Revoke and Let Live

A Secure Key Revocation API for Cryptographic Devices

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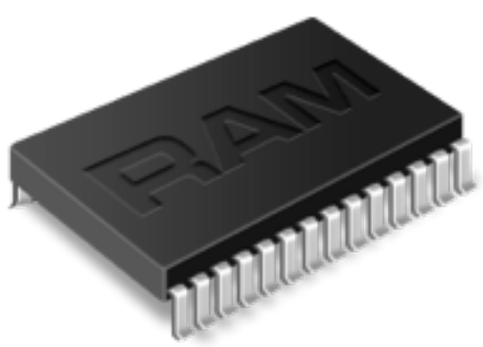
LORIA-CNRS, Nancy (FR)

June 28th, 2012

Security APIs

Trusted devices



Host machines

Security API

Goal : Enforce security of data stored inside the trusted device, even when connected to untrusted host machines.

Applications

- Smartphones,

- Bank Accounts,

- Electronic Ticketing Systems (e.g. Calypso),

- Vehicle-to-vehicle networking.

- ...

How does it work ?

Host machine

Trusted device

h_1	
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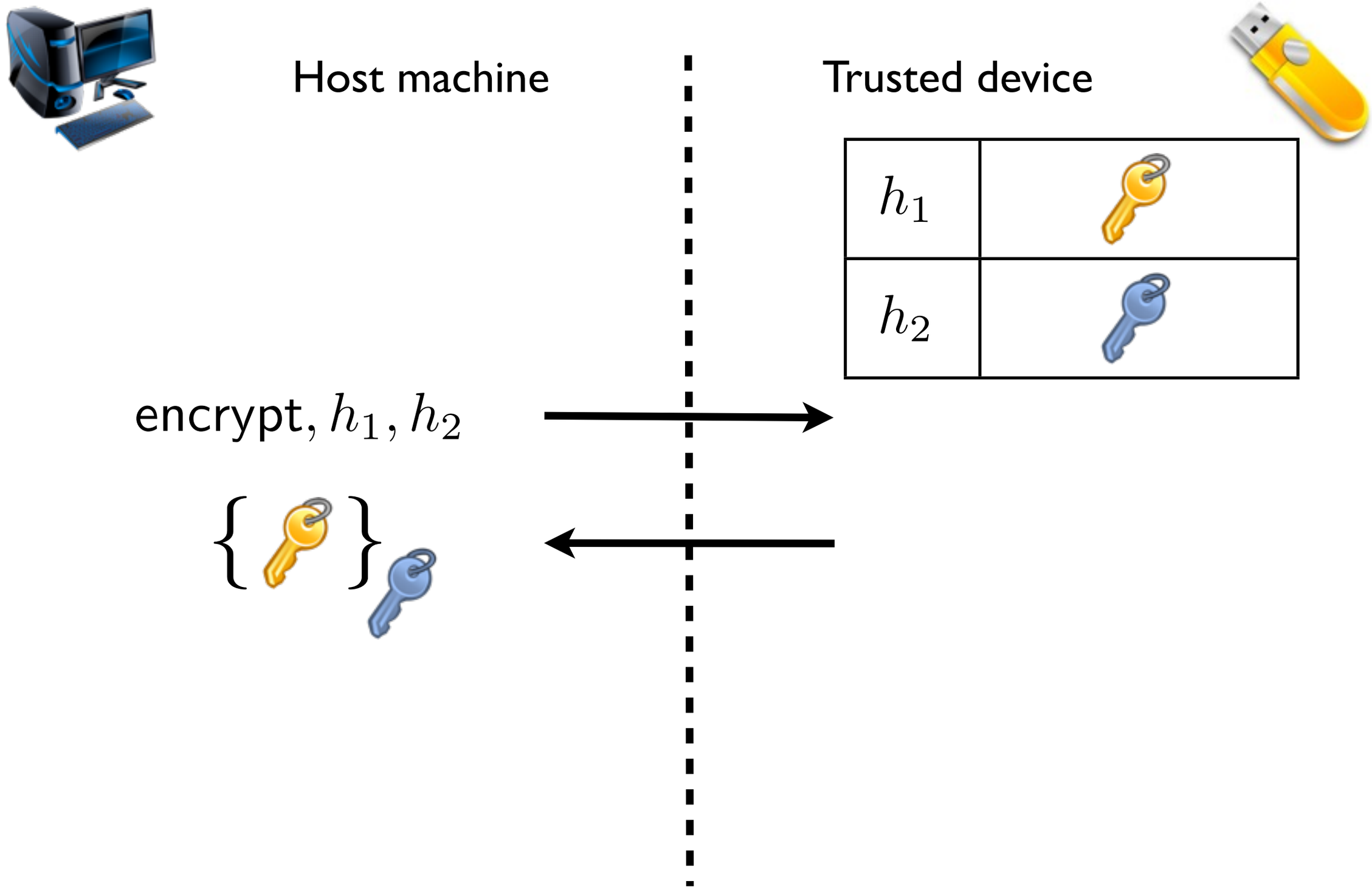

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h_3	

Related Work

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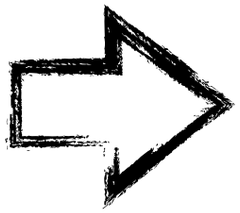

Use of long-term keys implying unrecoverable loss of devices if keys are lost

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⇨ **Attacked** by S. Möderschein & P. Modesti (solution proposed but not verified)

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The device should remain **functional** :

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Keys must remains **confidential** :

Information about key should not be recovered by the intruder.

Breaking keys in a TRD

There are ways for the attacker to **break some keys** of a Tamper-Resistant Device (TRD):

- Bruteforcing,
- Side-channel attack,
- ...

Our Contributions

- **Design** of an API satisfying previous properties with :
  - **update** functionality,
  - **revocation** functionality.

- A **formal proof of security** ensuring three properties :
  - Except is a **key** is lost then it **remains secret**,
  - the system is able to **recover itself** from a loss,
  - a **revocation immediately secures** the device.

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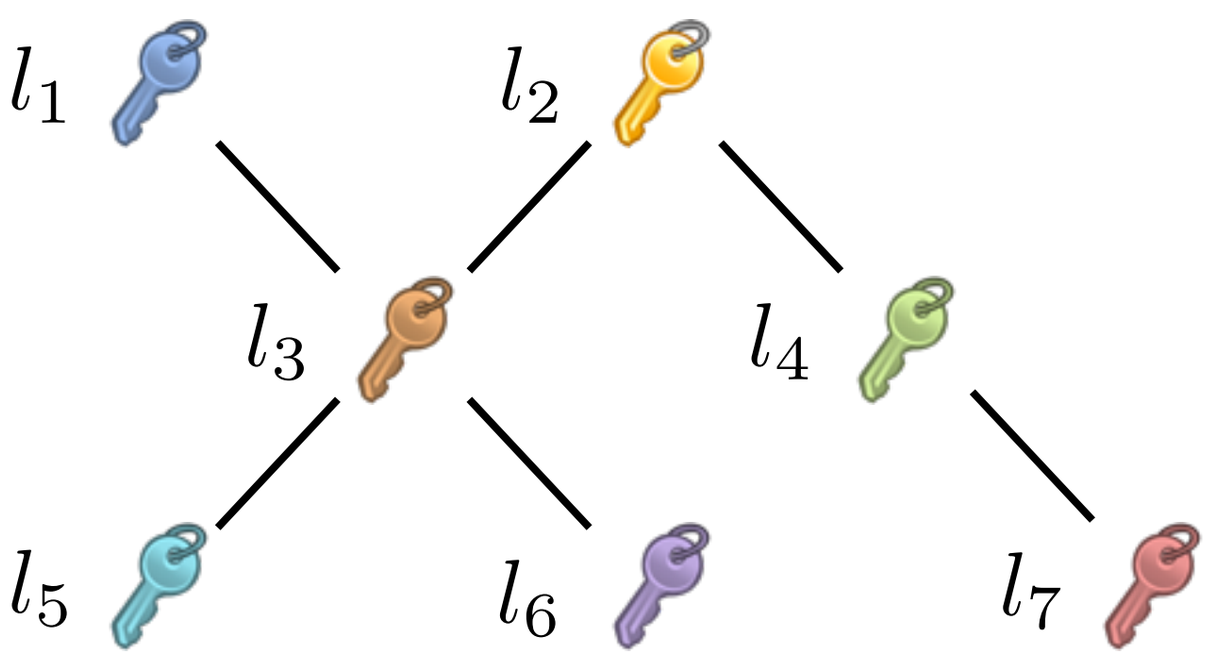

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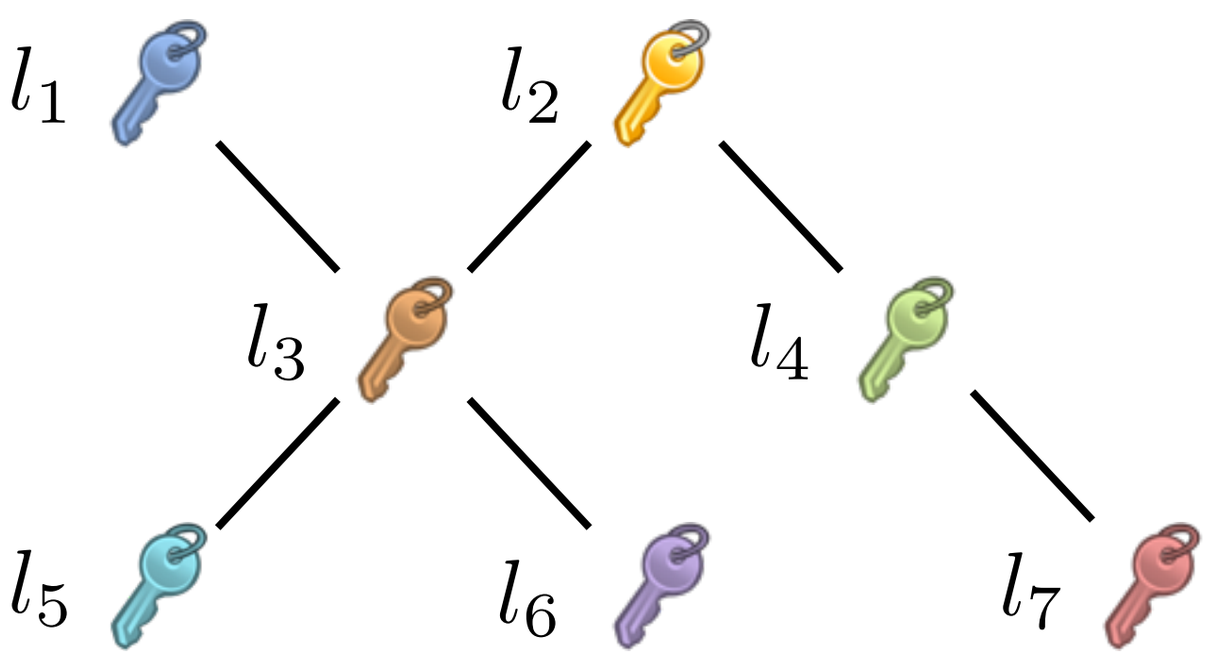

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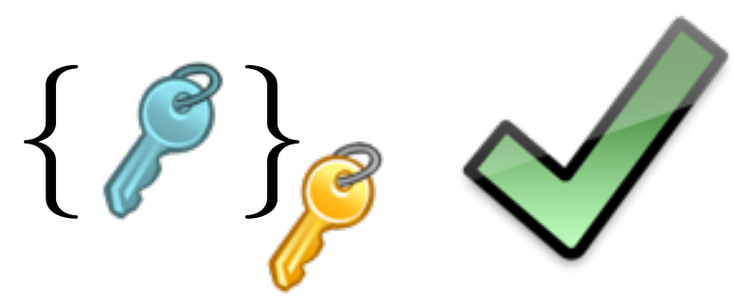

