I Know Where You've Been: Geo-Inference Attacks via the Browser Cache

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black hat ASIA 2015

NUS National University of Singapore

Geo-location in Browsers

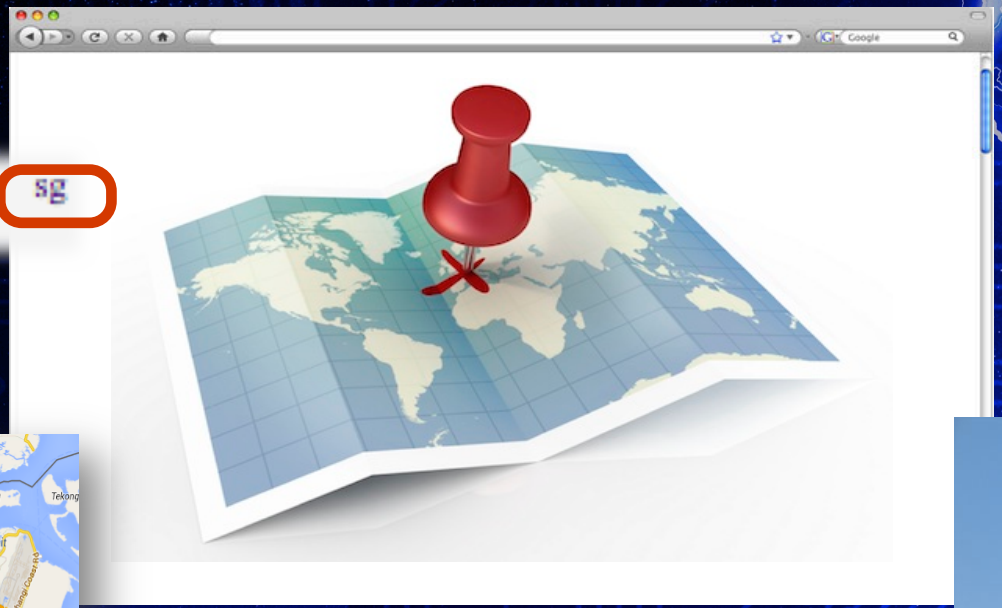
craigslist open source
craigslist blog
event
farm+garden
skill'd trade
sm biz ads
cds/dvd/vhs
cell phones
sporting
tickets
technical support
transport

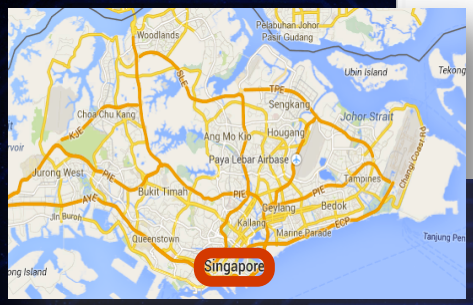
Geo-location in Browsers: Benefits & Threats

Benefits

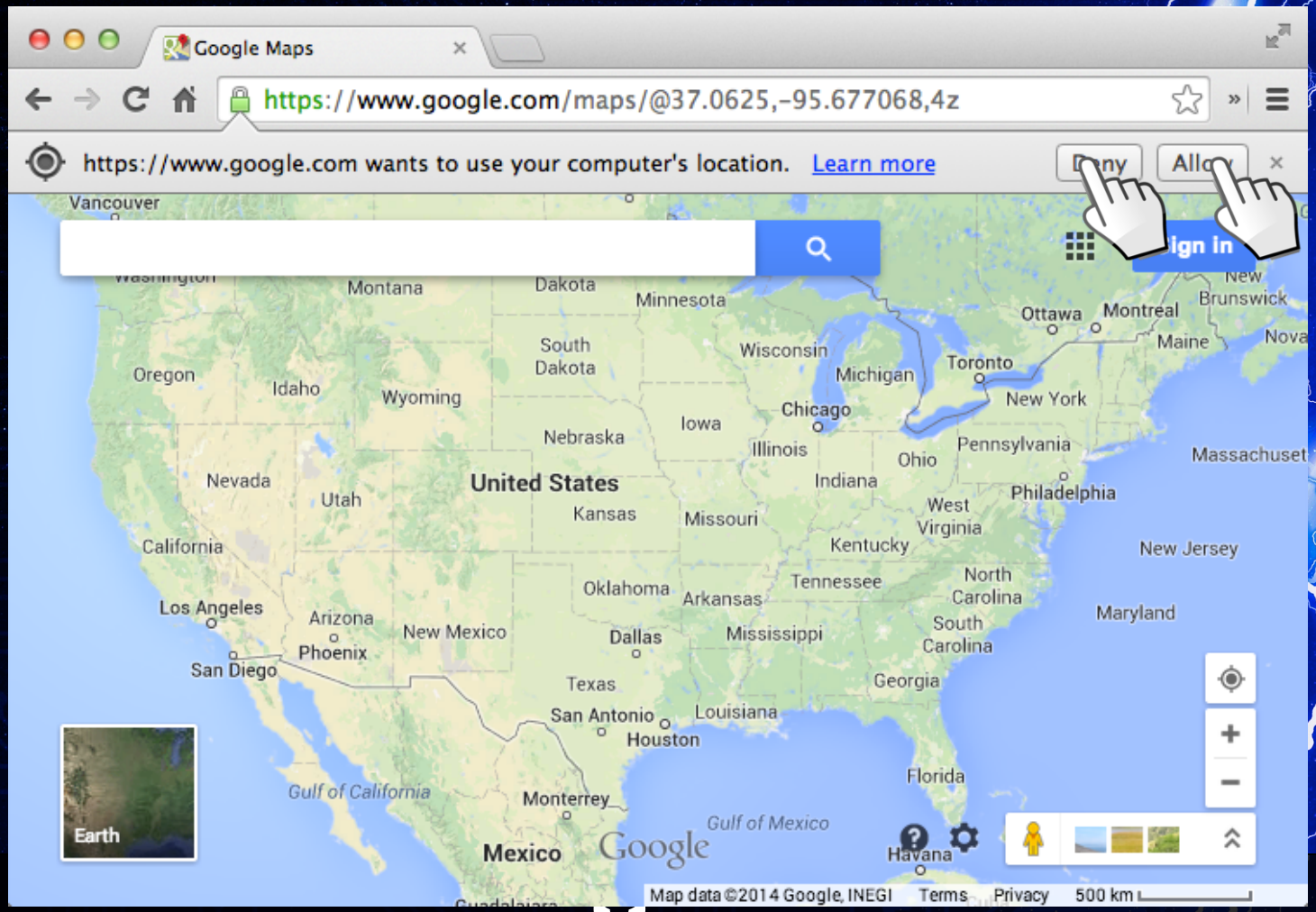
Threats

craigslist sg

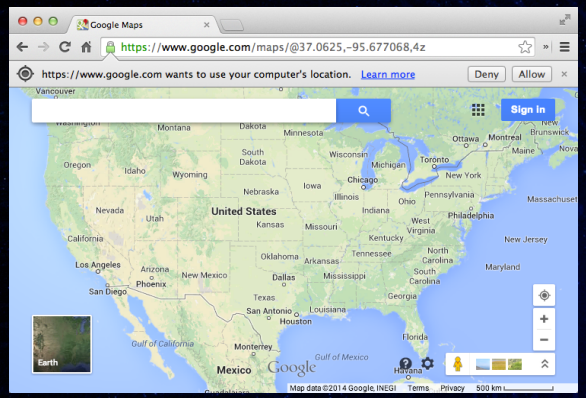


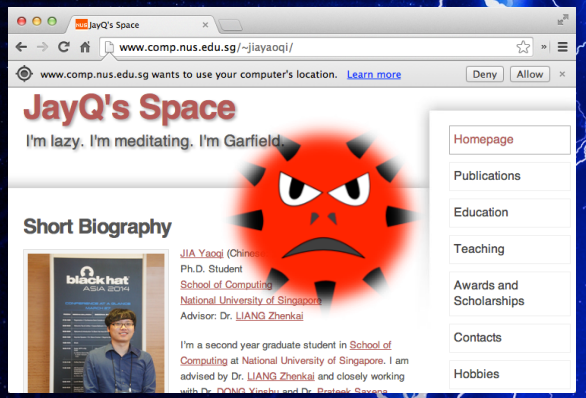


May I Access Your Geo-location?



