NTNU | Norwegian University of Science and Technology

LEGACY CRYPTO 1: CRYPTO WARS

TTM4205 – Lecture 5

Tjerand Silde

10.09.2024

Contents

Contents

Reference Group

I am looking for an MTKOM student to join the reference group. We will meet three times during the semester, and your feedback is extremely valuable.

Send me an email and/or talk to me in the break :)

Contents

Legacy Crypto is...

Legacy Crypto is...

- Old and outdated crypto

Legacy Crypto is...

- Old and outdated crypto
- Insecure, weakened, or flawed crypto

Legacy Crypto is...

- Old and outdated crypto
- Insecure, weakened, or flawed crypto
- Crypto regulated by export control

Legacy Crypto is...

- Old and outdated crypto
- Insecure, weakened, or flawed crypto
- Crypto regulated by export control
- Potentially backdoored crypto

Legacy Crypto is...

- Old and outdated crypto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

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- Old and outdated crypto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

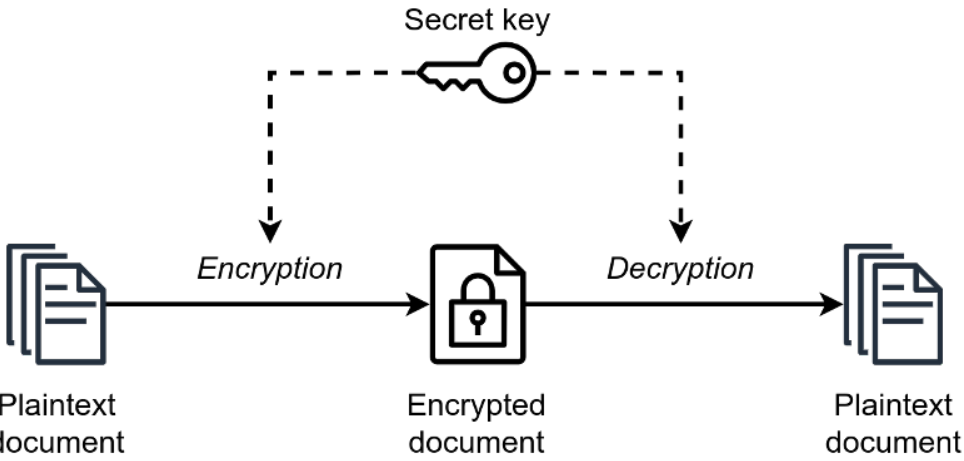
Secret Key Crypto

Public Key Crypto

Secret Key Crypto

Public Key Crypto

Secret Key Crypto



Contents

Crypto Wars

Essentially 30+ year ongoing debate between policymakers and technologists about encryption and surveillance

Typically portrayed as "Safety" vs. "Privacy" to get "Security"

Crypto War I

Crypto War I

- The 1990s: Wire-tapping vs. cryptography

Crypto War I

- The 1990s: Wire-tapping vs. cryptography
- AT&T phone calls encrypted with DH and DES

Crypto War I

- The 1990s: Wire-tapping vs. cryptography
- AT&T phone calls encrypted with DH and DES
- The Clipper-chip and key escrow (broken)

Crypto War I

- The 1990s: Wire-tapping vs. cryptography
- AT&T phone calls encrypted with DH and DES
- The Clipper-chip and key escrow (broken)
- Law vs. technology, export control, free speech

Crypto War I

- The 1990s: Wire-tapping vs. cryptography
- AT&T phone calls encrypted with DH and DES
- The Clipper-chip and key escrow (broken)
- Law vs. technology, export control, free speech
- EFF DES cracker broke 56 bit DES in 1998

Crypto War I

- The 1990s: Wire-tapping vs. cryptography
- AT&T phone calls encrypted with DH and DES
- The Clipper-chip and key escrow (broken)
- Law vs. technology, export control, free speech
- EFF DES cracker broke 56 bit DES in 1998
- The US government allows crypto from $\sim$ 2000

