Weak keys remain widespread in network devices

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Motivation

[Mining Your Ps & Qs: Detection of Widespread Weak Keys in Network Devices: Heninger Durumeric Wustrow Halderman 2012; Public Keys: Lenstra et al. 2012]

- 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

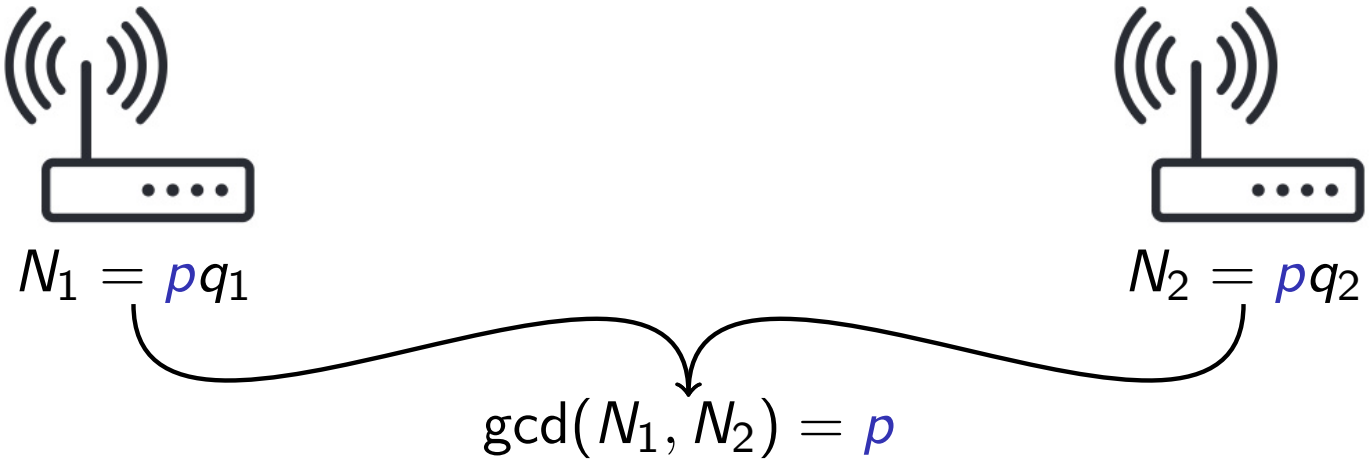
Public Key

$N = pq$ modulus

Private Key

p, q primes

Vulnerability



$\Longrightarrow$ Detect vulnerability by presence of factored key on host.