Sources of Users' Geo-locations

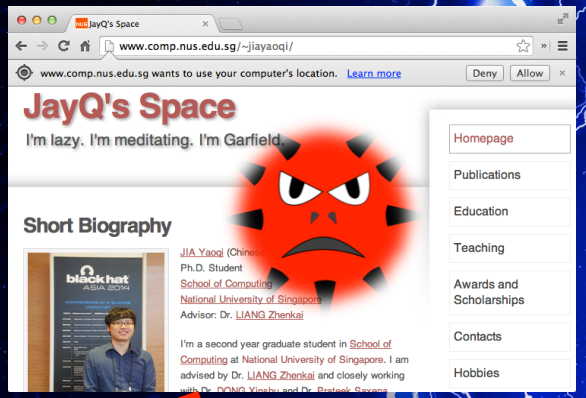


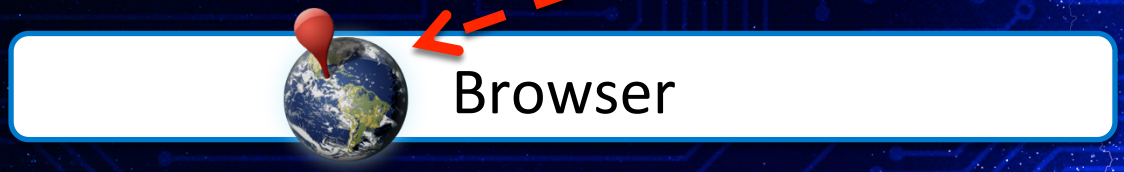


Browser

Not reliable

Problem Statement



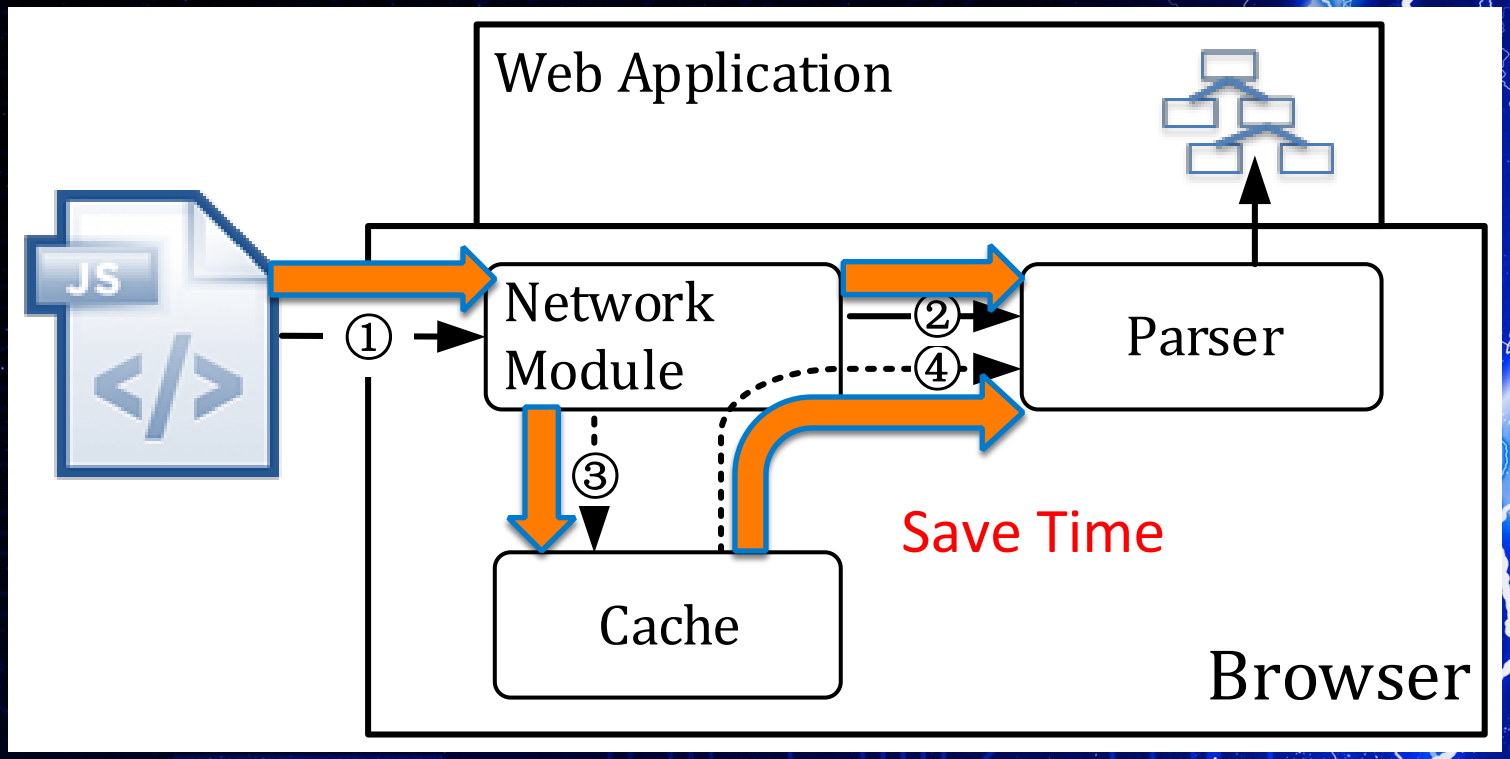


Can the attacker infer the user's geo-location from his browser?

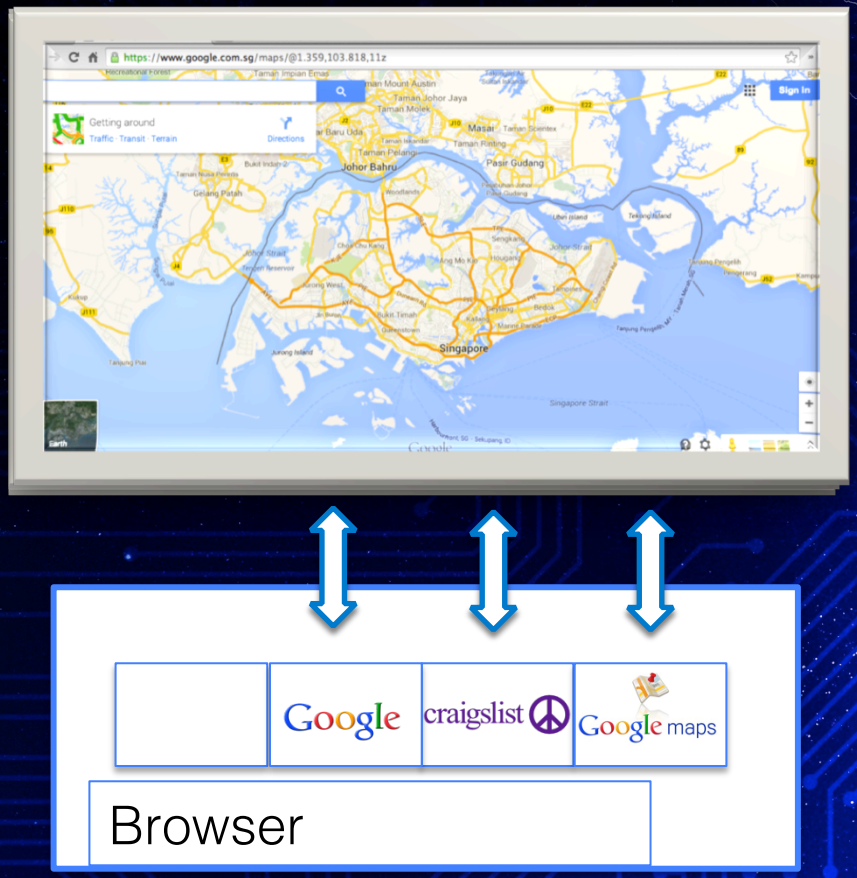
Our Agenda

- Geo-inference attacks via the browser cache
- Prevalence of geo-inference attacks
- Pros & cons of potential solutions
- Demo Video
- Q & A

Browser Cache



Browser Cache Stores Static Resources

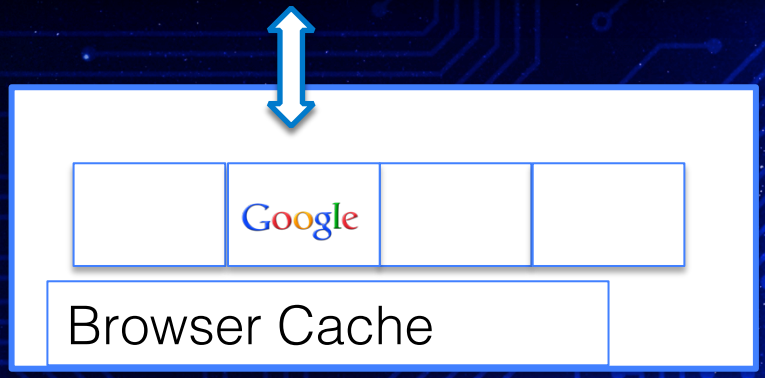


Browser stores site-related states

Directives in Response Headers to Control Cache

- **Static resources:**
  - Expires, Cache-Control: max-age, Last-Modified
- **Dynamic and sensitive resources:**
  - Cache-Control: no-cache, no store; Pragma: no-cache; Expires: 0

Benefits of Browser Cache



1st: 1360ms

2nd: 320ms

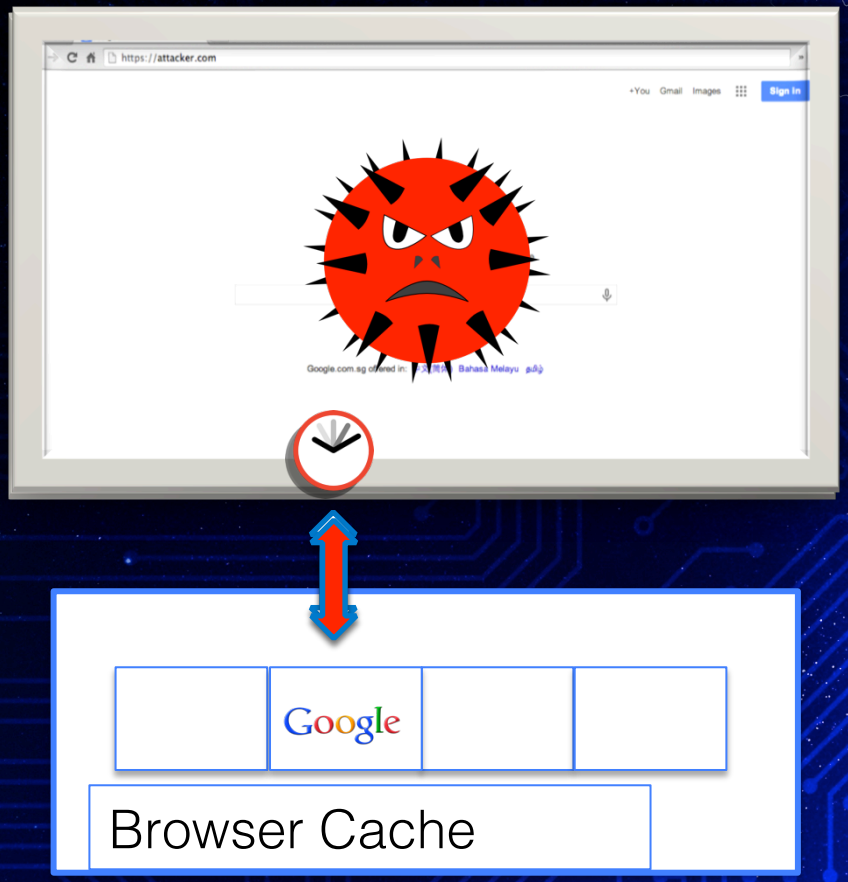
3rd: 350ms

Save Time!

Timing Channels via the Browser Cache

Felten, CCS'00, Sniff browsing history

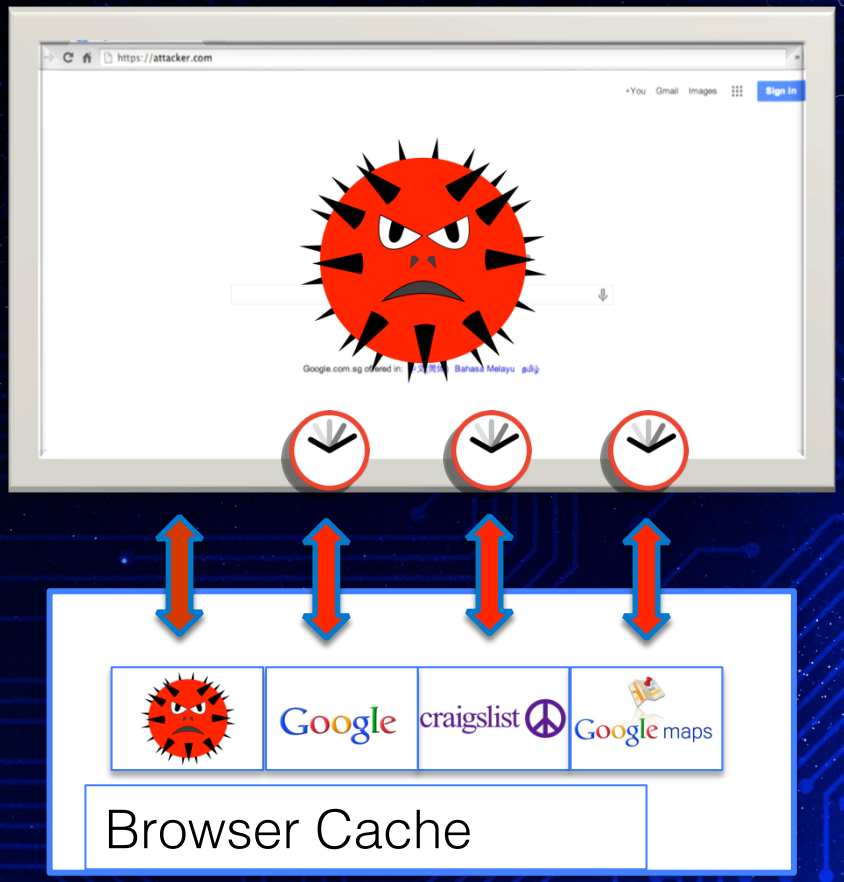
Bortz, WWW'07, More Scenarios



1st: 1360ms
2nd: 320ms
3rd: 350ms

Geo-Inference Attacks via the Browser Cache

Browser cache is shared across all sites



Infer users' geo-locations!

Attack Vector (I) : Measuring Image Load Time

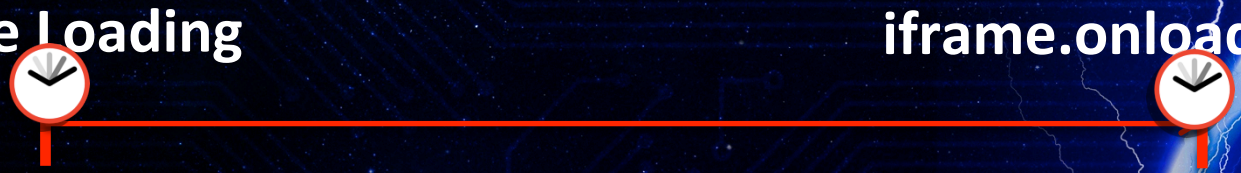
Before Loading

img.onload Fires

```
var image = document.createElement(`img');

image.setAttribute(`startTime', (new
Date().getTime()));

image.onload = function()

{

    var endTime = new Date().getTime();

    var loadTime = endTime -
parseInt(this.getAttribute(`startTime'));

    ......

}
```

attacker.com

Attack Vector (II) : Measuring Page Load Time




```
var page = document.createElement(`iframe');

page.setAttribute(`startTime', (new
Date()).getTime());

page.onload = function ()

{

    var endTime = (new Date()).getTime();

    var loadTime = ( endTime -
parseInt(this.getAttribute(`startTime')));

    ......

}
```

attacker.com

Attack Vector (III) :Measure the Load Time of XMLHttpRequests

onloadstart Fires

onloadend Fires

```
var starTime, endTime, loadTime;
var xmlhttp = new XMLHttpRequest();
xmlhttp.onloadstart = function(){
    startTime = (new Date()).getTime();
}
xmlhttp.onloadend = function(){
    endTime = (new Date()).getTime();
    loadTime = endTime - startTime;
    ......}
```

attacker.com

Attack Vector (IV) : Use <img>'s complete Property

```
function cached(url)
{
    var image = document.createElement(`img');
    image.src = url;
    return image.complete || image.width+image.height >
0;
}
```

attacker.com

Examples: What Can We Achieve?

- User's country?
- User's city?
- User's streets or neighborhood?

How to Infer a User's Country? (I)

- Google has 191 regional sites.
- One site represents one country or region.

google.com.sg/images/srpr/logo11w.png

How to Infer a User's Country? (II)

Google Canada

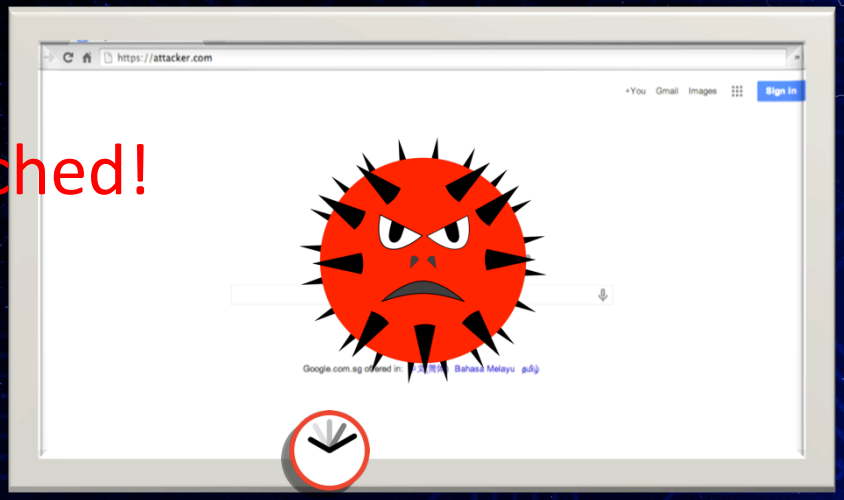
Google Singapore

Google Japan

Google UK

Google Deutschland

Cached!



How to Infer a User's City? (I)

- Craigslist provides local classifieds advertisements and forums for jobs, housing, etc.
- Craigslist has 712 city-specific sites.
- Users buy or sell second-hand stuff in their Craigslist's city-specific sites.

How to Infer a User's City? (II)

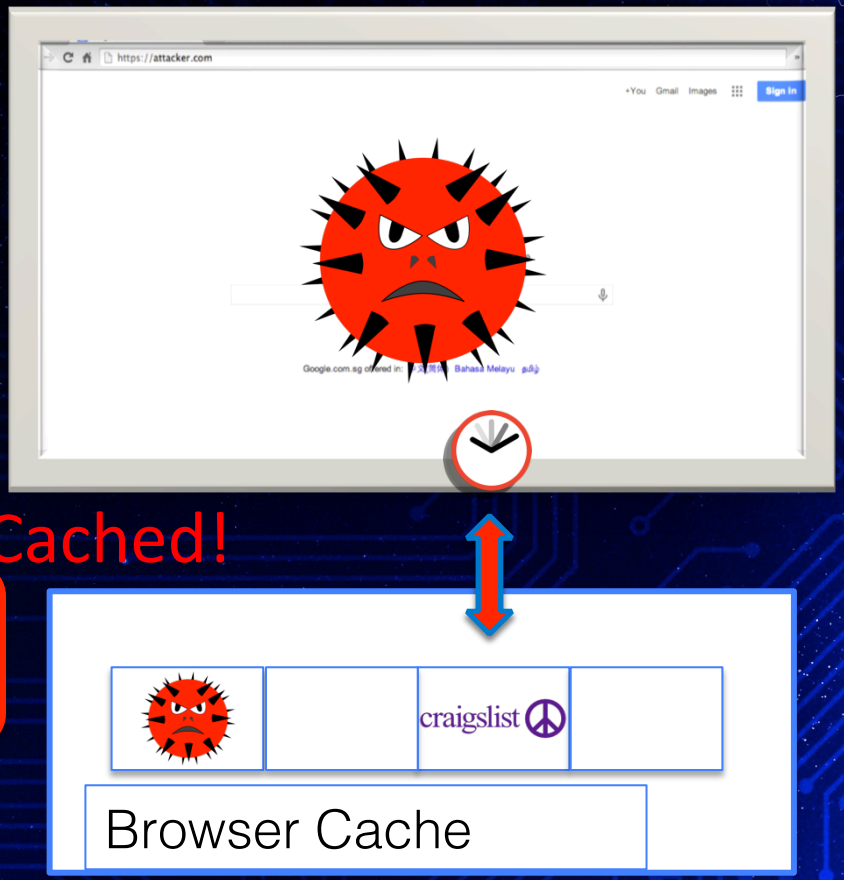
chicago.craigslist.org

sfbay.craigslist.org

newyork.craigslist.org

singapore.craigslist.com.sg

tokyo.craigslist.jp



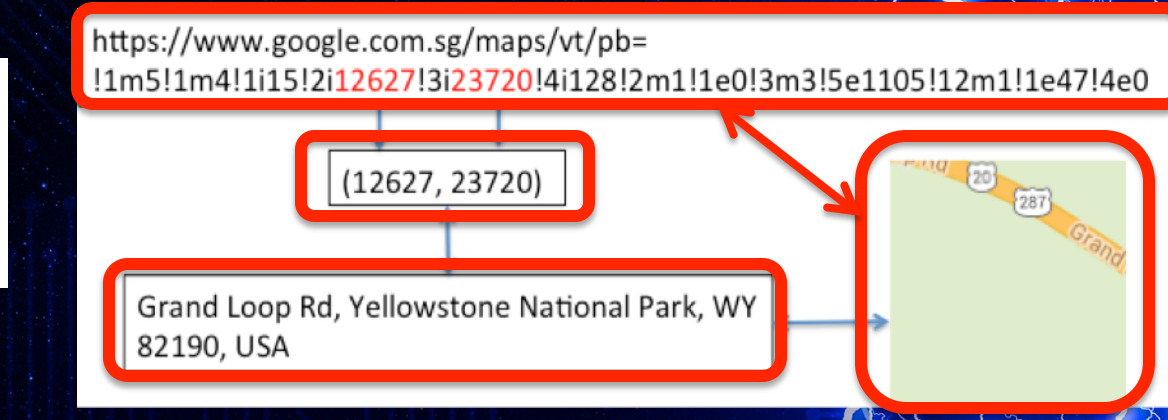
How to Infer a User's Neighborhood?(I)

Predictable URLs

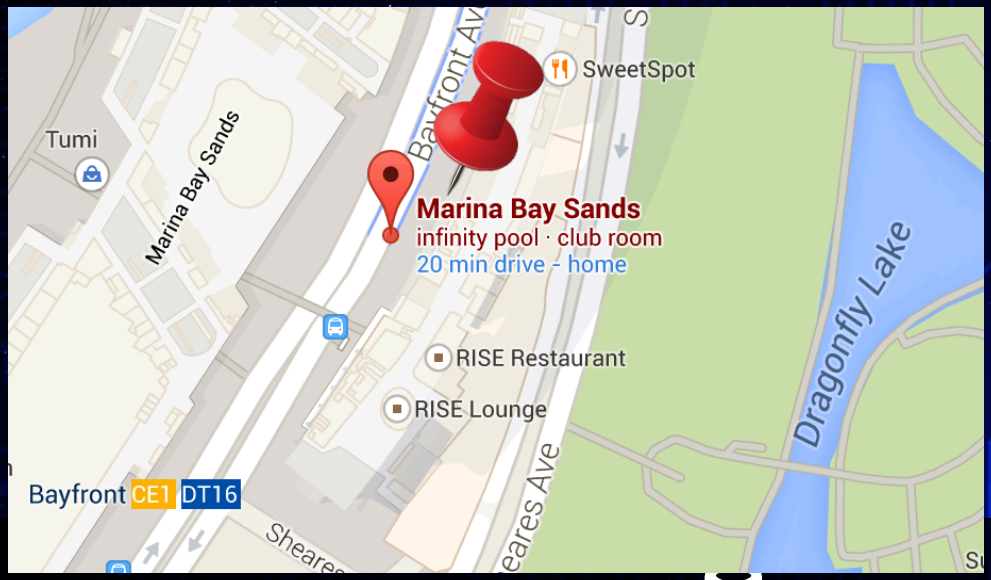
https://www.google.com.sg/maps/vt/pb=
!1m5!1m4!1i15!2i12627!3i23720!4i128!2m1!1e0!3m3!5e1105!12m1!1e47!4e0

(12627, 23720)

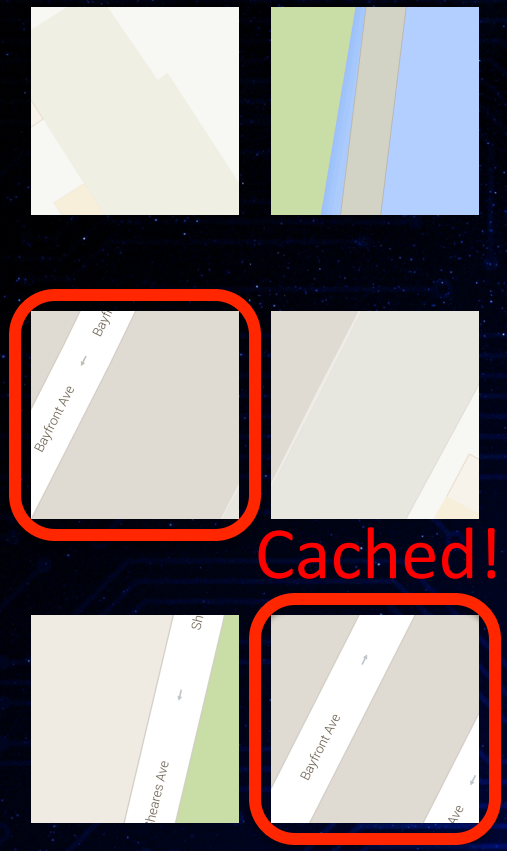
Grand Loop Rd, Yellowstone National Park, WY 82190, USA

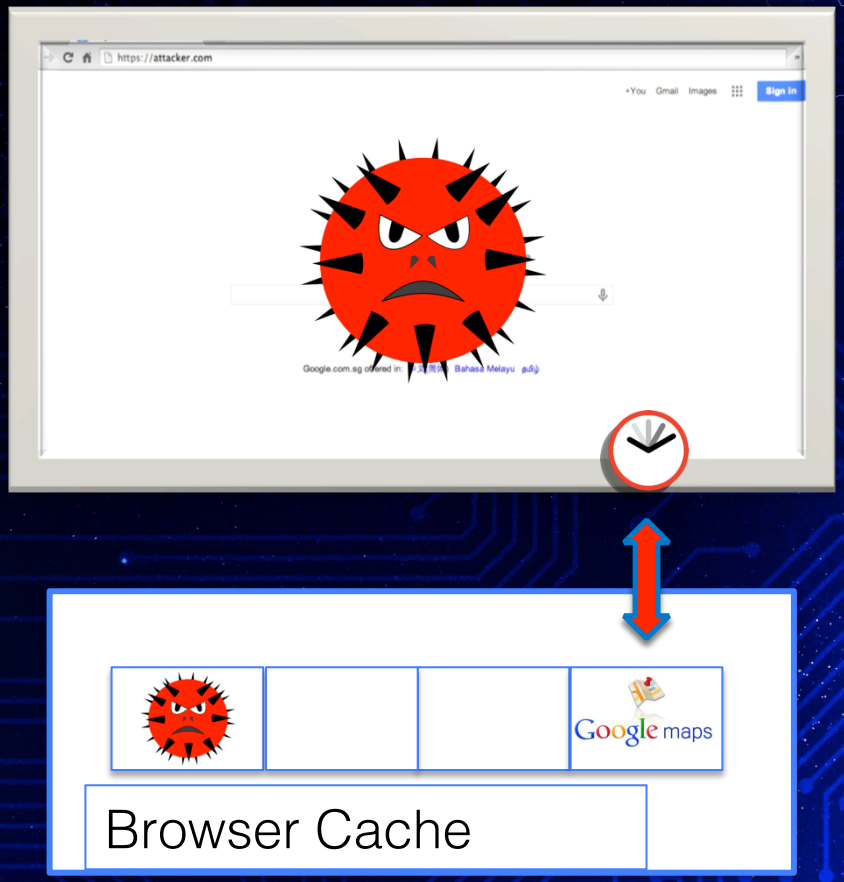


Map Tiles



How to Infer a User's Neighborhood? (II)





Evaluation

Questions to be answered:

- (Prevalence) How many browsers and websites are susceptible to geo-inference attacks?
- (Reliability) How big is the time difference between resources load time without cache and that with cache?

Evaluation Setup

- Websites: 191 Google's sites, 100 Craigslist's sites, and 55 top Alexa sites.
- Maps: Google Maps, and other 10 map service sites.
- Browsers: Five mainstream browsers and TorBrowser
- Locations: US, UK, Australia, Singapore, and Japan.

Alexa Top Websites with Location-Related Resources

62% of 55 top Alexa global sites

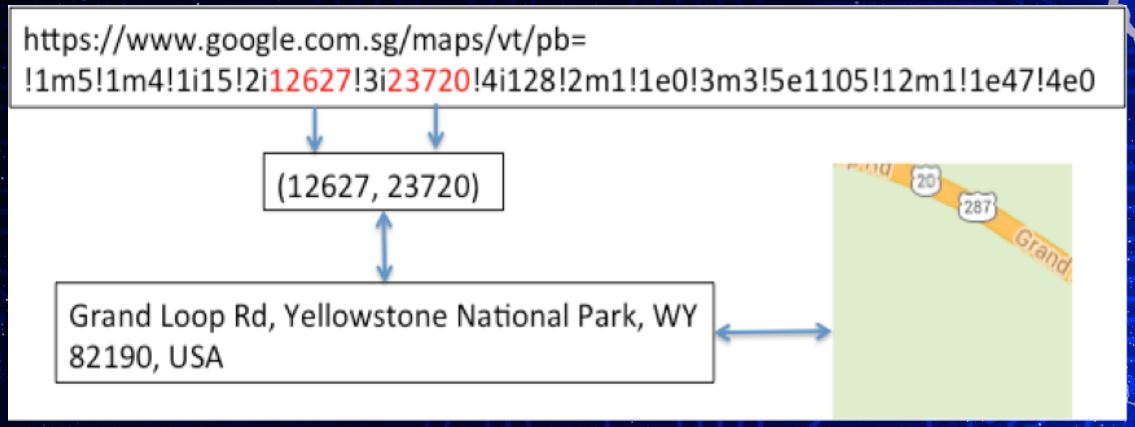
singapore.craigslist.com.sg

sg.yahoo.com

www.ebay.com.sg

Map Websites with Location-Related Resources

All of 11 map service sites



Susceptible Browsers & Platforms

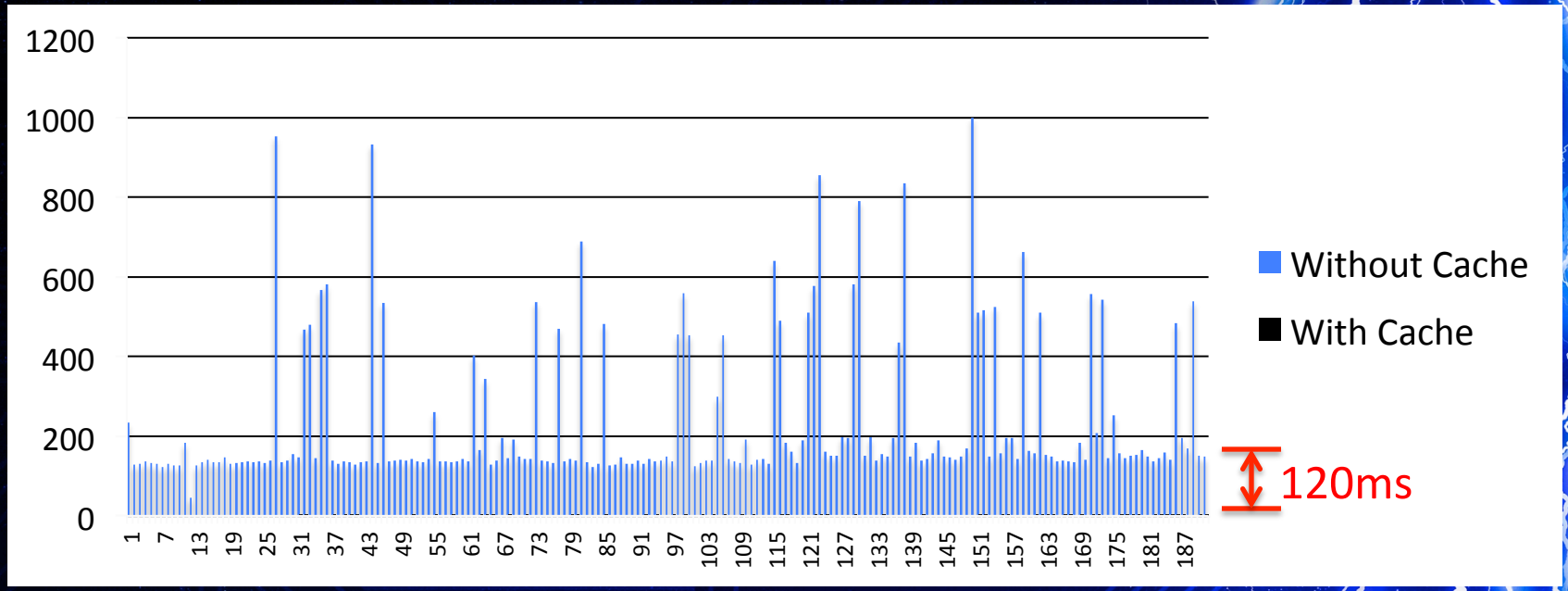
Mainstream Browsers

Partial

Desktop Platforms

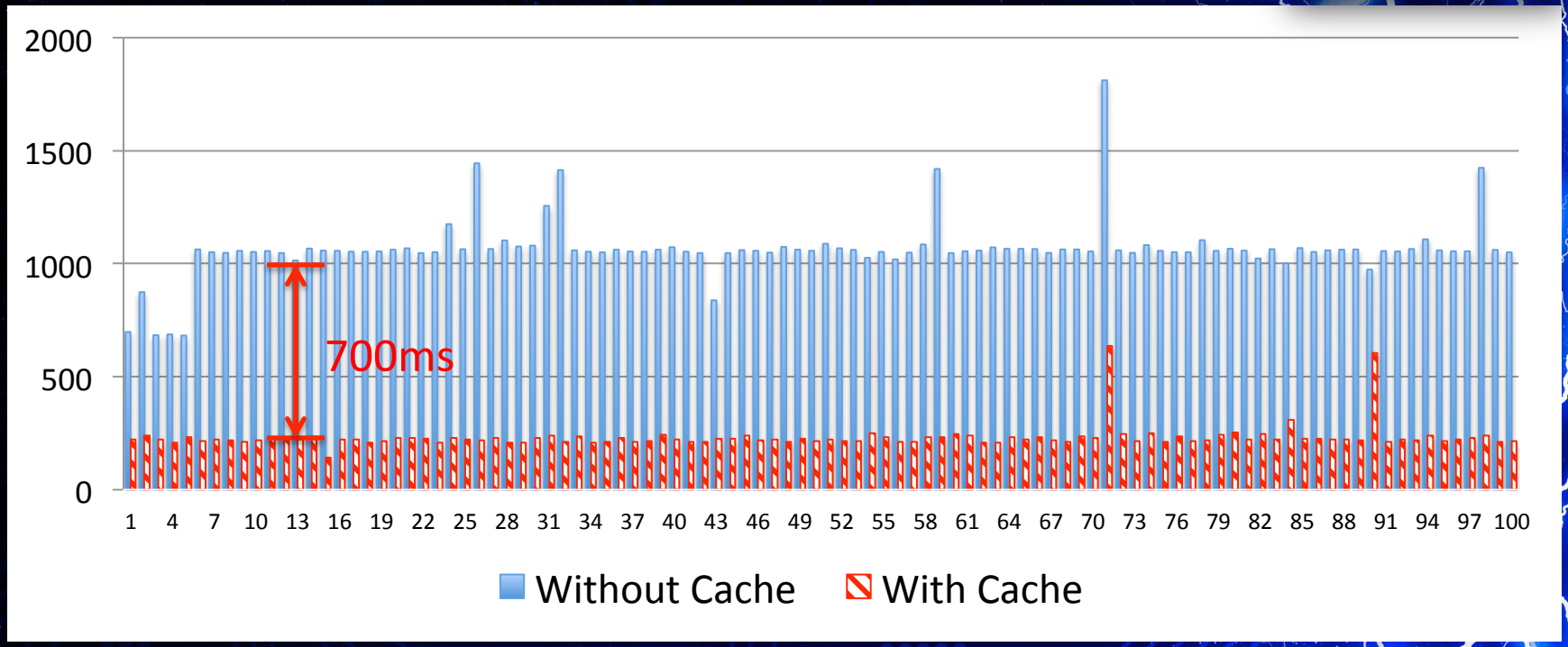
Mobile Platforms

Loading Time： Without Cache v.s. With Cache I



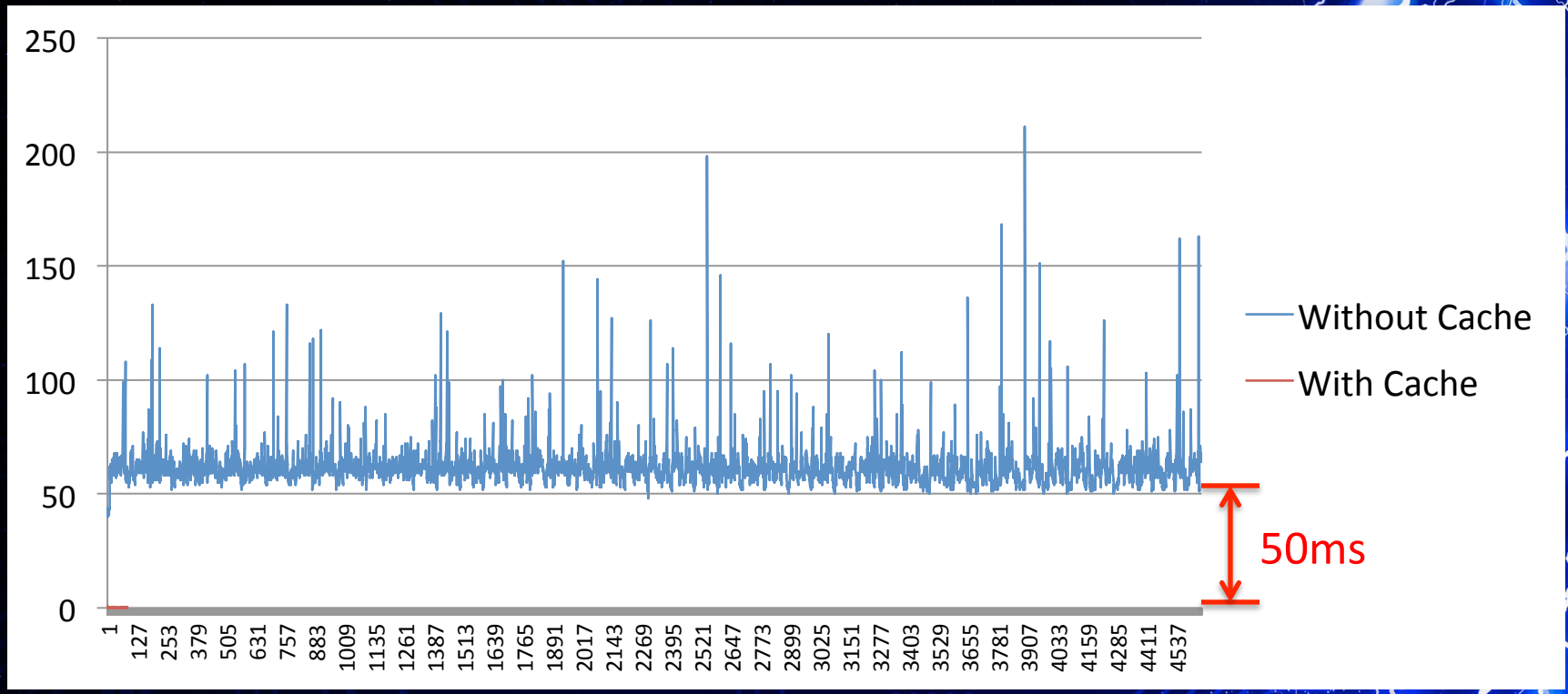
Difference in image load time (in millisecond): Without Cache (> 129 ms) v.s. With Cache (0 ~ 1 ms), for 191 Google's regional domains in Chrome on Mac OS X

