McTiny:

McEliece for tiny network servers

Daniel J. Bernstein,

uic.edu, rub.de

Joint work with:

Tanja Lange, tue.nl

My main question in this talk: Shouldn't NIST PQC simply standardize Classic McEliece, discard the other 25 proposals?

classic.mceliece.org submission team (alphabetical):

me;

- Tung Chou, osaka-u.ac.jp;
- Tanja Lange, tue.nl;
- Ingo von Maurich;
- Rafael Misoczki, intel.com;
- Ruben Niederhagen, fraunhofer.de;
- Edoardo Persichetti, fau.edu;
- Christiane Peters;
- Peter Schwabe, ru.nl;
- Nicolas Sendrier, inria.fr;
- Jakub Szefer, yale.edu;
- Wen Wang, yale.edu.

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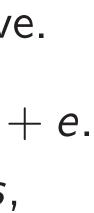
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One-wayness (OW-Passive)

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>25 subsequent publications analyzing one-wayness of system:

1981 Clark–Cain,

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- 1988 Lee–Brickell.
- 1988 Leon.
- 1989 Krouk.
- 1989 Stern.
- 1989 Dumer.
- 1990 Coffey–Goodman.
- 1990 van Tilburg.
- 1991 Dumer.
- 1991 Coffey–Goodman–Farrell.

1993 Chabanne–Courteau.

1993 Chabaud. 1994 van Tilburg. 1994 Canteaut-Chabanne. 1998 Canteaut–Chabaud. 1998 Canteaut–Sendrier. 2008 Bernstein–Lange–Peters. 2009 Bernstein–Lange–Peters– van Tilborg. 2009 Finiasz-Sendrier. 2011 Bernstein-Lange-Peters. 2011 May–Meurer–Thomae. 2012 Becker–Joux–May–Meurer. 2013 Hamdaoui–Sendrier. 2015 May–Ozerov. 2016 Canto Torres-Sendrier.

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mceliece6960119 parameter set (2008 Bernstein–Lange–Peters):

q = 8192, n = 6960, w = 119.

Also in submission: 8192128, 6688128, 460896, 348864.

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Niederreiter key compression

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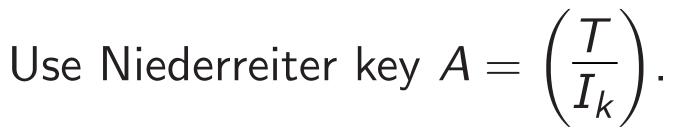
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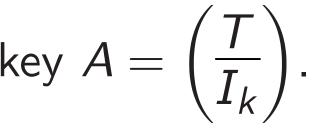
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Niederreiter ciphertext compression



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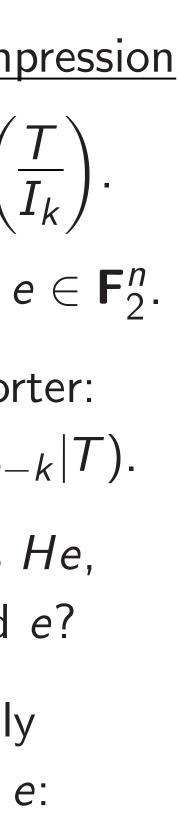
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The immaturity of lattice attacks Case study: SVP, the most famous lattice problem. 2006 Silverman: "Lattices, SVP and CVP, have been intensively studied for more than 100 years, both as intrinsic mathematical problems and for applications in pure and applied mathematics, physics and cryptography."