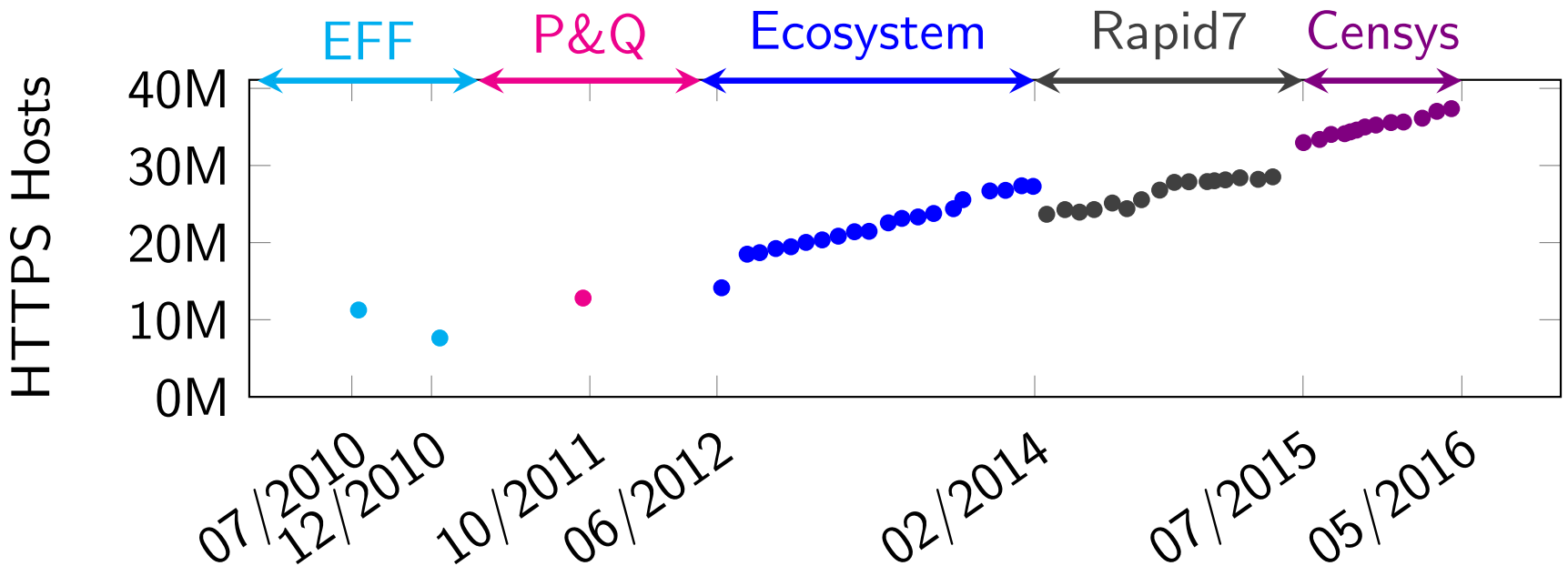
Methodology for this study

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

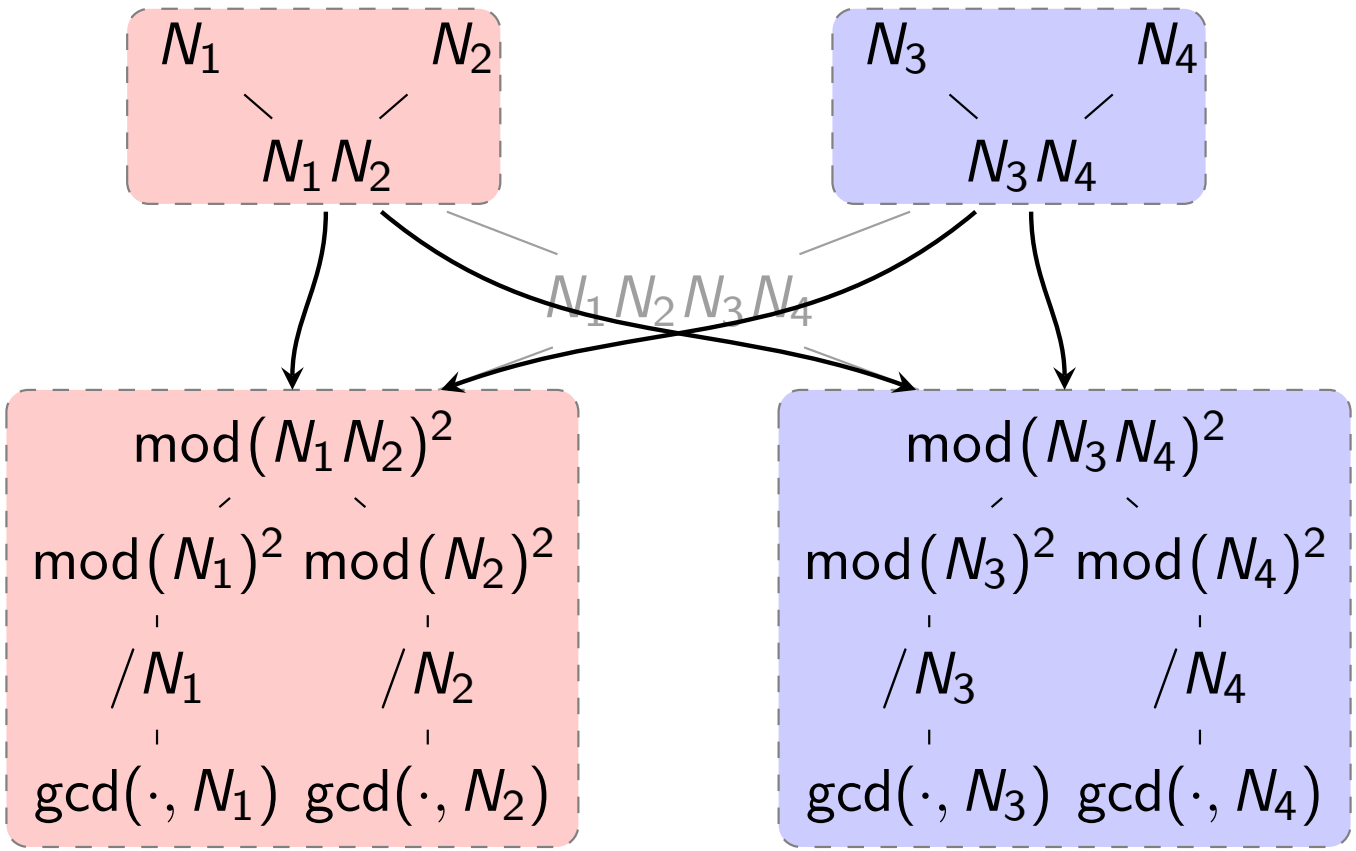
Data sources: how to read the plots

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



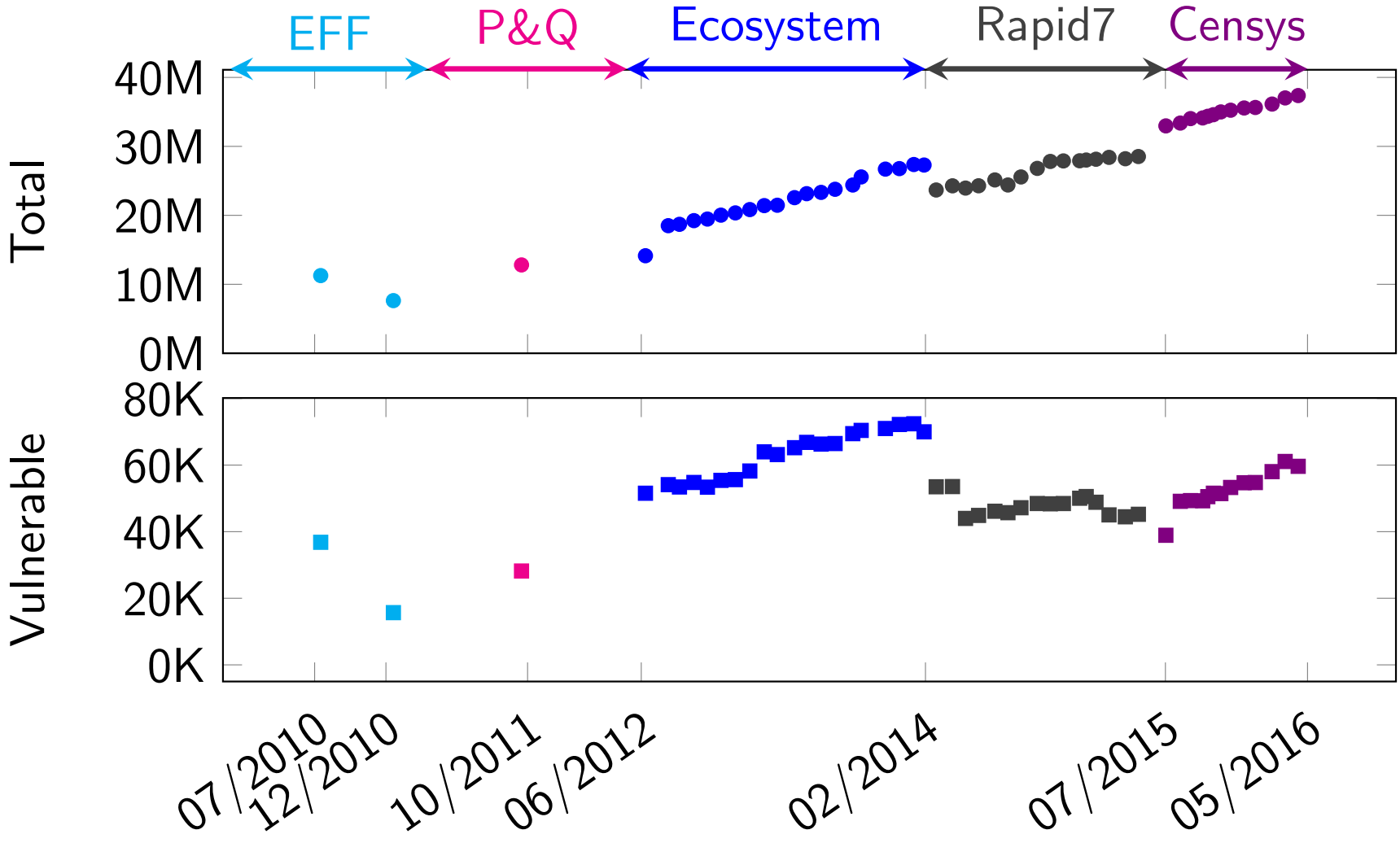
Computing pairwise greatest common divisors with batch GCD

- Pairwise GCD is infeasible (˜3500 CPU years)
- Parallelized version of an algorithm due to Bernstein
- Performed on cluster with 760 cores, 9TB RAM
- 1089 CPU hours; 86 wall-clock minutes



Six years of factoring keys

- 51 million distinct HTTPS RSA moduli : 0.43% vulnerable
- 65 million distinct HTTPS certificates : 2.2% vulnerable
- 1.5 billion HTTPS host records : 0.19% vulnerable



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`

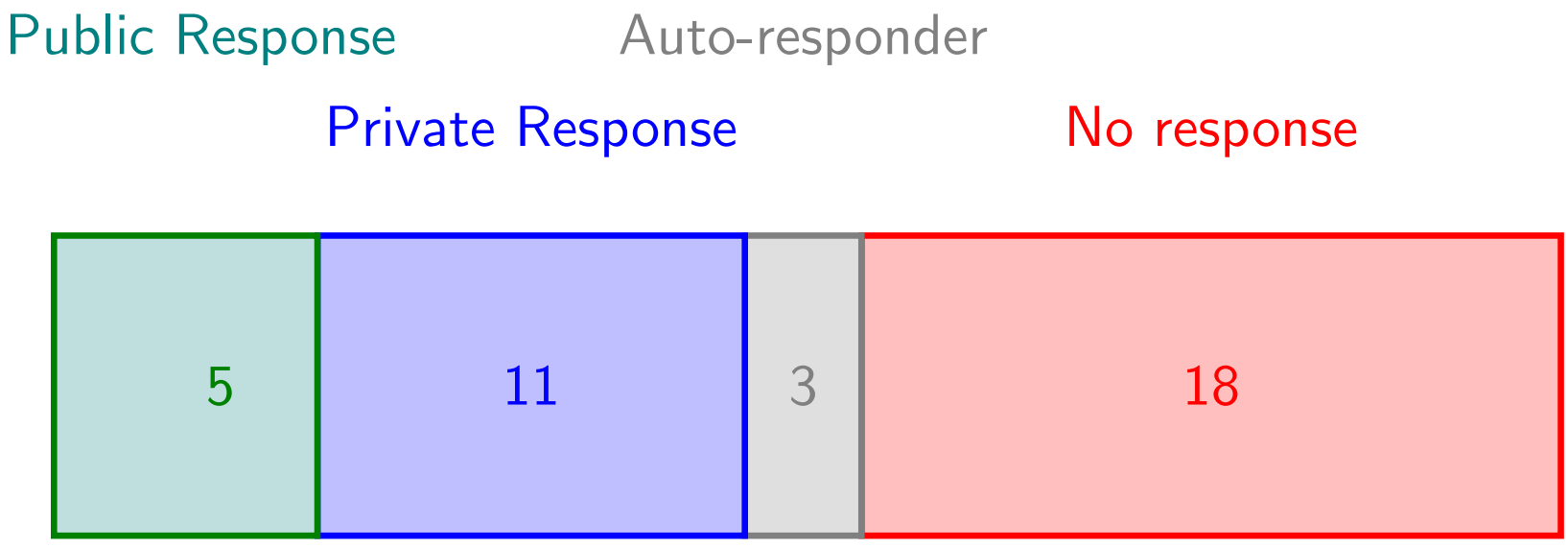
Shared primes heuristic

Shared prime $\Rightarrow$ same implementation.

