Safe and fast SSL/TLS-handshake

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2024-10-11

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Motivation

- unsecured channels subject to data exposure to third parties
- securing of data channel needed → SSL/TLS
- method of attributing identities to identity holders needed
- method of signaling cessation of identity usage needed
- x509/CRK (RFC 5280) and OCSP (RFC 6960) for identity handling/verification
- different methods of establishing secure channel

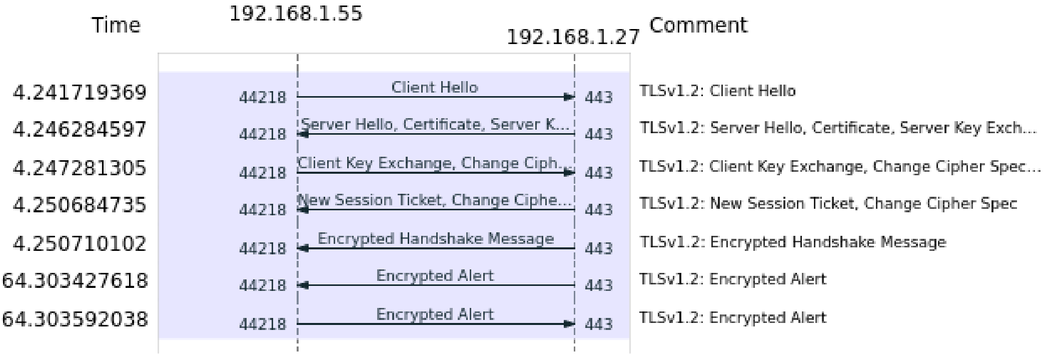
History

- 1994 SSL 1.0 concept
- 1995 SSL 2.0 first release (RFC 6101), MD5-hashing, one key for auth/enc, depr. 2011 (RFC 6176)
- 1996 SSL 3.0 (RFC 6101) subject to POODLE-attack (CVE-2014-3566[1]), depr. 2014 (RFC 7568)
- 1999 TLS 1.0 (RFC 2246), depr. 2021 (RFC 8996)
- 2006 TLS 1.1 (RFC 4346), protection against CBC-atacks, depr. 2022
- 2008 TLS 1.2 (RFC 5246), replaced MD5/SHA-1, algo selection mechanism
- 2018 TLS 1.3 (RFC 8446), defaults to AES256_GCM_SHA384, insecure algos removed, changed handshake/connection init

⇒ currently two productive versions

[1] https://security.googleblog.com/2014/10/this-poodle-bites-exploiting-ssl-30.html

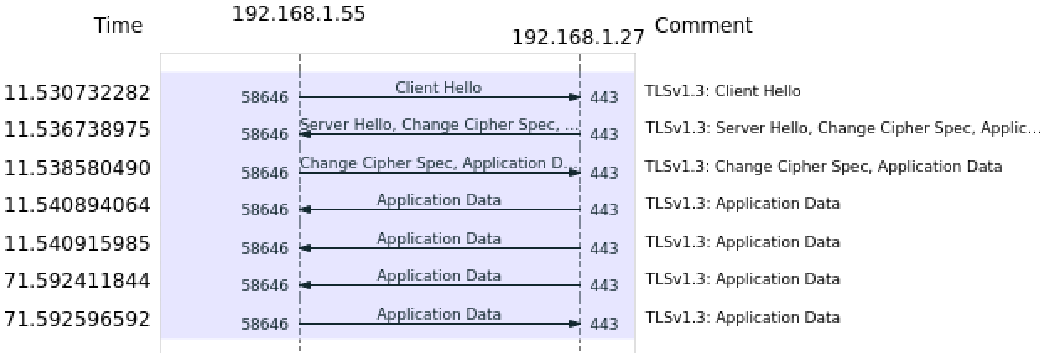
Structure of TLS



Time	192.168.1.55		192.168.1.27	Comment
4.241719369	44218	Client Hello →	443	TLSv1.2: Client Hello
4.246284597	44218	← Server Hello, Certificate, Server K...	443	TLSv1.2: Server Hello, Certificate, Server Key Exch...
4.247281305	44218	Client Key Exchange, Change Ciph... →	443	TLSv1.2: Client Key Exchange, Change Cipher Spec...
4.250684735	44218	← New Session Ticket, Change Ciphe...	443	TLSv1.2: New Session Ticket, Change Cipher Spec
4.250710102	44218	← Encrypted Handshake Message	443	TLSv1.2: Encrypted Handshake Message
64.303427618	44218	← Encrypted Alert	443	TLSv1.2: Encrypted Alert
64.303592038	44218	Encrypted Alert →	443	TLSv1.2: Encrypted Alert

