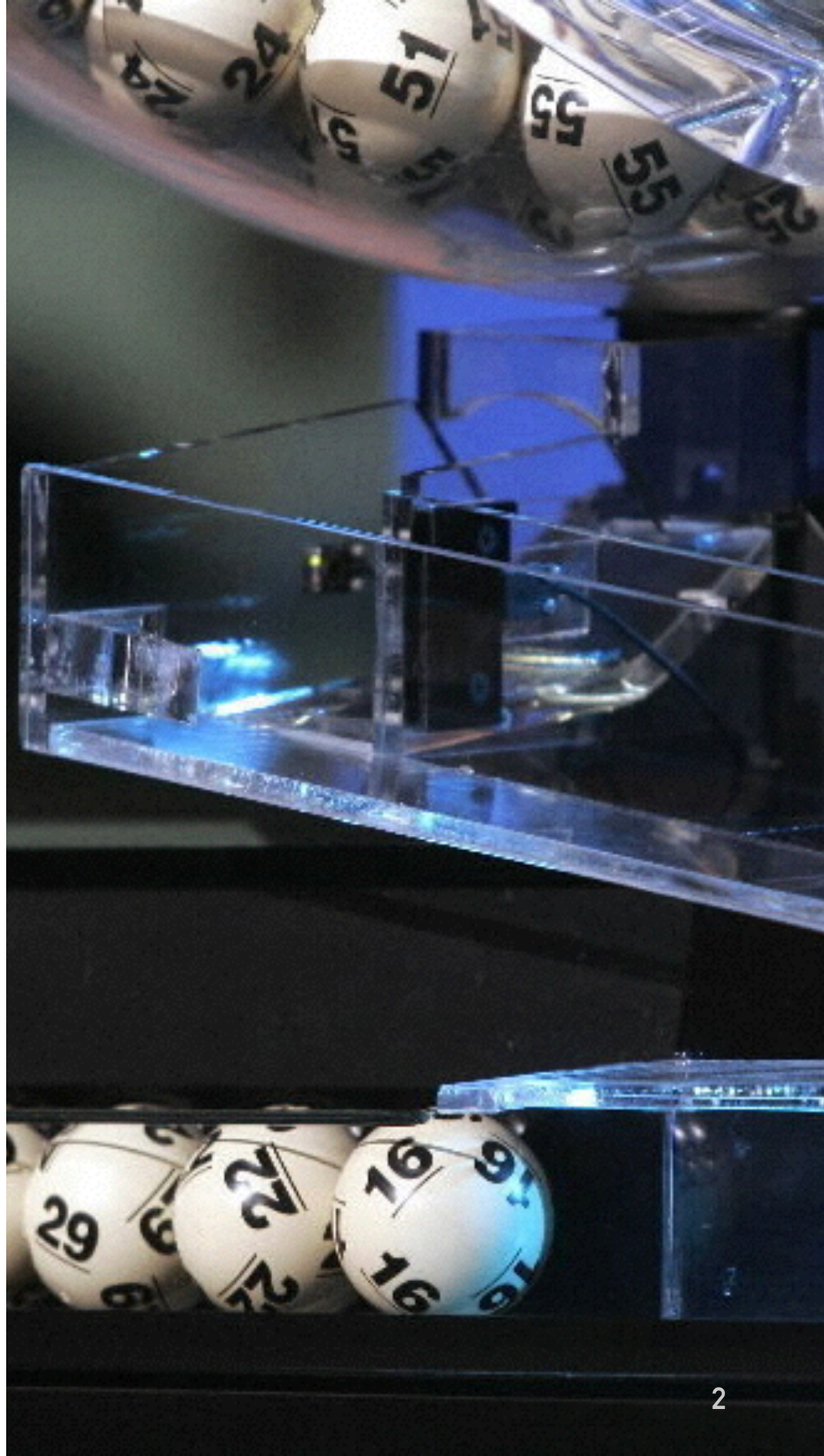
TRUST, AND PUBLIC ENTROPY: A UNICORN HUNT

Arjen K. Lenstra and Benjamin Wesolowski

WHAT IS PUBLIC RANDOMNESS

And what is it good for?



ELEMENTARY EXAMPLES

National lotteries

Sporting event draws

Tie breaking in elections

Totally based on randomness (presumably), and huge amounts of money or power at stake

A TOOL FOR DEMOCRACY

First known democracy in the world, in Athens: legislative and judicial power distributed to assemblies of **randomly selected citizens**

Require a secure random sampling procedure, that every sceptical citizen can trust and verify

TRANSACTION PROTECTION BY BEACONS

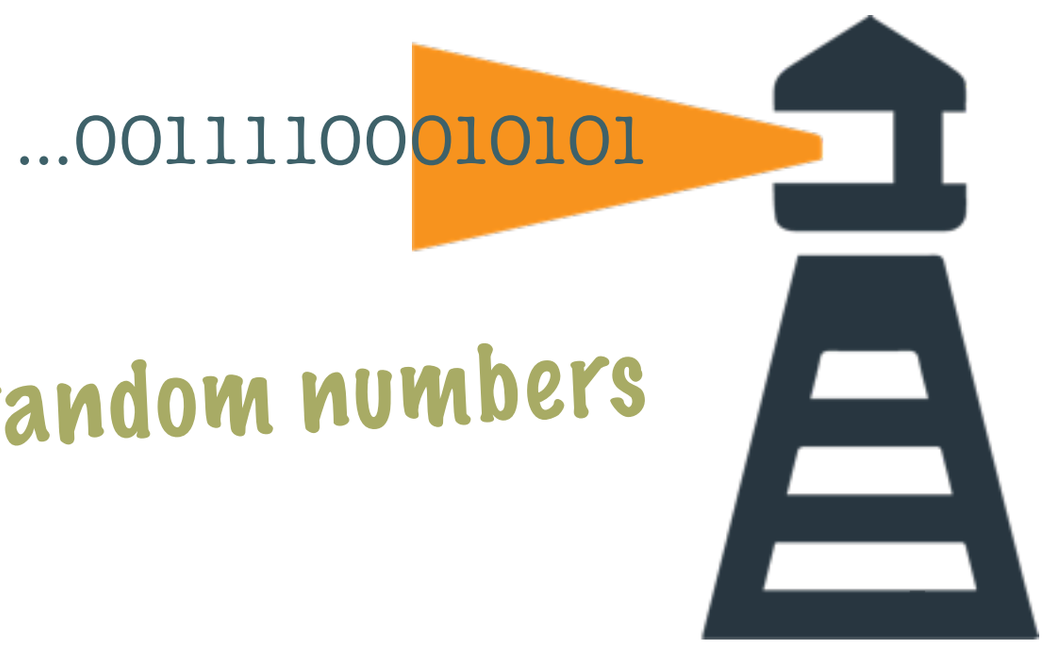
M. O. Rabin.

Transaction protection by beacons

Journal of Computer and System Sciences, 27(2):256-267, 1983.