Loading Time： Without Cache v.s. With Cache II



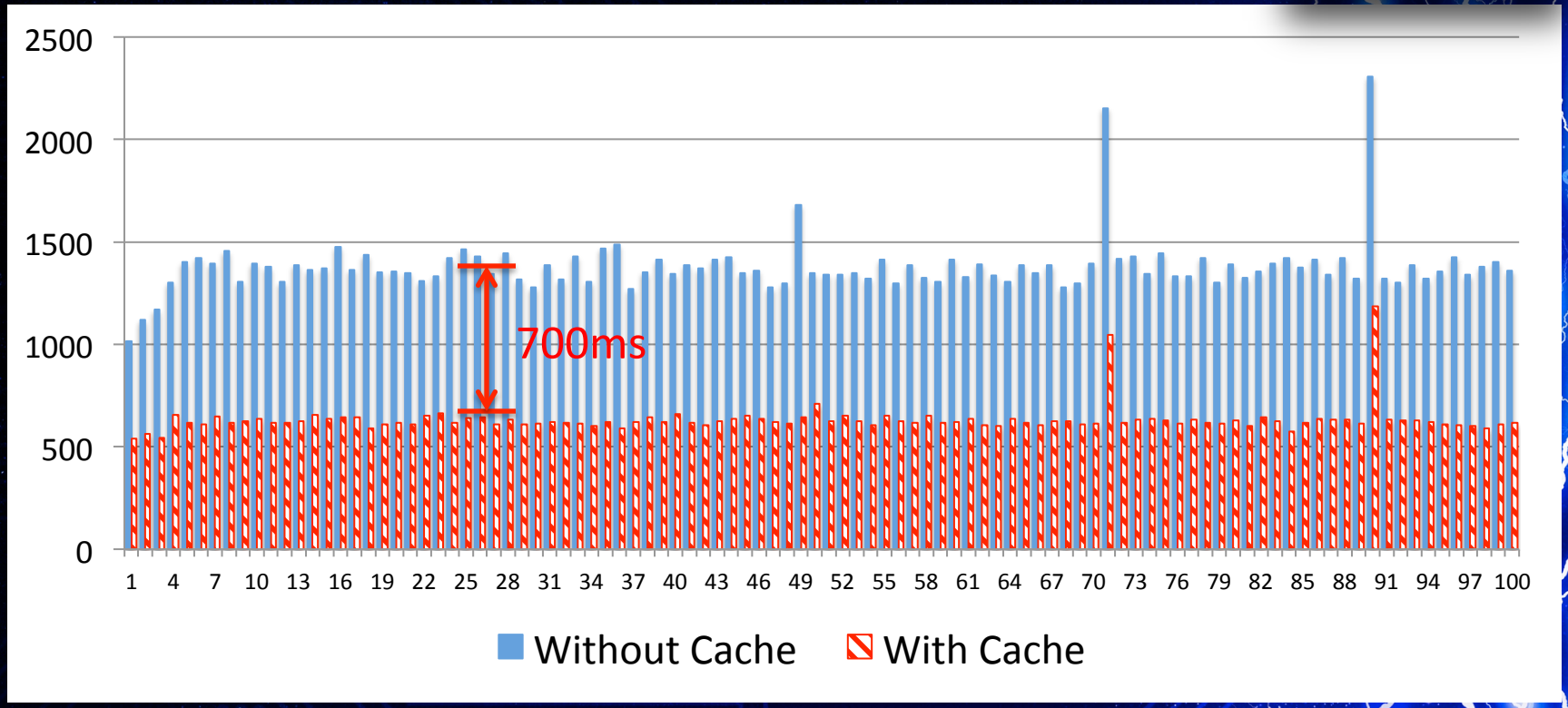
The significant difference between the page load time (in millisecond) of 100 Craigslist sites without cache (> 1000 ms) and with cache (≈ 220 ms) indicates geo-inference attacks with Craigslist

Loading Time : Without Cache v.s. With Cache III



Difference in page load time (in millisecond): Without Cache (> 50 ms) v.s. With Cache (0 ~ 1 ms), for 4,646 map tiles of New York City from Google Maps in Chrome on Mac OS X.

Loading Time (Android)



The page load time of 100 Craigslist sites on Android.

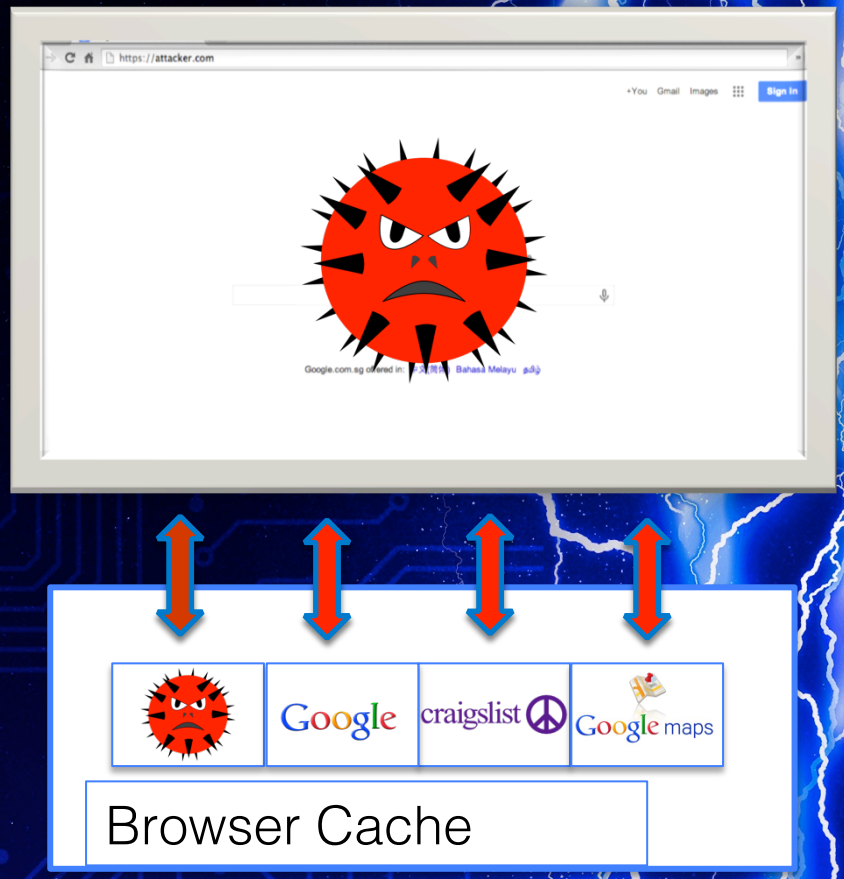
Discussion of Defense Solutions

- Private Browsing Mode
- Randomizing timing measurements
- TorBrowser and Segregating browser cache