Original notification

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

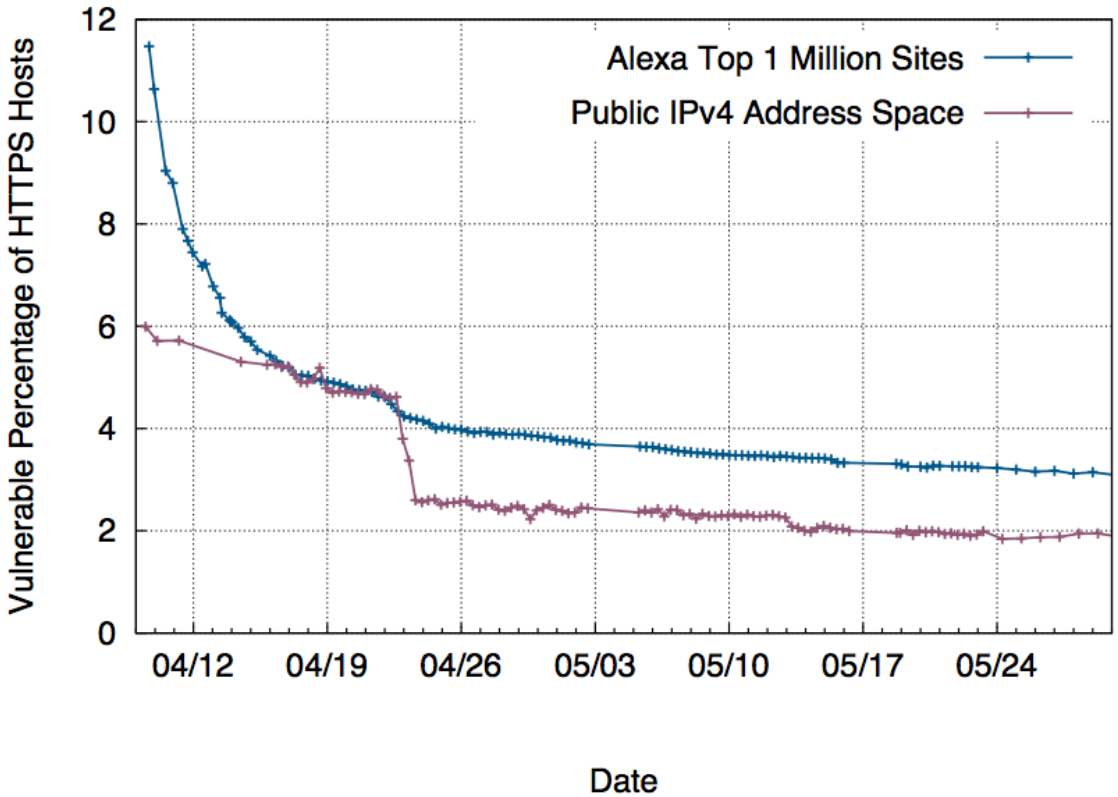
Vendor response to original notification



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]



[Durumeric et al. 2014]

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]
- Feasibility and effectiveness of notifications [Li et al. 2016, Stock et al. 2016]

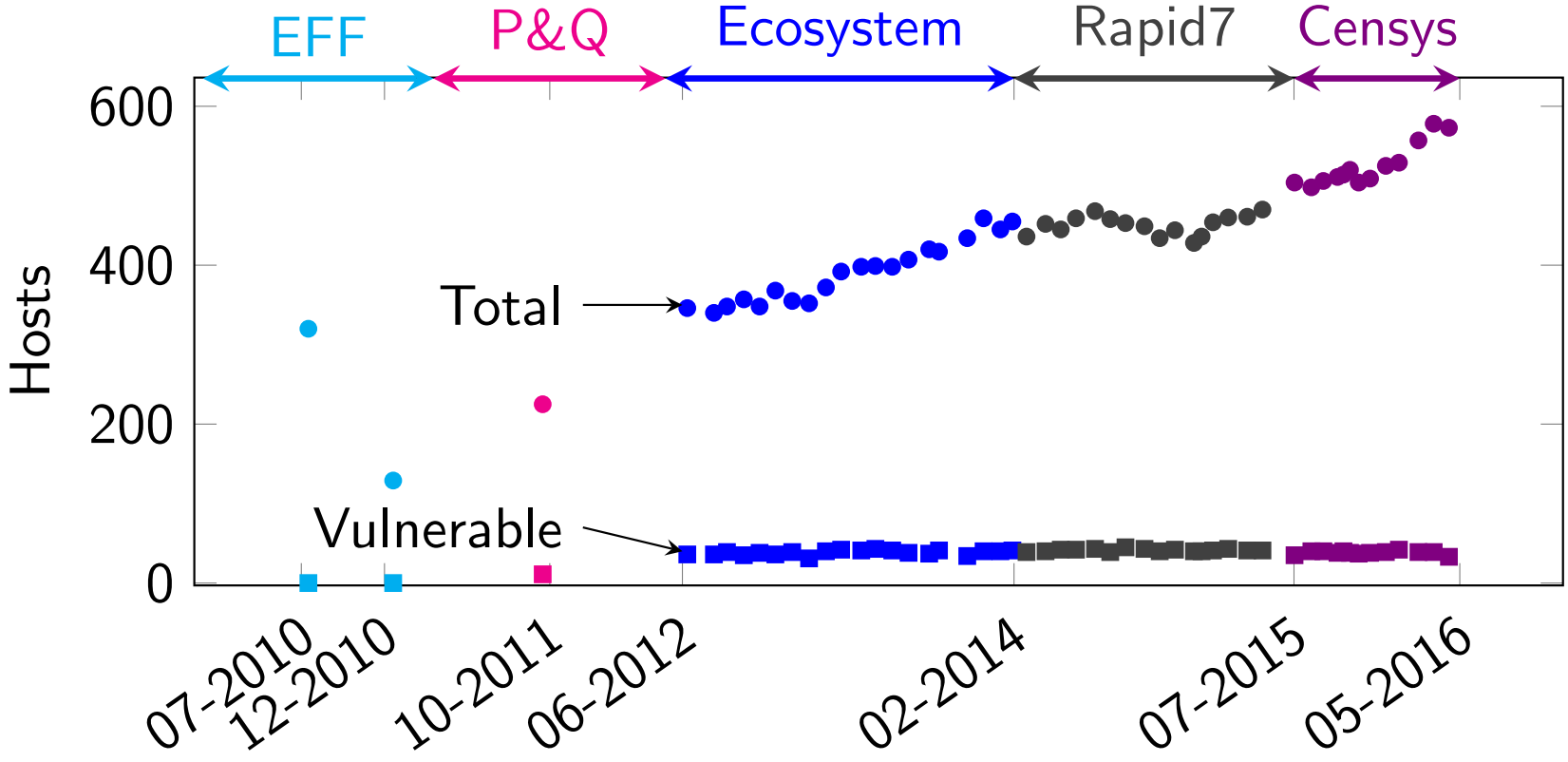
Questions

- 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)

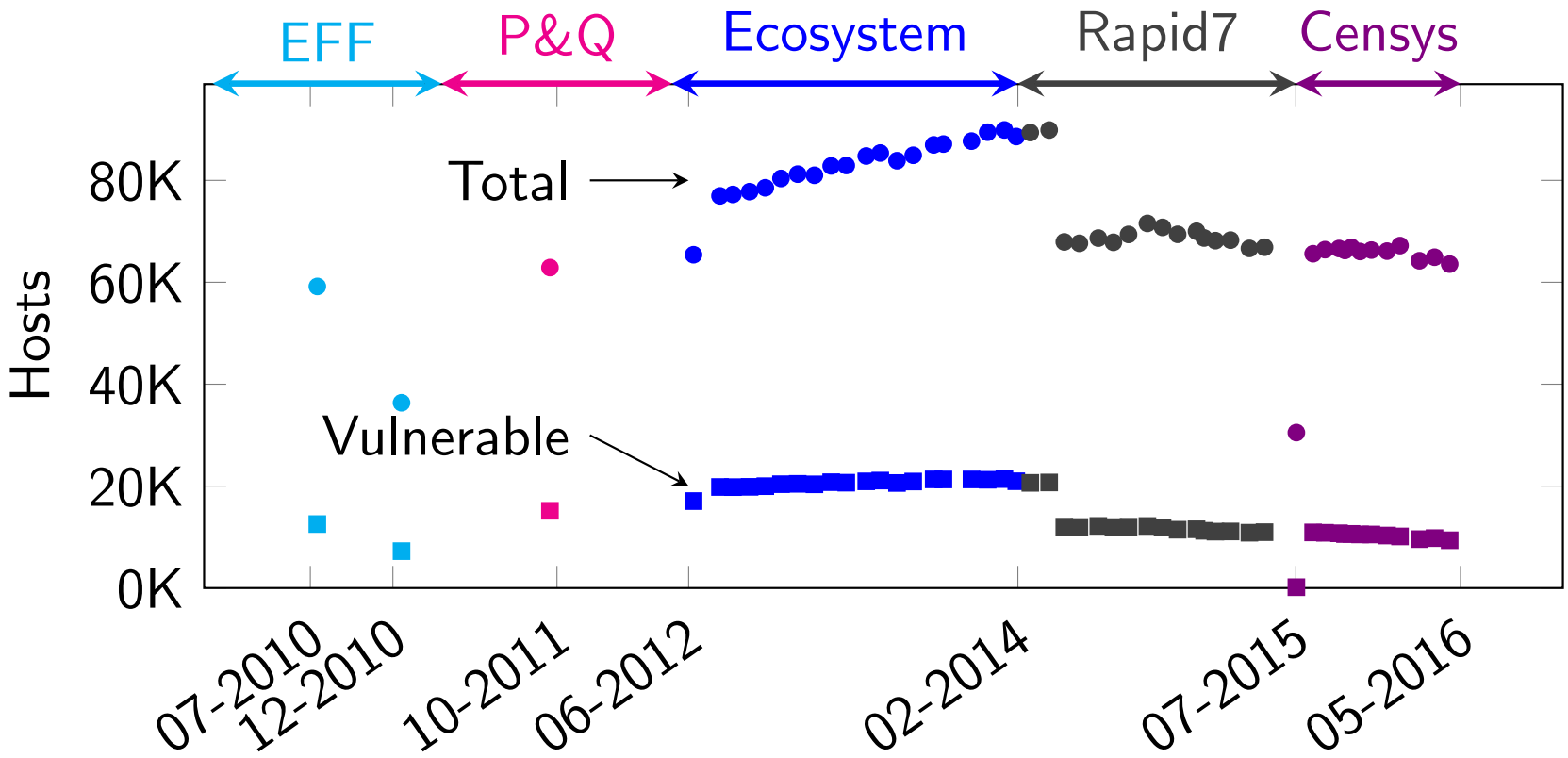
- Public advisory in June 2012
- Consistent population of vulnerable devices since 2012
- New devices not vulnerable, but old devices not patched



