable Document Format; application/pdf; pdf) (Acrobat Forms Data Format; application/vnd.fdf; fdf) (XML Version of Acrobat Forms Data Format; application/vnd.adobe.xfdf; xfdf) (Acrobat XML Data Package; application/vnd.adobe.xdp+xml; xdp) (Adobe FormFlow99 Data File; application/vnd.adobe.xfd+xml; xfd). Plugin 1: Adobe Acrobat; Adobe PDF Plug-In For Firefox and Netscape; nppdf32.dll; (Acrobat Portable Document Format; e PDF in XML Fo) (XML Version applicat d). Plugin 2: Goog Plugin 3: MicrosoftÂ® Windows Media Player Firefox Plugin; np-mswmp; np-mswmp.dll; (np-mswmp; application/x-ms-wmp; *) (; application/asx; *) (; video/x-ms-asf-plugin; *) (; application/x-mplayer2; *) (; video/x-ms-asf; asf,asx,*) (; video/x-ms-wm; wm,*) (; audio/x-ms-wma; wma,*) (; audio/x-ms-wax; wax,*) (; video/x-ms-wmv; wmv,*) (; video/x-ms-wvx; wvx,*). Plugin 4: Move Media Player; npmnqmp 07103010; npmnqmp07103010.dll; (npmnqmp; application/x-vnd.moveplayer.qm; qmx,qpl) (npmnqmp; application/x-vnd.moveplay2.qm;) (npmnqmp; application/x-vnd.movenetworks.qm;). Plugin 5: Mozilla Default Plug-in; Default Plug-in; npnul32.dll; (Mozilla Default Plug-in; *; *). Plugin 6: Shockwave Flash; Shockwave Flash 10.0 r32; NPSWF32.dll; (Adobe Flash movie; application/x-shockwave-flash; swf) (FutureSplash movie; application/futuresplash; spl). Plugin 7: Windows Genuine Advantage; 1.7.0059.0; npLegitCheckPlugin.dll; (npLegitCheckPlugin; application/WGA-plugin; *).

84% of browser fingerprints are unique

With Flash or Java, 94% are unique

<CANVAS>

- Programmatic drawing in the browser
  - Draw shapes, add text, 3D (via WebGL)
- Access to drawn pixels
  - Array of RGBA values
  - PNG-encoded data URL

Text Rendering …

```
<script type="text/javascript">
  var canvas =
    document.getElementById("drawing");
  var context = canvas.getContext("2d");
  context.font = "18pt Arial";
  context.textBaseline = "top";
  context.fillText("Some letters", 2, 2);
</script>
```

… Text Inspection

```
<script type="text/javascript">
  var canvas =
    document.getElementById("drawing");
  var context = canvas.getContext("2d");
  context.font = "18pt Arial";
  context.textBaseline = "top";
  context.fillText("Some letters", 2, 2);

  var pixels =
    canvas.toDataURL("image/png");
</script>
```

WebFonts

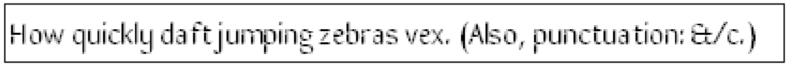
- Problem: Clients ship with ugly fonts
- Solution: Browsers should download fonts from the Internet on demand!

```
@font-face {  font-family: 'Sirin Stencil';
font-style: normal;  font-weight: 400;  src:
url(http://themes.googleusercontent.com/stat
ic/fonts/sirinstencil/v1/[...].woff)
format('woff');}
```

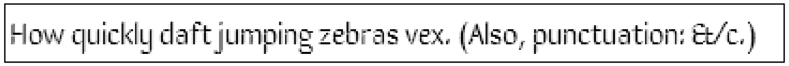
45 Ways To Sirin Stencil

```
context.font = "12pt 'Sirin Stencil'";
```

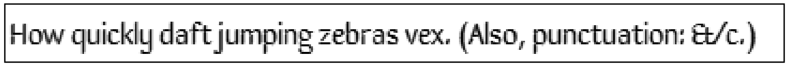
Windows



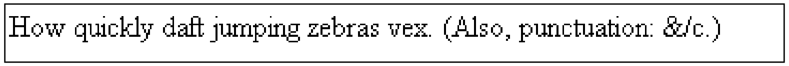
How quickly daft jumping zebras vex. (Also, punctuation: &/c.)



