SymCerts: Practical Symbolic Execution For Exposing Noncompliance in X.509 Certificate Validation Implementations

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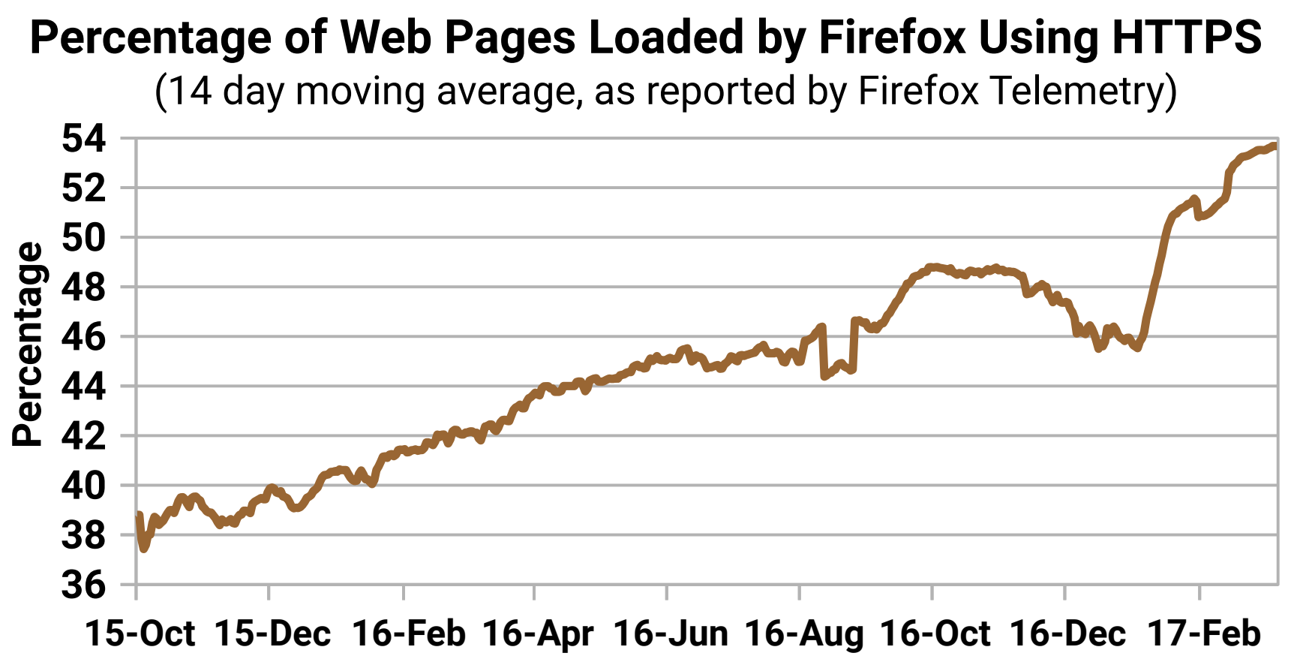
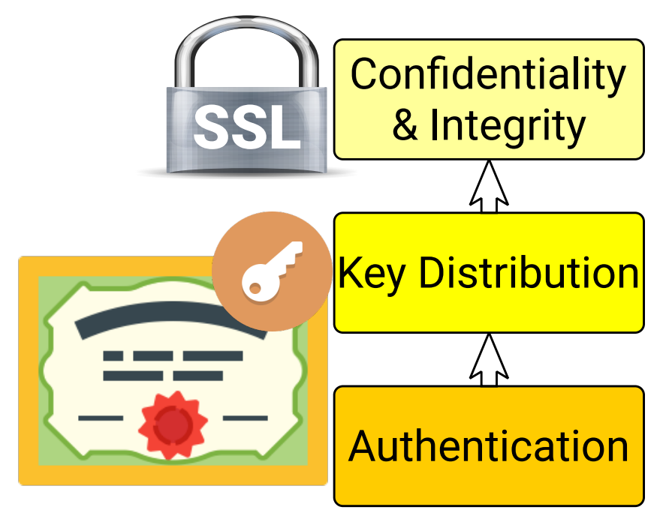
(1) The need for secure communications