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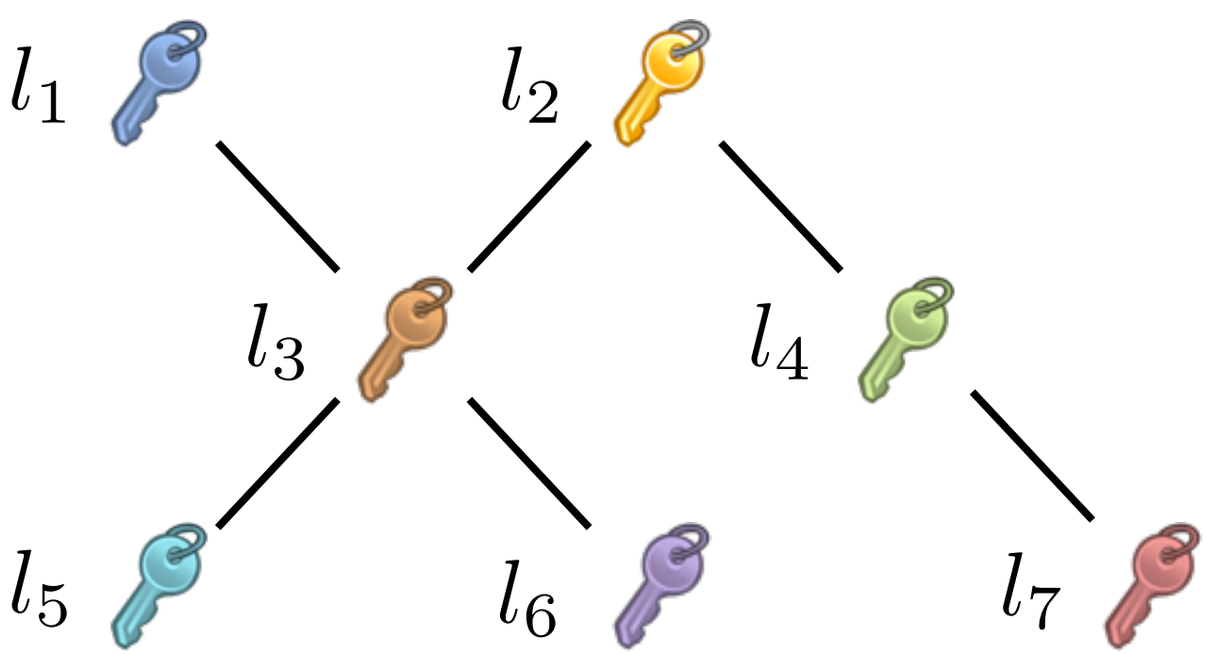

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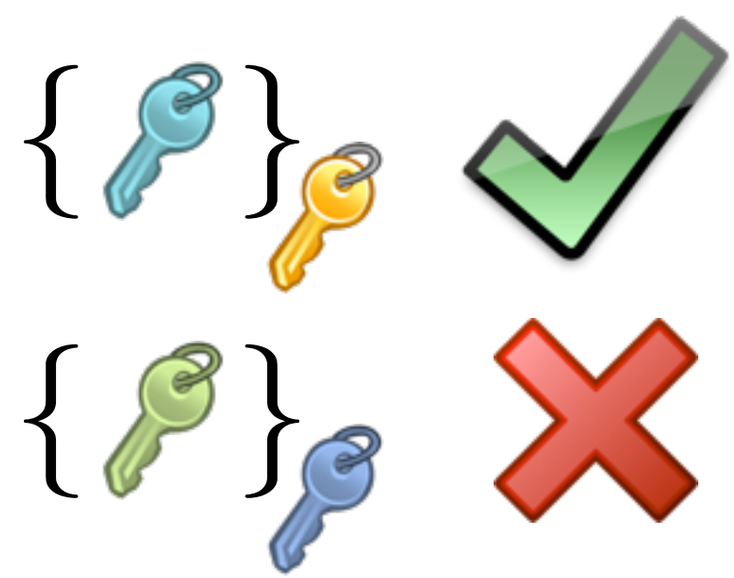

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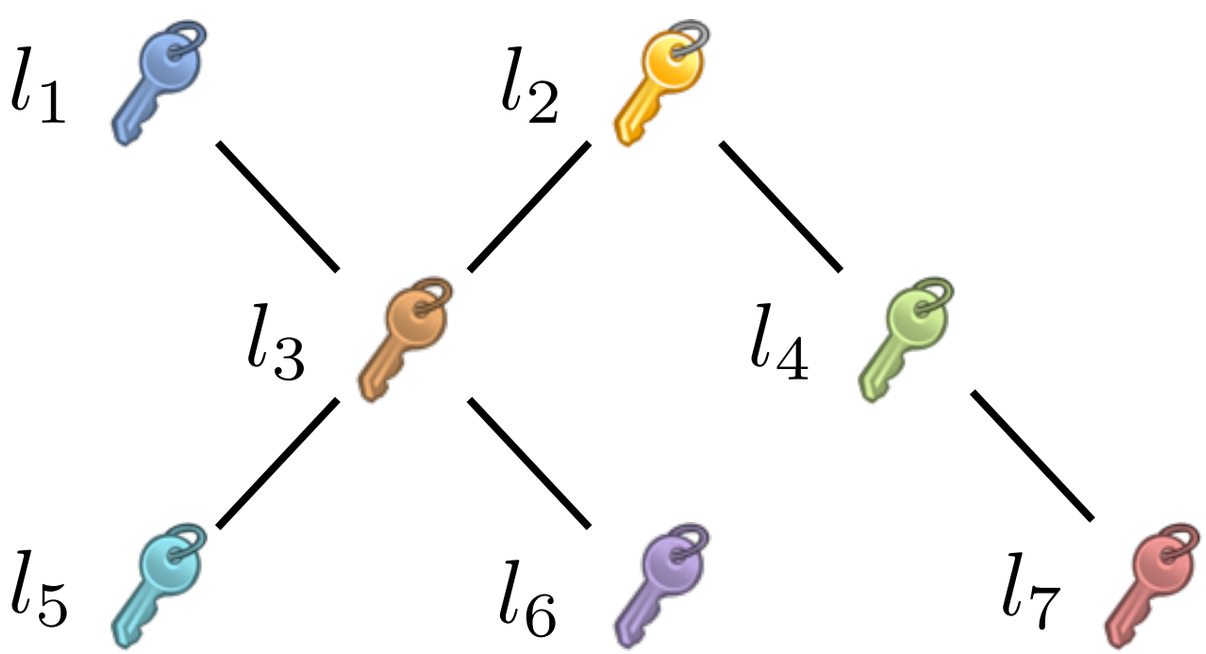

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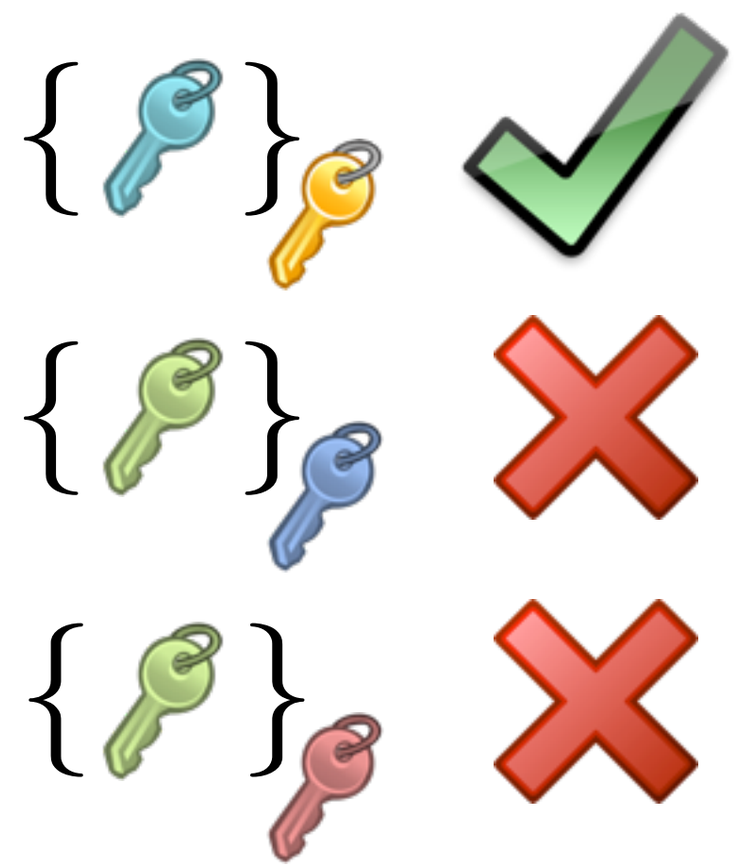

$l_4 \not< l_1$

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User's Commands

A set of **basic commands** :

$\mathsf{generatePublic}(m)$

$\mathsf{generateSecret}(l, m)$

Store in a handle of the TRD, a generate nonce or key, the level and m.

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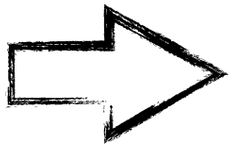
$\mathsf{encrypt}(\langle X_1, \ldots, X_n\rangle, h)$

$X_i = h_i$ or $X_i = n_i$



$\{Y_1, \ldots, Y_n\}$ 

Lower Level Keys Management

update$(C, h_1, \ldots, h_n)$

h_1	 , Max, v_1
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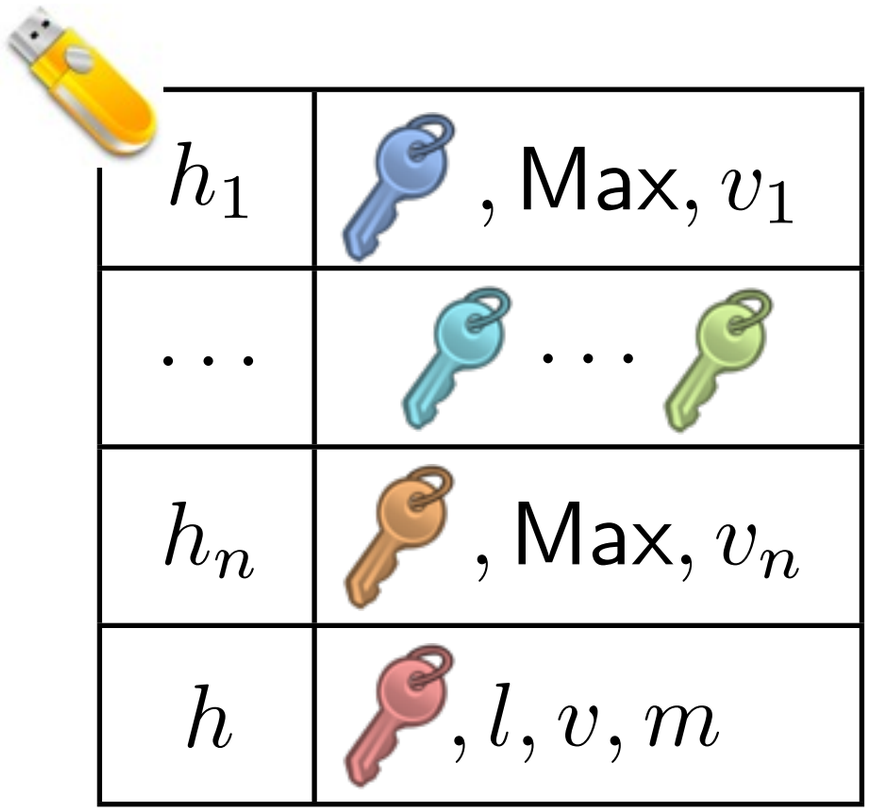

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Since revocation keys are sensitive, we allow the admin to update them...

