(Still) Exploiting TCP Timestamps

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About Me

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- @fenceposterror
- Bug in the matrix

Disclaimer

I will use IP on the slides synonym to IP address for space reasons.
Timestamps allows refer to TCP timestamps if not otherwise noted.

Outline

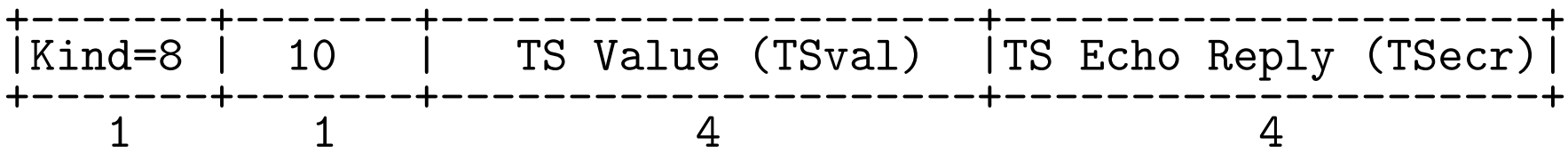
1. What are TCP Timestamps?
2. A History of Exploitation and Failed Remediation
3. More Fun with TCP Timestamps
4. What Now?

TCP Timestamps

- Introduced in 1992
- Described in RFC1323
- Extension to provide PAWS and improved RTTM
- A constant, strictly monotonous increasing number

A TCP Timestamp

Kind: 8
Length: 10 bytes



Attack Vector - Timestamp

2001 - Uptime Calculation

Attack Vector - Timestamp

2001: Uptime Calculation

- Timestamp != Uptime
- Multiple timestamps $\Rightarrow$ frequency of host $\Rightarrow$ timestamp & frequency $\Rightarrow$ uptime
- Uptime related to patch level

Attack Vector - Timestamp

2001: Uptime Calculation - Remediation

- Disable timestamps (bad idea)
- Randomize timestamps at boot (problems: lack of entropy, determination of initial value easy)
- Start each new TCP Connection with 0 (problem: still PAWS)
- Timestamp per IP/port pair (problem: only a question of time)
- More problems: Might break syn flood protection under linux
- Timestamp counter for each IP

Attack Vector - Timestamp

2015: Uptime Calculation

- Still possible[1] ...
- Also: timestamps observed over a longer period also lets us know their habits, e.g. when shutting down, when booting, ...

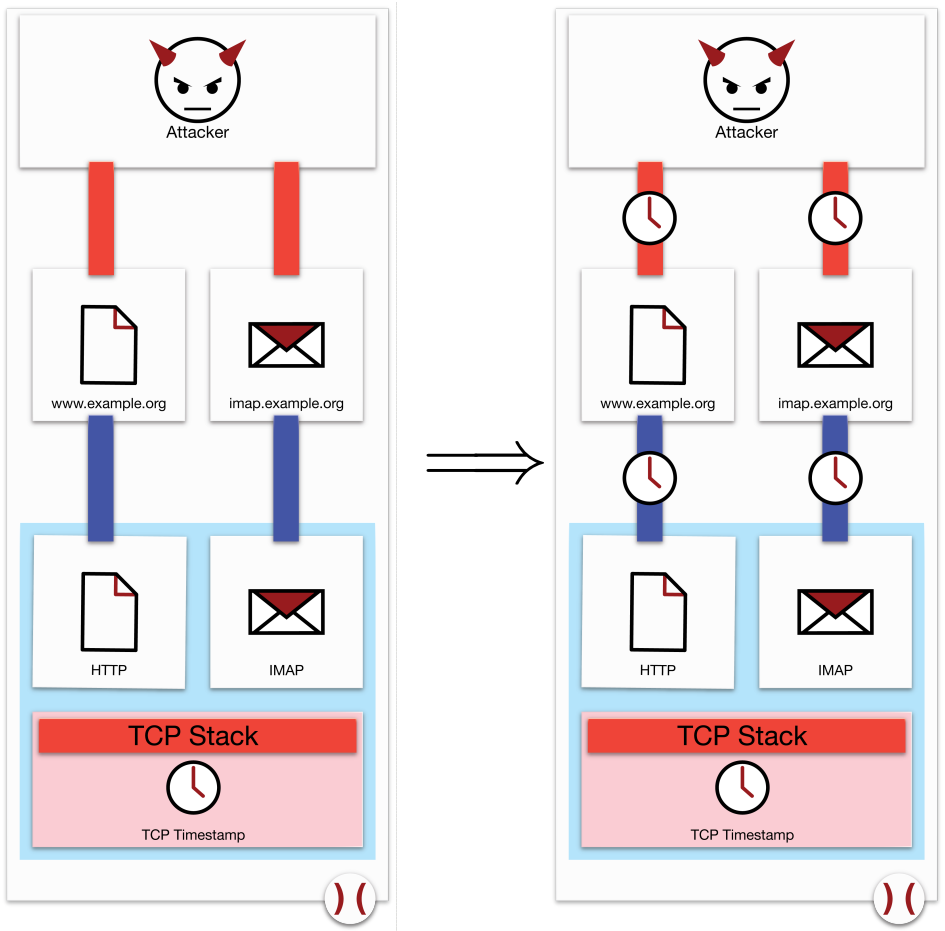
[1] It's a tiny bit more tricky for a small group of systems

