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Side-Channel Security

Chapter 7: Network Side Channels

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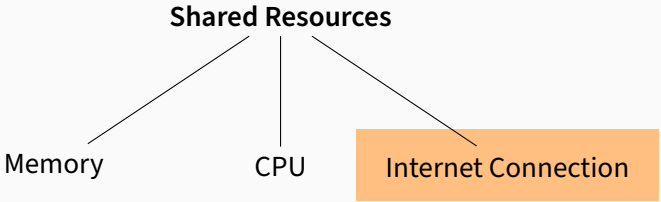
Introduction

What to Attack?



Demo: Network Traffic Depends on Activity

Website Fingerprinting

Every website causes a characteristic traffic pattern – a fingerprint:

- Hintz, 2003 [Hin03]: asset transfer sizes
- Panchenko et al. , 2011 [Pan+11]: packet sizes, directions, order
- Rimmer et al. , 2017 [Rim+17]: traffic shape (packet sizes, directions, timings), CNN classifier
- …

→ attacker-in-the-middle, mostly used against privacy-enhancing tunnels

Video Fingerprinting

Which video segment uses more bandwidth?

https://www.youtube.com/watch?v=LNI8rnxxVvQ

Video Fingerprinting

- Dynamic Adaptive Streaming over HTTP (DASH) [ISO22]
- usually encrypted
- split video into segments with a few seconds duration
- send segments on demand
- segment durations and sizes depend on content

→ fingerprint!

Video Fingerprinting

- Reed and Kranch, 2017 [RK17]: Netflix
- Schuster et al. , 2017 [SST17]: YouTube, Netflix, Amazon, Vimeo
- Gu et al. , 2018 [Gu+18]: self-hosted DASH server
- …

→ attacker-in-the-middle or with JavaScript

Other Traffic Analysis Attacks

- SSH keystroke timings [SWT01]
- deanonymization of Tor users [RSG98; AYR15; Wan+11]
- language [Wri+07] and phonemes [Whi+11] of VoIP calls
- other privacy-critical information [Che+10; LM18]

SnailLoad: Remote Traffic Analysis via TCP [Gas+24]

Some of you probably know the effect…

Internet Access Technologies

- DSL, Fiber, LTE, 5G: different throughput
- backbone connection **has orders of magnitude higher throughput**

→ buffering before last mile is necessary!

Packet Buffering

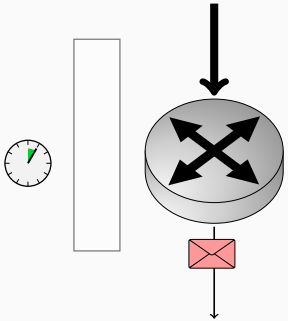


Figure 1: Connection idle

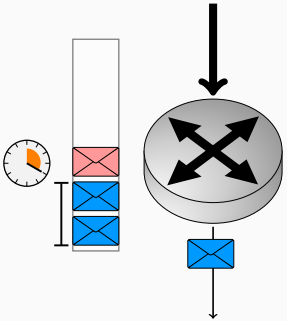


Figure 2: Connection busy

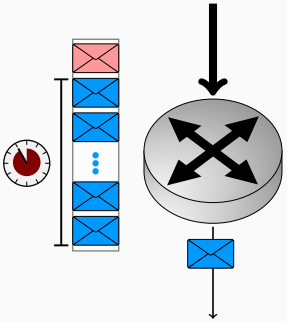


Figure 3: Bufferbloat

Network Activity Causes Latency Spikes

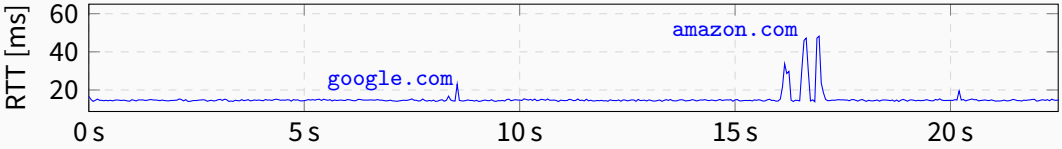


Figure 4: Same machine pinging `8.8.8.8`

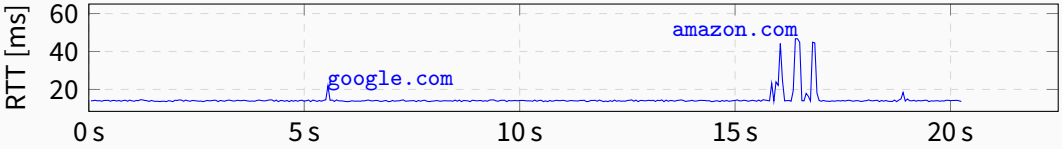


Figure 5: Different machine sharing the same internet connection pinging `8.8.8.8`

