Modelling ciphersuite and version negotiation in the TLS Protocol

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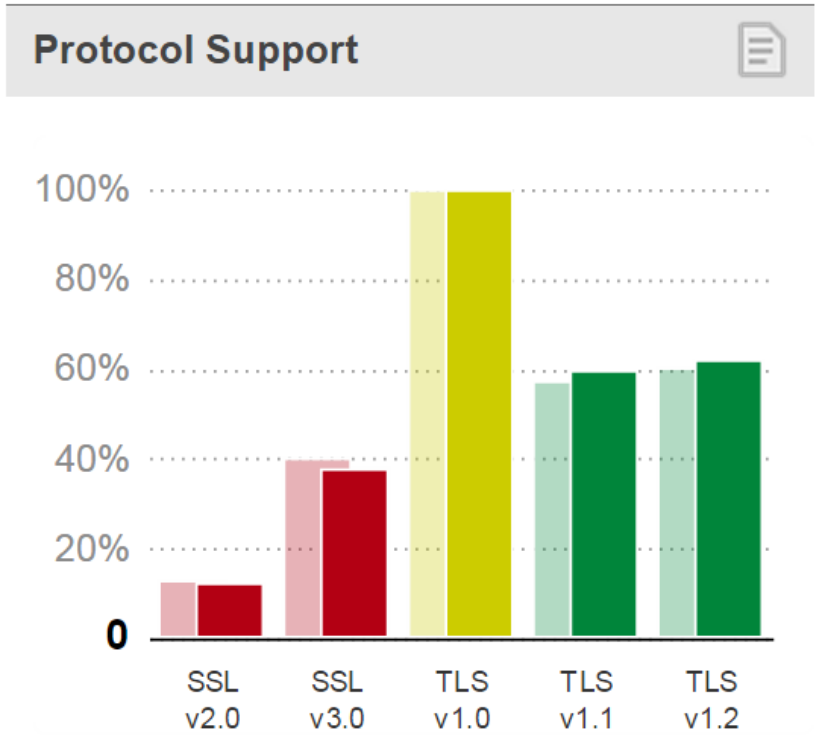
Outline

1. Motivation
2. Negotiation in the TLS Protocol
3. Modelling negotiation in a provable security framework
4. Analysis of TLS ciphersuite and version negotiation
5. Conclusions

Motivation

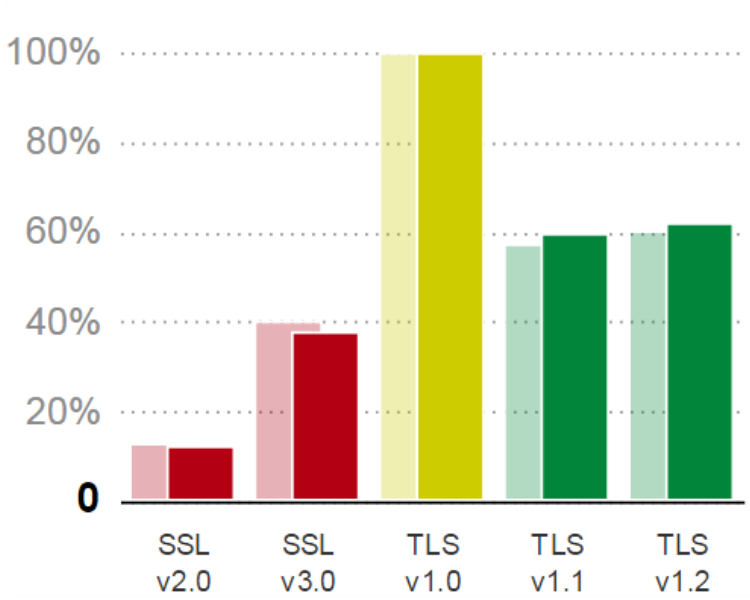
- TLS implementations have complex functionality
- Algorithmic agility is desired to increase interoperability
- Interoperability can affect security

Motivation

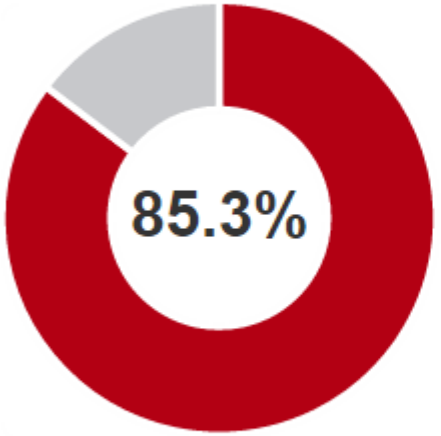

Protocol Support
100%
80%
60%
40%
20%
0
SSL v2.0
SSL v3.0
TLS v1.0
TLS v1.1
TLS v1.2

Motivation

Protocol Support



BEAST Attack



Sites that are vulnerable to the BEAST attack

125,153

+ 1.0 %

Version Downgrade Attacks

- Moeller and Langley - TLS extension to prevent downgrades
- SSLv2 provides **very** limited authentication properties
- SSLv3 vulnerable to BEAST and POODLE attacks

