Collision Spectrum, Entropy Loss, T-Sponges and Cryptanalysis of GLUON-64

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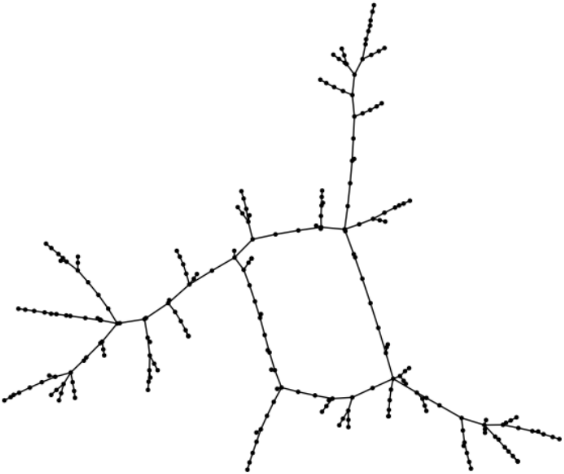

Known Results

CPS and Iterated (Pre)-Images

Applications to Cryptography

Application to GLUON-64

Conclusion

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For functions chosen uniformly at random among all the functions from $\mathcal{S}$ to itself (random mappings).

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Collision Probability Spectrum (CPS)

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We call *Collision Probability Spectrum* (CPS) of $g : \mathcal{S} \rightarrow \mathcal{S}$ the set $\{\mathfrak{c}_k\}_{k \geq 1}$

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Definition

The average number of non-zero roots is denoted κ and called *collision average*:

$$\kappa = \sum_{k \geq 1} \mathfrak{c}_k \cdot k - 1$$

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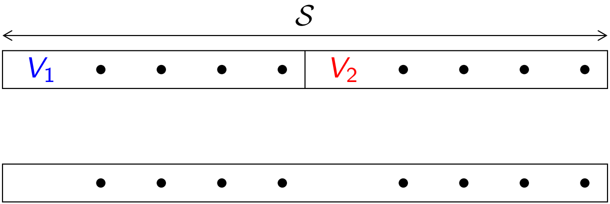

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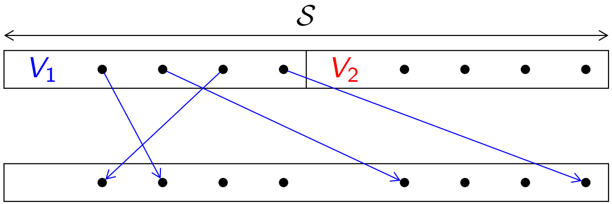

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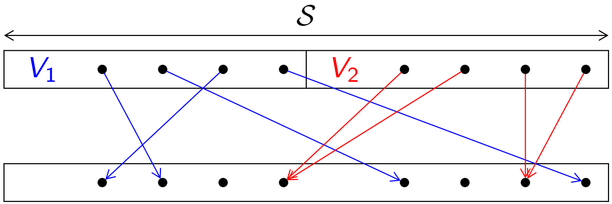

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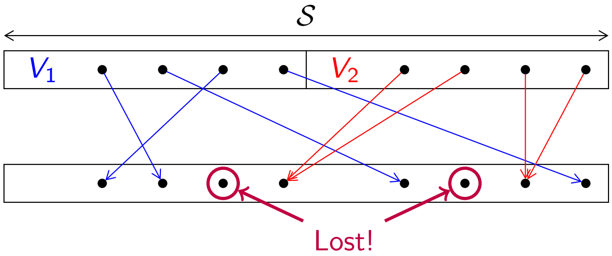

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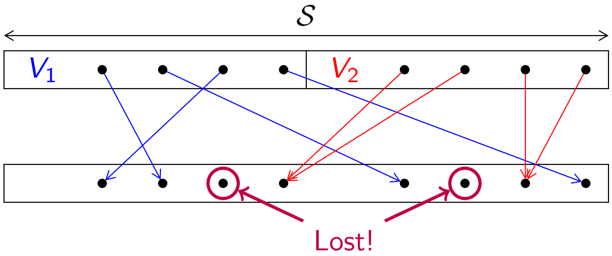

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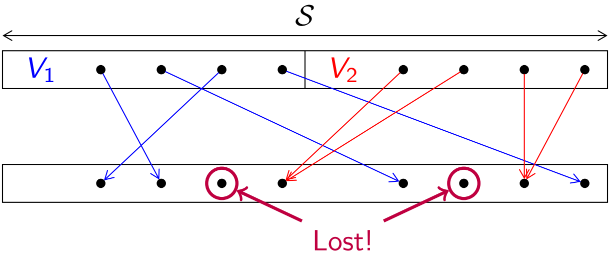

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Independence Assumption: In what follows, we assume that $x \in g(V_k)$ and $x \in V_j$ are independent for any k, j.