Attack Vector - Timestamp

2005 - Host Identification

Attack Vector - Timestamp

2005: Host Identification



Attack Vector - Timestamp

2005: Host Identification - Remediation

- Randomizing/Zeroing timestamps (loss of functionality)
- Use a different counter for each connection and initialize with 0 (problem: PAWS)
- Like above but with randomized start (problem: PAWS)

Attack Vector - Timestamp

2015: Host Identification

Still possible[2]...

[2] It's a tiny bit more tricky for a small group of systems

Attack Vector - Clock Skew

- Let's assume we did fix the aforementioned issues, are we done?
- no :(
- (Mainly) due to physical properties (heat, fabrication, ...) clock isn't exact
- This slight imperfection of clock can be used as identifier (clock skew)

Attack Vector - Clock Skew

2005 - Host Identification

Attack Vector - Clock Skew

2005: Host Identification

- Possible even if host/port tuple TCP timestamp solution got implemented
- Multiple IPs virtually hosted not possible with timestamp (because TS per OS)
- With clock skew not a problem, because they share hardware
- Interesting to track users

Attack Vector - Clock Skew

2005: Host Identification - Remediation

- Reduce device's clock skew (difficult!)
- Mask clock skew by multiplying timestamp with random value (breaks RFC)
- mod_skewmask: Mask clock skew with constant
- Encrypt timestamps (breaks RFC)
- Table mapping between random 32-bit values and internal representation of real timestamps (breaks RFC)

Attack Vector - Clock Skew

2015: Host Identification

Still possible[3] ...