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



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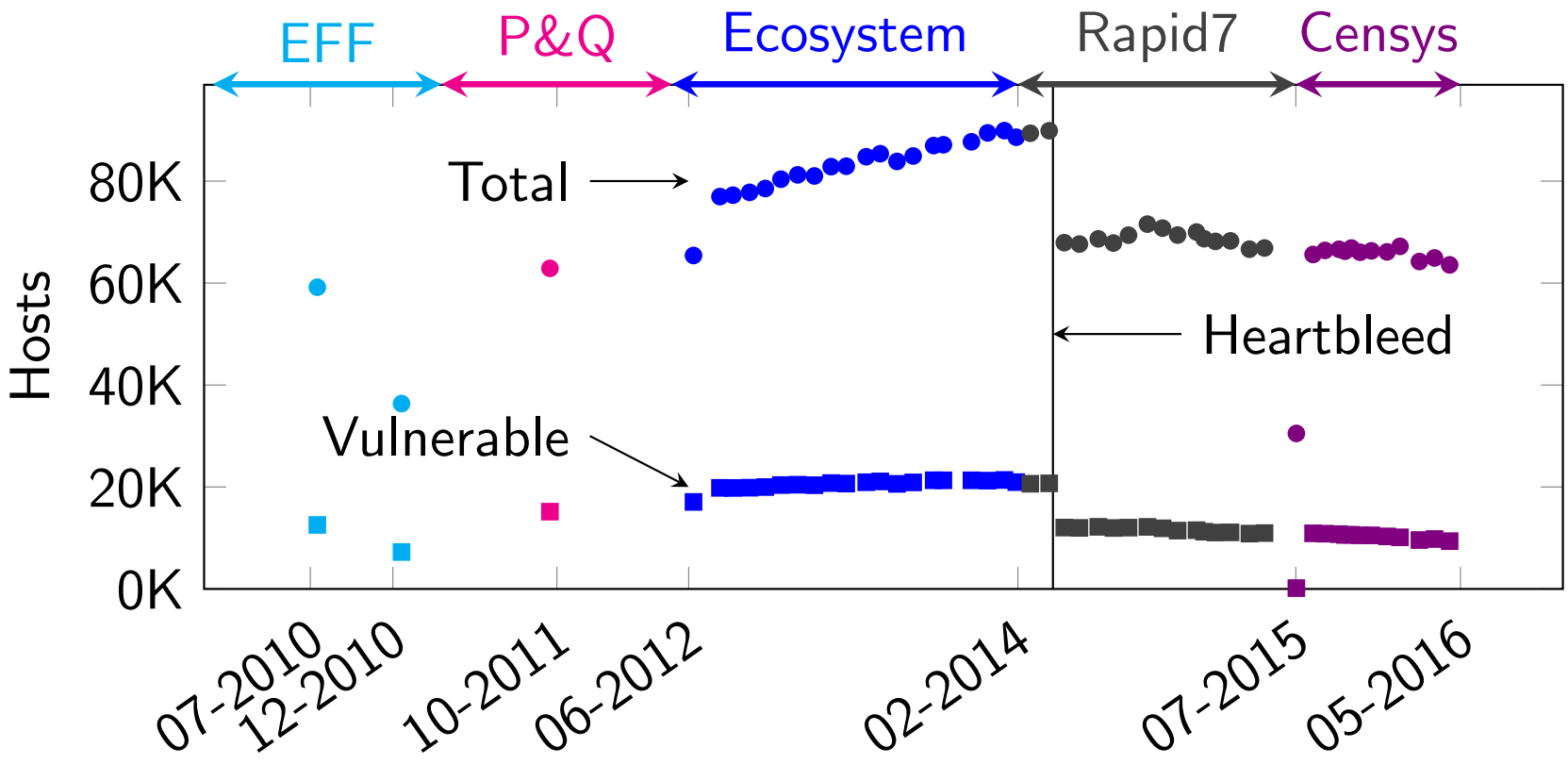
- 30,000 Juniper-fingerprinted hosts (9000 vulnerable) came offline after Heartbleed
- IPs do not reappear in later scans: TLS disabled, scans blocked, devices offline?



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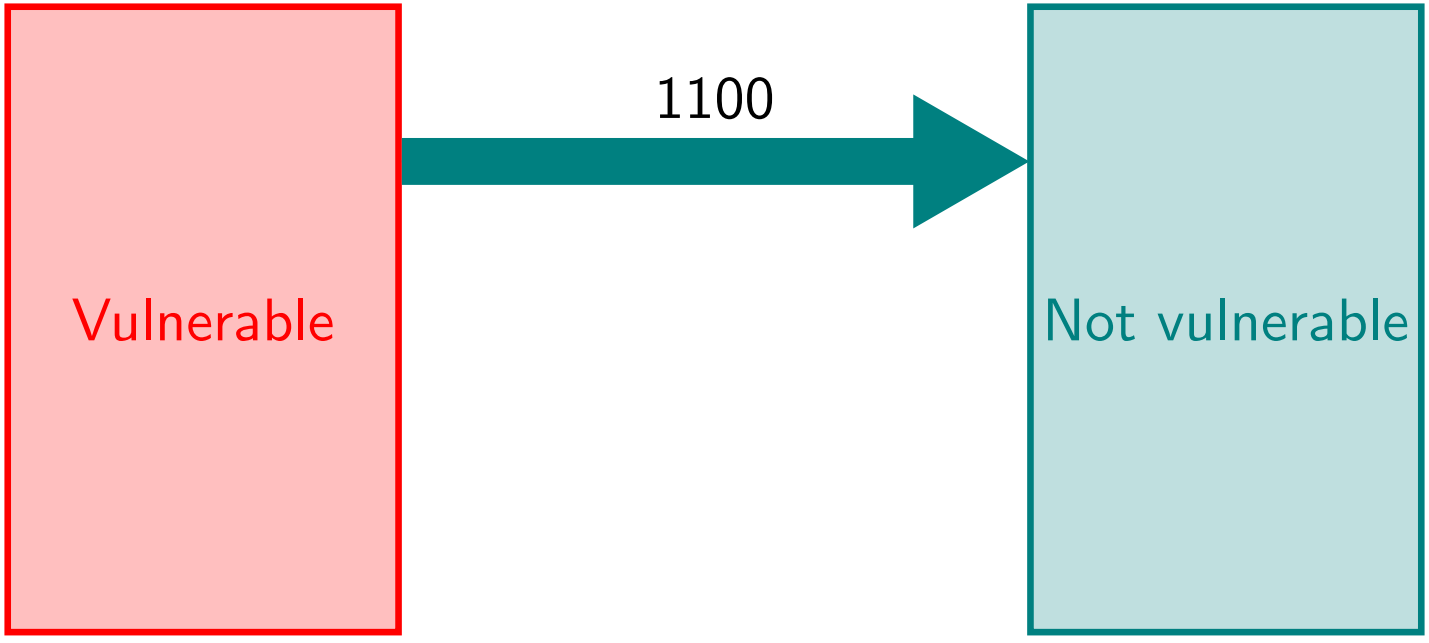