$\{\text{updateMax}, \text{🔑}, \text{🔑}, v\}_{\text{🔑}\ldots\text{🔑}}$

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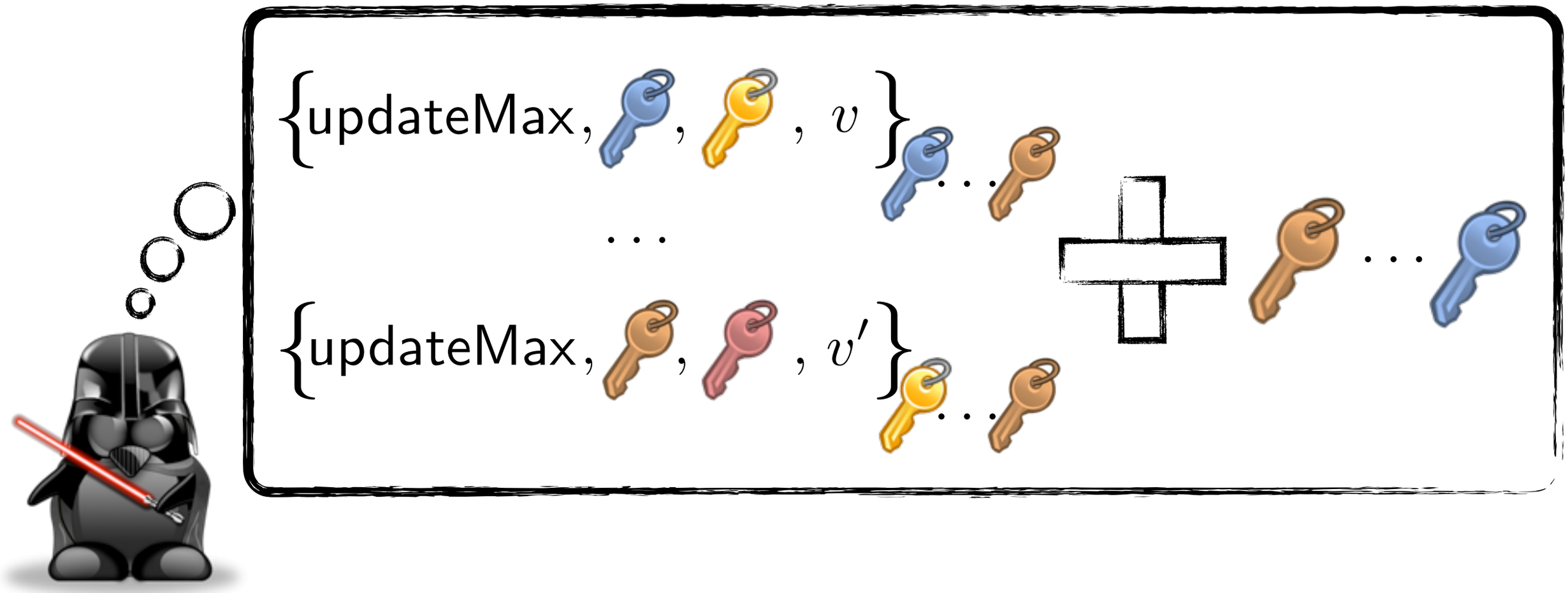

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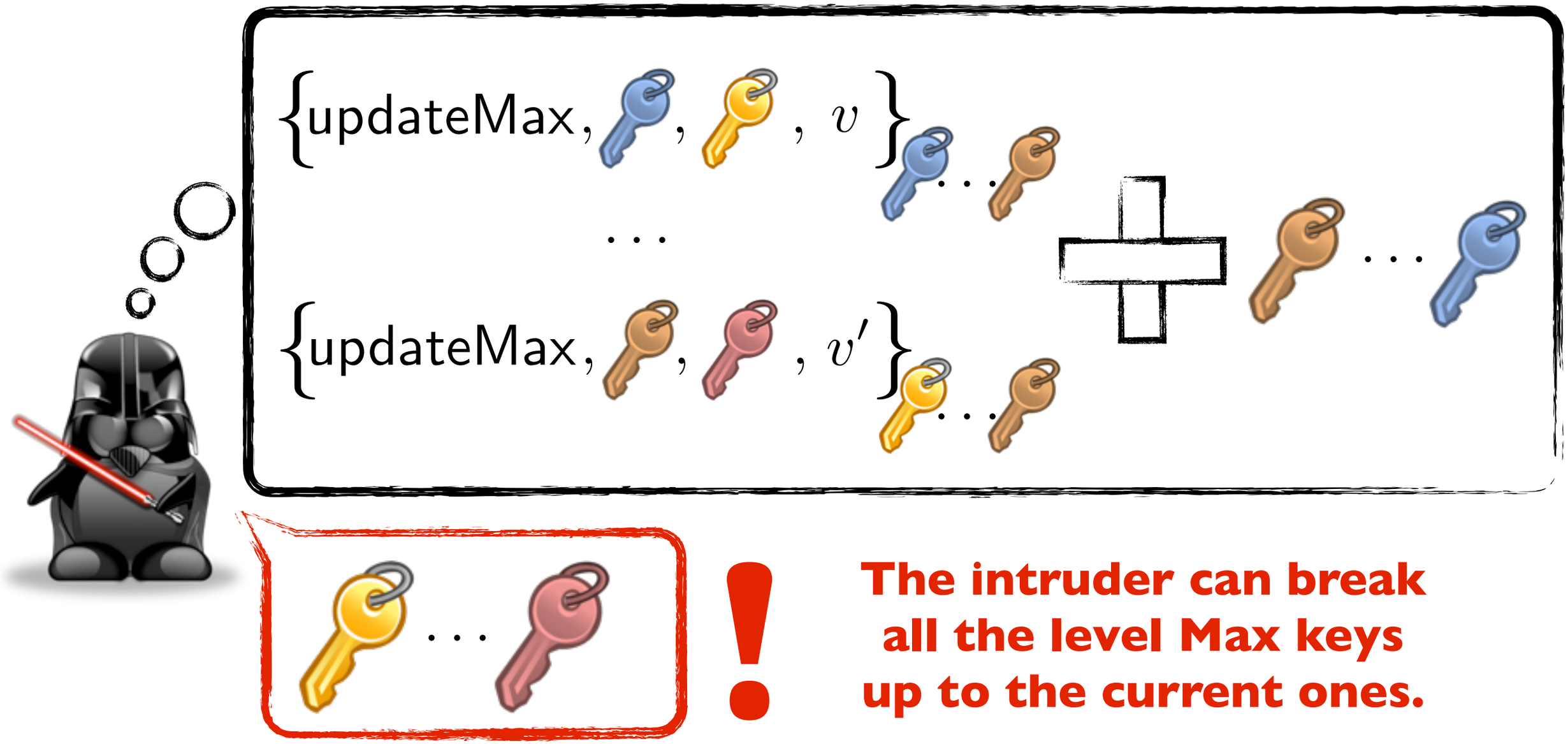

The intruder can break all the level Max keys up to the current ones.

Revocation Keys Management

Hypothesis :

Level Max commands are sent over a secure channel.

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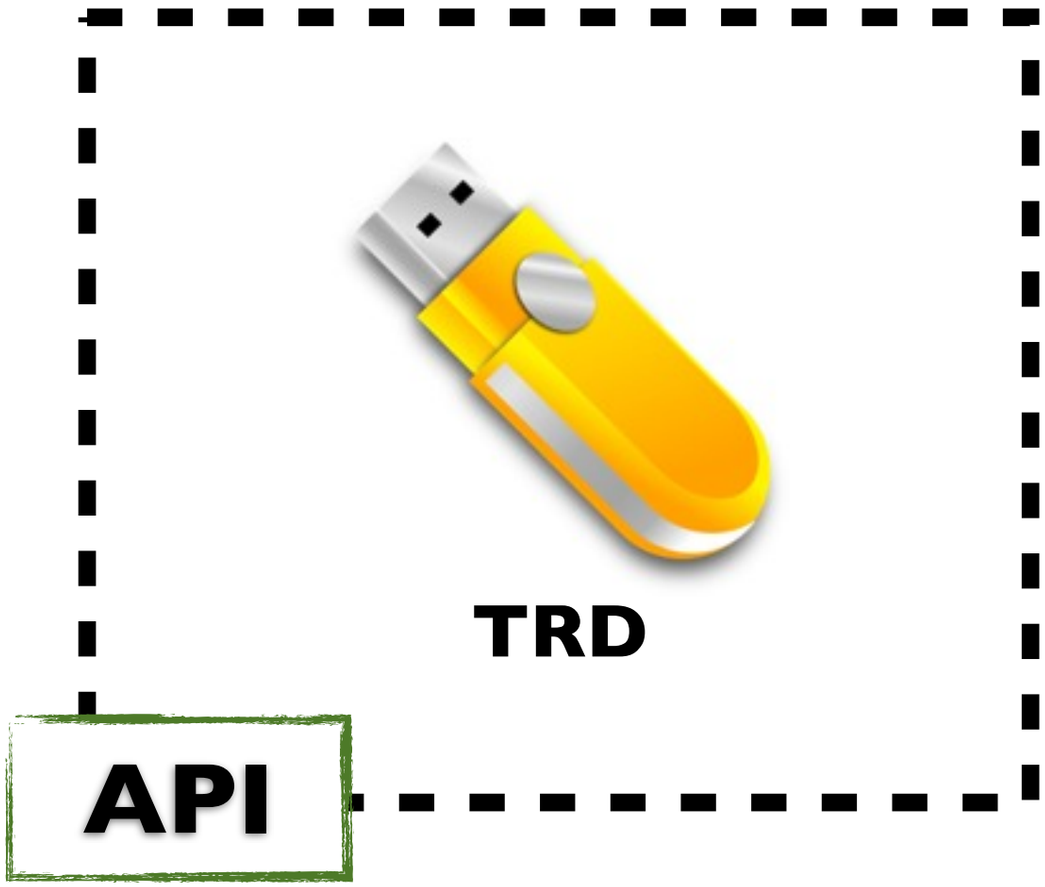
This can be achieved by several means :

- The administrator has a physical access to the TRD that needs to be updated,

- The user would connect his/her TRD to a trusted machine, on which a secure channel (e.g. via TLS) is established with the key administrator.

And now, what about Security ?



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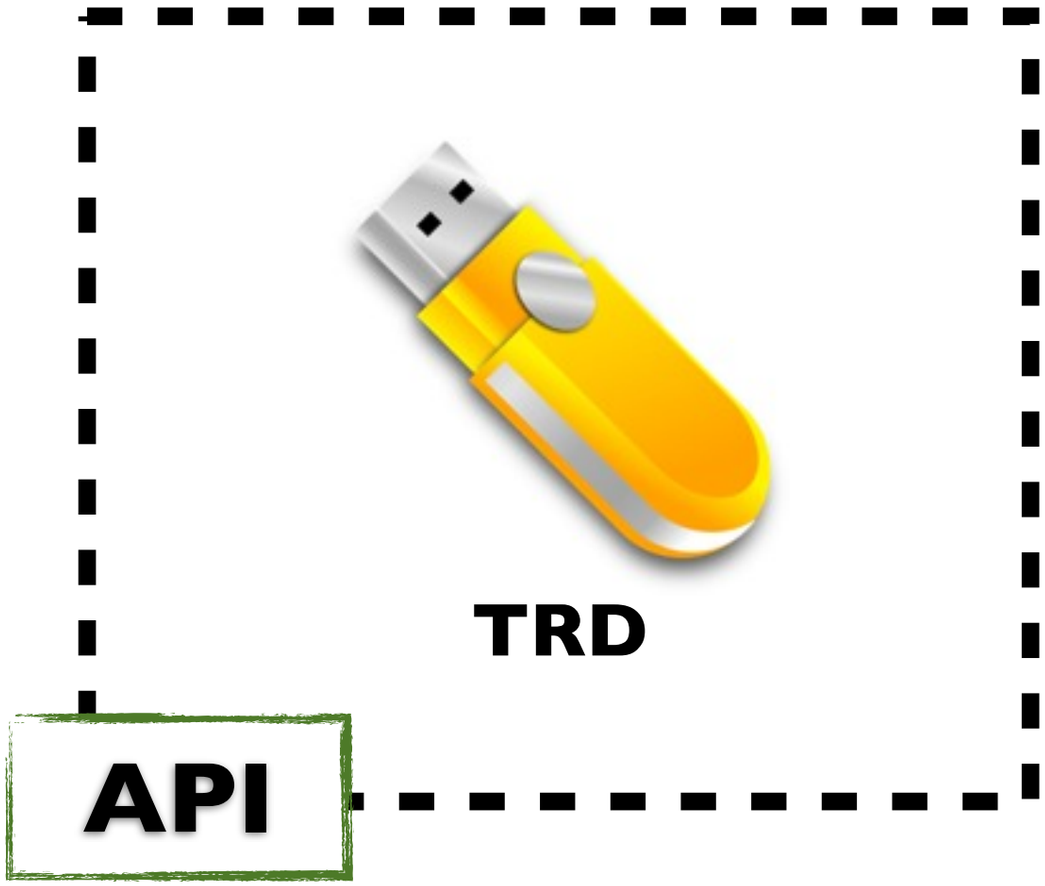