Iterated Output Shrinking and Collision Tree

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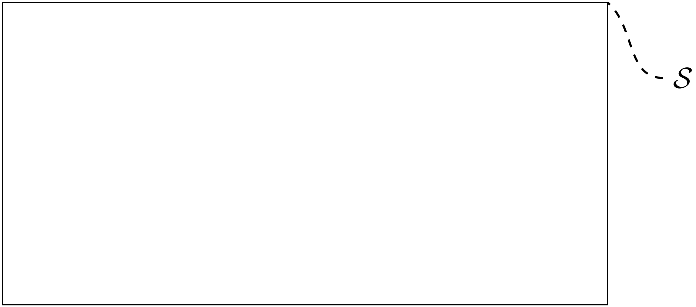

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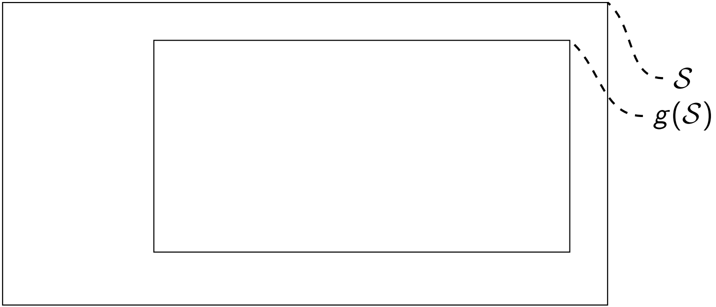

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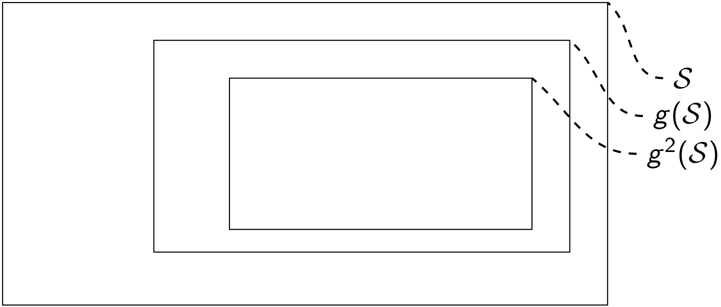

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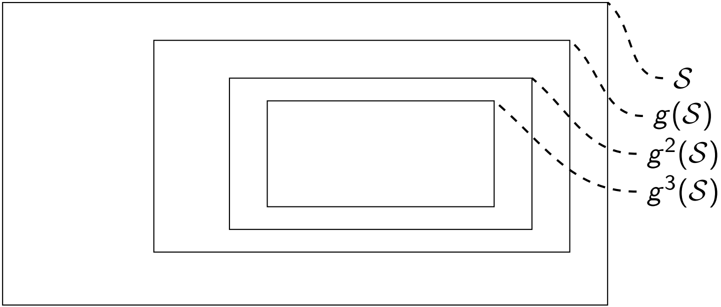

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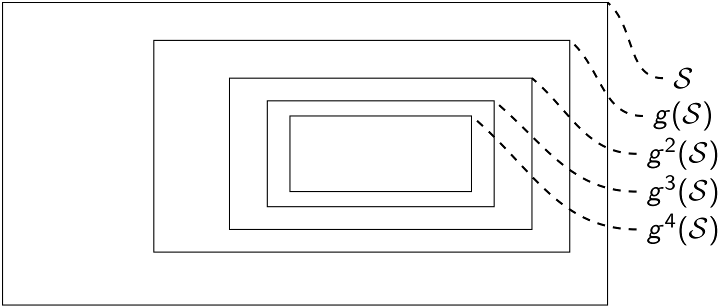

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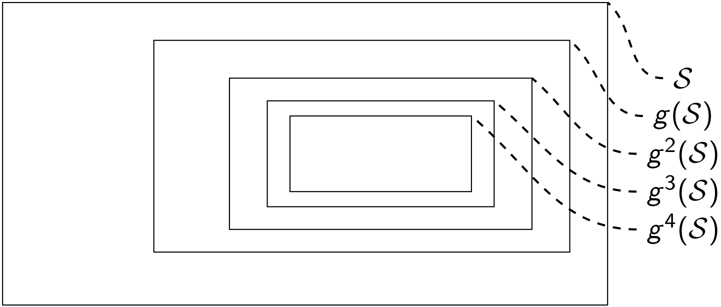