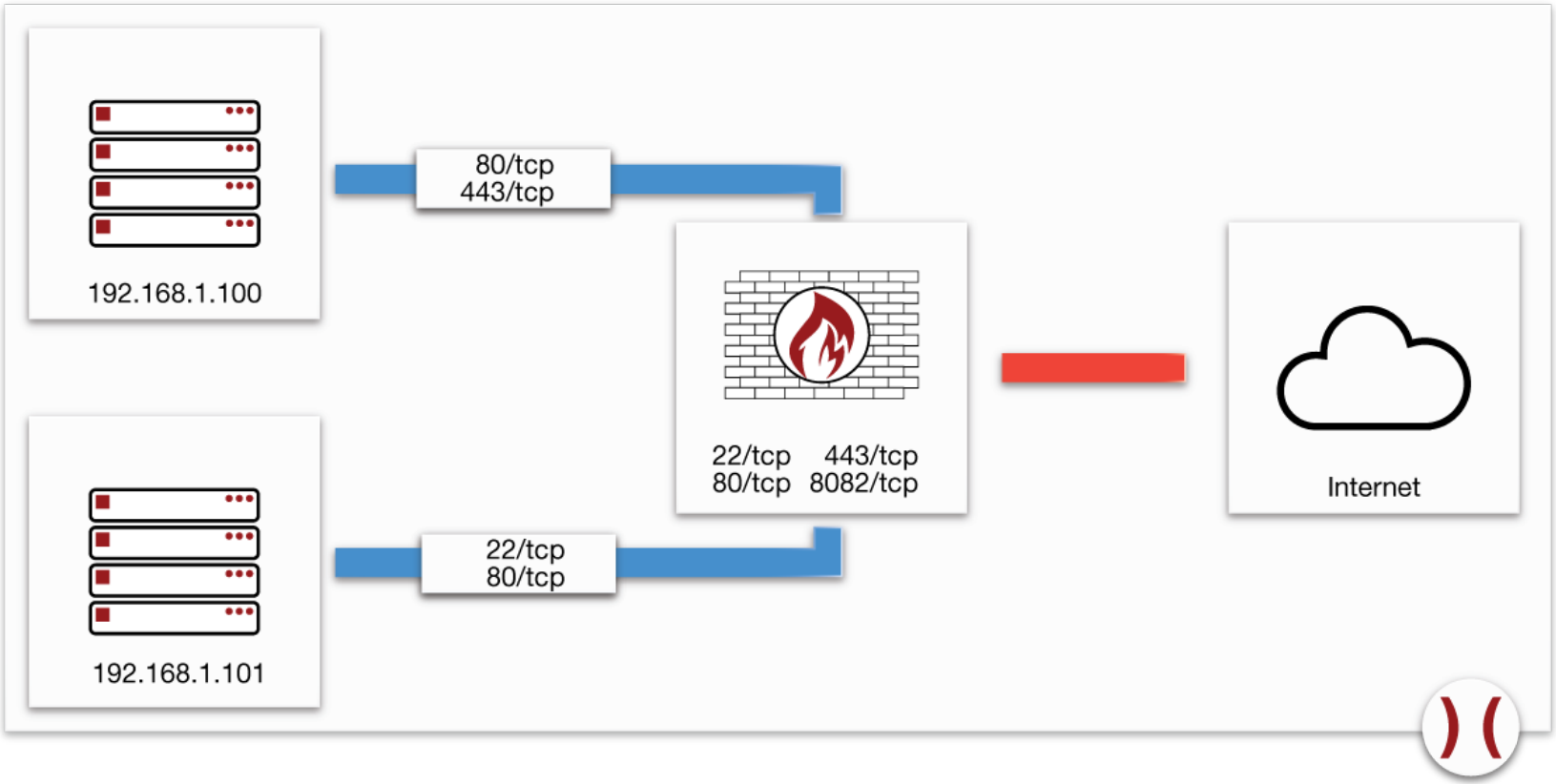
[3] Some honeypots try to avoid it

Attack Vector - Clock Skew

2005 - Network Layout Information Gathering

Attack Vector - Clock Skew

2005: Network Layout Information Gathering



Attack Vector - Clock Skew

2005: Network Layout Information Gathering - Remediation

- Same as for host identification

Attack Vector - Clock Skew

2015: Network Layout Information Gathering

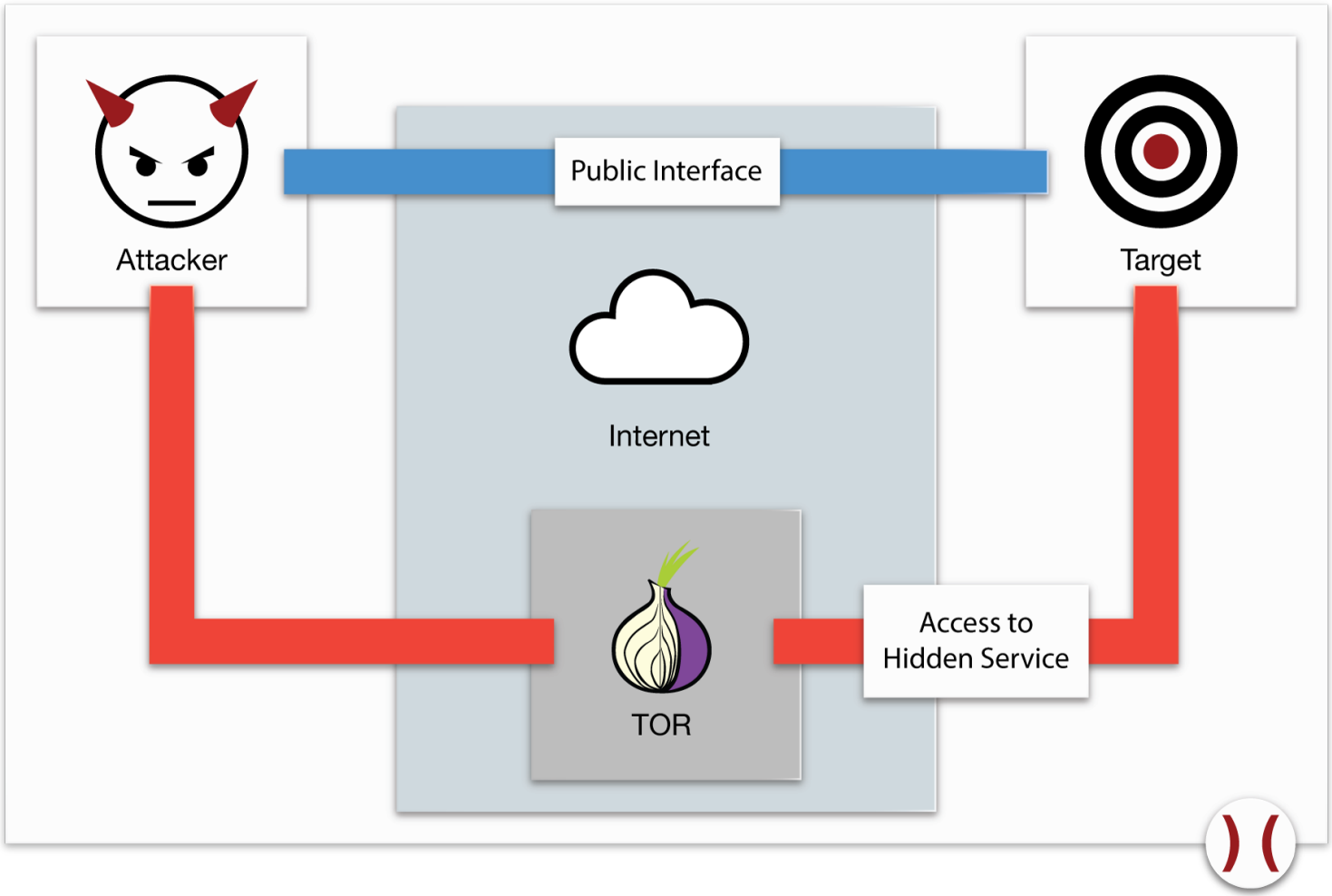
Still possible . . .

Attack Vector - Clock Skew

2006 - Reveal Hidden Services

Attack Vector - Clock Skew

2006: Reveal Hidden Services



Attack Vector - Clock Skew

2006: Reveal Hidden Services - Remediation

- Dummy Traffic
- Fixed QoS for all connections $\Rightarrow$ No anonymous stream affects another (problem: potential DoS if connections idle)
- Oven Controlled Crystal Oscillators (OCXO)
- Always run at maximum CPU load

Attack Vector - Clock Skew

2015: Reveal Hidden Services

Still possible . . .