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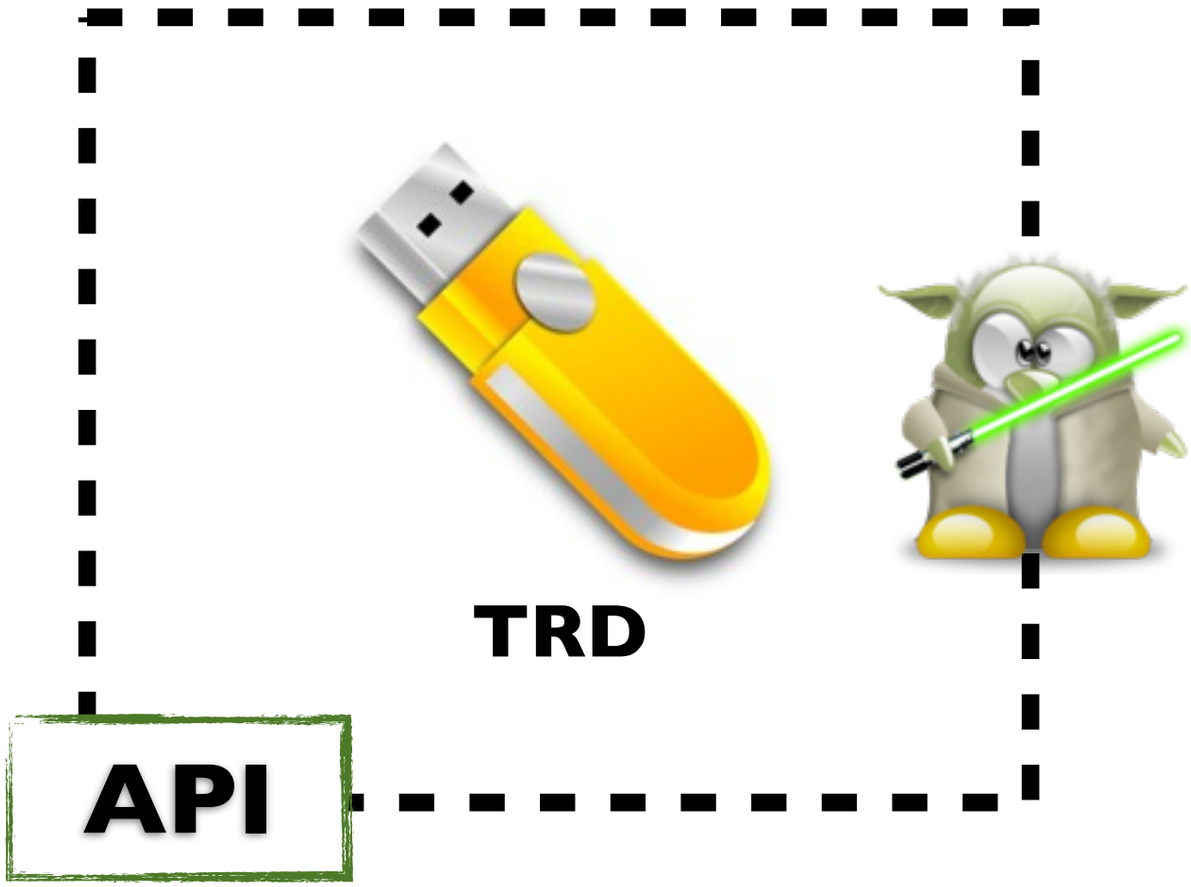


Abstraction

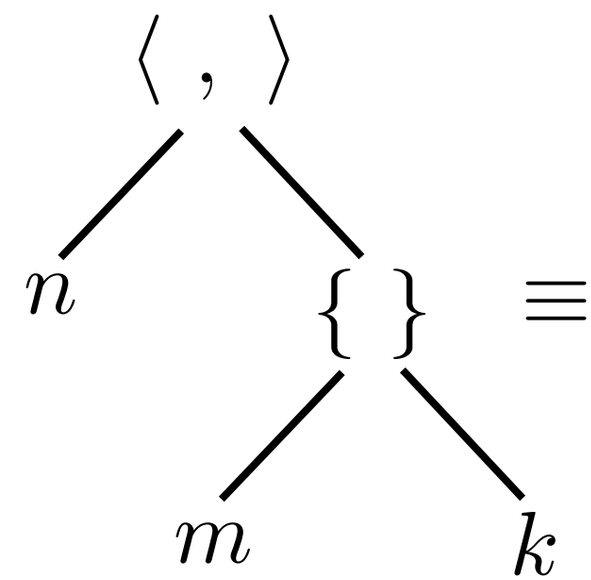
Messages are represented by **terms**

Nonces, keys :

$$n, m, \ldots, k_1, k_2, \ldots$$

Primitives :

$$\{m\}_k, \ \langle m_1, m_2 \rangle, \ldots$$

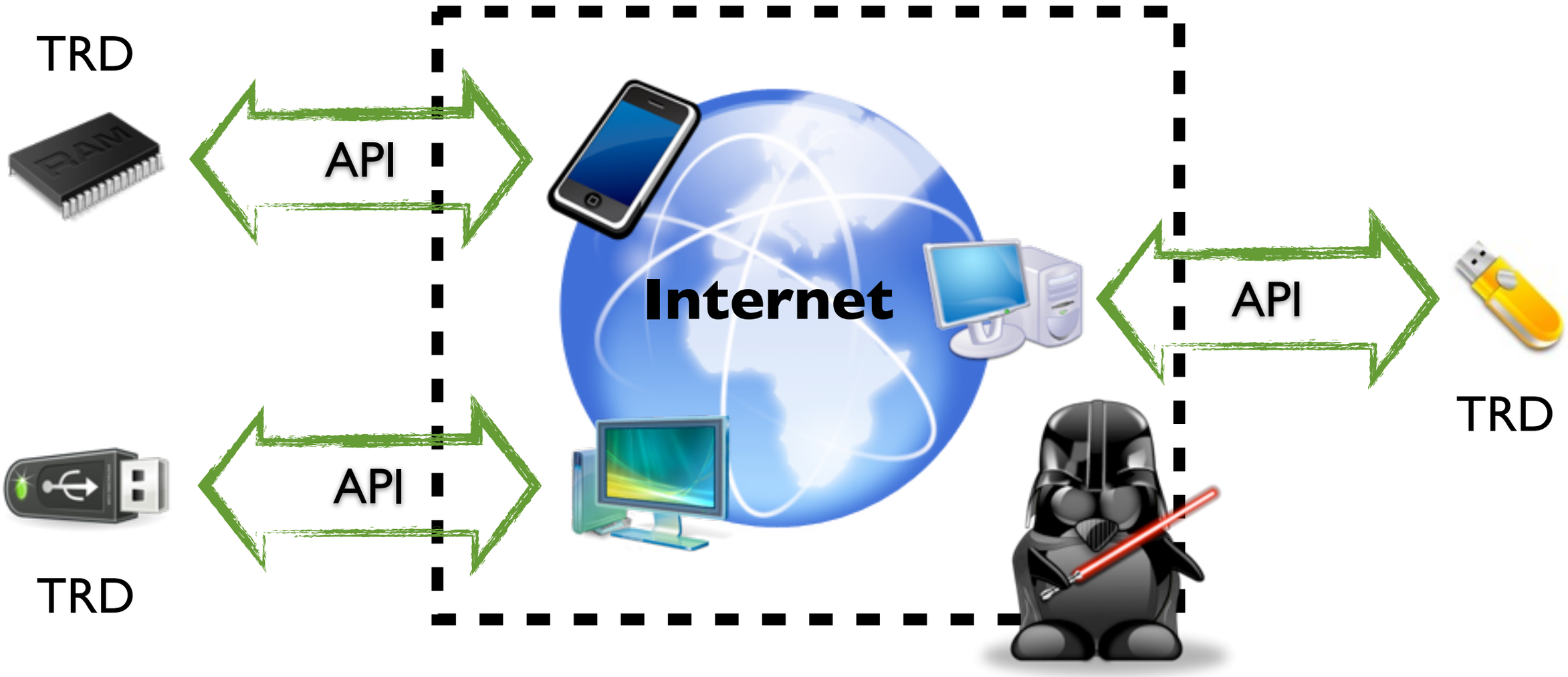


$$\equiv \langle n, \{m\}_k \rangle$$

Modeling deduction rules :

$$\frac{x \quad y}{\langle x, y \rangle} \qquad \frac{\langle x, y \rangle}{x} \qquad \frac{\langle x, y \rangle}{y} \qquad \frac{x \quad y}{\{x\}_y} \qquad \frac{\{x\}_y \quad y}{x}$$

Knowledge of the Intruder



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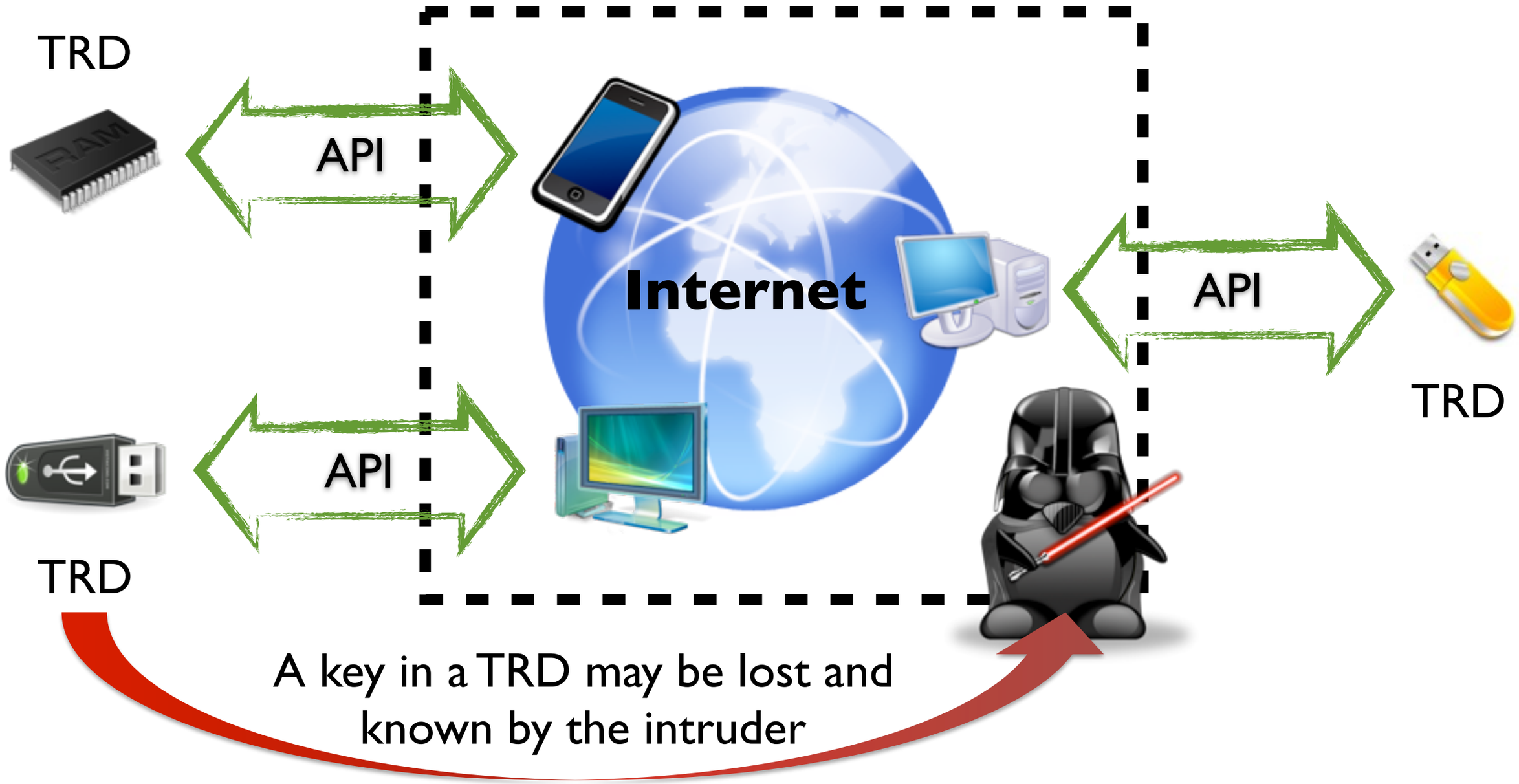