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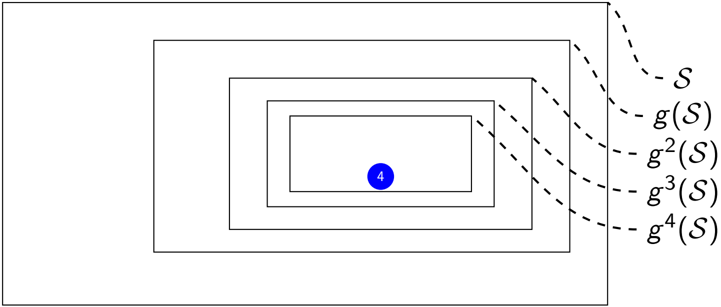

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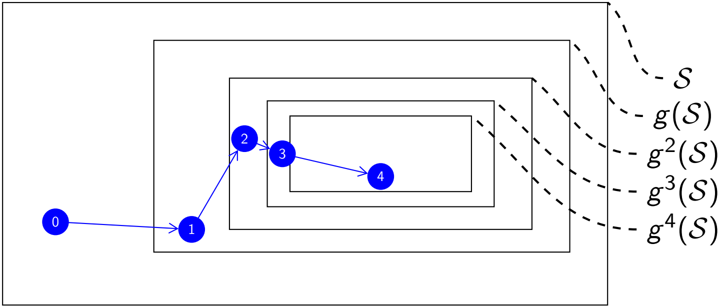

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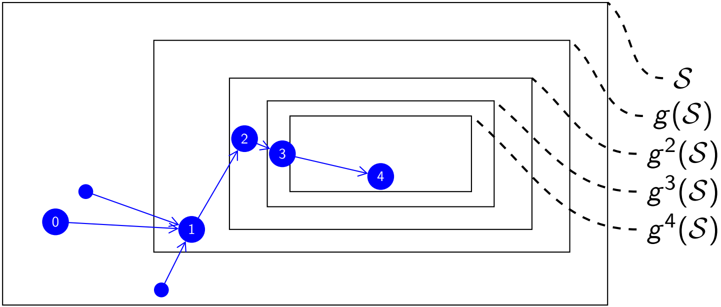

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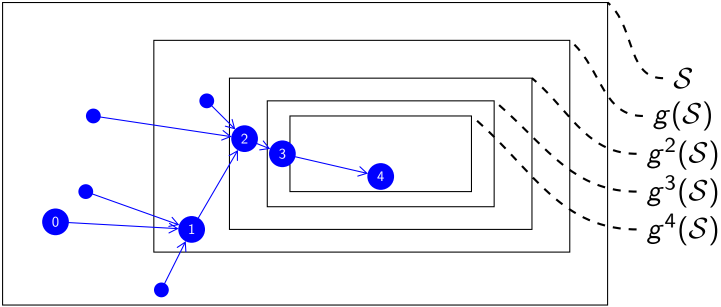

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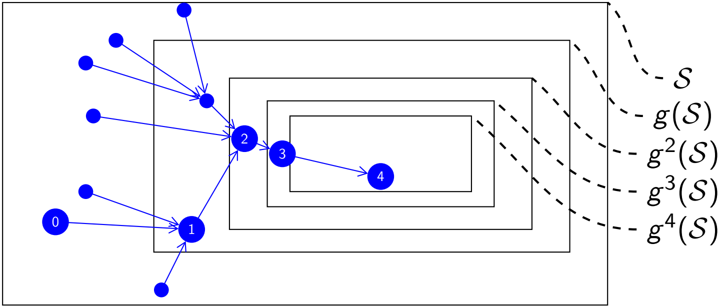

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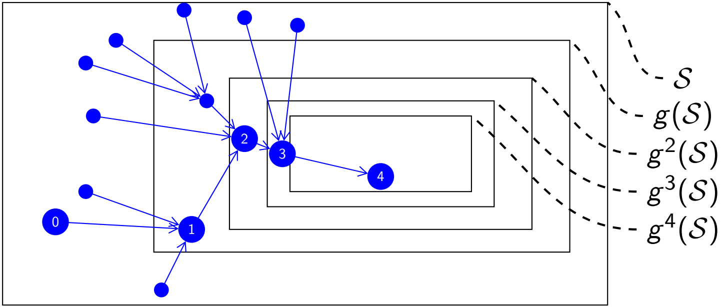

