Implementation Flaws in TLS Stacks: Lessons Learned and Study of TLS 1.3 Benefits

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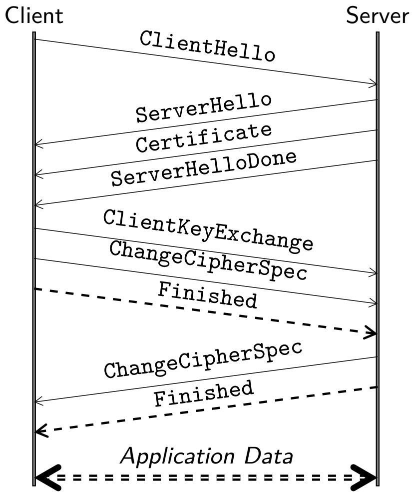
TLS in a nutshell

Protocol description



SSL/TLS is pervasive today

- HTTPS (many use cases)
- A generic method to secure protocols
- SSL VPN, EAP TLS...

Security goals

- Server (and optionnaly client) authentication
- Data confidentiality and integrity protection
- Anti-replay

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- 2014: 3SHAKE
- 2015: FREAK
- 2015: LogJam
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To overcome them, the IETF TLS WG started working on TLS 1.3 in 2014

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What about TLS implementations?

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Actually, it is easy to explain

- a ciphersuite is represented by a 16-bit integer
- for almost a decade, all suites had their first byte equal to 00
- why bother to inspect this byte?

Implementation Flaws

Common programming errors

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- CVE-2014-6321: WinShock (buffer overflow) in Windows

Focus on GnuTLS' `goto fail` (CVE-2014-0092)

The bug allows an attacker to circumvent client-side checks regarding server certificates (source: `lwn.net`, March 2014)

> *The `check_if_ca` function is supposed to return true (any non-zero value in C) or false (zero) depending on whether the issuer of the certificate is a certificate authority (CA). A true return should mean that the certificate passed muster and can be used further, but the bug meant that error returns were misinterpreted as certificate validations.*

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A similar bug was found in OpenSSL... in 2008 (CVE-2008-5077)!

> *The fix replaces a `if (!i)` with a `if (i<=0)`, where `i` is returned by a function checking a certificate which was interpreted as a boolean without taking into account other values corresponding to error codes*

Lessons learned

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What about TLS 1.3?

- with regards to these particular bugs, not much...

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- CVE-2014-1568: NSS/CyaSSL/PolarSSL Signature Forgery (ASN.1 Length Encodings)

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- CVE-2014-1568: NSS/CyaSSL/PolarSSL Signature Forgery (ASN.1 Length Encodings)
- CVE-2014-3511: OpenSSL downgrade attack (Record splitting)
- 2013: the Alert attack (Record boundaries) in OpenSSL (and others)
- *CVE-2014-0160: OpenSSL's Heartbleed (Record boundaries)*

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Reminder: the ASN.1 message should be DER-encoded, which is a strict set of encoding rules

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What about TLS 1.3?

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- … but some cases have been described and disambiguated

Implementation Flaws

The real impact of obsolete cryptography on security

Bleichenbacher (1/2)

RSA PKCS#1 v1.5

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Bleichenbacher attack (1998)

- main idea: send altered versions of a target encrypted message and observe the server behaviour
- if the attacker can distinguish a valid from an invalid padding, he can gather information on the plaintext
- this can be applied to TLS: the so-called “Million Message Attack”

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... and in 2017 with ROBOT (Return Of Bleichenbacher's Oracle Threat)... and in 2018 with CAT

Similar issues in the symmetric domain

Dangerous or fragile constructions also exist in the Record Protocol (which protects the application data with symmetric cryptography):

- RC4
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There again, developers must make hard choices to ensure compatibility while keeping their code maintainable and secure...

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- only modern robust constructions have been standardized
- *the only remaining legacy crypto is the RSA PKCS#1 v1.5 signature scheme used in certificates*

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The consequences of complex state machines

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In the default setting, all vulnerable servers nevertheless interpeted unsollicited messages, making them exploitable in practice

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- Skip Verify (client impersonation) in Mono stack, CyaSSL and OpenSSL
- CVE-2015-0204: FREAK (server impersonation) in OpenSSL, Apple SecureTransport and Microsoft SChannel and many others

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What about TLS 1.3?

- on one hand, TLS 1.3 simplified the messages
- ... but 0 RTT mode is a complex beast in TLS 1.3
- ... but TLS 1.3 added fake messages to accomodate middleboxes
- ... and we might have to live at least with TLS 1.2 for some time

Conclusion and Take away messages

Complexity leads to insecurity

Implementation flaws can happen at different levels

Specifications can help avoid complications

- better and unamibguous message formats
- up-to-date cryptographic primitives
- simple and formally-defined state machines

This would lead the standard to constrain implementers

Better languages, tools and methodologies

Several bugs could be avoided by using modern development tools

- modern programming languages
- strict compilers and static analysers
- tests, tests, tests

Beyond TLS 1.3

TLS 1.3 improved some implementation aspects

- but it also created new complexities
- and previous versions are far from gone

The IETF is currently standardizing QUIC

- a new secure transport layer on top of UDP
- reusing TLS 1.3
- with very complex constructions...

Questions?

Thank you for your attention

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