TLSv1.2 handshake

Structure of TLS



Time	192.168.1.55		192.168.1.27	Comment
11.530732282	58646	Client Hello →	443	TLSv1.3: Client Hello
11.536738975	58646	← Server Hello, Change Cipher Spec, ...	443	TLSv1.3: Server Hello, Change Cipher Spec, Applic...
11.538580490	58646	Change Cipher Spec, Application D... →	443	TLSv1.3: Change Cipher Spec, Application Data
11.540894064	58646	← Application Data	443	TLSv1.3: Application Data
11.540915985	58646	← Application Data	443	TLSv1.3: Application Data
71.592411844	58646	← Application Data	443	TLSv1.3: Application Data
71.592596592	58646	Application Data →	443	TLSv1.3: Application Data

TLSv1.3 handshake

TLSv1.3

- only AES and ChaCha20 as cipher
  → in total 5 options
- only Diffie-Hellman (incl./excl. elliptic curves)
- no (downgrade)renegotiation anymore

Performance considerations

different ciphers

- software based, ChaCha20 is up to 9x faster

type	2 bytes	31 bytes	136 bytes	1024 bytes	8192 bytes	16384 bytes
AES-256-GCM (Software)	3912.58k	43681.83k	119433.57k	220805.46k	240091.14k	241401.86k
ChaCha20-Poly1305 (Software)	5406.06k	79034.59k	256344.41k	1439373.99k	2491817.98k	2634612.74k

Performance considerations

hardware acceleration

- AES with CPU-support performs best
- also faster than ChaCha20
- not available on all CPU/with all compilers/with all software

type	2 bytes	31 bytes	136 bytes	1024 bytes	8192 bytes	16384 bytes
AES-256-GCM (Software)	3912.58k	43681.83k	119433.57k	220805.46k	240091.14k	241401.86k
AES-256-GCM (CPU-instructions)	12352.14k	156771.30k	600536.56k	2364060.33k	3829205.67k	4008596.82k
ChaCha20-Poly1305 (Software)	5406.06k	79034.59k	256344.41k	1439373.99k	2491817.98k	2634612.74k

Performance considerations

SSL offloading

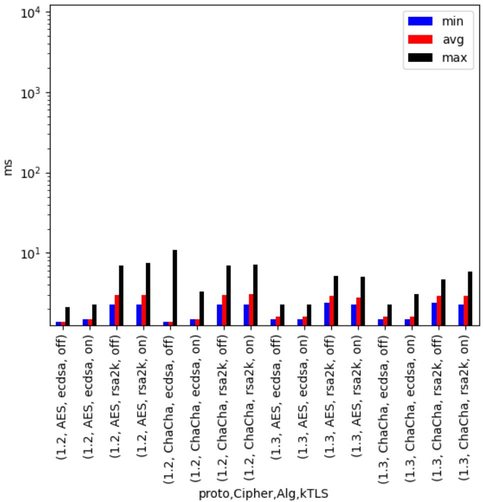
- three options
  1. software based (user level)
  2. kTLS (kernel level)
  3. NIC-offload (fully managed by hardware)
- should improve throughput due to less context switches

! may introduce operational problems

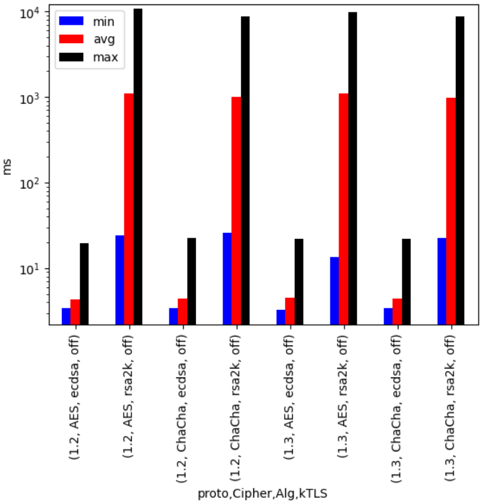
  ? possible issues with TCP-checksum on IPv6
  - size limits
  - issues with network-mounted resources

