CSE 484 / CSE M 584: Computer Security and Privacy

Loose Ends

(Finish Anonymity, "Fun" Side Channels)

Fall 2017

Franziska (Franzi) Roesner
franzi@cs.washington.edu

Thanks to Dan Boneh, Dieter Gollmann, Dan Halperin, Yoshi Kohno, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Admin

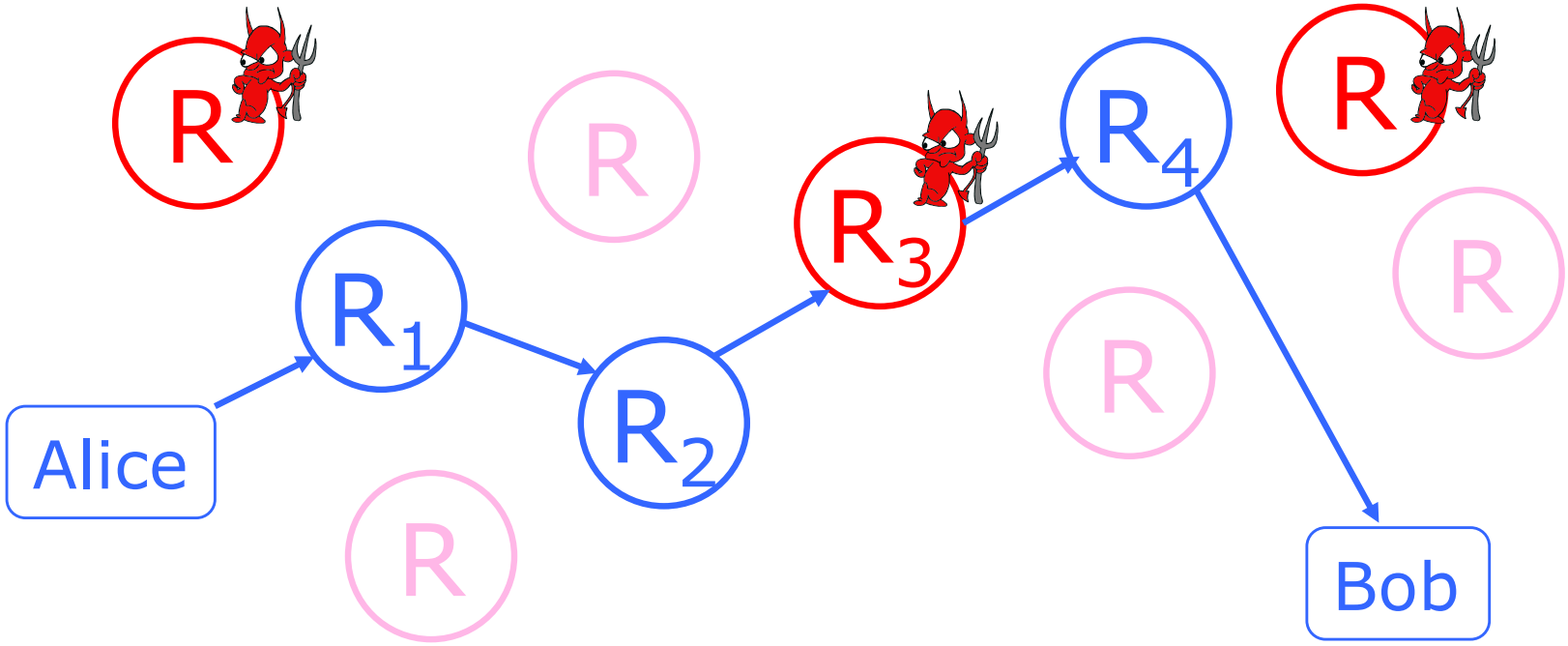
- **HW3 due** today @ 8pm

- **Final Projects due** Wednesday @ 11:59pm
  - Check out the rubric on the course website
- Extra credit: review up to 2 other presentations
  - We will make them available by 10am on Thursday

- Extra credit readings due today @ 11:59pm
- Today: finish anonymity, side channels

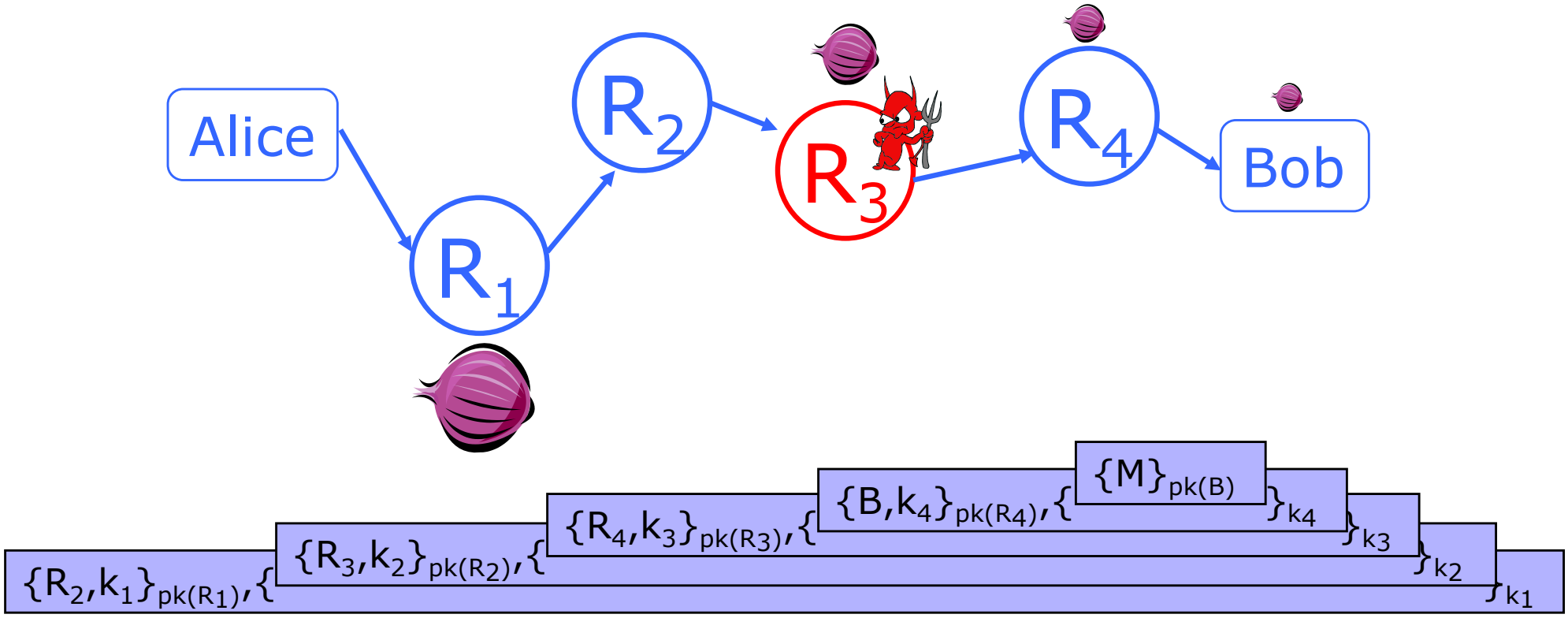
[Reed, Syverson, Goldschlag 1997]

Onion Routing



- Sender chooses a random sequence of routers
  - Some routers are honest, some controlled by attacker
  - Sender controls the length of the path