Introduces the notion of **random beacon**:

A random beacon is an online service *broadcasting* (allegedly) *unpredictable* random numbers at regular intervals (say, every minute)



random beacon = public stream of random numbers

TRANSACTION PROTECTION BY BEACONS

A few applications of trustworthy public randomness:

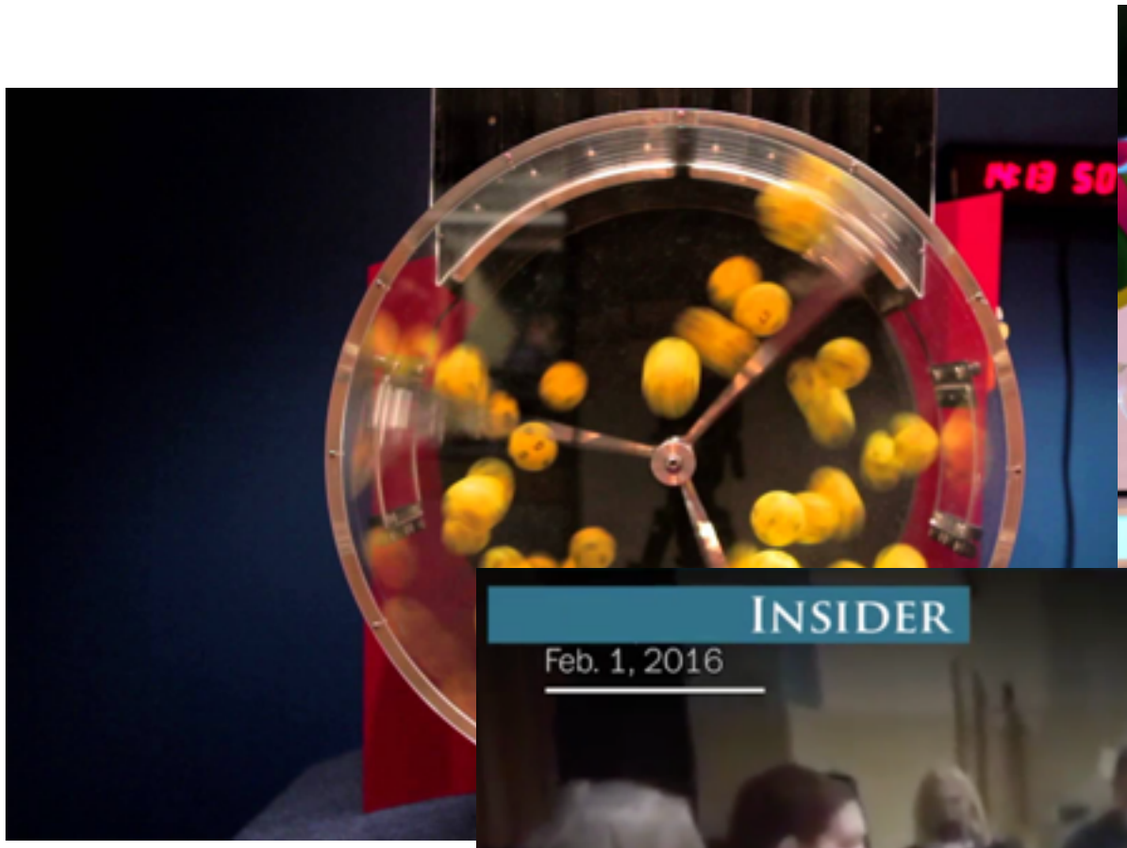
- **transaction protocols**: fair contract signing, confidential disclosure, mail certification
- **choice of standard parameters**: standard elliptic curves, constants in S-Boxes or round constants in hash algorithms…
- random challenges for **cryptographic elections**
- **smart contracts** in crypto-currencies: secure lotteries, non-interactive cut-and-choose protocols…
- **preventing selfish mining** in crypto-currencies

GENERATING PUBLIC RANDOMNESS

Can you trust someone else's entropy

THE (GOOD?) OLD WAY

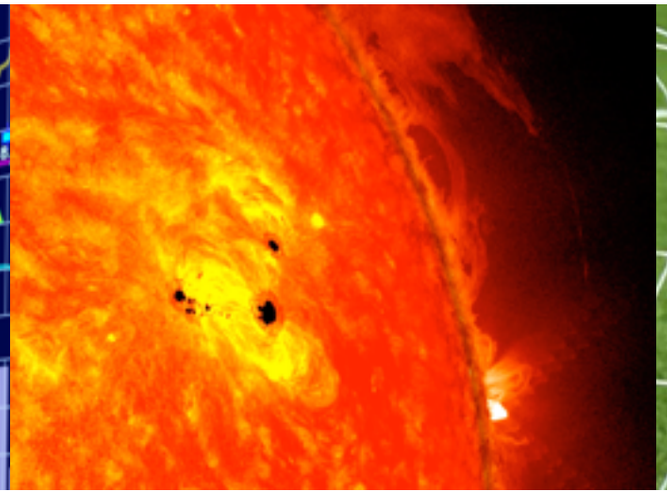
2600 YEARS LATER



Can the security be upgraded?…

USING WIDELY ACCESSIBLE ENTROPY






J. Clark and U. Hengartner.

On the use of financial data as a random beacon.

USENIX EVT/WOTE, 2010.

Easy to imagine that financial exchanges could subtly adjust the prices they announce to bias the “random” output

