Authenticating compromisable storage systems

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Joint work with Mark Ryan and Liqun Chen

Aim:
Backup sensitive data in the cloud.

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Problem:
How to secure the data?

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Solution:
Encrypt data before uploading it.

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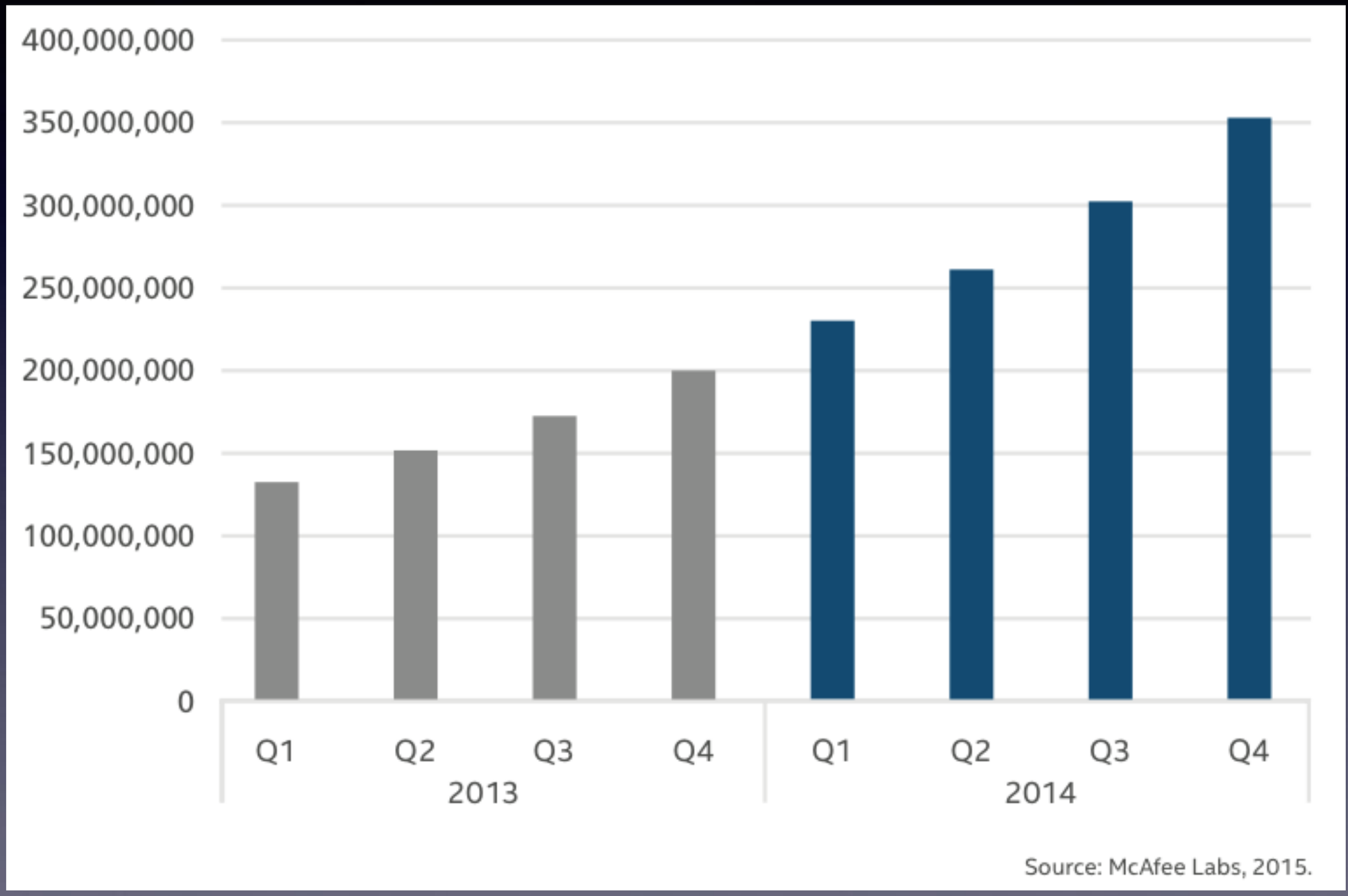
Solution Cont.:
Store it locally!

Operating systems with most security vulnerabilities

Operating system	# of vulnerabilities	# of HIGH vulnerabilities	# of MEDIUM vulnerabilities	# of LOW vulnerabilities
Apple Mac OS X	147	64	67	16
Apple iOS	127	32	72	23
Linux Kernel	119	24	74	21
Microsoft Windows Server 2008	38	26	12	0
Microsoft Windows 7	36	25	11	0
Microsoft Windows Server 2012	38	24	14	0
Microsoft Windows 8	36	24	12	0
Microsoft Windows 8.1	36	24	12	0
Microsoft Windows Vista	34	23	11	0
Microsoft Windows RT	30	22	8	0

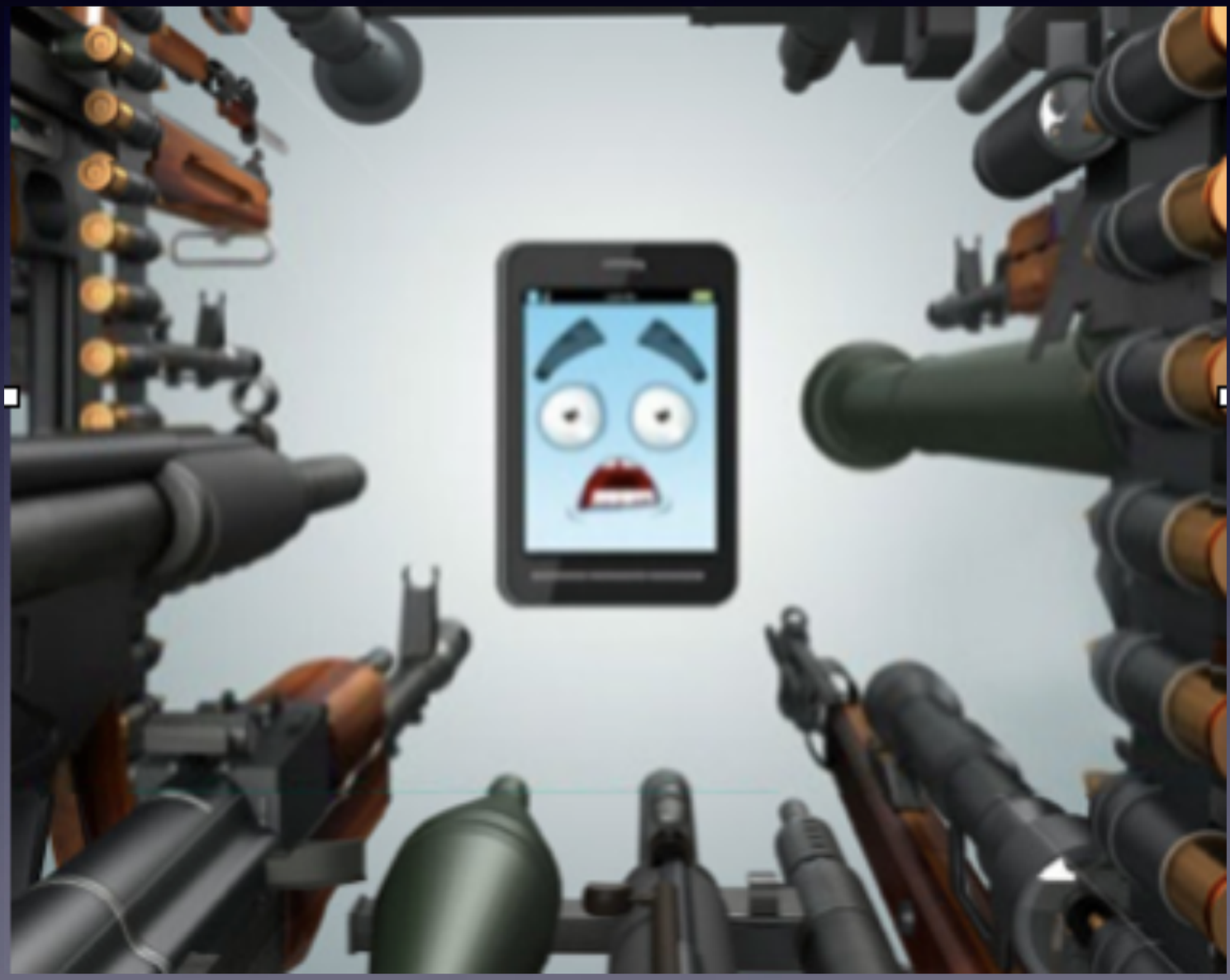
http://www.gfi.com/blog/most-vulnerable-operating-systems-and-applications-in-2014/