Idle and Busy Round-Trip-Times

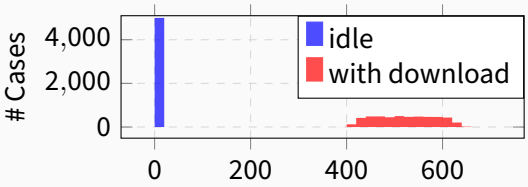


Figure 6: RTT [ms], ADSL-1, 50 Mbit/s

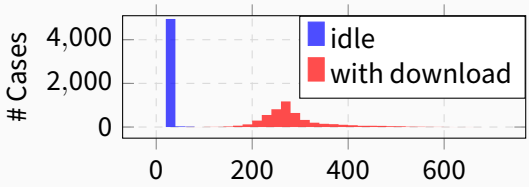


Figure 7: RTT [ms], LTE, 75 Mbit/s

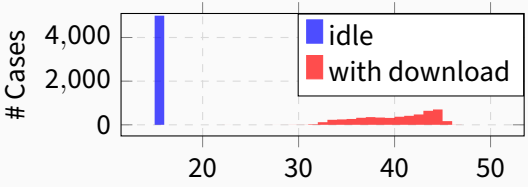


Figure 8: RTT [ms], FTTH-1, 80 Mbit/s

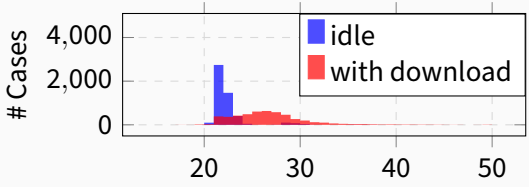
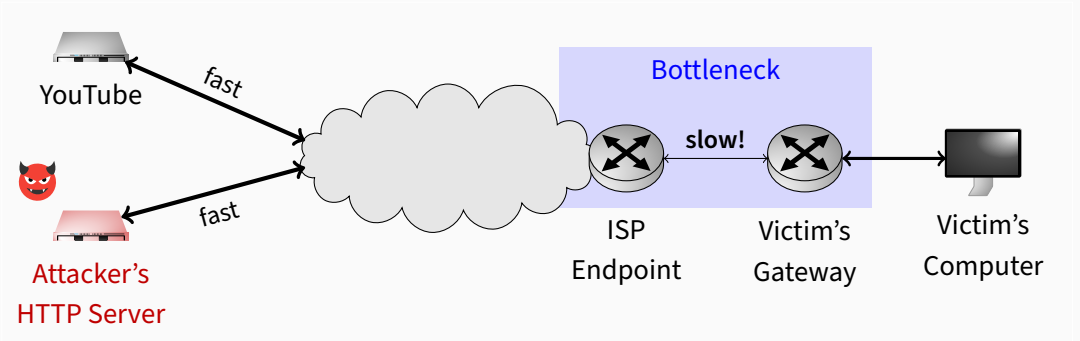


Figure 9: RTT [ms], Cable, 80 Mbit/s

Attack Setup



- Various scenarios: Compromised websites, malicious ads, emails, and more
- Different ways attackers can exploit network traffic to perform attacks

Polling the Server's Send Buffer To Measure RTTs


```
begin
    acked ← false;
    start ← get_current_time();
    send(sock, b, 1, 0);
    repeat
        if ioctl(sock, SIOCOUTQ) = 0 then
            acked ← true;
        end
    until acked;
    end ← get_current_time();
    return end − start;
end
```

Fingerprinting with Machine Learning

- use machine learning to analyze network traffic and infer user actions
- pre-process traces with an STFT
- KERAS (Tensorflow)

Table 1: CNN Parameters

Type	Parameters	Activation
Conv2D	filters=32, kernel size=[5,5], strides=[1,1]	ReLU
MaxPooling2D	pool size=[2,2], strides=[2,2]	-
Conv2D	filters=64, kernel size=[3,3], strides=[1,1]	ReLU
MaxPooling2D	pool size=[2,2], strides=[2,2]	-
Conv2D	filters=128, kernel size=[3,3], strides=[1,1]	ReLU
MaxPooling2D	pool size=[2,2], strides=[2,2]	-
Flatten	-	-
Dense	output size=1024	ReLU
Dense	output size=512	ReLU
Dense	output size=10	Softmax