- SSL/TLS is now the de facto standard for achiving secure communication

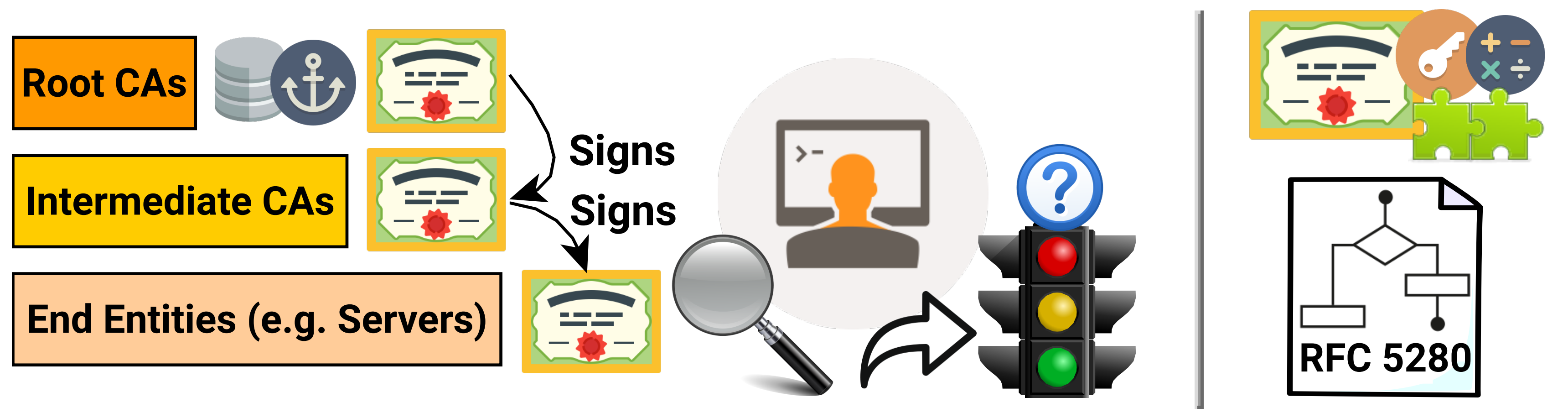

Percentage of Web Pages Loaded by Firefox Using HTTPS
(14 day moving average, as reported by Firefox Telemetry)

(2) Why do we care about X.509 certificates?

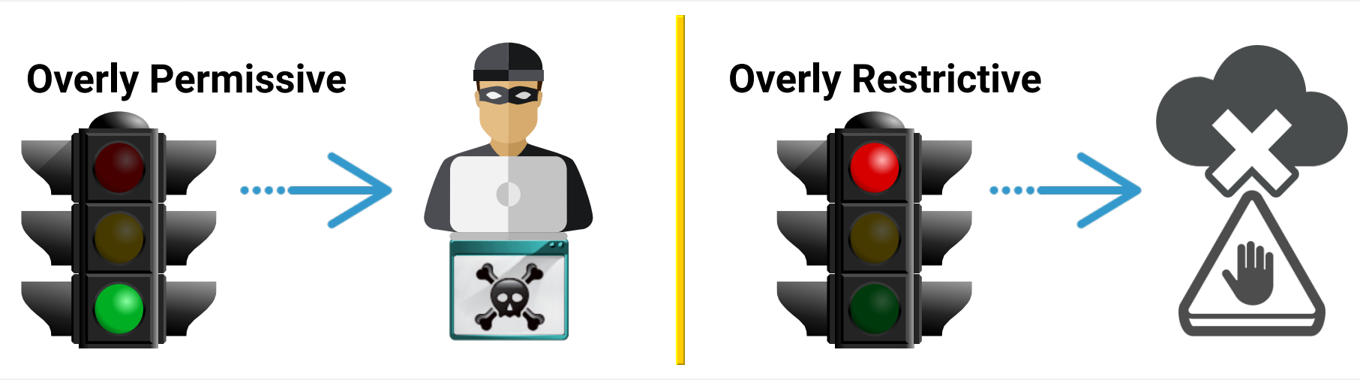
- X.509 is used in SSL/TLS
  → For Authentication and Key Distribution
- The security guarantees of SSL/TLS hinge on a correct implementation of the X.509 PKI



(3) How does X.509 work?