Total number of malware instances collected by McAfee Labs across PCs and Mobile devices



Source: McAfee Labs, 2015.

Your device is not secure!



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Solution Cont.:
(k,n)-secret sharing in different platforms!

(k,n)-secret sharing cryptosystem:

- Distribute a secret amongst n platforms;
- Each platform obtains a share of the secret;
- A secret can only be reconstructed if at least k shares are collected.

We hope that in the **life time** of the system, the attacker cannot compromise k servers.

Murphy’s law:
Anything that can go wrong will go wrong.

What could we do?

Our Goal: make an attacker's job more difficult.

Attacker’s work

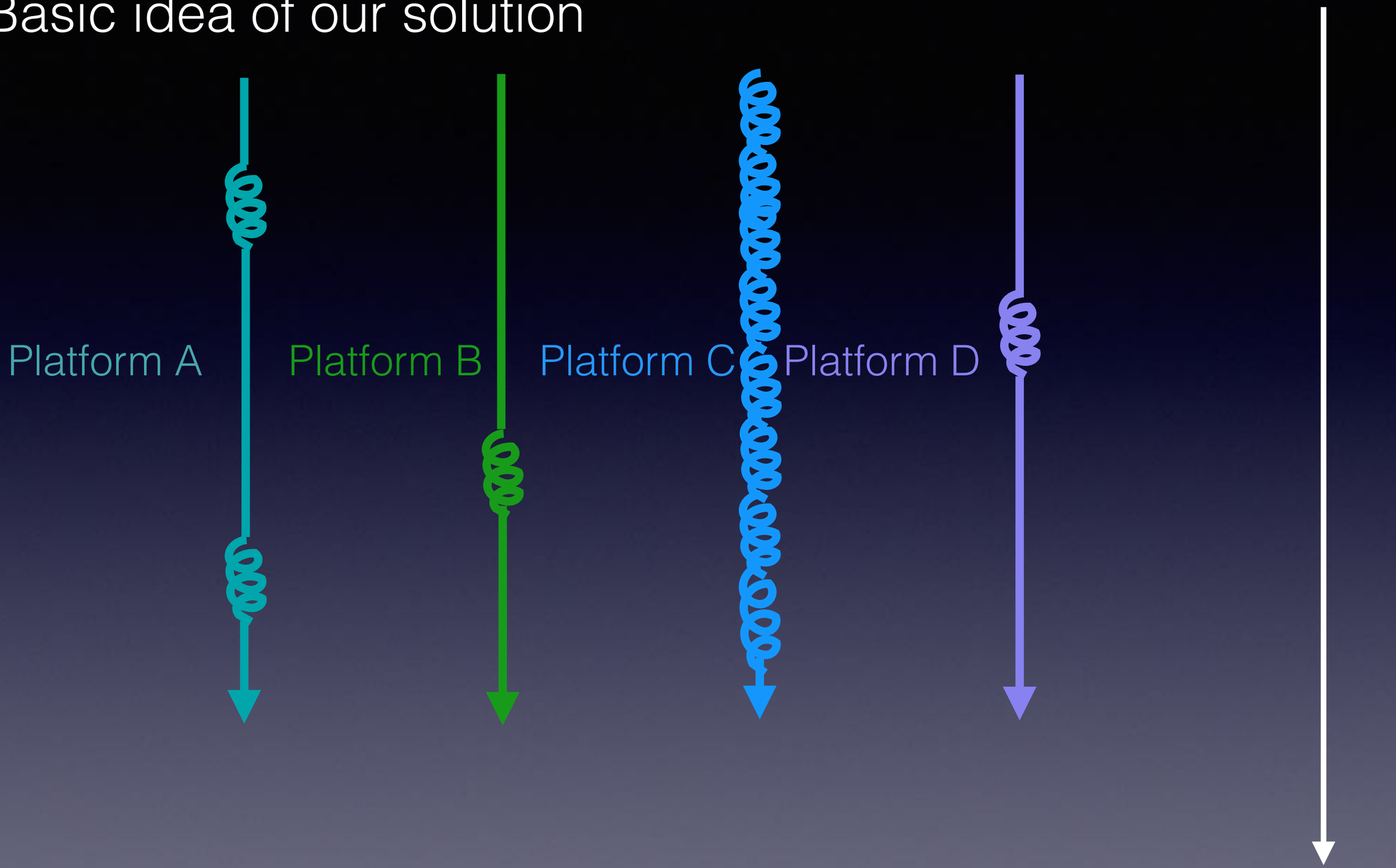
Compromise **k** platforms in the **life time** of the system

