TLSv1.3

...quite a big change

TLSv1.3

- Administrivia
- Process
- Protocol
- Issues

Administrivia

- TLSv1.3 = RFC8446
- Took 4 years to get done
- 160 pages (eek!) - do not ignore Apendices C,D and E!
- Written for implementers – you may need to read it more than once (some less clear forward references), but it’s pretty readable really

List of implementations at:

https://github.com/tlswg/tlswg-wiki/blob/master/IMPLEMENTATIONS.md

Process

- Work started in 2014, motivations included TLS attacks seen in theory and in the wild and Snowdonia
- Represents a **major** change in the protocol - version numbering bikeshed was well painted
- Academic cryptographers worked closely with implementers to (hopefully!) ensure we don’t see the same crypto/protocol failures in future
- Two academic workshops were held and the protocol design was modified numerous times to better match cryptographic theory
    - TRON: https://www.ndss-symposium.org/ndss2016/tron-workshop-programme/
    - TLS-DIV: https://www.mitls.org/tls:div/

Major Changes

- Drop less desirable algorithms and move to AEAD everywhere
- Change how new ciphersuites get defined and get RECOMMENDED
- Added "0-RTT" mode, a double-edged sword! (aka sharp implement)
- RSA key transport removed, all key exchanges provide forward secrecy
- More encryption of handshake including some extensions
- ECC is now built-in
- No more compression or custom DH groups
- Pre-shared keying, tickets and session handling all done in one way
- PKCS#1v1.5 -> RSA PSS for protocol signatures (but not certificates)
- Versioning muck – need to pretend to not be TLSv1.3 for deployment in the real world of middleboxes

TLSv1.3 Features

- These slides are **not** a replacement for reading the spec
- 1-RTT handshake
- HRR
- PSK/Resumption
- 0-RTT
- Ciphersuite re-factoring
- Key Derivation
- Versioning muck
- (Notable) extensions
- Record Protocol
- Security Properties

Full “1-RTT” Handshake

```
Client                                             Server

Key  ^ ClientHello
Exch | + key_share*
     | + signature_algorithms*
     | + psk_key_exchange_modes*
     v + pre_shared_key*         -------->
                                                ServerHello  ^ Key
                                               + key_share*  | Exch
                                          + pre_shared_key*  v
                                      {EncryptedExtensions}  ^  Server
                                      {CertificateRequest*}  v  Params
                                             {Certificate*}  ^
                                       {CertificateVerify*}  | Auth
                                                 {Finished}  v
                                 <--------     [Application Data*]
     ^ {Certificate*}
Auth | {CertificateVerify*}
     v {Finished}                -------->
       [Application Data]        <------->      [Application Data]
```

Handshake with HelloRetryRequest

```
Client                                               Server

ClientHello
+ key_share             -------->
                        <--------       HelloRetryRequest
                                              + key_share

ClientHello
+ key_share             -------->
                                              ServerHello
                                              + key_share
                                    {EncryptedExtensions}
                                    {CertificateRequest*}
                                           {Certificate*}
                                     {CertificateVerify*}
                                               {Finished}
                        <--------     [Application Data*]
{Certificate*}
{CertificateVerify*}
{Finished}              -------->
[Application Data]      <------->      [Application Data]
```

Resumption/Re-use of PSK

```
       Client                                                Server

Initial Handshake:
       ClientHello
       + key_share               -------->
                                                      ServerHello
                                                      + key_share
                                            {EncryptedExtensions}
                                            {CertificateRequest*}
                                                   {Certificate*}
                                             {CertificateVerify*}
                                                       {Finished}
                                 <--------    [Application Data*]
       {Certificate*}
       {CertificateVerify*}
       {Finished}                -------->
                                 <--------     [NewSessionTicket]
       [Application Data]        <------->     [Application Data]

Subsequent Handshake:
       ClientHello
       + key_share*
       + pre_shared_key          -------->
                                                      ServerHello
                                                 + pre_shared_key
                                                     + key_share*
                                            {EncryptedExtensions}
                                                       {Finished}
                                 <--------    [Application Data*]
       {Finished}                -------->
       [Application Data]        <------->     [Application Data]
```