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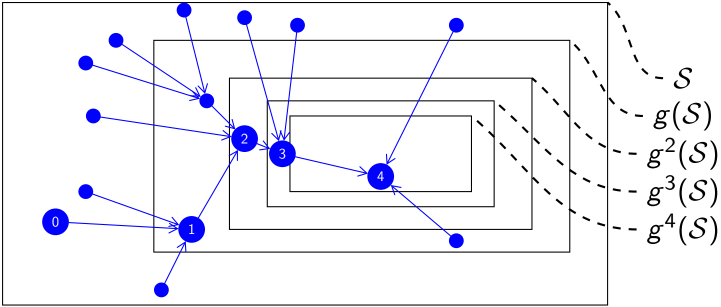

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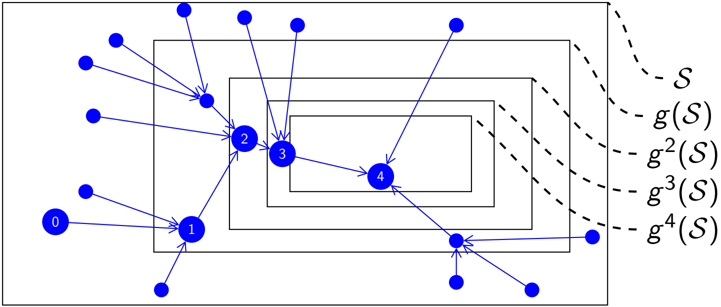

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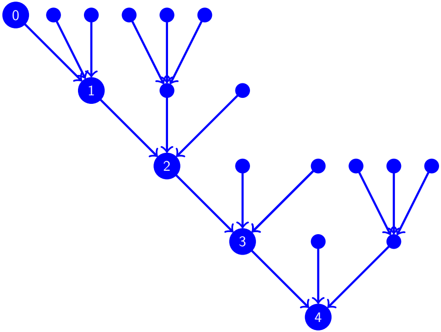

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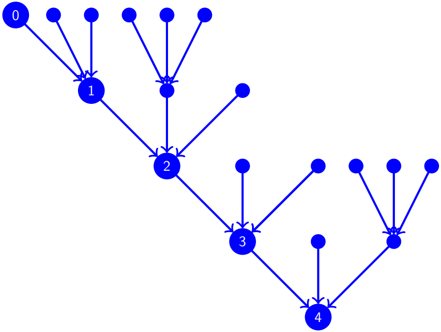


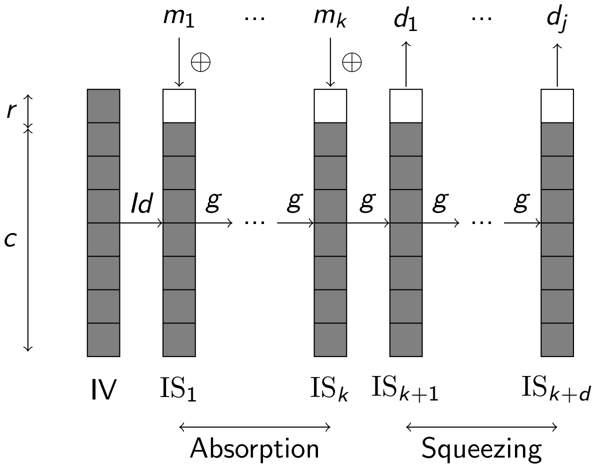
$$|g^i(\mathcal{S})| \sim \frac{|\mathcal{S}|}{i \cdot \kappa/2} \qquad \#\{ \text{ nodes in tree rooted in } g^i(\mathcal{S})\} \sim \frac{\kappa}{4} \cdot i^2$$

Known CPS's

Function	κ	$\lvert\mathcal{S}\rvert / \lvert g^i(\mathcal{S})\rvert$	tree size
MICKEY's update function	0.625	$2^{-1.7} \cdot i$	$2^{-2.7} \cdot i^2$
Random mapping	1	$2^{-1} \cdot i$	$2^{-2} \cdot i^2$
GLUON-64's update function	6.982	$2^{1.8} \cdot i$	$2^{0.8} \cdot i^2$

Plan

The T-sponge Construction



- c: capacity
- r: bitrate
- $m_1, ..., m_k$: Message
- $d_1, ..., d_j$: Digest
- g: random function

Flat Sponge Claim Revisited

If g is a function with collision average κ, then finding collisions with Q queries succeeds with probability

$$\frac{Q^2}{2^{c+1}} \cdot \left(1 + \frac{\kappa - 1}{2^r}\right).$$

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Intuition: $\mathcal{S}$ has size 2^{c+r}. Collisions occur because of the "trimming" of the bitrate ($2^r/2^{c+r} = 2^c$) and because of inner-collisions ($\kappa/2^{c+r}$).