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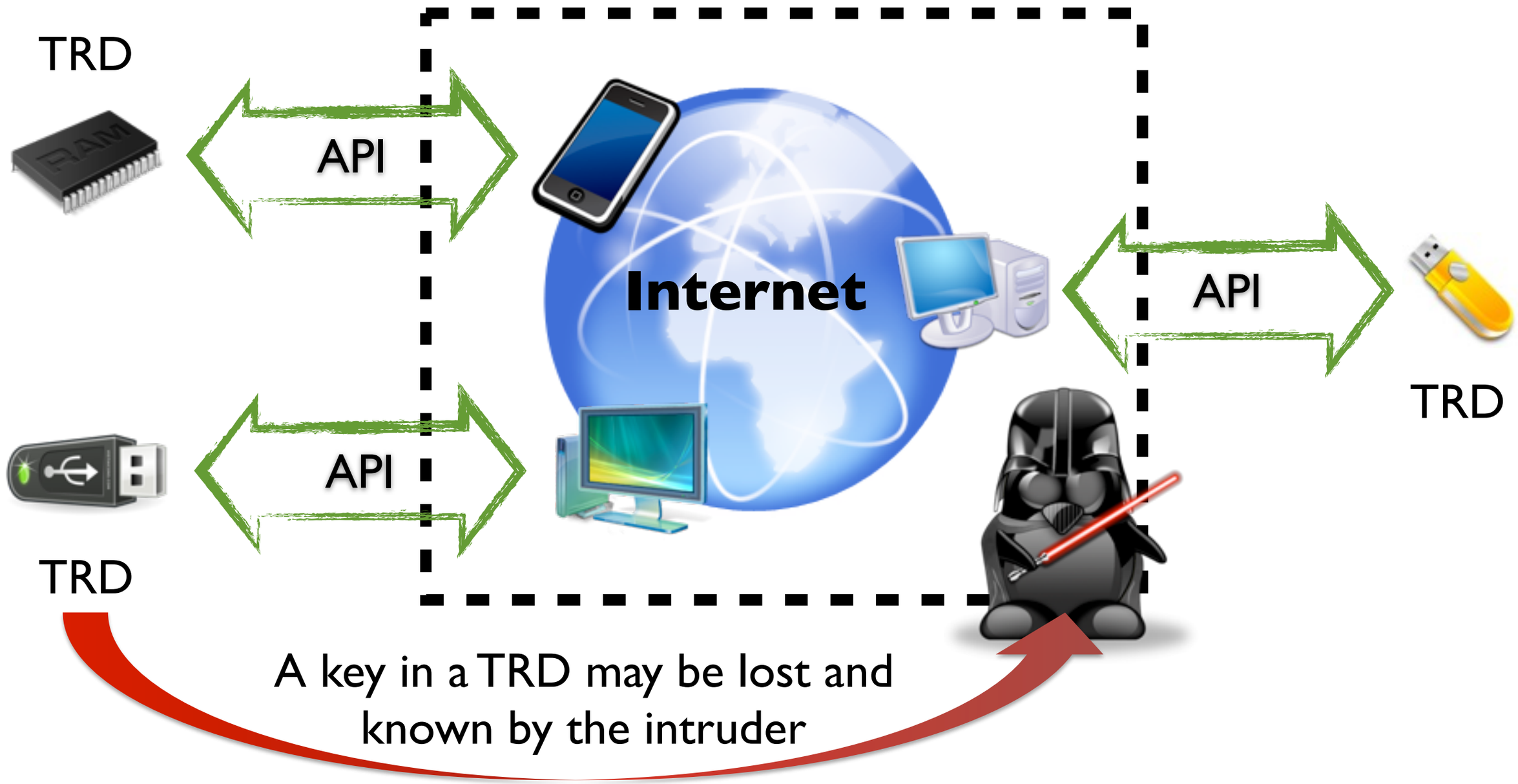
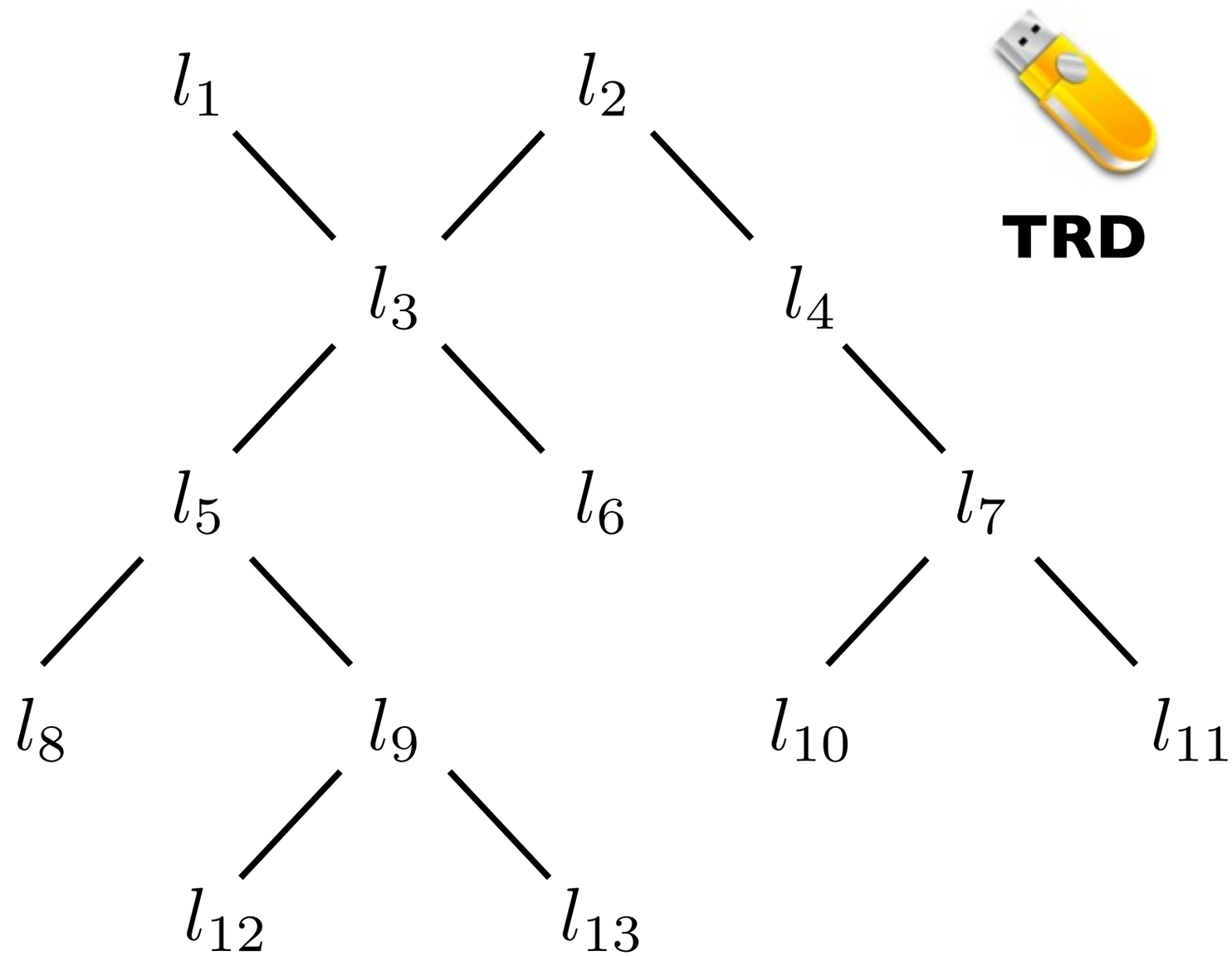


Hypothesis : Only a total of $N_{\text{Max}} - 1$ different « current » level Max keys for one TRD can be lost.

What about lost levels ?