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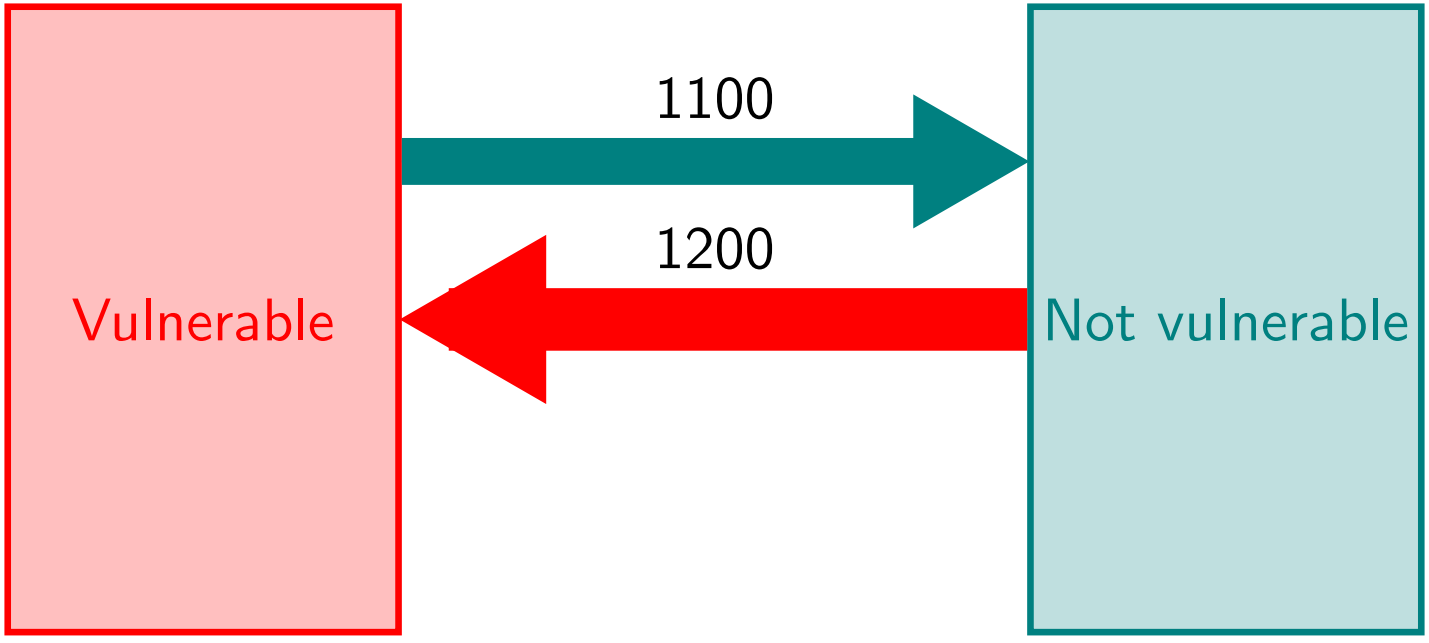

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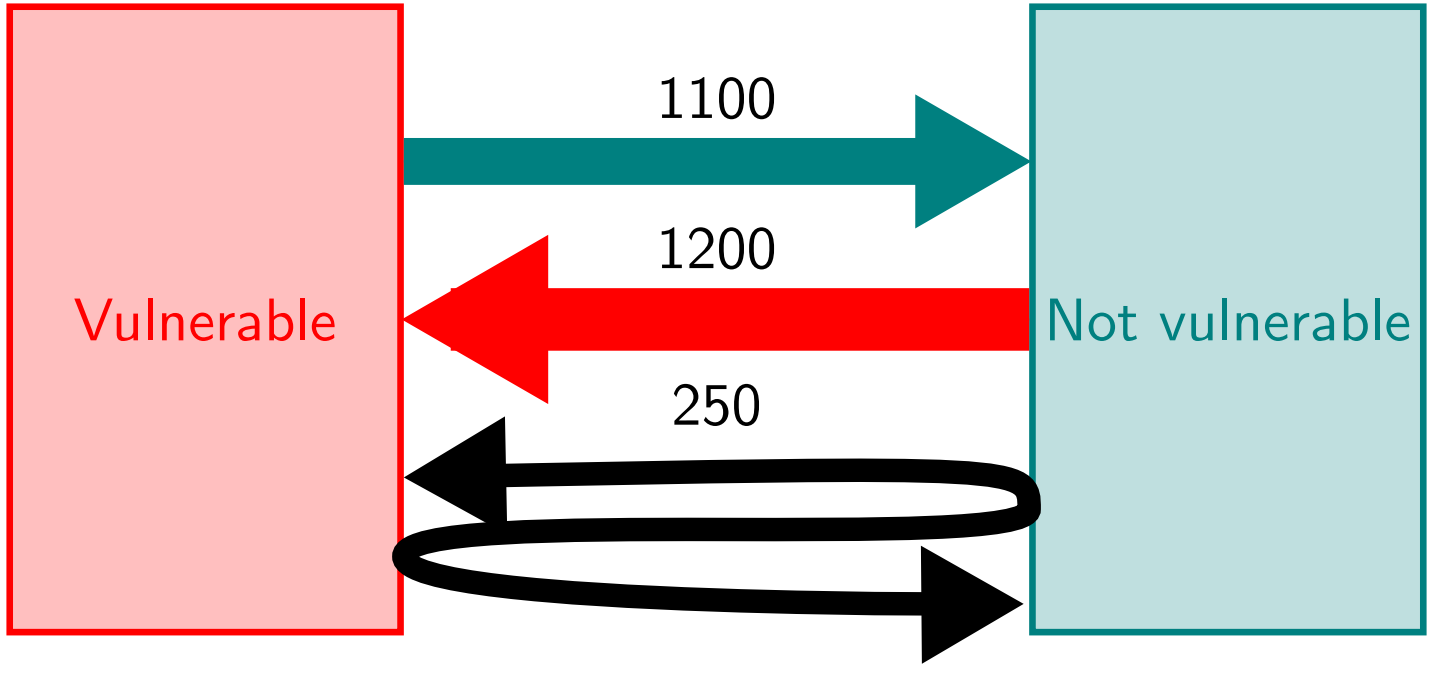
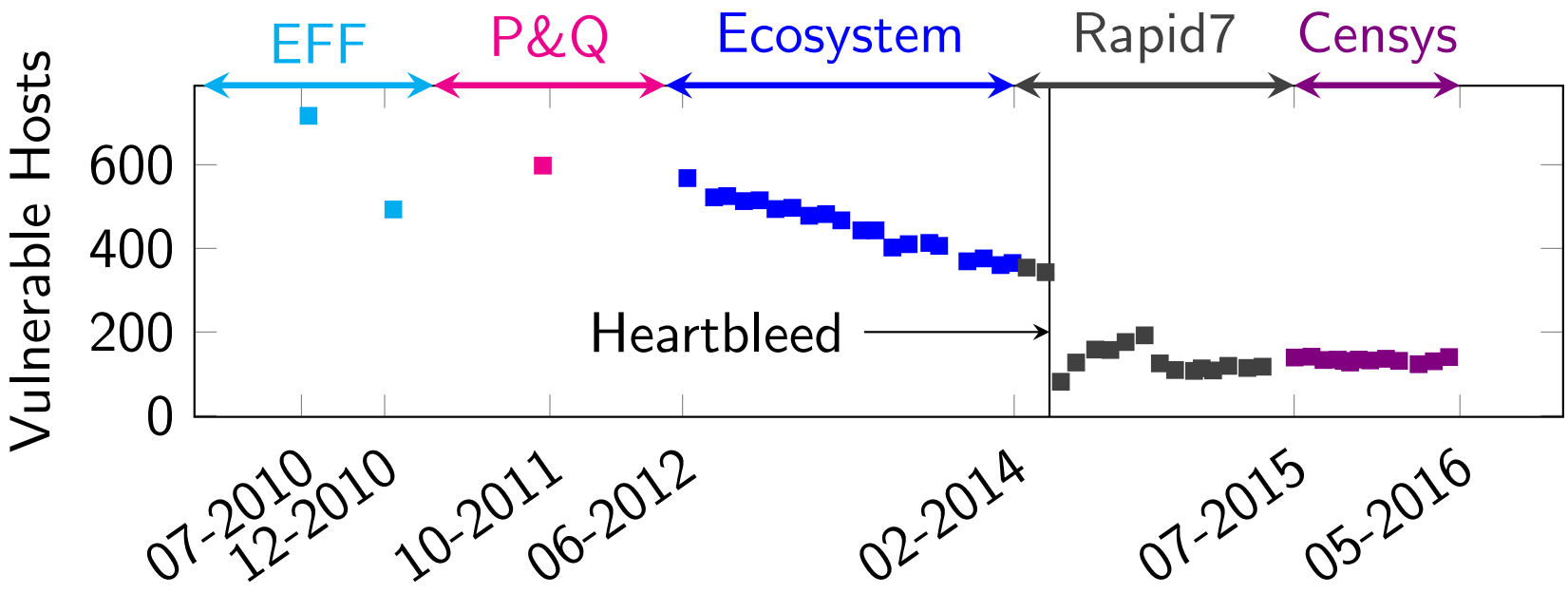