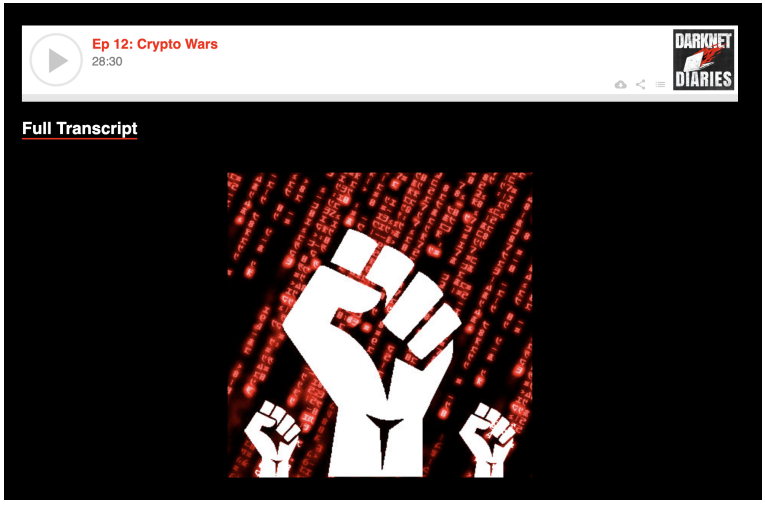


Figure: https://darknetdiaries.com/episode/12

Crypto War II

Crypto War II

- Roughly the years 2010-2016: The "Going dark" debate

Crypto War II

- Roughly the years 2010-2016: The "Going dark" debate
- Communication (calls, messages) usually not encrypted

Crypto War II

- Roughly the years 2010-2016: The "Going dark" debate
- Communication (calls, messages) usually not encrypted
- The stored data on phones and laptops was encrypted

Crypto War II

- Roughly the years 2010-2016: The "Going dark" debate
- Communication (calls, messages) usually not encrypted
- The stored data on phones and laptops was encrypted
- The 2013 Snowden revelations and mass surveillance

Crypto War II

- Roughly the years 2010-2016: The "Going dark" debate
- Communication (calls, messages) usually not encrypted
- The stored data on phones and laptops was encrypted
- The 2013 Snowden revelations and mass surveillance
- Crypto vs Mass Surveillance `http://cms16.item.ntnu.no`

Crypto War II

- Roughly the years 2010-2016: The "Going dark" debate
- Communication (calls, messages) usually not encrypted
- The stored data on phones and laptops was encrypted
- The 2013 Snowden revelations and mass surveillance
- Crypto vs Mass Surveillance `http://cms16.item.ntnu.no`
- The FBI vs. Apple case and breaking into devices

Crypto War II

- Roughly the years 2010-2016: The "Going dark" debate
- Communication (calls, messages) usually not encrypted
- The stored data on phones and laptops was encrypted
- The 2013 Snowden revelations and mass surveillance
- Crypto vs Mass Surveillance `http://cms16.item.ntnu.no`
- The FBI vs. Apple case and breaking into devices
- Standardized crypto backdoored by NSA (next lecture)

Figure: https://youtu.be/bB68G8tLh38

The Moral Character of Cryptographic Work*

Phillip Rogaway

Department of Computer Science
University of California, Davis, USA
rogaway@cs.ucdavis.edu

December 2015
(minor revisions March 2016)

Figure: https://web.cs.ucdavis.edu/~rogaway/papers/moral-fn.pdf

Crypto War III

Crypto War III

- 2017-now: The ongoing "Safety vs. Privacy" debate

Crypto War III

- 2017-now: The ongoing "Safety vs. Privacy" debate
- EARN IT ACT, ONLINE SAFETY BILL, CHAT CONTROL 2.0

Crypto War III

- 2017-now: The ongoing "Safety vs. Privacy" debate
- EARN IT ACT, ONLINE SAFETY BILL, CHAT CONTROL 2.0
- Age verification, content scanning, liable providers

Crypto War III

- 2017-now: The ongoing "Safety vs. Privacy" debate
- EARN IT ACT, ONLINE SAFETY BILL, CHAT CONTROL 2.0
- Age verification, content scanning, liable providers
- Essentially breaks end-to-end encryption in practice

