TLS “secrets“
What everyone forgot to tell you...

Florent Daignière – Matta Consulting Ltd

Blackhat USA

July 2013
1 Introduction
   - Who am I?
     - Secure Socket Layer
     - Forward secrecy

2 Where it all goes wrong...
   - Chosen extracts of the RFC
   - OpenSSL’s case
   - What about applications?
   - With the tin-foil hat on

3 Here comes the Tool

4 Conclusion
Who am I?

- Technical Director of a boutique security consultancy firm in London, UK
- One of the few Tiger Scheme trainers
- One of the core developers behind Freenet
- The guy who got a pwnie award last year for exposing the Most Epic FAIL!
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A bit of history...

**Versions of the protocol**

- SSLv2: released 1995
- SSLv3: released 1996
- TLSv1: released 1999
- TLSv1.1: released 2006
- TLSv1.2: released 2008

Unless you are stuck with IE6, you are unlikely to be using SSL!
A bit of history...

**Versions of the protocol**

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- TLSv1: released 1999
- TLSv1.1: released 2006
- TLSv1.2: released 2008

Unless you are stuck with IE6, you are unlikely to be using SSL!

Most likely you are using Transport Security Layer... Good; this is what my talk is about!
What bad excuses do people find Not to use/deploy SSL?

We are in 2013... but ‘performance’ seems to remain number one
What bad excuses do people find Not to use/deploy SSL?

We are in 2013... but ‘performance’ seems to remain number one

Let’s look into it...

- Handshaking is expensive (more on this later)
- If there’s a high-packet loss it adds significant amount of latency (more round trips)
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Let’s look into it...

- Handshaking is expensive (more on this later)
- If there’s a high-packet loss it adds significant amount of latency (more round trips)

Volume doesn’t matter... it’s symmetric encryption that modern processors do at several times wire-speed!
Cipher choice is of paramount importance!

- **AESNI**
  - aes-128 w/ AESNI is 170% faster than RC4
  - 3des is 95% slower than RC4
No silver bullet. Asymmetric cryptography is expensive. Whether it’s RSA / DSA / ECDSA doesn’t make much difference. Keysize does… but it would be unwise to optimize too much…
Performance of the Handshake

No silver bullet. Asymmetric cryptography is expensive. Whether it’s RSA / DSA / ECDSA doesn’t make much difference Keysize does… but it would be unwise to optimize too much...

The solution?
Handshake once... and resume sessions (using an abbreviated handshake) where possible!
SSL Session resumption

Without resume

Client

1. Client Hello
2. Server Hello
3. Client Key Exchange
   Change Cipher Spec
   Finished
4. Change Cipher Spec
   Finished

Server

0 ms
50 ms
100 ms
150 ms
200 ms
250 ms

GET / HTTP/1.0
SSL Session resumption

Without resume

1. Client Hello
2. Server Hello
   Certificate
   Server Hello Done
3. Client Key Exchange
   Change Cipher Spec
   Finished
4. Change Cipher Spec
   Finished

GET / HTTP/1.0

0 ms
50 ms
100 ms
150 ms
200 ms
250 ms

With resume

1. Client Hello
2. Server Hello
   Change Cipher Spec
   Finished
3. Change Cipher Spec
   Finished
4. GET / HTTP/1.0

0 ms
50 ms
100 ms
150 ms

How does it work?

For SSL and basic TLS

You get a session-id... that you present on each re-connection
What if we made it stateless?

- Store an arbitrary-sized, encrypted blob stored client-side
What if we made it stateless?

- Store an arbitrary-sized, encrypted blob stored client-side

RFC to the rescue!

4. Recommended Ticket Construction

This section describes a recommended format and protection for the ticket. Note that the ticket is opaque to the client, so the structure is subject to interoperability concerns, and implementations may diverge from this format. If implementations do diverge from this format, they must take security concerns seriously. Clients MUST NOT examine the ticket under the assumption that it complies with this document.

The ticket uses two different keys: one 128-bit key for Advanced Encryption Standard (AES) [AES] in Cipher Block Chaining (CBC) mode [CBC] encryption and one 256-bit key for HMAC-SHA-256 [RFC4543].

The ticket is structured as follows:

```c
struct {
    opaque key_name[16];
    opaque iv[16];
    opaque encrypted_state<0..2^16-1>;
    opaque mac[32];
} ticket;
```

Here, key_name serves to identify a particular set of keys used to protect the ticket. It enables the server to easily recognize tickets it has issued. The key_name should be randomly generated to avoid collisions between servers. One possibility is to generate new random keys and key_name every time the server is started.

The actual state information in encrypted_state is encrypted using 128-bit AES in CBC mode with the given IV. The Message Authentication Code (MAC) is calculated using HMAC-SHA-256 over key_name (16 octets) and IV (16 octets), followed by the length of encrypted_state (16 bytes) and encrypted_state itself.
RFC 5077 - what does it look like?

For SSL and basic TLS

You get a blob... that you present on each re-connection
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What is forward secrecy?

- Attacker cannot decrypt a conversation even if he records the entire session and subsequently steals their associated long-term secrets.
- The session keys are not derivable from information stored after the session concludes.
Why would you want forward secrecy?

A Crypto Nerd’s Imagination:
His laptop’s encrypted. Let’s build a million-dollar cluster to crack it.

No good! It’s 4096-bit RSA!
Blast! Our evil plan is foiled!

What would actually happen:
His laptop’s encrypted. Drug him and hit him with this $5 wrench until he tells us the password.

Got it.
Where do you have no forward secrecy? (whereas you should!)