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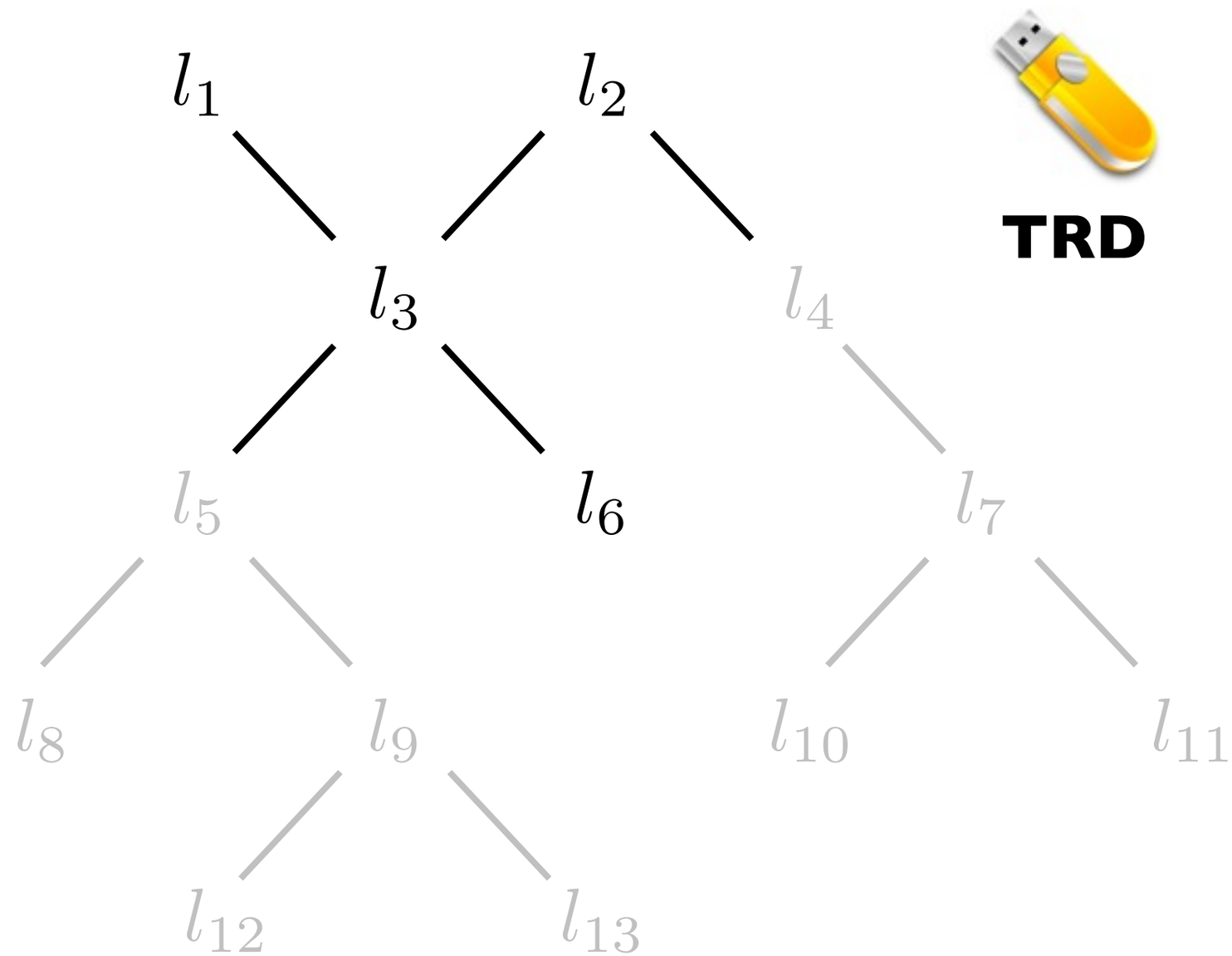
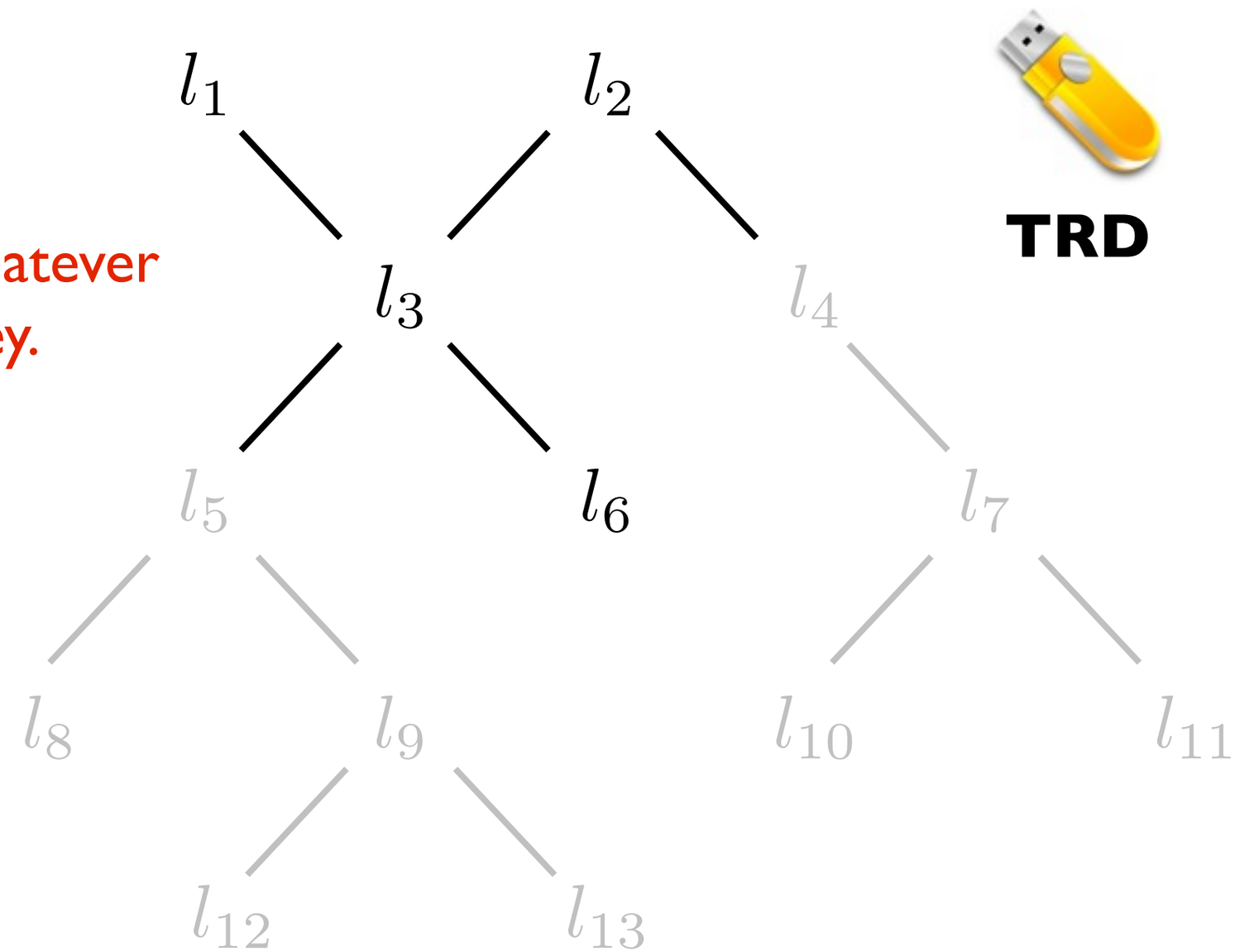


What about lost levels ?

The intruder has control over whatever is under a level with a lost key.



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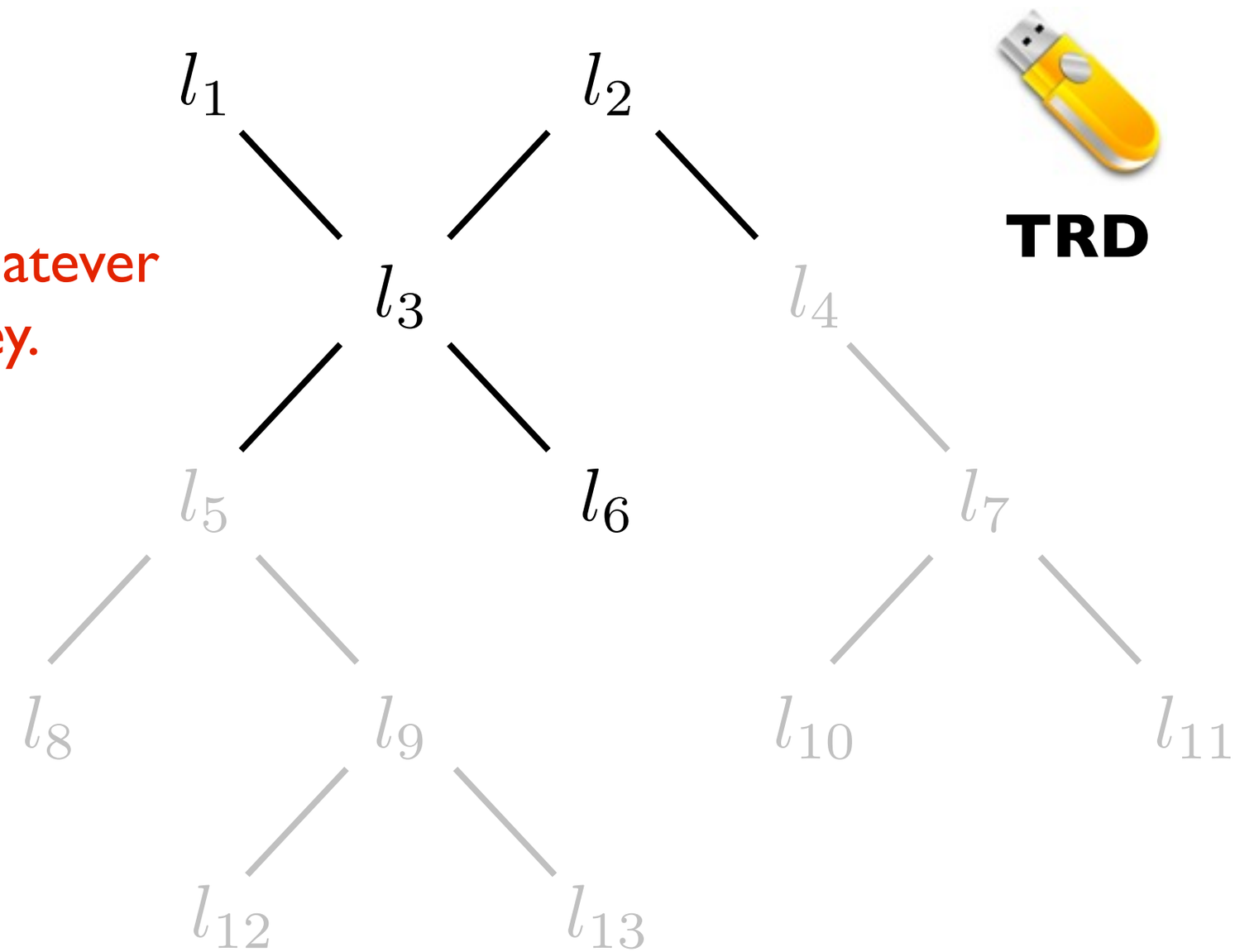

It may use a encrypt command to **get a key** with a lower level in a TRD containing a lost key.

Ex : Obtaining $\{\langle$  $, l_9, v, m\rangle\}$  with  lost and of level l_5 .

Secrecy Result

«I keep my secrets secret !»

Even if the **intruder** may :

- **control the network** and host machines,
- **break some keys** (but not too many revocation keys),

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We have :

Theorem

Keys remains **secret** (not deducible) provided :

- A **valid expiration date**,
- They're **not « under a lost »**.

Self Repair Property

«It's just a flesh wound !»

Theorem (Stated for one level)

Assume that all keys are secret at time t except those under a level l.

Then at time $t + \Delta(l)$, all keys are secret except those under levels $l_1, \ldots, l_n$ such that $l_i < l$.

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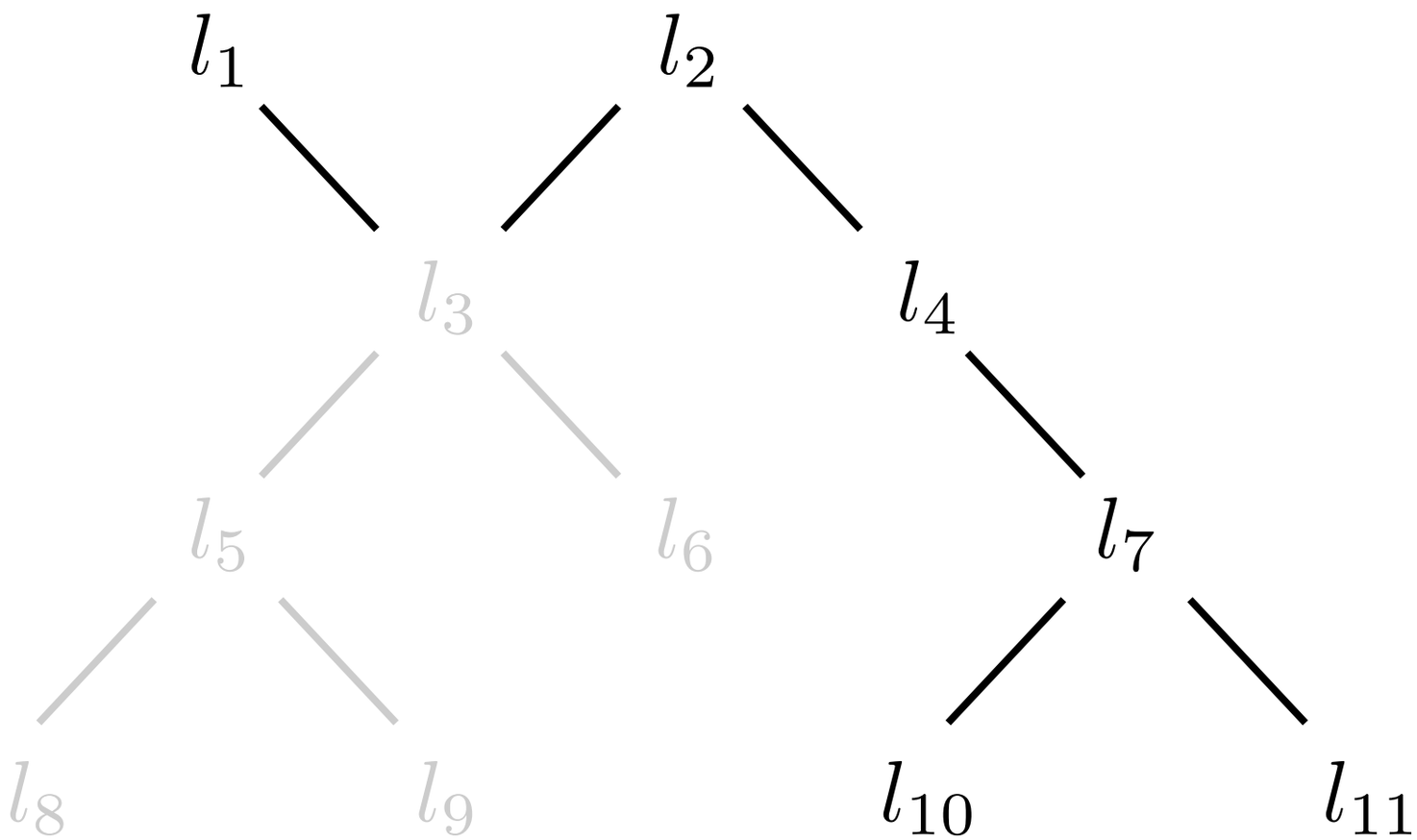