Crypto War III

- 2017-now: The ongoing "Safety vs. Privacy" debate
- EARN IT ACT, ONLINE SAFETY BILL, CHAT CONTROL 2.0
- Age verification, content scanning, liable providers
- Essentially breaks end-to-end encryption in practice
- Wants to use AI to discover illegal online content

Crypto War III

- 2017-now: The ongoing "Safety vs. Privacy" debate
- EARN IT ACT, ONLINE SAFETY BILL, CHAT CONTROL 2.0
- Age verification, content scanning, liable providers
- Essentially breaks end-to-end encryption in practice
- Wants to use AI to discover illegal online content
- Swiss Police in 2022: "80 % of reports are false"

Crypto War III

- 2017-now: The ongoing "Safety vs. Privacy" debate
- EARN IT ACT, ONLINE SAFETY BILL, CHAT CONTROL 2.0
- Age verification, content scanning, liable providers
- Essentially breaks end-to-end encryption in practice
- Wants to use AI to discover illegal online content
- Swiss Police in 2022: "80 % of reports are false"
- No one knows what is target of scanning $=$ backdoor

Keys Under Doormats:

MANDATING INSECURITY BY REQUIRING GOVERNMENT ACCESS TO ALL DATA AND COMMUNICATIONS

Harold Abelson, Ross Anderson, Steven M. Bellovin, Josh Benaloh, Matt Blaze, Whitfield Diffie, John Gilmore, Matthew Green, Susan Landau, Peter G. Neumann, Ronald L. Rivest, Jeffrey I. Schiller, Bruce Schneier, Michael Specter, Daniel J. Weitzner

Figure: https://www.schneier.com/wp-content/uploads/2016/09/paper-keys-under-doormats-CSAIL.pdf

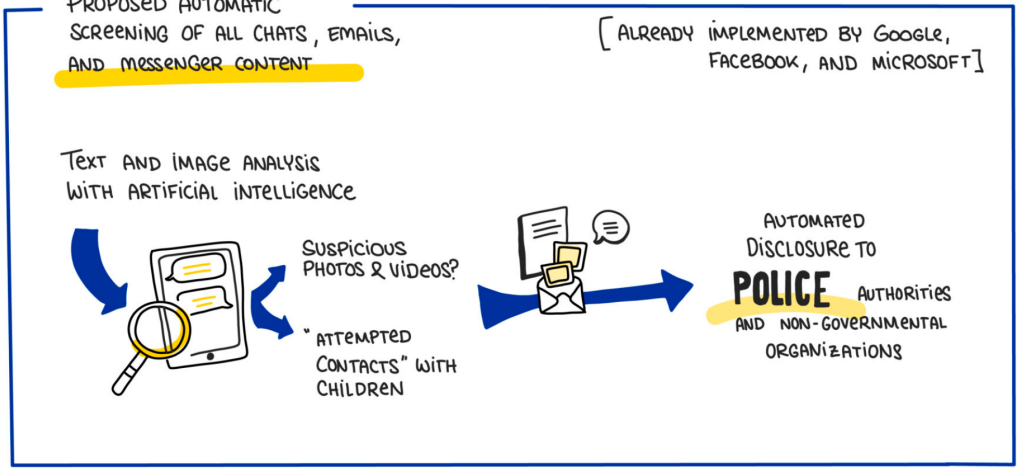
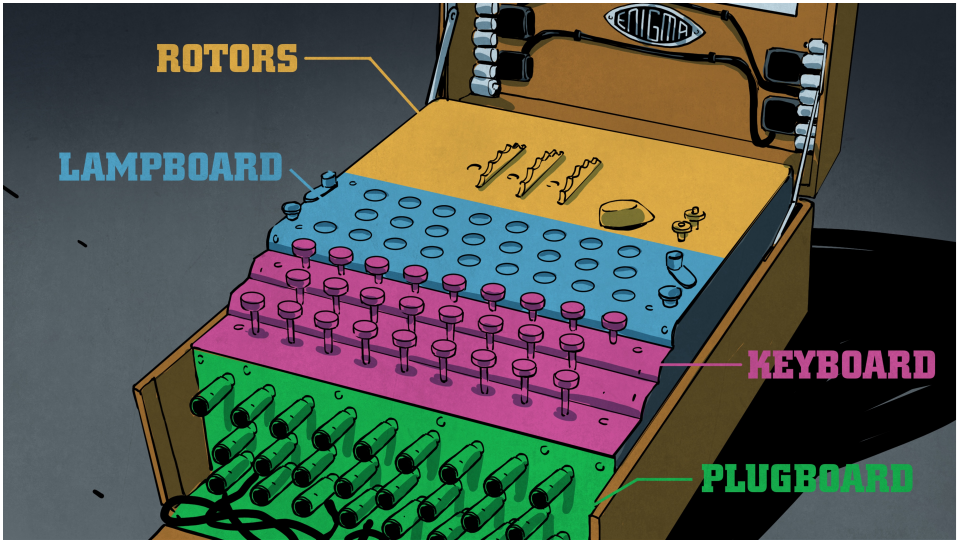