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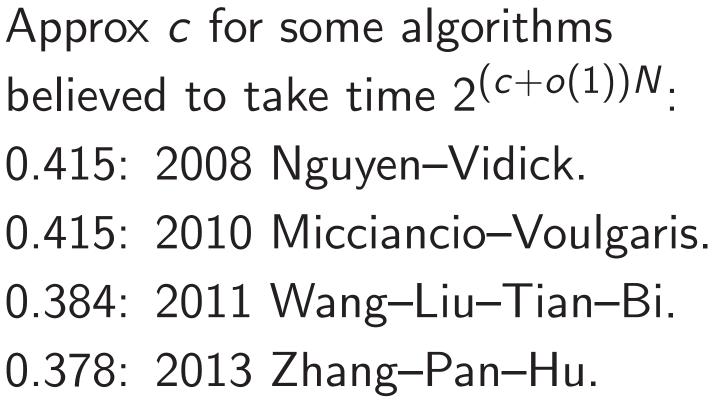
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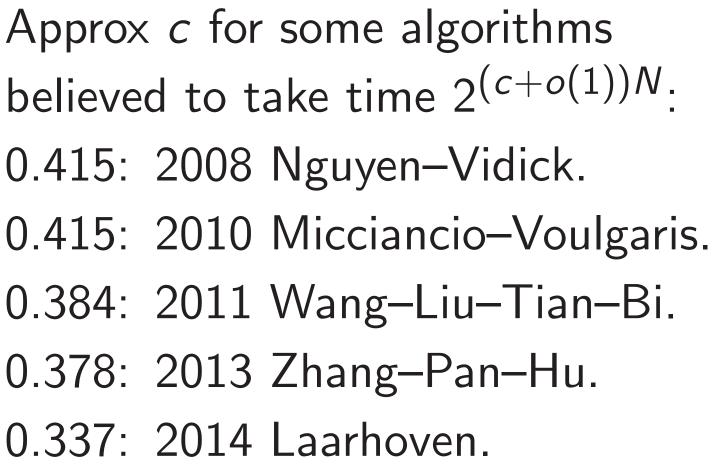
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- 6688128 enc 153
- 6960119 enc 154
- 8192128 enc 183
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Cycles on Intel Haswell CPU

- op cycles
- enc 45888
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- 6688128 enc 153372
- 6960119 enc 154972
- 8192128 enc 183892
 - l dec 136840
- 460896 dec 273872
- 6688128 dec 320428
- 6960119 dec 302460
- 8192128 dec 324008

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6960119	dec	30
8192128	dec	32

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Cycles on Intel Haswell CPU core:

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6960119	enc	154972
8192128	enc	183892
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460896	dec	273872
6688128	dec	320428
6960119	dec	302460
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6960119	dec	302460
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6960119	enc	154972			460896
8192128	enc	183892			460896
					668812
348864					668812
460896	dec	273872			696011
6688128	dec	320428			696011
6960119	dec	302460			819212
8192128	dec	324008			819212

/ait, you're leaving out th st important cost! It's cr have such slow keygen!" ор Су 140870 8864 keygen 82232 8864f keygen 441517 0896 keygen 282869 0896f keygen keygen 1180468 88128 625470 88128f keygen keygen 1109340 60119 564570 60119f keygen 933422 92128 keygen 678860 92128f keygen

<u>Time</u>

Cycles on Intel Haswell CPU core:

params	ор	cycles
348864	enc	45888
460896	enc	82684
6688128	enc	153372
6960119	enc	154972
8192128	enc	183892
348864	dec	136840
460896	dec	273872
6688128	dec	320428
6960119	dec	302460
8192128	dec	324008

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"Wait, you most impo to have su	ortant c
params	ор
348864	keyge
348864f	keyge
460896	keyge
460896f	keyge
6688128	keyge
6688128f	keyge
6960119	keyge
6960119f	keyge
8192128	keyge
8192128f	keyge

aving out the cost! It's crazy w keygen!"

cycles

- en 140870324
- en 82232360
- en 441517292
- en 282869316
- en 1180468912
- en 625470504
- en 1109340668
- en 564570384
- en 933422948
- en 678860388

n Intel Ha	swell CP	U core:
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	ор	cycles
	enc	45888
	enc	82684
3	enc	153372
)	enc	154972
3	enc	183892
	dec	136840
	dec	273872
3	dec	320428
)	dec	302460
3	dec	324008

"Wait, you're leaving out the most important cost! It's crazy to have such slow keygen!"

params	ор	C
348864	keygen	14087
348864f	keygen	8223
460896	keygen	44151
460896f	keygen	28286
6688128	keygen	118046
6688128f	keygen	62547
6960119	keygen	110934
6960119f	keygen	56457
8192128	keygen	93342
8192128f	keygen	67886

