NTNU | Norwegian University of Science and Technology

LEGACY CRYPTO 2: ATTACKS ON TLS

TTM4205 – Lecture 6

Tjerand Silde

13.09.2024

Contents

Contents

Reference Group Meeting

We now have four reference group members:

- Adrian Tokle Storset (adriats), from MSTCNNS
- Daniel Nils Braun (danienbr), exchange student
- Jiaqi Chen (jiaqic), from SECCLO
- Emil Bragstad (emil.bragstad), from MTKOM

The first meeting will be on September 23rd.Please provide feedback!

ChipWhisperer Lab

- The assignment will be made available on Monday September 16
- The lab submission deadline will be Friday December 6th
- Caroline will give a setup tutorial on Tuesday September 17th
- You will get access to a computer lab and ChipWhisperer equipment
- The lab consists of four parts, each part worth 5 points
- Each part consists of several tasks that you need to complete
- There is a bonus problem worth 5 points if you are interested

Contents

Legacy Crypto is...

- Old and outdated crypto
- Insecure, weakened, or flawed crypto
- Crypto regulated by export control
- Potentially backdoored crypto
- Key escrow and surveillance
- Downgradable crypto protocols

Two Categories

Secret Key Crypto

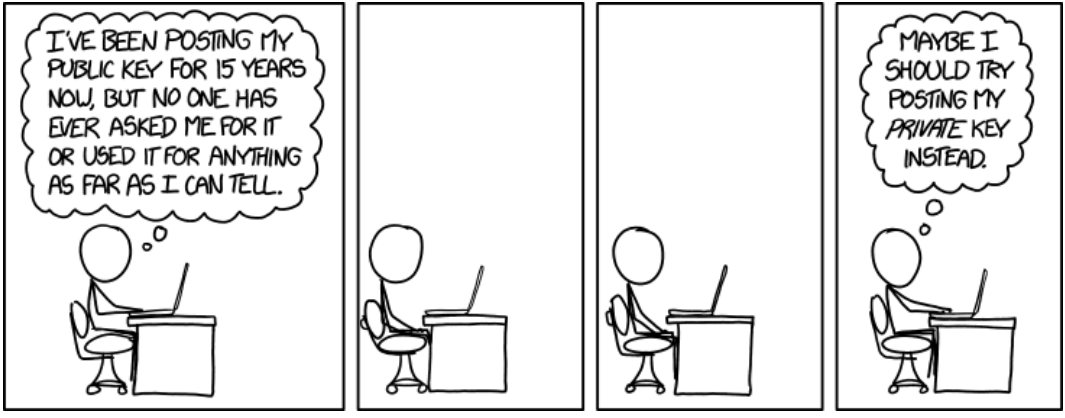
Public Key Crypto

Today

Secret Key Crypto

Public Key Crypto

Public Key Crypto



Contents

Legacy Ciphers

While we have attacks against symmetric key ciphers making them obsolete, we do not have groundbreaking attacks against legacy public key ciphers.

However, we need to be careful when setting parameters and composing different schemes in more complex protocols.

Here are some examples...

Weak DH

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- Non-prime group $\mathbb{Z}_q^* \rightarrow$ Leaks Legendre symbol of m
  - computing DL depends on largest prime factor $p|(q-1)$
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- Supersingular curves $\rightarrow$ Can break Decisional DH
- Choose safe curves? $\rightarrow$ Standardized P-256, X25519, ...

ECC in Practice

Elliptic Curve Cryptography in Practice

Joppe W. Bos[1], J. Alex Halderman[2], Nadia Heninger[3], Jonathan Moore, Michael Naehrig[1], and Eric Wustrow[2]

[1] Microsoft Research
[2] University of Michigan
[3] University of Pennsylvania

Figure: https://eprint.iacr.org/2013/734.pdf

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- PKCS 1 padding $\rightarrow$ Bleichenbacher's padding attack