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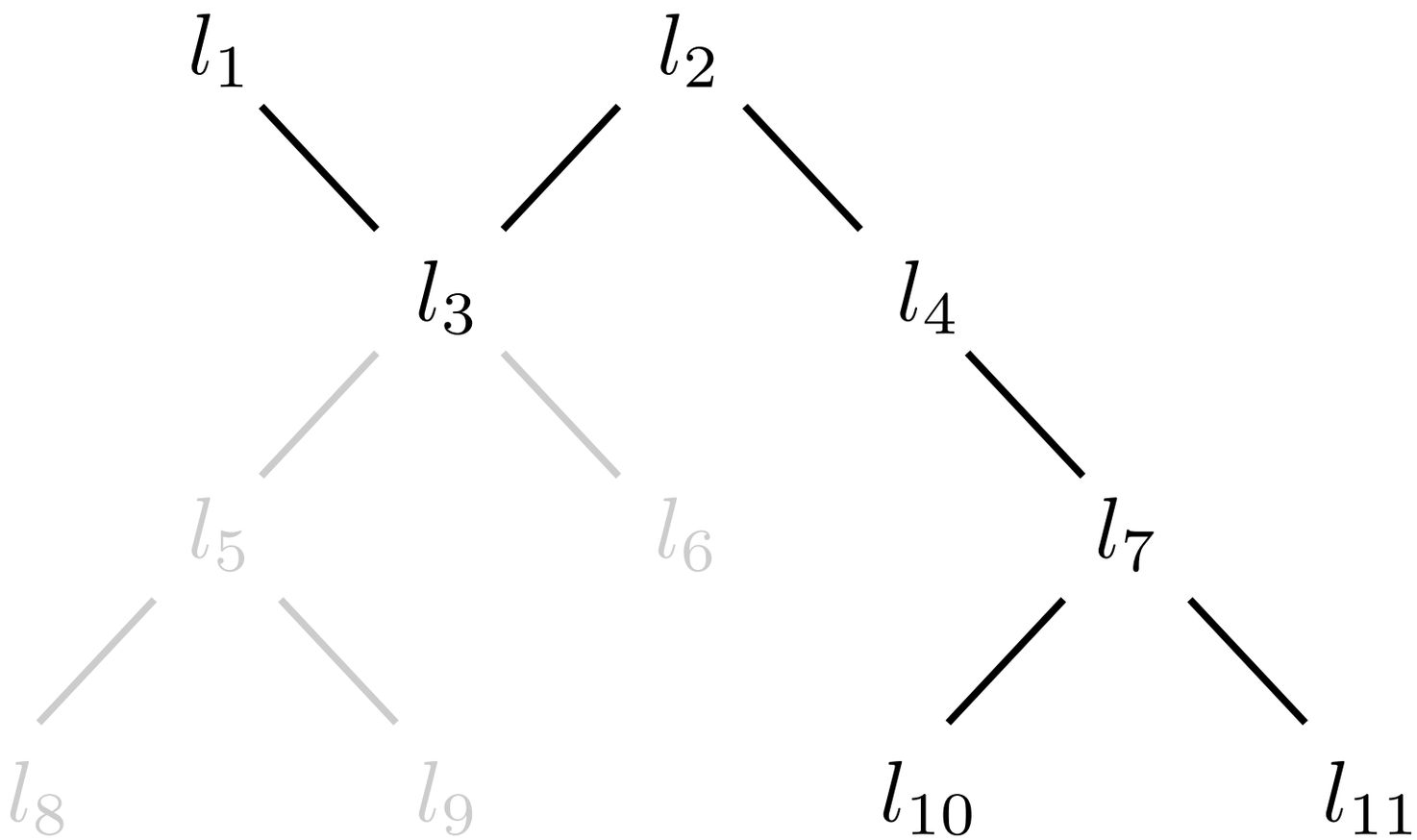

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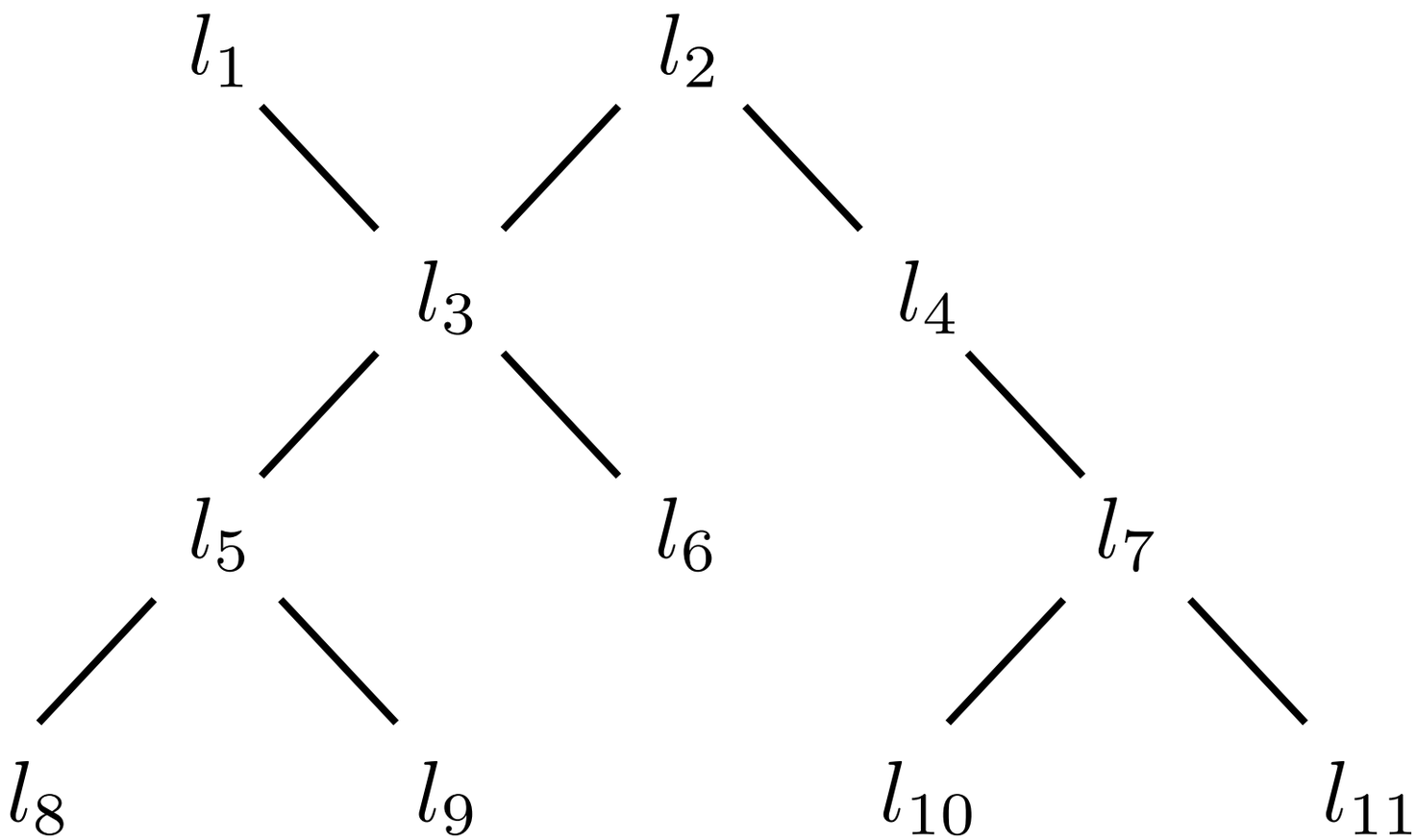

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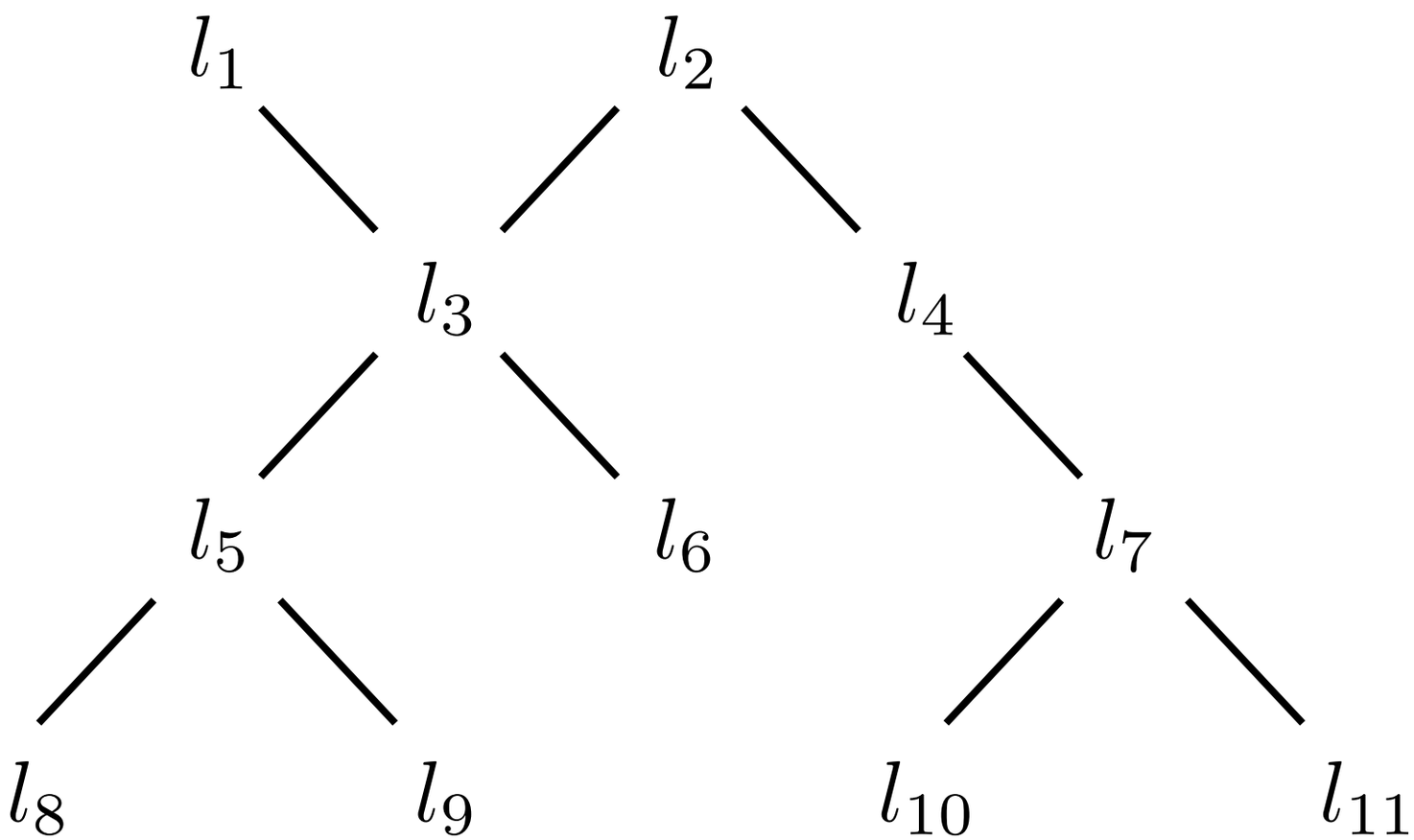
Assume that all keys are secret at time t except those under a level l.