Video Fingerprinting

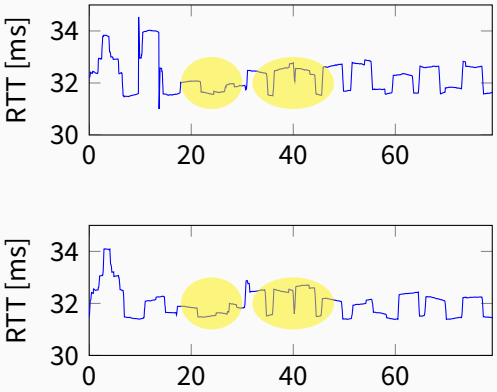


Figure 10: Video A, Time in seconds on x axis

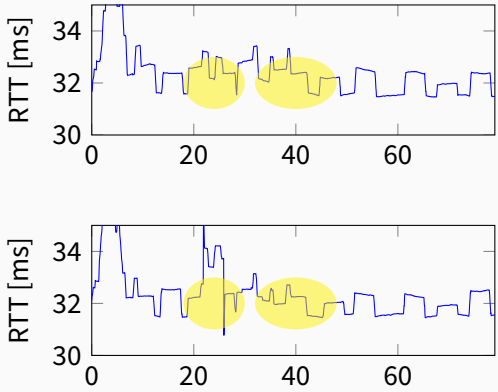
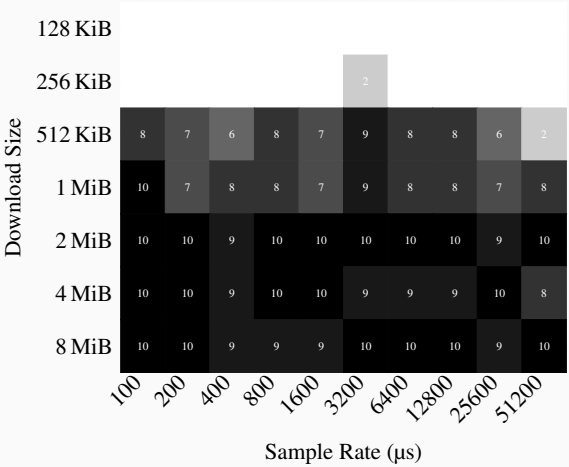
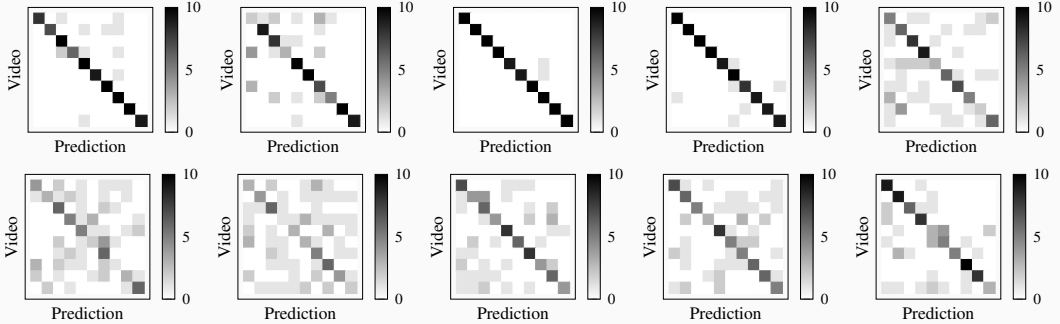


Figure 11: Video B, Time in seconds on x axis

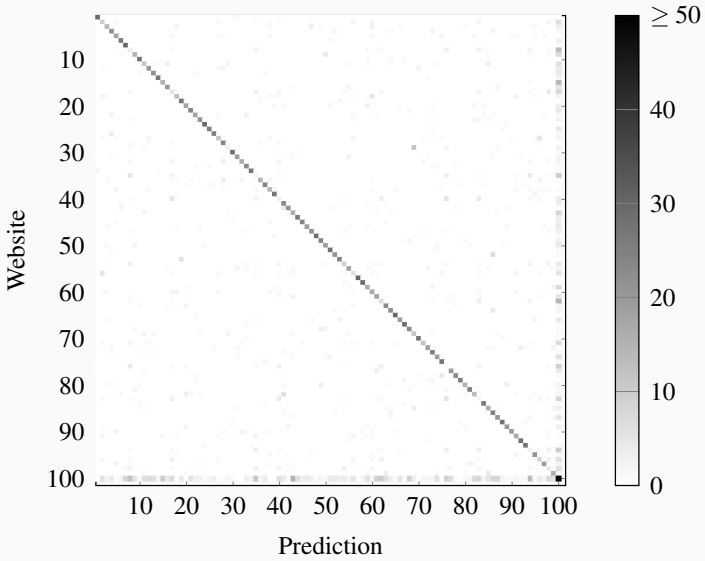
How large does the website have to be?



