NTNU | Norwegian University of Science and Technology

LEGACY CRYPTO 1

TTM4205 – Lecture 5

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05.09.2023

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Uniped Observation

I am completing a course in University Pedagogy (Uniped) this year, and today, I have so-called *collegial coaching*. This means that a few other lecturers from different departments at NTNU will observe my lecture and provide feedback afterward. They are **not** observing you.

Reference Group

I am looking for (at least) three students to form a reference group in this course, preferably students from different programs. 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 :)

Open PhD Position

Figure: https://www.jobbnorge.no/en/available-jobs/job/246480/phd-candidate-in-cryptography-engineering

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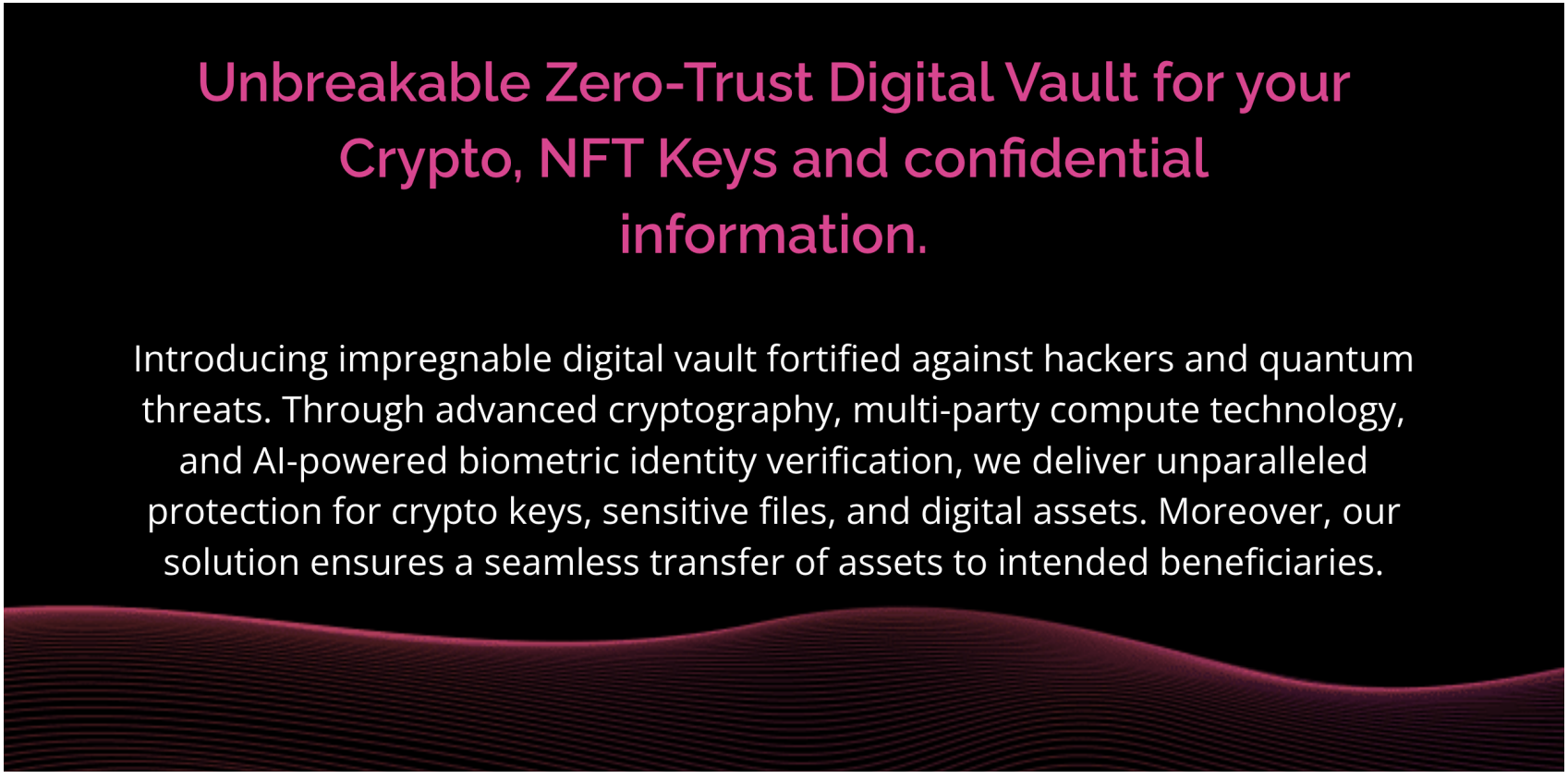
- Key escrow and surveillance
- Downgradable crypto protocols