COMBINING LOTTERIES

results of national lotteries around the world in February 2016

published in January 2016

The Million Dollar Curve

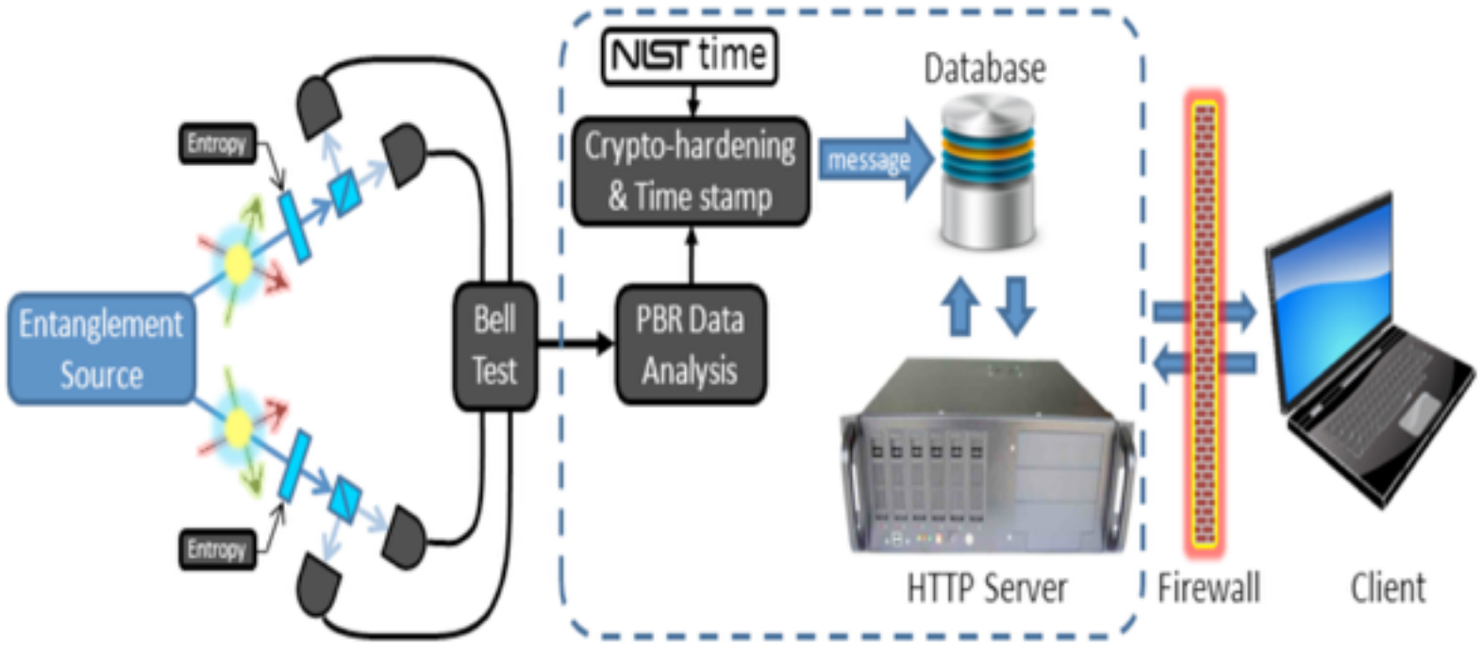
http://cryptoexperts.github.io/million-dollar-curve/, CryptoExperts

COMBINING LOTTERIES

- Cannot produce a regular stream of numbers like a beacon (not a problem for their application)
- Last draw attack
- Again, you have to trust some third party…

http://www.businesspundit.com/5-of-the-biggest-lottery-scandals/

THE NIST RANDOM BEACON

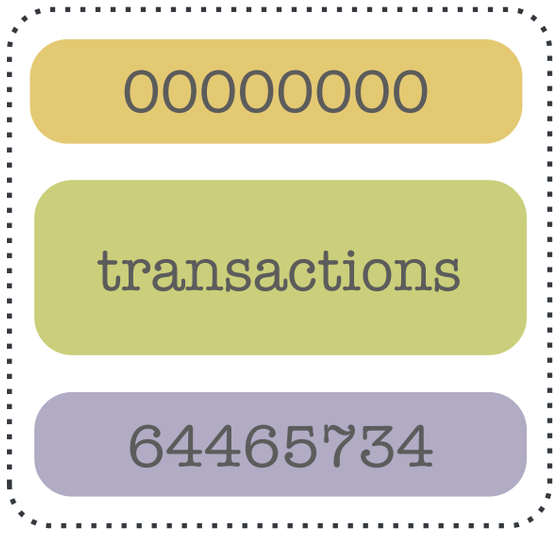


- 512 random bits per minute
- generated based on quantum mechanical phenomena, “true randomness”
- No proof that the numbers are properly generated can be provided

Can we get rid of the trust assumptions,

in favor of computational assumptions?

The Bitcoin blockchain



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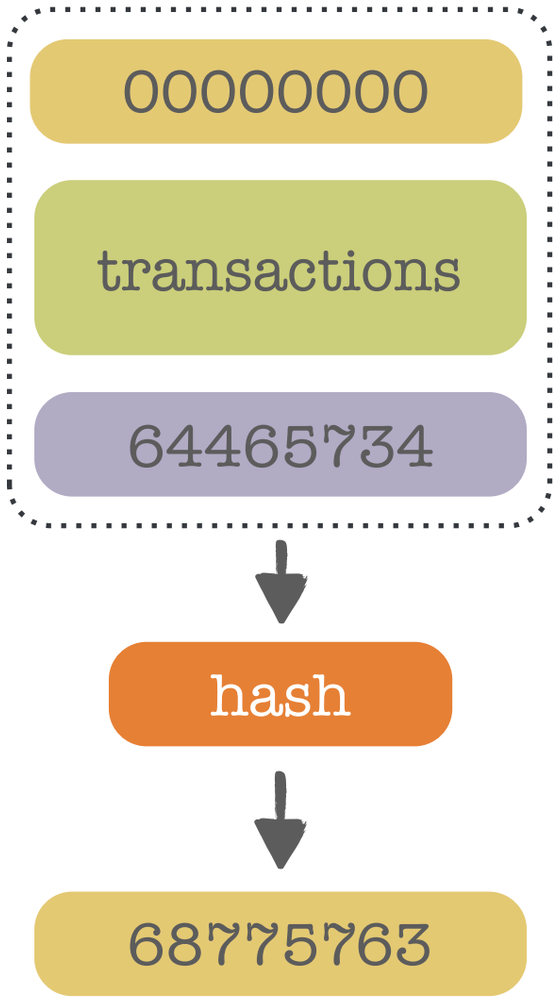

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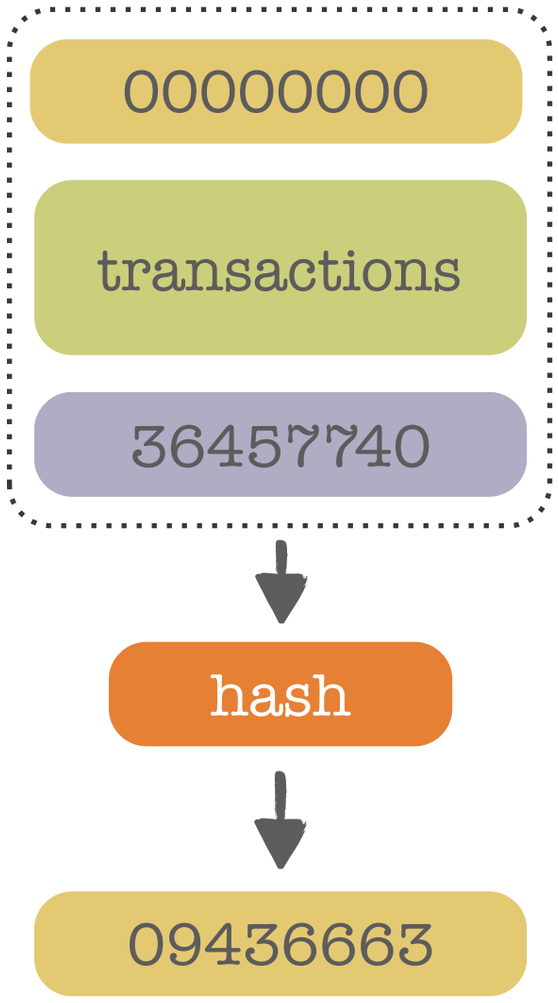