Route Establishment



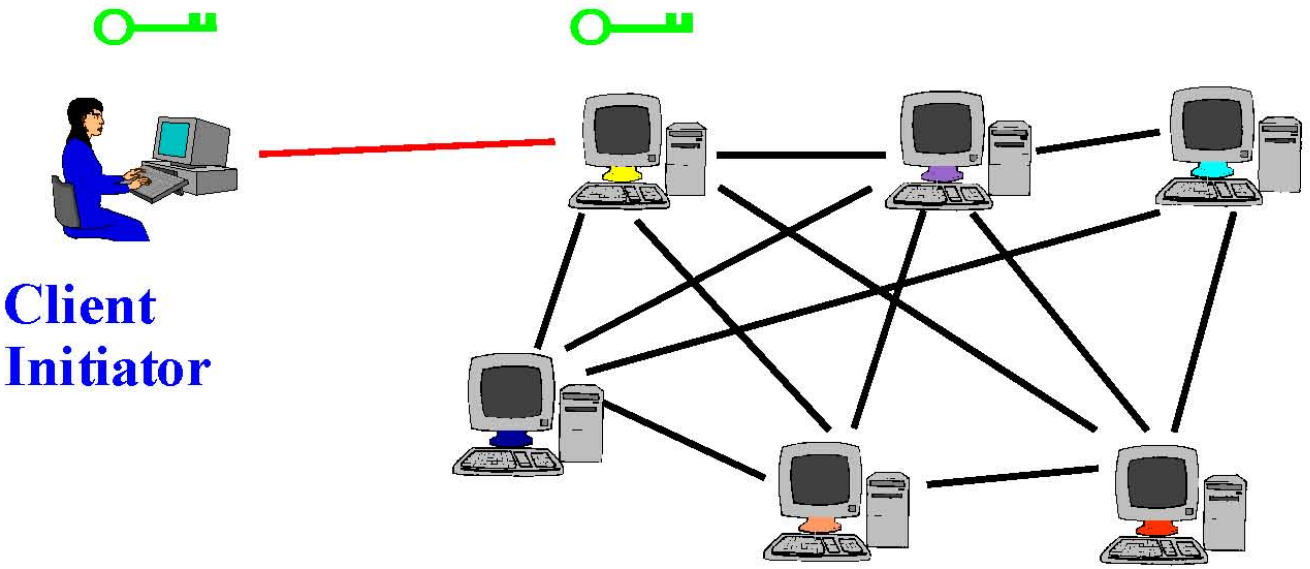
- Routing info for each link encrypted with router's public key
- Each router learns only the identity of the next router

Tor

- Second-generation onion routing network
  - http://tor.eff.org
  - Developed by Roger Dingledine, Nick Mathewson and Paul Syverson
  - Specifically designed for low-latency anonymous Internet communications
- Running since October 2003
- "Easy-to-use" client proxy
  - Freely available, can use it for anonymous browsing

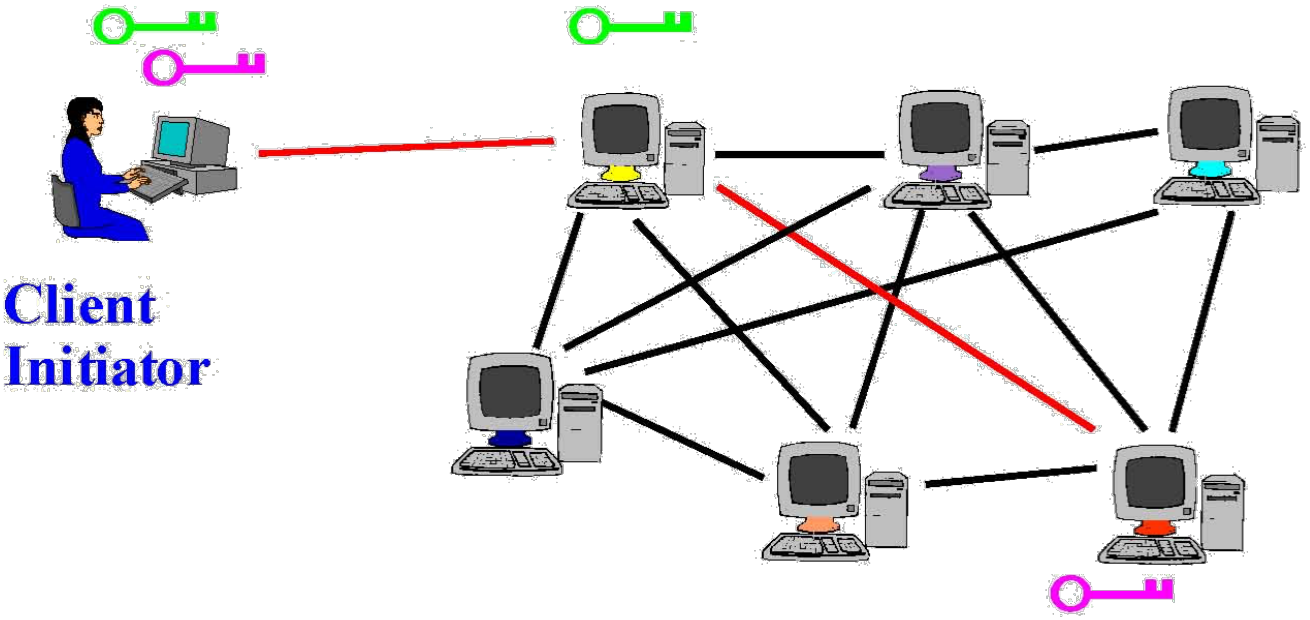
Tor Circuit Setup (1)

- Client proxy establishes a symmetric session key and circuit with Onion Router #1



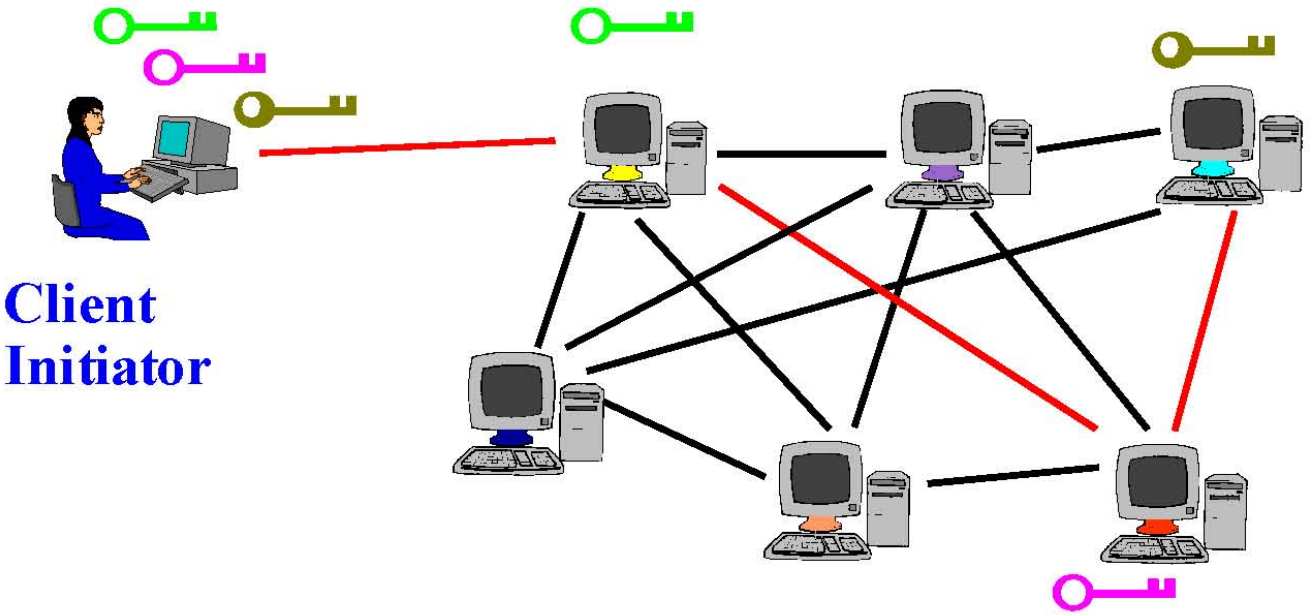
Tor Circuit Setup (2)

- Client proxy extends the circuit by establishing a symmetric session key with Onion Router #2
  - Tunnel through Onion Router #1