Possible Targets

- Users
- Servers

Conclusion

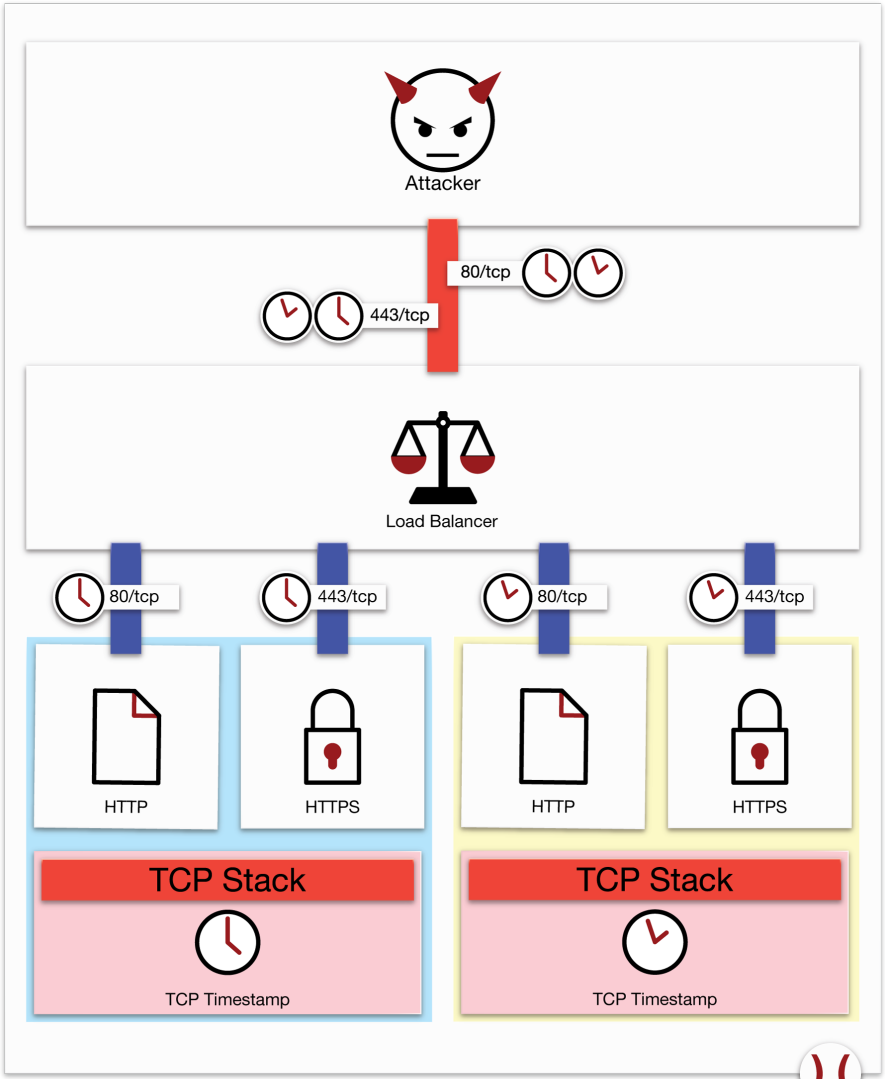
More or less everyone/everything is affected

More Fun with TCP Timestamps

2015 - Reveal Active-Active Loadbalancing

More Fun with TCP Timestamps

2015 Load-Balanced Check!



More Fun with TCP Timestamps

2015 Load-Balanced Check!

```
HPING www.microsoft.com (wlan0 23.200.143.77): S set, 40 headers + 0 data bytes
len=56 ip=23.200.143.77 ttl=50 id=0 sport=80 flags=SA seq=0 win=14480 rtt=1028.0 ms
  TCP timestamp: tcpts=2861966256

len=56 ip=23.200.143.77 ttl=50 id=0 sport=80 flags=SA seq=1 win=14480 rtt=539.9 ms
  TCP timestamp: tcpts=2861966477
  HZ seems hz=100
  System uptime seems: 331 days, 5 hours, 54 minutes, 24 seconds

DUP! len=56 ip=23.200.143.77 ttl=50 id=0 sport=80 flags=SA seq=1 win=14480 rtt=1160.5 ms
  TCP timestamp: tcpts=2861967371
  HZ seems hz=1000
  System uptime seems: 33 days, 2 hours, 59 minutes, 27 seconds

len=56 ip=23.200.143.77 ttl=50 id=0 sport=80 flags=SA seq=2 win=14480 rtt=256.0 ms
  TCP timestamp: tcpts=2861967487
  HZ seems hz=100
  System uptime seems: 331 days, 5 hours, 54 minutes, 34 seconds

len=56 ip=23.200.143.77 ttl=50 id=0 sport=80 flags=SA seq=3 win=14480 rtt=540.3 ms
  TCP timestamp: tcpts=2802823847
```

More Fun with TCP Timestamps

2007/2015 - Network Layout Information Gathering

More Fun with TCP Timestamps

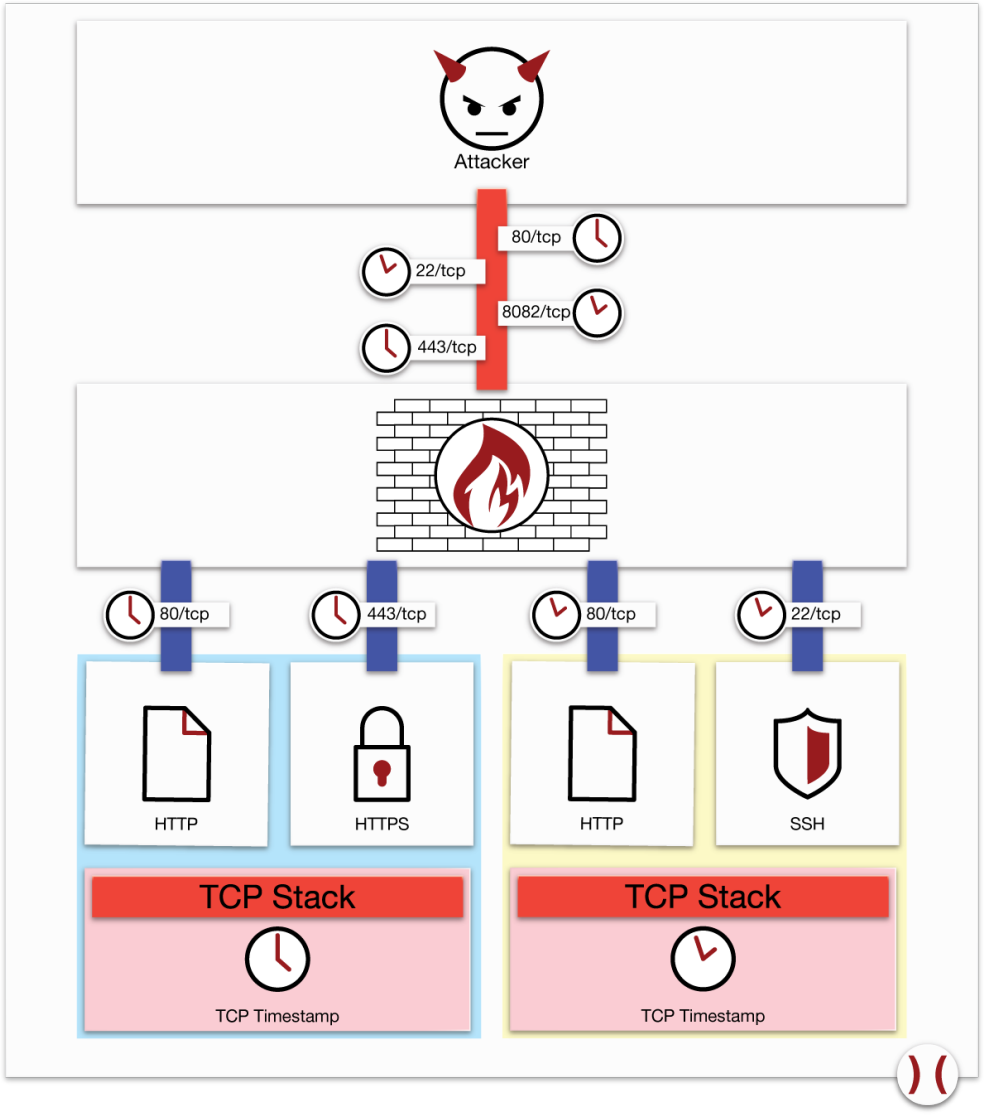
2015: Network Layout Information Gathering

DEMO[4]

[4] https://github.com/luh2/timestamps

More Fun with TCP Timestamps

2015: Network Layout Information Gathering



More Fun with TCP Timestamps

2015: Network Layout Information Gathering

- Count IPs behind a NAT (if you are the receiving end of connections) (2007)
- Identify hosts behind a NAT (if you have multiple ports open) (2015)
- TCP timestamp is the same $\Rightarrow$ services on same host
- TCP timestamp is different $\Rightarrow$ services on different hosts
- Some ports answer with no timestamp $\Rightarrow$ Can't tell

More Fun with TCP Timestamps

2015: Network Layout Information Gathering

- No tool that exploits this knowledge
- Does someone want to write a Nmap script?

More Fun with TCP Timestamps

2007/2015: Network Layout Information Gathering - Remediation

- Increment randomly (defeats RTTM)
- Rewrite timestamp on NAT device

More Fun with TCP Timestamps

2015 - Improve OS Fingerprints of NAT-ed Devices

More Fun with TCP Timestamps

2015 Improve OS Fingerprints

- Repeat: What is a OS Fingerprint?
- Nmap doesn't assume aforementioned scenario, but direct fingerprinting
- Use knowledge which ports belong together
- Don't use closed ports

More Fun with TCP Timestamps

2015 Improve Fingerprints!

DEMO

Proposed Solutions

- Terminate TCP connection at firewall

Why Haven't We Fixed This?

Quote: Kohno et al.

[...] it is possible to extract security-relevant signals from data canonically considered to be noise.

- "There are other ways to gather the same intel"-excuse
- Not considered important
- Not many good solutions so far

More Timestamps

- ICMP Timestamp (CVE-1999-0524)
- TLS Timestamp (Tor Bug #7277)
- HTTP Timestamp (Murdoch, 2013)
- ...

Summary of (presented) Attacks

- TCP Timestamps
  - 2001 - Uptime Calculation
  - 2005 - Host Identification
  - 2015 - Network Layout Information Gathering
  - 2015 - Reveal Active-Active Loadbalancing
  - 2015 - Improve OS Fingerprints of NAT-ed Devices
- Clock Skew
  - 2005 - Host Identification / User Tracking
  - 2005 - Network Layout Information Gathering
  - 2006 - Reveal Hidden Services

What Now?

Good solutions/suggestions welcome!

For Further Reading

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SkewMask: Frustrating ClockSkew Fingerprinting Attempts.
December, 2007

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IEEE Transactions on Dependable and Secure Computing, vol. 2, no. 2, pp. 93–108, May 2005.

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Proceeding LASER '12 Proceedings of the 2012 Workshop on Learning from Authoritative Security Experiment Results, Pages 9-18.

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For Further Reading 2

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TCP Extensions for High Performance.
Network Working Group, Request for Comments: 1323, May 1992

S. Bellovin.
Defending Against Sequence Number Attacks.
Network Working Group, Request for Comments: 1948, May 1996

M. Silbersack.
Improving TCP/IP security through randomization without sacrificing interoperability.
University of Wisconsin – Milwaukee, 2005

S. Murdoch.
Hot or not: revealing hidden services by their clock skew.
Proceeding CCS '06 Proceedings of the 13th ACM conference on Computer and communications security, Pages 27 - 36

So Long and Thanks For All The Fish

Me: @fenceposterror

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