“0-RTT” Early Data

```
Client                                               Server

ClientHello
+ early_data
+ key_share*
+ psk_key_exchange_modes
+ pre_shared_key
(Application Data*)     -------->
                                                ServerHello
                                           + pre_shared_key
                                               + key_share*
                                      {EncryptedExtensions}
                                              + early_data*
                                                 {Finished}
                        <--------       [Application Data*]
(EndOfEarlyData)
{Finished}              -------->

[Application Data]      <------->        [Application Data]
```

“0-RTT” Issues

- “0-RTT” is a DANGEROUS IMPLEMENT
    - “0-RTT” isn’t really quite accurate terminology – client needs first to have a PSK, and of course doesn’t get an answer for at least one RTT and there could be a DNS RTT first
- Browsers want to send HTTP GET requests in “first flight” - without this feature it’s likely TLSv1.3 would not be adopted in the web
    - People need more incentives than just better security to cause them to upgrade
- Problem: **early-data can be REPLAYed**
    - Attacker records 0-RTT messages incl. early data
    - Replay that against another instance of a load-balanced server, e.g. in another data-centre where load-balanced instances can’t easily share an anti-replay cache
    - Example: DPRIVE – DNS/TLS with anycast recursives
- Bigger problem: properly handling the semantics of early-data is neither simple nor obvious, but the attraction of go-faster-stripes is simple and obvious
- Smaller problem – early-data not authenticated until server validates client’s Finished – can cause API headaches in servers, - do not act on early-data until after Finished is checked
    - Web servers might or might not (yuk) adhere to this rule, as in theory (but not in practice), HTTP GET and some other HTTP request methods are idempotent; see RFC 8470

Ciphersuite Re-factoring

- As the handshake has changed a lot, the WG decided to separate out record layer crypto from key exchange and authentication so...
- TLSv1.3 ciphersuites only reflect the record layer encryption (bulk cipher and key derivation function hash function) and not the key exchange and authentication parameters
    - TLS_AES_128_GCM_SHA256 is a TLSv1.3 ciphersuite
    - TLS_RSA_WITH_AES_128_CBC_SHA256 is a TLSv1.2 ciphersuite
- Key exchange and authentication parameters are dealt with in handshake extensions in TLSv1.3, e.g. using the key_share, supported_groups and signature_algorithms extensions in ClientHello and other handshake messages

Key Schedule/Derivation Function

```
HKDF-Expand-Label(Secret, Label, Context, Length) =
     HKDF-Expand(Secret, HkdfLabel, Length)

Where HkdfLabel is specified as:

struct {
    uint16 length = Length;
    opaque label<7..255> = "tls13 " + Label;
    opaque context<0..255> = Context;
} HkdfLabel;

Derive-Secret(Secret, Label, Messages) =
     HKDF-Expand-Label(Secret, Label,
                       Transcript-Hash(Messages), Hash.length)


HKDF is defined in RFC 5869
```

Key Schedule/Derivation (1/2)

```
                 0
                 |
                 v
   PSK ->  HKDF-Extract = Early Secret
                 |
                 +-----> Derive-Secret(.,
                 |                      "ext binder" |
                 |                      "res binder",
                 |                      "")
                 |                      = binder_key
                 |
                 +-----> Derive-Secret(., "c e traffic",
                 |                      ClientHello)
                 |                      = client_early_traffic_secret
                 |
                 +-----> Derive-Secret(., "e exp master",
                 |                      ClientHello)
                 |                      = early_exporter_master_secret
                 v
           Derive-Secret(., "derived", "")
                 |
                 v
(EC)DHE -> HKDF-Extract = Handshake Secret
```

