TLS 1.3:
What developers should know about the APIs

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TLS 1.3: RFC 8446

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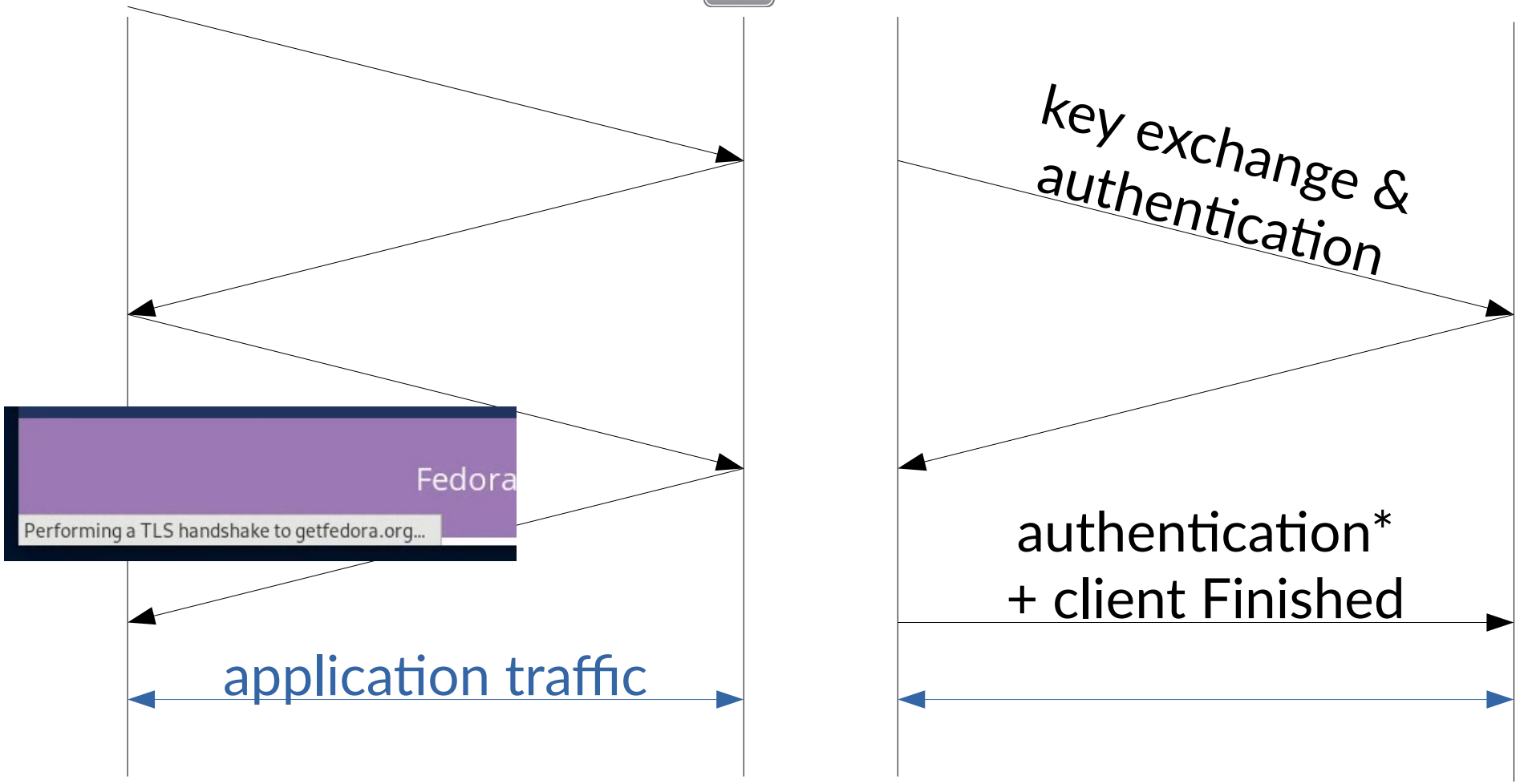
- Low latency
- More security
- Cleaner protocol

Low latency: 1-RTT handshake

TLS 1.2: 2-RTT

TLS 1.3: 1-RTT



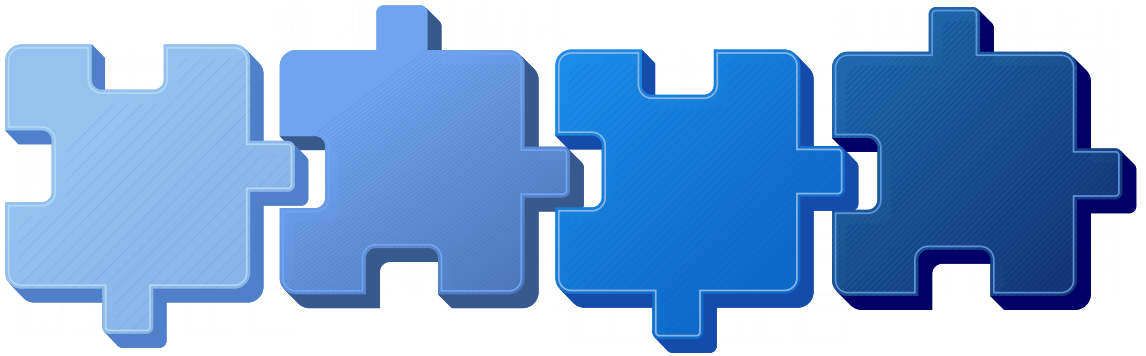
More security

- No RSA / static DH key exchange
- Legacy algorithms were removed
- All symmetric ciphers are AEAD