Version Downgrade Attack

TLS 1.1

- Client attempts handshake
- Version Failure Response (unauthenticated)

TLS 1.0

- Client attempts handshake
- Version Failure Response (unauthenticated)

SSLv3

- Client attempts handshake
- Success! (but not really…)

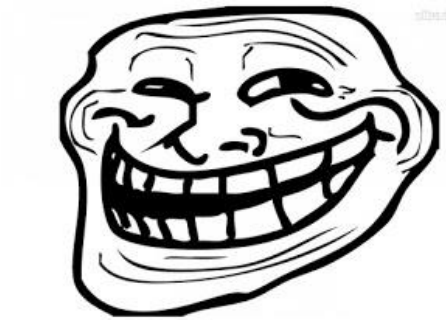
Ciphersuite Downgrade Attacks

- FREAK attack – (Beurdouche, Bhargavan, Delignat-Lavaud, Fournet, Kohlweiss, Pironti, Strub, Zinzindohoue, Zanella-Béguelin; 2015)
  - Implementation errors allow the negotiation of Export-RSA despite no indicated support

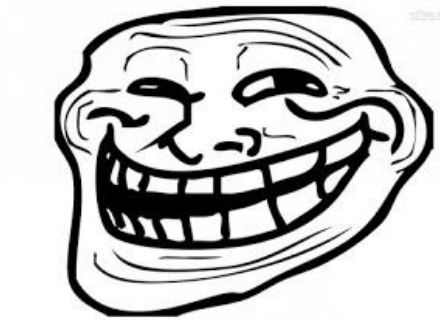
- Logjam Attack – (Adrian, Bhargavan, Durumeric, Gaudry, Green, Halderman, Heninger, Springall, Thomé, Valenta, VanderSloot, Wustrow, Zanella-Beguelin, and Zimmermann; 2015)
  - Protocol logic misinterprets export-DHE shares as “normal” DHE shares

Ciphersuite Downgrade Attacks

ClientHello:
bad_ciphersuite,
good_ciphersuite



Ciphersuite Downgrade Attacks



ClientHello’:
bad_ciphersuite

Ciphersuite Downgrade Attacks

ServerHello:
bad_ciphersuite

Ciphersuite Downgrade Attacks

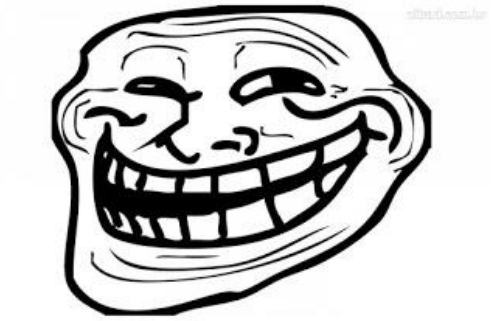
Finished: good ciphersuite, bad_ciphersuite,

Ciphersuite Downgrade Attacks

Finished’:
bad_ciphersuite

Ciphersuite Downgrade Attacks

Finished:
bad_ciphersuite



Observations

- Clearly negotiation from a family of protocols can affect security of the protocol as a whole

- What can we say about the security of the collection of protocols?

Talking about negotiation

- Treat the handshake as two phases:
  - A negotiation phase: common to all handshake runs
  - A sub-protocol phase: uses negotiated values to execute key-exchange/authentication, etc.

- "Optimal" negotiation:
  - Both parties have ordered list of preferences
  - Also have an "optimality function"
  - Negotiation is optimal if they output same value and it's the output of *opt(list, list')*

Using previous results

- Can see from downgrade attacks that security of the negotiation relates to the authentication of transcript

- Negotiation-Authentication Theorem:
  - Condition 1: All Negotiation Phase messages are in the session identifier
  - Condition 2: If no modification of messages, negotiation always “optimal”

Ciphersuite Negotiation “secure”

- 1. All negotiation messages contained in transcript
- 2. Ciphersuite negotiation optimal without active adversary

- If all ciphersuites result in secure authentication properties then negotiating to any given ciphersuite is secure

Version Negotiation (no fallback) “secure”

- 1. All negotiation messages contained in transcript
- 2. Version negotiation optimal without active adversary

- If all versions result in secure authentication properties then negotiating to any given version is secure

Version Negotiation (w/ fallback) “secure”

- 1. All negotiation messages contained in transcript?

Version Negotiation (w/ fallback) insecure

- 1. All negotiation messages contained in transcript?

NOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO

Version Negotiation (w/ fallback) insecure

- 1. All negotiation messages contained in transcript?

NOOOOOOOOOOOOOOOOOOOOOOOOOO

- Negotiation occurs across multiple handshakes, session identifier is only the transcript of the most recent handshake

Version Negotiation (w/ SCSV) “secure”

- 1. All negotiation messages contained in transcript
- 2. Version negotiation optimal without active adversary

- HOWEVER: Non-contiguous support of TLS version (i.e. supporting 1.2 and 1.0 but not 1.1) can break version negotiation with SCSV

Conclusions

- When considering negotiation security, think:

Weakest Link Security

- Additionally:

Always authenticate everything

Thanks!

Questions?