- cycles

1. What that this a proble

swell	CPU	core:
vcles		
888		
684		
372		
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"Wait, you're leaving out the most important cost! It's crazy to have such slow keygen!" params op cycles

params	op	Cycles
348864	keygen	140870324
348864f	keygen	82232360
460896	keygen	441517292
460896f	keygen	282869316
6688128	keygen	1180468912
6688128f	keygen	625470504
6960119	keygen	1109340668
6960119f	keygen	564570384
8192128	keygen	933422948
8192128f	keygen	678860388

What evidence that this keygen ti a problem for appl

19 core:	"Wait, you're leaving out the most important cost! It's crazy to have such slow keygen!"		
	params	ор	cycles
	348864	keygen	140870324
	348864f	keygen	82232360
	460896	keygen	441517292
	460896f	keygen	282869316
	6688128	keygen	1180468912
	6688128f	keygen	625470504
	6960119	keygen	1109340668
	6960119f	keygen	564570384
	8192128	keygen	933422948
	8192128f	keygen	678860388

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"Wait, you're leaving out the most important cost! It's crazy to have such slow keygen!"

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used a huge number of times.

a key can be generated once and

"Wait, you're leaving out the most important cost! It's crazy to have such slow keygen!"

params	ор	cycles
348864	keygen	140870324
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3. McEliece's binary operations are very well suited for hardware. See 2018 Wang–Szefer– Niederhagen. Isn't this what's most important for the future?

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ор	cycles
keygen	140870324
keygen	82232360
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keygen	1180468912
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Bytes co

- params
- 348864
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ing out the ost! It's crazy keygen!"	20
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Bytes communicat

params object

- 348864 cipherte
- 460896 cipherte
- 6688128 cipherte
- 6960119 ciphertex 8192128 ciphertex
- 348864 key
- 460896 key
- 6688128 key
- 6960119 key
- 8192128 key

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3. McEliece's binary operations are very well suited for hardware. See 2018 Wang–Szefer– Niederhagen. Isn't this what's most important for the future?

21

Bytes communicated

params	object	byte	
348864	ciphertext	12	
460896	ciphertext	18	
6688128	ciphertext	24	
6960119	ciphertext	22	
8192128	ciphertext	24	
348864	key	26112	
460896	key	52416	
6688128	key	104499	
6960119	key	104731	
8192128	key	135782	
"It's crazy to have big keys!			

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 Niederhagen. Isn't this what's most important for the future?

21	<u>Bytes communic</u>		
	params	object	
	348864	cipherte	
	460896	cipherte	
	6688128	cipherte	
	6960119	cipherte	
	8192128	cipherte	
	348864	key	
	460896	key	
	6688128	key	
	6960119	key	
	8192128	key	
	"It's crazy	v to have	

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bytes

- ext 128 ext 188 ext 240 ext 226 ext 240
 - 261120 524160 1044992 1047319 1357824
- It's crazy to have big keys!"

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CCA2 security, so

n be generated once and uge number of times.

iece's binary operations well suited for hardware. 8 Wang–Szefer–

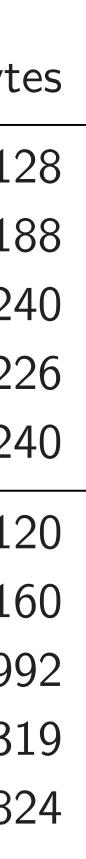
agen. Isn't this what's portant for the future?

Bytes communicated

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params	object	byt
348864	ciphertext	1
460896	ciphertext	1
6688128	ciphertext	2
6960119	ciphertext	2
8192128	ciphertext	2
348864	key	2611
460896	key	5241
6688128	key	10449
6960119	key	10473
8192128	key	13578

"It's crazy to have big keys!"



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Bytes communicated

params	object	bytes
348864	ciphertext	128
460896	ciphertext	188
6688128	ciphertext	240
6960119	ciphertext	226
8192128	ciphertext	240
348864	key	261120
460896	key	524160
6688128	key	1044992
6960119	key	1047319
8192128	key	1357824

"It's crazy to have big keys!"

