Exploiting Data-Usage Statistics for Website Fingerprinting Attacks on Android

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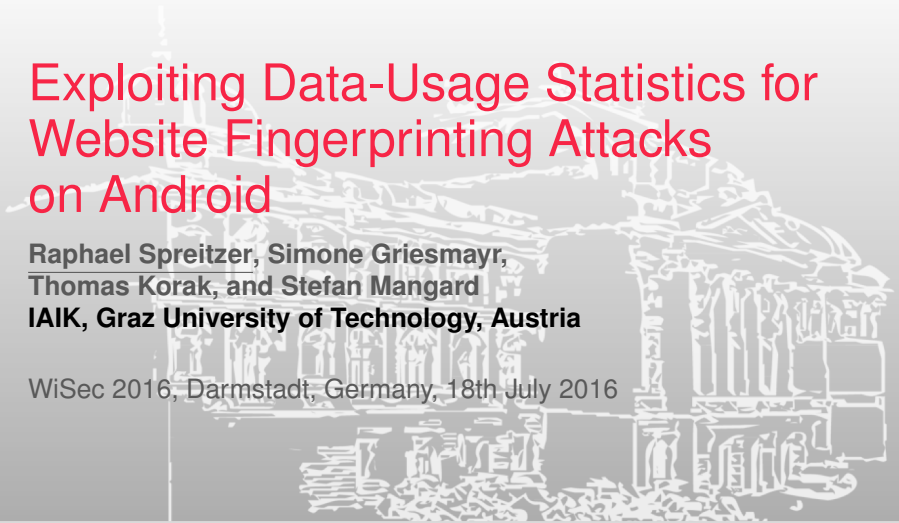


Contributions

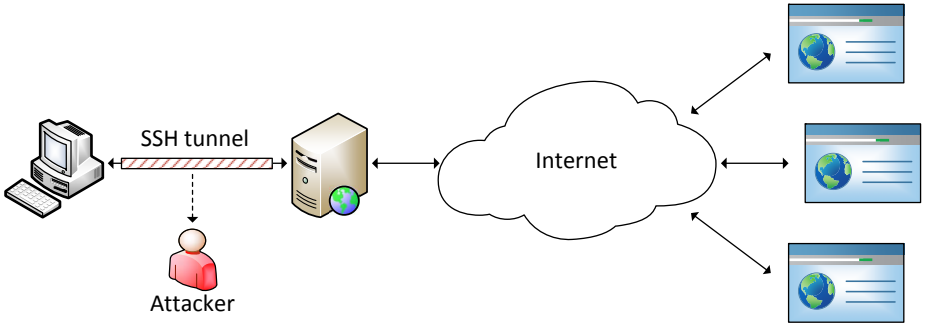
Side-channel attack to infer browsing behavior

- Unprivileged application
- Data-usage statistics
- High accuracy
- Also works when traffic is routed through Tor
- `READ_HISTORY_BOOKMARKS` does not provide protection

Website Fingerprinting

Traditional attack scenario

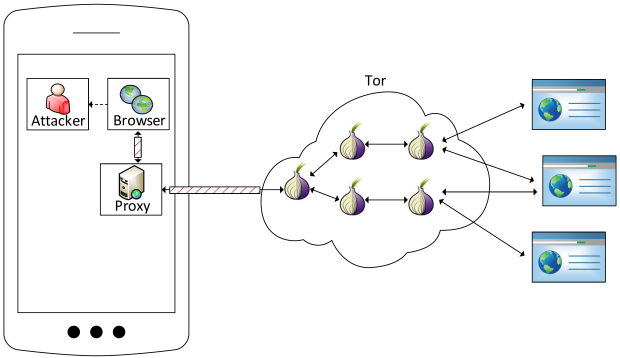
- Attacker located somewhere on the victim's network
- Traffic analysis techniques to infer browsing behavior



Website Fingerprinting

Attack scenario against smartphones

- Malicious application running in unprivileged mode
- Observe information “leaking” from browser application



Data-Usage Statistics

What is this?