Protocol refactoring

- Ciphersuites
- Session resumption

Ciphersuites



Key Exchange | Cipher Algorithm | MAC Algorithm | Hash Algorithm

TLS 1.2

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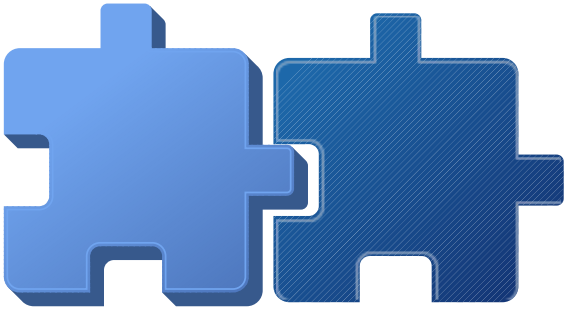


Cipher Algorithm (AEAD) | Hash Algorithm

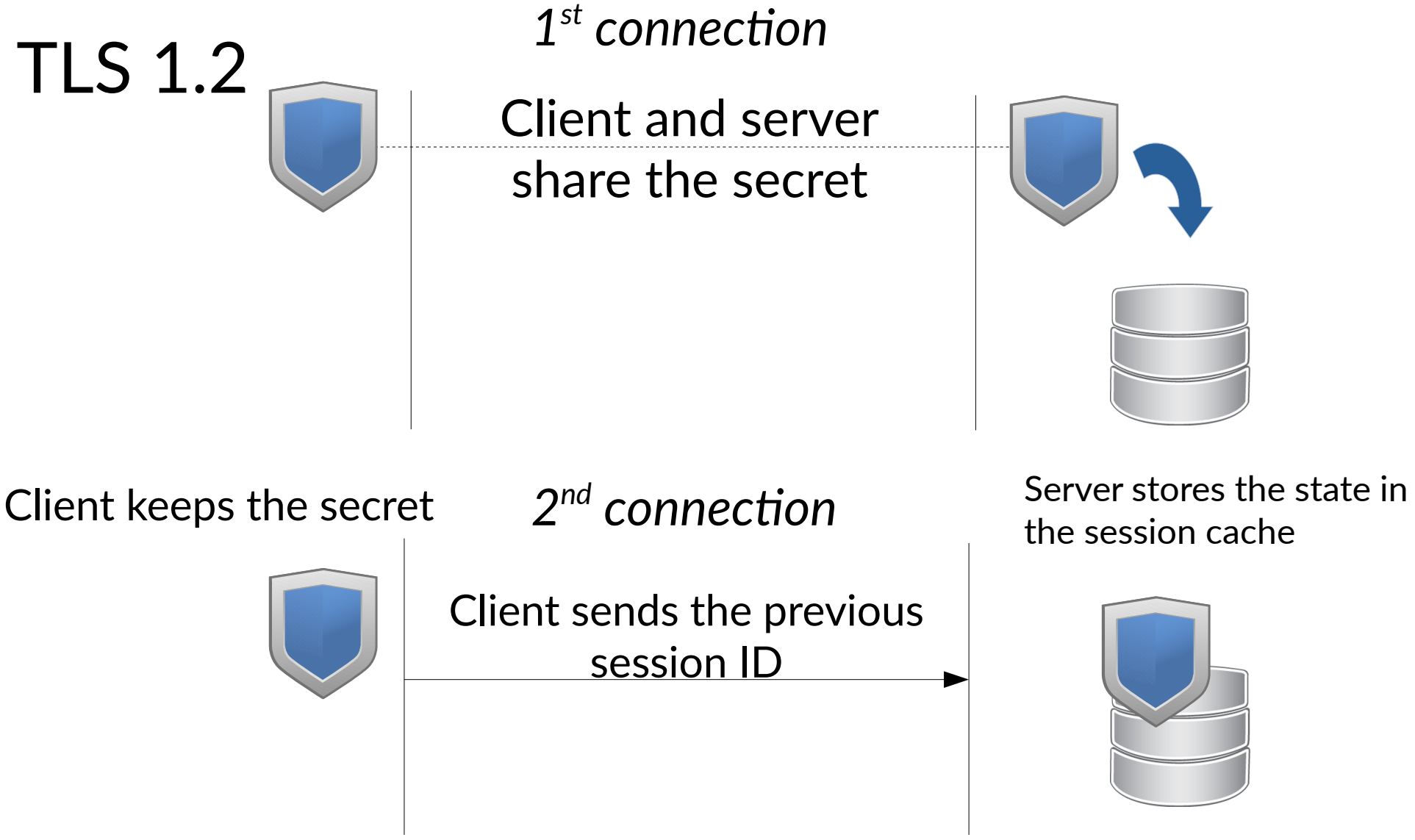
TLS 1.3

= 5

`key_share` extension

Session resumption

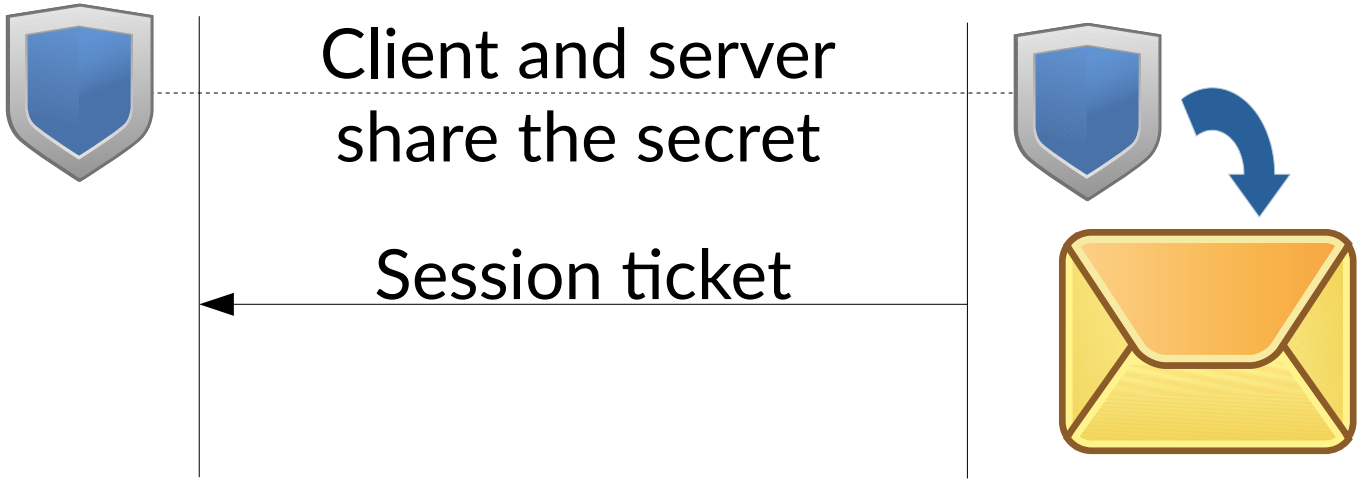
TLS 1.2



Session resumption

TLS 1.3

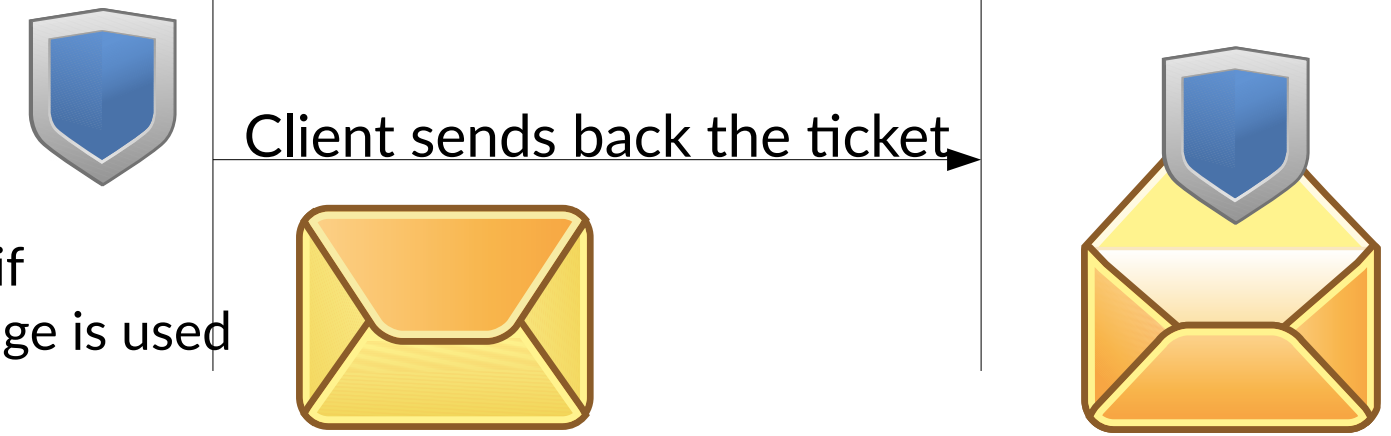
1st connection



Client keeps the secret

2nd connection

Server doesn't need to
keep the secret



Forward secure if
DHE key exchange is used

How can I use TLS 1.3?

- Enabled in major libraries
  - OpenSSL, GnuTLS, NSS OS  
- ~~No~~ Little code changes are needed
  - for typical use-cases
- New features need new API

New features

- Post-handshake authentication
- Key update
- Length hiding
- 0-RTT mode

What is a good API?

- Usability
- Flexibility

Usability

- Easy to use, hard to misuse
- “Huffman coding” by usage pattern
  - *Less* code for *common* use-cases
  - *More* code for *uncommon* use-cases
- Default to be safe

Flexibility

- Scale from embedded to servers
  - Decouple *resource access* from the code
  - Provide callbacks
- Future proof
  - There will probably be TLS 1.4
  - Don’t assume parameters are fixed

What is a good API?

Usability

Flexibility

Existing design choices

- I/O abstraction
  - Generic I/O used for both TLS and non-TLS
- Handshake
  - Explicitly triggered or implicitly during I/O
- Resumption data
  - Manually or automatically tracked