IBM

Remote Supervisor Adapter II, BladeCenter Management Module

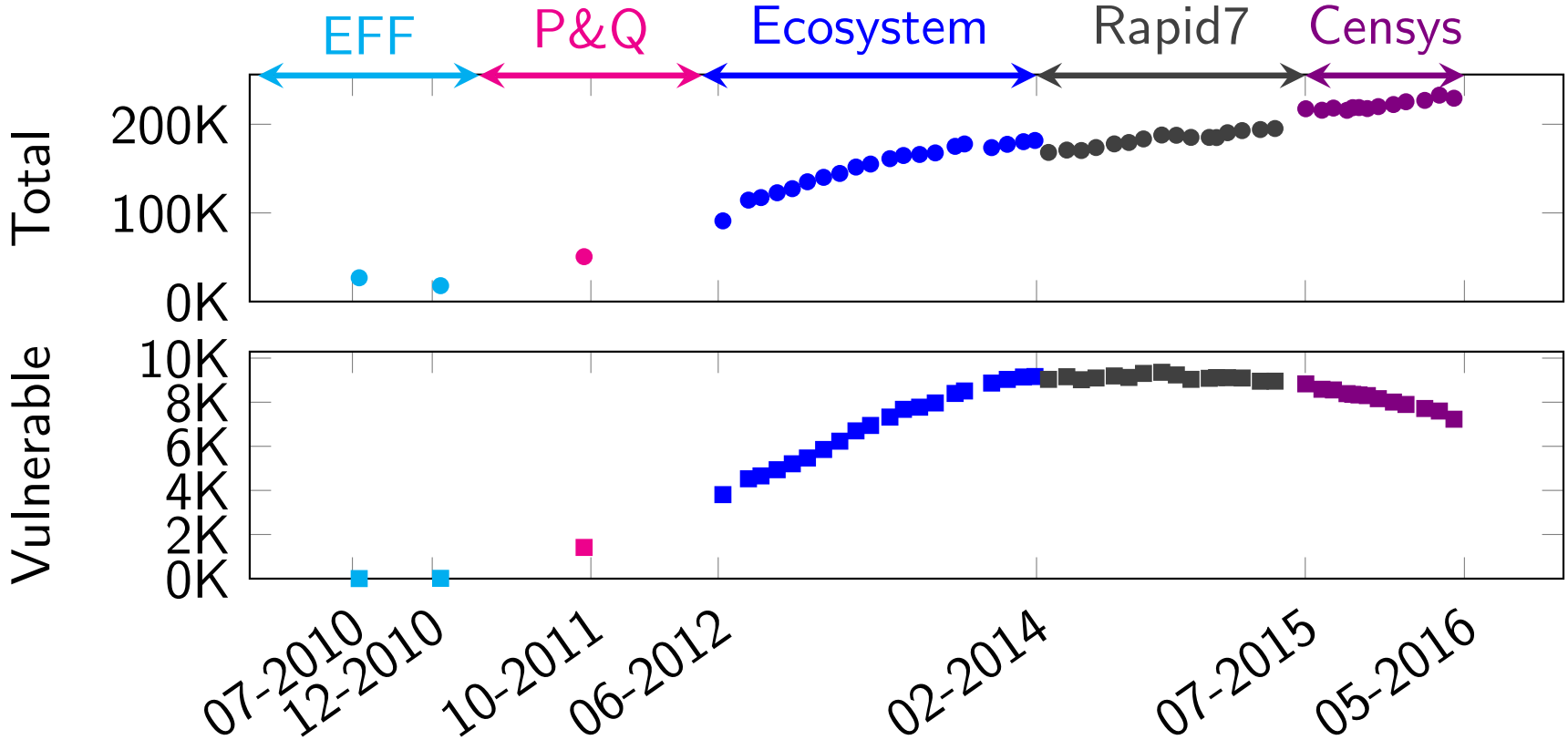
- Public security advisory (CVE-2012-2187) in September 2012
- Prime generation bug: 36 possible public keys from 9 primes
- 100% of fingerprintable moduli are vulnerable



Cisco

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

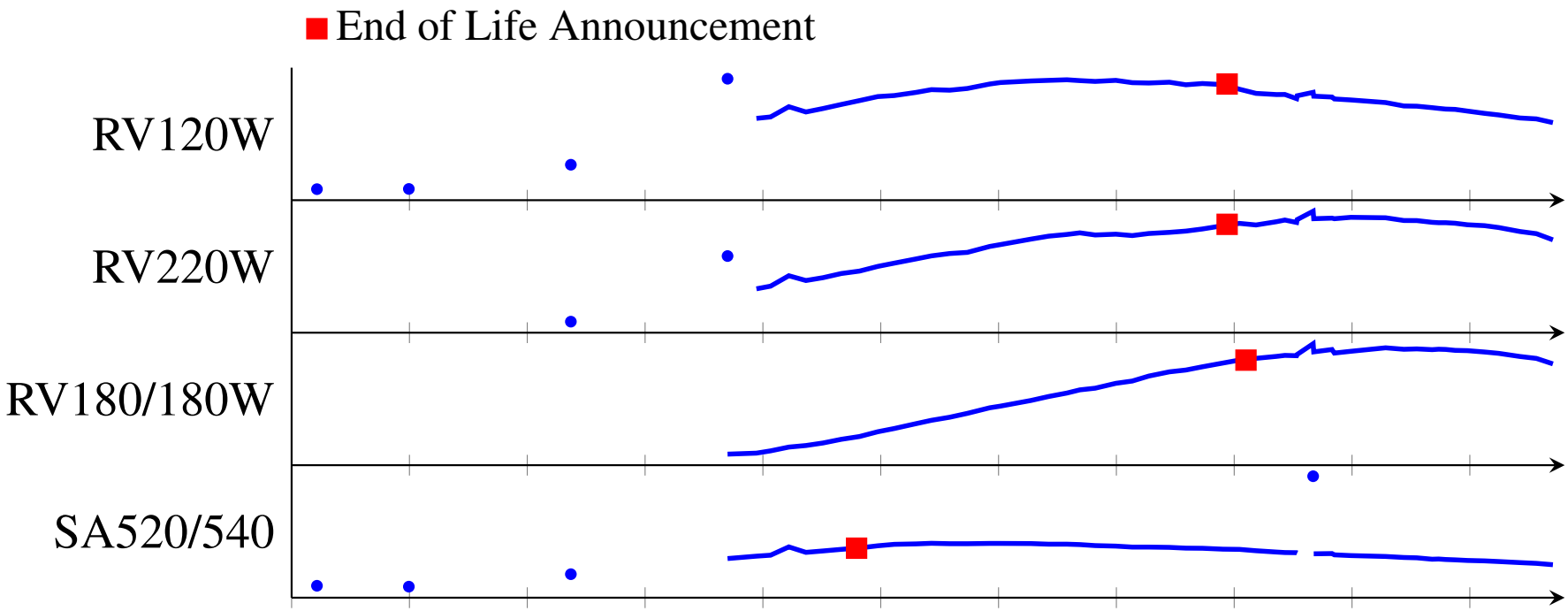
- Substantial private response; no public advisory
- Vulnerable population rises for several years after notification



Cisco

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

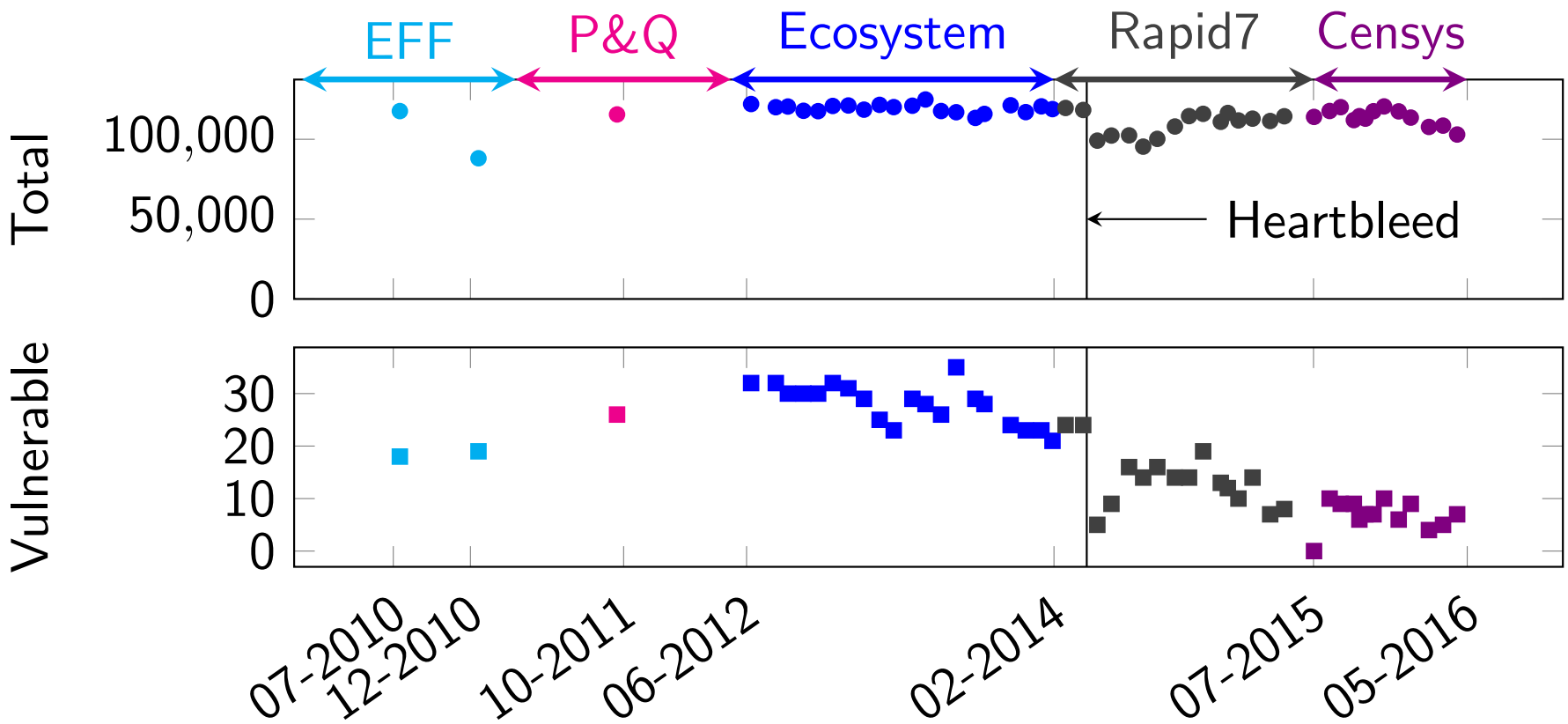
- 91.5% of vulnerable certificates include model identifier
- 10 of 14 have end-of-life announcement by May 2016
- Vulnerable devices are reaching end-of-life, not being patched



HP

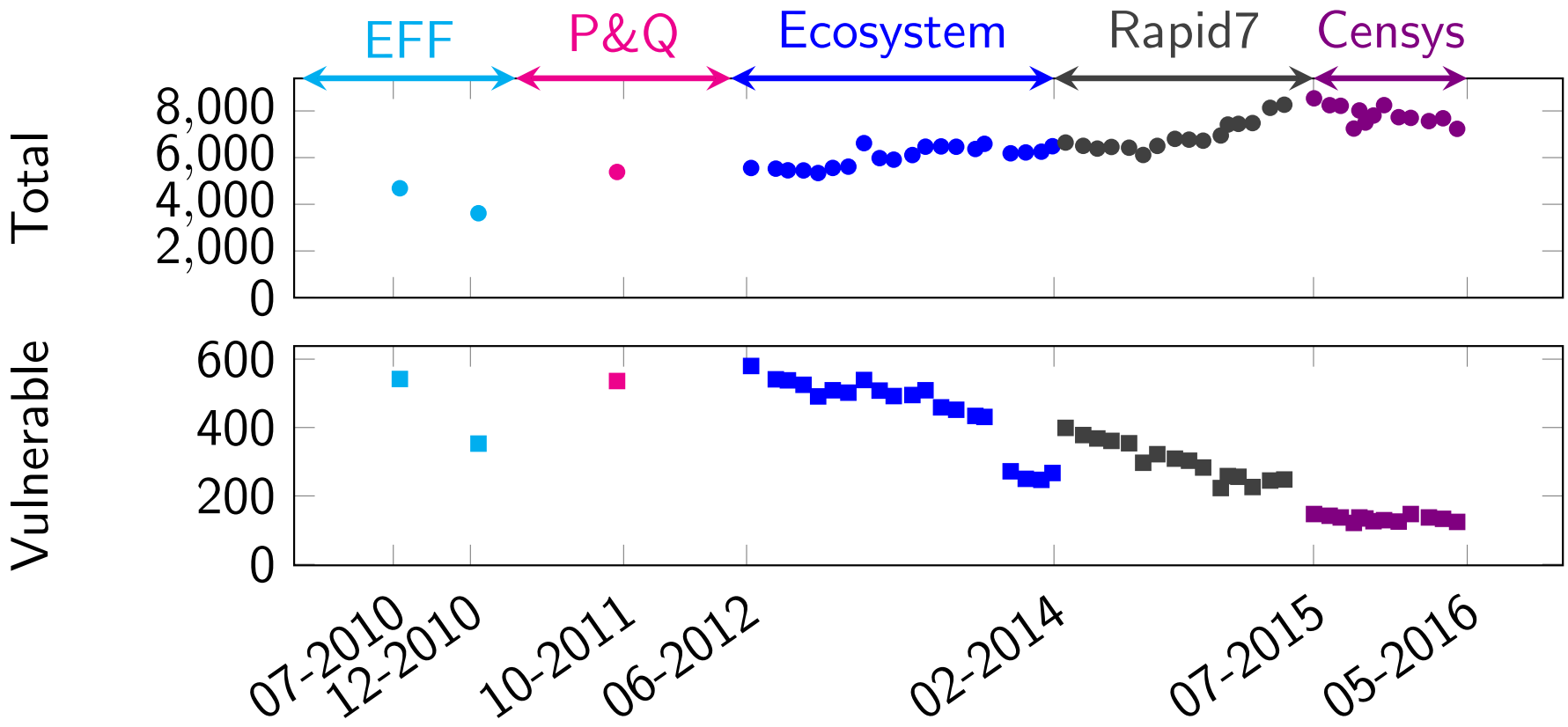
Integrated Lights-Out management card

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



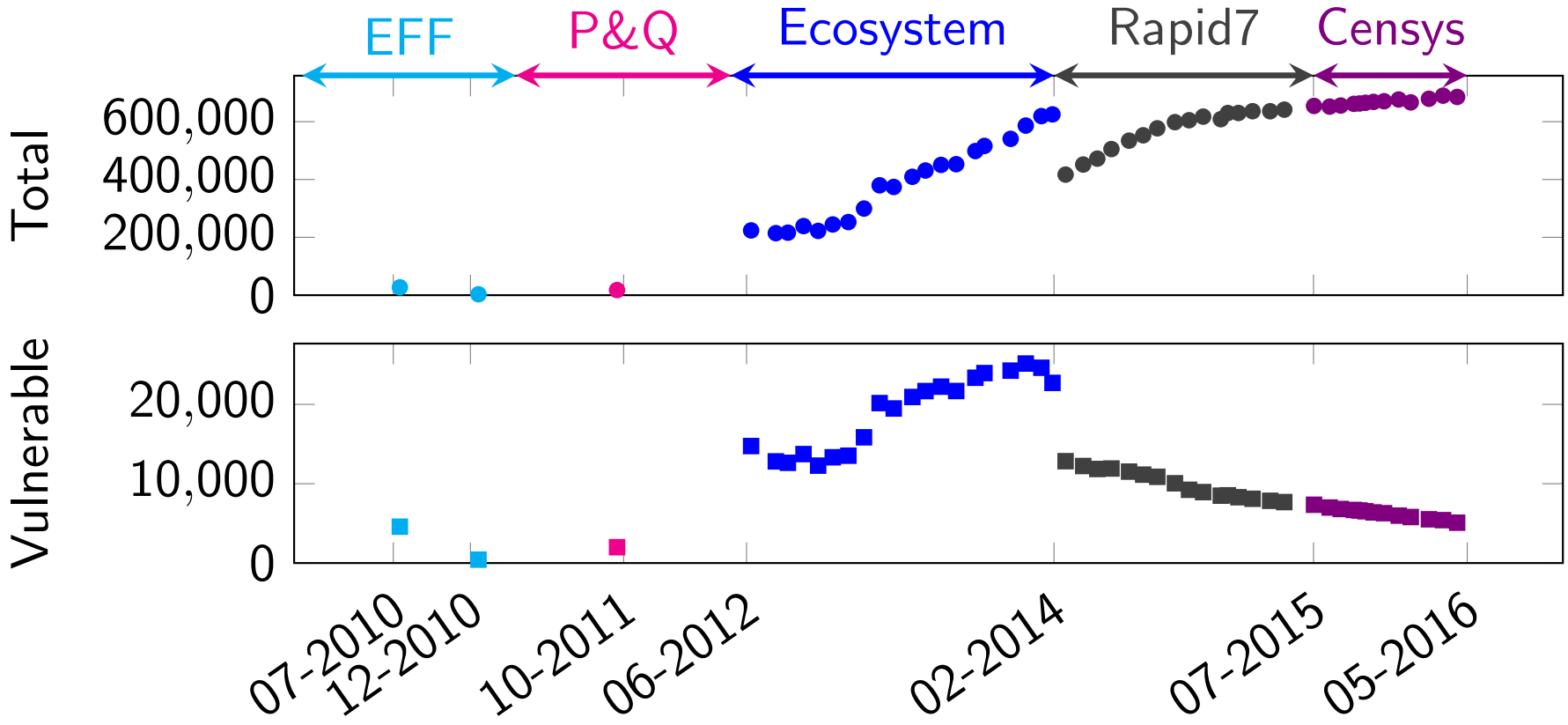
Xerox

- Did not respond to 2012 notification
- Evidence of patching or deprecating starting in 2012