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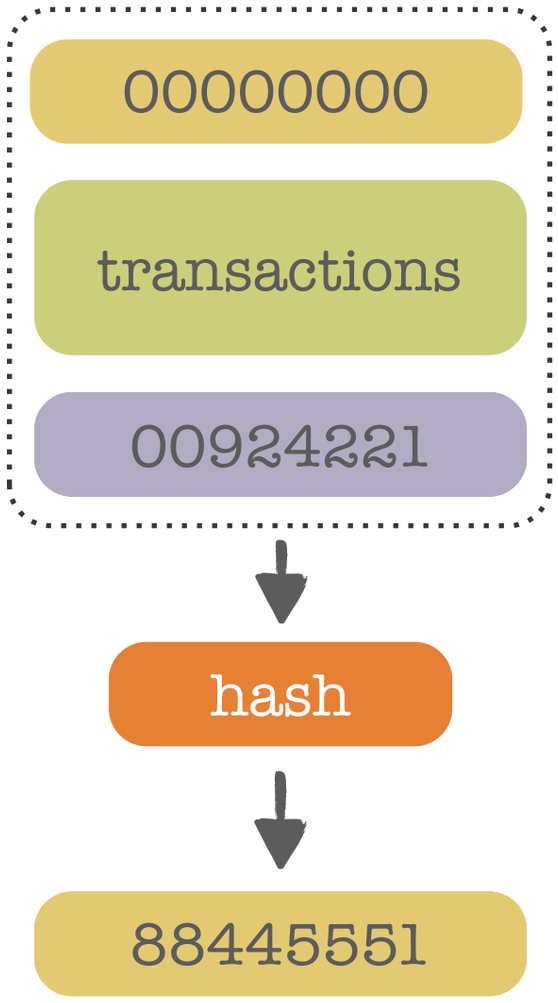

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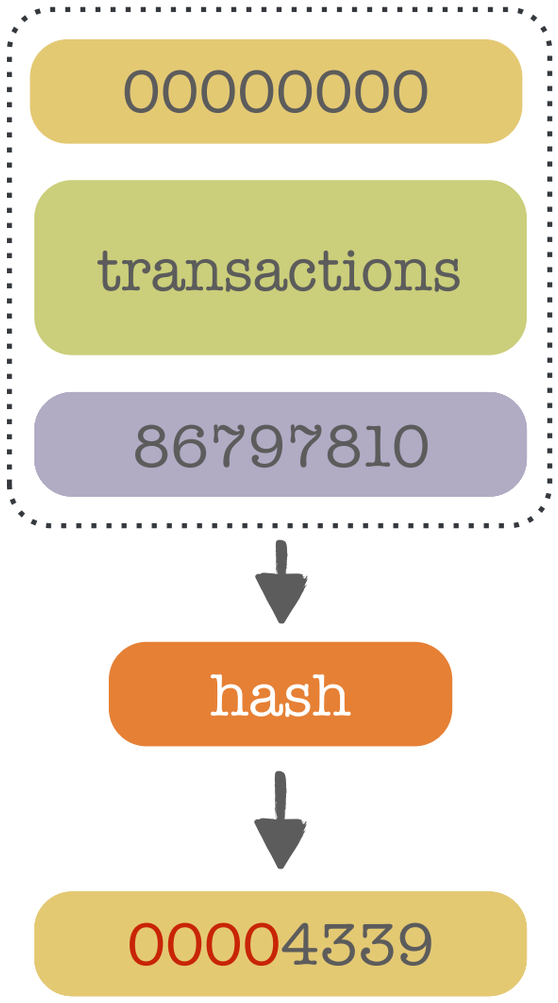
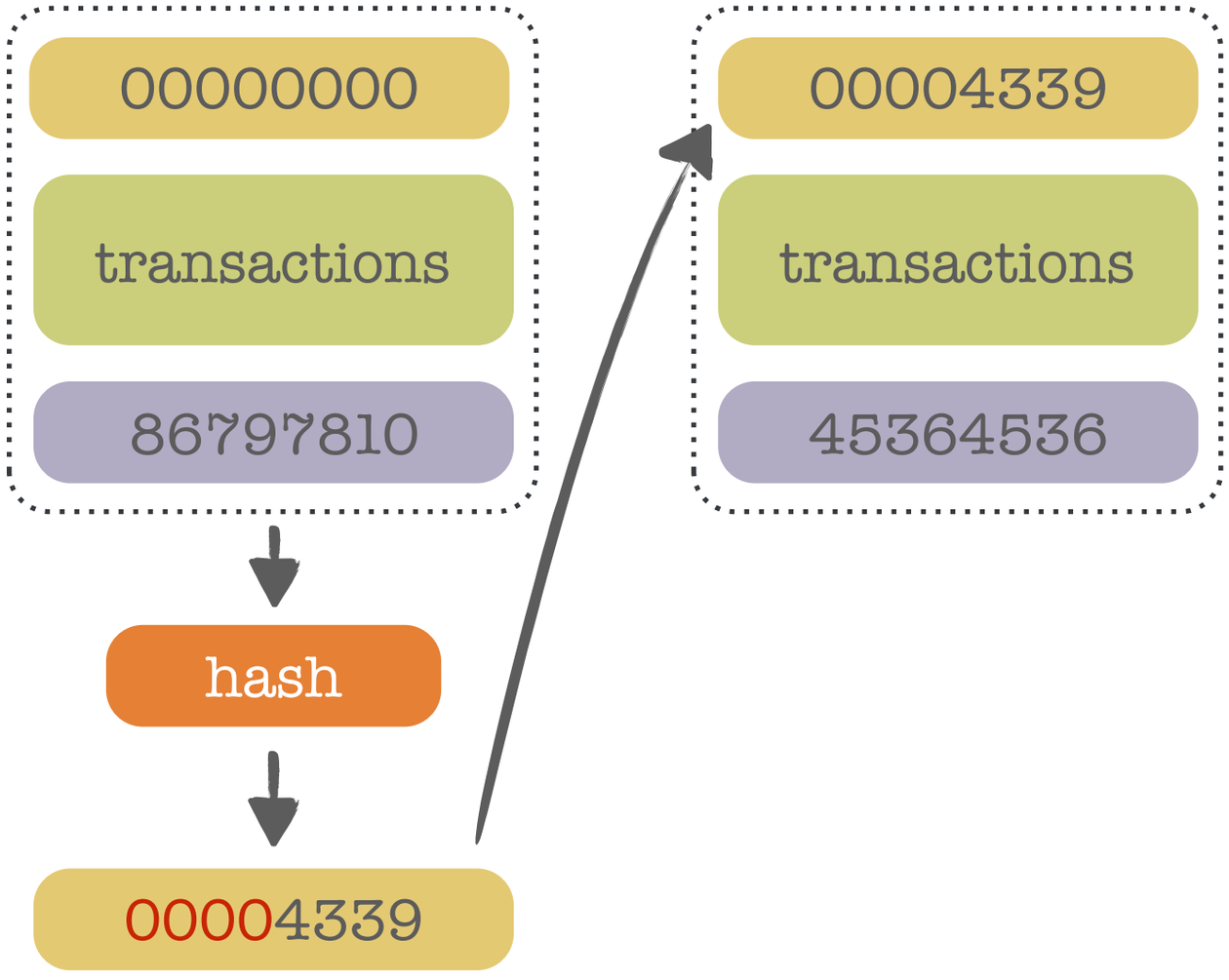


