

UCognito: Private Browsing without Tears

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Private Browsing Mode



Private Browsing



Incognito Mode
Guest Mode



InPrivate



Private Window

Private Browsing Mode



Private Browsing



Incognito Mode
Guest Mode



InPrivate



Private Window

Questions:

- Same ?
- Expected ?
- Implemented ?
- Private ?

Private Browsing Mode



Private Browsing



Incognito Mode
Guest Mode



InPrivate



Private Window

Questions:

- Same ?
- Expected ?
- Implemented ?
- Private ?

Problem:

Different Definitions of Private Browsing

Category	Use		Store	
	Incognito	Guest	Incognito	Guest
Browsing history	✓	✗	✗	✗
Cookies	✗	✗	✗	✗
Cache	✗	✗	✗	✗
Local storage	✗	✗	✗	✗
Flash storage	✗	✗	✗	✗
Download entries	✓	✗	✗	✗
Autofills	✓	✗	✗	✗
Bookmarks	✓	✗	✓	✗
Per-site zoom	✓	✗	✗	✗
Per-site permission	✓	✗	✗	✗
SSL self-signed cert	✗	✗	✗	✗
SSL client cert	✓	✓	✓	✓
Add-on storage	✓	✗	✓	✗

Problem:

Different Definitions of Private Browsing

Use of persistent data in private browsing mode	Firefox	Chrome Incognito	Opera	Safari	IE
Download entries	✗	✓	✓	✓	✗
SSL self-signed certificate	✓	✗	✗	✓	✗
Add-on enabled by default	✓	✗	✗	✓	✓

Private Browsing Mode



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Private Window

Questions:

- Same ?
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Private Browsing

Firefox won't remember any history for this window.

In a Private Browsing window, Firefox won't keep any browser history, search history, download history, web form history, cookies, or temporary internet files. However, files you download and bookmarks you make will be kept.

To stop Private Browsing, you can close this window.

- While this computer won't have a record of your browsing history, your internet service provider or employer can still track the pages you visit.

[Learn More](#)



New Tab



Translate

You've gone incognito. Pages you view in this window won't appear in your browser history or search history, **and they won't leave other traces** like cookies, on your computer after you close **all** open incognito windows. Any files you download or bookmarks you create will be preserved, however.



Going incognito doesn't affect the behavior of other people, servers, or software. Be wary of:

- Websites that collect or share information about you
- Internet service providers or employers that track the pages you visit
- Malicious software that tracks your keystrokes in exchange for free smileys
- Surveillance by secret agents
- People standing behind you

[Learn more](#) about incognito browsing.



Because Google Chrome does not control how extensions handle your personal data, all extensions have been disabled for incognito windows. You can reenable them individually in the [extensions manager](#).

Private Browsing Mode



Private Browsing



Incognito Mode
Guest Mode



InPrivate



Private Window

Questions:

- Same ?
- Expected ?
- **Implemented ?**
- Private ?

Problem:

Implementation is `mimicking` and ad-hoc

```
1 // @network/cookie/nsCookieService.cpp
2 DBState *mDBState;
3 nsRefPtr<DBState> mDefaultDBState; // DB for normal mode
4 nsRefPtr<DBState> mPrivateDBState; // DB for private mode
5
6 // invoked when initializing session
7 void nsCookieService::InitDBStates() {
8     ...
9     mDefaultDBState = new DBState(); // DB for normal mode
10    mPrivateDBState = new DBState(); // DB for private mode
11    // default: normal mode
12    mDBState = mDefaultDBState;
13    ...
14 }
15
16 // invoked when storing cookies
17 void nsCookieService::SetCookieStringInternal() {
18     ...
19     // decide which cookie DB to use, depending on the mode
20    mDBState = aIsPrivate ? mPrivateDBState : mDefaultDBState;
21    ...
22 }
```

Problem:

Implementation is `mimicking` and ad-hoc

```
1 // @network/cookie/nsCookieService.cpp
2 DBState *mDBState;
3 nsRefPtr<DBState> mDefaultDBState; // DB for normal mode
4 nsRefPtr<DBState> mPrivateDBState; // DB for private mode
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6 // invoked when initializing session
7 void nsCookieService::InitDBStates() {
8     ...
9     mDefaultDBState = new DBState(); // DB for normal mode
10    mPrivateDBState = new DBState(); // DB for private mode
11    // default: normal mode
12    mDBState = mDefaultDBState;
13    ...
14 }
15
16 // invoked when storing cookies
17 void nsCookieService::SetCookieStringInternal() {
18     ...
19     // decide which cookie DB to use, depending on the mode
20    mDBState = aIsPrivate ? mPrivateDBState : mDefaultDBState;
21    ...
22 }
```

Problem:

Code complexity goes exponentially

- How many duplications ?
 - cookie, history, cache, download entries, autofills, bookmarks, flash storage ...
 - per-site permission, per-site zoom level, SSL certs ...
 - html5 local storage, indexedDB ...