How quickly daft jumping zebras vex. (Also, punctuation: &/c.)



How quickly daft jumping zebras vex. (Also, punctuation: &/c.)



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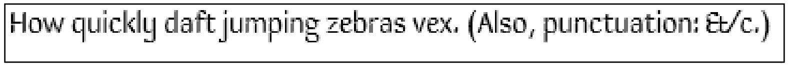

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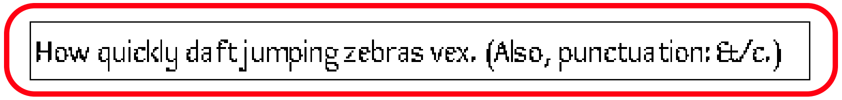
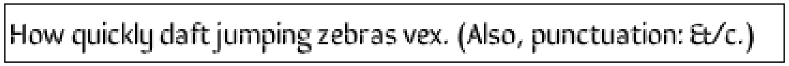


How quickly daft jumping zebras vex. (Also, punctuation: &/c.)

OS X



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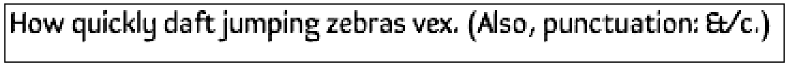

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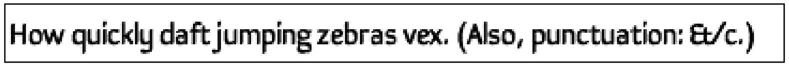

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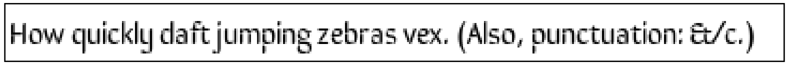
Linux



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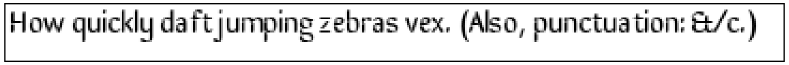

