rustls

modern, fast, safer TLS

Introduction

This talk:

- Small dose of memory safety evangelism
- Currently implemented features
- TLS vulnerabilities & rationale for rustls's design
- Performance
- Testing
- Future work

Introduction

rustls:

- TLS1.2 and TLS1.3 TLS library
- Written in Rust
- MIT/Apache/ISC triple licensed

Timeline:

- Born: 2nd May 2016
- First handshake: 27th May 2016
- First release: 26th August 2016

Let's talk about memory safety

"About the security content of iOS 10.3.3"

Stand-in for a large piece of software written in memory-unsafe languages

Multiple vendors -> different dev methodologies, varying tooling, skill levels, etc.

- 47 CVEs total
- **36** CVEs are memory unsafety issues

"A memory corruption issue was addressed with improved bounds checking."

https://support.apple.com/en-us/HT207923


Rust
EVANGELISM
STRIKE FORCE


golang
ALSO
TOTALLY GREAT

node.js memory unsafe in all versions prior to v8.0.0, May 2017!

Rust

- Memory safe & concurrency safe
- Good FFI for integration into existing systems
- Excellent type system
- Speed -- typically as fast as C, occasionally faster
- No runtime overhead (no GC or interpreter)

rustls -- design approach

make something that is easy and **safe** for 90% of uses

- but perhaps might not ever cater to the remaining 10%

"if in doubt, leave it out"

don't require configuration for 90% of such uses

- sane, well-regarded defaults

"The most dangerous code in the world: validating SSL certificates in non-browser software" - Boneh et al, ACM CCS'12

"Our main conclusion is that *SSL certificate validation is completely broken in many critical software applications and libraries*" ...

"For the most part, the actual SSL libraries used in these programs are correct" ...

"The primary cause of these vulnerabilities is the developers' misunderstanding of the numerous options, parameters, and return values of SSL libraries" ...

"many SSL libraries are unsafe by default, requiring higher-level software to correctly set their options, provide hostname verification functions [...]"

"APIs should present high-level abstractions to developers, such as "confidential and authenticated tunnel," as opposed to requiring them to explicitly deal with low-level details such as hostname verification"

https://www.cs.utexas.edu/~shmat/shmat_ccs12.pdf

Current TLS feature list

TLS1.2 and TLS1.3-draft-18 (+ drafts 19, 20)

Client and server end

AES-128-GCM, AES-256-GCM, chacha20poly1305 suites (9 in total)