Key Schedule/Derivation (2/2)

```
(EC)DHE -> HKDF-Extract = Handshake Secret
             |
             +-----> Derive-Secret(., "c hs traffic",
             |                     ClientHello...ServerHello)
             |                     = client_handshake_traffic_secret
             |
             +-----> Derive-Secret(., "s hs traffic",
             |                     ClientHello...ServerHello)
             |                     = server_handshake_traffic_secret
             v
       Derive-Secret(., "derived", "")
             |
             v
   0 -> HKDF-Extract = Master Secret
             |
             +-----> Derive-Secret(., "c ap traffic",
             |                     ClientHello...server Finished)
             |                     = client_application_traffic_secret_0
             |
             +-----> Derive-Secret(., "s ap traffic",
             |                     ClientHello...server Finished)
             |                     = server_application_traffic_secret_0
             |
             +-----> Derive-Secret(., "exp master",
             |                     ClientHello...server Finished)
             |                     = exporter_master_secret
             |
             +-----> Derive-Secret(., "res master",
                                   ClientHello...client Finished)
                                   = resumption_master_secret
```

Versioning Muck

- Middleboxes break things, so TLSv1.3 pretends to be TLSv1.2 in various ways
- supported_versions extension is where the real info is now
- ClientHello/ServerHello pretend to be TLSv1.0 or TLSv1.2
- “Dummy” change_cipher_spec messages (see Appendix D.4) make the handshake look more like TLSv1.2
- HelloRetryRequest pretends to be a TLSv1.2 ServerHello (magic values distinguish HRR)
- Record layer messages pretend to be TLSv1.2
- Absent this muck, at least 5-10% of TLSv1.3 sessions fail
- Appendix D also covers additional cases, e.g. where only some load-balanced server instances are updated at the moment (maybe due to reboots/failures or slow rollout of a new TLSv1.3 deployment)

Notable Extensions

- There are lots, some are mandatory to use for TLSv1.3, some are in-practice mandatory for the web, some not mentioned so far include:
- cookie – helps with DDoS and DTLS
- post_handshake_auth – is how TLS client auth is supported in TLSv1.3
- psk_key_exchange_modes and pre_shared_key – when using PSK
- encrypted_extensions – used from server -> client
- Some TLSv1.2 extensions remain usable in TLSv1.3 e.g. ALPN (RFC 7301)

Record Layer

- Now AEAD and differently derived keys but same max record size (2^14 octets) and same external headers (incl. fake version)
- AEAD => “MAC-then-encrypt” issues that caused a number of problems go away

Security Properties

- See Appendix E of the spec, and the references therin, the TRON and TLS-DIV proceedings, and other publications
- Forward secrecy is not absolute – TLSv1.3 attempts to provide FS wrt long term private keys but e.g. DH public vaue re-use for performance reasons can result is less than perfect FS
- TLSv1.3 attempts to confidentiality protect identities, which is new. Server identity protection however cannot resist active attack.
- Separation between key purposes is much more deliberate and far less ad-hoc than earlier versions of TLS.
- Remember the security differences wrt “0-RTT”
- Traffic analysis still works – padding mechanism exists but HOWTO use it successfully is a work-in-progress

Outstanding Issues

- Middle-box issues: not yet for sure that pretending to be earlier versions will work at scale, and when MitM product vendors update their stuff – evidence so far seems promising, though is mainly from Mozilla/Google and not AFAIK peer-reviewed or based on open-data
- Will TLSv1.3 displace earlier versions of TLS? For the web? Seems likely. In other applications? Not clear yet. “0-RTT” go faster stripes may encourage adoption/deployment, but might also lead to problems. Some claims that TLSv1.3 is too big a change, e.g. for smaller devices, and will be ignored. (No evidence so far.)
- QUIC re-uses the TLSv1.3 handshake and, if they get anti-ossification features just right, could maybe just about result in a future where we depend on QUIC for security and not TLS, and where QUIC evolves away from TLS. The future is never certain:-)

Summary

- TLSv1.3 specification is done
- Sufficient implementations exist, and it'll get at least some widespread deployment, but TLSv1.2 will be around for years to come (maybe decades?)
- Other than "0-RTT" - changes are all improvements IMO, some significant
- Careful though – it'd not be the first time we thought we'd gotten something new correct and were ultimately proven wrong