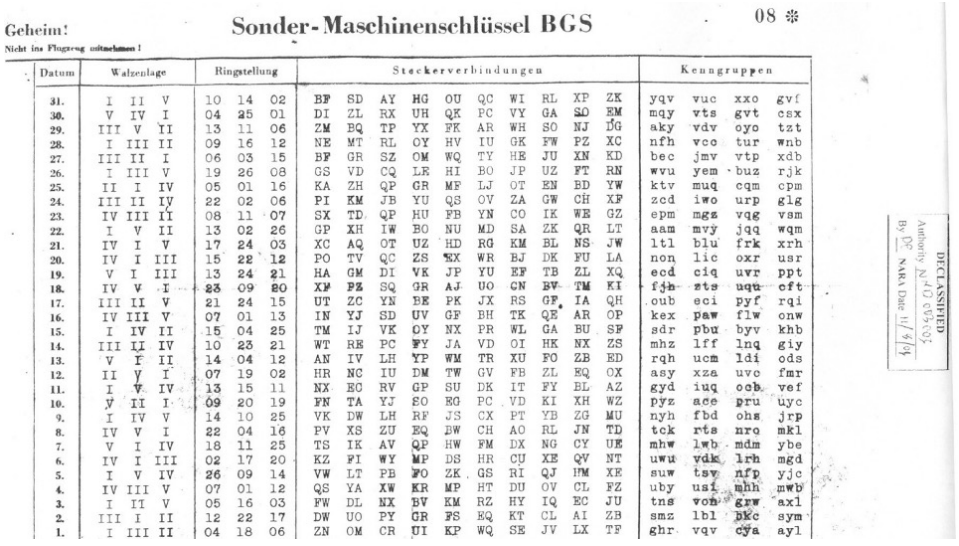
Figure: https://www.patrick-breyer.de/en/posts/chat-control

Contents

Enigma Machine



Code Table



Geheim!

Nicht ins Flugzeug mitnehmen!