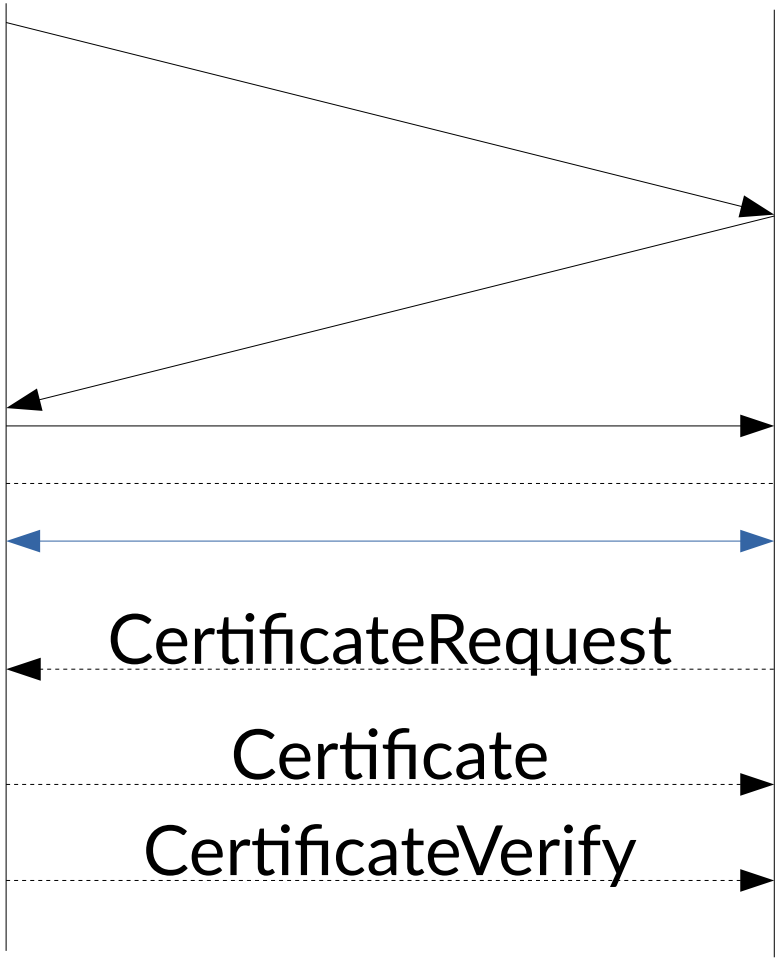
Existing design choices

	I/O abstraction	Handshake	Resumption data
OpenSSL OS	Yes (BIO)	Implicit / explicit	Automatic (cached per-ctx)
GnuTLS 	No	Explicit	Manual
NSS 	Yes (NSPR)	Implicit / explicit	Automatic (cached per-process)

New features, new API

- Post-handshake authentication
- Key update
- Length hiding
- 0-RTT mode

Post-handshake auth



- The server can request client-auth *at any time* with a CertificateRequest message
- Re-associate client's identity with a different certificate
- Can delay client authentication until a resource is actually requested

Post-handshake auth

```
/* client: indicate post handshake auth */
SSL_set_post_handshake_auth(client, 1);
```

```
/* server: request post handshake auth */
SSL_verify_client_post_handshake(server);
```

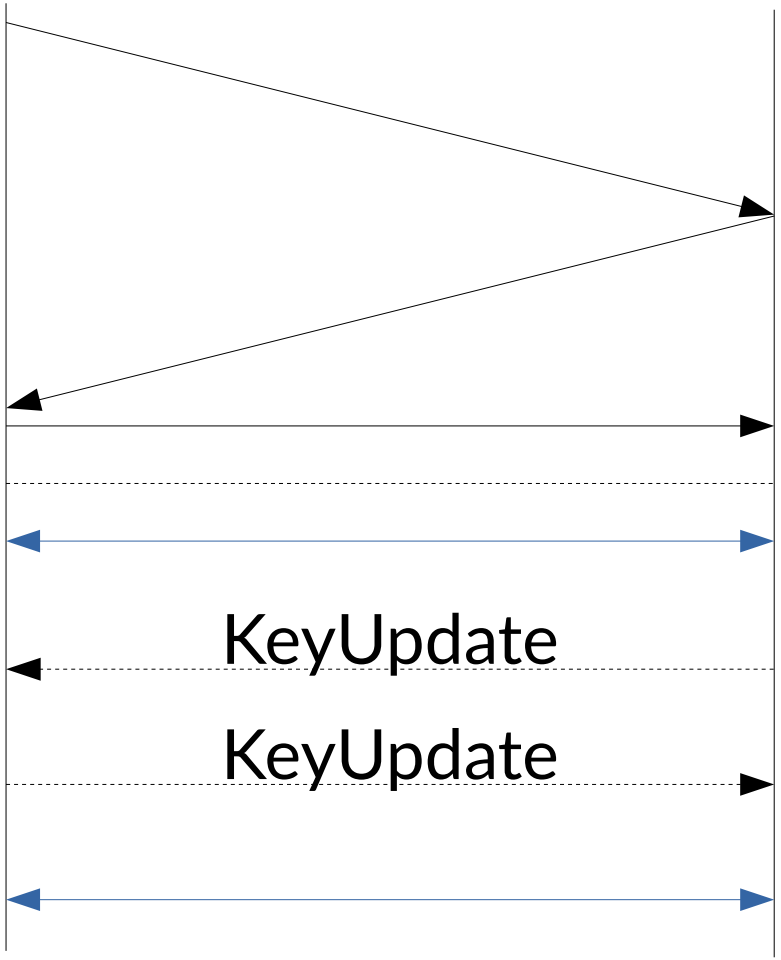
OS

```
/* client: indicate post handshake auth */
gnutls_init(&client, ...|GNUTLS_POST_HANDSHAKE_AUTH);
```

```
/* server: request post handshake auth */
gnutls_reauth(server, 0);
```

Not implemented

Key update



- Peers can update traffic keys with a KeyUpdate message
- There is a limit of data that can be safely encrypted with a single key
  - GnuTLS and NSS implement automatic key updates