- impact questionable

Performance



Intel Xeon Gold 6150, 500 parallel connections

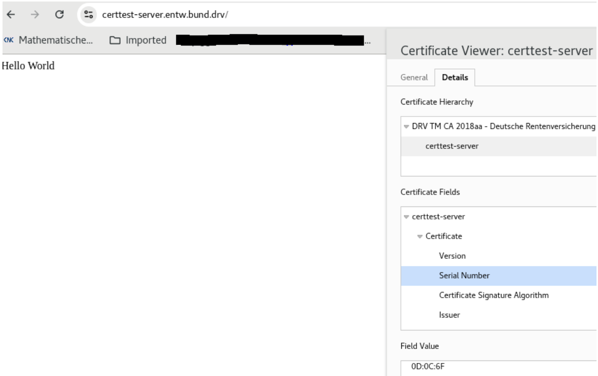


Raspberry Pi 4, 500 parallel connections

how to: fast and safe TLS handshake

- ▶ disable old ciphers
- ∼ OCSP
  - ! Let's Encrypt removes OCSP soon
- ∼ OCSP-Stapling
  - ! Chrome ignores CRL or OCSP, only knows of revoked certificate if stapled result
- ▶ use elliptic curve for keys
- ▶ use LARGE packages
- ▶ SSL offloading (e.g. Nvidia ConnectX-7 for 400G connections)

Caveats



certtest-server.entw.bund.drv/

[redacted]

Hello World

Certificate Viewer: certtest-server

Certificate Hierarchy

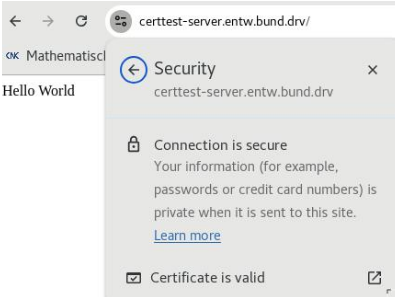
- DRV TM CA 2018aa - Deutsche Rentenversicherung
  - certtest-server

Certificate Fields

- certtest-server
  - Certificate
    - Version
    - Serial Number
    - Certificate Signature Algorithm
    - Issuer

Field Value

0D:0C:6F



certtest-server.entw.bund.drv/

Hello World

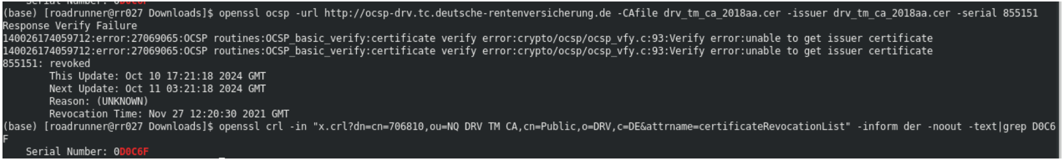
Security

certtest-server.entw.bund.drv

Connection is secure

Your information (for example, passwords or credit card numbers) is private when it is sent to this site. Learn more

Certificate is valid



```
(base) [roadrunner@rr027 Downloads]$ openssl ocsp -url http://ocsp-drv.tc.deutsche-rentenversicherung.de -CAfile drv_tm_ca_2018aa.cer -issuer drv_tm_ca_2018aa.cer -serial 855151
Response Verify Failure
140026174059712:error:27069065:OCSP routines:OCSP_basic_verify:certificate verify error:crypto/ocsp/ocsp_vfy.c:93:Verify error:unable to get issuer certificate
140026174059712:error:27069065:OCSP routines:OCSP_basic_verify:certificate verify error:crypto/ocsp/ocsp_vfy.c:93:Verify error:unable to get issuer certificate
855151: revoked
        This Update: Oct 10 17:21:18 2024 GMT
        Next Update: Oct 11 03:21:18 2024 GMT
        Reason: (UNKNOWN)
        Revocation Time: Nov 27 12:20:30 2021 GMT
(base) [roadrunner@rr027 Downloads]$ openssl crl -in "x.crl?dn=cn=706810,ou=NQ DRV TM CA,cn=Public,o=DRV,c=DE&attrname=certificateRevocationList" -inform der -noout -text|grep D0C6
F
    Serial Number: 0D0C6F
```