- Browsing the internet (more on this later)
- WiFi (WPA-PSK / WPA-EAP-tunnel)
- Cell phones (2G/3G/4G)
- ... everywhere?
How do you get Forward Secrecy?

How do you get forward secrecy?
Using a Diffie-Hellman construct!
How do you get Forward Secrecy?

Using a Diffie-Hellman construct!

How much does it cost?

- RSA 2048:
  - Client: 0.88 seconds
  - Server: 3.81 seconds

- DHE 2048:
  - Client: 2.70 seconds
  - Server: 11.68 seconds

- ECDHE 2048:
  - Client: 2.70 seconds
  - Server: 4.85 seconds

- ECDHE-64 2048:
  - Client: 1.54 seconds
  - Server: 4.39 seconds

CPU time in seconds
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5. Security Considerations

5.5. Ticket Protection Key Management

A full description of the management of the keys used to protect the ticket is beyond the scope of this document. A list of RECOMMENDED practices is given below.

- The keys should be generated securely following the randomness recommendations in [RFC4086].
- The keys and cryptographic protection algorithms should be at least 128 bits in strength. Some ciphersuites and applications may require cryptographic protection greater than 128 bits in strength.
- The keys should not be used for any purpose other than generating and verifying tickets.
- The keys should be changed regularly.
- The keys should be changed if the ticket format or cryptographic protection algorithms change.

"beyond the scope of this document"?!?
5. Security Considerations

5.6. Ticket Lifetime

The TLS server controls the lifetime of the ticket. Servers determine the acceptable lifetime based on the operational and security requirements of the environments in which they are deployed. The ticket lifetime may be longer than the 24-hour lifetime recommended in [RFC4346]. TLS clients may be given a hint of the lifetime of the ticket. Since the lifetime of a ticket may be unspecified, a client has its own local policy that determines when it discards tickets.

"The ticket lifetime may be longer than the 24-hour..."
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4. Conclusion
OpenSSL won’t keep you safe!

How do they do it?

- Tickets are enabled by default
- Encrypted using AES128-CBC
- Keys are stored in the SSL_CTX
- No rekeying
OpenSSL won’t keep you safe!

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What does it mean?

- No point in using anything fancier than AES128-CBC!
- Your PFS interval is the program’s lifetime!
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What about applications?

**nginx**

PFS interval is the program lifespan

Haha, but I use Apache!
What about applications?

**nginx**

PFS interval is the program lifespan

Haha, but I use Apache!

**Apache HTTPd**

PFS interval is:
* pre r1200040 the program lifespan
* post r1200040 the user is in charge of key management!

Vendors don’t care; do you?
Tor’s case

Yes, Tor is affected.

Ephemeral long-term keys (rotating certificates)

... that’s the PFS interval, unless ...
What about ’sensitive’ applications?

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In which case, you can keep the SSL_CTX in memory forever
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1) Connect to all relays you want to bust
2) Repeat (but don’t rinse) every
MAX_SSL_KEY_LIFETIME_INTERNAL (2h)
3) Bust the operators/relays, get the keys, decrypt the traffic.

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One layer of the onion is gone; two to go!
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How does that affect me?

<table>
<thead>
<tr>
<th>Website</th>
<th>seconds</th>
<th>1h</th>
<th>24h</th>
<th>48h</th>
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<td>N</td>
<td>N</td>
</tr>
<tr>
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<td>Y</td>
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<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
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</tr>
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<td><a href="http://www.yahoo.com">www.yahoo.com</a></td>
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<tr>
<td><a href="http://www.fbi.gov">www.fbi.gov</a></td>
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</tr>
<tr>
<td><a href="http://www.royal.gov.uk">www.royal.gov.uk</a></td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wouldn’t having the key of tickets be convenient?
How would someone go about stealing the secret?
Well, it depends on who you are I guess.
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If you are the government

You just ask politely...
And should your request be politely declined...
you use a PRISM to “see“ it through the interwebz! ;)

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TLS “secrets“... What everyone forgot to tell you...
Key management

How would someone go about stealing the secret?
Well, it depends on who you are I guess.

If you are the government
You just ask politely...
And should your request be politely declined...
you use a PRISM to “see“ it through the interwebz! ;)

If you are not the government
You can ask your mate who is in the planet-alignment-business to
give you one of his “useless“ memory disclosure bugs.
Odds are he has plenty, as it’s now pretty much required to get
reliable exploitation.
Key management

If you don’t have a mate doing exploitation...

Well, you must be LEO then.
If you don’t have a mate doing exploitation...
Well, you must be LEO then. Jokes aside, you can do forensics and my tool can probably help you.
Demo time...
...

How does it work?

Using and abusing PTRACE to extract the master encryption key; allowing to decrypt the session tickets sent over the wire... Which in turn contain the Master Session Key allowing to derive the key used to decrypt the cipher text and recover the plaintext.
How does it work?

Using and abusing PTRACE to extract the master encryption key;
Demo

Demo time...

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Conclusion and take-aways

If you are an auditor
You shouldn’t focus on getting people to use a cipher strength providing more than 128 bits of security.

If you are a pentester
You should learn to use and abuse SSL to bypass “intermediary“ devices preventing you from doing your job.

If you are a end-user
You might want to reconfigure your clients and disable RFC5077 support.
References

- https://issues.apache.org/bugzilla/show_bug.cgi?id=50869
- https://httpd.apache.org/docs/trunk/mod/mod_ssl.html#sslsessionticketkeyfile
- https://trac.torproject.org/projects/tor/ticket/7139
Thank you!

I blog at http://blog.trustmatta.com
and tweet at @nextgens1
You can find the source-code of the tool at
https://github.com/nextgens/

Important!

Please don’t forget to fill in the feedback form!