Key update

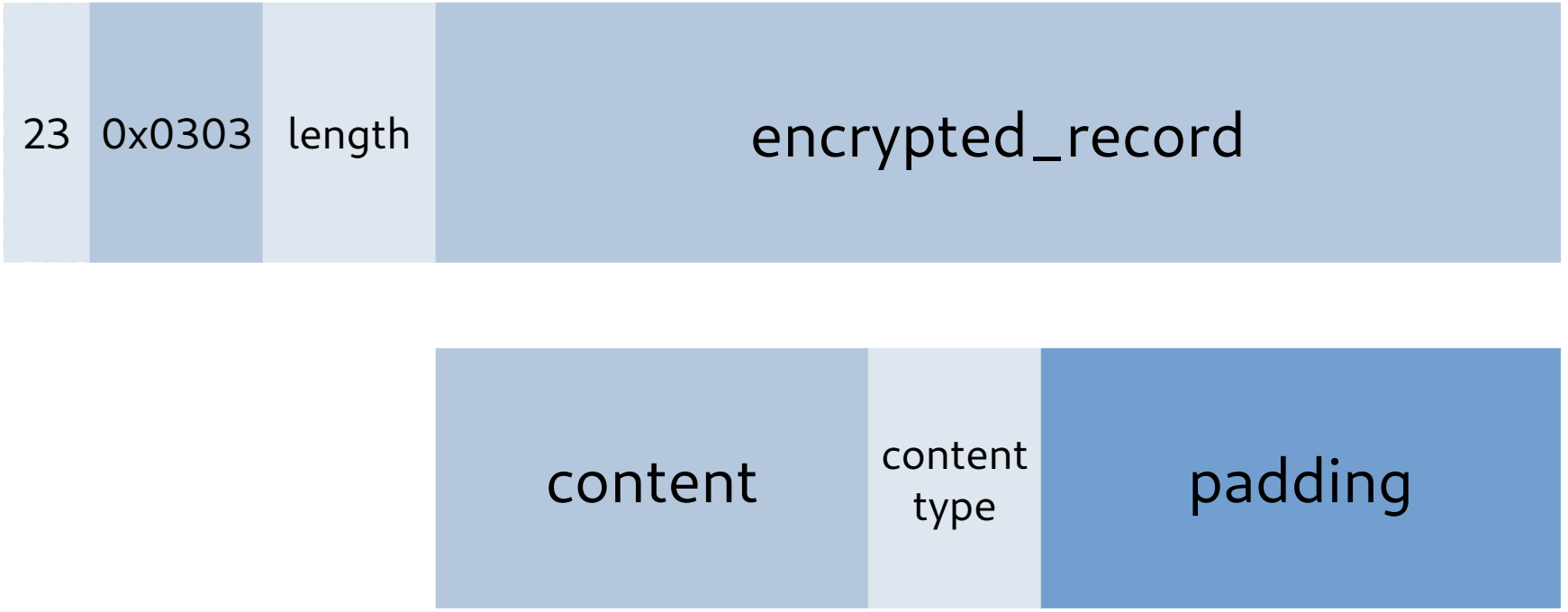
```
/* schedule key update, and request the peer to
 * update their key */
SSL_key_update(s, SSL_KEY_UPDATE_REQUESTED);
```

OS

```
/* schedule key update, and request the peer to
 * update their key */
gnutls_session_key_update(s, GNUTLS_KU_PEER);
```

```
/* schedule key update, and request the peer to
 * update their key */
SSL_KeyUpdate(s, PR_TRUE);
```

Length hiding



Prevent attackers being able to guess the actual content length

Length hiding

```c
/* default to pad multiple of 4096 */
SSL_set_block_padding(s, 4096);

/* override the padding with a callback per message */
SSL_set_record_padding_callback(s, padding_cb);

/* send application data */
SSL_write(s, data, size);
```

```c
static size_t
padding_cb(SSL *s, int type, size_t len, void *arg)
{
  /* return new padding */
}
```

OS

Length hiding

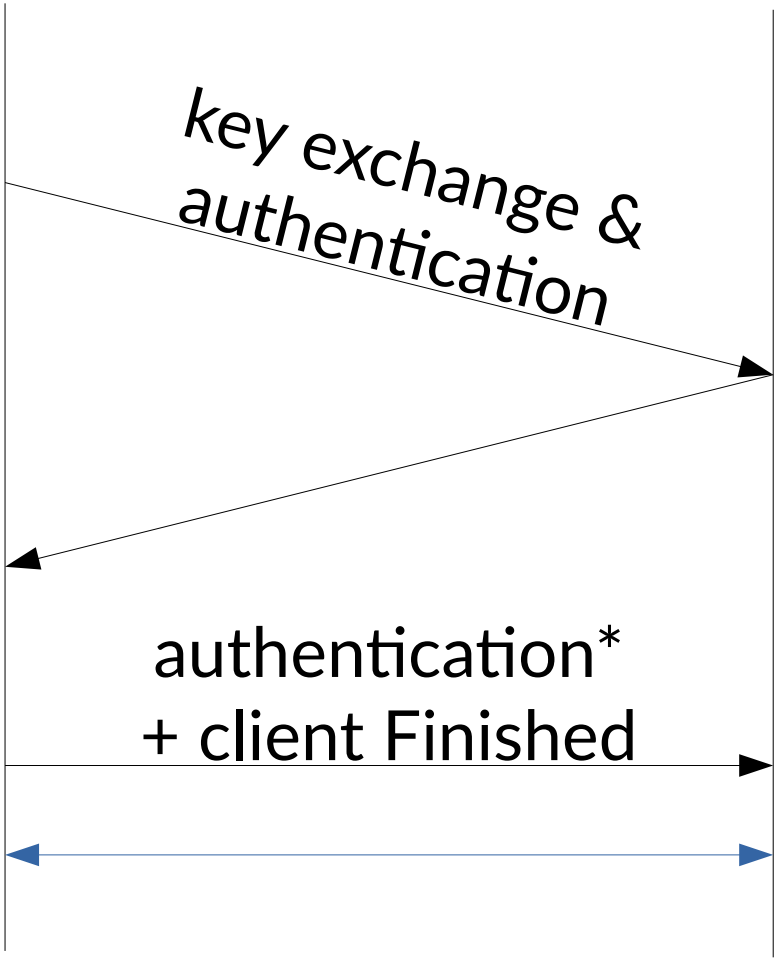
```
/* send application data without padding */
gnutls_record_send(s, data, size, 0);

/* send application data with arbitrary padding */
gnutls_record_send2(s, data, size, pad, 0);
```