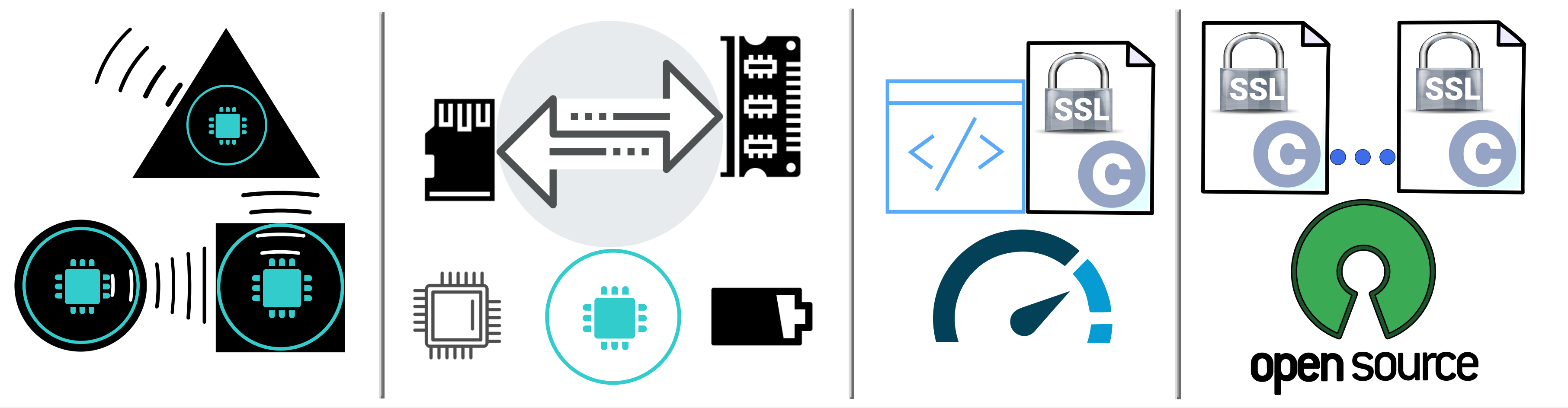


(4) Implications of bugs in X.509 implementations



- Violating specifications can lead to 2 contrasting pitfalls

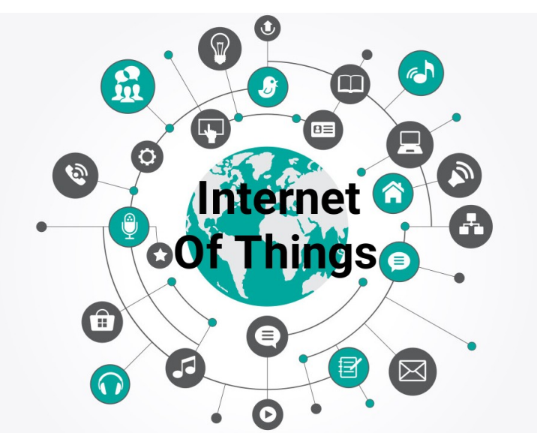
(5) Small Footprint SSL/TLS libraries for IoT