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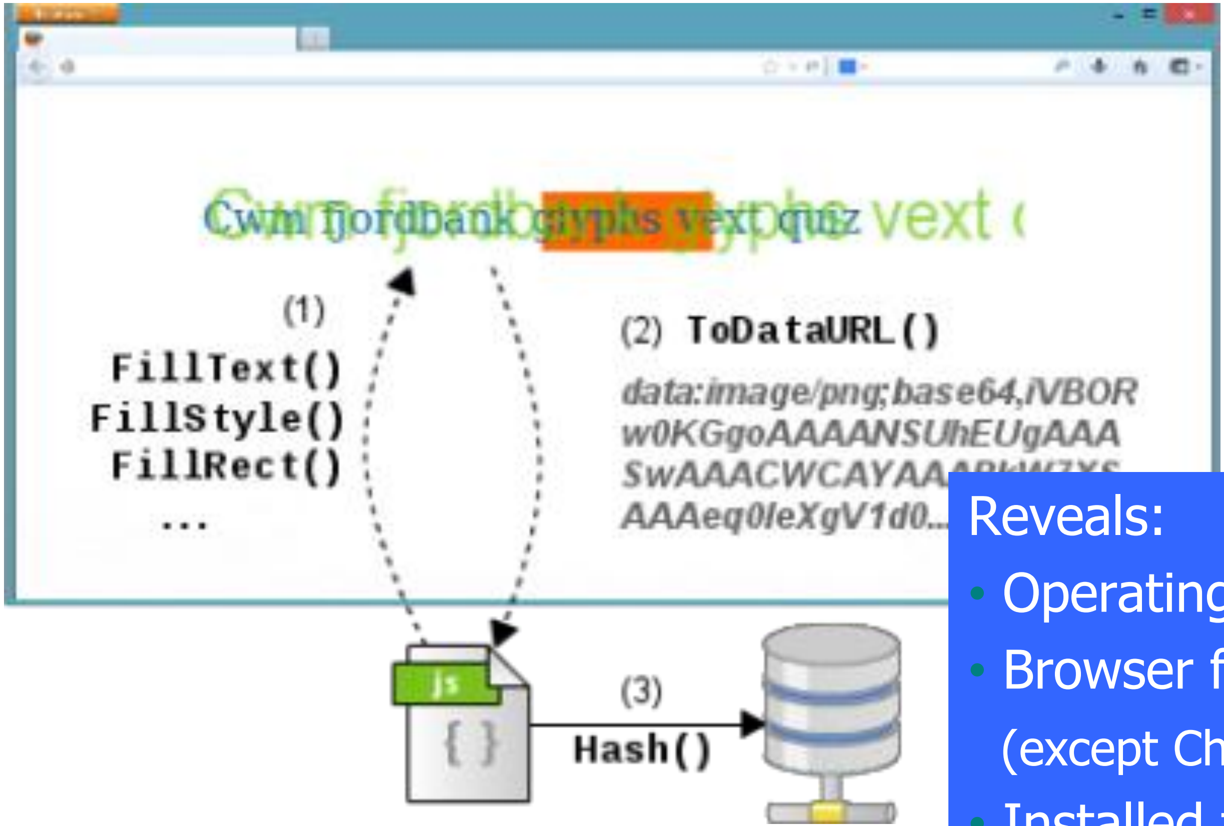
Canvas Fingerprinting

[Mowery and Shacham. "Pixel Perfect". W2SP 2012]



```
data:image/png;base64,iVBOR
w0KGgoAAAANSUhEUgAAA
SwAAACWCAYAA
AAAeq0leXgV1d0...
```

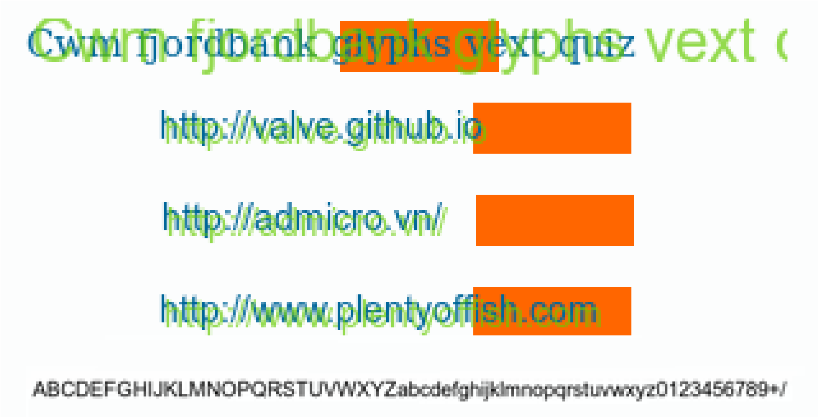
Reveals:

- Operating system family
- Browser family
  (except Chrome, Safari on OS X)
- Installed fonts
- Font smoothing parameters

How Pervasive?

[Acar et al. “The Web Never Forgets”. CCS 2014]

- Present in 5.5% of top 100,000 websites
- Fingerprinting code comes from 20 different domains
  - addthis.com by far the most popular (95%)


Cwm fjordbank glyphs vext quiz
Cwm fjordbank glyphs vext
http://valve.github.io
http://admicro.vn/
http://www.plentyoffish.com
ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789+/

Draws
Cwm fjordbank glyphs vext quiz
into the canvas

Why this text?