- Track the amount of incoming/outgoing network traffic
- Users can stick to their data plan
- Available to all apps w/o any permission

Availability

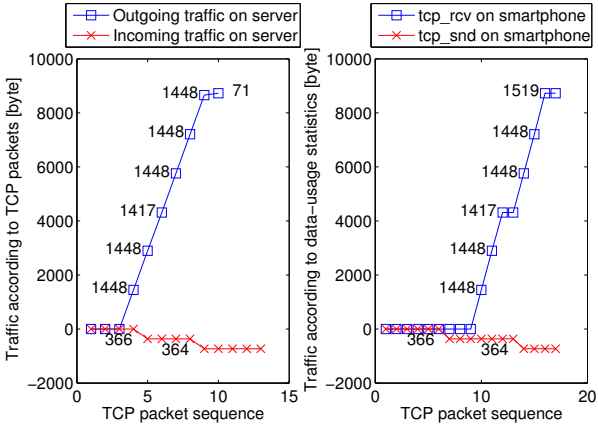
- `/proc/uid_stat/[uid]/tcp_rcv|tcp_snd`
- Android API `TrafficStats.getUidRxBytes`, `.getUidTxBytes`
- How to get `uid`?
  - `ActivityManager.getRunningAppProcesses()` (`REAL_GET_TASKS`?)
  - `PackageManager.getInstalledApplications()`

High resolution (single TCP packet lengths)

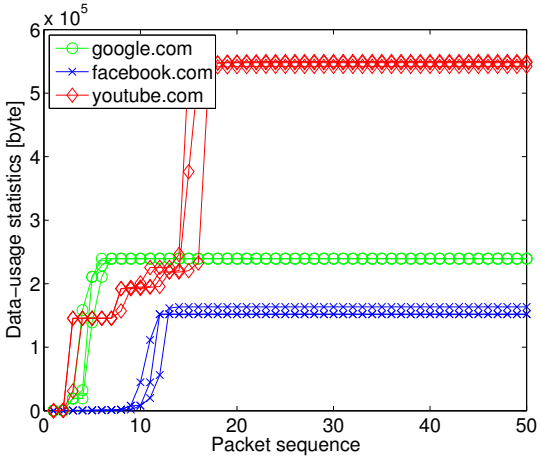
Data-Usage Statistics

Experiment

- Local server hosting a website (`tcpdump`)
- Launch website on Android (data-usage statistics)



Usage Statistics for Real Websites



Websites are distinguishable

- Stable: signatures of repeated visits to the same page are similar
- Diverse: signatures of different pages vary

Adversary Model and Attack Scenario

Adversary model

- Traditional: nw-based attacker
- Unprivileged app distributed via app market

Attack

1. Training phase (offline)
2. Attack phase (online)

Website Fingerprinting

Training phase

- Observe data-usage statistics while loading specific websites
- $\Rightarrow$ build signature database
- No “fancy” machine-learning approach
- $\Rightarrow$ no expensive training phase necessary

Website Fingerprinting

Attack phase

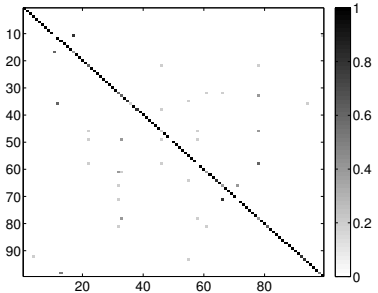
1. Distribute malicious application
2. Observe data-usage statistics for browser application
3. Infer visited website by means of signature database
   - Similarity metric for traces