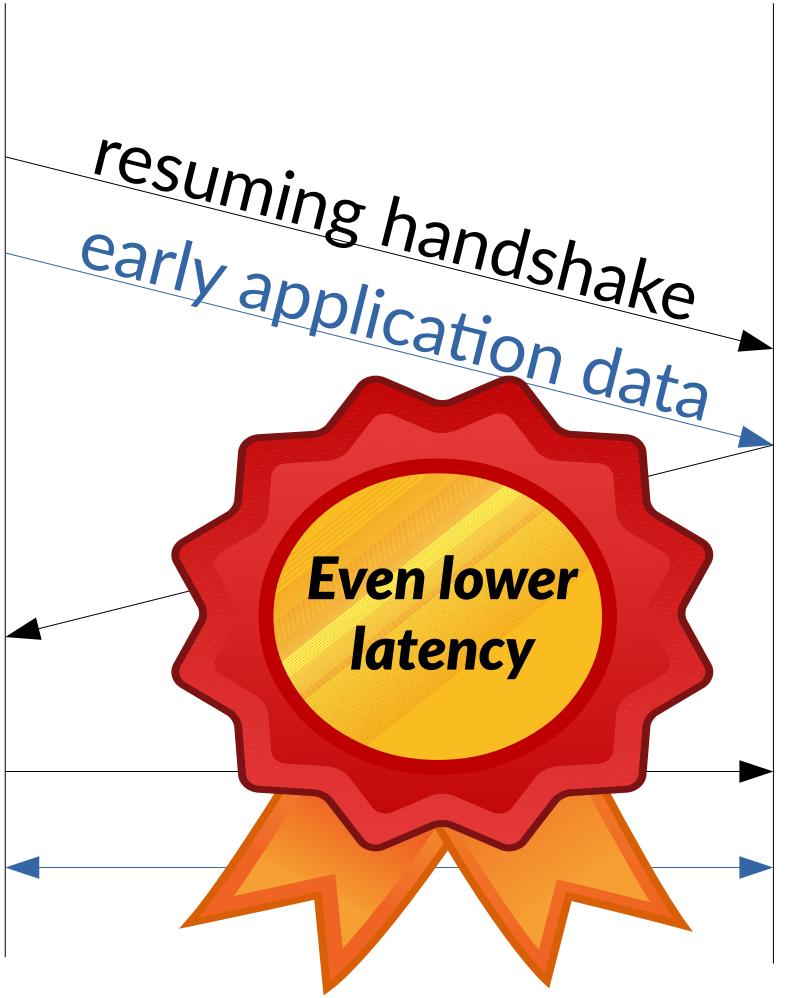
Not implemented

0-RTT mode

TLS 1.3: 1-RTT

TLS 1.3: 0-RTT





0-RTT: Sending

1. Check the maximum amount of data the server would accept
2. Send early data
3. Check if the server has accepted it; otherwise re-send the data as 1-RTT

0-RTT: Sending

1
```
/* check the maximum data the server would accept */
maxsize =
  SSL_SESSION_get_max_early_data(SSL_get0_session(client));
if (size > maxsize)
  return -1;
```

2
```
/* send early data before handshake */
SSL_write_early_data(client, data, size, &written);
/* do handshake, either explicitly or implicitly */
```

3
```
/* check if the early data was accepted */
status = SSL_get_early_data_status(client);
if (status != SSL_EARLY_DATA_ACCEPTED) {
  /* early data was rejected; resend it as 1-RTT */
  SSL_write(client, data, size);
}
```

OS

0-RTT: Sending

1
```
/* check the maximum data the server would accept */
maxsize =
  gnutls_record_get_max_early_data_size(client);
if (size > maxsize)
  return -1;
```

2
```
/* send early data before handshake */
gnutls_record_send_early_data(client, data, size);
gnutls_handshake(client);
```

3
```
/* check if the early data was accepted */
flags = gnutls_session_get_flags(client);
if (!(flags & GNUTLS_SFLAGS_EARLY_DATA)) {
  /* early data was rejected; resend it as 1-RTT */
  gnutls_record_send(client, data, size);
}
```