“Don’t Worry, It’s All Anonymous”

- Is it?
- What’s the difference between
  - “anonymous”
  - “pseudonymous”
  - “identified”
- Which technology changed data collection from anonymous to pseudonymous?

How Websites Get Your Identity

Third party is sometimes the site itself

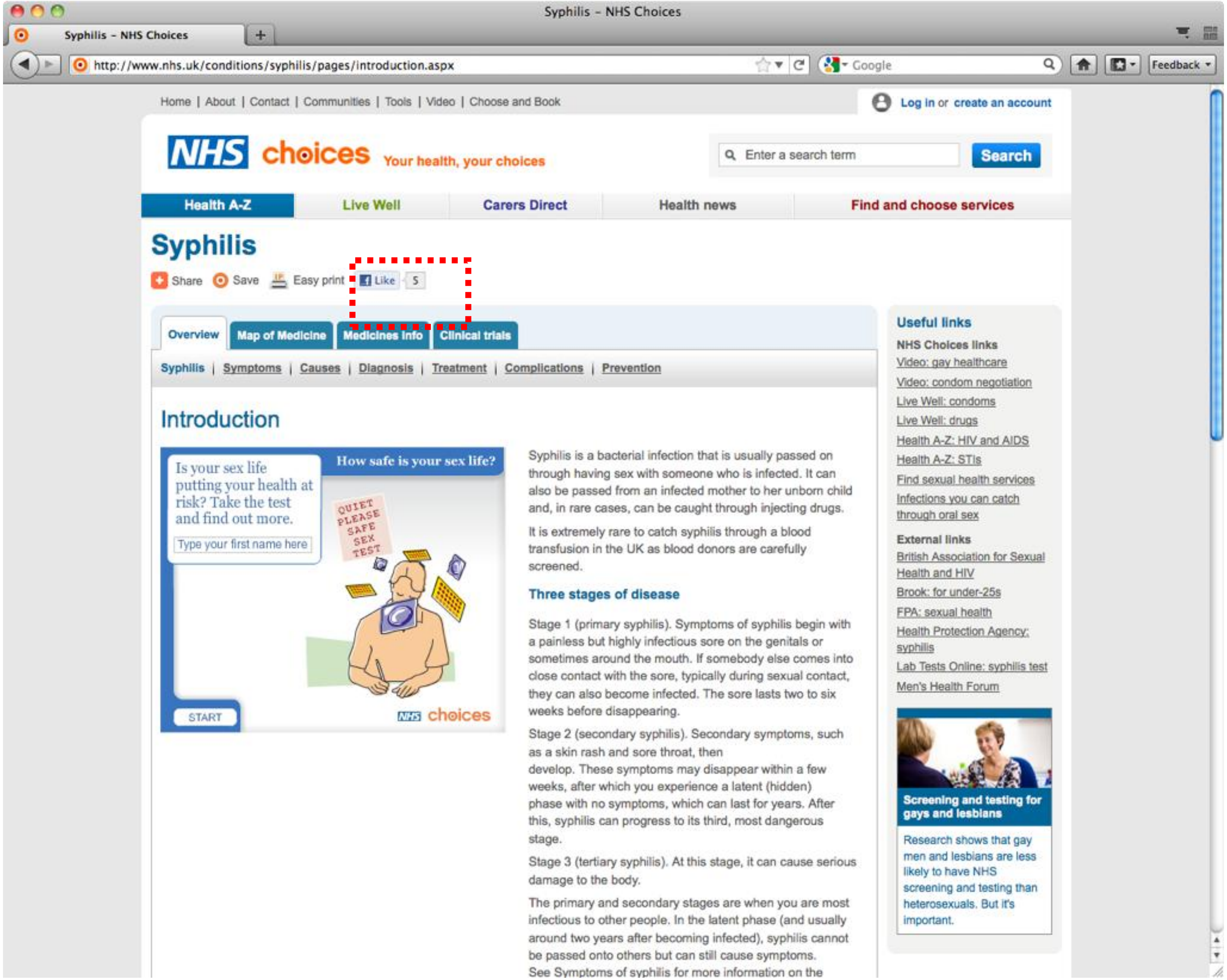
Leakage of identifiers

```
GET http://ad.doubleclick.net/adj/...
Referer: http://submit.SPORTS.com/...?email=jdoe@email.com
Cookie: id=35c192bcfe0000b1...
```