Attacker's work

Compromise **k** platforms in the ~~**life time**~~ **time** of the system

a **short period**

Basic idea of our solution



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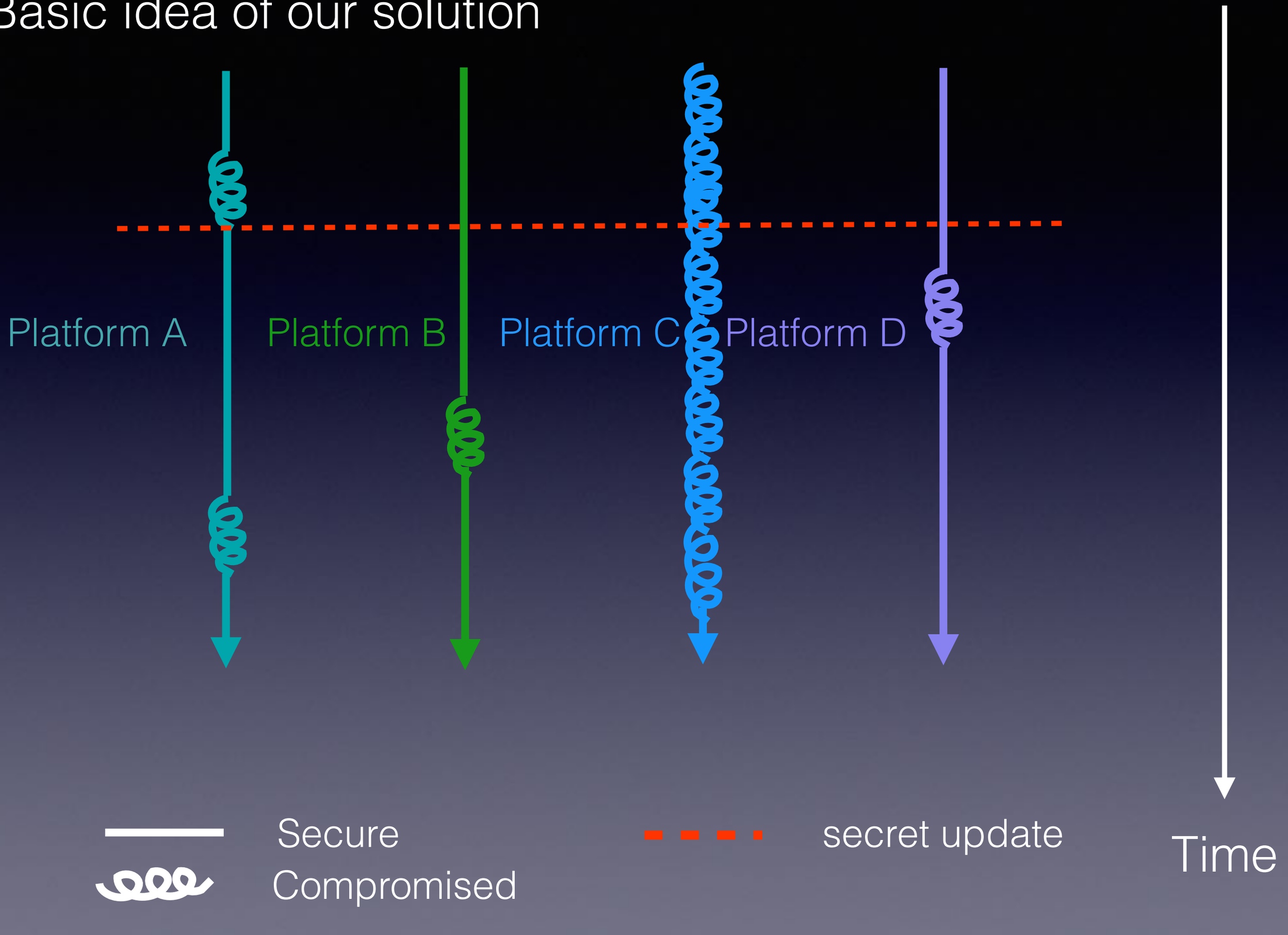

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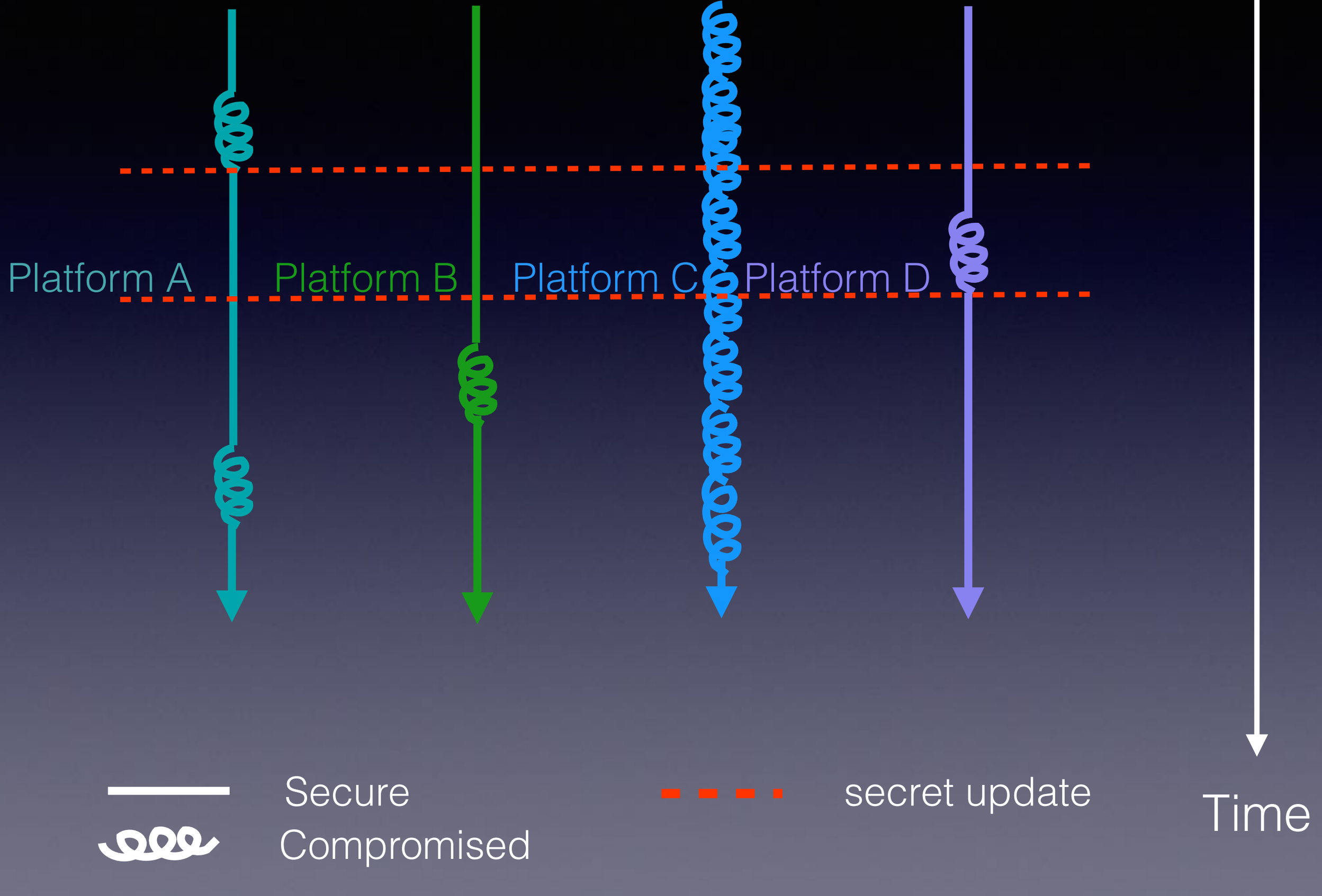