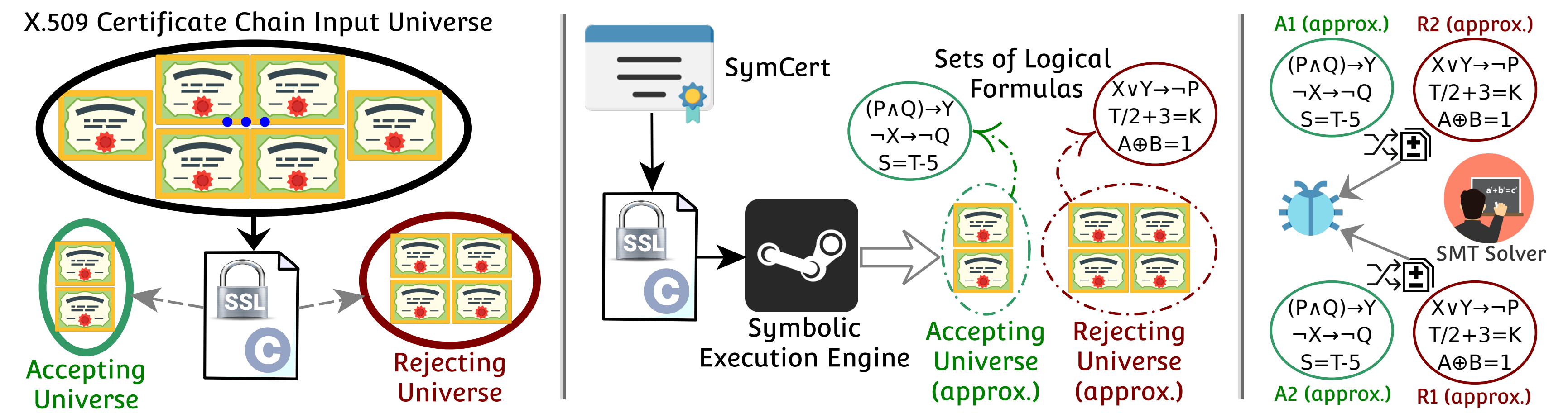
(6) Research Problem

Goal: **Find RFC Violations** in X.509 implementations made for IoT.

- Related Work
  → SSL/TLS protocol state machine and bug finder
  → Cryptographic proofs and reworked state machine
  → Detect incorrect SSL/TLS API usage in applications



(7) Our approach



(8) Making Symbolic Execution practical

- Focus our analysis on small-footprint, small code-base libraries
- Adding domain specific optimizations
  → Does not check cryptographic correctness
  → Concrete *Length* values in encoded *SymCerts*
  → Simplify strings (e.g. in name matching)

(9) Summary of Experiments and Findings

- We tested 9 implmentations from 4 families of SSL/TLS libraries.

Library - version	Released	RFC Violations	Library - version	Released	RFC Violations
axTLS - 1.4.3	Jul 2011	7	CyaSSL - 2.7.0	Jun 2013	7
axTLS - 1.5.3	Apr 2015	6	wolfSSL - 3.6.6	Aug 2015	2
tropicSSL - (Github)	Mar 2013	10	MatrixSSL - 3.4.2	Feb 2013	6
PolarSSL - 1.2.8	Jun 2013	4	MatrixSSL - 3.7.2	Apr 2015	5
mbedTLS - 2.1.4	Jan 2016	1		**Total:**	**48**

- Findings have been **reported and well-received** by library developers.

→ Many of the problems are **fixed in new releases** following our reports.

(10) Notable findings and their implications

- Misintrept *UTCTime* (MatrixSSL 3.7.2, axTLS 1.4.3 and 1.5.3, tropicSSL)
  → e.g. in MatrixSSL 3.7.2 **expiration date can shift by 100 years**
- Misinterpret OID of *ExtKeyUsage* (wolfSSL 3.6.6, MatrixSSL 3.7.2)
  → Overly Permissive (and compatibility issues with custom OID)
- Incorrect Extension Parsing (CyaSSL 2.7.0) → Crash
- Rejects *GeneralizedTime* (tropicSSL, axTLS 1.4.3) → Overly Restrictive
- Incomplete Extension Handling (various libraries) → Overly Permissive

Takeaway

- X.509 handling in IoT SSL/TLS libraries all deviate from specification
- If there is a vulnerability in the library, it's hopeless for Applications
- We provide automated approach and toolchain for finding violations
- Our experiments turn out to be quite prolific → many problems are fixed
- New versions of SSL/TLS libraries are generally better → Patch often!

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