

Real Issues with TLS (and Fixes)

*Oh crap, the TLS ecosystem isn't near-perfect.
Some people work on fixes.
Others work on finding more problems.

That's life as a really popular security protocol.*

TLS Issues

RFC 7457 - Summarizing Known Attacks on
Transport Layer Security (TLS) and Datagram
TLS (DTLS) – Feb 2015

Good source of references to attacks/bugs as of that
date

More continues to happen of course...

Contents

- Issues in rough age-order
 - Weak key generation
 - CA screw-ups
 - Bleichenbacher
 - Re-negotiation
 - CA screw-ups
 - Weak key generation
 - Stuxnet/Flame
 - BEAST
 - CRIME
 - Lucky-13
 - DROWN
- More to come no doubt
- Some possible Futures for TLS

Don't panic!

- Many issues have been found over the years with TLS implementations and a few issues with the protocol itself
- It is still far far easier to properly use TLS and get security than it is to re-invent TLS
 - So use it!
 - But make sure you're using it properly

Ancient Crappy Key Generation

- 1996-era Netscape mucked up key generation

<https://people.eecs.berkeley.edu/~daw/papers/ddj-netscape.html>

Problem: TLS pre-master secret could be guessed

- Only really 47 bits of entropy and not 128
- Fix: More entropy and better code
 - No protocol change needed

Ancient CA Screw-Ups

- 2001, social engineering works then and now
- VeriSign issued code-signing certs to someone who was not microsoft.com
- Fixes:
 - VeriSign revoked certs
 - MSFT issued a patch:

<https://technet.microsoft.com/library/security/ms01-017>

- Interesting sign of how bad revocation really was (and is!), user-agents need patching for serious revocations!

Bleichenbacher

- 1998 Adaptive chosen ciphertext attack
 - First of those afaik that was near-practical
 - Paper/ppt in course materials
- Really an attack on PKCS#1 and not TLS
 - But impacts TLS implemtentations
- Problem: responding to bad padding too early in handshake
- Bleichenbacher just keeps on giving (to security researchers):
 - Timing attacks on code, not just protocol
 - Java exception handling to generate random PMK
 - Cross-protocol attacks and fallback attacks – DROWN (later)
 - ROBOT (later)
- Fixes:
 - Don't do that – RFC 3218
 - Use OAEP – still not really done today because of “legacy” APIs

Re-Negotiation

- 2009: lots of time passed!
- Problem: Re-negotiation new session not bound to initial TLS session
 - MITM can force renegotio but URL from original session used with 2nd session's privileges
- Fix: RFC 5746, developed in 3 months start to finish, a breaking backwards incompatible protocol change

CA Screw-Ups (1 - diginotar)

- 2011, diginotar.nl were a public CA present in browser root stores
<https://en.wikipedia.org/wiki/DigiNotar>
- Someone hacks into diginotar servers, issues certificates for google.com, microsoft.com etc., abuses those certificates
- Weeks later diginotar confess and are kicked from browser root stores and go bust
- Problem: lack of NameConstraints or equivalent in web PKI
- Fixes:
 - diginotar liquidated
 - NameConstraints: work-in-progress :-(

CA Screw-Ups (2 - “comodogate”)

- 2011 again, good/bad year for this
- Not Commodo's direct fault, but their responsibility

https://www.theregister.co.uk/2011/03/28/comodo_gate_hacker_breaks_cover/

- Comodo partner/RA hacked, certificate requests for google.com, microsoft.com etc., submitted from RA to CA and certificates issued
- Certificates revoked quickly but lack of sanity checks within CA infrastructure damaging
- Fixes:
 - Commodo now do more sanity checking on requests from RAs
 - NameConstraints: work-in-progress :-(

Internet-Scale Weak-Key Generation

- 2012 – Build DB of $O(10^6)$ keys and look for problems...
<https://freedom-to-tinker.com/blog/nadiah/new-research-theres-no-need-panic-over-factorable-keys-just-mind-your-ps-and-qs/>
- Problem: many embedded devices generate keys before they have any real entropy on first boot; with RSA, 1st prime from pair likely to collide with someone else when there are millions of devices (TLS/SSH servers) visible on the Internet
 - >1% of 15 million keys had common factors
 - Common RSA modulus factors => easy to factor, GCD calculation is easy regardless of size
- Fixes:
 - More entropy (somehow;-)
 - Better code (somehow:-)
- Interesting thing:
 - Building a DB of almost all public keys used on the public Internet is quite feasible
 - Now there's a thought! More on that later.