Sonder-Maschinenschlüssel BGS

08 ❊

Datum	Walzenlage	Ringstellung	Steckerverbindungen	Kenngruppen
31.	I II V	10 14 02	BF SD AY HG OU QC WI RL XP ZK	yqv vuc xxo gvf
30.	V IV I	04 25 01	DI ZL RX UH QK PC VY GA SO EM	mqy vts gvt csx
29.	III V II	13 11 06	ZM BQ TP YX FK AR WH SO NJ JG	aky vdv oyo tzt
28.	I III II	09 16 12	NE MT RL OY HV IU GK FW PZ XC	nfh vco tur wnb
27.	III II I	06 03 15	BF GR SZ OM WQ TY HE JU XN KD	bec jmv vtp xdb
26.	I III V	19 26 08	GS VD CQ LE HI BO JP UZ FT RN	wvu yem buz rjk
25.	II I IV	05 01 16	KA ZH QP GR MF LJ OT EN BD YW	ktv muq cqm cpm
24.	III II IV	22 02 06	PI KM JB YU QS OV ZA GW CH XF	zcd iwo urp glg
23.	IV III II	08 11 07	SX TD QP HU FB YN CO IK WE GZ	epm mgz vqg vsm
22.	I V II	13 02 26	GP XH IW BO NU MD SA ZK QR LT	aam mvy jqq wqm
21.	IV I V	17 24 03	XC AQ OT UZ HD RG KM BL NS JW	ltl blu frk xrh
20.	IV I III	15 22 12	PO TV QC ZS SX WR BJ DK FU LA	non lic oxr usr
19.	V I III	13 24 21	HA GM DI VK JP YU EF TB ZL XQ	ecd ciq uvr ppt
18.	IV V I	23 09 20	XF PZ SQ GR AJ UO CN BV TM KI	fjh zts uqu cft
17.	III II V	21 24 15	UT ZC YN BE PK JX RS GF IA QH	oub eci pyf rqi
16.	IV III V	07 01 13	IN YJ SD UV GF BH TK QE AR OP	kex paw flw onw
15.	I IV II	15 04 25	TM IJ VK OY NX PR WL GA BU SF	sdr pbu byv khb
14.	III II IV	10 23 21	WT RE PC FY JA VD OI HK NX ZS	mhz lff lnq giy
13.	V I II	14 04 12	AN IV LH YP WM TR XU FO ZB ED	rqh ucm ldi ods
12.	II V I	07 19 02	HR NC IU DM TW GV FB ZL EQ OX	asy xza uvc fmr
11.	I V IV	13 15 11	NX EC RV GP SU DK IT FY BL AZ	gyd iuq ocb vef
10.	V II I	09 20 19	FN TA YJ SO EG PC VD KI XH WZ	pyz ace pru uyc
9.	I IV V	14 10 25	VK DW LH RF JS CX PT YB ZG MU	nyh fbd ohs jrp
8.	IV V I	22 04 16	PV XS ZU EQ BW CH AO RL JN TD	tck rts nro mkl
7.	V I IV	18 11 25	TS IK AV QP HW FM DX NG CY UE	mhw lwb mdm ybe
6.	IV I III	02 17 20	KZ FI WY MP DS HR CU XE QV NT	uwu vdk lrh mgd
5.	I V IV	26 09 14	VW LT PB FO ZK GS RI QJ HM XE	suw tsv nfp yjc
4.	IV III V	07 01 12	QS YA XW KR MP HT DU OV CL FZ	uby usi mhh mwb
3.	I II V	05 16 03	FW DL NX BV KM RZ HY IQ EC JU	tns von grw axl
2.	III I II	12 22 17	DW UO PY GR FS EQ KT CL AI ZB	smz lbl bkc sym
1.	I III II	04 18 06	ZN OM CR UI KP WQ SE JV LX TF	ghr vqv cya ayl

DECLASSIFIED
Authority NND 969049
By DP NARA Date 11/9/99

Security of Enigma

Security of Enigma

- Choose three rotors out of five

Security of Enigma

- Choose three rotors out of five
- Each rotor has 26 starting positions

Security of Enigma

- Choose three rotors out of five
- Each rotor has 26 starting positions
- Plugboard connecting ten letter-pairs

Security of Enigma

- Choose three rotors out of five
- Each rotor has 26 starting positions
- Plugboard connecting ten letter-pairs
- Leads to roughly 2^{67} possible settings

Security of Enigma

- Choose three rotors out of five
- Each rotor has 26 starting positions
- Plugboard connecting ten letter-pairs
- Leads to roughly 2^{67} possible settings
- Impossible to break until recent years...