Forward secrecy, always: curve25519, nistp256 or nistp384

Server authentication, always -- integrated cert chain and hostname verification

Optional client authentication

All kinds of resumption

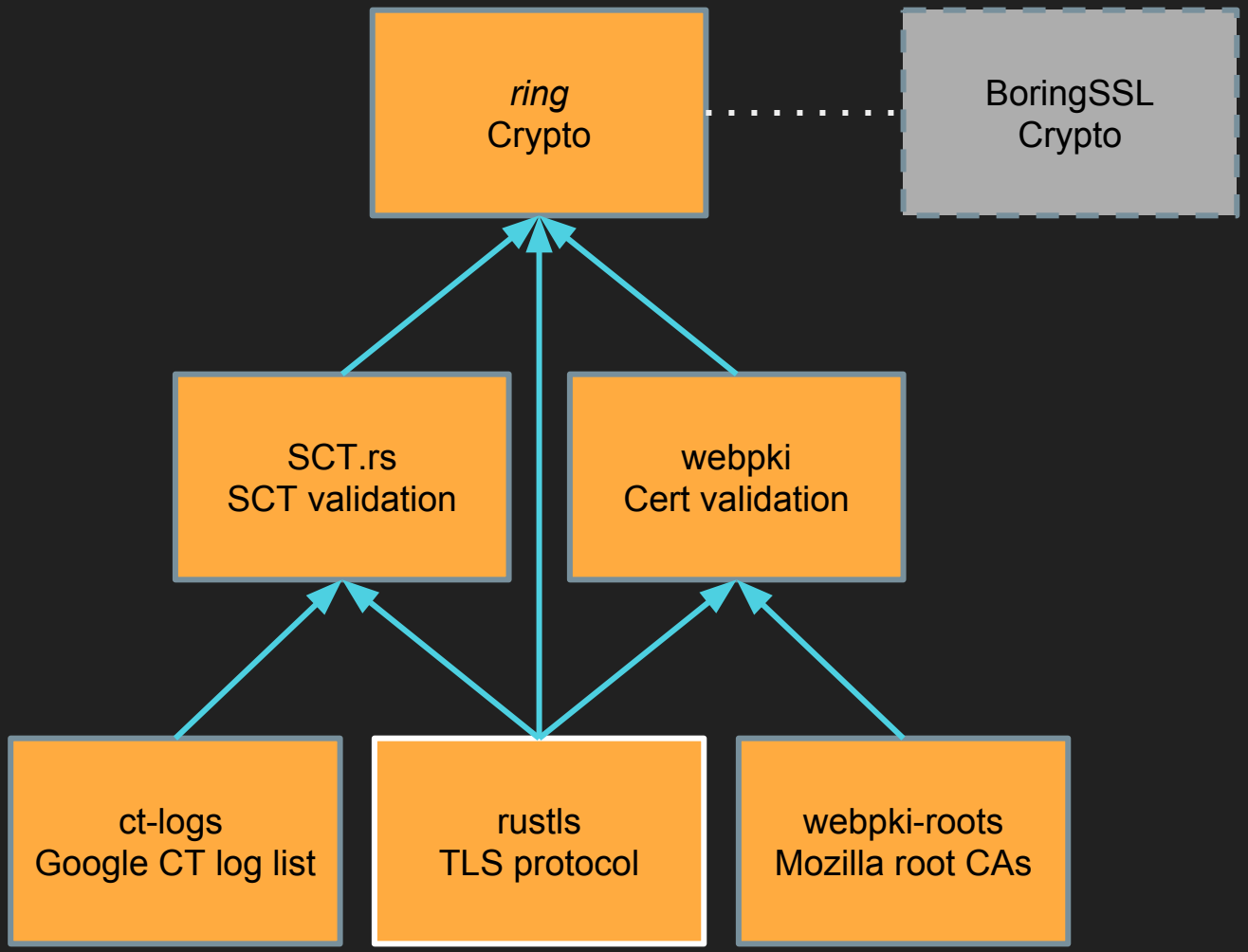
Current TLS feature list

Extended master secret support (RFC7627)

OCSP and SCT pinning

Integrated SCT verification

Dependencies



Past TLS problems

Past TLS protocol problems

Past TLS protocol problems

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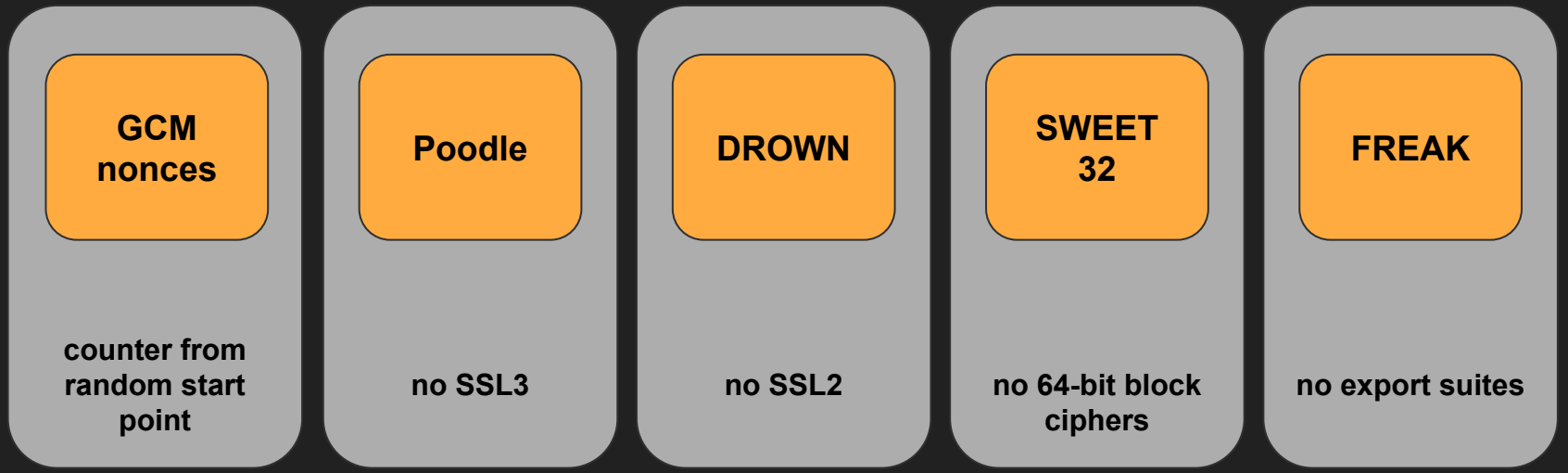