Stuxnet/Flame – BIG Bad Actors

- 199x-201x: Stuxnet and Flame
- Stuxnet: involved compromised code-signing private keys
- Flame: Stuxnet + new MD5 prefix-collision attack for out of date Windows deployments + really really stupid conflation of different PKIs in MSFT ecosystem

<https://arstechnica.com/information-technology/2012/06/flame-crypto-breakthrough/>

- Above is a bit overstated maybe on the “breakthrough” part
- Problems:
 - NameConstraints again,
 - Private key handling (stuxnet)
 - Outmoded PKIs (MD5 – sheesh!)
 - Major state actors have major resources and do not have the interests of the Internet at heart (at least for the parts of their organisations that create attacks)
- Fixes:
 - Do PKI better (we all wish;-)
 - Don't stick with crap algorithms like MD5

BEAST – Back to TLS

- 2011 – BEAST

<https://www.ietf.org/proceedings/85/slides/slides-85-saag-1.pdf>

- BEAST combines active content on page with a network MITM who can passively watch to allow for cookie recovery within TLS
 - TLS with CBC, next block IV is last block's ciphertext; URLConnection class allows client code to split info into small chunks; allows messing with TLS application layer PDUs; allows client code that can't read cookie to emit data so that collaborating MITM can detect when client code guessed correct cookie
 - Complicated – see the slides referenced above
- Fix:
 - Partly: Use TLS 1.2 and not earlier

CRIME – TLS Compression Not So Good in the end

- 2012 – CRIME

<https://www.ietf.org/proceedings/85/slides/slides-85-saag-1.pdf>

- Easier than BEAST – if you compress things then they get smaller; that allows you to guess and detect good guesses from ciphertext size
 - Feed back HTML to client with guesses, each embedded in an img reference and see which gets smaller; smaller one is the one that's been seen before so you've learned a character of a cookie; repeat for next characters
- Fixes:
 - Turn off compression
 - What to do for HTTP/2.0? HPACK for headers, application layer and not in TLS otherwise

Lucky-13 – CBC Problematic Again!

- 2013 – Lucky-13 CBC timing side-channel
<http://www.isg.rhul.ac.uk/tls/Lucky13.html>
(yeah, not https:// above - ick)
- CBC ciphersuites allow for a timing attack based on the size of HMAC-SHA1 input and timing on SHA1; millisecond differences between good and bad padding expose plaintext
- Attack more practical against DTLS (UDP/connectionless) than TLS (TCP/connection-oriented)
- Fixes:
 - Use TLS1.2 with AEAD ciphers
- Of note:
 - Researchers worked with vendors/standards community to get fixes out while research paper embargoed
 - Everyone loved 'em for that

RC4 Problematic in TLS

- 2013, mid-March

<http://www.isg.rhul.ac.uk/tls/>

- Found position-based biases in RC4 ciphertext bytes, based on analysis of $\sim 2^{40}$ inputs; repeated encryption of same plaintext at same position (e.g. Cookie) vulnerable, more problematic if limited alphabet (e.g., base32); result is plaintext recovery with about 2^{24} or 2^{30} TLS sessions
- Fixes:
 - Don't use RC4
- Of note:
 - Same researchers as Lucky-13, same modus-operandi, same love

DROWN – SSLv2!!

- March 2016
- Old SSLv2 code that can still be accessed re-enables Bleichenbacher
 - Yes, they have a web site: <https://drownattack.com/>
 - Nice cross-protocol attack, similar to
 - <https://www.nds.rub.de/research/publications/ccs15/>
- Affects millions of sites on the Internet
- Fix:
 - Get rid of old, old code!
 - Don't over-prioritize interop and ignore everything else

startcom/wosign - 2016

- Startcom CA sold on the q.t.
- Buyer a CA that had “interesting” practices
- CA (WoSign) couldn’t justify those to browsers
- Dropped from root stores, e.g.:

<https://threatpost.com/apple-to-block-wosign-intermediate-certificates/121044/>

The good news: CT helped!

ROBOT - 2017

- Return Of Bleichenbacher's Oracle Threat
<https://robotattack.org/>
- Mostly re-testing for Bleichenbacher on the Alexa top 1M
- Main point: demonstrated real issues remaining in real deployments
- To avoid: just don't support RSA key transport at all

Trustico - 2018

- Ongoing fun now...
 - CA re-seller email 23k private keys to CA
 - Apparently wanting those revoked due to business changes
- And of course someone showed their web site was extremely borkable...
 - <https://arstechnica.com/information-technology/2018/03/trustico-website-goes-dark-after-someone-drops-critical-flaw-on-twitter/>

TLS MITM Products

- 20xx-date: Vendors sell TLS MITM products for “corporate policy enforcement”

<https://directorblue.blogspot.ie/2006/07/think-your-ssl-traffic-is-secure-if.html>

- Reasons:
 - Good: inbound malware scanning
 - Bad: everything else
- Some CA operators “collaborated” with this bad practice:
 - https://bugzilla.mozilla.org/show_bug.cgi?id=724929
- Getting more common, but IETF have refused numerous vendor requests to standardise this behaviour
- Fixes:
 - New PKI approaches/features that detect country-level misbehaviour will hit this
 - End-to-end use of TLS for speed and avoiding advertising will hit this

So where are we?

- (D)TLS is imperfect in various ways
 - PKI name constraints and other imperfections
 - Too many TLS ciphersuites (with weaknesses)
 - Significant change takes years (before old bad code can be deleted)
- (D)TLS is still the best bet for many things
 - PKI is better than non-existent non-PKI (old-bad-but-existing-infrastructure often wins)
 - Plenty of good TLS ciphersuites esp. TLS 1.2 AEAD
 - Change only takes years because of success!