$$SIM(t_1, t_2) = \frac{|t_1 \cap t_2|}{|t_1 \cup t_2|}$$

Results

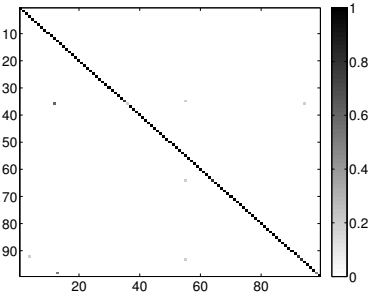
Intra-day classification rate

- 100 most popular websites globally



89% of 500 page visits

confusion of google*.* pages



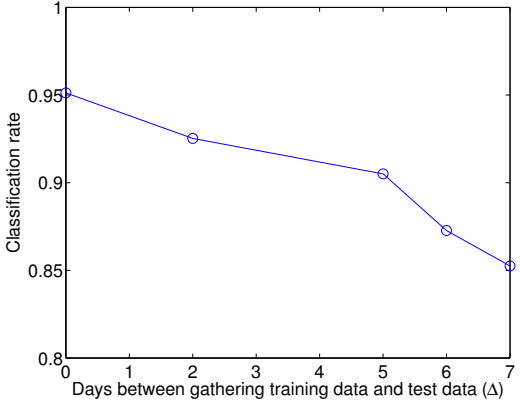
98% of 500 page visits

with google*.* pages merged

Results

Inter-day classification for Tor

- 100 most popular websites in the US



Results

Websites with the highest number of misclassifications

Δ	Website	# misclassifications
2 days	ask.com	5 times
2 days	twitch.tv	5 times
2 days	cnn.com	3 times
5 days	bbc.com	5 times
5 days	indeed.com	5 times
5 days	nytimes.com	5 times
5 days	twitch.tv	5 times
5 days	espn.go.com	4 times

Comparison

Work	Exploited information	Countermeasure	# websites	Classification rate
Ours	Client-side data-usage statistics	None	500	**97%**
Jana and Shmatikov [JS12]	Client-side memory footprint	None	100	35%
Ours	Client-side data-usage statistics	Tor	100	**95%**
Wang et al. [WCN+14]	TCP packets	Tor	100	95%
Wang and Goldberg [WG13]	TCP packets	Tor	100	91%
Cai et al. [CZJJ12]	TCP packets captured via tshark	Tor	100	84%
Panchenko et al. [PNZE11]	Client-side tcpdump	Tor	775	55%
Herrmann et al. [HWF09]	Client-side tcpdump	Tor	775	3%

Advantages

- Ease of applicability (unprivileged app vs on the wire)
- Computational performance (no training vs 608 000 CPU seconds)
- Classification rates
- No traffic noise due to other apps

Countermeasures

Against NW-based fingerprinting attacks

- Traffic morphing, HTTPOS, BuFLO, Glove
- Tor?

Client-side countermeasures

- Permission-based approaches? [ZDH+13]
  - Request permission to monitor data-usage statistics?
  - Let developers specify how statistics should be published?

$\Rightarrow$ update data-usage statistics on a more coarse-grained level

Conclusions

Fundamental weaknesses in Android

- Seemingly innocuous information
- . . . that turns out to be a serious information leak

Unprivileged app can infer browsing behavior, although

- Orweb or “private/incognito” modes do not store browsing history
- Traffic is routed through Tor
- `READ_HISTORY_BOOKMARKS` should protect this sensitive information

$\Rightarrow$ Privacy issue

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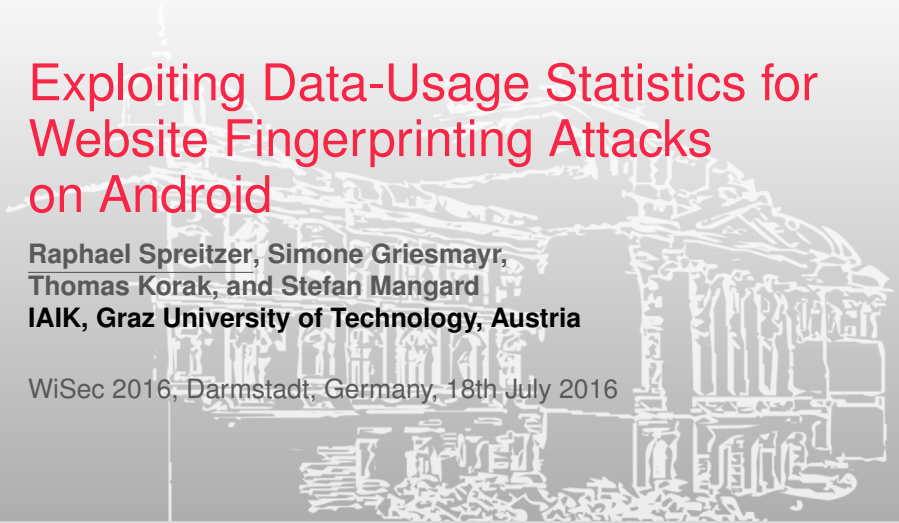

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