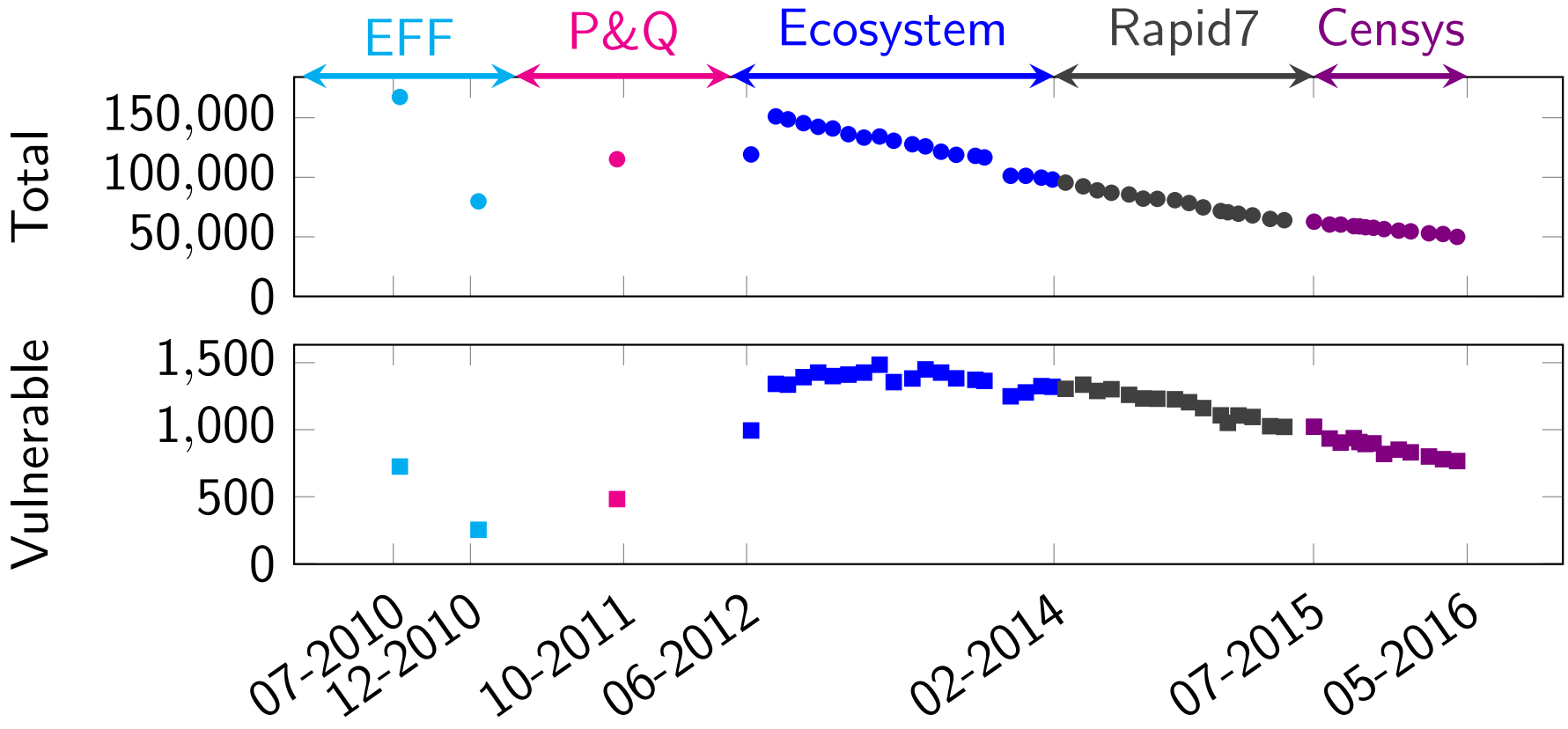
Fritz!Box

- Did not respond to 2012 notification
- Evidence of patching or deprecating in 2014
- Some artifacts from scanning methodologies



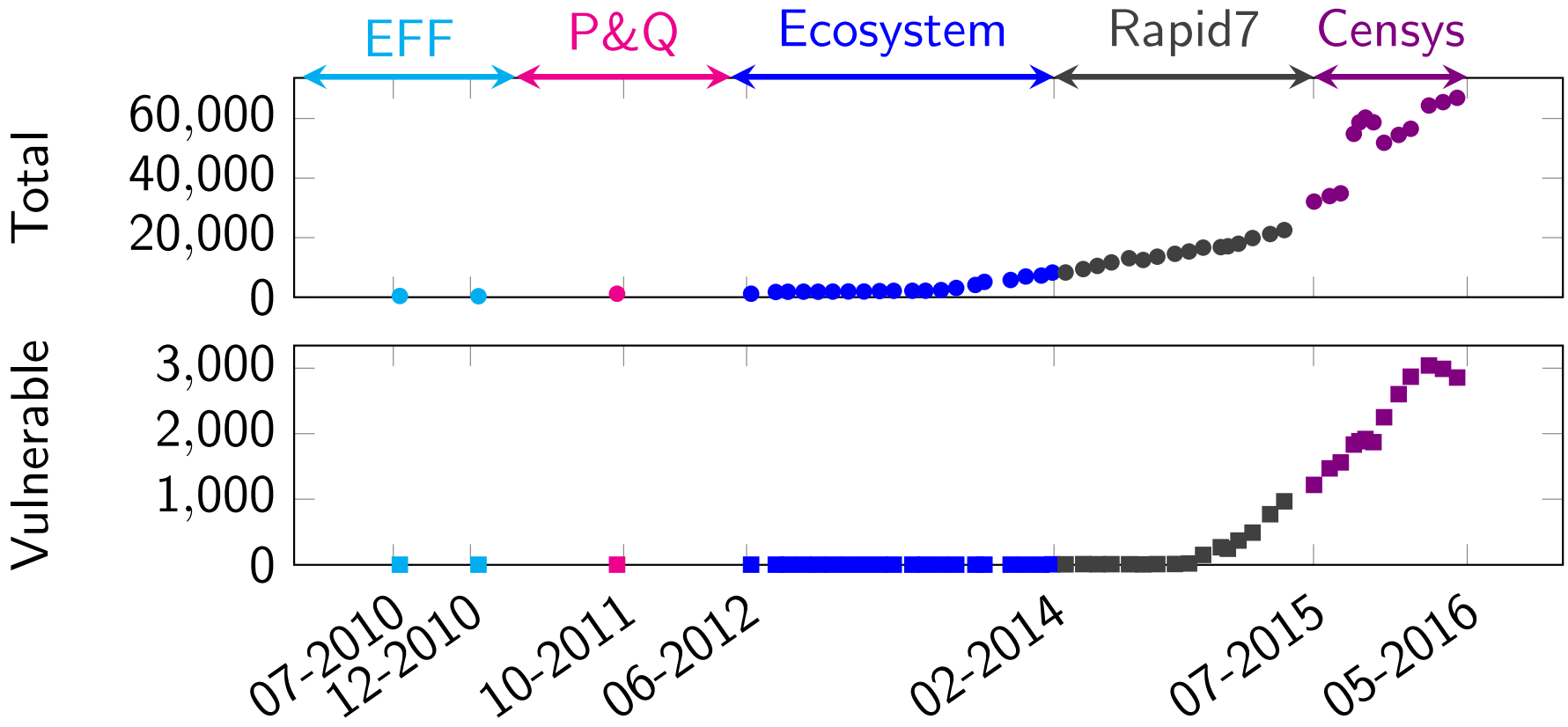
Linksys

- 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



New notifications in 2016

- Two public advisories (Huawei, Siemens)
- One private, substantial response (AdTran)
- One no-response via dedicated security contact (DLink)
- Two no-responses through customer service / information request channels (Sangfor, Schmid Telecom)

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 signficant patching behavior [Arora et al. 2010, Li et al. 2016]

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