Aside: HTTP/2

- HTTP is definitely one of the most important protocols on the Internet
- HTTP/1.1 and earlier are not very efficient in various ways, e.g., header verbosity, head-of-line blocking
- HTTP/2 recently finished (RFC7540), based on SPDY, to make improvements (without semantic change vs. HTTP/1.1)
- Part of that work involved negotiating HTTP/2 usage and not HTTP/1.x usage
 - Doing do without additional round-trips is a MUST
- One important way to negotiate HTTP/2 will be via TLS handshake
 - Claim: HTTP/TLS gives better speed and connectivity than cleartext HTTP!
 - Done via “Application Layer Protocol Negotiation” (ALPN) as TLS handshake extension (RFC7301)
- Notes:
 - This replaces TCP port numbers – architects faint!
 - This makes TLS critical for deployment of HTTP/2
 - This annoys middlebox vendors/operators - Hmmmmmmmm
 - QUIC (<https://tools.ietf.org/wg/quic>) will annoy them even more

Things to do: TLS

- ALPN in TLS handshake for HTTP/2.0
- “Strict” TLS sites
- Key Pinning (more in a 'mo)
- Protection of TLS handshake elements
 - Make TLS more like IKE and maybe simpler (for a while)
- Finish TLS 1.3 that first does D-H and then current TLS like stuff
 - Hopefully with far fewer ciphersuites!
- Probably some more things related to webRTCweb
 - (D)TLS is mandatory-to-use there for some things
 - Mandatory-to-use is new and different from mandatory-to-implement, which is common for IETF

Strict TLS

- If a web site offers TLS then great, that's hard to spoof
- If however, I spoof that same content but without TLS, user's won't notice
 - “Studies” show users don't notice lock-icon, green URL bar, etc.
- However, browser can notice that a site I normally access over TLS is now in clear
 - While off, browser can't by itself know that's bad and users also can't know
- But a few sites might be able to tell browser “once you've ever been here via TLS, you should never believe if you see this site in clear”
 - For example, paypal.com seem keen on this
 - Creates potential new way to shoot oneself in the foot – turn on HSTS with the wrong key; sub-/parent-domain handling within same “administrative” domain
 - Sidebar: public-suffix list is a pain
- New HTTP header: HSTS – HTTP Strict Transport Security (RFC 6797)
 - Site says: TLS MUST be used to access this site (and optionally sub-domains) between now and now+timeout and browser MUST NOT allow cleartext access to the above
 - Newer HSTS headers win over old (pushes duration out to future indefinitely)
 - HSTS MUST be first seen over TLS of course

TLS Key Pinning

- Provide an HTTP header that allows browser to “pin” site TLS server certificate to one or two site public keys or CA public key (RFC 7469)
- Coarse-grained mitigation for NameConstraints issue
- Can allow site to “brick” itself, so HPKP is mostly deprecated by sensible deployments
 - Note: HSTS is ok, HPKP less so

Things to Do: PKI

- Figure out a way to get over NameConstraints issue
- Current approaches:
 - CAA - site tells CA which CA is ok
 - DANE – site tells client which key/CA is ok
 - Certificate Transparency (CT, RFC6962) and similar – large DB of “ok” public keys used so browsers can cross-check PKI but also so sites can check if someone else claims to be them
 - Similar: SovereignKeys and Convergence/Perspectives and EFF SSL observatory
 - Right now, CT looks “best” maybe, but we'll see

CAA – Certification Authority Authorization

- If a site publishes the list of CAs with which it wants to do business, then other (non-stupid) CAs can detect some badness that might currently pass unnoticed
 - Some compromised RA asks company-CA to issue certificate for example.com but example.com has publicly said they get certs from Foo and Bar CAs only
 - RFC 6844, is now being deployed due to CAB forum preferences, and it's not hard (if you can write to DNS)

DANE – DNS based Authentication of Named Entities

- Allows for addition of TLS server certificate information to DNS
 - RFC 6698
- REQUIRES DNSSEC for security
 - Without DNSSEC DANE would make TLS security worse
- TLSA RR (new) can contain (hash of) site or CA keys for a given TLS server/service in various combinations
- Web deployment not really happening so far
 - Browsers don't seem to like it for various reasons
 - Could be a good idea whose time has yet to come
- Work ongoing to see if useful for SMTP (MTA<->MTA security)

Large DB of Public Keys

- EFF SSL Observatory
<https://www.eff.org/observatory>
- Approaches that touch clients:
 - Convergence/Perspectives
<http://convergence.io/details.html>
 - SovereignKeys
<https://www.eff.org/sovereign-keys>
 - Certificate Transparency
<http://www.certificate-transparency.org/>

Conclusions

- TLS and PKI are and will continue to be attacked
 - The most commonly used end-to-end security mechanism is an attractive target for researchers and bad actors
- 20 years of experience seems to show:
 - TLS is robust enough and can evolve slowly
 - Evolution is too slow esp., for deployment
 - TLS is too hard to use properly for some application developers
 - TLS1.3 (modulo 0rtt) will be a fine improvement
- Don't panic:-)