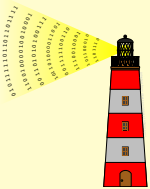
Notes about the NIST Reference for Randomness Beacons

Cryptographic Technology Group

National Institute of Standards and Technology (USA)



Presentation at The Randomness Summit 2023

March 30th, 2023 @ Tokyo, Japan

Suggested reading: NISTIR 8213 Draft

A Reference for Randomness Beacons:

Format and Protocol Version 2

* Luís Brandão: At NIST as a Foreign Guest Researcher (non-employee), Contractor from Strativia. Expressed opinions are from the speaker and should not be construed as official NIST views. Joint work with Harold Booth, John Kelsey, and René Peralta.

Outline

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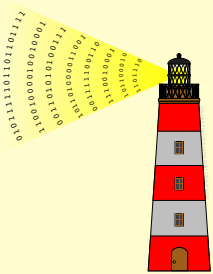
A Randomness Beacon

A service that produces timed outputs of fresh public randomness.



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High-level description:

- Periodically *pulsates* randomness (e.g., 1 per min)
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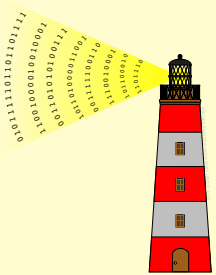
- Any past pulse is publicly accessible
- The sequence of pulses forms a hash-chain



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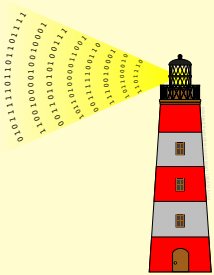

Can be useful for:

Not good for:

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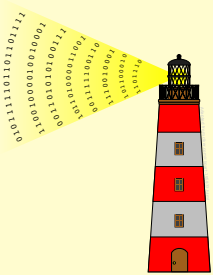

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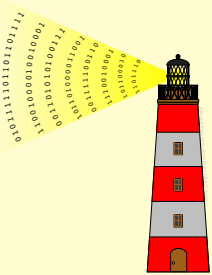

Can be useful for: (i) public auditability of randomized processes; (ii) coordination between many parties; (iii) prove something happened after a certain time.

Not good for: selecting your secret keys

Conceived applications

Clinical trials.
The public can check the trial was properly randomized.

Legal metrology.
Ensure fresh proofs of software possession by measuring instruments.

Financial audits.
Select public official for audit, without risk of political biasing.

Judge selection.
Defenders and prosecutors verify unbiased choice of judge to court case.

Quality control.
Build audit trail for later verification of the selected sample.

Historical notes

- **2011:** Start of Beacon project @ NIST, to promote development of randomness Beacons.
- **2012:** Internal grant: research QRNG, and implement a NIST Rand. Beacon.
- **2013-Sep till 2018-Dec:** NIST Beacon service version 1.0 online
- **2015:** Experimental validation of Bell loophole-free inequalities.

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- **2013-Sep till 2018-Dec:** NIST Beacon service version 1.0 online
- **2015:** Experimental validation of Bell loophole-free inequalities.
- **2018:** QRNG based on photon detection (by Physics Measurement Lab).
- **2018-Jul till present:** NIST Beacon service version 2.0 online
- **2019-May:** "Draft NISTIR 8213: *A Reference for Randomness Beacons* (version 2)
- **2023 (upcoming):** Final version of NISTIR 8213 and open-source code.

NIST Project: Interoperable Randomness Beacons

In 2019: project renamed to differentiate various tracks.