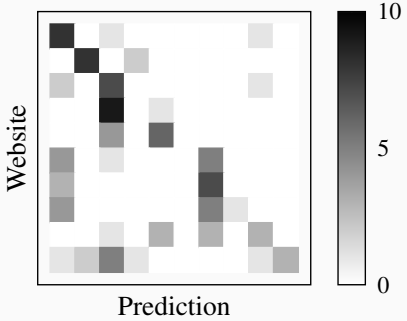
Video Fingerprinting on 10 different connections



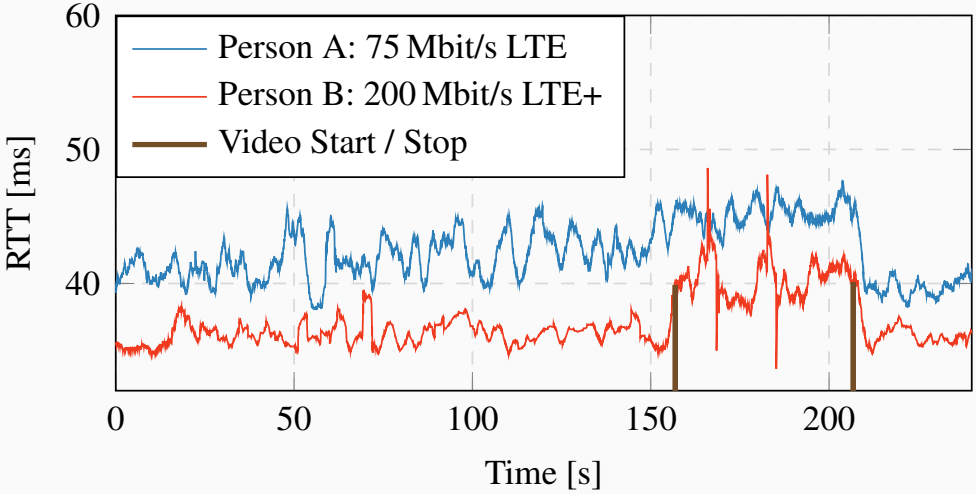
Top-100 Open-World Website Fingerprinting



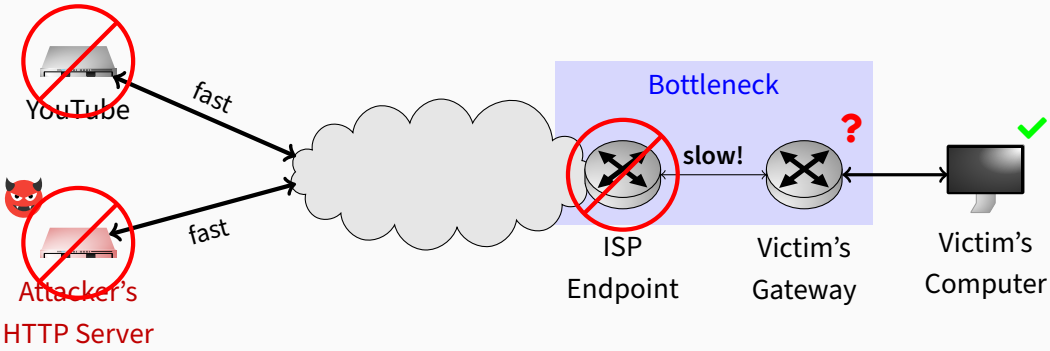
Cross-Connection Website Fingerprinting



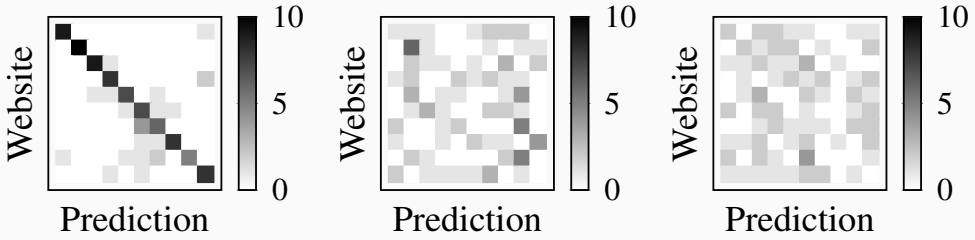
Video Call Detection



What about Mitigations?



Impact of Noise on Website Fingerprinting



Context, Impact, Disclosure

- SnailLoad is a generic problem of heterogenous networks (with different throughputs)
- Many “remote” attacks can now be transformed to truly remote attacks
- We disclosed to Google / YouTube
  - they investigated the issue for several weeks
  - concluded that it is a generic problem

Take Aways

- Any connection to a remote server can obtain high-resolution traces of your activity
- Traces can leak websites and videos watched
- Throughput difference is the root cause $\rightarrow$ not trivial to fix
- Paper + Demo: `https://snailload.com`

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References

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