Flaws of Enigma

Flaws of Enigma

- A plaintext letter can never be encrypted to itself

Flaws of Enigma

- A plaintext letter can never be encrypted to itself
- They had access to known plaintexts every day

Flaws of Enigma

- A plaintext letter can never be encrypted to itself
- They had access to known plaintexts every day
- Each contradiction removed millions of settings

Flaws of Enigma

- A plaintext letter can never be encrypted to itself
- They had access to known plaintexts every day
- Each contradiction removed millions of settings
- It took two hours to brute force a key each day

Flaws of Enigma

- A plaintext letter can never be encrypted to itself
- They had access to known plaintexts every day
- Each contradiction removed millions of settings
- It took two hours to brute force a key each day
- Alan Turing and his team broke the code in 1941

Facts about Enigma

Facts about Enigma

- The UK disclosed that they broke it in 1970

Facts about Enigma

- The UK disclosed that they broke it in 1970
- There are roughly 300 (publicly known) copies

Facts about Enigma

- The UK disclosed that they broke it in 1970
- There are roughly 300 (publicly known) copies
- Some versions of Enigma have four rotors

Facts about Enigma

- The UK disclosed that they broke it in 1970
- There are roughly 300 (publicly known) copies
- Some versions of Enigma have four rotors
- The auction value is between 3 and 5 MNOK

Enigma at NTNU

More Enigma

Figure: Numberphile: https://youtu.be/G2_Q9FoD-oQ, and at Computerphile: https://youtube.com/playlist?list=PLzH6n4zXuckodsatCTEuxaygCHizMSO_I

Contents

Crypto AG

A Swiss company named Crypto AG, funded by the Swede named Boris Hagelin, sold encryption machines to nation states all over the world after the second world war. They were similar to the Enigma machine.

Widespread Usage

THE AMERICAS	EUROPE	AFRICA	MIDDLE EAST	REST OF ASIA
Argentina	Austria	Algeria	Iran	Bangladesh
Brazil	Czechoslovakia	Angola	Iraq	Burma
Chile	Greece	Egypt	Jordan	India
Colombia	Hungary	Gabon	Kuwait	Indonesia
Honduras	Ireland	Ghana	Lebanon	Japan
Mexico	Italy	Guinea	Oman	Malaysia
Nicaragua	Portugal	Ivory Coast	Qatar	Pakistan
Peru	Romania	Libya	Saudi Arabia	Philippines
Uruguay	Spain	Mauritius	Syria	South Korea
Venezuela	Turkey	Morocco	U.A.E.	Thailand
	Vatican City	Nigeria		Vietnam
	Yugoslavia	Rep. of the Congo		
		South Africa		
		Sudan		
		Tanzania		
		Tunisia		
		Zaire		
		Zimbabwe		

WORLDWIDE ORGANIZATION
United Nations

The records show that at least four countries — Israel, Sweden, Switzerland and the United Kingdom — were aware of the operation or were provided intelligence from it by the United States or West Germany.

CIA Backdoor

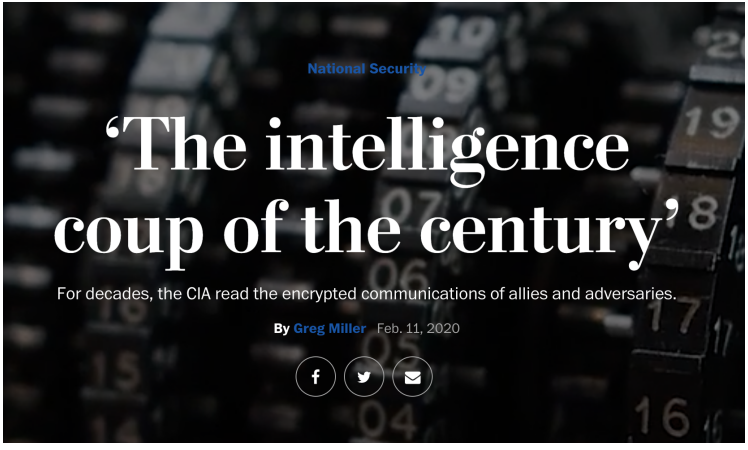


Figure: https://www.washingtonpost.com/graphics/2020/world/national-security/cia-crypto-encryption-machines-espionage

Contents

Legacy Ciphers

Several newer ciphers developed in the 1990s and 2000s were the leading standard for many years, and we still find them in a variety of protocols and products that are still used on or connected to the Internet today.