- **Track A: promote a reference for randomness beacons**
- **Track B: maintain a NIST Randomness Beacon implementatation**
- **Track C: promote the deployment of multiple independent Beacons**
- **Track D: promote applicaitons of beacon-issued randomness**
- **Track E: complementary initiatives about trusted randomness**

https://csrc.nist.gov/projects/interoperable-randomness-beacons

Outline

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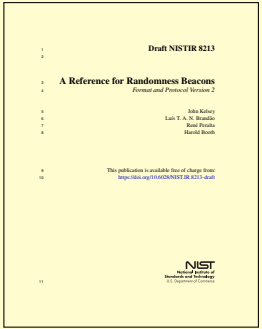
Subtitle: Format and Protocol Version 2. https://doi.org/10.6028/NIST.IR.8213-draft (May 2019)



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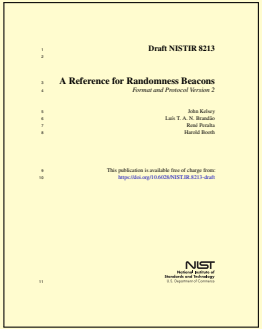
- protocol for beacon operations
- using Beacon randomness
- security considerations



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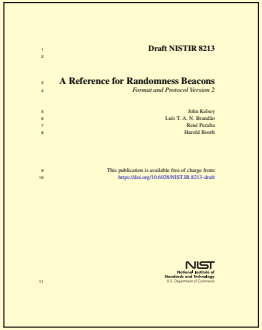

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Final version will be published in 2023, along with open-source code.

Fetching pulses

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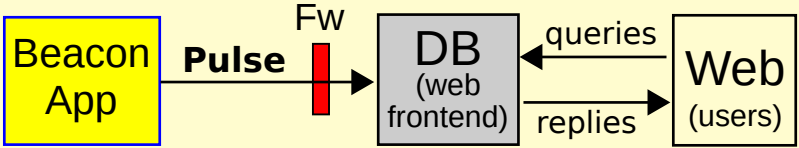
Beacon App: a *pulse release* means *sending the pulse to the database*



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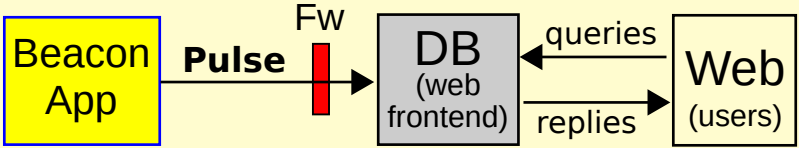
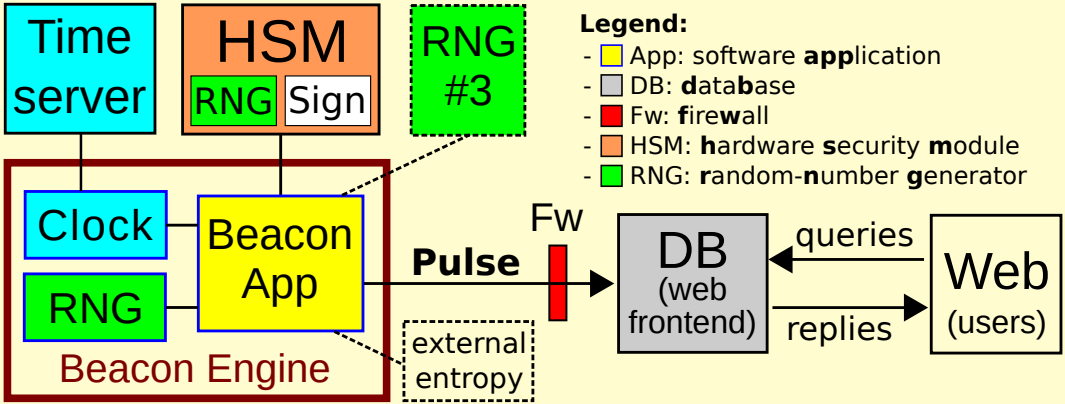


Users request pulses from the database using a URI/URL.

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

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

Components of the Beacon service, at a high level



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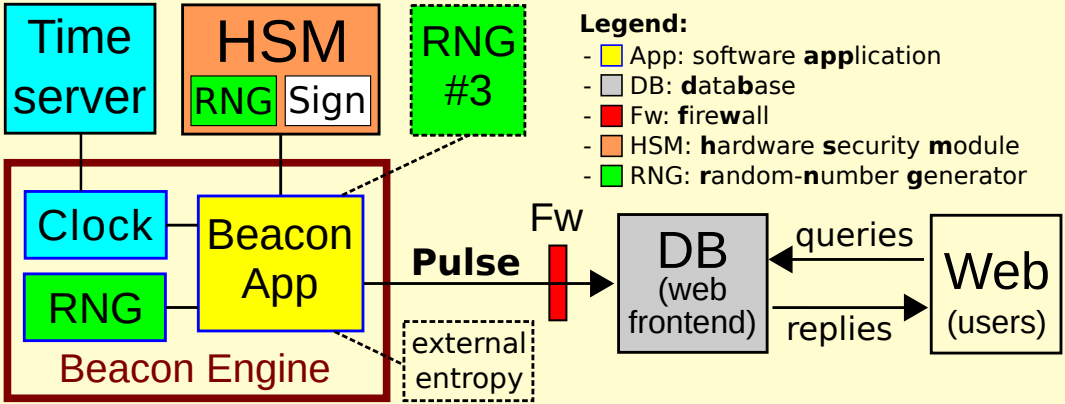

But what exactly is a *pulse*, what is its randomness, ...?

Outline

The two “rands” in a pulse

randLocal (a.k.a. local random value):

randOut (a.k.a. output value):

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randLocal (a.k.a. local random value):

- Hash (SHA512) of randomness output by ≥ 2 RNGs
- Pre-committed 1 minute in advance of release
- Useful for combining beacons

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- Hash (SHA512) of randomness output by ≥ 2 RNGs
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randOut (a.k.a. output value):

- Hash of all other fields
- **Fresh** at the time of release
- The actual randomness to be used by applications

The two “rands” in a pulse

Pulse i
T_i=2019-05-17T16:1**3**:00.000Z
...
out.Prev: R_{i-1}=0110...
...
rand**Local**: r_i = 1001...
preCom: C_i = 0101...
...
sig: S_i = 1010...
rand**Out**: R_i = 1110...

Pulse i+1
T_i=2019-05-17T16:1**4**:00.000Z
...
out.Prev: R_i = 1110...
...
rand**Local**: r_{i+1} = 1101...
preCom: C_{i+1} = 0010...
...
sig: S_{i+1} = 0111...
rand**Out**: R_{i+1} = 1011...

The two "rands" in a pulse

`randLocal`: r_{i+1} $= \text{Hash}(\rho_{1,i} \mid\mid \rho_{2,i}\ [\mid\mid \rho_{3,i}])$, with random $\rho_{j,i}$ from i^{th} RNG

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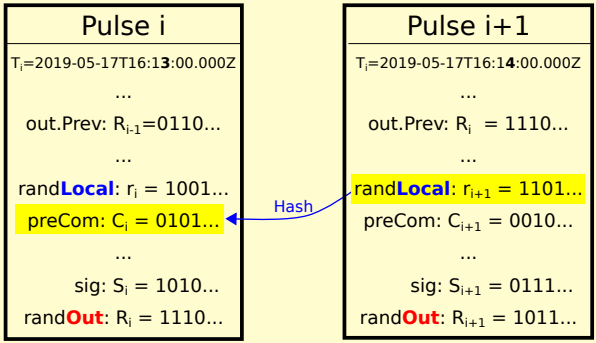

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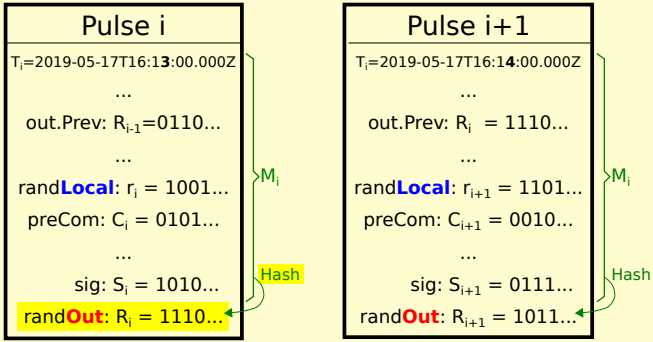

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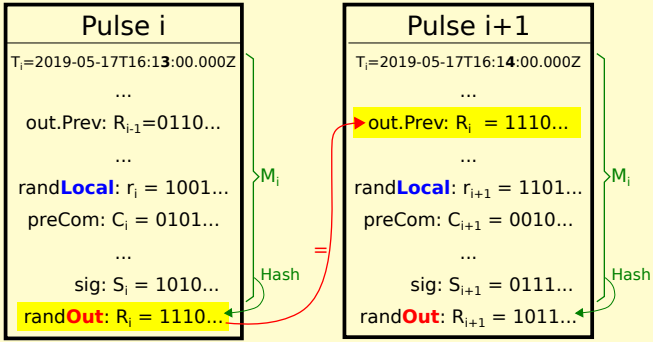

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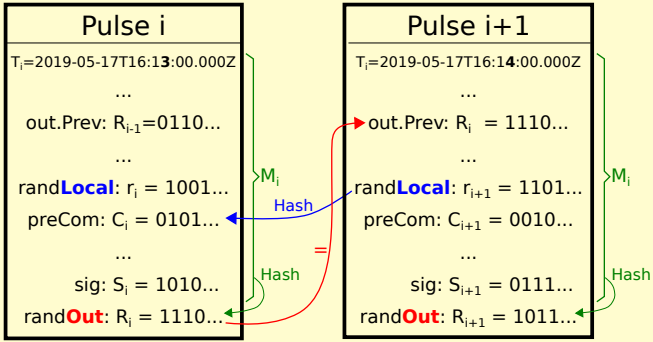

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A pulse (simplified example)

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uri:str="https://beacon.nist.gov/beacon/2.0/chain/1/pulse/220394"
version:str="2.0"
...
period:dec="60000"
...
chainId:dec="1"
pulseId:dec="220394"
time:str="2018-12-26T16:07:00.000Z"
randLocal:hex="5FF1E0C019C42C77FA72D522...(512 bits total)"
...
out.Prev:hex="BA646CC4E7AE195D2C85E9D3...(512 bits total)"
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- Other features: signature

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- Other features: signature, precommit `randLocal`, chain `randOut`, ...

Outline

Other notes on Beacon operation

- **Skiplists:** for efficient verification chain verification
- **Combining beacons:** Coin-flipping based on preCom before opened localRand
- **Timing requirements:** various "promises" and recommendations
- **Beacon interface:** specifies how to get useful info from a beacon
- **External values:** to mitigate advanced computation attacks (by malicious beacon)
- **Future guidance (extra documents):** recommendations on using beacon randomness, external values, combining beacons, ...

Skiplists — efficient chain verification

How to prove that an **old** pulse is consistent with a **recent** pulse?

Example: ANCHOR = **2019-05-17 14:12** → TARGET = **2016-02-14 17:45**

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Efficient: check a **skiplist** (< 125 pulses), using the 5 *past output* fields:

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Efficient: check a **skiplist** (< 125 pulses), using the 5 *past output* fields:

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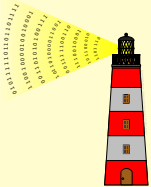
- **Stay tuned:** Soon **NISTIR 8213** final; open-source code of NIST Beacon.

- Draft NISTIR 8213: https://doi.org/10.6028/NIST.IR.8213-draft
- Email for feedback on the NISTIR 8213: beacon-nistir@nist.gov
- https://csrc.nist.gov/projects/interoperable-randomness-beacons



Thank you for your attention

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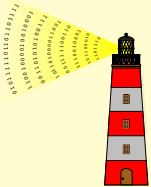

Presentation at the The Randomness Summit 2023

March 30th, 2023 @ Tokyo, Japan

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