Randomness Beacons as Enablers of Public Auditability

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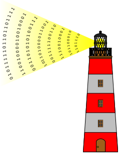
National Institute of Standards and Technology



Presentation at STPPA 01
Special Topics on Privacy and Public Auditability
January 27, 2020 @ Gaithersburg, Maryland, USA

Some slides are based on previous presentations (IMFD Oct 2019, ICMC May 2019).

The Reference for Randomness Beacons is joint work with John Kelsey, Rene Peralta and Harlod Booth.

The Interoperable Randomness Beacons project is joint work with others in the Cryptographic Technology Group.

Outline

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1. Introduction
2. Randomness Beacons (format and operations)
3. Usages of beacon randomness
4. Concluding remarks

Goals of this presentation:

- Brief overview of the NIST Reference for Randomness Beacons
- Allude to possible public-auditability applications

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At a high level (from Wikipedia):

Randomness

Public Good

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- “a good [for which] individuals cannot be excluded from use, [and] use by one individual does not reduce availability to others.”

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- "the lack of pattern or predictability in events [...] a measure of uncertainty of an outcome"

Public Good

- "a good [for which] individuals cannot be excluded from use, [and] use by one individual does not reduce availability to others."

Audit

- "a systematic and independent examination [...] to ascertain how far the [...] statements [...] present a true and fair view [...]"

A Randomness Beacon

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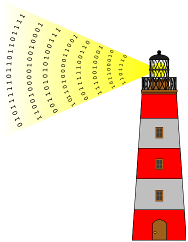
A service that produces timed outputs of fresh public randomness

(The idea goes back at least till 1983 — proposed by Rabin to aid crypto operations.)



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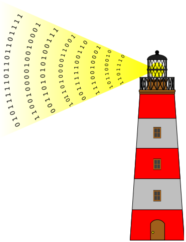

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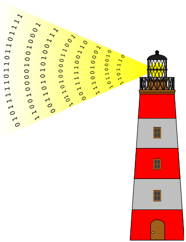

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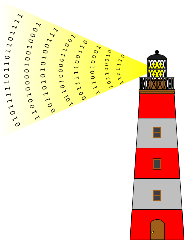

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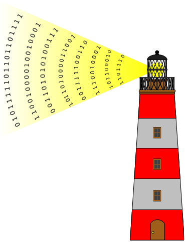

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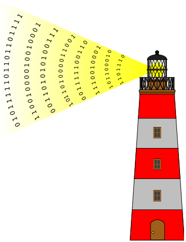

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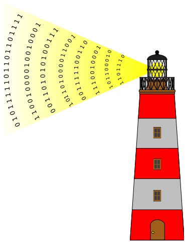

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- public auditability of randomized processes
- coordination between multiple parties (e.g., who does/wins something)
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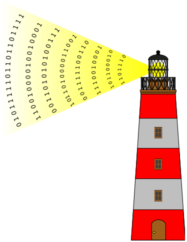

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NOT good for: selecting your secret keys

An example/conceivable application

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Security aspects

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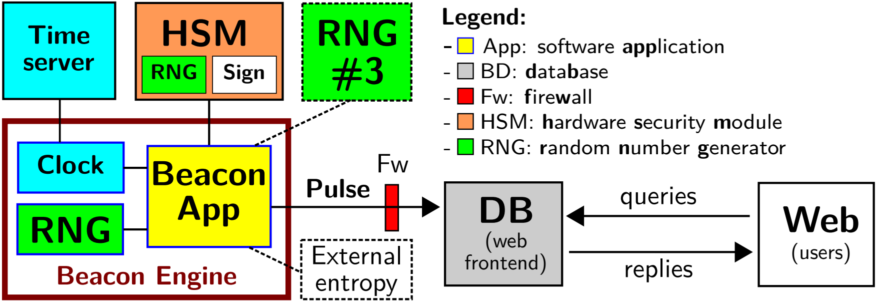
Security aspects

- Can the beacon be influenced to select (or not select) a particular official?
- Can an attacker learn in advance which officials will be selected?
- What interests are at stake? What resources does an adversary have?