Security bugs

XSUH: cross-site URL hijacking

Third party buys your identity


Syphilis - NHS Choices
http://www.nhs.uk/conditions/syphilis/pages/introduction.aspx
Google
Feedback
Home | About | Contact | Communities | Tools | Video | Choose and Book
Log in or create an account
NHS choices Your health, your choices
Enter a search term
Search
Health A-Z
Live Well
Carers Direct
Health news
Find and choose services
Share
Save
Easy print
Like
5
Overview
Map of Medicine
Medicines info
Clinical trials
Syphilis | Symptoms | Causes | Diagnosis | Treatment | Complications | Prevention
How safe is your sex life?
Is your sex life putting your health at risk? Take the test and find out more.
Type your first name here
QUIET PLEASE SAFE SEX TEST
START
NHS choices

Syphilis

Introduction

Syphilis is a bacterial infection that is usually passed on through having sex with someone who is infected. It can also be passed from an infected mother to her unborn child and, in rare cases, can be caught through injecting drugs.

It is extremely rare to catch syphilis through a blood transfusion in the UK as blood donors are carefully screened.

Three stages of disease

Stage 1 (primary syphilis). Symptoms of syphilis begin with a painless but highly infectious sore on the genitals or sometimes around the mouth. If somebody else comes into close contact with the sore, typically during sexual contact, they can also become infected. The sore lasts two to six weeks before disappearing.

Stage 2 (secondary syphilis). Secondary symptoms, such as a skin rash and sore throat, then develop. These symptoms may disappear within a few weeks, after which you experience a latent (hidden) phase with no symptoms, which can last for years. After this, syphilis can progress to its third, most dangerous stage.

Stage 3 (tertiary syphilis). At this stage, it can cause serious damage to the body.

The primary and secondary stages are when you are most infectious to other people. In the latent phase (and usually around two years after becoming infected), syphilis cannot be passed onto others but can still cause symptoms. See Symptoms of syphilis for more information on the

Useful links

NHS Choices links

- Video: gay healthcare
- Video: condom negotiation
- Live Well: condoms
- Live Well: drugs
- Health A-Z: HIV and AIDS
- Health A-Z: STIs
- Find sexual health services
- Infections you can catch through oral sex

External links

- British Association for Sexual Health and HIV
- Brook: for under-25s
- FPA: sexual health
- Health Protection Agency: syphilis
- Lab Tests Online: syphilis test
- Men's Health Forum

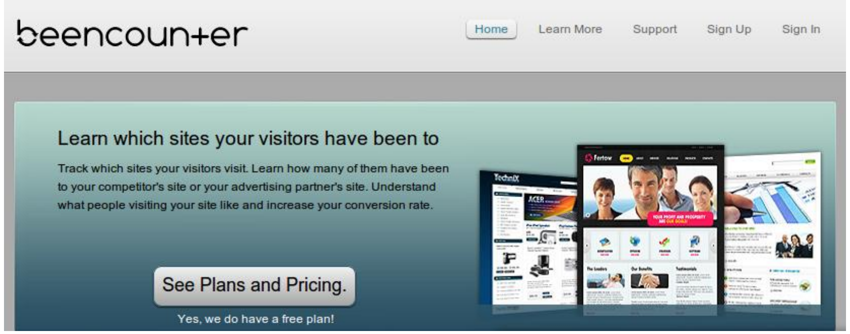
Screening and testing for gays and lesbians

Research shows that gay men and lesbians are less likely to have NHS screening and testing than heterosexuals. But it's important.