0-RTT: Sending

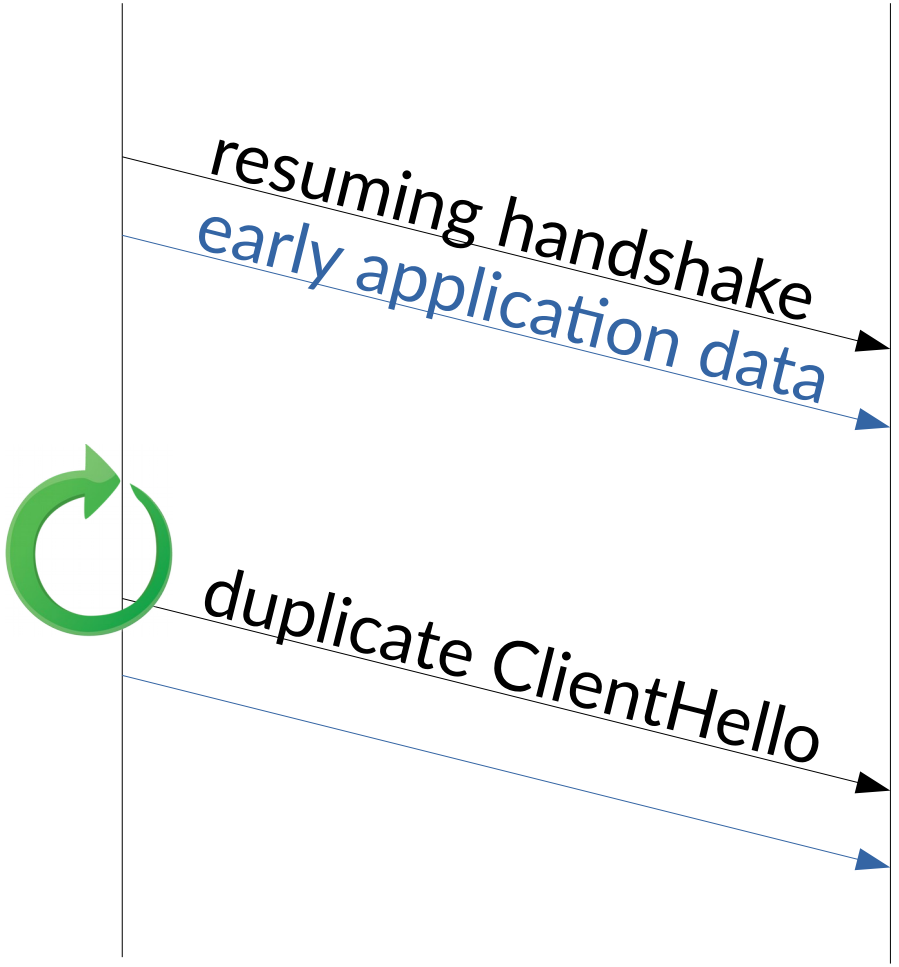
1
```
/* enable 0-RTT */
SSL_OptionSet(client, SSL_ENABLE_0RTT_DATA, PR_TRUE);
/* check the maximum data the server would accept */
SSL_GetResumptionTokenInfo(tokenData, tokenLen,
                           &token, &len);
if (size > maxsize)
  return -1;
```

2
```
/* send early data before handshake */
PR_Send(client, data, size);
/* do handshake, either explicitly or implicitly */
```

3
```
/* check if the early data was accepted */
SSL_GetChannelInfo(client, &info, sizeof(info));
if (!info.earlyDataAccepted) {
  /* early data was rejected; resend it as 1-RTT */
  PR_Send(client, data, size);
}
```