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Definition

Given a space $\mathcal{S}$, functions $g_k : \mathcal{S} \rightarrow \mathcal{S}$ and a sequence of keys $\{k_1, ..., k_m\}$, a *keyed walk* starting in x_0 is such that

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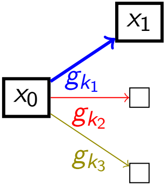

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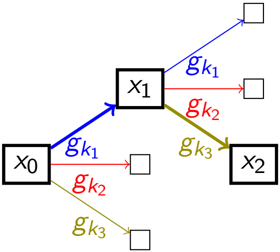

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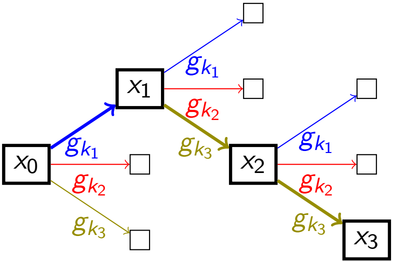

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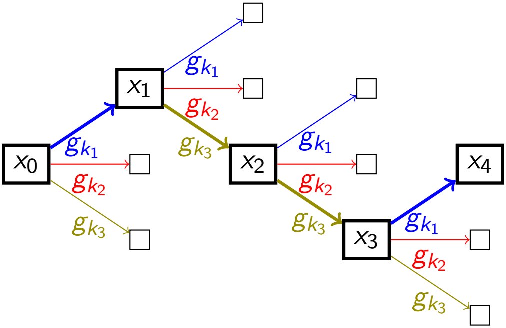

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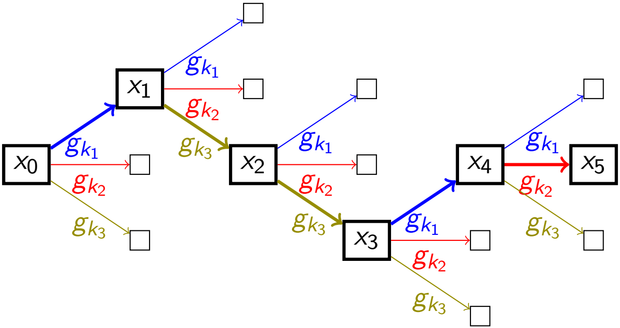

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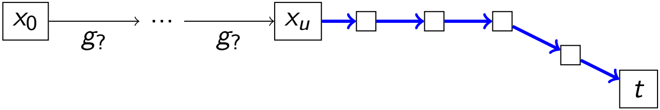

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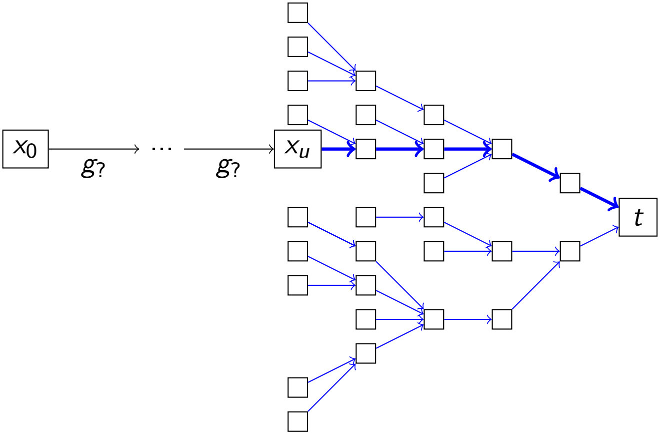

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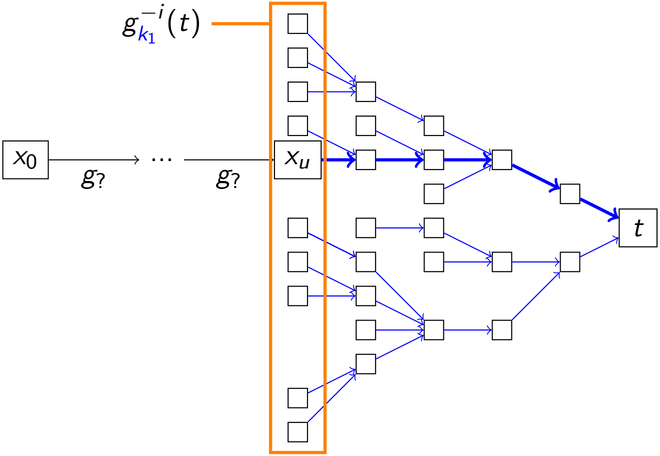

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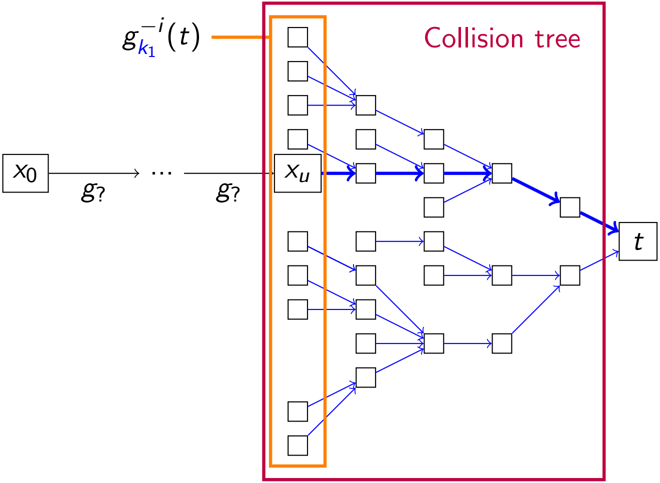

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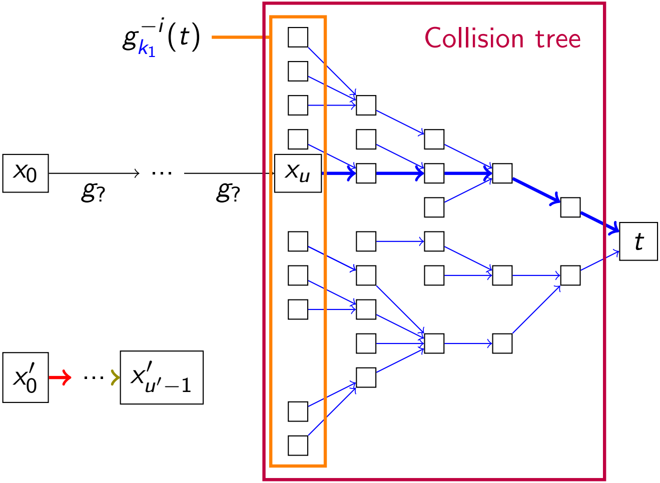

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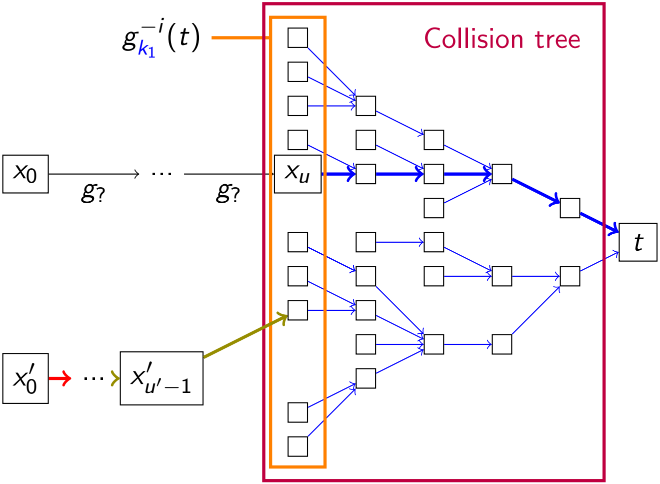

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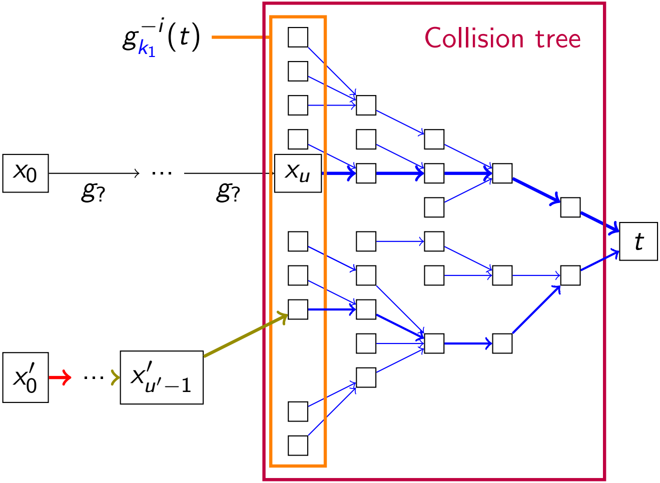