History Sniffing

How can a webpage figure out which sites you visited previously?

- Color of links
  - CSS :visited property
  - getComputedStyle()
- Cached Web content timing
- DNS timing



Learn which sites your visitors have been to

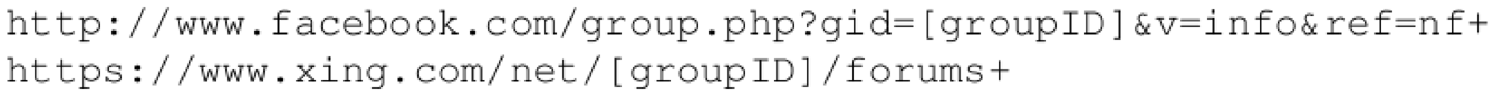
Track which sites your visitors visit. Learn how many of them have been to your competitor's site or your advertising partner's site. Understand what people visiting your site like and increase your conversion rate.

Yes, we do have a free plan!

Identity Sniffing

[Wondracek et al. Oakland 2010]

- All social networking sites allow users to join groups
- Users typically join multiple groups
  - Some of these groups are public
- Group-specific URLs are predictable



```
http://www.facebook.com/group.php?gid=[groupID]&v=info&ref=nf+
https://www.xing.com/net/[groupID]/forums+
```

- Intersection of group affiliations acts as a fingerprint
  - Can sometimes infer identity by computing the intersection of group membership lists

One-Click Fraud

[Cristin et al. CCS 2010]

Thank you for your patronage! You successfully registered for our premium online services, at an incredible price of 50,000 JPY. Please promptly send your payment by bank transfer to ABC Ltd at Ginko Bank, Account 1234567. Questions? Please contact us at 080-1234-1234.

Your IP address is 10.1.2.3, you run Firefox 3.5 over Windows XP, and you are connecting from Tokyo.

Failure to send your payment promptly will force us to mail you a postcard reminder to your home address. Customers refusing to pay will be prosecuted to the fullest extent of the law. Once again, thank you for your patronage!