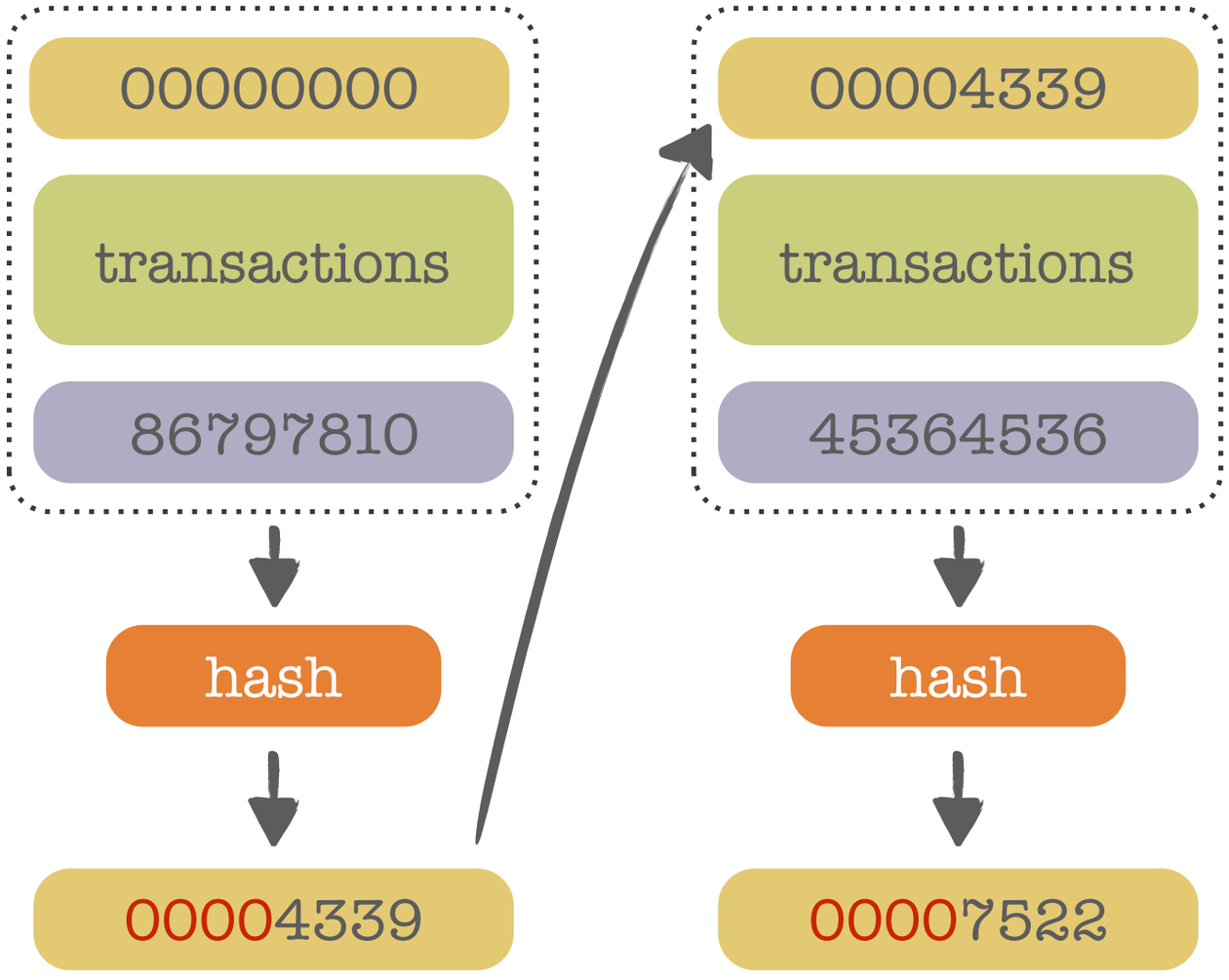
BITCOIN ENTROPY

The Bitcoin blockchain



BITCOIN ENTROPY

The Bitcoin blockchain



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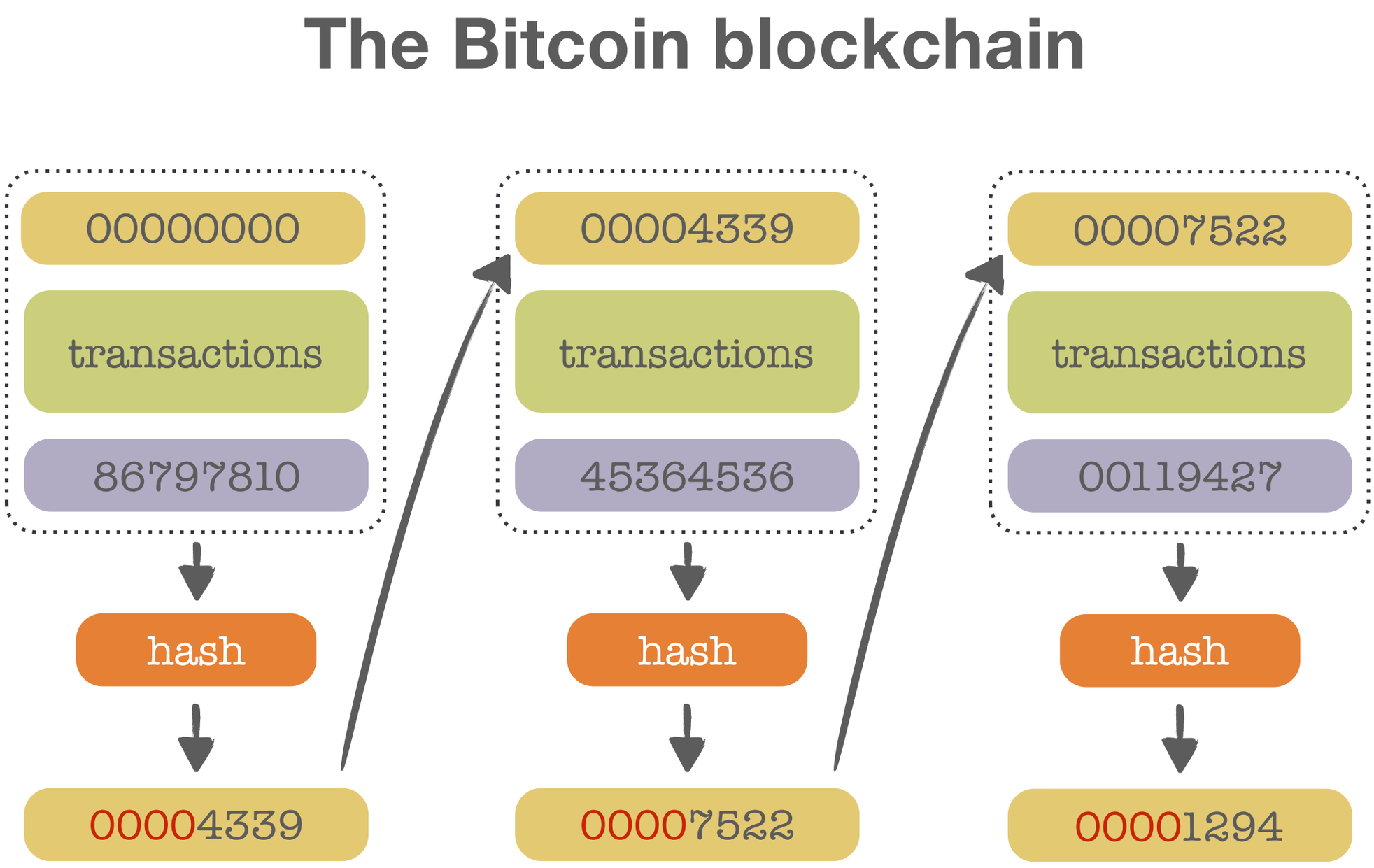