Legacy Crypto ≠ Crypto Legacy



Two Categories

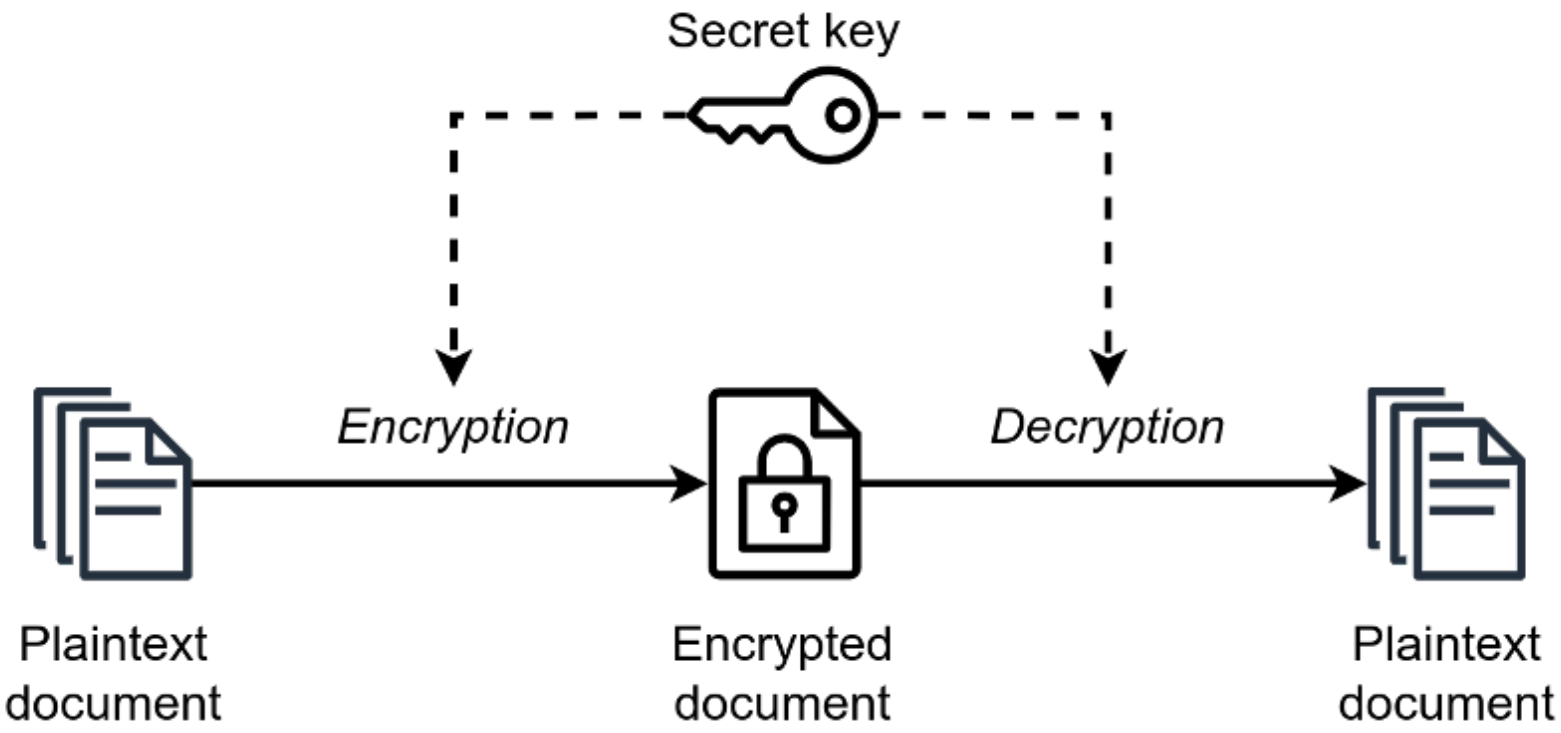
Secret Key Crypto

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

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- EFF DES cracker broke 56 bit DES in 1998
- The US government allows crypto from ~ 2000