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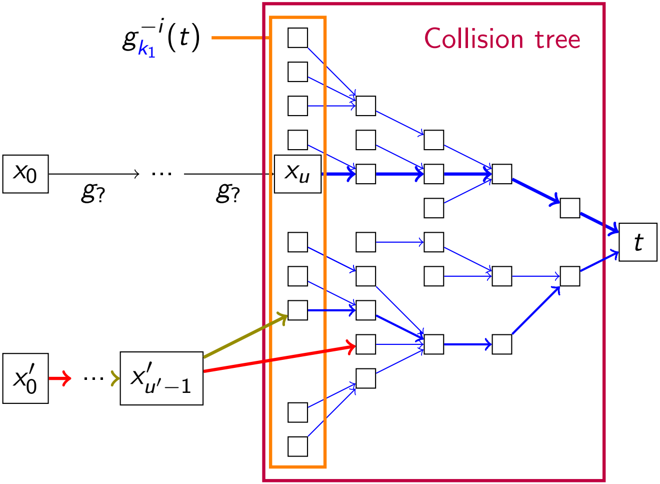

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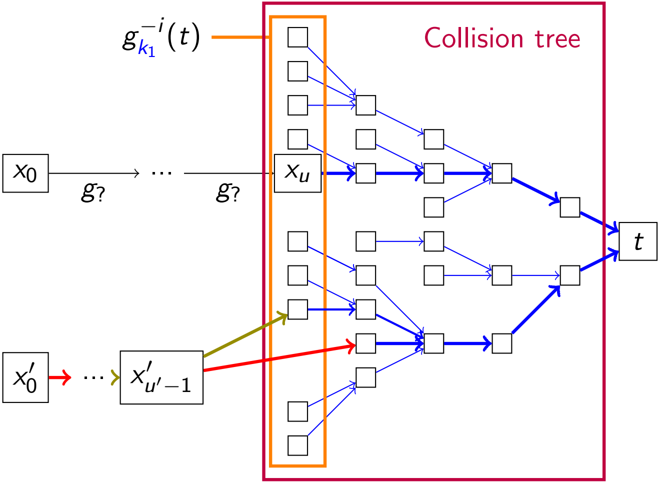

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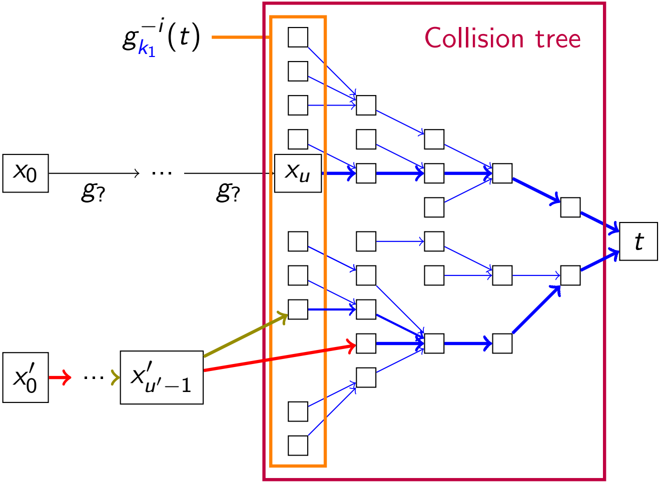

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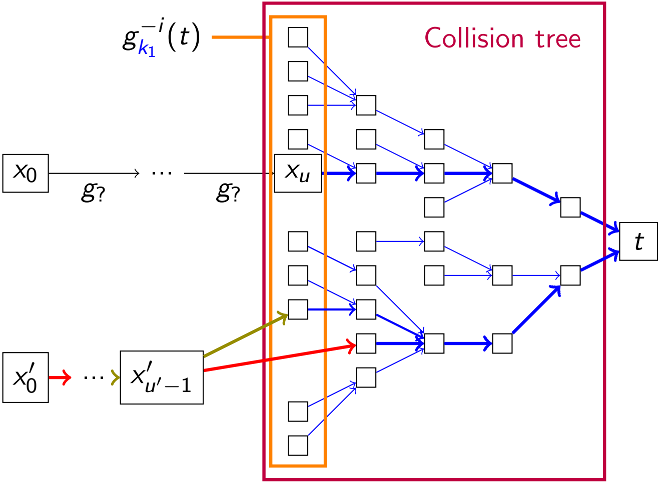

