Beyond $2^{c/2}$ Security in Sponge-Based Authenticated Encryption Modes

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Authenticated Encryption

- Encryption and authentication in one
- Applications: SSH, IPsec, TLS, IEEE 802.11
- CAESAR competition

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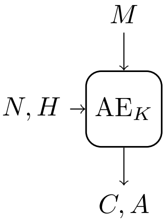

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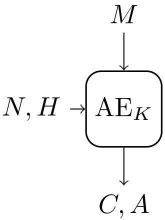
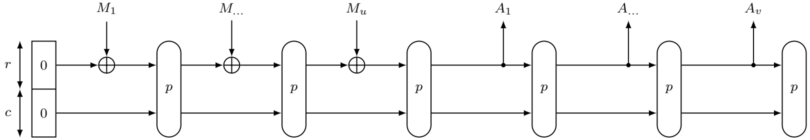


- Security goals: privacy + integrity
  - Nonce-dependent or security against nonce-reuse

Sponge Functions



- Bertoni, Daemen, Peeters, and Van Assche (2007)
- Based on permutation p
- $b = r + c$

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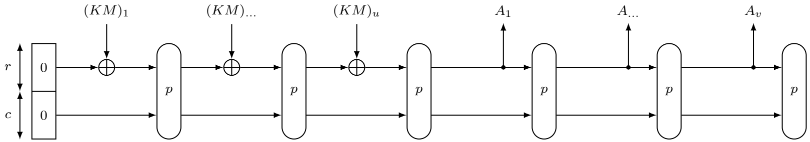

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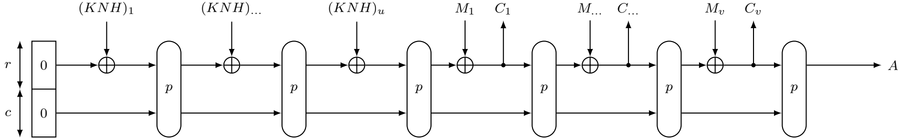

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- AE: SpongeWrap (duplexing mode)

Sponge Functions

Sponge (hash) $2^{c/2}$ security

c = capacity κ = key size τ = tag size

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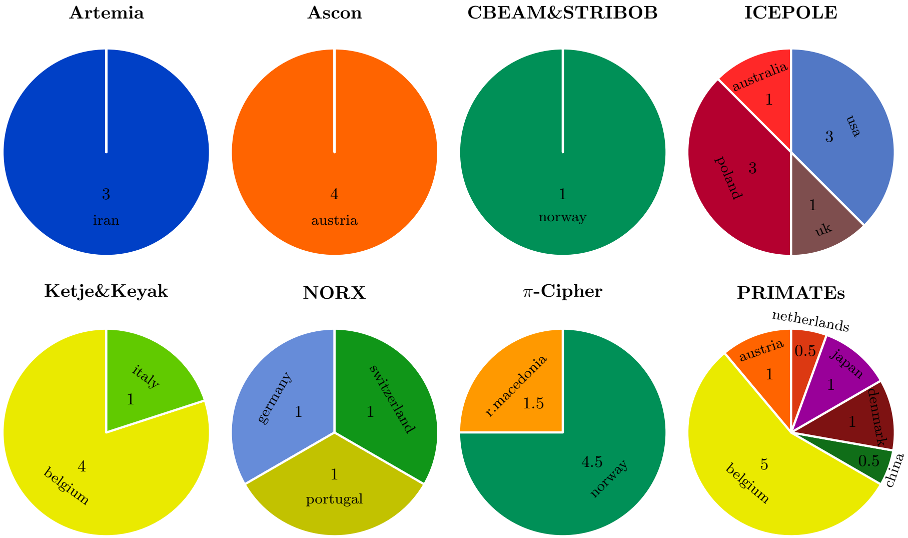
	$\approx \min\{2^{c/2}, 2^{\kappa}\}$ security
SpongeWrap (AE)	$\min\{2^{c/2}, 2^{\kappa}\}$ security (privacy)
	$\min\{2^{c/2}, 2^{\kappa}, 2^{\tau}\}$ security (integrity)