Then at time $t + \Delta(l)$, all keys are secret except those under levels $l_1, \ldots, l_n$ such that $l_i < l$.



It assumes that you **do not lose** a level higher than the one you «try» to repair.

Blacklist Opportunity

«For those who are in a hurry...»

$\mathsf{blacklist}(C, h_1, \ldots, h_n)$

$\mathsf{Ex}: C = \{\langle \mathsf{blacklist}, \langle l_3, t_3 \rangle \rangle\}$ 

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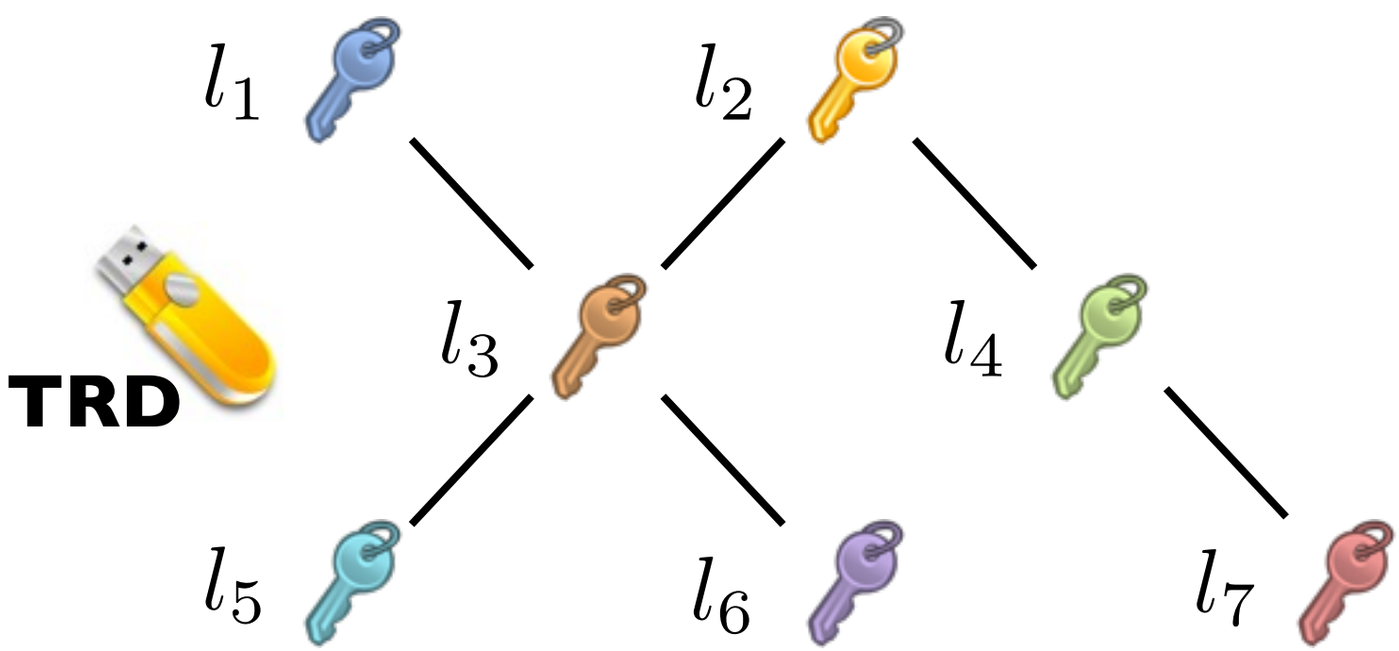

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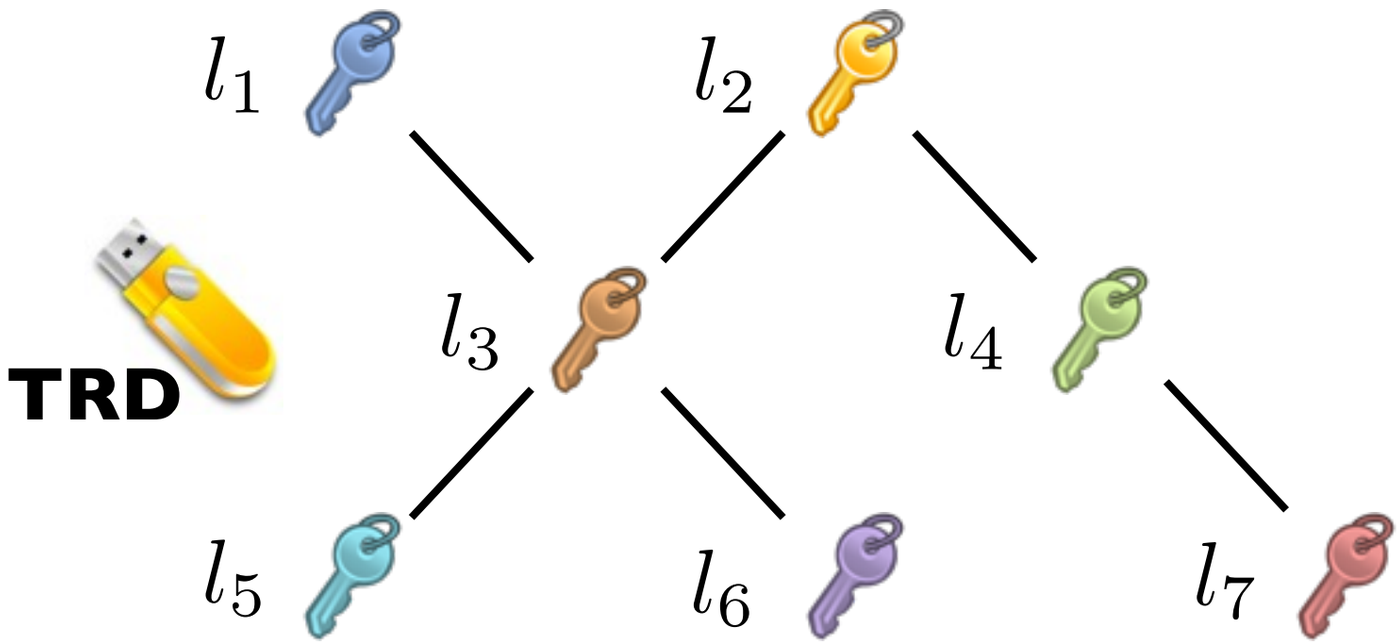


$(l_3, t_3) \longrightarrow$

Blacklist Opportunity

«For those who are in a hurry...»

$\mathsf{blacklist}(C, h_1, \ldots, h_n)$

Ex : $C = \{\langle \mathsf{blacklist}, \langle l_3, t_3 \rangle \rangle\}$

l_1

l_2

TRD

l_4

$(l_3, t_3) \longrightarrow$

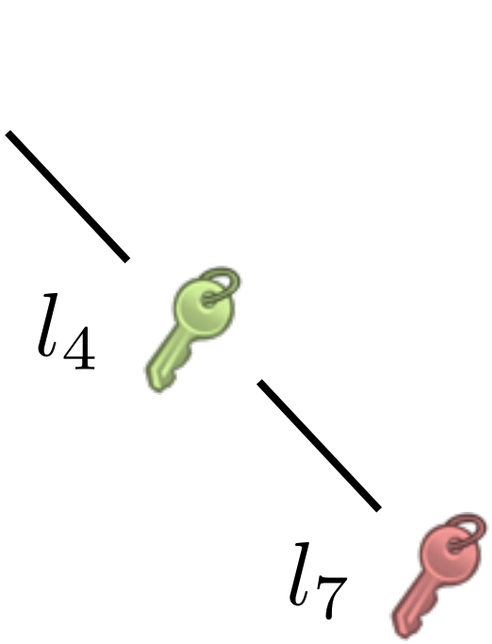
l_7

Blacklist Opportunity

«For those who are in a hurry...»

$\mathsf{blacklist}(C, h_1, \ldots, h_n)$

Ex : $C = \{\langle \mathsf{blacklist}, \langle l_3, t_3 \rangle \rangle\}$



$(l_3, t_3) \longrightarrow$

Theorem (Stated for one level)

Assume that all keys are secret at time t except those under a level l.

If we blacklist level l on a TRD , then, **immediatly**, all keys are secret except those under levels $l_1, \ldots, l_n$ such that $l_i < l$, for the TRD.

Concluding by Future Work

- **Weaken assumptions**, especially on hidden level Max messages (maybe requiring more cryptographic primitives),

- **Extending** our API to **asymmetric encryption**,

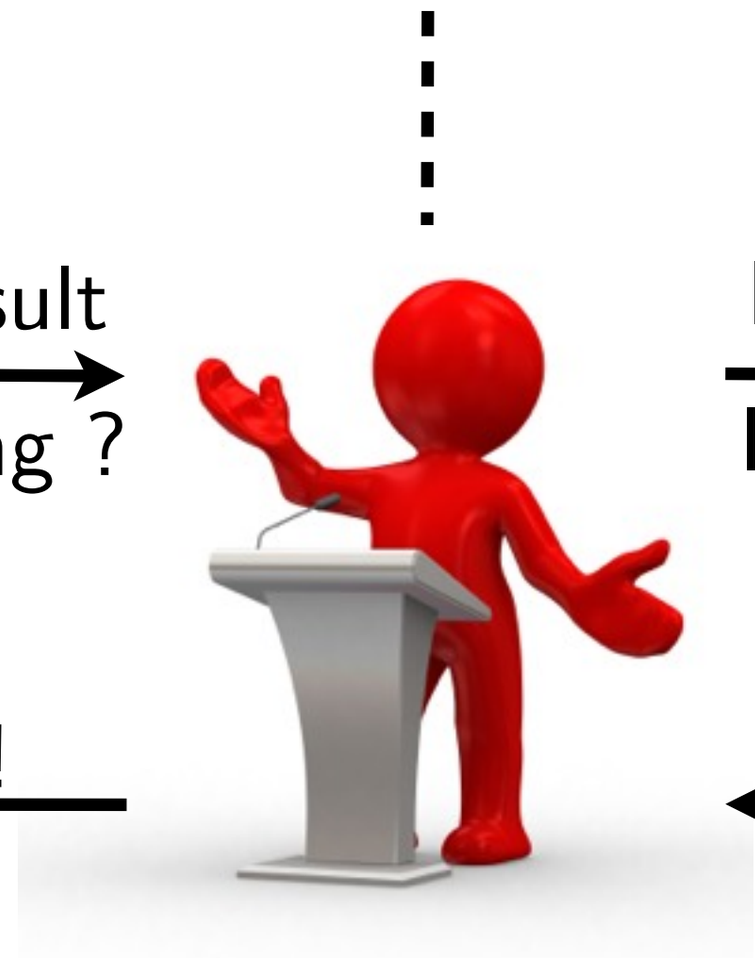
- **Adapting** the result taking account of possible **clock drift**, or replacing the clock by a sort of nonce based freshness test,

- **Implementing** the API in order to carry out some performance tests.

Thank you for your attention !

IsTheResult

Interesting ?



IsTheResult

Interesting ?

Sure !

Perhaps

Public
(Host Machines)

Speaker
(Security API)

Truth
(Trusted device)