Problem:

Code complexity goes exponentially

- How many duplications ?
 - cookie, history, cache, download entries, autofills, bookmarks, flash storage ...
 - per-site permission, per-site zoom level, SSL certs ...

- html5 local storage, indexedDB ...

X 3 !!!

Normal mode
Incognito mode
Guest mode

Problem:

Lack of elegant support for add-ons

```
1 // 1. Detecting private browsing mode @MDN
2 Components.utils.import(
3     "resource://gre/modules/PrivateBrowsingUtils.jsm");
4 if (!PrivateBrowsingUtils.isWindowPrivate(window)) {
5     ...
6 }
7
8 // 2. Detecting mode changes @MDN
9 function pbObserver() { /* clear private data */ }
10 var os = Components.classes["@mozilla.org/observer-service;1"]
11     .getService(Components.interfaces.nsIObserverService);
12 os.addObserver(pbObserver, "last-pb-context-exited", false);
```

Warning: Google Chrome cannot prevent extensions from recording your browsing history. To disable this extension in incognito mode, unselect this option.

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Private Window

Questions:

- Same ?
- Expected ?
- Implemented ?
- Private ?

Problem: Not secure by default

- How many places to instrument ?
 - cookie, history, cache, download entries, autofills, bookmarks, flash storage ...

ok, these are common

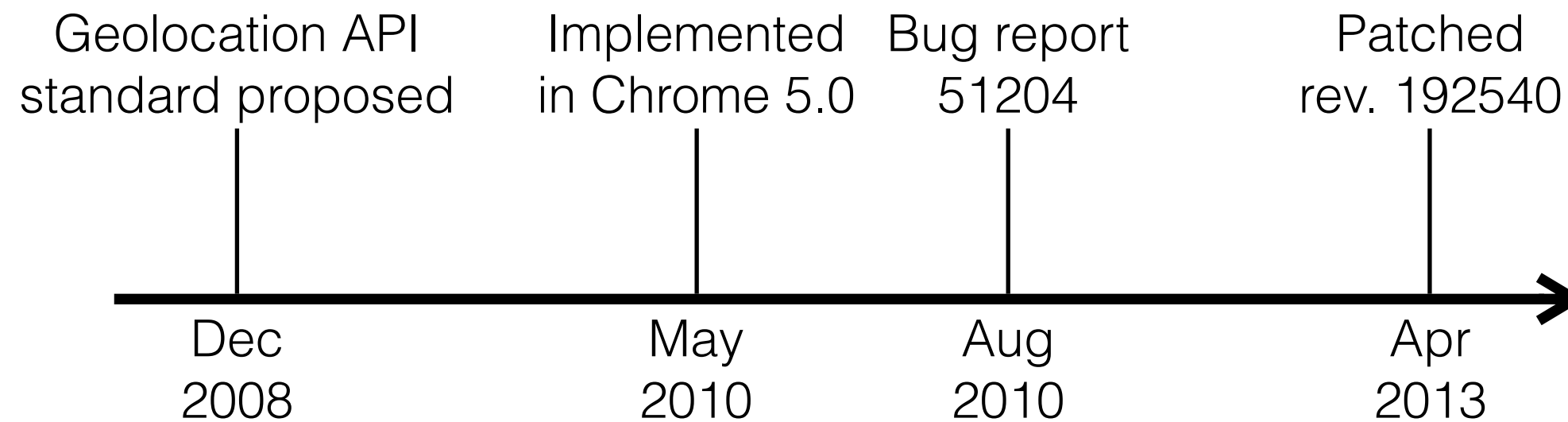
- per-site permission, per-site zoom level, SSL certs ...

hmm, we can think of these

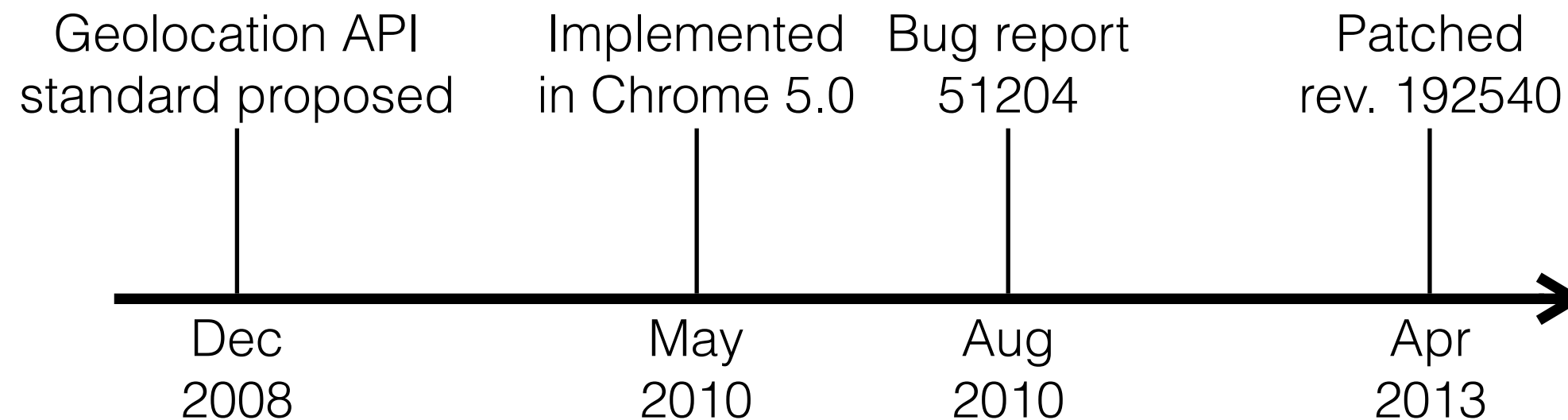
- html5 local storage, indexedDB ...

new features are coming in!

Problem: Not secure by default



Problem: Not secure by default



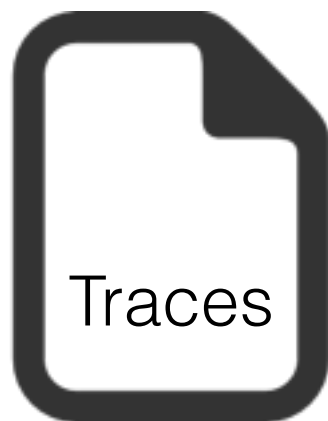
Any more of such cases ?

Uverifier: Testing Private Browsing Mode

- Stealthiness
 - **Do not store** any data generated during private session, unless explicitly specified
- Freshness
 - **Do not use** any data from previous browsing sessions during your private session, unless explicitly specified

Uverifier: Key idea

```
open(<file>, "w")  
.....  
write(<file>, .....)  
.....  
no delete(<file>)
```



```
open(<file>, "r")  
.....  
read(<file>, .....)
```



Uverifier: Stealthiness goal

Private mode

```
open(<file>, "w")
```

```
.....
```

```
write(<file>, .....
```

```
.....
```

```
no delete(<file>)
```



Uverifier: Freshness goal

Normal mode

```
open(<file>, "w")  
.....  
write(<file>, .....)  
.....  
no delete(<file>)
```

Private mode

```
open(<file>, "r")  
.....  
read(<file>, .....)
```



PNaCl cache reveals browsing history

- PNaCl translation cache reveals whether you have previously visited a website.
- <http://gonativeclient.appspot.com/demo/lua> (demo)

PNaCl cache explanation

Normal mode

```
open(<file>, "w")  
.....  
write(<file>, .....)  
.....  
no delete(<file>)
```

Private mode

```
open(<file>, "r")  
.....  
read(<file>, .....)
```



<profile>/PnaclTranslationCache/index
<profile>/PnaclTranslationCache/data_1
<profile>/PnaclTranslationCache/data_2
<profile>/PnaclTranslationCache/data_3

UCognito: Decouple private mode implementation from browser codebase.



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Private Window

UCognito: Decouple private mode implementation from browser codebase.



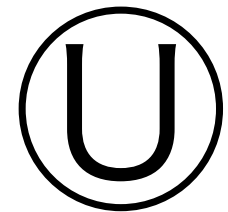
UCognito: Decouple private mode implementation from browser codebase.



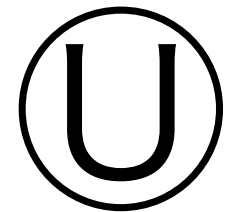
Questions:

- Same ?
- Expected ?
- Implemented ?
- Private ?

UCognito Architecture



Step 0: Specify Policies



Autofill



Bookmarks



Cookies

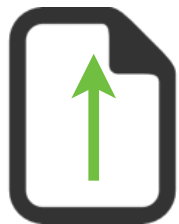
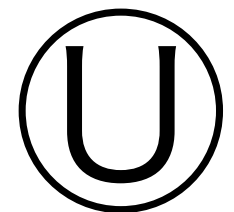


Cache

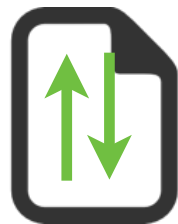
.....



Step 0: Specify Policies



Autofill



Bookmarks



Cookies

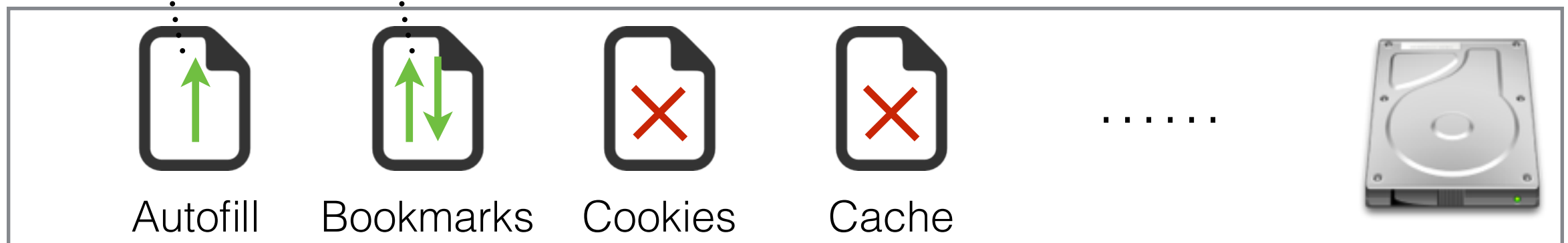
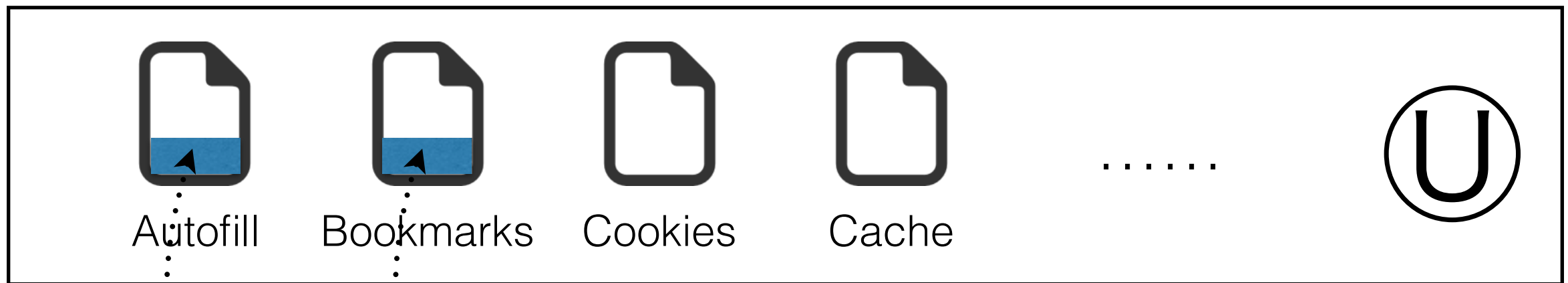


Cache

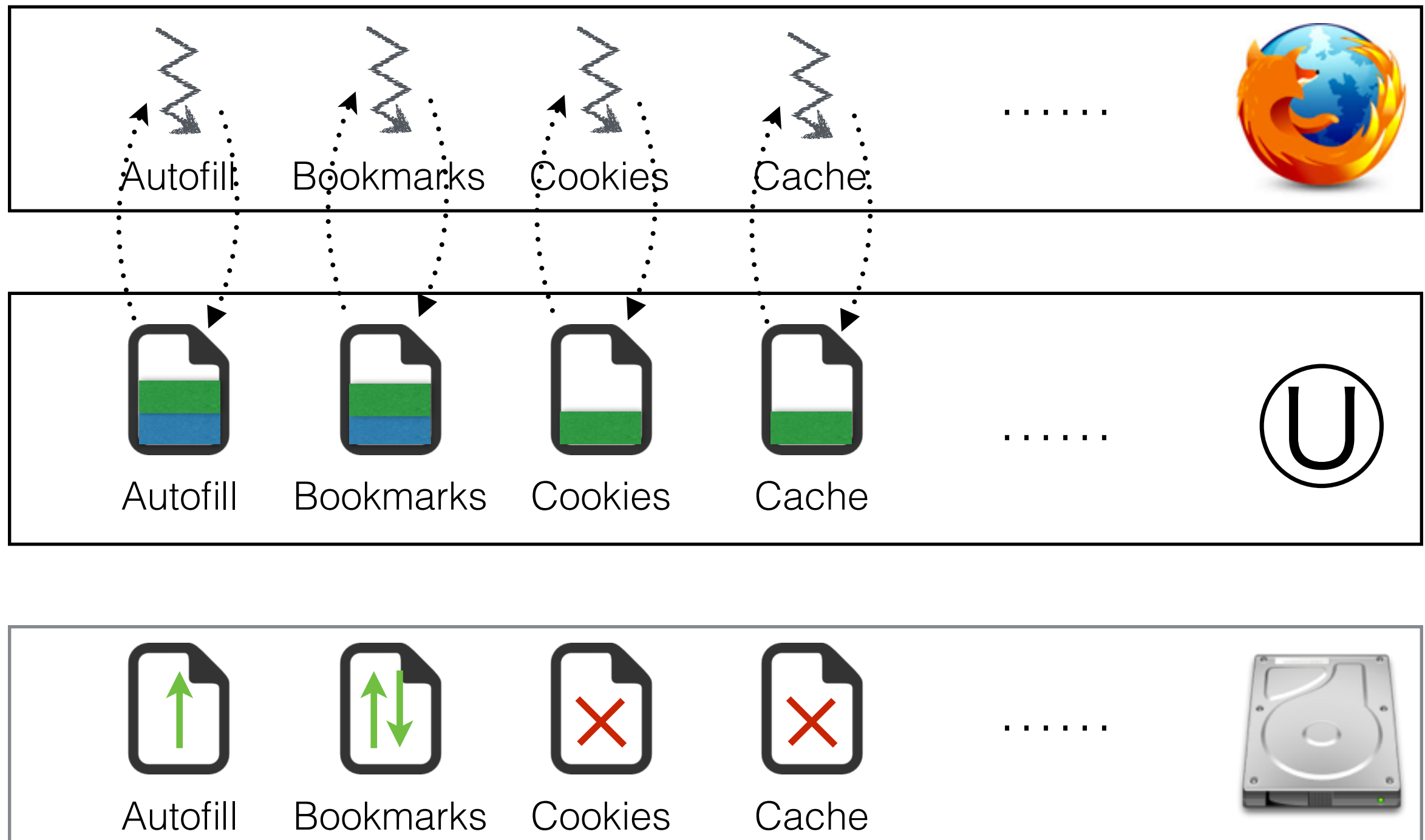
.....



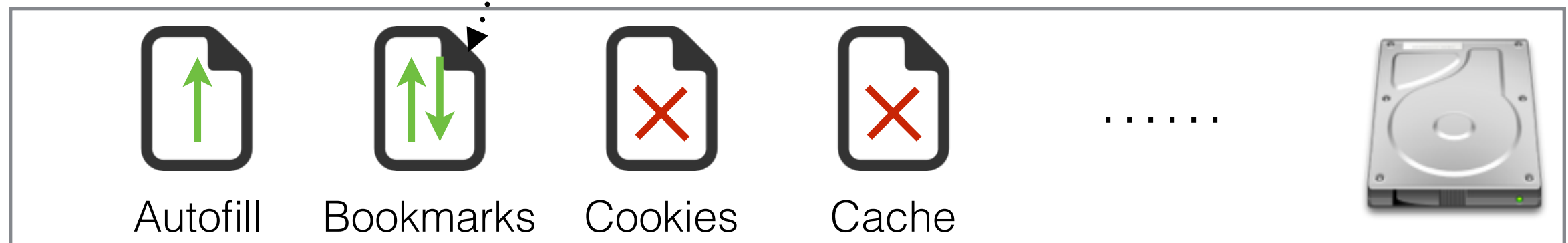
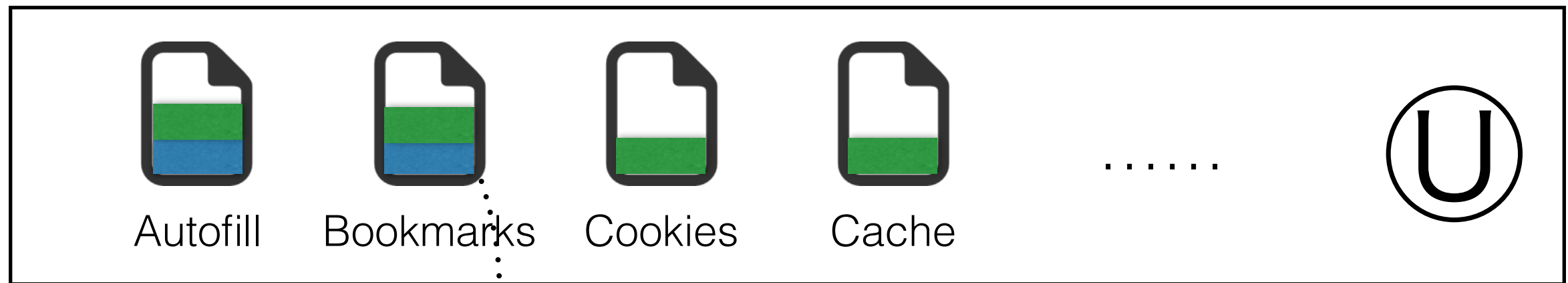
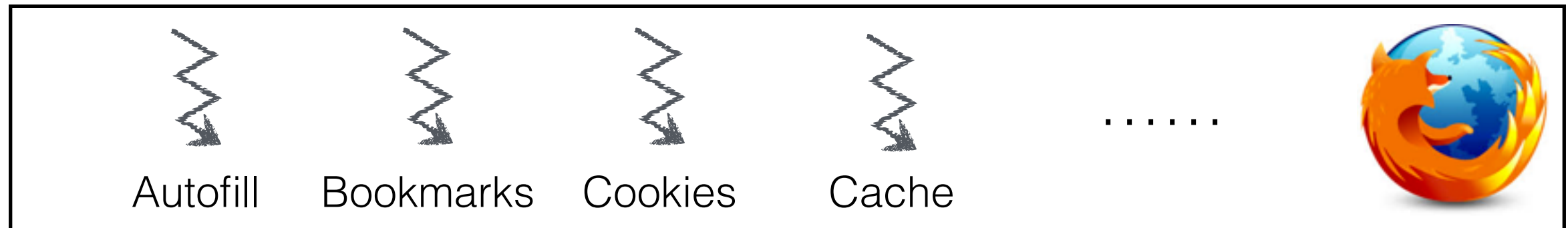
Step 1: Starting UCognito



Step 2: Browsing



Step 3: Cleaning



UCognito Sandbox

- Goal: redirecting all path to a contained location
 - e.g., `/home/user/profile/*` → `/tmp/<pid>/home/user/profile/*`
- Implementation: *seccomp-bpf*
 - Leverage MBox, a lightweight sandboxing for non-root users
 - Place hooks on 50 system calls that deals with file paths, e.g., *open*, *creat*, *unlink*, *stat* etc

UCognito Policy System

- Goal: control trace storage and trace usage on a per-file granularity
- Design:
 - **CLEAN**: disallow loading of any traces, run browser at its pristine stage
 - **COPY**: allow use of existing traces, carrying existing information to the sandbox
 - **WRITE**: allow storing of new traces, committing data in sandbox back to file system

Default Policy

```
1 # exclude all files in home directory
2 [clean]
3 ~/
```

Whitelist principle:

By default, nothing is allowed to be stored or used unless specified in a policy

Category	Use	Store
Browsing history	×	×
Cookies	×	×
Cache	×	×
Local storage	×	×
Flash storage	×	×
Download entries	×	×
Autofills	×	×
Bookmarks	×	×
Per-site zoom	×	×
Per-site permission	×	×
SSL self-signed cert	×	×
SSL client cert	×	×
Add-on storage	×	×
(All others)	×	×

Chrome Guest Mode

```
1 # exclude all files in home directory
2 [clean]
3 ~/
4
5 # Use: SSL client certificates
6 [copy]
7 ~/.pki/nssdb/cert9.db
8
9 # write-back client certificates
10 [write]
11 ~/.pki/nssdb/cert9.db
```

Category	Use	Store
Browsing history	✗	✗
Cookies	✗	✗
Cache	✗	✗
Local storage	✗	✗
Flash storage	✗	✗
Download entries	✗	✗
Autofills	✗	✗
Bookmarks	✗	✗
Per-site zoom	✗	✗
Per-site permission	✗	✗
SSL self-signed cert	✗	✗
SSL client cert	✓	✓
Add-on storage	✗	✗
(All others)	✗	✗

Chrome Incognito Mode

```

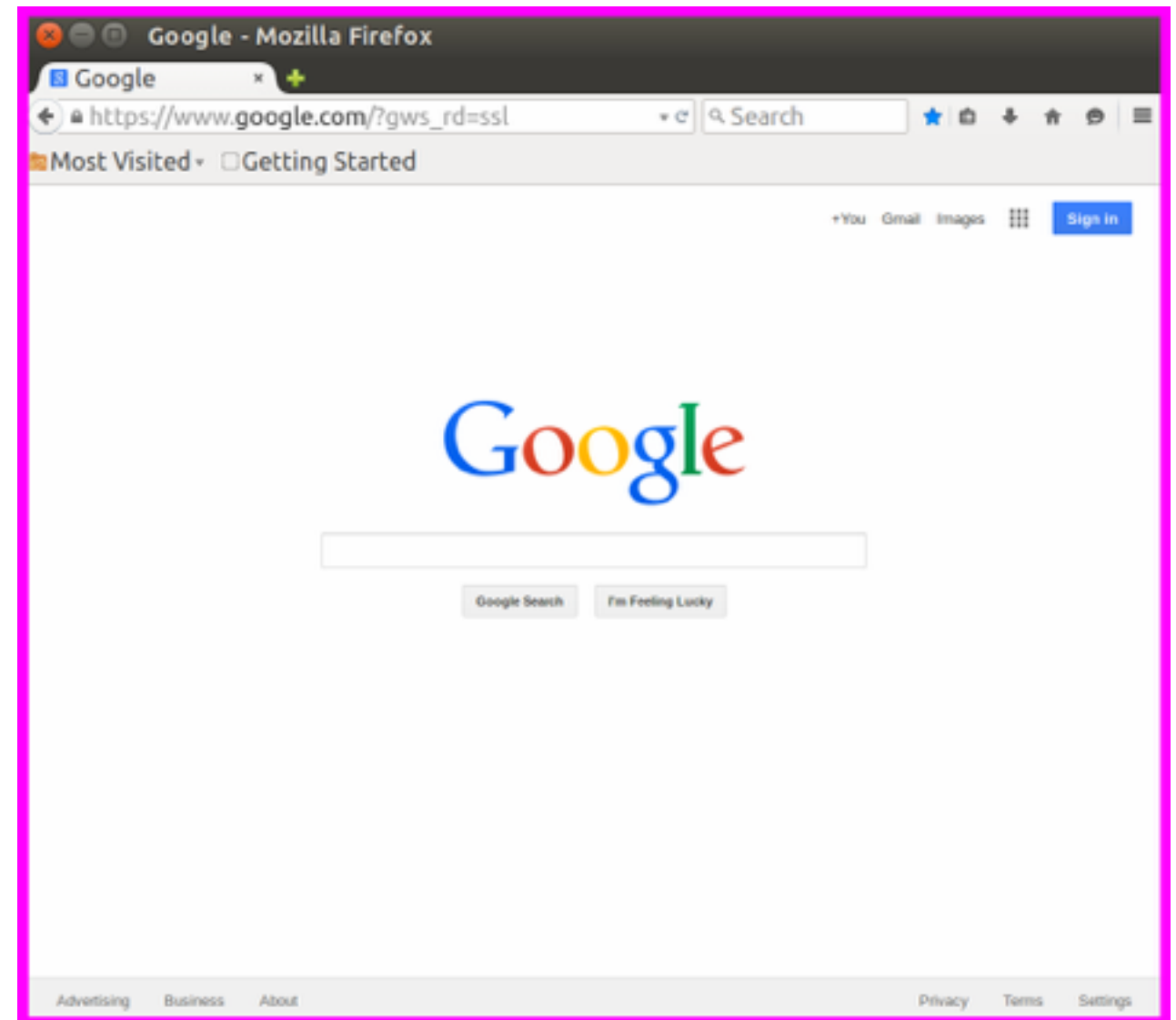
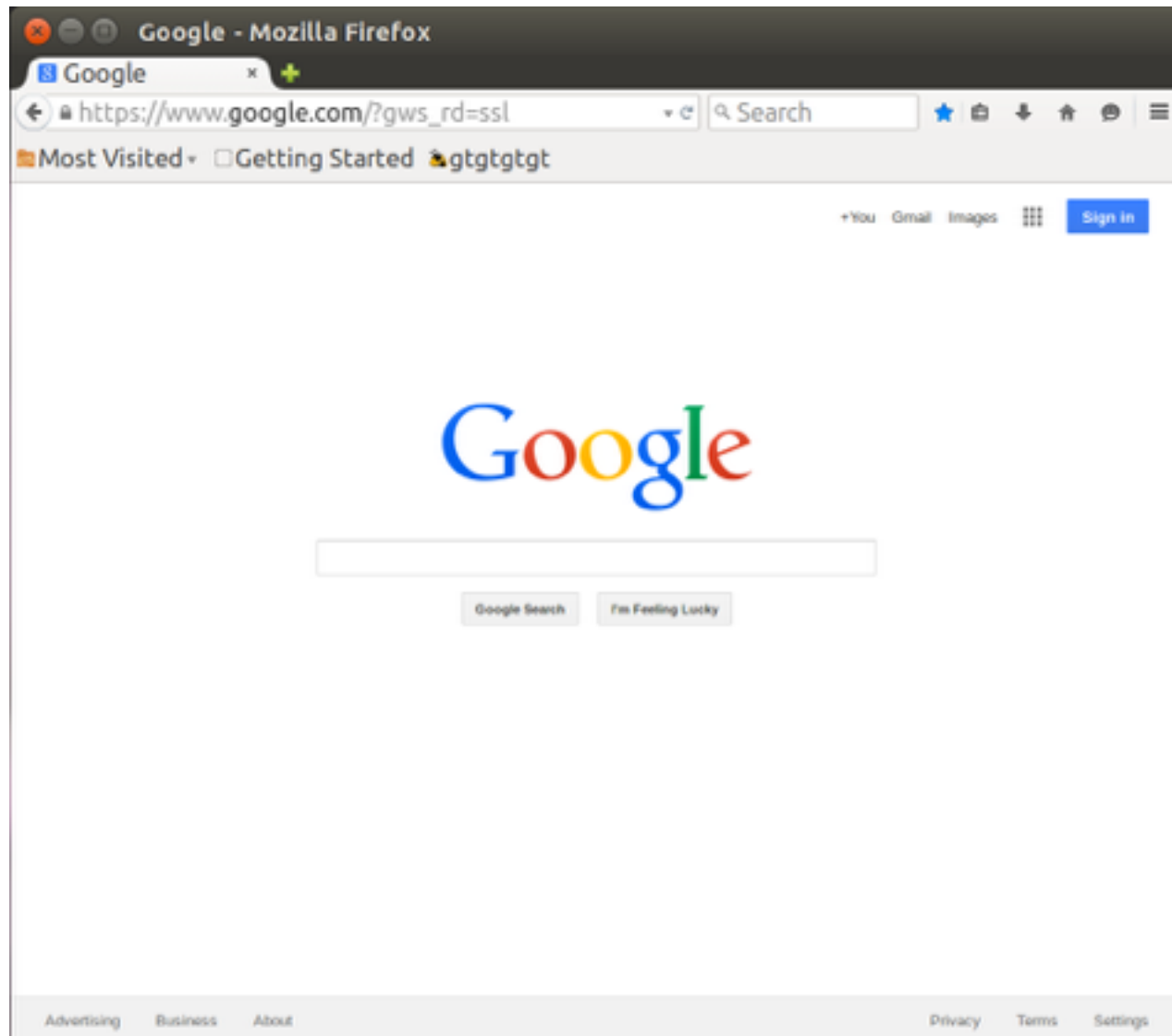
1 # copy section: copying files from the user profiles
2 [copy]
3 # Use: browsing history
4 ~/.config/google-chrome/Default/History
5 ~/.config/google-chrome/Default/History-journal
6 ~/.config/google-chrome/Default/Visited Links
7 ~/.config/google-chrome/Default/Favicons
8 ~/.config/google-chrome/Default/Favicons-journal
9 ~/.config/google-chrome/Default/Top Sites
10 ~/.config/google-chrome/Default/Top Sites-journal
11
12 # Use: autofill data
13 ~/.config/google-chrome/Default/Login Data
14 ~/.config/google-chrome/Default/Login Data-journal
15 ~/.config/google-chrome/Default/Web Data
16 ~/.config/google-chrome/Default/Web Data-journal
17
18 # Use: per-site preferences
19 ~/.config/google-chrome/Default/Preferences
20 ~/.config/google-chrome/Default/Secure Preferences
21
22 # Use: SSL certificates
23 ~/.config/google-chrome/Default/TransportSecurity
24 ~/.config/google-chrome/Default/Origin Bound Certs
25 ~/.config/google-chrome/Default/Origin Bound Certs-journal
26
27 # Use: SSL client certificates
28 ~/.pki/nssdb/cert9.db
29
30 # Use: bookmarks
31 ~/.config/google-chrome/Default/Bookmarks
32
33 # Use: extension storage
34 ~/.config/google-chrome/Default/Local Extension Settings/
35
36 # clean section: exclude files & sub-directories
37 [clean]
38 # exclude all other files in the home directory
39 ~/
40
41 # write section: write-back data to the user profile
42 [write]
43 # write-back bookmarks
44 ~/.config/google-chrome/Default/Bookmarks
45 # write-back client certificates
46 ~/.pki/nssdb/cert9.db
47 # write-back extension storages
48 ~/.config/google-chrome/Default/Local Extension Settings/

```

Category	Use	Store
Browsing history	✓	✗
Cookies	✗	✗
Cache	✗	✗
Local storage	✗	✗
Flash storage	✗	✗
Download entries	✓	✗
Autofills	✓	✗
Bookmarks	✓	✓
Per-site zoom	✓	✗
Per-site permission	✓	✗
SSL self-signed cert	✗	✗
SSL client cert	✓	✓
Add-on storage	✓	✓
(All others)	✗	✗

UI and UX

\$ ucognito -P chrome_incognito.cfg -- google-chrome



Preventing privacy violation cases

- UCognito is able to prevent all the cases in our paper
- UCognito provides natural support to add-ons

Add-on	# Users	Incognito	UCognito
Session Buddy	373409	history, cache, cookies, etc	✗
StayFocusd	600944	Sync Extension Settings	✗
Better History	248112	Extension State	✗
Lazarus Form Recovery	125709	Extension DB	✗

Performance overhead on Javascript benchmarks

Add-on	Firefox		Chrome	
	Base	UCognito	Base	UCognito
Karken (ms)	1171.1	1171.2 (0.0%)	1108.6	1115.2 (0.6%)
Sun spider (ms)	158.3	159.8 (0.9%)	173.1	177.4 (2.5%)
Octane (pts)	27164	27013 (-0.6%)	27266	27018 (-0.9%)

- Only hook system calls that deals with file paths
- Not hooking *read*, *write*, *send*, *recv* which are very frequently called in networked applications

Performance overhead on real websites

	Firefox		Chrome	
Website (ms)	Base	UCognito	Base	UCognito
<u>google.com</u>	277	280 (0.79%)	193	196 (1.55%)
<u>bing.com</u>	208	208 (0.29%)	190	193 (1.58%)
<u>twitter.com</u>	1021	1030 (0.92%)	599	614 (2.50%)
<u>facebook.com</u>	444	447 (0.63%)	256	259 (1.18%)

Policy flexibility

places.sqlite

Category	Use	Store
Browsing history	✓	✗
Cookies	✗	✗
Cache	✗	✗
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Download entries	✗	✗
Autofills	✓	✗
Bookmarks	✓	✓
Per-site zoom	✓	✗
Per-site permission	✓	✗
SSL self-signed cert	✓	✗
SSL client cert	✓	✓
Add-on storage	✓	✓
(All others)	✗	✗

Demo

Discussion:

Customizable / personalized private mode



Specify default
set of policies



Toggle policies
to meet own expectations

Discussion: Portability

- Not solely for browsers, in fact, other applications that are yet to have a private mode available would benefit from this design.



Discussion: Cross-platform

- *seccomp-bpf*: available since Linux Kernel 3.5
- *ptrace*: already available on Mac OS and has substitution on MS Windows



Conclusion



UCognito

Layer



UCognito
Mode

Solved:

- Same !
- Expected !
- Implemented !
- Private !
- Many more

Thank you !

Q & A