c = capacity $\quad$ κ = key size $\quad$ τ = tag size

Sponge-Based CAESAR Modes



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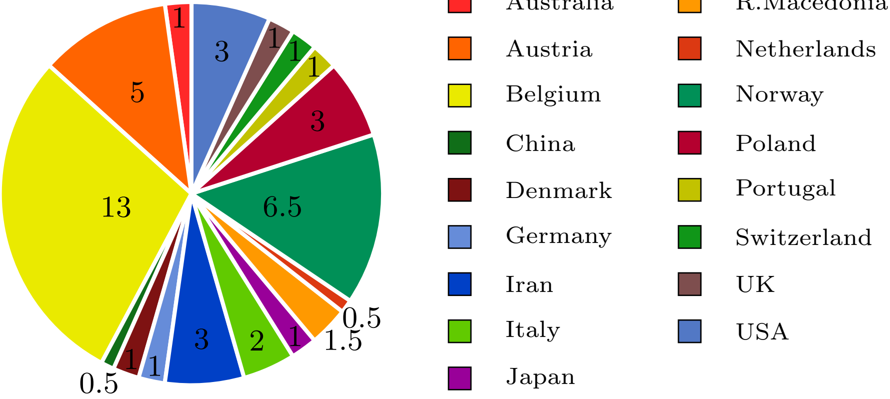
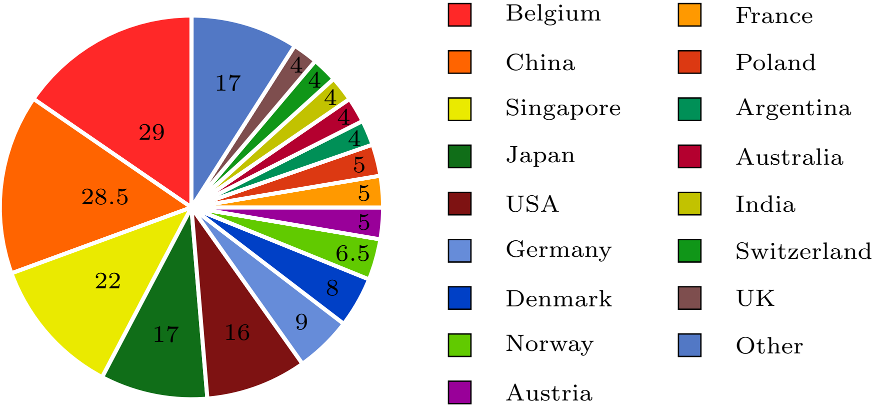


Intermezzo – All CAESAR Contributors



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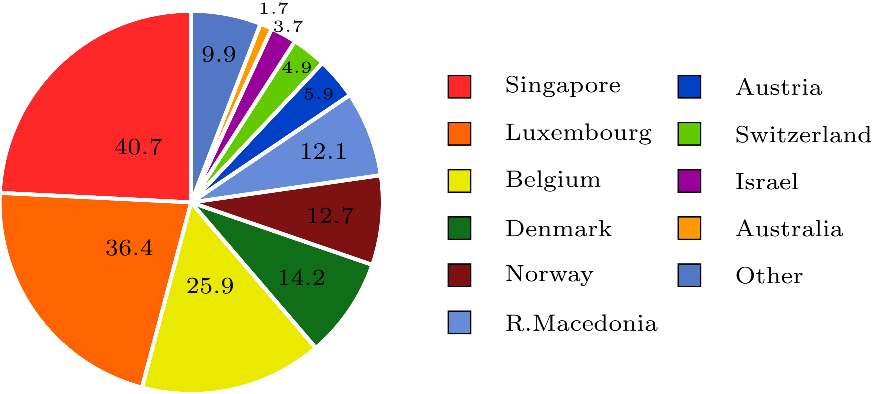