0-RTT mode: Risks

- No forward secrecy
- Replay attacks



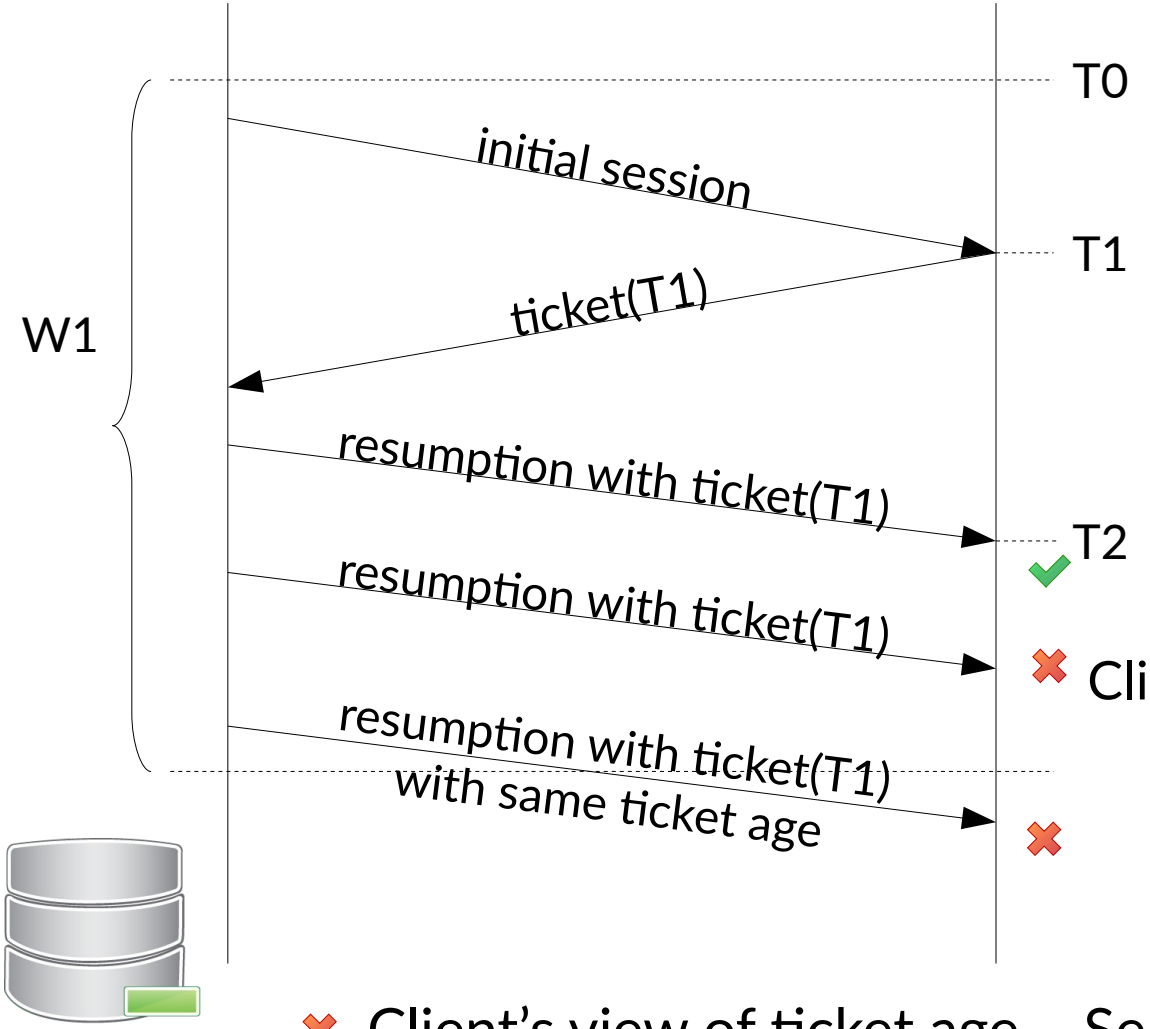
0-RTT: Anti-replay

- Single use tickets
  - OpenSSL
- Client Hello recording
  - GnuTLS, NSS

Single-use tickets

- Record issued session tickets in DB
- Remove ticket once it is used
  - Not limited to 0-RTT
  - Session tickets are long lived: ~1 week

Client Hello recording



record ClientHello within a certain time window ~10 sec

✖ Client sends duplicated ClientHello

✖ Client's view of ticket age – Server's view of ticket age > ~10 sec

0-RTT: Receiving

1. Enable 0-RTT with anti-replay
2. Accept or reject early data

0-RTT: Receiving

1

```
/* enable 0-RTT */
SSL_set_max_early_data(server, 65535); /* optional */

/* anti-replay mechanism is on by default,
 * implemented using server session cache */
```

2

```
/* receive early data, before application data */
while (ret != SSL_READ_EARLY_DATA_FINISH) {
  ret = SSL_read_early_data(server, buf, sizeof(buf),
                            &readbytes);
  if (ret == SSL_READ_EARLY_DATA_SUCCESS)
    /* early data received */;
}
```

OS

0-RTT: Receiving

1

```
/* enable early data receiving */
gnutls_init(&server, ...|GNUTLS_ENABLE_EARLY_DATA);
/* optional */
gnutls_record_set_max_early_data_size(server, 65535);
/* set up anti-replay mechanism */
gnutls_anti_replay_init(&ar);
gnutls_anti_replay_add_function(ar, ar_add_func);
gnutls_anti_replay_set_window(ar, 10000); /* optional */
gnutls_anti_replay_enable(server, ar);
```

```
static void
ar_add_func(void *ptr, time_t exp_time,
            const gnutls_datum_t *key,
            const gnutls_datum_t *data)
{
  /* add key/data if it doesn't exist */
}
```

0-RTT: Receiving

2

```
/* retrieve early data through a handshake hook */
gnutls_handshake_set_hook_function(server,
        GNUTLS_HANDSHAKE_END_OF_EARLY_DATA,
        handshake_hook_func);
```

```
static int
handshake_hook_func(gnutls_session_t session,
                    unsigned int htype,
                    unsigned when,
                    unsigned int incoming,
                    const gnutls_datum_t *msg)
{
  …
  return gnutls_record_recv_early_data(session,
                                       buf,
                                       sizeof(buf));
}
```

0-RTT: Receiving

1
```
/* enable early data receiving */
SSL_OptionSet(server, SSL_ENABLE_0RTT_DATA, PR_TRUE);
SSL_SetMaxEarlyDataSize(server, 65535); /* optional */

/* setup anti-replay mechanism
 * NSS internally uses Bloom filters to detect dupes
 * where k = 7, bits = 14
 */
SSL_SetupAntiReplay(10 * PR_USEC_PER_SEC, 7, 14);
```

2
```
/* receive early data as part of normal data */
PR_Read(server, buf, sizeof(buf));
```

Summary

- TLS 1.3 > TLS 1.2
- TLS 1.3 also brings additional features
- Those features need new API
- API designs have *reasons* behind them

Resources

- TLS 1.3 – OpenSSLWiki
  - https://wiki.openssl.org/index.php/TLS1.3
- GnuTLS and TLS 1.3
  - https://nikmav.blogspot.com/2018/05/gnutls-and-tls-13.html
- NSS
  - https://hg.mozilla.org/projects/nss/raw-file/tip/lib/ssl/sslexp.h