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UNIVERSITÉ DU LUXEMBOURG

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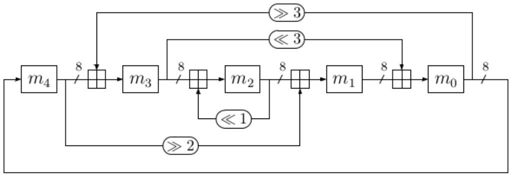

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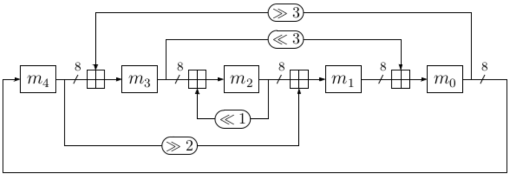
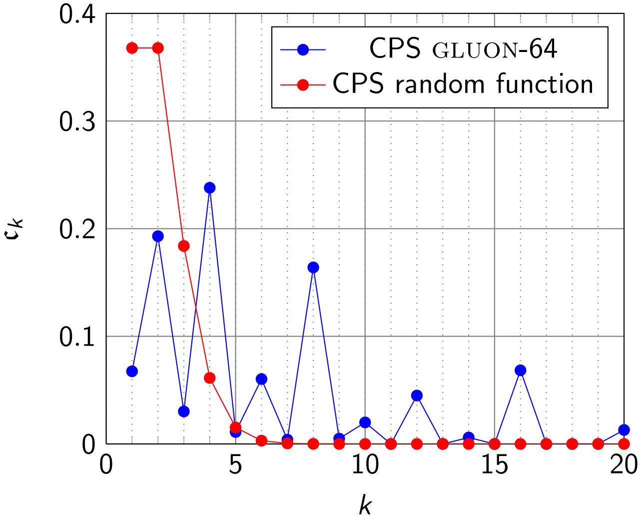
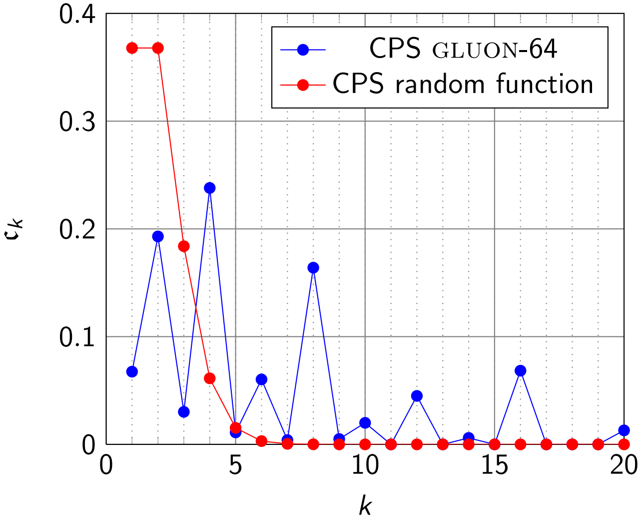


Possible (with a SAT-solver) to enumerate the solutions of

$$(\rho^{10} \circ \mathrm{pad})(x + a) = (\rho^{10} \circ \mathrm{pad})(a)$$


CPS GLUON-64
CPS random function
0.4
0.3
0.2
0.1
0
c_k
0
5
10
15
20
k



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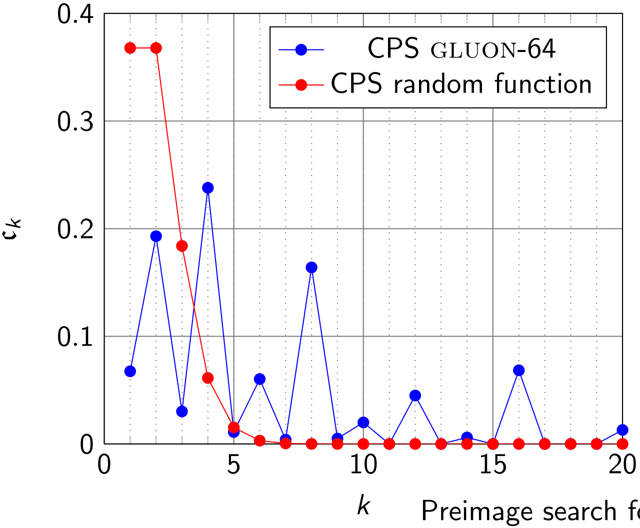

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Thank you!