Twenty Years of Attacks on the RSA Cryptosystem

Dan Boneh
dabo@cs.stanford.edu

Figure: https://crypto.stanford.edu/~dabo/papers/RSA-survey.pdf

RSA Challenges

Challenge Name	Digits	Bits	Date Factored	Factored by
RSA-100	100	330	Apr 1, 1991	A. K. Lenstra
RSA-110	110	364	Apr 14, 1992	A. K. Lenstra and M.S. Manasse
RSA-120	120	397	Jul 9, 1993	T. Denny et al.
RSA-130	130	430	Apr 10, 1996	A. K. Lenstra et al.
RSA-140	140	463	Feb 2, 1999	H. te Riele et al.
RSA-150	150	496	Apr 16, 2004	K. Aoki et al.
RSA-155	155	512	Aug 22, 1999	H. te Riele et al.
RSA-160	160	530	Apr 1, 2003	J. Franke et al.
RSA-170	170	563	Dec 29, 2009	D. Bonenberger and M. Krone
RSA-576	174	576	Dec 3, 2003	J. Franke et al.
RSA-180	180	596	May 8, 2010	S. A. Danilov and I. A. Popovyan
RSA-190	190	629	Nov 8, 2010	A. Timofeev and I. A. Popovyan
RSA-640	193	640	Nov 2, 2005	J. Franke et al.
RSA-200	200	663	May 9, 2005	J. Franke et al.
RSA-210	210	696	Sep 26, 2013	R. Propper
RSA-704	212	704	Jul 2, 2012	S. Bai, E. Thomé and P. Zimmermann
RSA-220	220	729	May 13, 2016	S. Bai, P. Gaudry, A. Kruppa, E. Thomé and P. Zimmermann
RSA-230	230	762	Aug 15, 2018	S. S. Gross
RSA-768	232	768	Dec 12, 2009	T. Kleinjung et al.
RSA-240	240	795	Nov 24, 2019	F. Boudot, P. Gaudry, A. Guillevic, N. Heninger, E. Thomé and P. Zimmermann
RSA-250	250	829	Feb 28, 2020	F. Boudot, P. Gaudry, A. Guillevic, N. Heninger, E. Thomé and P. Zimmermann

Table 1. The solved RSA Challenges

Figure: https://eprint.iacr.org/2021/894.pdf

Key Sizes

	Parameter	Legacy	Future System Use	
			Near Term	Long Term
Symmetric Key Size	k	80	128	256
Hash Function Output Size	m	160	256	512
MAC Output Size	m	80	128	256
RSA Problem	$\ell(n) \geq$	1024	3072	15360
Finite Field DLP	$\ell(p^n) \geq$	1024	3072	15360
	$\ell(p), \ell(q) \geq$	160	256	512
ECDLP	$\ell(q) \geq$	160	256	512
Pairing	$\ell(q^n) \geq$	1024	3072	15360
	$\ell(p), \ell(q) \geq$	160	256	512

Table 2. Key Size Analysis, where $\ell(\cdot)$ refers to the bit-length of the parameter.

Figure: https://eprint.iacr.org/2021/894.pdf

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Static Finite Field DH

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Static Finite Field DH

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- Export Diffie-Hellman accept 512 bit prime groups
- One week of pre-computation $\rightarrow$ DL takes 1 min
- 2015: two 1024 groups break 18% HTTPS and 26% SSH