Architecture of the Beacon service



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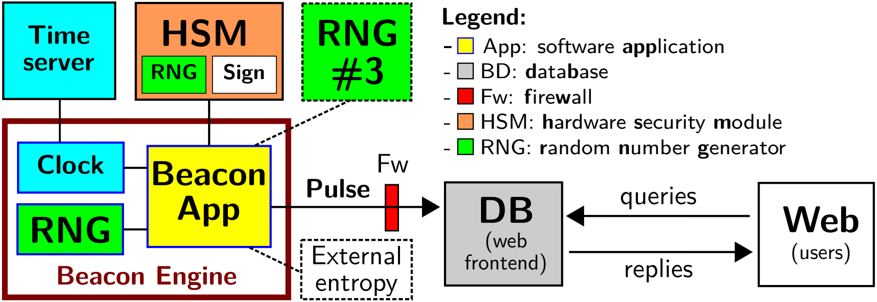

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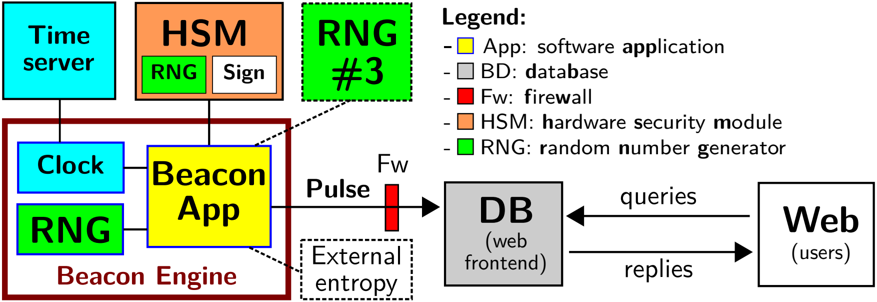

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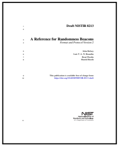
A **Reference** for Randomness Beacons:

Format and Protocol Version 2

https://doi.org/10.6028/NIST.IR.8213-draft



NIST project: Interoperable Randomness Beacons

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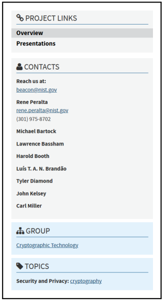
The project has four main tracks:

- **A.** promote a reference for randomness beacons;
- **B.** maintain a NIST Beacon implementation;
- **C.** promote the deployment of Beacons by multiple independent organizations;
- **D.** promote usages of beacon-issued randomness

Also interested in assisting initiatives about trusted randomness, e.g., quantum RNGs and certifiable randomness.



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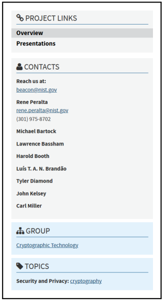


Some milestones:

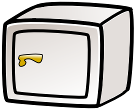
- 2013: Prototype NIST beacon v1.0
- 2018: Quantum RNG by Physics Measurement Lab
- 2018: Deployment of NIST beacon v2.0
- 2019: Publication of Reference for randomness beacons

Outline 2

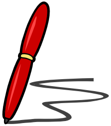
Some concepts useful in this talk

- **Hash:**

- **Commitment:**



- **[Digital] Signature:**



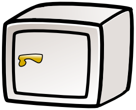
Some concepts useful in this talk

- **Hash:**

  — like a fingerprint of data ('unique' string 512 of bits)
  — looks random if its originator data is unknown

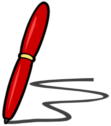
- **Commitment:**

  — like a vault that hides data, until it is opened
  — once closed, cannot change what is inside



- **[Digital] Signature:**

  — like a physical signature, but cannot be forged
  — a signature copied to another document is invalid



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- Two main random values (“rands”): `randLocal` and `randOut`.
- Other features: signed

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- Each pulse is indexed
- Two main random values (“rands”): `randLocal` and `randOut`.
- Other features: signed, committed `randLocal`, chained `randOut`, ...

The two “rands” in a pulse

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randLocal (local random value):

randOut (output value):

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randLocal (local random value):

- **What:** Hash of randomness produced by ≥ 2 RNGs
- **How:** **Pre-committed** 1 minute in advance of release
- **Why:** Randomness contribution to combine with randomness of other beacons

randOut (output value):

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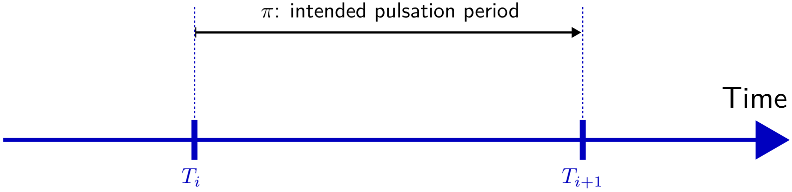
randOut (output value):

- **What:** Hash of all other fields
- **How:** **Fresh** at the time of release
- **Why:** Randomness seed for applications that completely trust this beacon