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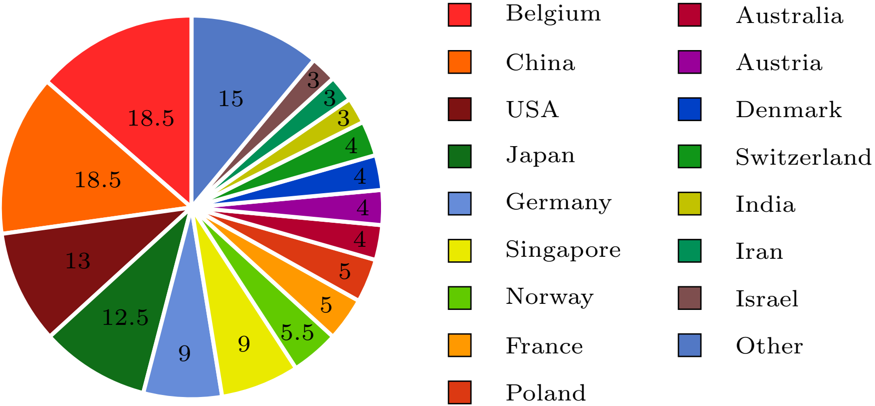

Sponge-Based CAESAR Modes

nonce-dependent	security against nonce-reuse
Artemia	APE[2,3]
Ascon	
CBEAM/STRIBOB[1]	
ICEPOLE	
Ketje	
Keyak	
NORX	
π-Cipher	
GIBBON/HANUMAN[2]	

[1] CBEAM and STRIBOB use BLNK sponge mode

[2] PRIMATEs = {GIBBON, HANUMAN, APE}

[3] also used in submission Prøst

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parameters based on $2^{c/2}$ and $(2^a, 2^{c-a})$ results

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parameters based on $2^{c/2}$ and $(2^a, 2^{c-a})$ results

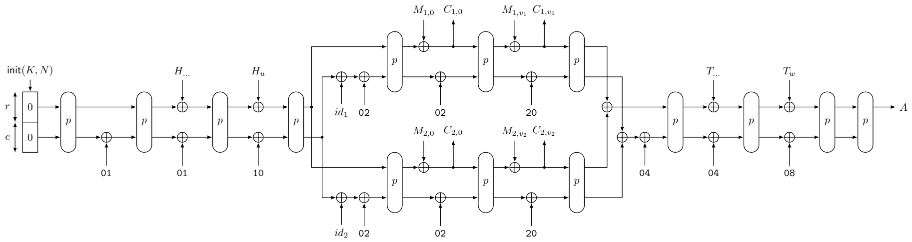
$2^{c/2}$ security (tight)

Nonce changes everything!

Sponge-Based CAESAR Modes

	b	c	r	κ	**security**
Ascon	320	192	128	96	**96**
	320	256	64	128	**128**
CBEAM	256	190	66	128	**128**
ICEPOLE	1280	254	1026	128	**128**
	1280	318	962	256	**256**
Keyak	800	252	548	128	**128**
	1600	252	1348	128	**128**
NORX	512	192	320	128	**128**
	1024	384	640	256	**256**
GIBBON/ HANUMAN	200	159	41	80	**80**
	280	239	41	120	**120**
STRIBOB	512	254	258	192	**192**

NORX



- Submission by Aumasson, Jovanovic, and Neves
- Initialization with K and unique N
- Header – message – trailer
- Parallelism $D \in \{0, \dots, 255\}$ (here, $D = 2$)

NORX: Mode Security

Privacy

$\min\{2^{b/2}, 2^c, 2^\kappa\}$ security

Integrity

$\min\{2^{b/2}, 2^c, 2^\kappa, 2^\tau\}$ security

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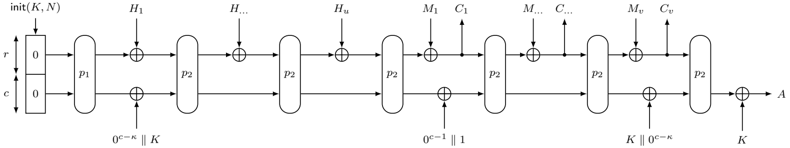
Main Implication

putting $c = \kappa$ does not decrease mode security level

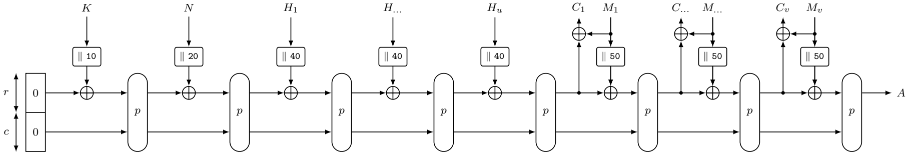
Generalization

- Generalizes to SpongeWrap and DuplexWrap
- Generalizes to CAESAR submission modes
    - Ascon
    - BLNK (used in CBEAM and STRIBOB)
    - ICEPOLE
    - Keyak
    - GIBBON and HANUMAN (two PRIMATEs)