Private Browsing Mode is not the Cure

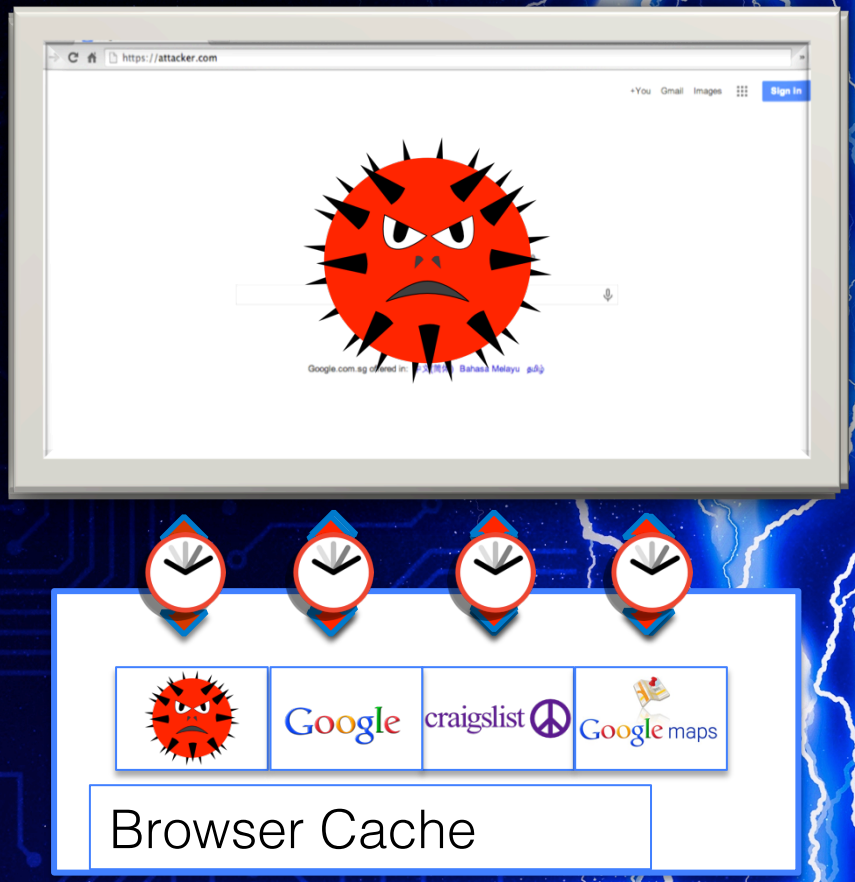
Private Browsing Mode

- Clear browser cache after closing the window.
- Disable disk cache, not the in-memory cache.
- It cannot prevent one site from inferring the user's geo-location from other sites.



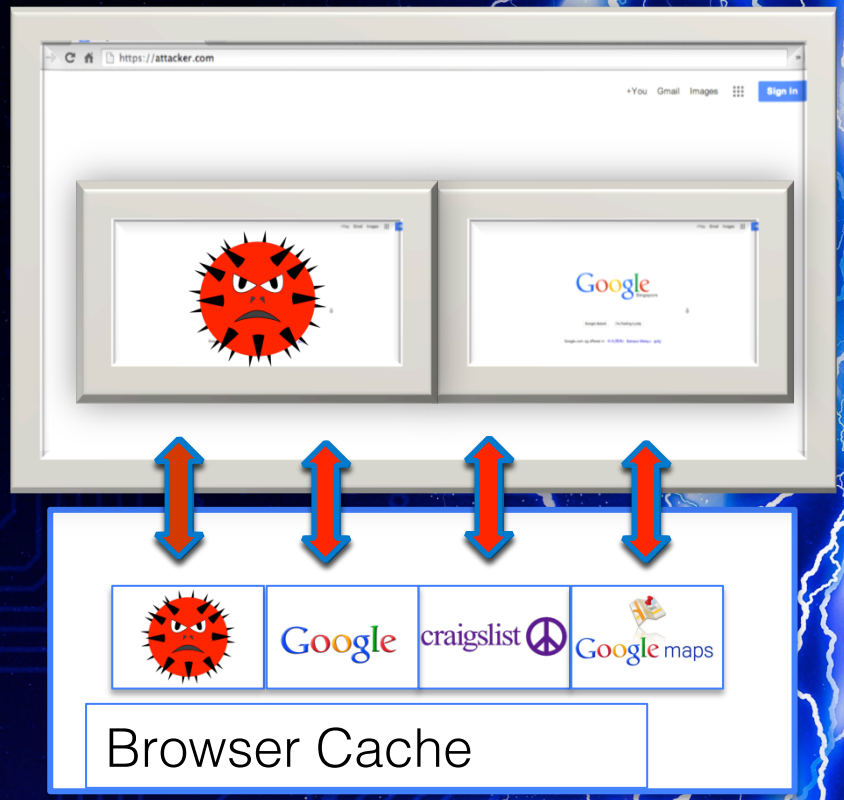
Randomizing Timing Measurements

- Add noise into timing measurement mechanisms.
- Affect web applications' functionalities
- Intricate engineering effort.

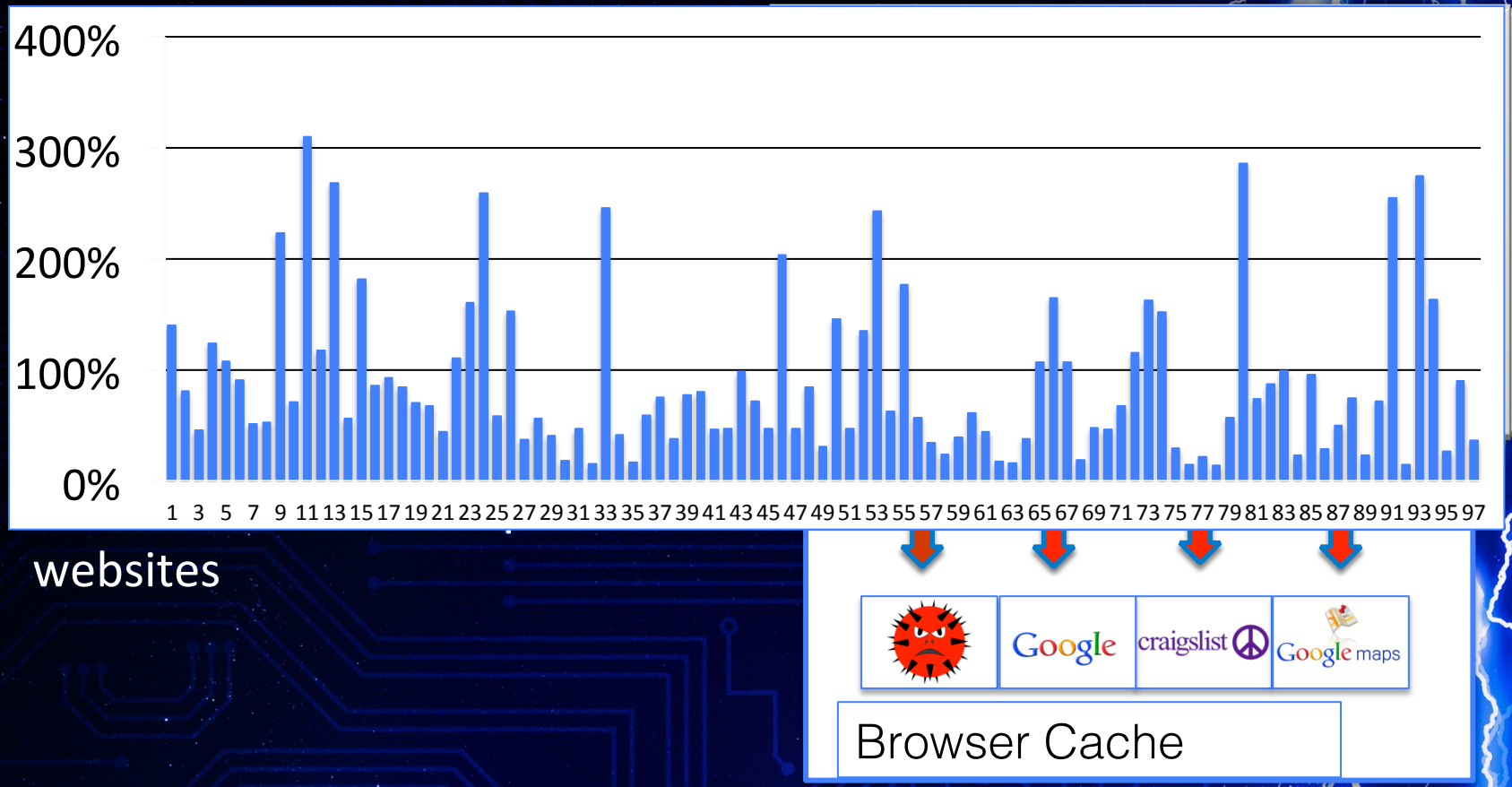


TorBrowser is not Perfect

- Adds an additional "id=string" property to label every cache entry with the top-level window's domain.
- Insufficient for mashup websites, all the embedded sites in frames share the same top-level window's domain, i.e., the mashup's domain.



Segregating Browser Cache



To Cache or Not To Cache?

- No cache for location-sensitive resources.
  - Cache-Control: no-cache for HTTP response header
- Open challenge to design an efficient and secure caching mechanism in browsers.

Take-away

- Timing channels are still open on mainstream browsers.
- Knowing the power of geo-inference attack (inferring country, city, neighbourhood) and be cautious about it.
- Never give additional permissions to unfamiliar sites or open it for a long time.
- Clear cache before and after visiting a site with your credentials, e.g., online banking site.

Demo Video

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