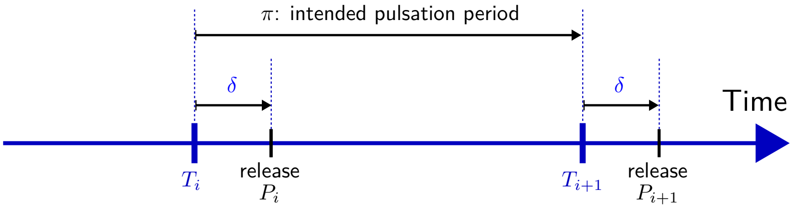
Timing for generation and release



Timing for generation and release

1. No advanced release of pulse ($\delta \geq 0$)
2. Generate with entropy (≥ 2 RNGs)

} $\Rightarrow$ **Unpredictability**



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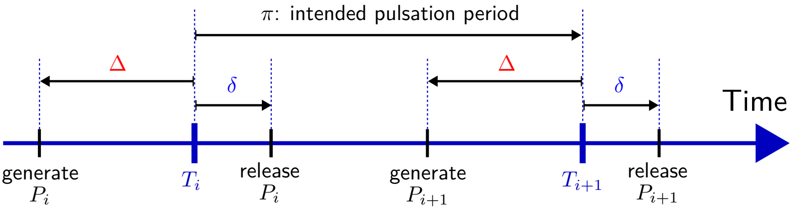

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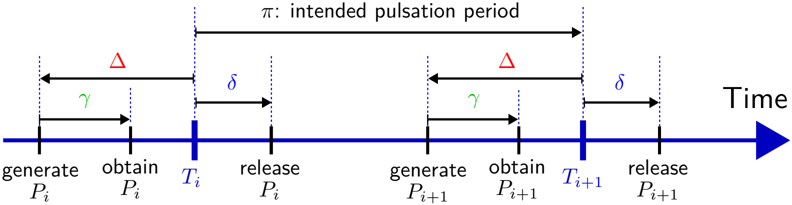
4. No delayed release (small γ and δ) $\Rightarrow$ **Timeliness**



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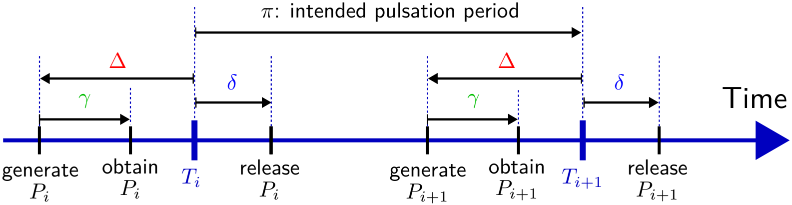

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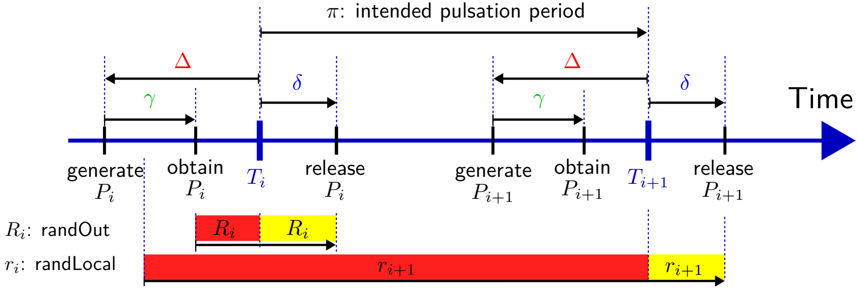
4. No delayed release (small γ and δ) $\Rightarrow$ **Timeliness**
5. Unambiguous indexation $\Rightarrow$ **Unambiguity**



(The actual requirements specify allowed intervals for δ and Δ)

Fetching pulses

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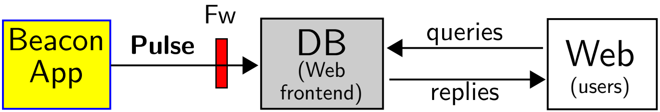
Beacon App: a pulse release means sending it to the database



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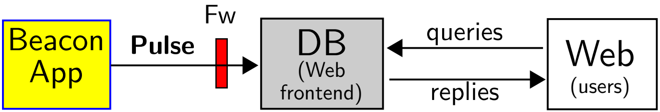

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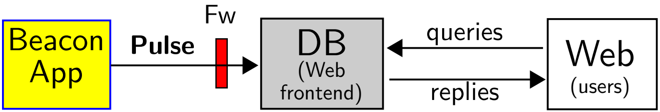

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https://beacon.nist.gov/beacon/2.0/chain/last/pulse/last

Example: URL for the latest pulse in chain 1 of the NIST randomness Beacon (version 2)

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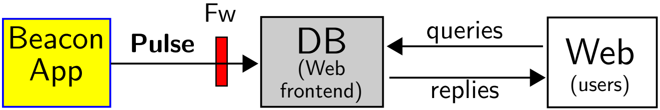