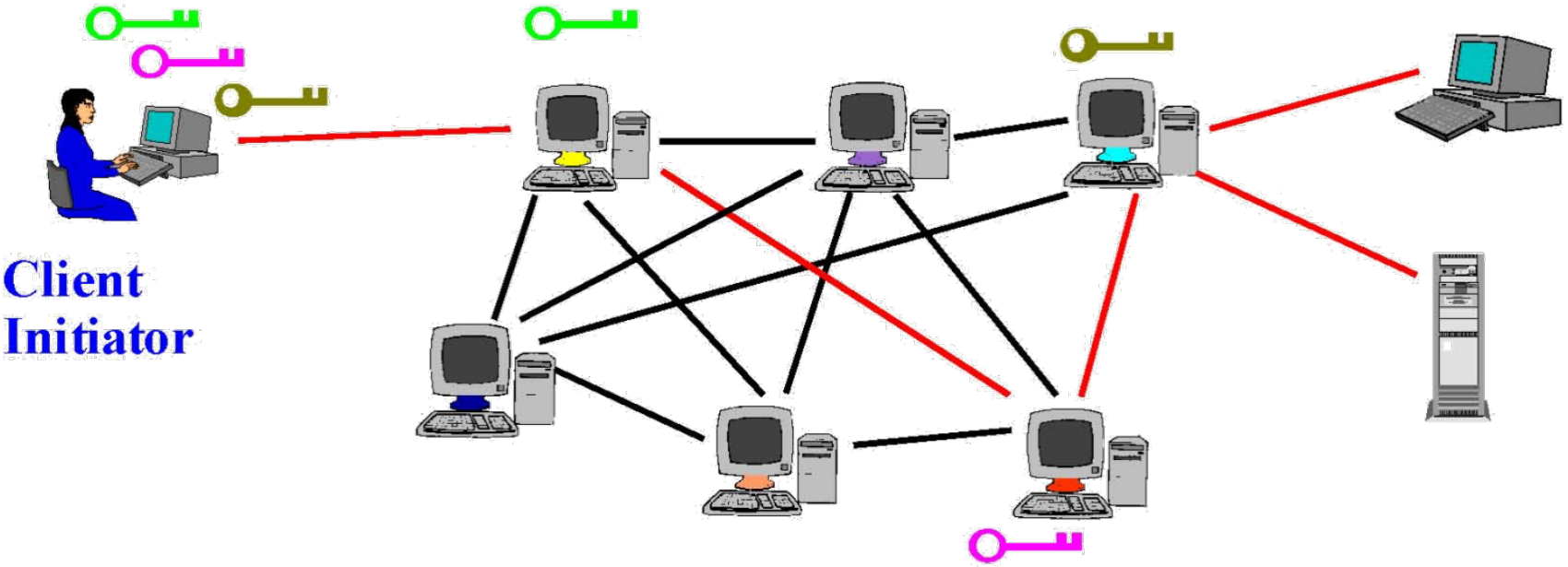
Tor Circuit Setup (3)

- Client proxy extends the circuit by establishing a symmetric session key with Onion Router #3
  - Tunnel through Onion Routers #1 and #2



Using a Tor Circuit

- Client applications connect and communicate over the established Tor circuit.



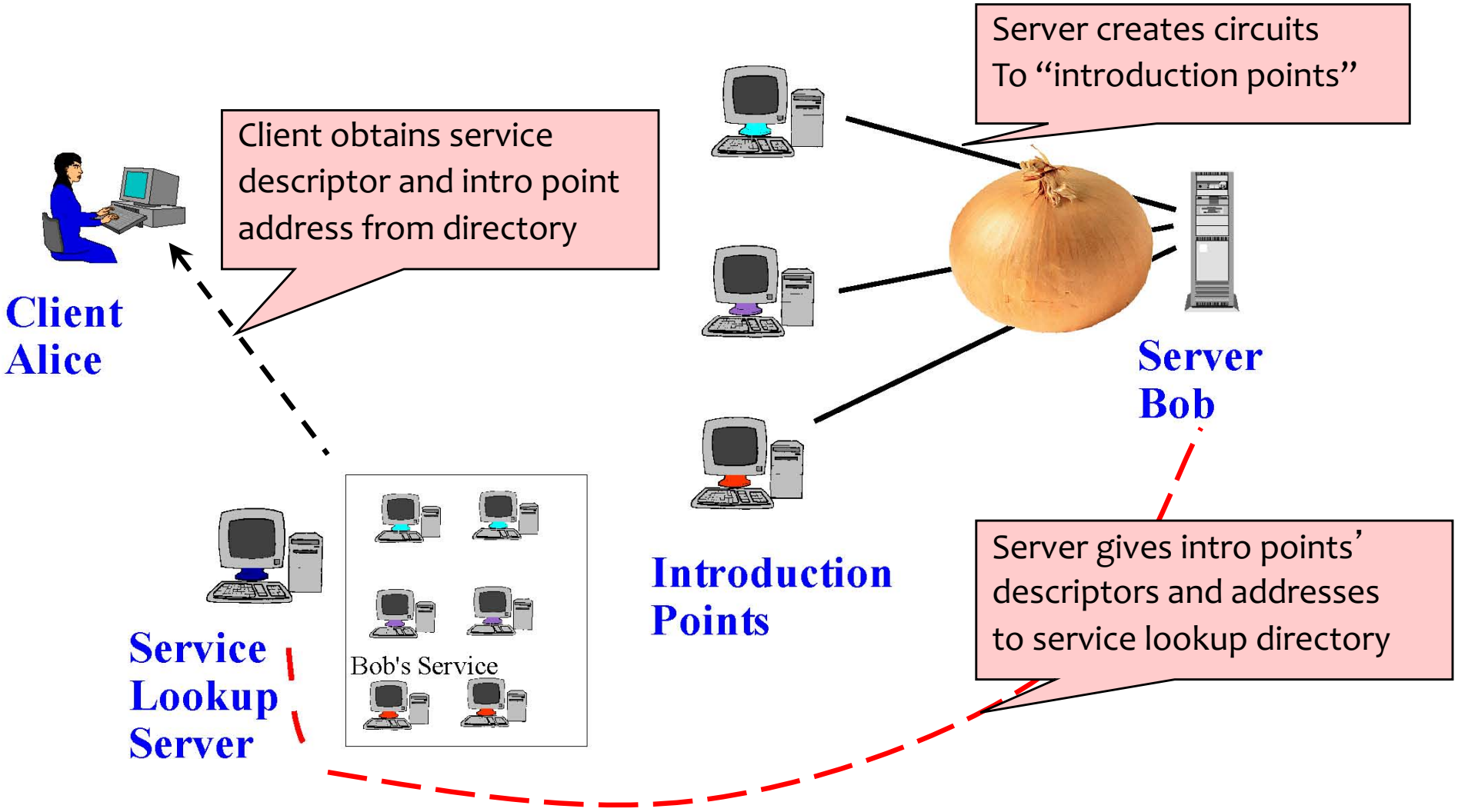
Tor Management Issues

- Many applications can share one circuit
  - Multiple TCP streams over one anonymous connection
- Tor router doesn't need root privileges
  - Encourages people to set up their own routers
  - More participants = better anonymity for everyone
- Directory servers
  - Maintain lists of active onion routers, their locations, current public keys, etc.
  - Control how new routers join the network
    - "Sybil attack": attacker creates a large number of routers
  - Directory servers' keys ship with Tor code