There has been a variety of attacks, and here are some examples...

MD5

- Hash function outputting 128 bits
- Designed by Ron Rivest in 1991
- First specific collisions found in 2004
- First general collisions found in 2006
- Used to create fake X509 certificates
- Revoked in most (!) applications by 2014 (!)

MD5

Year	Identical-prefix collision cost	Chosen-prefix collision cost
< 2004	2^{64} generic	2^{64} generic
2004	**2^{40} [WY05]**	–
2005	2^{37} [Kli05]	–
2006	2^{32} [Kli06, Ste06]	**2^{49} [SLdW07c]**
2007	2^{25} [Ste07]	–
2008	2^{21} [XLF08]	–
2009	2^{16} [SSA+09]	2^{39} [SSA+09]
2020	2^{16} [SSA+09]	2^{39} [SSA+09]

Figure: https://www.marc-stevens.nl/research/papers/CC21Chapter-S.pdf

RADIUS/UDP vulnerable to improved MD5 collision attack

2024-07-09

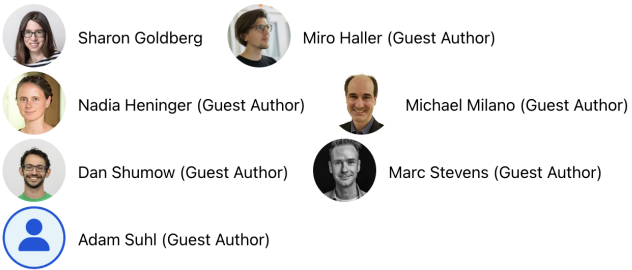


Figure: https://blog.cloudflare.com/radius-udp-vulnerable-md5-attack

MD5

RADIUS/UDP Considered Harmful

Sharon Goldberg, *Cloudflare*
Miro Haller, *UC San Diego*
Nadia Heninger, *UC San Diego*
Mike Milano, *BastionZero*
Dan Shumow, *Microsoft Research*
Marc Stevens, *Centrum Wiskunde & Informatica*
Adam Suhl, *UC San Diego*

Figure: `https://www.blastradius.fail/pdf/radius.pdf`

SHA-1

- Hash function outputting 160 bits
- Designed by the NSA in 1995
- First specific collisions found in 2017
- First general collisions found in 2020
- Revoked in most (!) applications by 2020 (!)

SHA-1

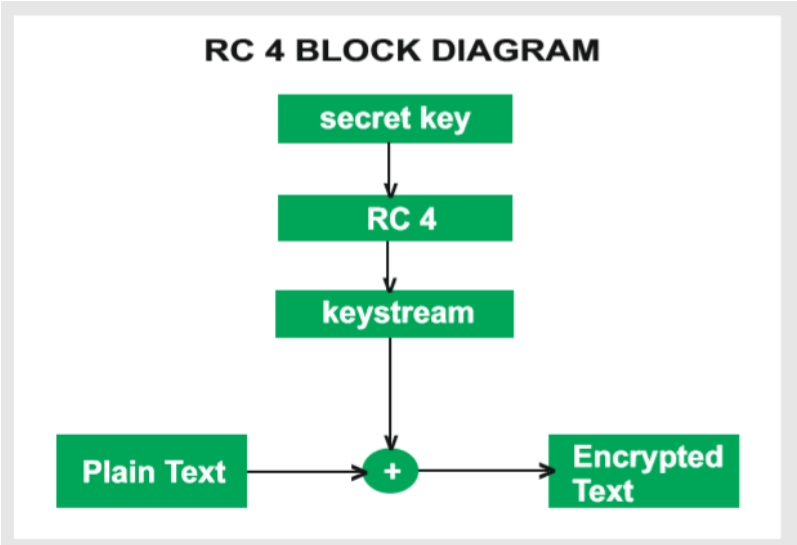
Year	Identical-prefix collision cost		Chosen-prefix collision cost	
< 2005	2^{80}	generic	2^{80}	generic
2005	2^{69}	[WYY05b]	–	
	(u : 2^{63}	[WYY05a])	–	
2007	(u : 2^{61}	[MRR07])	–	
2009	(w : 2^{52}	[MHP09])	–	
2013	2^{61}	[Ste13b]	2^{77}	[Ste13b]
2017	**G : $2^{63.1}$**	**[SBK+17]**	–	
2019	–		G : 2^{67}	[LP19]
2020	2^{61} / G : $2^{61.2}$	[Ste13b] / [LP20]	**G : $2^{63.4}$**	**[LP20]**