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What evidence do that these key size a problem for appl

/e	21	Bytes communicated		
		params	object	bytes
		348864	ciphertext	128
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		6688128	ciphertext	240
e and		6960119	ciphertext	226
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ware.		460896	key	524160
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	ciphertext	128
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Denial of service

Standard low-cost strategy: make a of connections to up all memory ava for keeping track of SYN flood, HTTP Server is forced to some connections, connections from

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Denial of service

Standard low-cost attack

- strategy: make a huge num
- of connections to a server, f
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Server is forced to stop serv some connections, including connections from honest clie

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- This forces the public key to fit into a network packet. Is that 1500 bytes? Or 1280? Either way, your key is too big.

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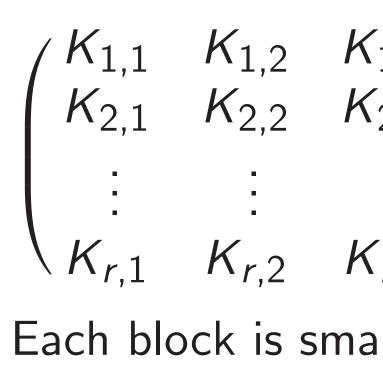
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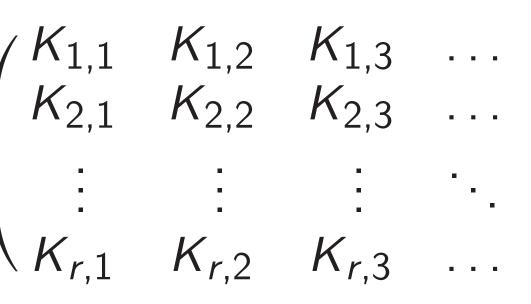
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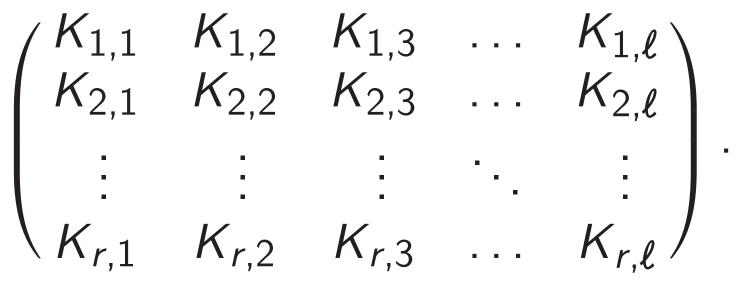
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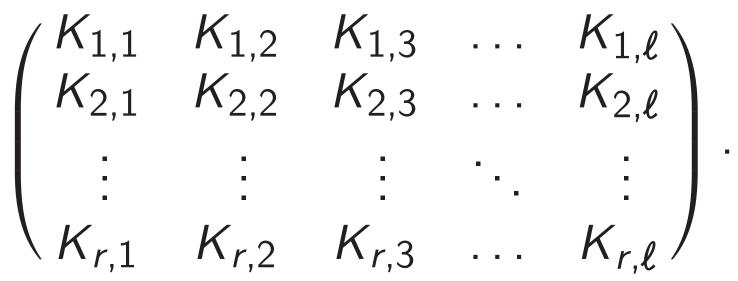
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3. Client sends $K_{i,i}$ to server. Server sends back $K_{i,j}e_j$ encrypted to a server cookie key.

Server cookie key is not per-client. Key is erased after a few minutes.



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$\begin{pmatrix} K_{1,1} \\ K_{2,1} \end{pmatrix}$	<i>K</i> _{2,2}	<i>K</i> _{2,3}	
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$\begin{pmatrix} K_{1,1} \\ K_{2,1} \end{pmatrix}$	$K_{1,2} \\ K_{2,2}$	K _{1,3} K _{2,3}	· · · ·	$\left. \begin{array}{c} K_{1,\ell} \\ K_{2,\ell} \end{array} \right)$		
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6. Server sends final Ke directly to client, encrypted by session key but *not* by cookie key.

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Forward secrecy: Once cookie key and secret key for K are erased, client and server cannot decrypt.