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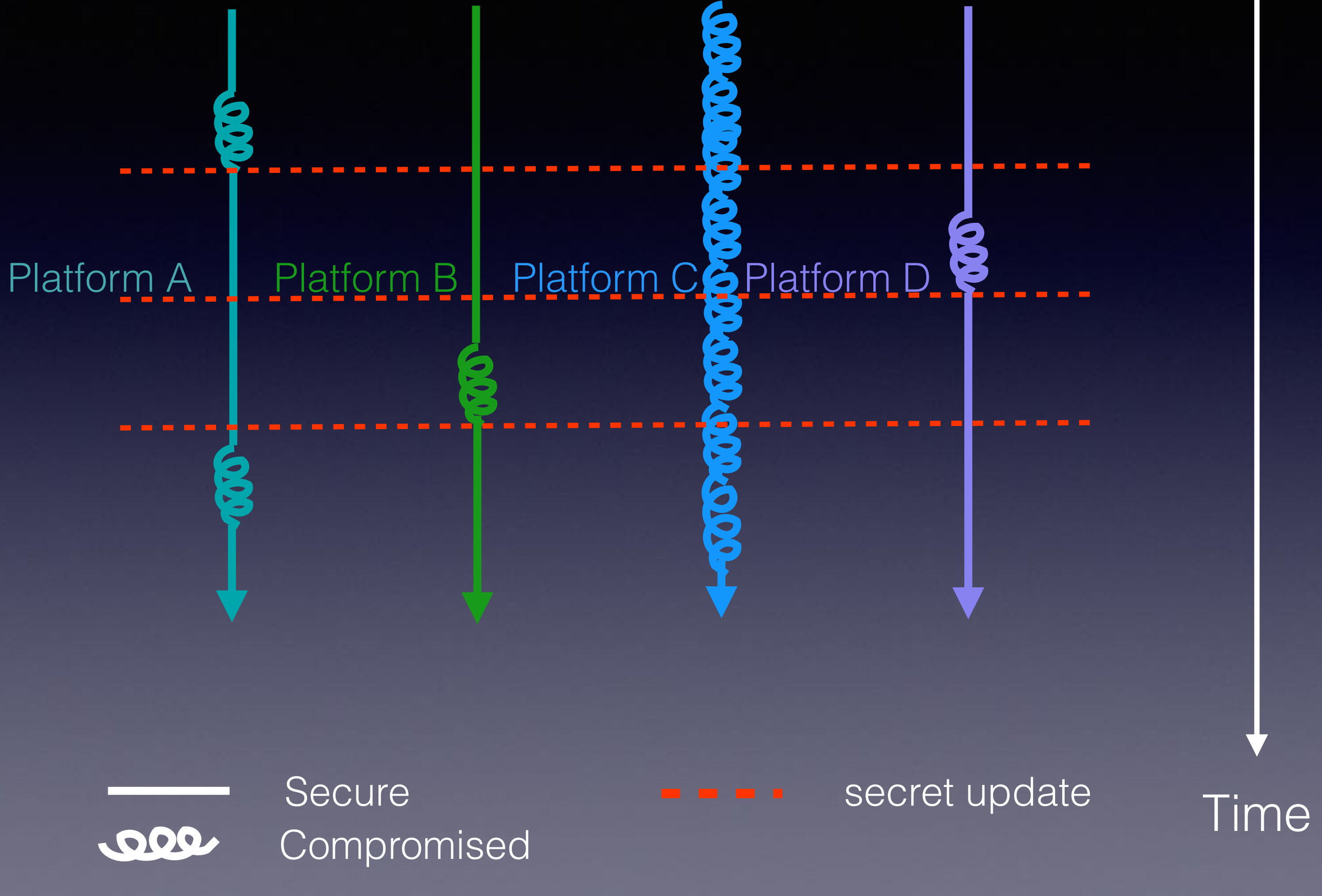

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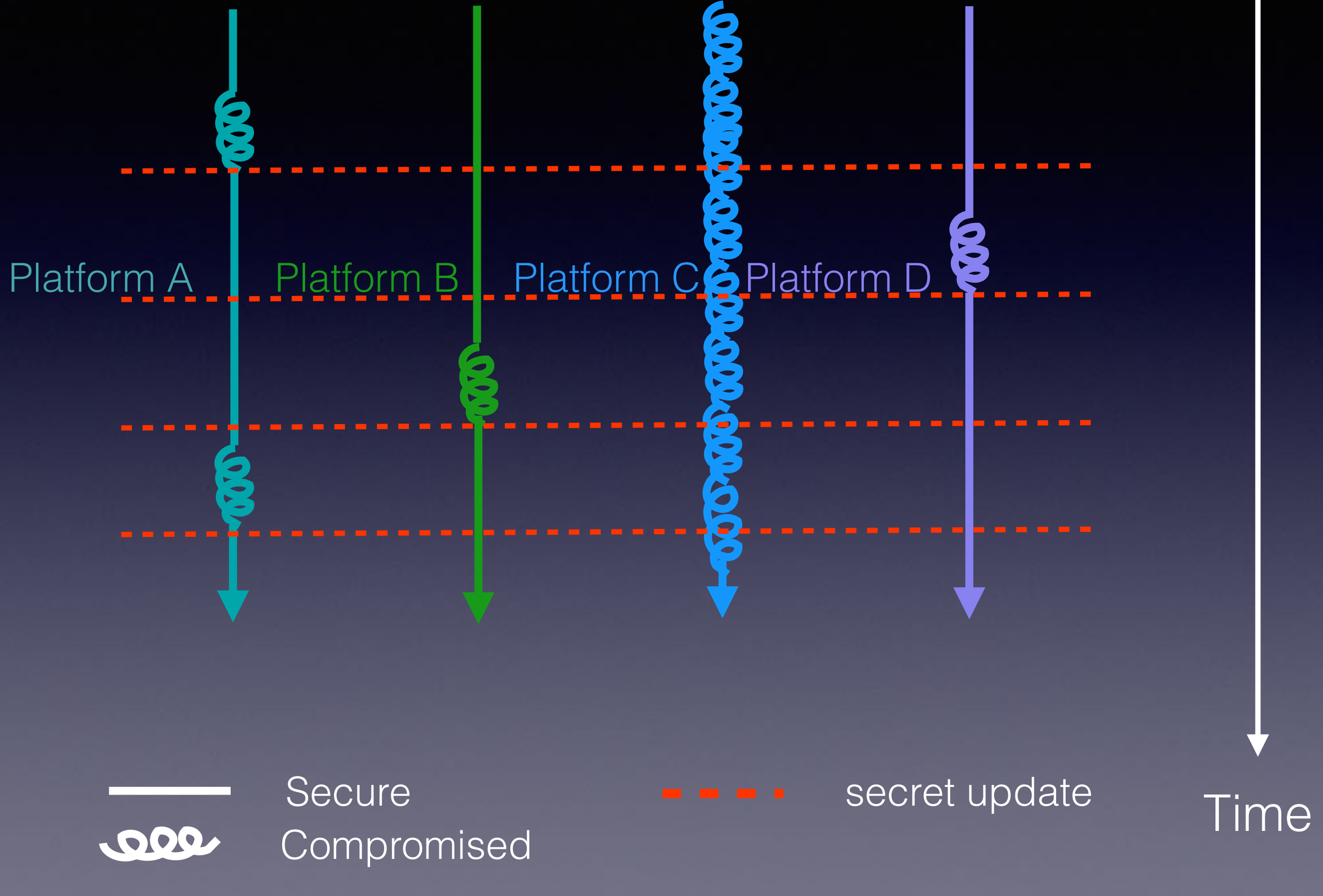

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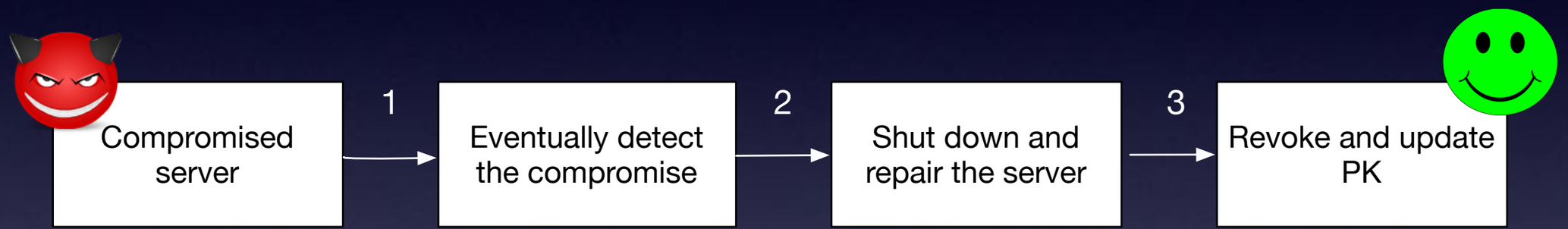