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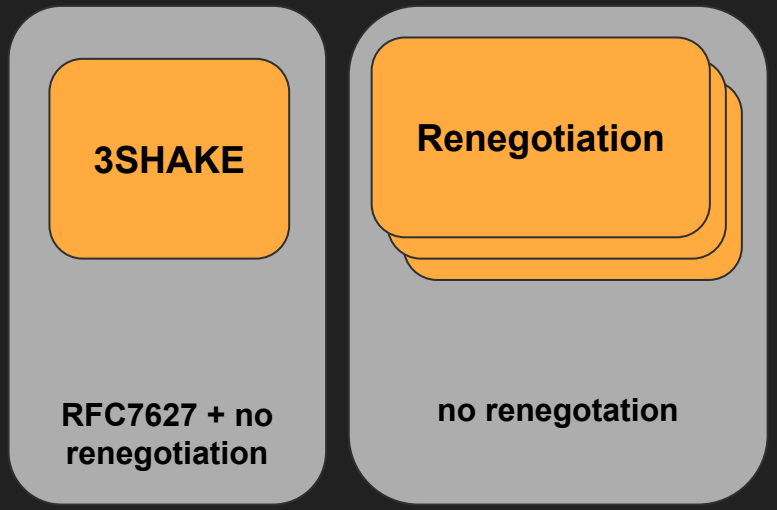
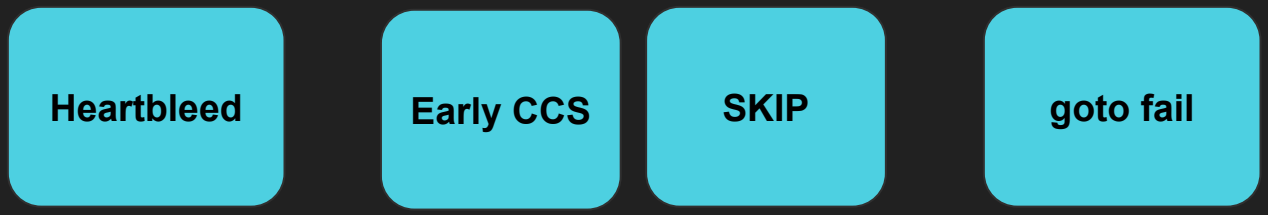


TLS1.3 vs TLS1.2 vs rustls's TLS1.2 subset

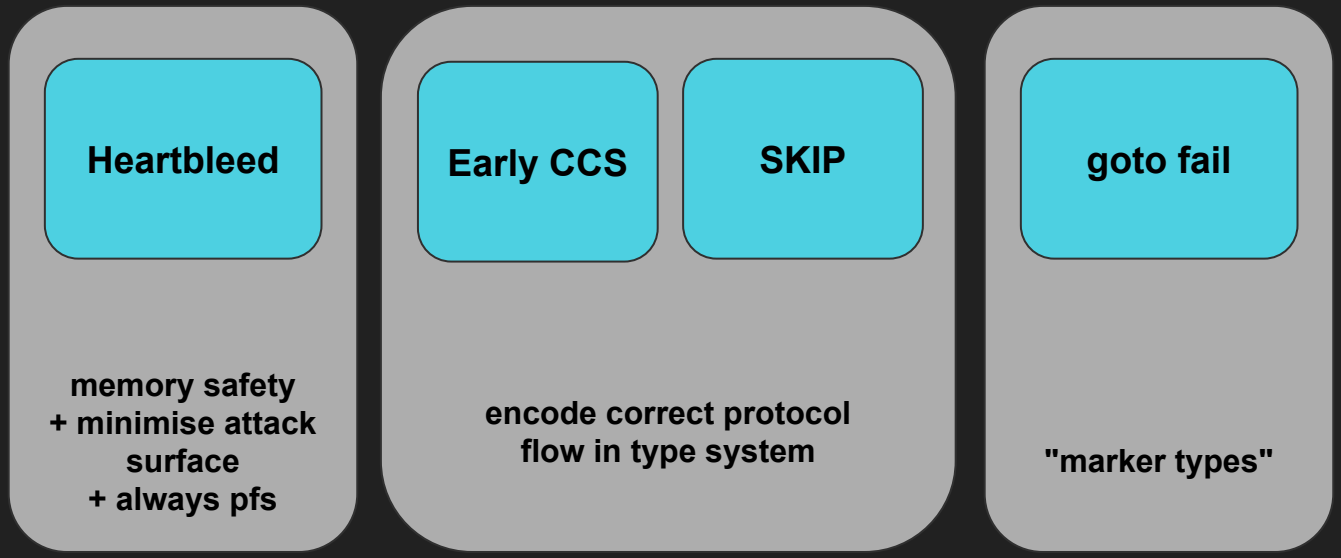
	TLS1.2 standard	TLS1.2 (rustls subset)	TLS1.3 standard
RC4	Yes	No	No
CBC	Mandatory	No	No
Compression	Yes	No	No
Reneg	Yes (+ 2 fixes)	No	No*
PFS	Yes	Mandatory	Mandatory
SHA1 signatures	Mandatory	No	Yes

* renegotation killed, replaced with simple rekeying sub-protocol

Past TLS implementation problems



Past TLS implementation problems



"Marker types"

(please note: unlikely to be a new idea)

Generalised "goto fail" problem:

- "Adversary": duplicates any source line into adjacent position
- How do we make a signature verification function that deals with this?
- Problem is fundamentally: *absence of an error is a poor indicator of signature validity*

This idea:

- Unique, zero-sized, behaviourless, explicitly constructed type
- Represents **positive** outcome of signature verification

"Marker types"

In rustls:

- Protocol states after important verifications require values of these types
- This binds entering those states to the verification
- The compiler then checks we didn't skip verification somehow
- Code review: are these types only constructed at precisely the right point?

Zero run-time cost

"Marker types"

```
let fin = constant_time::verify_slices_are_equal(&expect_verify_data, &finished.0)
    .map_err(|_| {
        sess.common.send_fatal_alert(AlertDescription::DecryptError);
        TLSError::DecryptError
    })
    .map(|_| verify::FinishedMessageVerified::assertion())?;


...


struct ExpectTLS12Traffic {
    _cert_verified: verify::ServerCertVerified,
    _sig_verified: verify::HandshakeSignatureValid,
    _fin_verified: verify::FinishedMessageVerified,
}
```

Testing

automated test suite made up of:

- integration tests against openssl and some public web servers
- api-level tests
- unit tests of library internals
- 'bogo' - the BoringSSL test suite, built from the golang TLS stack
  - hugely comprehensive and impressive
  - found some good bugs in rustls
- 'TryTLS' - python test suite concentrating on common implementation errors
- performance benchmarks

currently ~95% line coverage

Performance

date	send speed (Gbps per core)	recv speed (Gbps per core)
2016-09-04	1.5	2.3
2016-09-20	2.0	6.5
2016-09-27	4.4	6.2
2017-01-26	15.9	15.0
2017-05-10	22.7	21.4

all measurements taken on the same i5-6500 at 3.2GHz
TLS1.2, suite `TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256`
OpenSSL 1.1.0f does raw AES128-GCM at ~37 Gbps here

Future work

- Work out what to do with TLS1.3 0RTT data
  - feature that can break the normal TLS security guarantees, like replay protection
  - leaky abstraction -- application must know it is happening
  - requires application-level profile rfc -- none exist so currently shouldn't be deployed
- OCSP verification
- PSK support
- Write some glue for use from non-rust programs
  - libtls interface from libressl project seems like a good choice
- Third party audit

thanks

Repo: https://github.com/ctz/rustls

Test server: https://rustls.jbp.io/

Twitter: @jpixton

Mail: jbp@jbp.io

Slides: https://github.com/ctz/talks

detailed TLS non-feature list

feature	why unsupported
RC4	biases ruin confidentiality
DES/3DES	block size too small
export suites	deliberately bad
CBC suites	IV chaining, mac-then-encrypt, ...
renegotiation	no binding between sessions; underspecified

feature	why unsupported
compression	unsafe with mix of secret and attacker-controller data
MD5/SHA1	not collision resistant
static RSA KX	no forward secrecy
discrete log DH	cannot be negotiated in TLS1.2, poor performance

about TLS1.0/1.1

hard decision

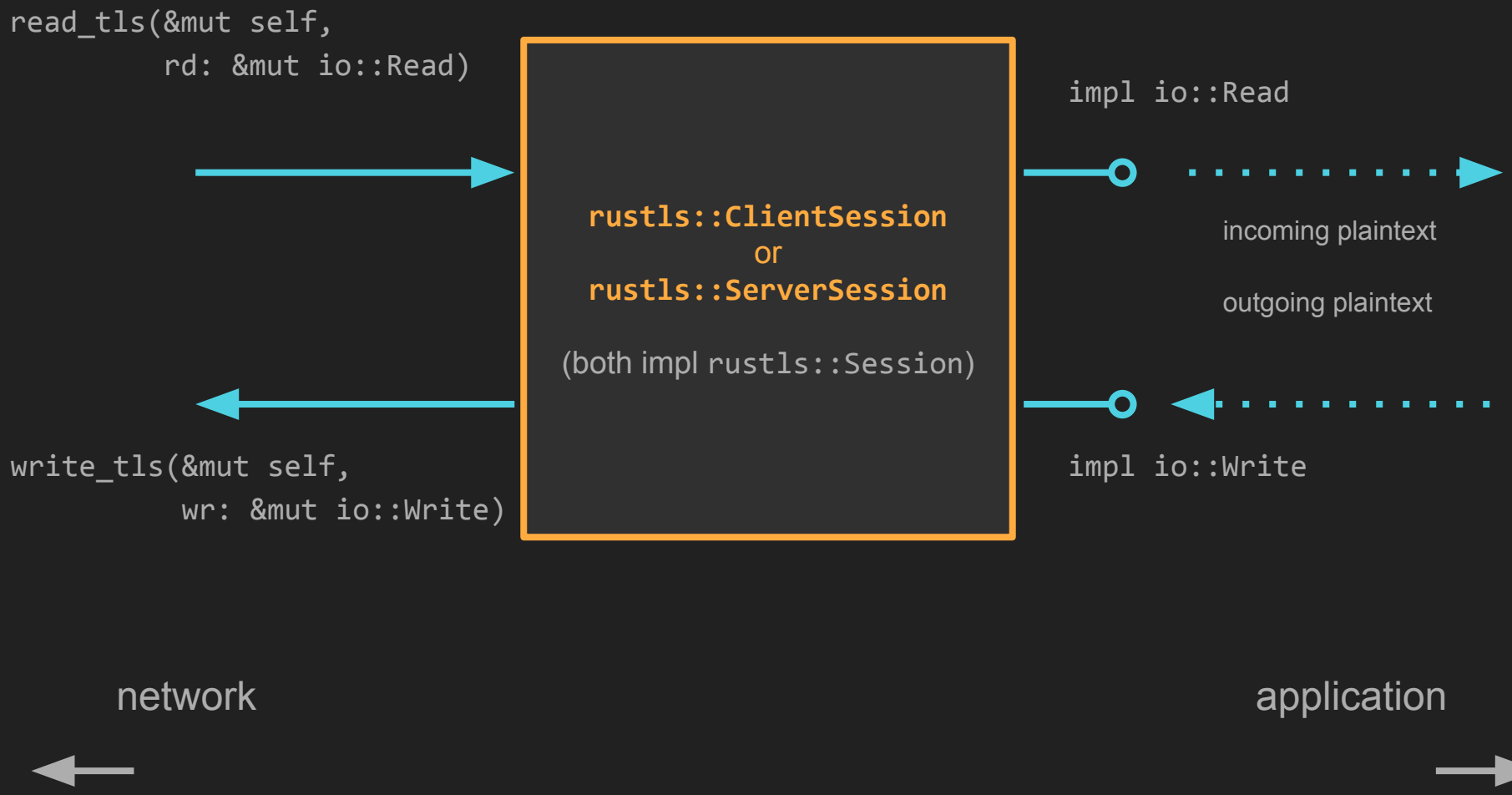
no obviously safe ciphersuites

- closest has design flaws that resulted in "Lucky13" vuln
- countermeasures possible, but unconvincing

long tail of old/misconfigured servers

early stages of death? (PCI from June 2018, Apple ATS, Cloudflare 'Require Modern TLS')

api


read_tls(&mut self,
rd: &mut io::Read)
rustls::ClientSession
or
rustls::ServerSession
(both impl rustls::Session)
impl io::Read
incoming plaintext
outgoing plaintext
write_tls(&mut self,
wr: &mut io::Write)
impl io::Write
network
application

api

```
pub trait Session: Read + Write + Send {

   fn read_tls(&mut self, rd: &mut Read) -> Result<usize, io::Error>;


   fn write_tls(&mut self, wr: &mut Write) -> Result<usize, io::Error>;


   fn process_new_packets(&mut self) -> Result<(), TLSError>;

(...)

}
```

api

to make a `rustls::ClientSession` you need a `rustls::ClientConfig` and the server's dns name