Ep 12: Crypto Wars
28:30

DARKNET DIARIES

Full Transcript

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

Crypto War II

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- The FBI vs. Apple case and breaking into devices
- Standardized crypto backdoored by NSA (next lecture)

Figure: `https://youtu.be/bB68G8tLh38`

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- Swiss Police in 2022: "80 % of reports are false"
- No one knows what is target of scanning $=$ backdoor

Keys Under Doormats:

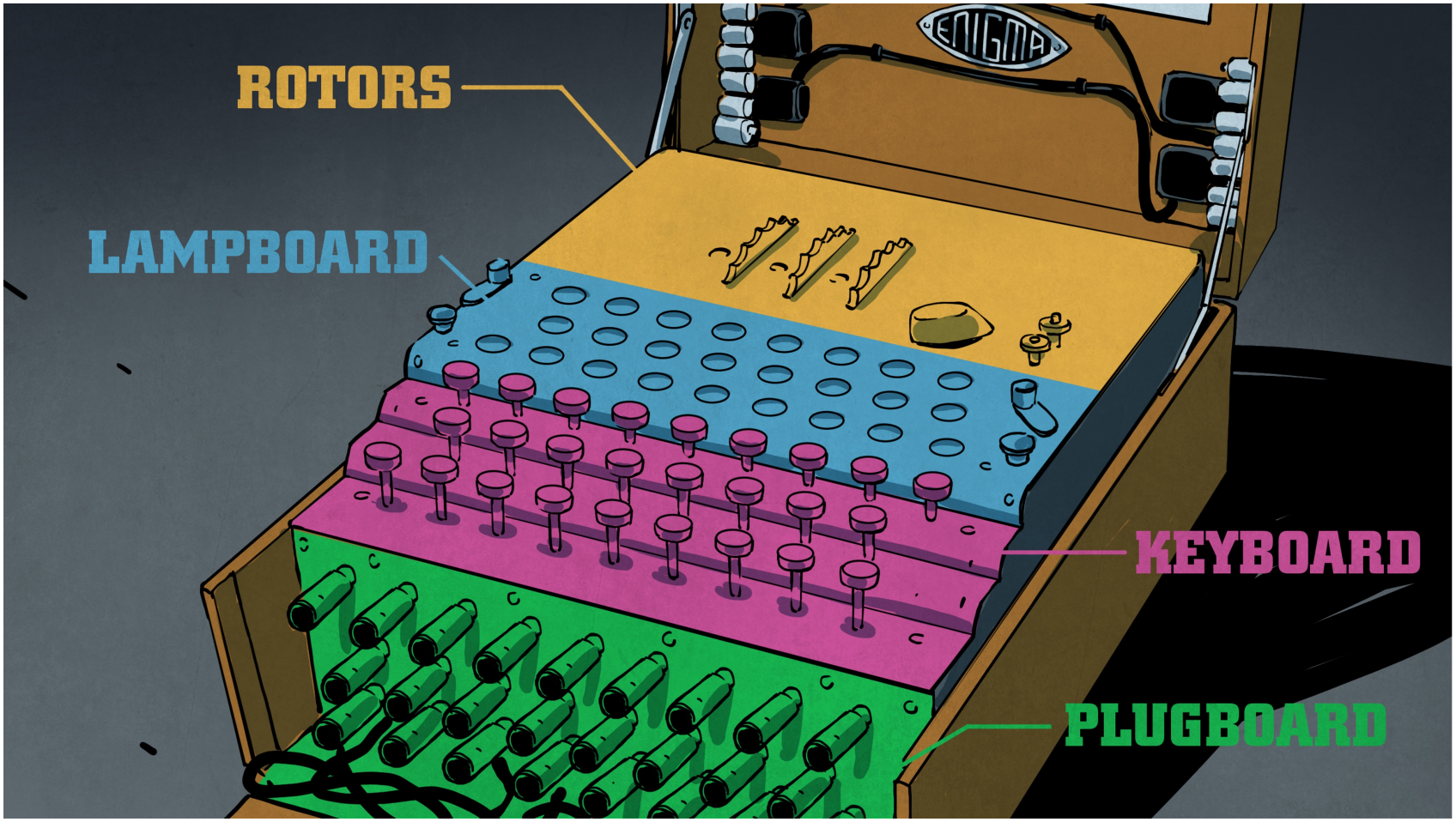
MANDATING INSECURITY BY REQUIRING GOVERNMENT ACCESS TO ALL DATA AND COMMUNICATIONS