Logjam Attack

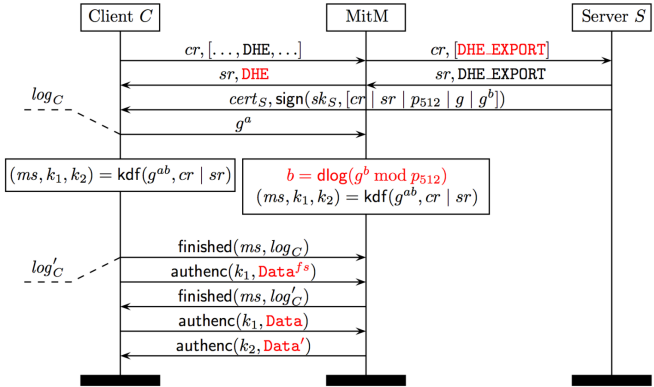

Figure: `https://weakdh.org/imperfect-forward-secrecy.pdf`

Old Attacks on TLS

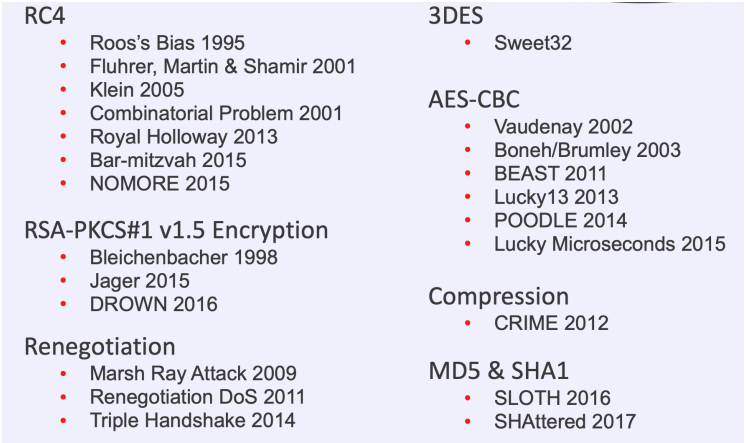

Figure: https://owasp.org/www-chapter-london/assets/slides/OWASPLondon20180125_TLSv1.3_Andy_Brodie.pdf

TLS: a long year of downgrade attacks

• POODLE	TLS 1.2 → SSLv3	[Dec'14]
• FREAK	RSA-2048 → RSA-512	[Mar'15]
• LOGJAM	DH-2048 → DH-512	[May'15]
• BLEICH?	RSA-Sign → RSA-Enc	[Aug'15]
• SLOTH	RSA-SHA256 → RSA-MD5	[Jan'16]

Figure: https://rwc.iacr.org/2016/Slides/Downgrade.pdf

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- Removed RSA for key exchange
- Removed RC4, 3DES and Camellia
- Removed MD5 and SHA-1 hash functions
- Removed AES-CBC encryption mode
- Removed static (EC) Diffie-Hellman
- Only standardized groups/curves

New Cipher Suits

TLS 1.3 only allows for 5 different cipher suits:

- (EC)DHE-AES-128-GCM-SHA256
- (EC)DHE-AES-256GCM-SHA384
- (EC)DHE-CHACHA20-POLY1305-SHA256
- (EC)DHE-AES-128-CCM-SHA256
- (EC)DHE-AES-128-CCM-8-SHA256

Matthew Green's Blog

- Standards: https://blog.cryptographyengineering.com/2011/10/04/how-standards-go-wrong-constructive
- Logjam: https://blog.cryptographyengineering.com/2015/05/22/attack-of-week-logjam
- FREAK: https://blog.cryptographyengineering.com/2015/03/03/attack-of-week-freak-or-factoring-nsa

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Dual EC

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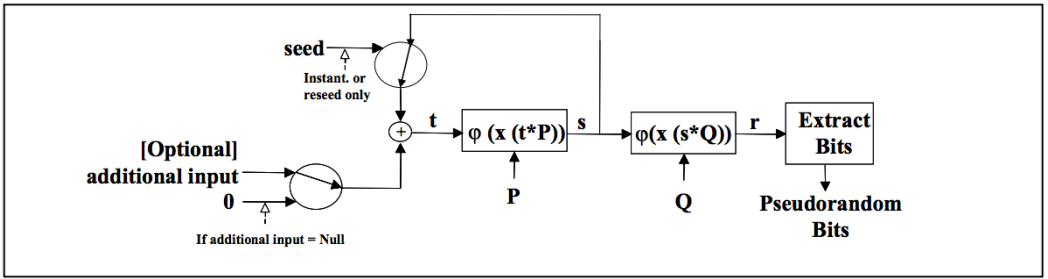
- Let ϕ be a function that truncates $x(P)$ to bits

Dual EC


seed
Instant. or
reseed only
[Optional]
additional input
0
If additional input = Null
t
φ (x (t*P))
P
s
φ(x (s*Q))
Q
r
Extract
Bits
Pseudorandom
Bits