- one `ClientConfig` per process, typically
- contains root certificates
- plus a trait impl that persists data between sessions for resumption

similarly for `rustls::ServerSession` and `rustls::ServerConfig`

- `ServerConfig` contains a trait impl that chooses what certificate chain & private key to use for session

api usability

a `rustls::Session` buffers outgoing data if needed

- so you can send your HTTP request before the TLS handshake completes
- data only sent if handshake successful
- data sent in same flight as last message in handshake

the 'bring your own IO' interface has moderate usability cost

- allows compatibility with all IO models: non-blocking, thready, async

internals

msgs/*.rs: things that can de/serialise all the TLS types into convenient rust structs

```
Message { typ: Handshake, version: TLSv1_2, payload: Handshake(HandshakeMessagePayload
{ typ: ServerHello, payload: ServerHello(ServerHelloPayload { server_version: TLSv1_2,
random: Random([87, ..., 186]), session_id: SessionID, cipher_suite:
TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256, compression_method: Null, extensions:
[RenegotiationInfo(PayloadU8([])), ServerNameAcknowledgement,
SessionTicketAcknowledgement, ECPointFormats([Uncompressed])] }) }) }
```

internals

server_hs.rs/client_hs.rs: state machine for server/client

- complexity hotspot (~1300/~1500 lines each). ripe for refactoring.
- consists of functions of form:

```
fn handle_server_hello(sess: &mut ClientSessionImpl, m: Message) -> Result<&'static State, TLSError>
{ … }

pub static EXPECT_SERVER_HELLO: State = State {
    expect: Expectation {
        content_types: &[ContentType::Handshake],
        handshake_types: &[HandshakeType::ServerHello],
    },
    handle: handle_server_hello,
};
```

internals

- cipher.rs: TLS record layer encryption. a few implementations of these traits:

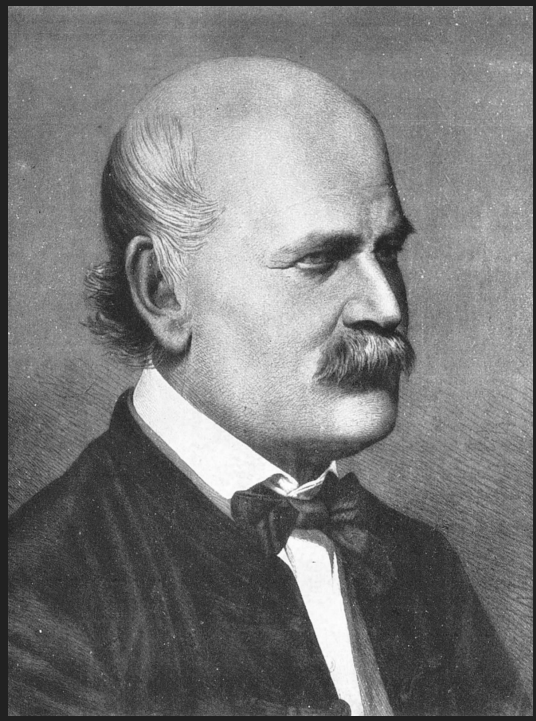
```
pub trait MessageDecrypter : Send + Sync {
    fn decrypt(&self, m: Message, seq: u64) -> Result<Message, TLSError>;
}

pub trait MessageEncrypter : Send + Sync {
    fn encrypt(&self, m: BorrowMessage, seq: u64) -> Result<Message, TLSError>;
}
```

Hand washing

Ignaz Semmelweis (1818-1865)

Noticed two adjacent maternity wards had different postpartum infection rates (10% vs 4% mortality)

One staffed solely by midwives, other by doctors and medical students.



Proposed hand washing between autopsies and deliveries

Mortality rate equalised

Hand washing

"Doctors are gentlemen and a gentleman’s hands are clean"

Dr. Charles Meigs, 1854

"I am a good driver"

Random driver

"I can write correct code"

Random Programmer