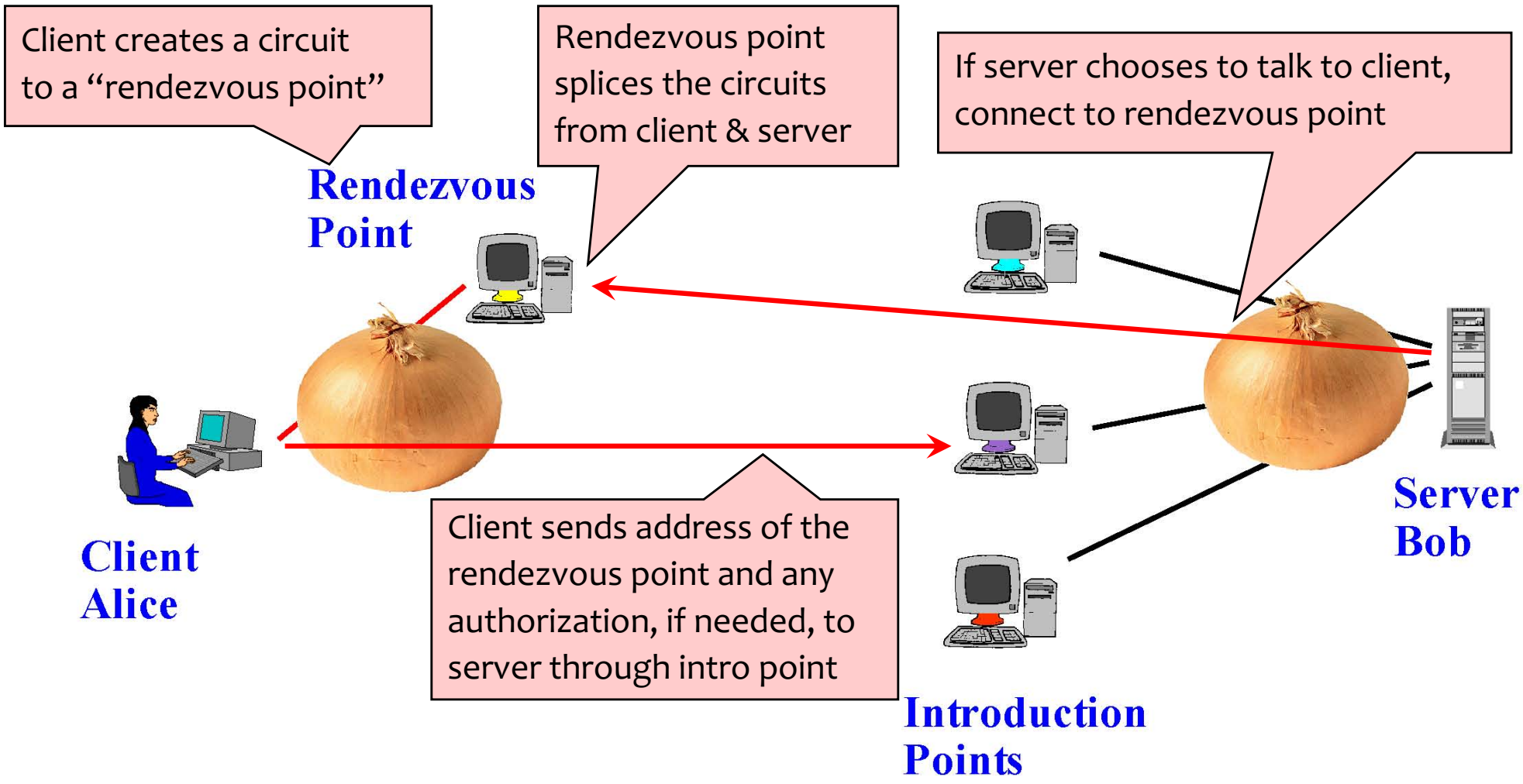
Location Hidden Service

- **Goal:** deploy a server on the Internet that anyone can connect to without knowing where it is or who runs it
- Accessible from anywhere
- Resistant to censorship
- Can survive a full-blown DoS attack
- Resistant to physical attack
  - Can't find the physical server!

Creating a Location Hidden Server



Using a Location Hidden Server

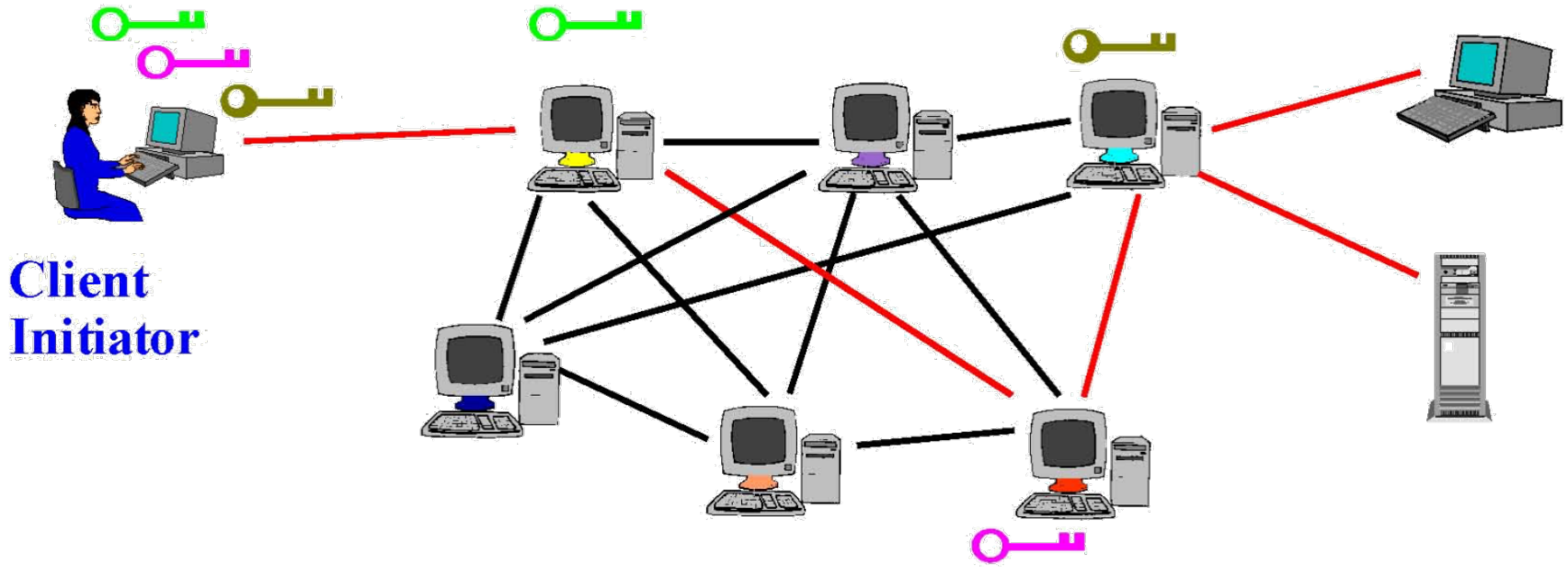


Attacks on Anonymity

- Passive traffic analysis
  - Infer from network traffic who is talking to whom
  - To hide your traffic, must carry other people's traffic!
- Active traffic analysis
  - Inject packets or put a timing signature on packet flow
- Compromise of network nodes
  - Attacker may compromise some routers
  - It is not obvious which nodes have been compromised
    - Attacker may be passively logging traffic
  - Better not to trust any individual router
    - Assume that some fraction of routers is good, don't know which

Some Caution

- Tor isn't completely effective by itself
  - Tracking cookies, fingerprinting, etc.
  - Exit nodes can see everything!



SIDE CHANNELS

Side Channel Attacks

- Attacks based on information that can be gleaned from the physical implementation of a system, rather than breaking its theoretical properties
  - Most commonly/devastatingly used against cryptosystems
  - But also prevalent in other contexts, e.g., due to widespread smartphone sensors

Cache-Based Side Channels

Type	Enc.	Year	Attack description	Victim machine		Samples	Crypt. key
Active Time-driven [9]	AES	2006	Final Round Analysis	UP	Pentium III	$2^{13.0}$	Full 128-bit key
Active Time-driven [30]	AES	2005	Prime+Evict (Synchronous Attack)	SMP	Athlon 64	$2^{18.9}$	Full 128-bit key
Active Time-driven [40]	DES	2003	Prime+Evict (Synchronous Attack)	UP	Pentium III	$2^{26.0}$	Full 56-bit key
Passive Time-driven [4]	AES	2007	Statistical Timing Attack (Remote)	SMT	Pentium 4 with HT	$2^{20.0}$	Full 128-bit key
Passive Time-driven [8]	AES	2005	Statistical Timing Attack (Remote)	UP	Pentium III	$2^{27.5}$	Full 128-bit key
Trace-driven [14]	AES	2011	Asynchronous Probe	UP	Pentium 4 M	$2^{6.6}$	Full 128-bit key
Trace-driven [29]	AES	2007	Final Round Analysis	UP	Pentium III	$2^{4.3}$	Full 128-bit key
Trace-driven [3]	AES	2006	First/Second Round Analysis	-	-	$2^{3.9}$	Full 128-bit key
Trace-driven [30]	AES	2005	Prime+Probe (Synchronous Attack)	SMP	Pentium 4 with HT	$2^{13.0}$	Full 128-bit key
Trace-driven [32]	RSA	2005	Asynchronous Probe	SMT	Xeon with HT	-	310-bit of 512-bit key

Table 1: Overview of cache-based side channel attacks: UP, SMT and SMP stand for uniprocessor, simultaneous multithreading and symmetric multiprocessing, respectively.