Dual EC

A Security Analysis of the NIST SP 800-90 Elliptic Curve Random Number Generator

Daniel R. L. Brown* and Kristian Gjøsteen†

February 15, 2007

Figure: https://eprint.iacr.org/2007/048.pdf

Dual EC

This is provably biased if you know DLOG $\log_P Q$

Dual EC

DUAL_EC **Backdoor** (Simplified)

The user	The attacker
• Two parameters (P, Q) • Compute next state $s_{i+1} = P^{s_i} \bmod N$ • Compute next output $r_i = Q^{s_i} \bmod N$	• Keep x such that $P = Q^x \bmod N$ • Observe any output r_i • Compute next state $s_{i+1} = r_i^x \bmod N$ • Predict all future outputs!

$$s_{i+1} = P^{s_i} = (Q^x)^{s_i} = (Q^{s_i})^x = {r_i}^x \bmod \mathrm{N}$$

Figure: https://www.cs.au.dk/~orlandi/orlandi_backdoors.pdf

Matthew Green's Blog

- Dual-EC-DRBG: https://blog.cryptographyengineering.com/2013/09/18/the-many-flaws-of-dualecdrbg
- RSA warning: https://blog.cryptographyengineering.com/2013/09/20/rsa-warns-developers-against-its-own
- NSA random number: https://blog.cryptographyengineering.com/2013/12/28/a-few-more-notes-on-nsa-random-number
- Juniper backdoor: https://blog.cryptographyengineering.com/2015/12/22/on-juniper-backdoor

Micali-Schnorr?

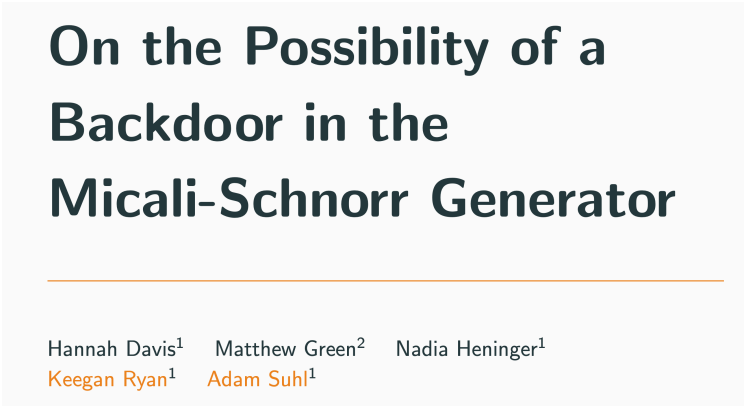


Figure: paper: https://eprint.iacr.org/2023/440.pdf, talk: https://www.youtube.com/watch?v=608NQdTn39Q&t=2629s, slides: https://iacr.org/submit/files/slides/2023/rwc/rwc2023/119/slides.pdf

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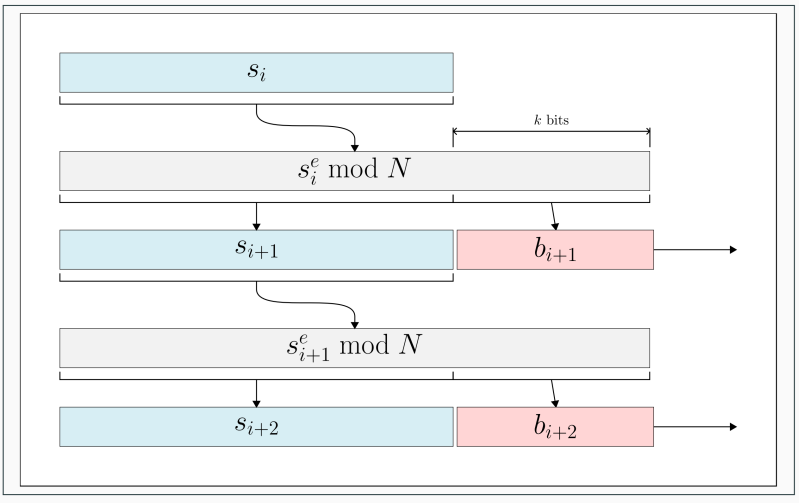

Unclear how to recover the state using RSA decryption.

Questions?