Figure: https://www.marc-stevens.nl/research/papers/CC21Chapter-S.pdf

RC4

- Symmetric stream cipher using at least 40 bit keys
- Designed by Ron Rivest in 1987 (public in 1994)
- Used in the WEP (1997), WPA (2003), SSL/TLS (1995)
- Detectable bias after only 256 bytes of data
- Long list of attacks. Broken in WEP in 2004.
- Revoked in most (!) applications by 2015 (!)

RC4


RC 4 BLOCK DIAGRAM
secret key
RC 4
keystream
Plain Text
+
Encrypted Text

Weaknesses in the Key Scheduling Algorithm of RC4

Scott Fluhrer[1], Itsik Mantin[2], and Adi Shamir[2]

[1] Cisco Systems, Inc., 170 West Tasman Drive, San Jose, CA 95134
sfluhrer@cisco.com
[2] Computer Science department, The Weizmann Institute, Rehovot 76100, Israel.
{itsik,shamir}@wisdom.weizmann.ac.il

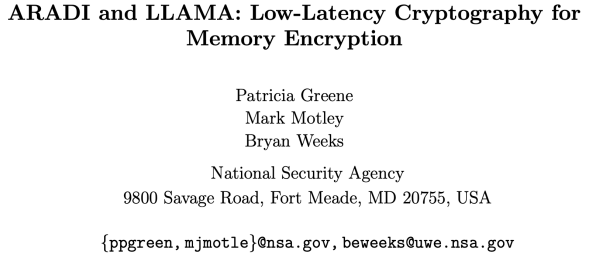
Figure: https://www.mattblaze.org/papers/others/rc4_ksaproc.pdf

3DES

- DES: Symmetric block cipher using 56 bit keys
- Proposed in 1981, standardized in 1995 by NIST
- 3DES: Using DES three times with three keys
- Meet-in-the-Middle attack: 112 bits of security
- Revoked in most applications by 2019

Contents

ARADI and LLAMA



ARADI and LLAMA: Low-Latency Cryptography for Memory Encryption

Patricia Greene
Mark Motley
Bryan Weeks

National Security Agency
9800 Savage Road, Fort Meade, MD 20755, USA

{ppgreen, mjmotle}@nsa.gov, beweeks@uwe.nsa.gov

Abstract

In this paper, we describe a low-latency block cipher (ARADI) and authenticated encryption mode (LLAMA) intended to support memory encryption applications.

Figure: https://eprint.iacr.org/2024/1240.pdf

ARADI and LLAMA

A Note on ARADI and LLAMA

Roberto Avanzi[1,2], Orr Dunkelman[3] and Shibam Ghosh[3]

[1] Qualcomm Germany GmbH, Munich, Germany
ravanzi@qti.qualcomm.com
[2] Caesarea Rothschild Institute, University of Haifa, Haifa, Israel
roberto.avanzi@gmail.com
[3] Computer Science Department, University of Haifa, Haifa, Israel
orrd@cs.haifa.ac.il, sghosh03@campus.haifa.ac.il

Abstract. Recently, the NSA has proposed a block cipher called `ARADI` and a mode of operation called `LLAMA` for memory encryption applications. In this note, we comment on this proposal, on its suitability for the intended application, and describe an attack on `LLAMA` that breaks confidentiality of ciphertext and allows a straightforward forgery attack breaking integrity of ciphertext (*INT-CTXT*) using a related-*Initialization Vector* (IV) attack. Both attacks have negligible complexity.

Figure: https://eprint.iacr.org/2024/1328.pdf

Questions?