"By exploiting side channels that arise from shared CPU caches, researchers have demonstrated attacks extracting encryption keys of popular cryptographic algorithms such as AES, DES, and RSA."

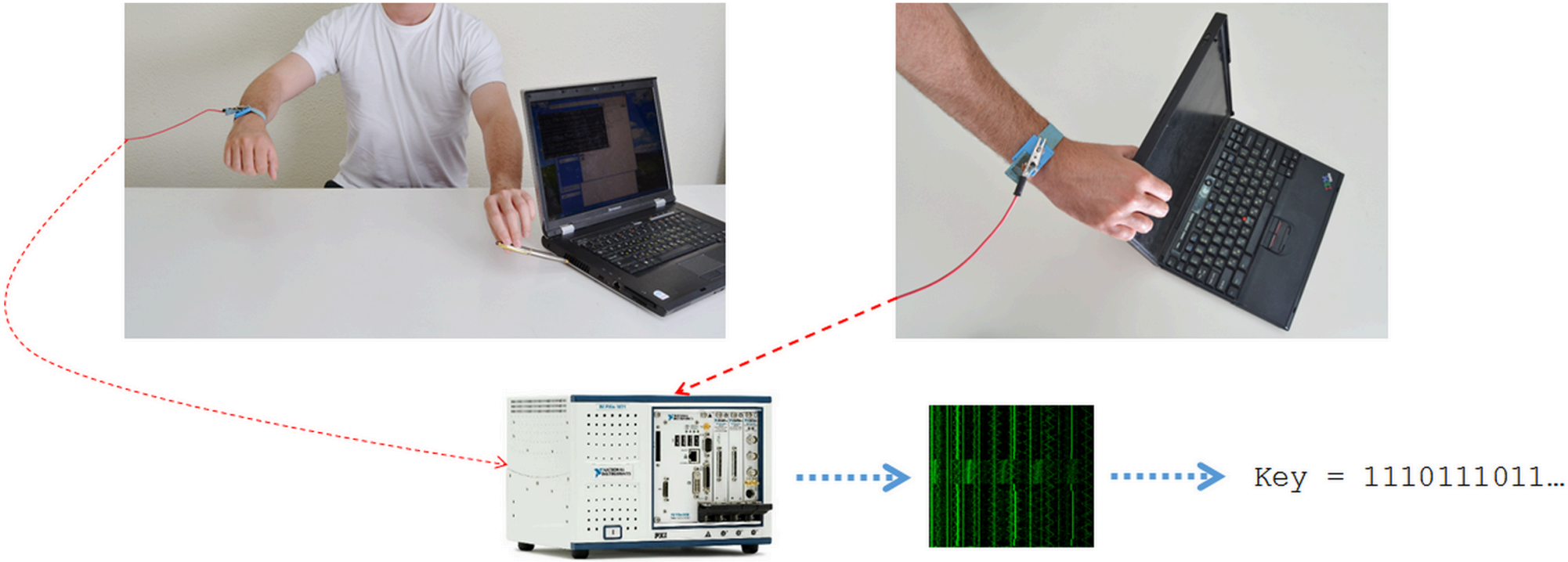
Kim et al. "STEALTHMEM: System-Level Protection Against Cache-Based Side Channel Attacks in the Cloud" USENIX Security 2012

Others (on Cryptosystems)

- Timing attacks
- Power analysis
- Etc.

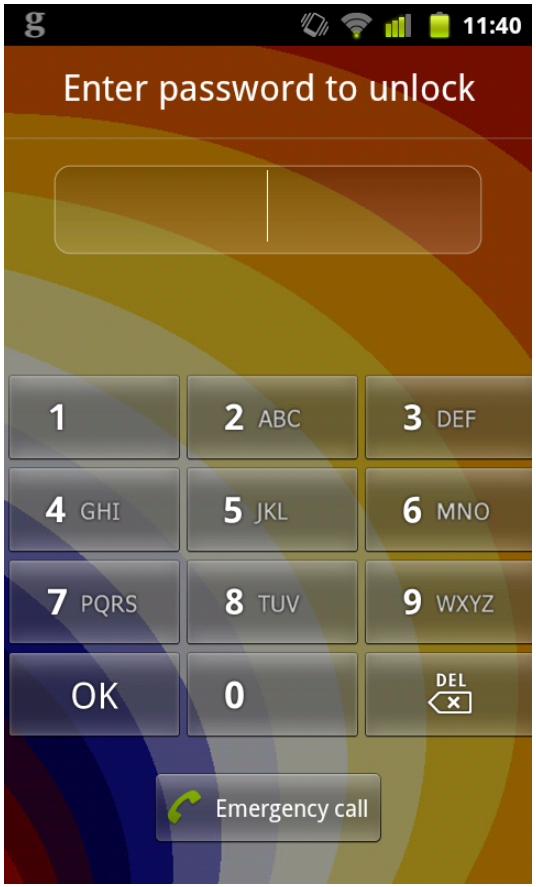
If you do something different for secret key bits 1 vs. 0, attacker can learn something…

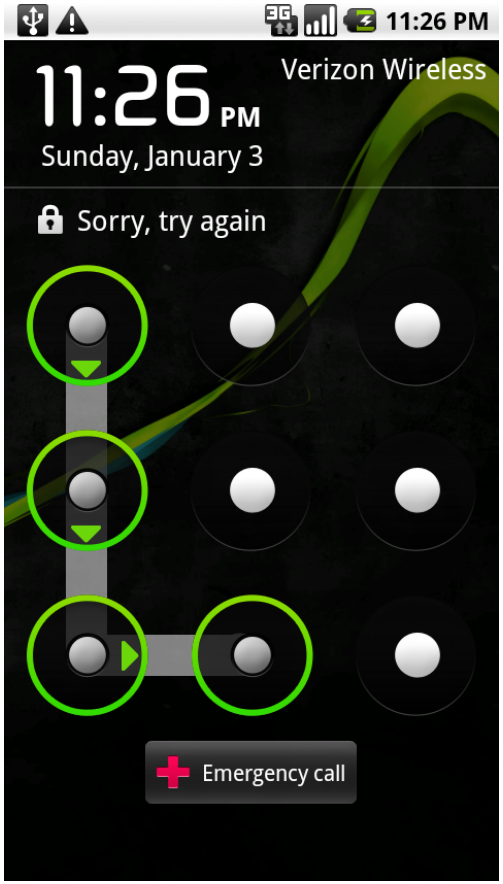
Key Extraction via Electric Potential



Genkin et al. "Get Your Hands Off My Laptop: Physical Side-Channel Key-Extraction Attacks On PCs" CHES 2014