BIG in JAPAN

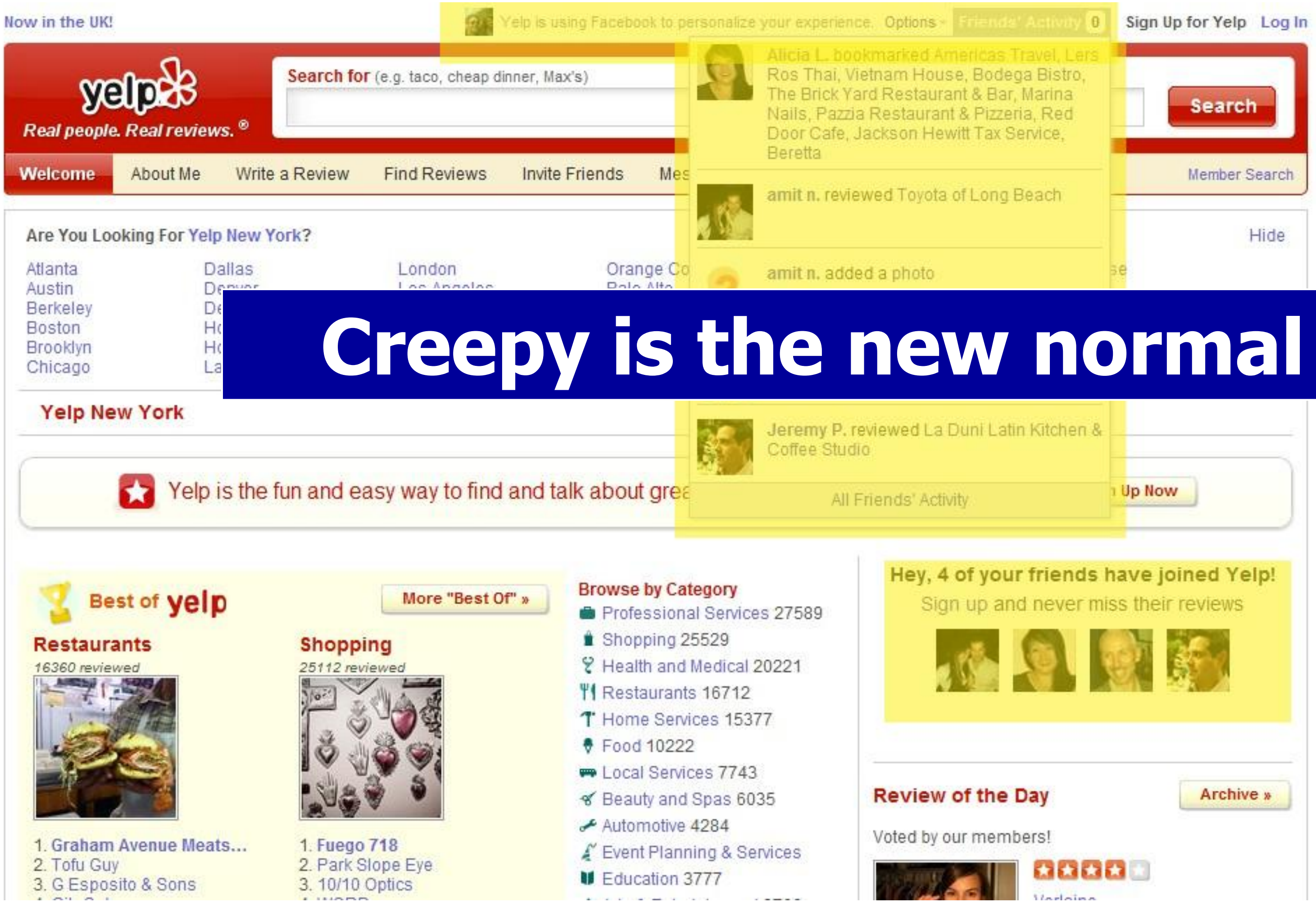
One-Click Fraud

- Estimated costs to victims:
  USD 260 million / year

- What's going on here?
- Why only Japan?
  - Cultural factors:
    susceptibility to authoritative language
    threat of public shaming

Credible because the website does have your real identity!

Instant Personalization



Yelp is using Facebook to personalize your experience.

Alicia L. bookmarked Americas Travel, Lers Ros Thai, Vietnam House, Bodega Bistro, The Brick Yard Restaurant & Bar, Marina Nails, Pazzia Restaurant & Pizzeria, Red Door Cafe, Jackson Hewitt Tax Service, Beretta

amit n. reviewed Toyota of Long Beach

amit n. added a photo

Jeremy P. reviewed La Duni Latin Kitchen & Coffee Studio

All Friends' Activity

Are You Looking For Yelp New York?

Atlanta
Austin
Berkeley
Boston
Brooklyn
Chicago

Dallas
Denver

London
Los Angeles

Orange Co
Palo Alto

Yelp New York

Yelp is the fun and easy way to find and talk about grea

Best of yelp

Restaurants
16360 reviewed

1. Graham Avenue Meats...
2. Tofu Guy
3. G Esposito & Sons

Shopping
25112 reviewed

1. Fuego 718
2. Park Slope Eye
3. 10/10 Optics

Browse by Category

Professional Services	27589
Shopping	25529
Health and Medical	20221
Restaurants	16712
Home Services	15377
Food	10222
Local Services	7743
Beauty and Spas	6035
Automotive	4284
Event Planning & Services	
Education	3777

Hey, 4 of your friends have joined Yelp!
Sign up and never miss their reviews

Review of the Day
Voted by our members!

Creepy is the new normal

Do Not Track

Basics

HTTP header

- DNT: 1

Standardization

Browser support in FF4, IE9

Beginning to see adoption (AP, NAI)… or not

Privacy protections

No tracking across sites

- Who is the "third" party?

Can't be based on domain
Example: amazonaws.com, ad.hi5.com …

No intrusive tracking

Limits on regular log data

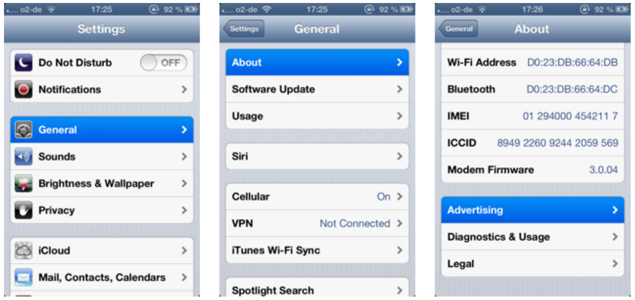
Exceptions for fraud prevention, etc.

DNT Adoption Issues

"But the NAI code also recognizes that companies sometimes need to continue to collect data for operational reasons that are separate from ad targeting based on a user's online behavior. For example, online advertising companies may need to gather data to prove to advertisers that an ad has been delivered and should be paid for; to limit the number of times a user sees the same ad; or to prevent fraud."

Translation: we're going to keep tracking you, but we'll simply call it "operational reasons."

Brave New World?



o2-de 17:25 92 %

Settings

- Do Not Disturb OFF
- Notifications
- General
- Sounds
- Brightness & Wallpaper
- Privacy
- iCloud
- Mail, Contacts, Calendars

o2-de 17:25 92 %

Settings General

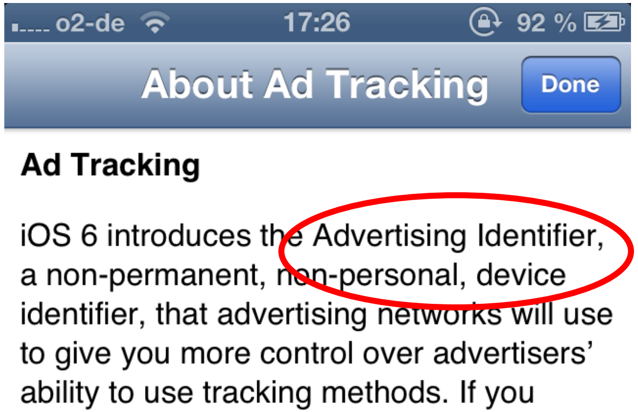
- About
- Software Update
- Usage
- Siri
- Cellular On
- VPN Not Connected
- iTunes Wi-Fi Sync
- Spotlight Search

o2-de 17:26 92 %

General About

Wi-Fi Address	D0:23:DB:66:64:DB
Bluetooth	D0:23:DB:66:64:DC
IMEI	01 294000 454211 7
ICCID	8949 2260 9244 2059 569
Modem Firmware	3.0.04

- Advertising
- Diagnostics & Usage
- Legal



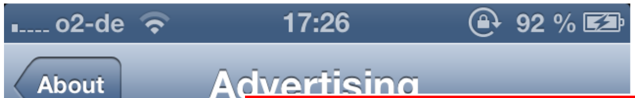
o2-de 17:26 92 %

About Ad Tracking Done

Ad Tracking

iOS 6 introduces the Advertising Identifier, a non-permanent, non-personal, device identifier, that advertising networks will use to give you more control over advertisers' ability to use tracking methods. If you

Advertising Identifier. However,
ertising networks transition to
e Advertising Identifier you may
ve targeted ads from other
s.



o2-de 17:26 92 %

About Advertising

Limit Ad Trac

How are these identifiers different from third-party cookies?

ng the
rebuilt
Atlas from the ground up to tackle today's marketing challenges, like reaching people across devices and bridging the gap between online impressions and offline purchases

Google AdID