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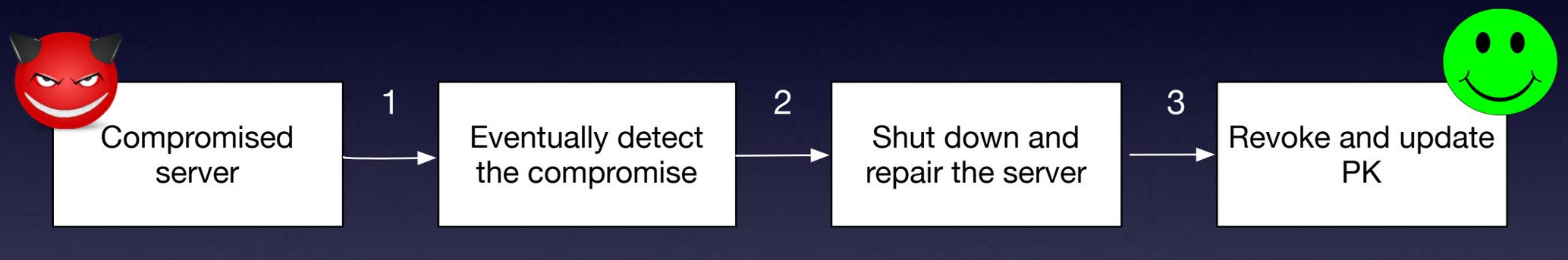

   However, PKI has its own security problem and several compromised CAs are discovered in recent years.
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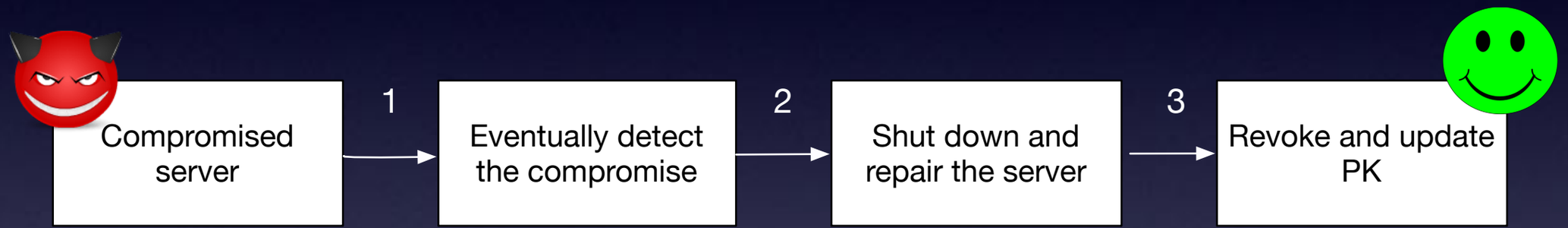

   However, PKI has its own security problem and several compromised CAs are discovered in recent years.
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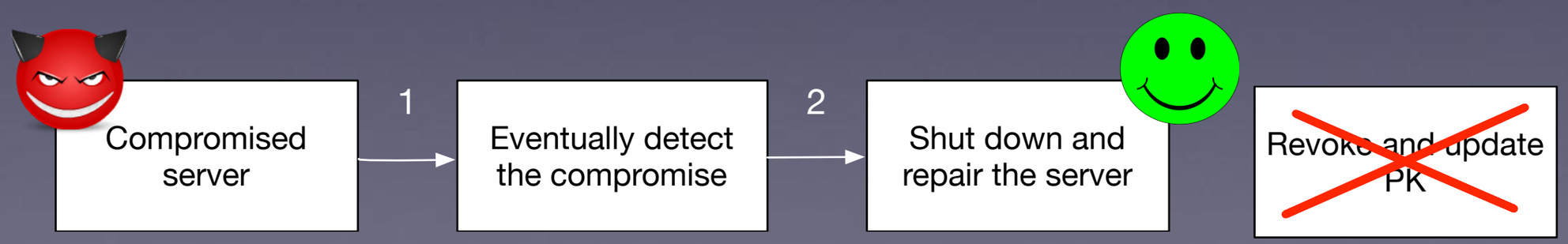
   Goal: A fixed group PK to avoid revoking and re-distributing PK



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Our solution

- A constant group public key that will not change

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2. How to update secret keys without changing the corresponding group PK?

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3. How to avoid having users' involvement in the secret update?

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- We designed a new cryptographic system based on Bilinear paring to provide these features.

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1. How to authenticate a server if the server has already been compromised?
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- We designed a new cryptographic system based on Bilinear paring to provide these features.
- We define a formal model of the system, and provide formal security proofs.

Protocol (simplified)

Initialisation

G_1, G_2: groups of prime order q
$e : G_1^2 \to G_2$
$g \in G_1$ and $Z = e(g, g) \in G_2$ are random generators.

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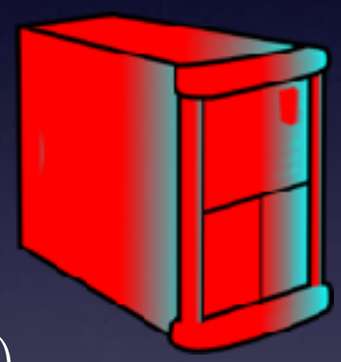
(a, g^a)

(a_1, g^{a_1})



(b, g^b)

(b_1, g^{b_1})

(c, g^c)

(c_1, g^{c_1})

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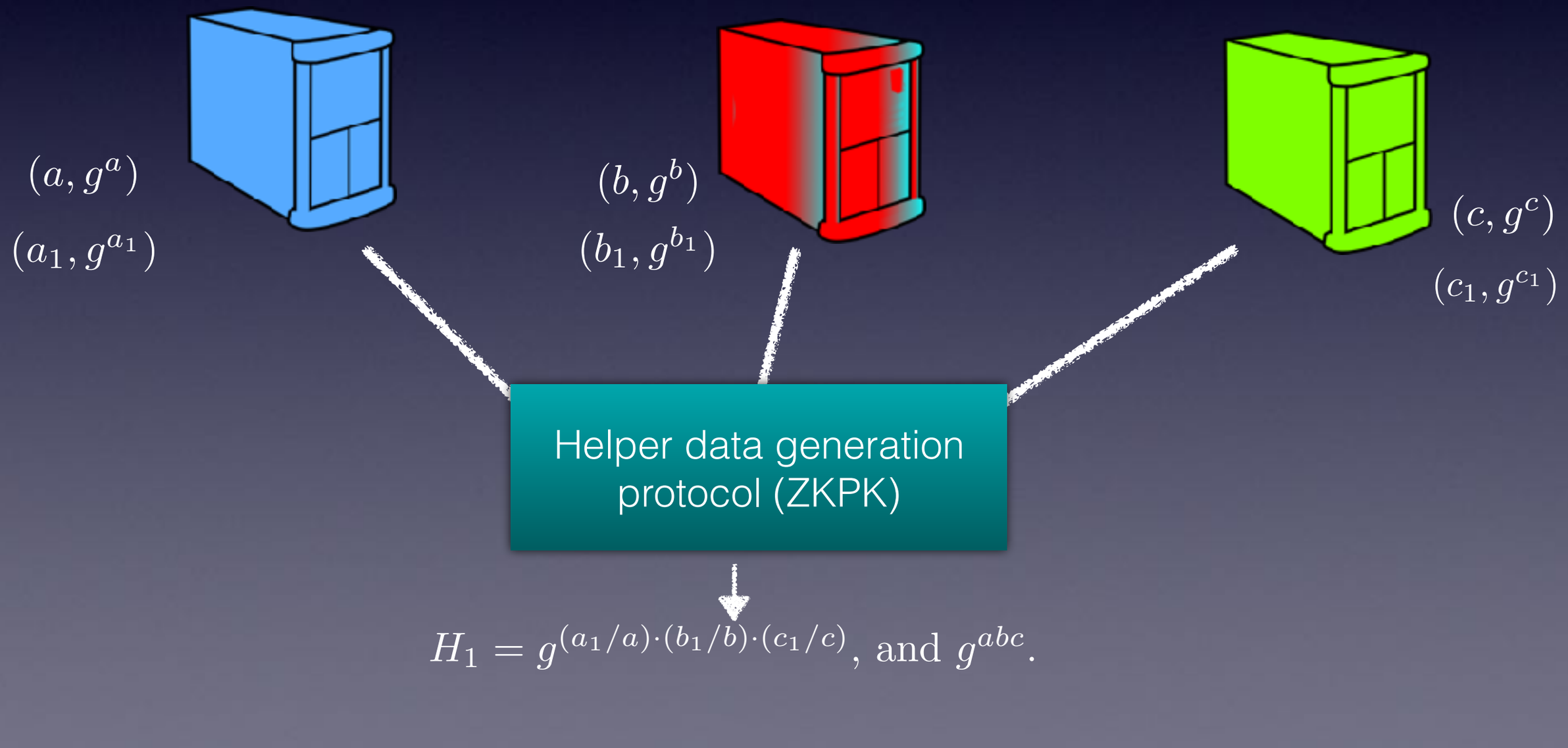

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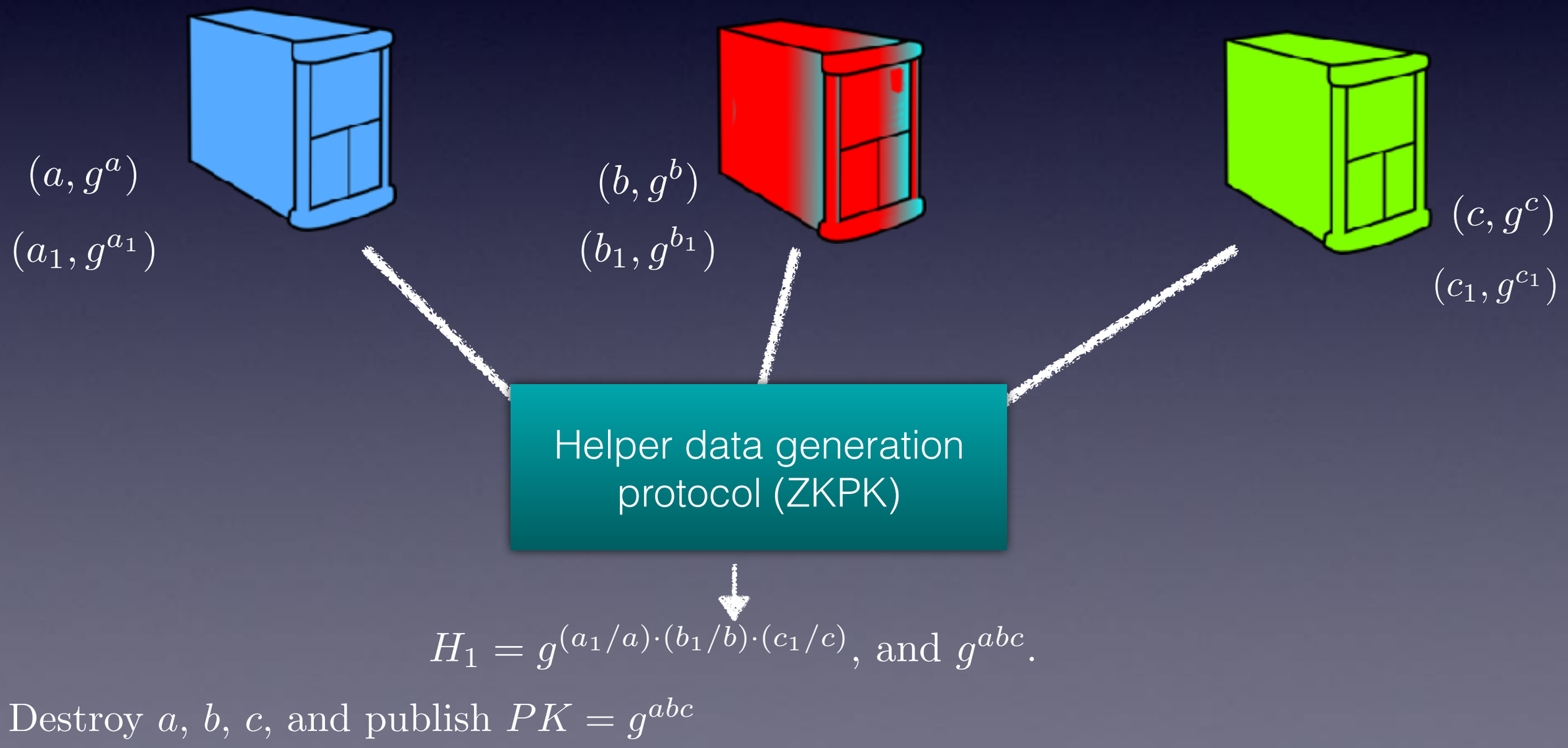
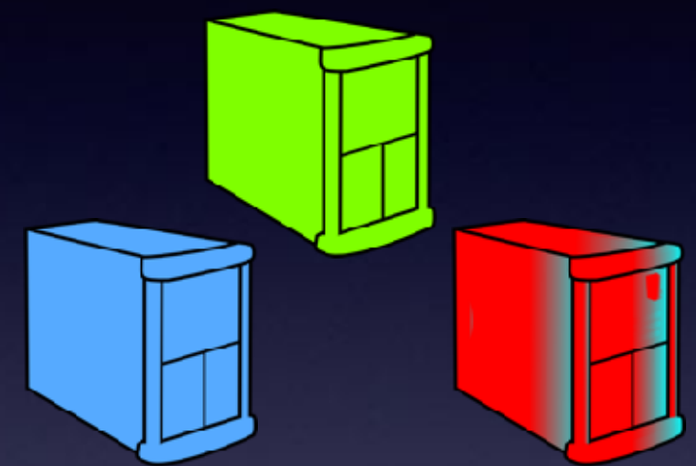


$H_1 = g^{(a_1/a)\cdot(b_1/b)\cdot(c_1/c)}$, and g^{abc}.