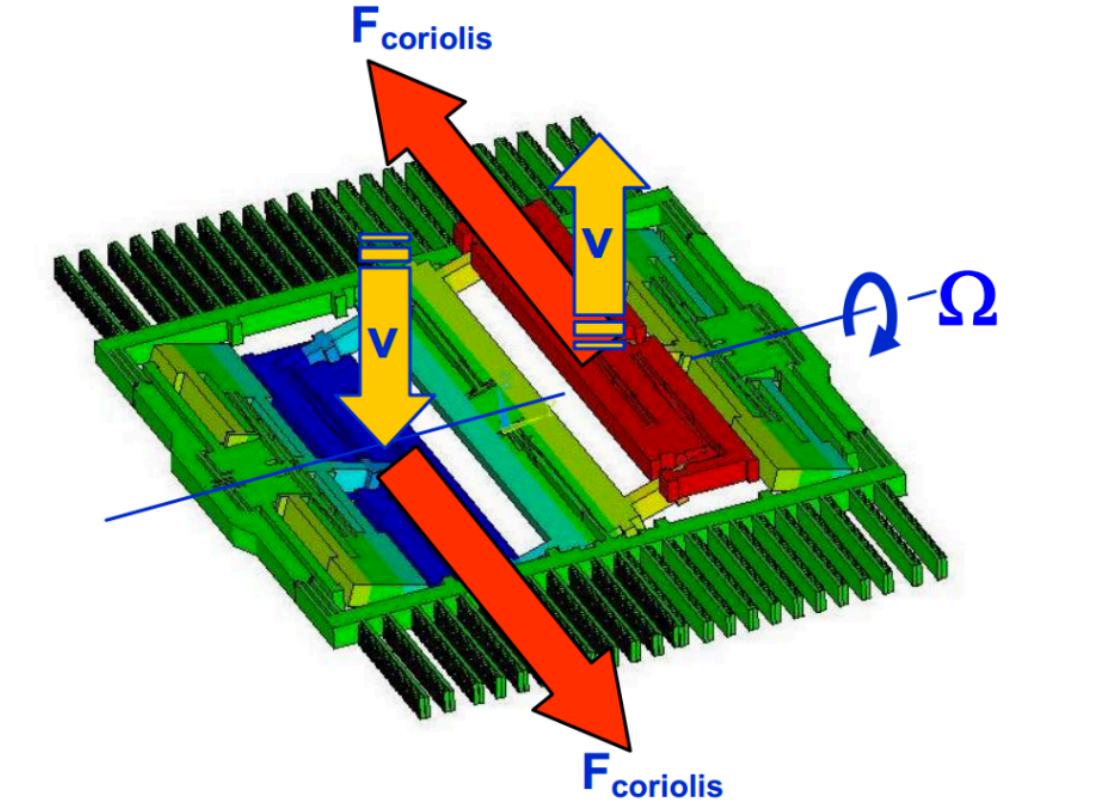
Accelerometer Eavesdropping





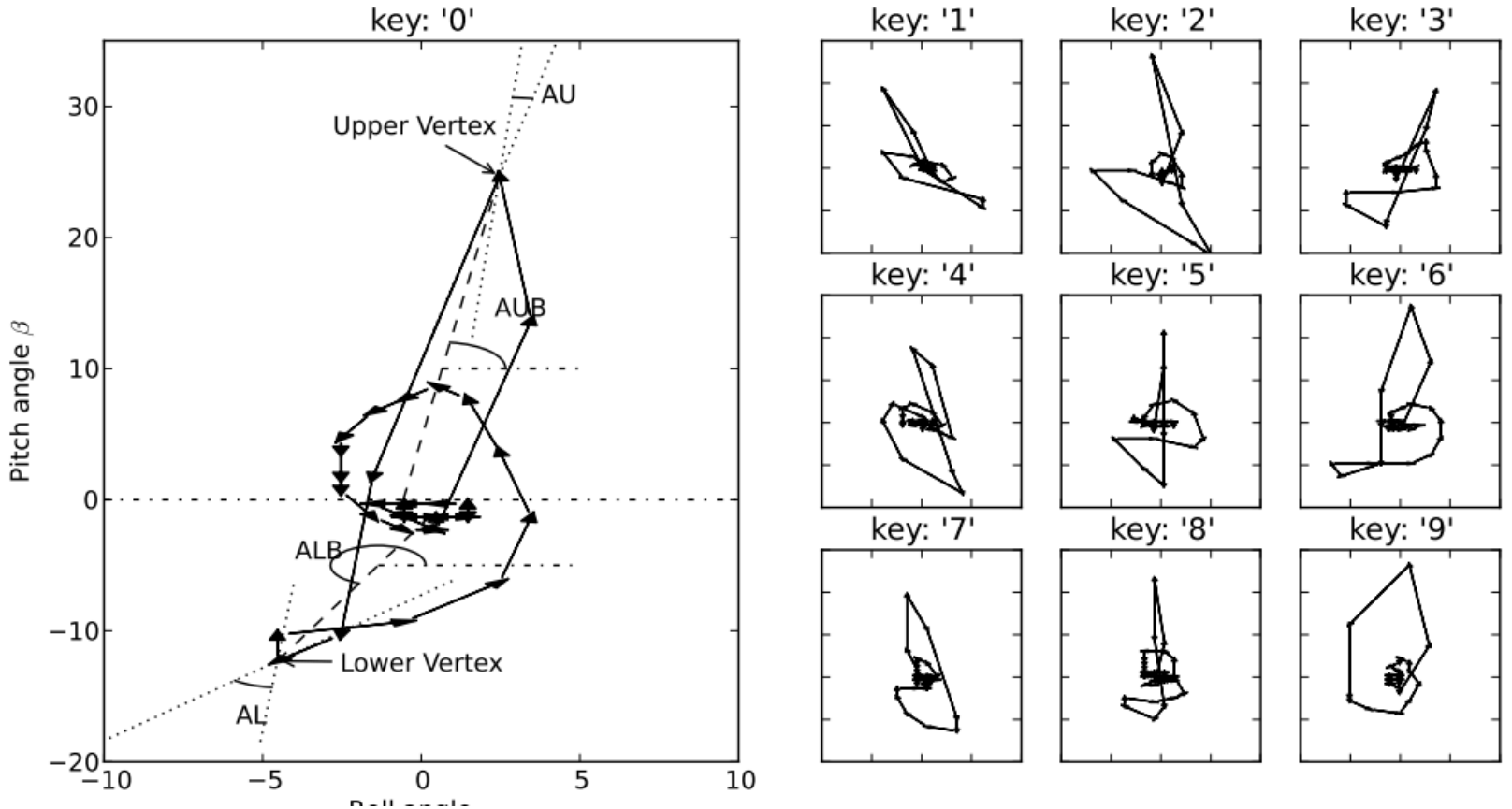
Aviv et al. "Practicality of Accelerometer Side Channels on Smartphones" ACSAC 2012

Gyroscope Eavesdropping



Michalevsky et al. "Gyrophone: Recognizing Speech from Gyroscope Signals" USENIX Security 2014

More Gyroscope



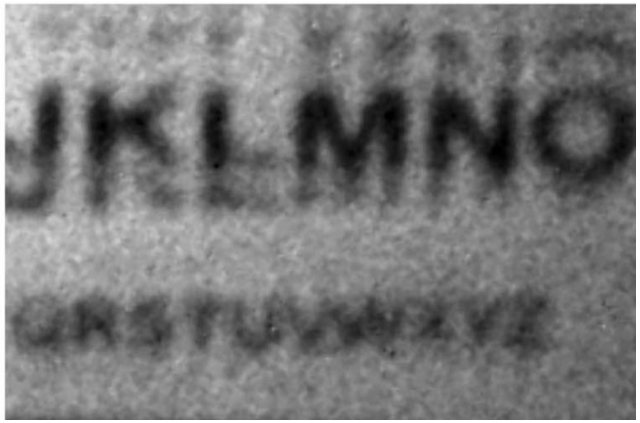
Chen et al. "TouchLogger: Inferring Keystrokes On Touch Screen From Smartphone Motion" HotSec 2011