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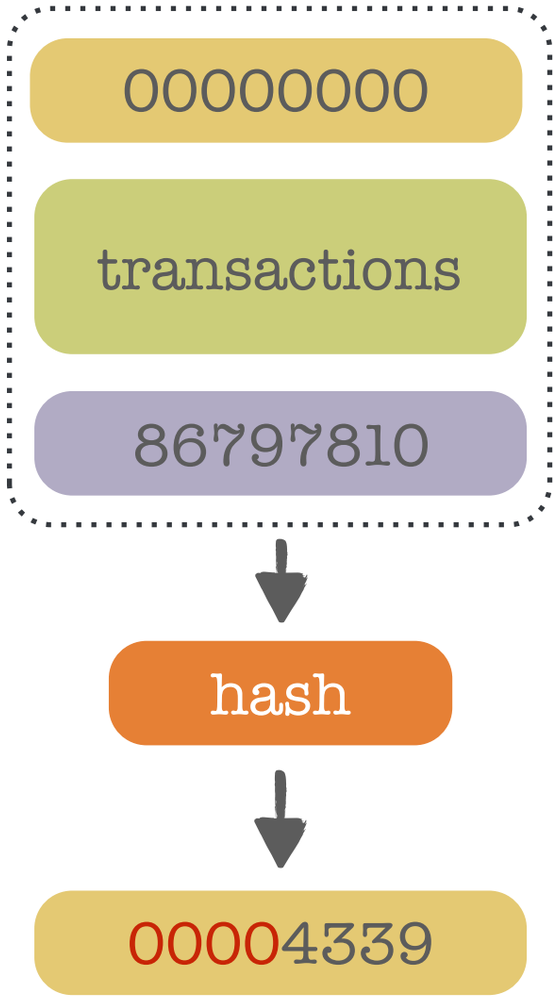
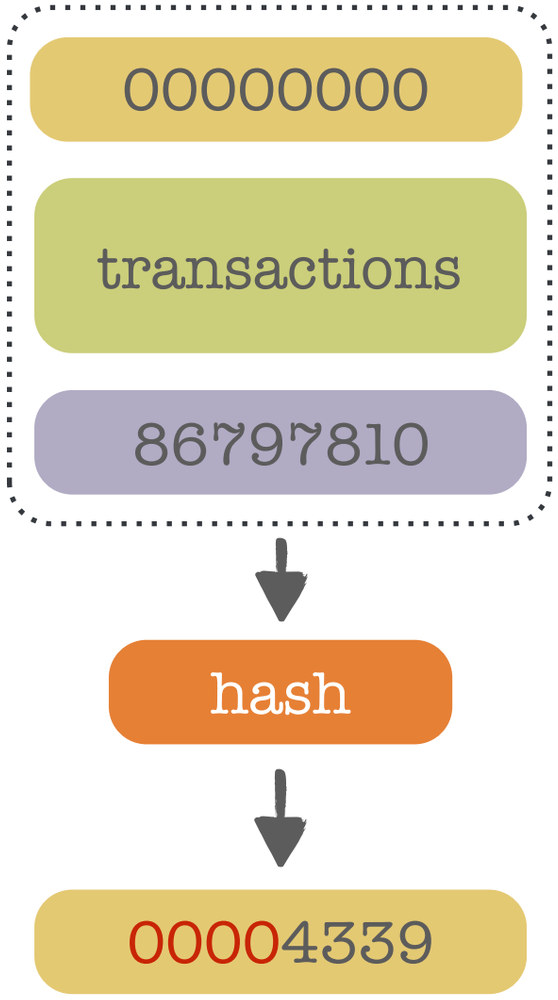


Finding [ ] such that [ ] starts with enough leading zeros is called **mining**, performed by **miners**, who get a reward when they find a valid block

BITCOIN ENTROPY

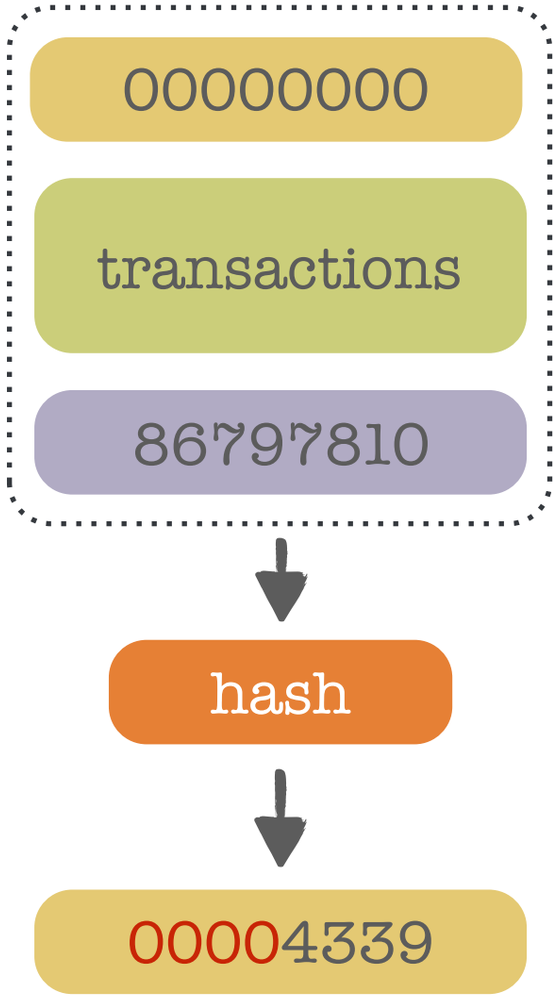


Idea: use `4339` as a random number

Protocol is decentralised, mining is costly. Should render manipulations difficult

How difficult?