Destroy a, b, c, and publish $PK = g^{abc}$

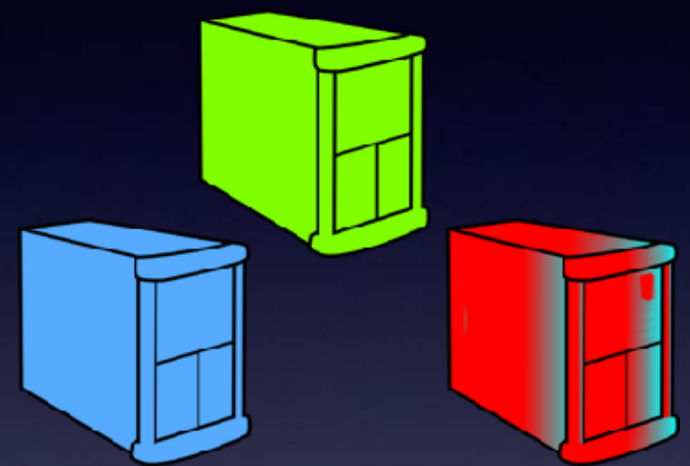
Encryption



- generate $k \in \mathbb{Z}_q$
- compute PK^k and sZ^k
- compute proof P of knowledge about k

Encryption

$(\alpha = PK^k, \beta = sZ^k, P)$



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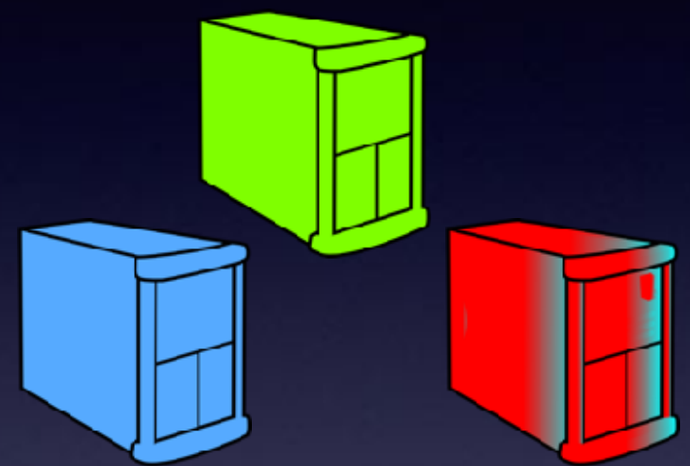

- generate $k \in \mathbb{Z}_q$
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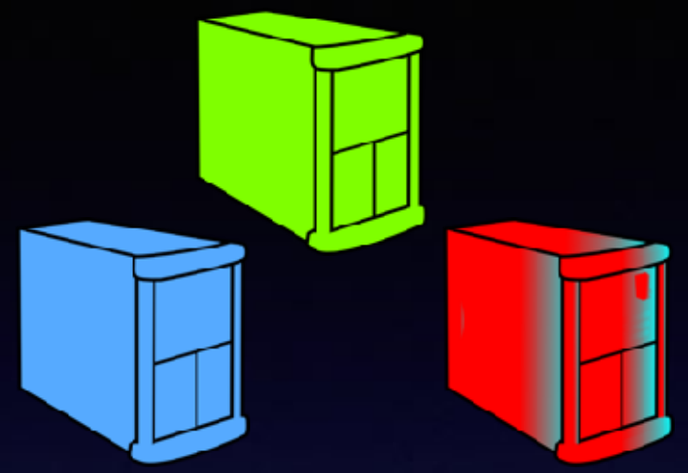
- compute proof P of knowledge about k

- verify P
- store (α, β)

Decryption

User authentication



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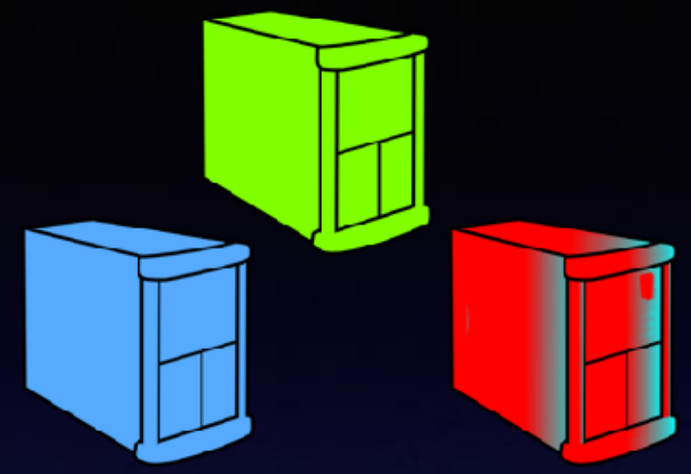

- calculate γ, s.t.

$$\gamma = e(\alpha, H_1)$$
$$= e(g^{abck}, g^{(a_1/a)\cdot(b_1/b)\cdot(c_1/c)})$$
$$= Z^{a_1 b_1 c_1 k}$$

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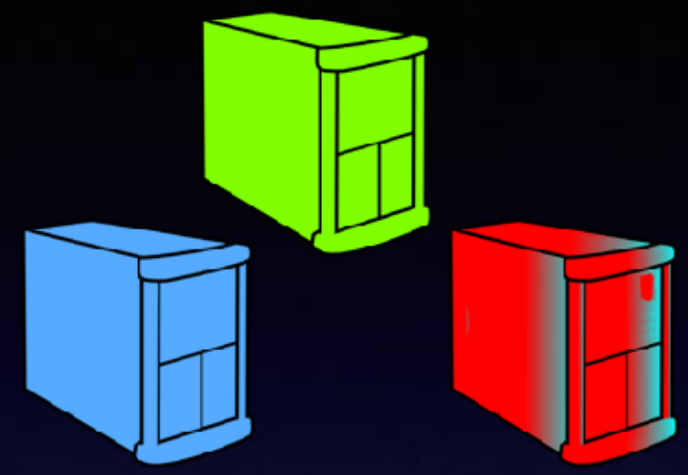
User authentication



$(\beta, \gamma) = (sZ^k, Z^{a_1 b_1 c_1 k})$

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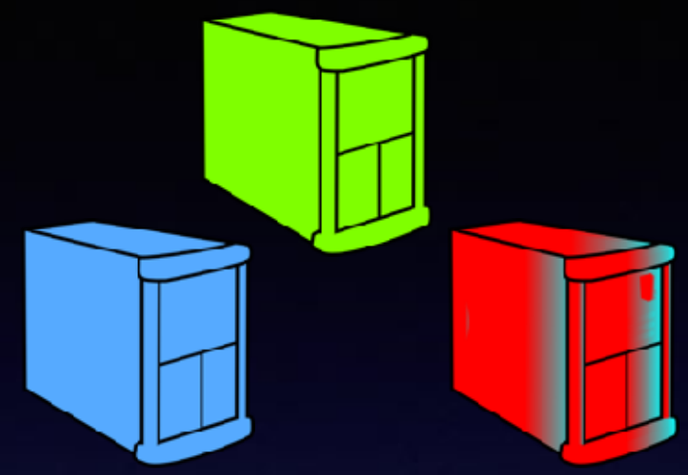

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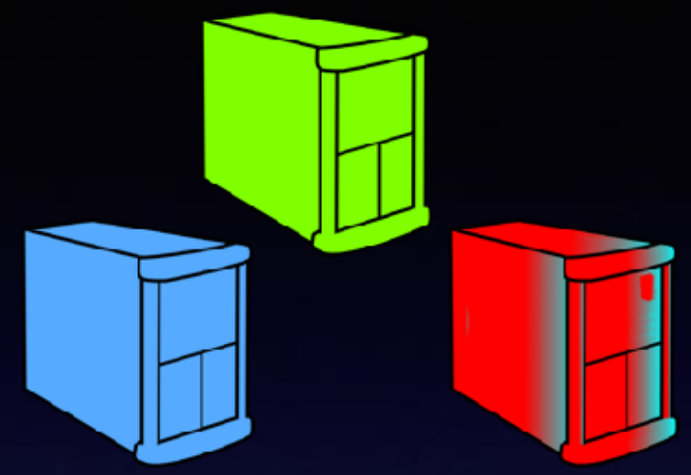