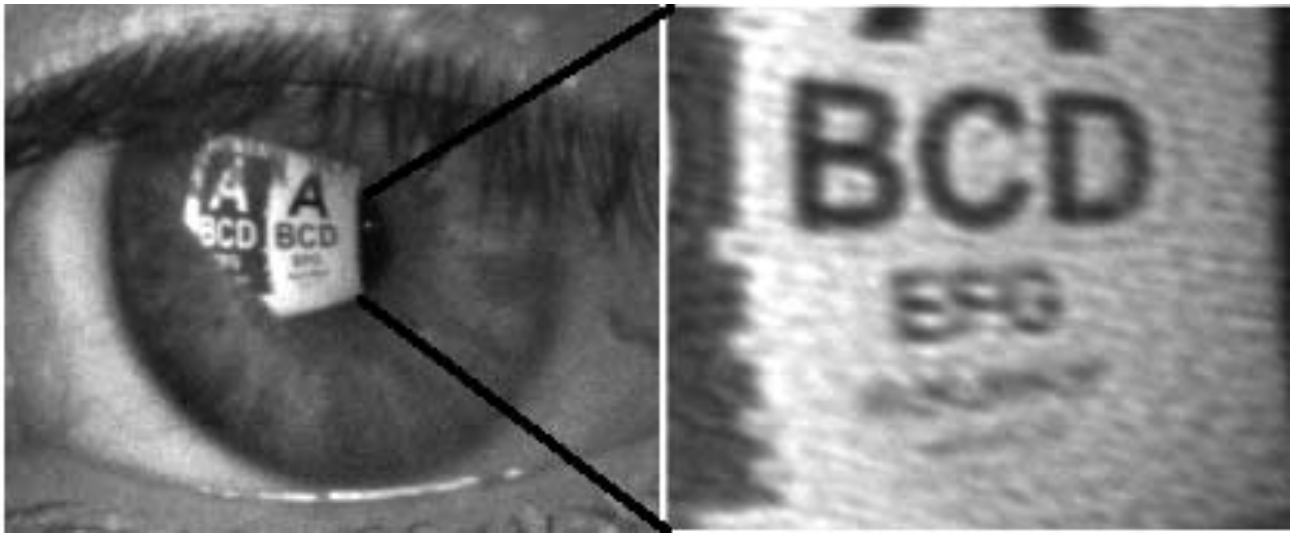
Keyboard Eavesdropping

Zhuang et al. "Keyboard Acoustic Emanations Revisited" CCS 2005
Vuagnoux et al. "Compromising Electromagnetic Emanations of Wired and Wireless Keyboards" USENIX Security 2009

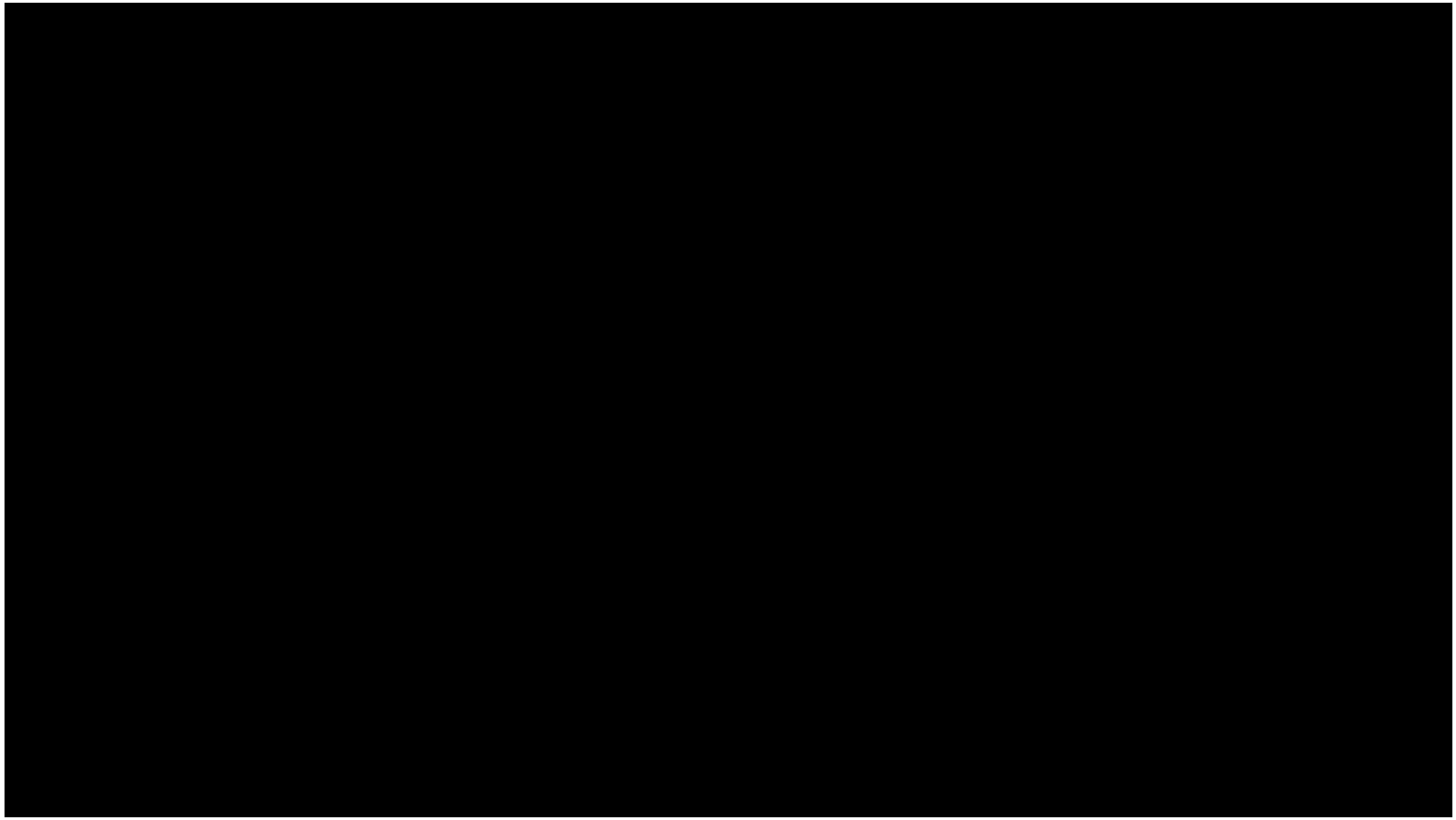
[Backes et al.]

Compromising Reflections





Audio from Video



Davis et al. “The Visual Microphone: Passive Recovery of Sound from Video” SIGGRAPH 2014