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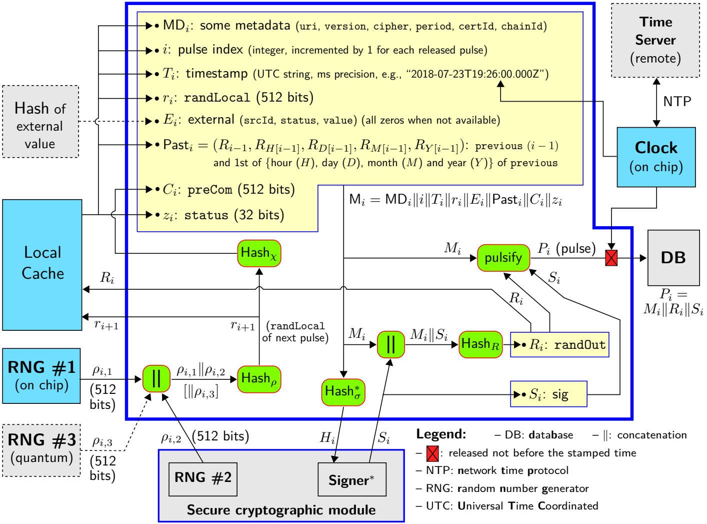
Example: URL for the latest pulse in chain 1 of the NIST randomness Beacon (version 2)

Other queries exist: by pulseId; skiplists; certificates; external values...

A possible diagram of pulse generation



For simplicity, the diagram omits serialization details (e.g., field lengths and padding) and some metadata fields.

Outline 3

Using Beacon randomness (if I trust the Beacon)

(some simplifications for purpose of presentation)

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What happens if a malicious Beacon targets your application (e.g., the Comptroller), to affect the unpredictability?

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- Combine randomness from various beacons
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- Combine a local secret (and committed) value
  – The beacon cannot predict which seed the application will get

Some Beacons in development

Three countries are developing Beacons to match the current reference:

- (United States) NIST Randomness Beacon
  https://beacon.nist.gov/home
- (Chile) Random UChile
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We would like others to join

Some conceivable applications

"*You have been randomly selected for additional screening*"

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- Select random test vs. control groups for clinical trials
- Select random government officials for financial audits
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Advanced features: zero-knowledge proofs (ZKP) to enable auditability with privacy

Use case: public auditability with privacy

Challenge: random selection depending on private attributes

Public		Private initial			Private derivative	
# (i)	Rand id	Name (N)	a	b	Weight (w)	Acc. (W)
1	371	**C**ai	1	2	0.1	0.1
2	942	**E**ve	2	7	0.3	0.4
3	107	**B**ob	1	5	0.2	0.6
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1. $a_i \in A$ (e.g., annual salary); $b_i \in B$ (e.g., years in position);
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3. $\sum_i w_i = 1$ (correct sum of weights);
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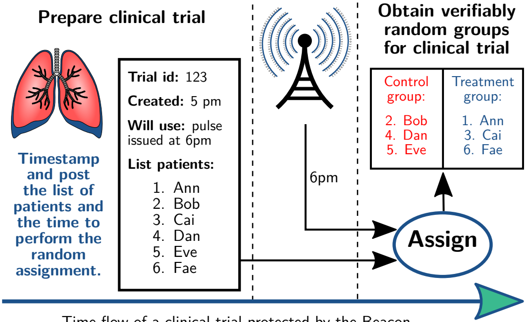
Derive $R : 0 < R \leq 1$ (random) from the Beacon and determine # j: $W_{\max(1,j-1)} < R \leq W_j$

- **Prove in ZK** that j is consistent with R and the table of commitments

Use case: randomized clinical trials

- **Setting:** a placebo-controlled clinical trial assigns patients to either the **treatment** group or the **control** group.
- **Goal:** After the study, it is possible to convince others that the trial was properly randomized.



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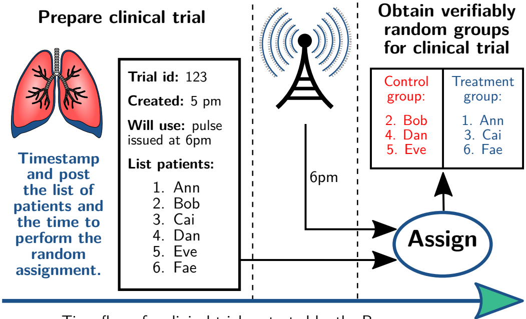

Time flow of a clinical trial protected by the Beacon

Apply commitments and zero-knowledge proofs to hide private data while proving correctness.

Outline 4

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- **We would like to have your collaboration!**

- NISTIR 8213: https://doi.org/10.6028/NIST.IR.8213-draft
- Beacon project: https://csrc.nist.gov/Projects/Interoperable-Randomness-Beacons

Thank you

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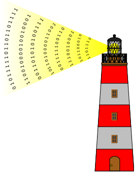

Randomness Beacons as Enablers of Public Auditability

Presentation at Special Topics on Privacy and Public Auditability

January 27, 2020 @ Gaithersburg, Maryland, USA

luis.brandao@nist.gov

List of slides