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Remove $a_1 b_1 c_1$ from the exponent

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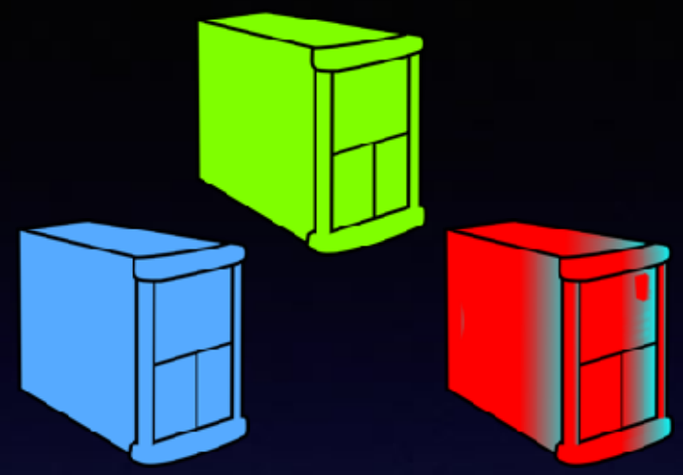

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$Z^{kk'}$

- recover Z^k
- decrypt $\beta = sZ^k$

Updating keys and ciphertext

$sk_a = a_1$, $PK = g^{abc}$
$H_1 = g^{(a_1/a)\cdot(b_1/b)\cdot(c_1/c)}$ and
a set of (α, β)

- generate a_2
- compute $H_2 = H_1^{(a_2/a_1)\cdot(b_2/b_1)\cdot(c_2/c_1)} = g^{(a_2/a)\cdot(b_2/b)\cdot(c_2/c)}$ with other servers
- destroy old a_1
- replace H_1 by using H_2

*No need to update any ciphertext.

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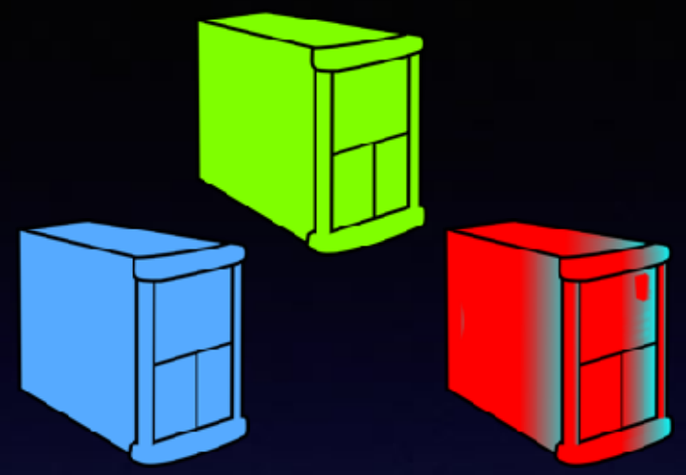

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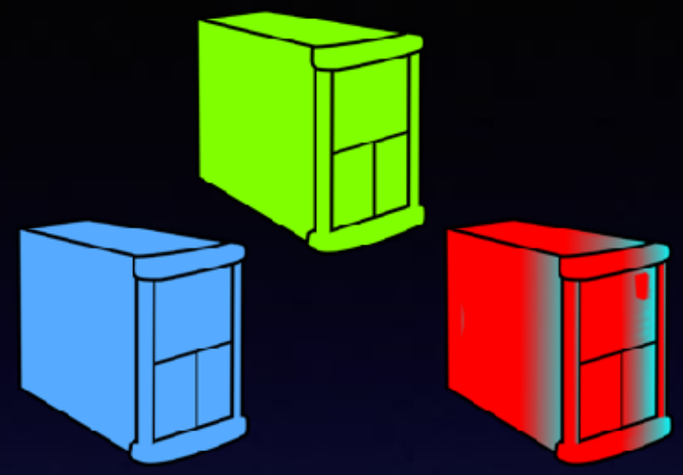

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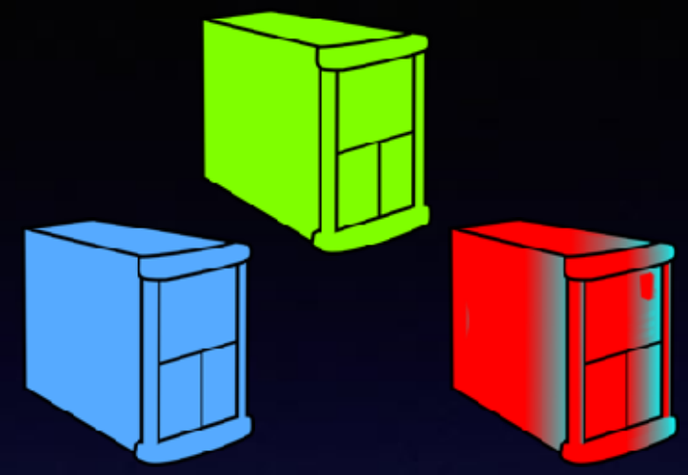

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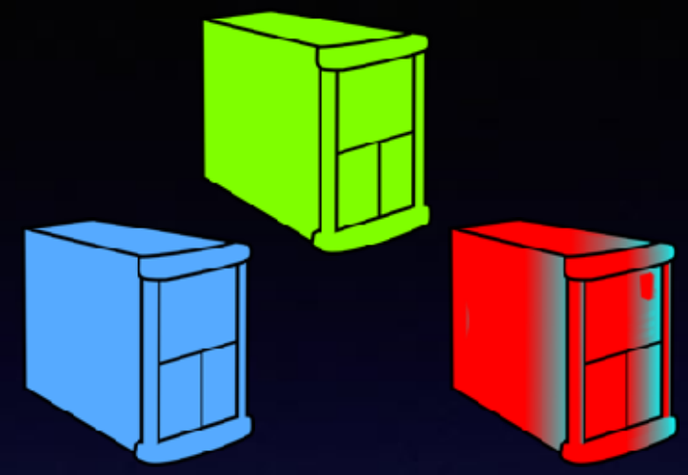

$(\beta, \gamma) = (sZ^k, Z^{a_1 b_1 c_1 k})$

- calculate γ, s.t.

$$\begin{aligned}\gamma &= e(\alpha, H_1) \\ &= e(g^{abck}, g^{(a_1/a)\cdot(b_1/b)\cdot(c_1/c)}) \\ &= Z^{a_1 b_1 c_1 k}\end{aligned}$$

- generate $k' \in \mathbb{Z}_q$
- computes $\gamma^{k'} = Z^{a_1 b_1 c_1 k k'}$

$\gamma^{k'} = Z^{a_2 b_2 c_2 k k'}$

$\gamma = e(\alpha, H_2)$

$= e(g^{abck}, g^{(a_2/a)(b_2/b)(c_2/c)})$

$= Z^{a_2 b_2 c_2 k}$

$\gamma^{k'}$

$Z^{kk'}$

Remove $a_1 b_1 c_1$ from the exponent

$a_2 b_2 c_2$

- recover Z^k
- decrypt $\beta = sZ^k$

Recap:

- A scheme to update secret keys without changing the group PK
- For each update, the ciphertext remains the same
- No-user involvement in the key update process

Thanks!