Identifying Web Pages: Traffic Analysis

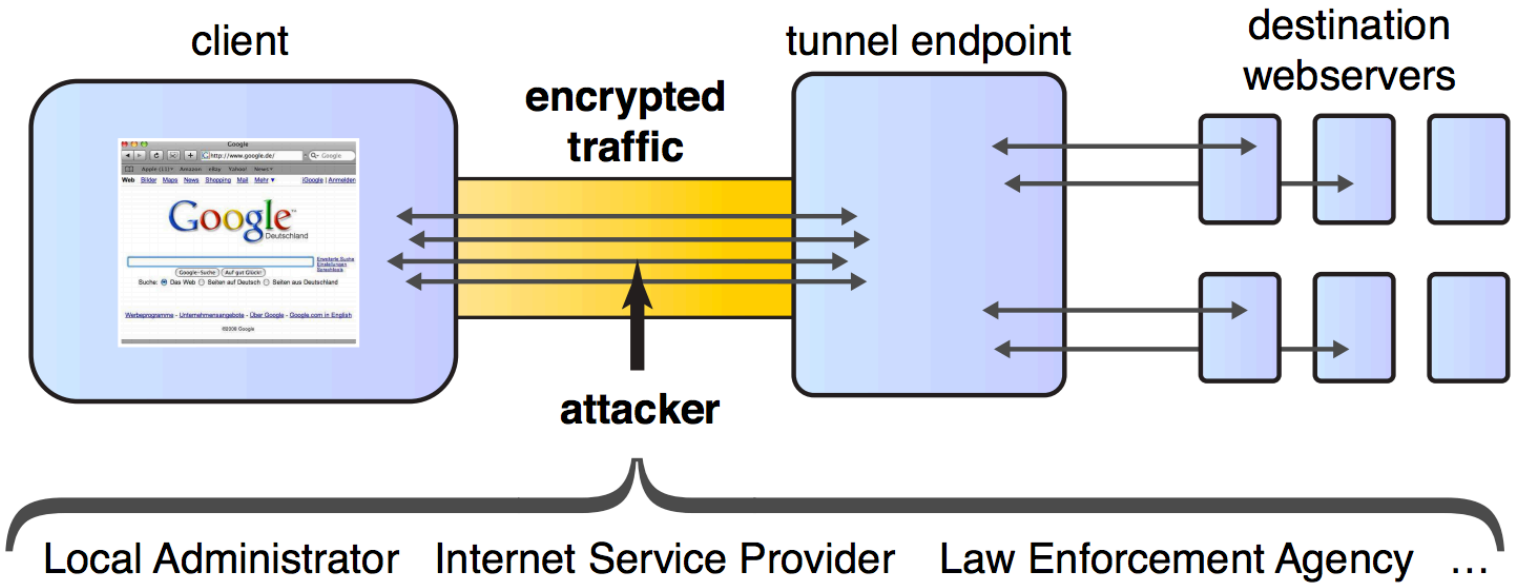
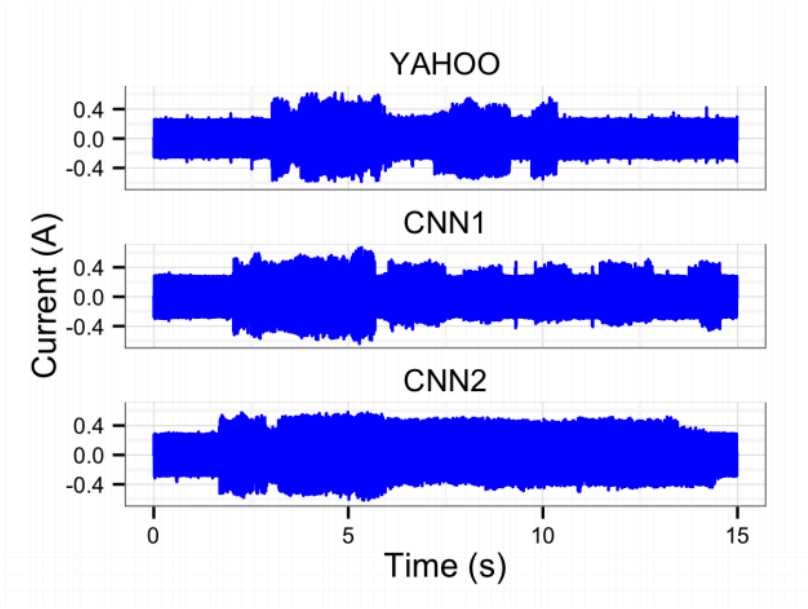


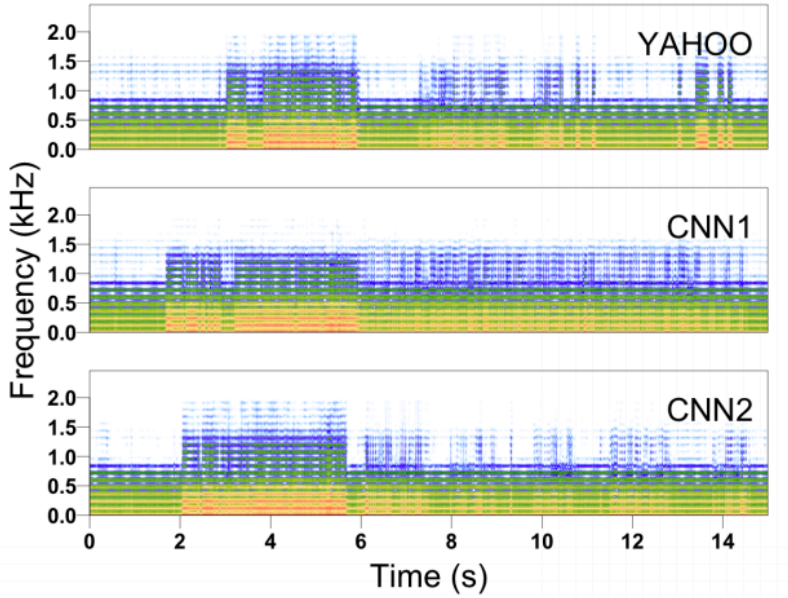
Figure 1: Website fingerprinting scenario and conceivable attackers

Herrmann et al. "Website Fingerprinting: Attacking Popular Privacy Enhancing Technologies with the Multinomial Naïve-Bayes Classifier" CCSW 2009

Identifying Web Pages: Electrical Outlets



(a) Time-domain plots



(b) Spectrogram plots

Fig. 1: Time- and frequency-domain plots of several power traces as a MacBook loads two different pages. In the frequency domain, brighter colors represent more energy at a given frequency. Despite the lack of obviously characteristic information in the time domain, the classifier correctly identifies all of the above traces.

Clark et al. "Current Events: Identifying Webpages by Tapping the Electrical Outlet" ESORICS 2013

Powerline Eavesdropping

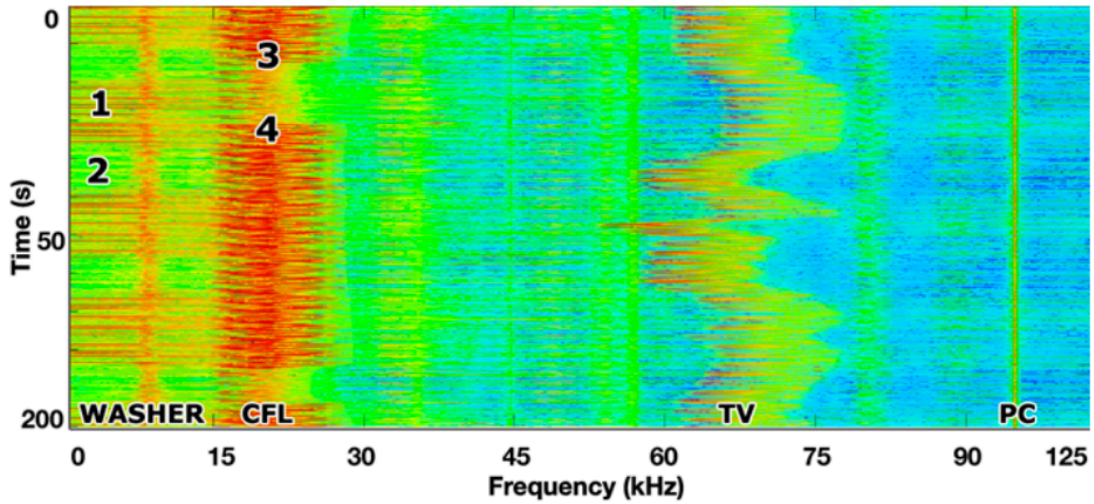


Figure 1: Frequency spectrogram showing various electrical appliances in the home. Washer cycle on (1) and off (2). CFL lamp turning off briefly (3) and then on (4). Note that the TV's (Sharp 42" LCD) EMI shifts in frequency, which happens as screen content changes.

Enev et al.: Televisions, Video Privacy, and Powerline Electromagnetic Interference, CCS 2011

WRAP-UP

This Quarter

- Overview of:
  - Security mindset
  - Software security
  - Cryptography
  - Web security
  - Web privacy
  - Authentication
  - Mobile platform security
  - Usable security
  - Physical security
  - Anonymity
  - Side channels

Lots We Didn't Cover…

- Deep dive into any of the above topics
- (Most) network security
- (Most) recent attacks/vulnerabilities
- (Most) specific protocols (e.g., Kerberos)
- Spam
- Social engineering
- Cryptocurrencies (e.g., Bitcoin)
- Emerging technologies (e.g., augmented reality, smart homes, brain-computer interfaces, synthetic biology, …)
- …

Thanks for a great quarter!

- Feel free to still email / stop by
  - Worksheets?

- Please fill out course evaluation: https://uw.iasystem.org/survey/183478