Generalization



Ascon



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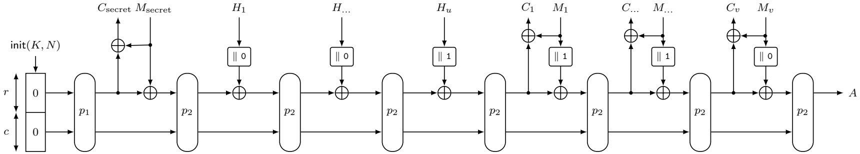
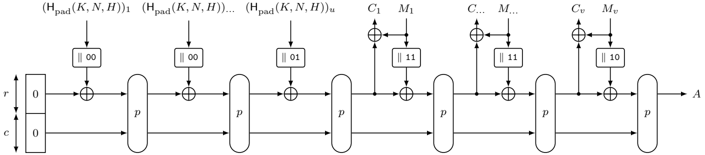


ICEPOLE

Generalization



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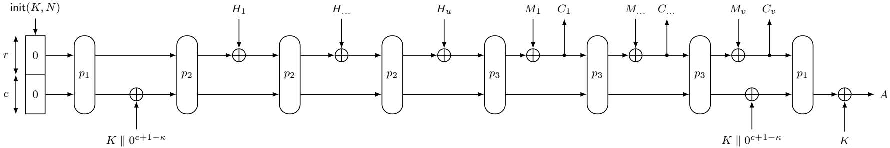
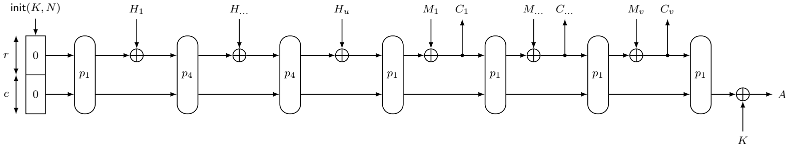


GIBBON (PRIMATEs)



HANUMAN (PRIMATEs)

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New Security Levels

	b	c	r	$\frac{r}{r_{\text{old}}}$	κ	**security**
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	320	128	192	3	128	**128**
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NORX	512	128	384	1.2	128	**128**
	1024	256	768	1.2	256	**256**
GIBBON/ HANUMAN	200	80	120	2.93	80	**80**
	280	120	160	3.90	120	**120**
STRIBOB	512	192	320	1.24	192	**192**

Conclusions

From $\min\{2^{c/2}, 2^{\kappa}\}$ to $\min\{2^{b/2}, 2^{c}, 2^{\kappa}\}$

- Applies to
  - SpongeWrap and DuplexWrap
  - Modes of Ascon, CBEAM, ICEPOLE, Keyak, NORX, PRIMATEs, and STRIBOB

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Thank you for your attention!

http://eprint.iacr.org/2014/373

SUPPORTING SLIDES

NORX: Privacy

$\min\{2^{b/2}, 2^c, 2^\kappa\}$ security

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$$\min\{2^{b/2}, 2^c, 2^\kappa\} \text{ security}$$

Security Model

- Adversary tries to distinguish $(p, \mathcal{E}_K^p)$ from $(p, \$)$
  - Random permutation p, key K, and AE $\$$
  - Define m = total complexity = $q + \sigma_\mathcal{E}$

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- Everything "fine" as long as no collision or key guess

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  $\longrightarrow \rho q/2^c$ (multiplicity)
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Security Model

- Adversary with access to $(p, \mathcal{E}_K^p, \mathcal{D}_K^p)$ aims to forge
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$\sigma_\mathcal{D}$ relatively small

- As long as no collisions, forgery $\rightarrow \sigma_\mathcal{D}/2^\tau$