BITCOIN ENTROPY



Idea: use 4339 as a random number

Problem: Groups of colluding miners can bias the output

If 25% of the miners are colluding, they can bias a coin toss from probability 0.5 to 0.74!

(Antpool and F2Pool each control more that 26%)

Numbers from Cécile Pierrot and B. W., *Malleability of the blockchain's entropy*, to be presented at ArcticCrypt Conference 2016

UNICORN: UNCONTESTABLE RANDOM NUMBERS

Arjen Lenstra and B. W.

A random zoo: sloth, unicorn and trx.

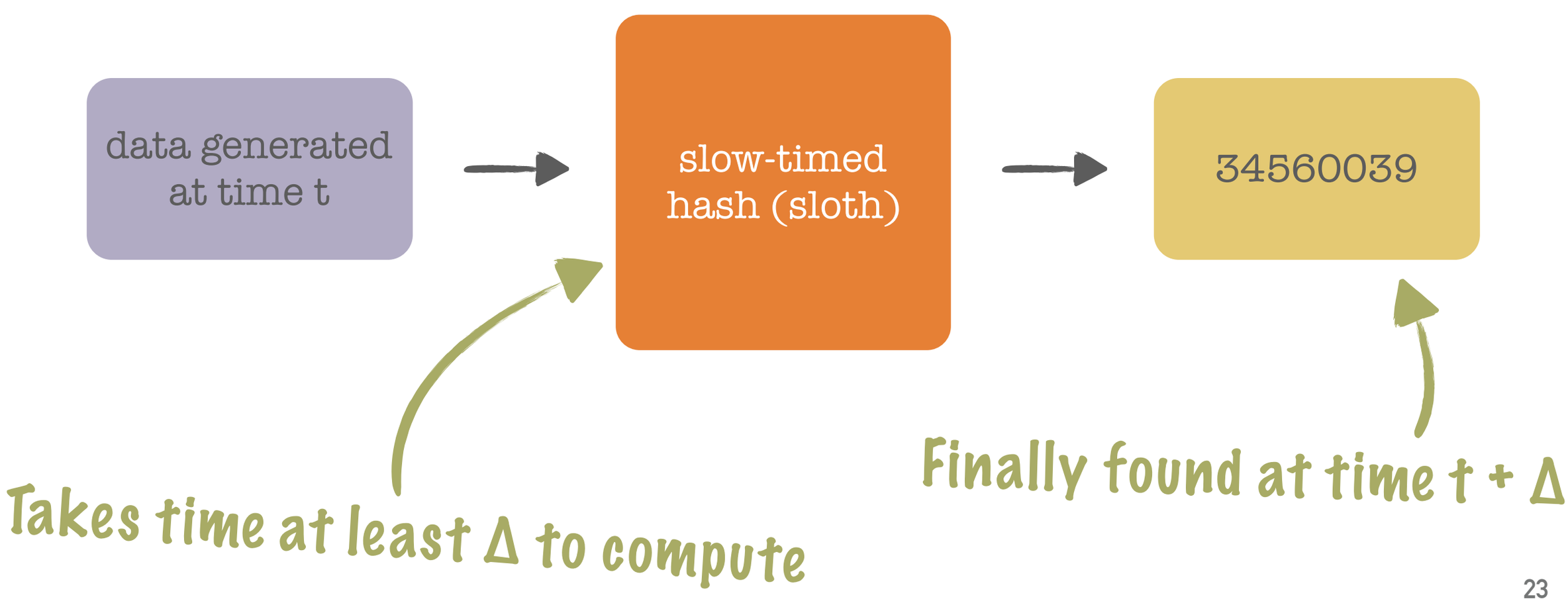
http://eprint.iacr.org/2015/366.

UNICORN: UNCONTESTABLE RANDOM NUMBERS

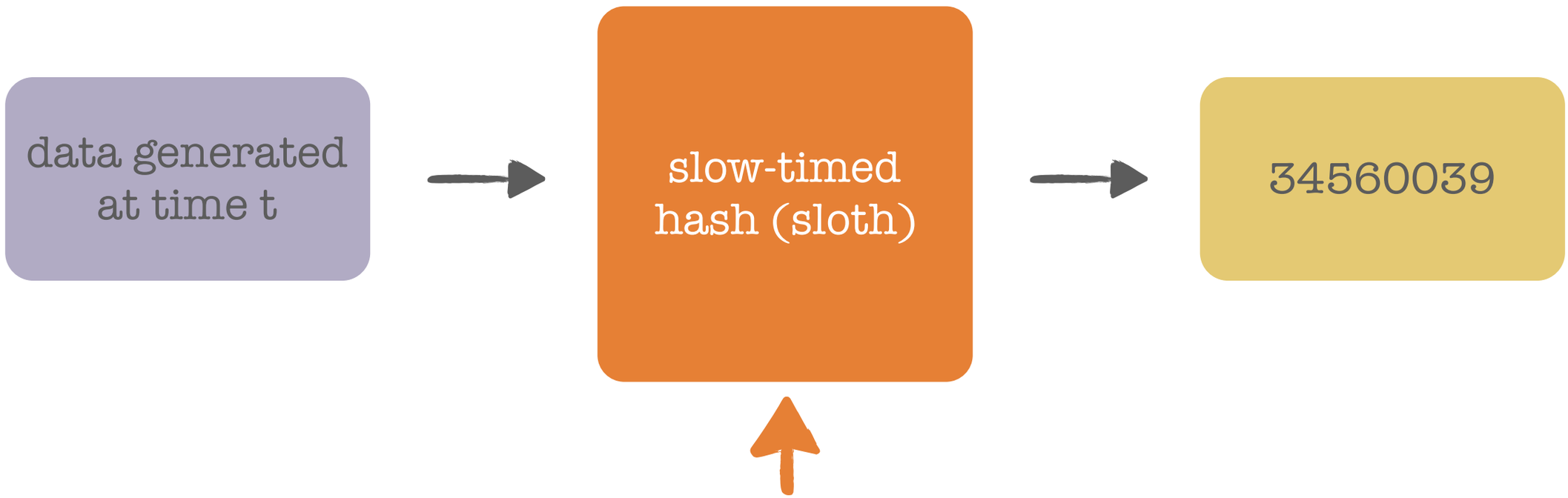
1. **Open protocol**: anyone is able to take part in the generation process (and it is very easy)
2. **Verifiable**: anyone can verify everything went right
3. **Secure**: even if only one single participant is honest (and that can be you, thanks to 1.)

