Weak keys remain widespread in network devices

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Motivation

Factored 0.5% of HTTPS RSA public keys on the internet

Weak keys were due to random number generator failures

Affected only small network devices

Major disclosure process to companies producing vulnerable products
What happened? A follow-up study.

- What happened since 2012?
- Did vendors fix their broken implementations?
- Can we observe patching behavior in end users?
Background on Ps and Qs: The GCD Vulnerability

Public Key

\[ N = pq \text{ modulo } \]

Private Key

\[ p, q \text{ primes} \]

Vulnerability

\[ \gcd(N_1, N_2) = p \]

\[ \rightarrow \text{Detect vulnerability by presence of factored key on host.} \]
Methodology for this study

What happens when we ask vendors to fix a vulnerability?

1. Aggregated internet-wide TLS scans from 2010-2016
2. Computed GCDs for 81.2 million RSA moduli
3. Identified vendors of vulnerable implementations
4. Examined results based on response to 2012 notification
Data sources: how to read the plots

- Scan sources along top of plot
- Scan dates on x-axis
- Absolute counts on y-axis

![Graph showing data over time with sources and date markers]
Fingerprinting specific implementations

Certificate subjects
- Cisco: OU=RV120W, O=Cisco Systems, Inc.
- Juniper: CN=system generated
- HP: O=Hewlett-Packard
- Xerox: O=Xerox Corporation
- Innominate: O=Innominate

Shared primes heuristic
Shared prime $\Rightarrow$ same implementation.
Original notification

- Low response rates from vendors
- Took place March-June 2012

Vendor response to original notification

<table>
<thead>
<tr>
<th></th>
<th>Public Response</th>
<th>Private Response</th>
<th>Auto-responder</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>5</td>
<td>11</td>
<td>3</td>
<td>18</td>
</tr>
</tbody>
</table>
Research questions: what are we looking for?

Prior work: what we hope to see

- Patch one implementation, notify many users [Debian OpenSSL: Yilek et al. 2009; Heartbleed: Durumeric et al. 2014]
Research questions: what are we looking for?

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Questions

- What happened with different vendors?
- Did patch rates improve when vendors released a public advisory?
- Do we see the same trends as previous studies?
Innominate
mGuard network security devices (Smart, PCI, Industrial RS, Blade, Delta, EAGLE)

- Public advisory in June 2012
- Consistent population of vulnerable devices since 2012
- New devices not vulnerable, but old devices not patched
Juniper
SRX Series Service Gateways (SRX100, SRX110, SRX210, SRX220, SRX240, SRX550, SRX650), LN1000 Mobile Secure Router

- Public security bulletin in April 2012, out-of-cycle security notice in July 2012
- Majority of factored keys in 2012 were Juniper hosts
- Weird behavior in April 2014
Juniper
SRX Series Service Gateways (SRX100, SRX110, SRX210, SRX220, SRX240, SRX550, SRX650), LN1000 Mobile Secure Router

- 30,000 Juniper-fingerprinted hosts (9000 vulnerable) came offline after Heartbleed
- IPs do not reappear in later scans: TLS disabled, scans blocked, devices offline?
IBM
Remote Supervisor Adapter II, BladeCenter Management Module

- Public security advisory (CVE-2012-2187) in September 2012
- Prime generation bug: 36 possible public keys from 9 primes
- 100% of fingerprintable moduli are vulnerable

![Graph showing vulnerable hosts over time]

- EFF
- P&Q
- Ecosystem
- Rapid7
- Censys

Heartbleed
Cisco
RV120W/220W, WRVS4400N, SA520/520W, RVS4000, SA540, RV180/180W, RV130, RV320, RV130W, ISA550/550W, ISA570

- Substantial private response; no public advisory
- Vulnerable population rises for several years after notification

![Graph showing the growth in vulnerable and total devices over time for different entities, including EFF, P&Q, Ecosystem, Rapid7, and Censys.](image)
HP

Integrated Lights-Out management card

- Substantial private response; no public advisory
- Internet reports: Integrated Lights-Out (iLO) management cards crash when scanned for Heartbleed

![Graph showing Heartbleed vulnerabilities over time with data points for EFF, P&Q, Ecosystem, Rapid7, and Censys. The x-axis represents dates from 07-2010 to 05-2016, and the y-axis represents the number of vulnerable and total systems. The Heartbleed vulnerability is highlighted with a timeline across the dates.]
Linksys

- Did not respond to 2012 notification
- No evidence of patching: vulnerability decrease correlated with total decrease
Huawei

- Introduced vulnerability in 2014
- Security advisory published Aug 2016
End-User Patching Behavior

- Few vendors released patches; limited visibility into patching behavior.

- Patching rate is low: Decreasing vulnerability due to device churn.

- Low patch rate for devices has distressing implications for “Internet of Things” security [Yu et al. 2015]

- Vulnerability publicity campaigns (Heartbleed) effective, with unintended consequences
Failure in the Vendor Notification Process

- Security contact information is not available (16/42 vendors had discoverable contacts)

- Few public security advisories

- Organizations such as CERT/CC may increase vendor responses, but don’t result in significant patching behavior [Arora et al. 2010, Li et al. 2016]
“Care must be taken that enough entropy has been added to the pool to support particular output uses desired.”

“Once one has gathered sufficient entropy, it can be used as the seed to produce the required amount of cryptographically strong pseudo-randomness”
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