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

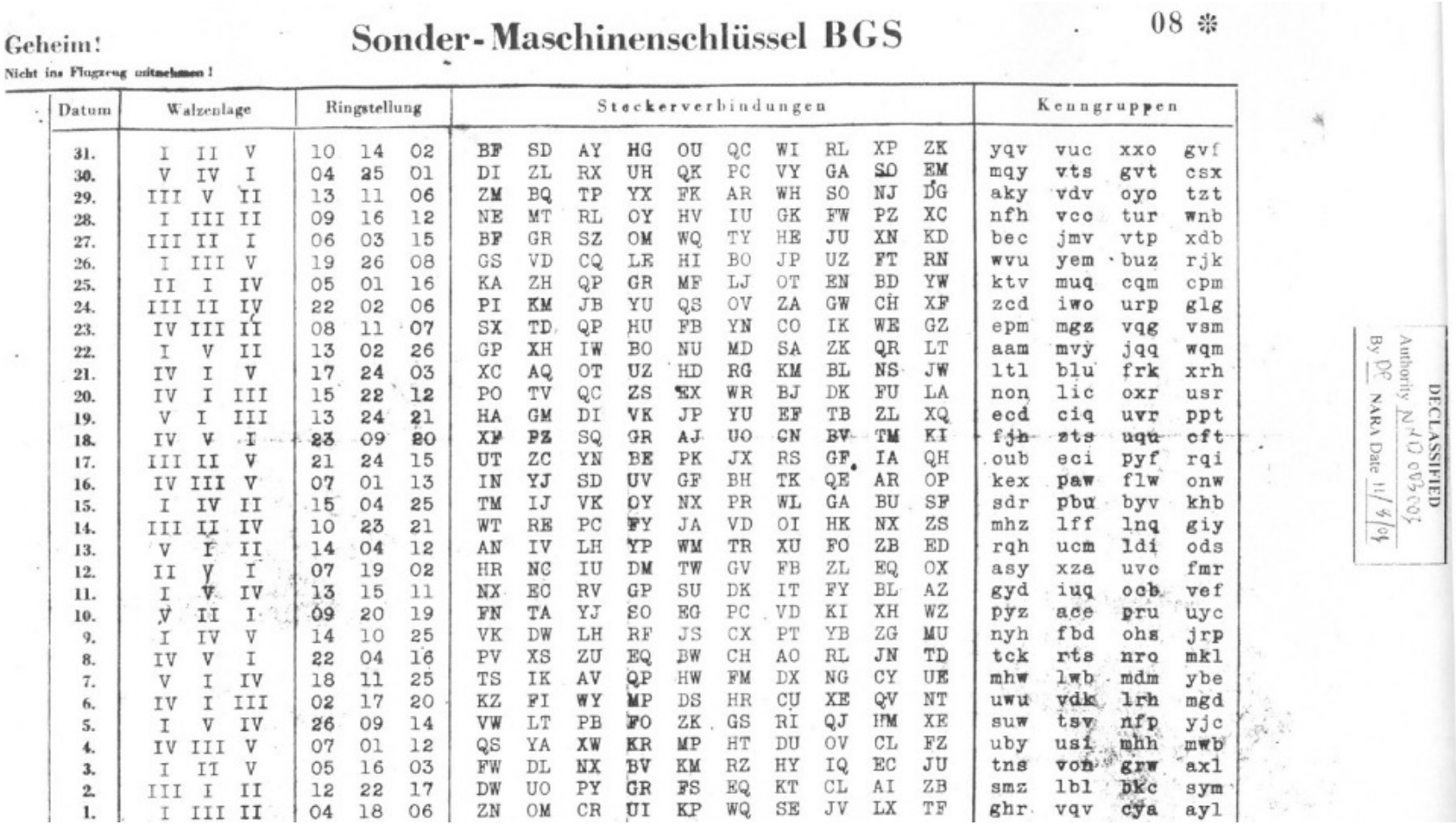
Figure: `https://spar.isi.jhu.edu/~mgreen/paper-keys-under-doormats.pdf`

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 DG	aky vdv oyo tzt
28.	I III II	09 16 12	NE MT RL OY HV IU GK FW PZ XC	nfh vcc 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 LR 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 EX 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 IM 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

Security of Enigma

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- Choose three rotors out of five

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

Flaws of Enigma

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- A plaintext letter can never be encrypted to itself
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- 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

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- 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

Legacy Ciphers

We have several newer ciphers developed in the 1990s and early 2000s that 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...

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`

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 (!)

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

AES-CBC

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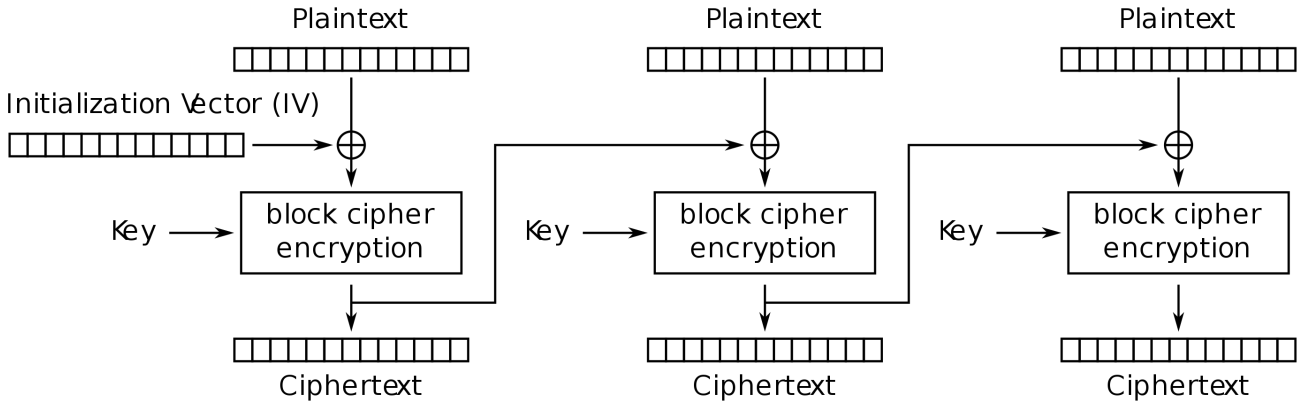
- Revoked from some applications (e.g. TLS) in 2018

AES-CBC



Cipher Block Chaining (CBC) mode encryption

CBC Attack

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- Add one byte ends with 01, two with 02, etc. ...

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CBC Attack

- Each block must be of exactly 128 bits
- Shorter message leads to padding at the end
- Add one byte ends with 01, two with 02, etc. ...
- An API outputs errors when wrong padding
- The error message or timing might leak info...

CBC Attack

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- Vary last byte of C_1 until correct to find last byte of X
- Find next byte by $C_1[15] = X[15] \oplus 02$ and vary $C_1[14]$
- Continue until you have all bytes of X, max $128 \cdot 16$ trials

CBC Attack

Security Flaws Induced by CBC Padding
Applications to SSL, IPSEC, WTLS...

Serge Vaudenay

Swiss Federal Institute of Technology (EPFL)
Serge.Vaudenay@epfl.ch

Figure: https://www.iacr.org/cryptodb/archive/2002/EUROCRYPT/2850/2850.pdf

Contents

From TLS 1.2 to 1.3

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

Old Attacks on TLS

RC4
- Roos's Bias 1995
- Fluhrer, Martin & Shamir 2001
- Klein 2005
- Combinatorial Problem 2001
- Royal Holloway 2013
- Bar-mitzvah 2015
- NOMORE 2015

RSA-PKCS#1 v1.5 Encryption
- Bleichenbacher 1998
- Jager 2015
- DROWN 2016

Renegotiation
- Marsh Ray Attack 2009
- Renegotiation DoS 2011
- Triple Handshake 2014

3DES
- Sweet32

AES-CBC
- Vaudenay 2002
- Boneh/Brumley 2003
- BEAST 2011
- Lucky13 2013
- POODLE 2014
- Lucky Microseconds 2015

Compression
- CRIME 2012

MD5 & SHA1
- SLOTH 2016
- SHAttered 2017

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

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

Standards

Figure: https://blog.cryptographyengineering.com/2011/10/04/how-standards-go-wrong-constructive

Questions?