UNICORN: UNCONTESTABLE RANDOM NUMBERS

Observation: a number can be fully determined at point in time *t*, while none of its bits can be known by anyone before time *t* + Δ, for some delay Δ



UNICORN: UNCONTESTABLE RANDOM NUMBERS



Sloth must be guaranteed to take time at least Δ to compute, irrespective of available parallel resources

Trivial example: SHA-2 iterated millions of times

Better example: *sloth*, based on square root extractions in finite fields (efficiently verifiable, with only some squarings)

UNICORN: UNCONTESTABLE RANDOM NUMBERS

- Latest news at time *t*, weather data, stock values, latest output of the NIST beacon
- Screenshot of a public online bulletin board
- Latest tweets containing the hashtag #unicorn

By sending a tweet at the right moment, you are guaranteed nobody knew [redacted] before time *t*

UNICORN: UNCONTESTABLE RANDOM NUMBERS

At time *t*, the input [redacted] of *sloth* is published, and the computation begins

UNICORN: UNCONTESTABLE RANDOM NUMBERS

By sending a tweet at the right moment, you are guaranteed nobody knew [redacted] before time *t*

\+

sloth takes time Δ to finish

=

not a single bit of [redacted] is known before t + Δ

UNICORN: UNCONTESTABLE RANDOM NUMBERS

not a single bit of  is known before $t + \Delta$

+

 is fixed (and public) at time t

=

Nobody can willingly bias even a single bit of 

DESIGNING A SECURE RANDOM BEACON

Guarantees and constraints

TRUSTWORTHY ENTROPY, RATHER THAN TRUSTED ENTROPY

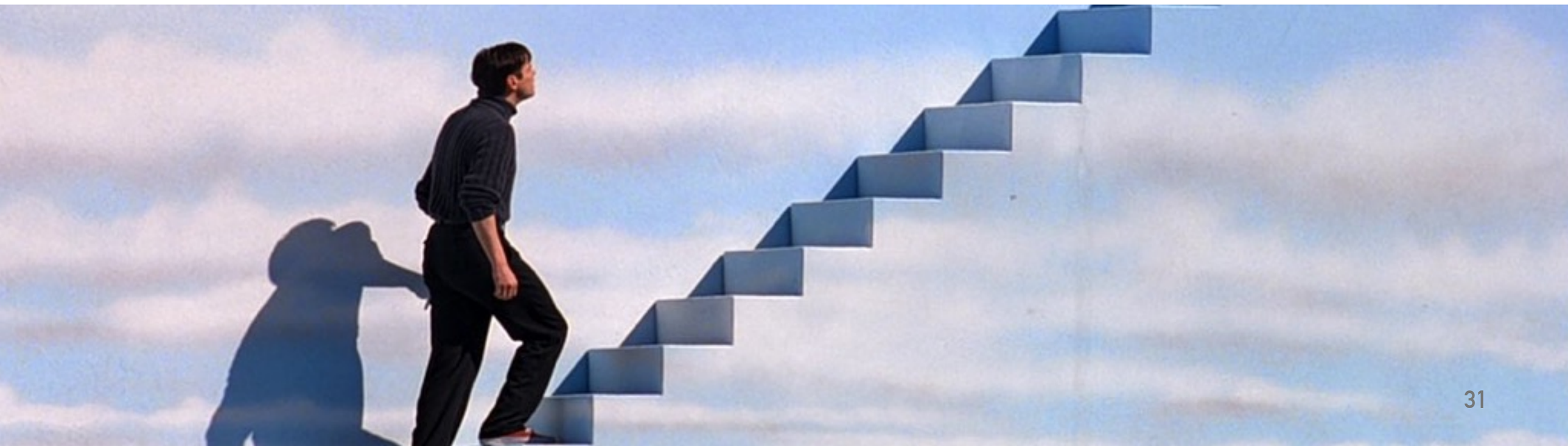
Get rid of the trust assumption: **prove** to everybody that your random numbers are not manipulated

THE TRUMAN SHOW MODEL

A user of a secure beacon may trust nobody but himself

- lotteries are rigged
- Bitcoin miners are all colluding against him
- and with everybody else in the world but him

Yet he should still be able to verify that the output numbers are not manipulated

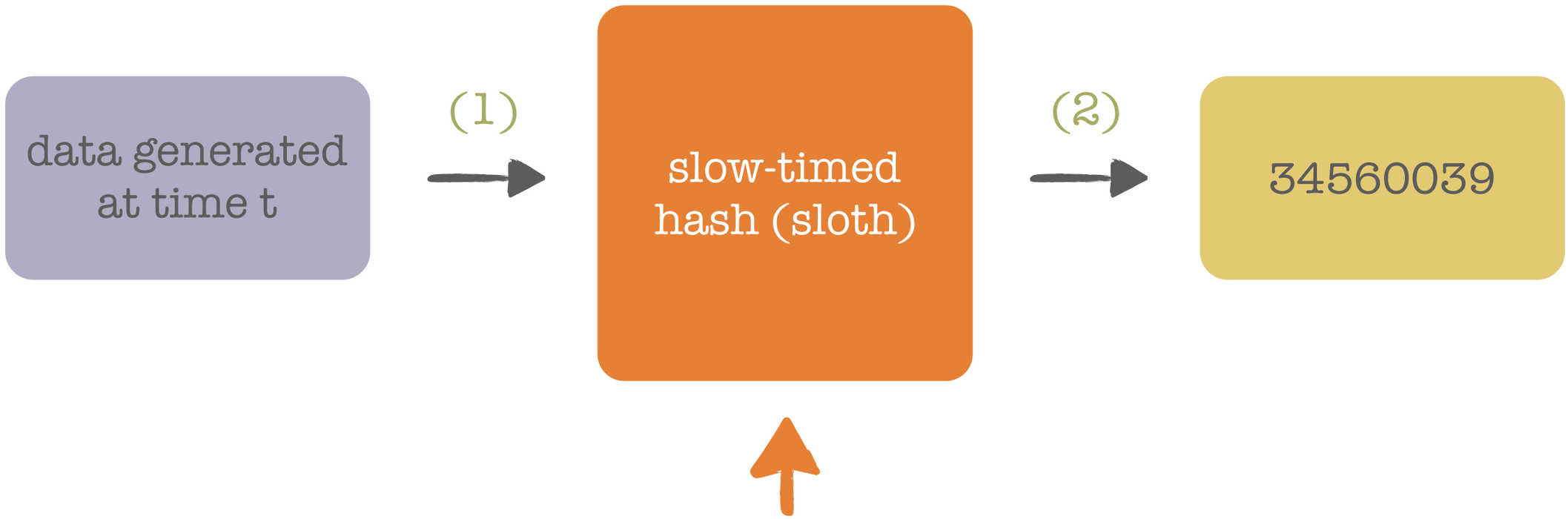


OPEN PUBLIC INPUT

The *unicorn* protocol needs public input, for people to make sure the data wasn't known by anyone before *t*

We argue open public input is necessary in the Truman Show model, in order to **fix the random number in time** even for the most skeptical users

TIME DELAY



The *unicorn* protocol suffers a delay in its execution

We also argue that in this model, there must be a delay separating the moment where the output is determined (1), and the moment it can be known (2)

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE