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Integrating Multiple Randomness Sources in an SP 800-90C RBGC Framework

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What the What, Now?

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- We examine the implications of the “new” SP 800-90C document.
- We look at an SP 800-90C restriction on the Get_entropy_bitstring() interface and highlight some consequences of this restriction to common design patterns.
- We present a design that resolves many of these issues.
- We discuss some relevant parts of CMVP’s recently proposed draft SP 800-90C IGs.

SP 800-90?

These NIST documents define how randomness can be produced in FIPS 140-3, with likely broader eventual applicability.

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- SP 800-90A defines specific DRBGs (CSPRNGs with specifically designed interfaces and capabilities) which provide computational resistance to attack.
- SP 800-90B defines interfaces and capabilities for Entropy Sources suitable for seeding the SP 800-90A DRBGs.
- SP 800-90C defines a few specific design patterns (RBGs) which combine DRBGs and Entropy Sources.
- In the mid-term (say, 18 months), all key generation in FIPS 140-3 modules will need to occur using validated SP 800-90C RBGs.

Interfaces

SP 800-90C has some requirements placed at the level of abstract interfaces.

- The Get_entropy_bitstring() interface is the only way that 90C constructions get entropy they can credit.
- Get_entropy_bitstring() has some restrictions.

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"The Get_entropy_bitstring process **shall** only be used to access one or more **validated** entropy sources. Any non-validated entropy sources **shall** be accessed by a separate process to avoid possible misuse."

- 90C Section 3.1, Item 1

An Interface Restriction

Abstract interface requirements can impose design restrictions.

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- Many situations exist where a single source base or binary is used across multiple Operating Environments (OEs).
- The validation status of the OEs' Entropy Sources (ESs) varies, and there is little that vendors can do about that.
  - E.g., Intel and AMD RdSeed ESV certificates apply to very specific chips.
  - Many such designs are well-engineered physical noise sources and when such ESs are available their output ought to be integrated into the DRBG internal state as a matter of good engineering practice, even if their output cannot be credited as contributing entropy.

JEnt Limitations

JEnt is a common approach to satisfying the entropy requirements, but it is hardware-dependent and fragile.

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- The Jitter Entropy Library (JEnt) is commonly used in OEs where the underlying hardware ES may or may not be validated.
- Modern JEnt is mostly straightforward to validate for specific hardware, but...
  - It is a classic non-physical (found) Entropy Source and developing a conservative entropy bound for it is fraught.
  - It requires configuration based on hardware-specific testing.
  - The resulting validations are fragile and are hardware- and configuration-specific.

Multiple OE Flexibility

Complying with CMVP requirements should not result in a less secure system.

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- To account for the shifting ES validation status across multiple OEs / implementations, we need a way to combine the contributions of validated and non-validated ESs.
  - The validation status of each ES may not be known by the implementation *a priori*, but…
  - Validation status of these ESs for all evaluated OEs will be known and verified during the 90C (and FIPS) validation.
- Vendors seeking ease of validation commonly exclude reasonable ESs for transient validation status reasons.
  - This effectively incentivizes brittle designs to reduce validation effort.

A Modest Proposal

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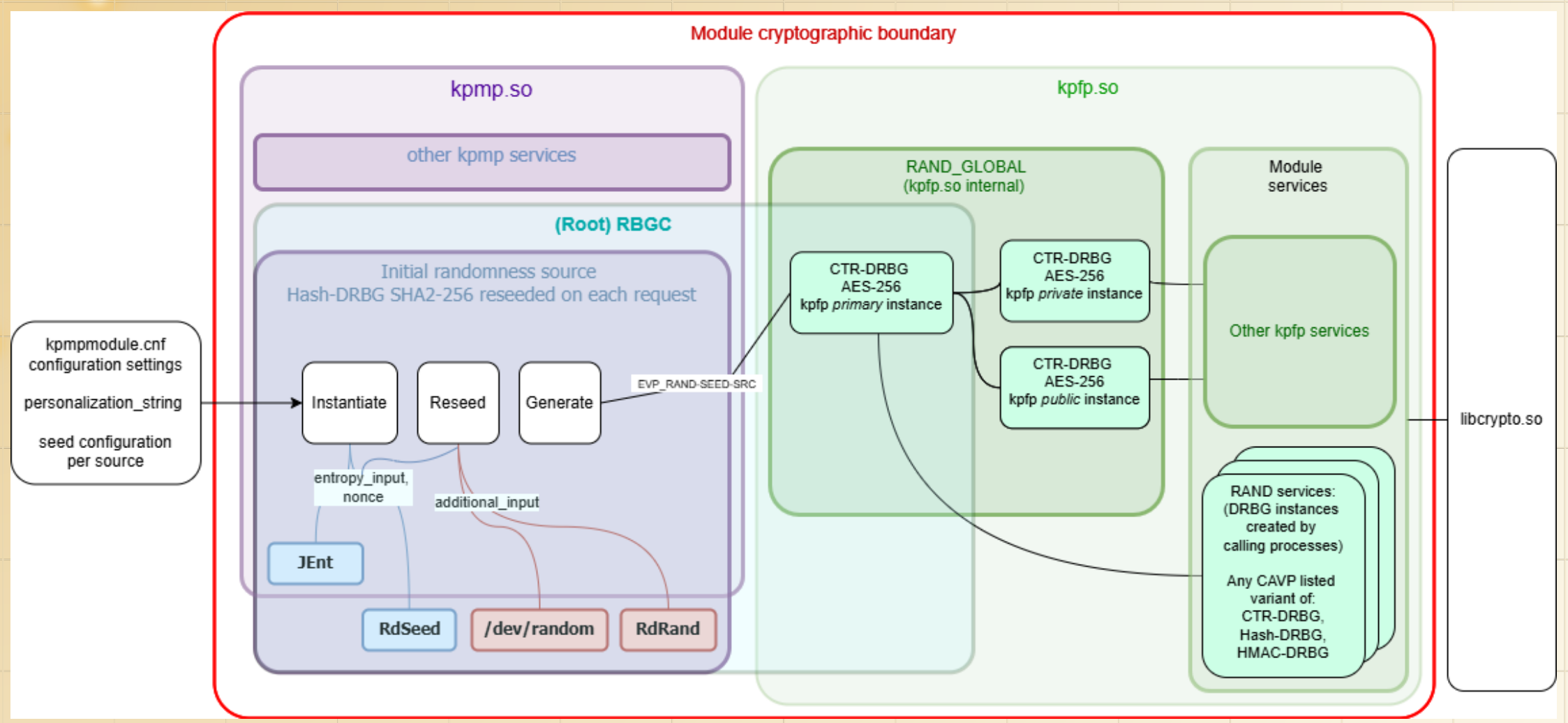
We propose a solution that:

- Offers SP 800-90A/B/C compliance using a full RBGC construction.
- Addresses the Get_entropy_bitstring() non-validated entropy source exclusion issue.
- Is easily integrated into existing libraries.
  - Many libraries (and their users) presume that all seeds are full entropy.
  - Most libraries lack a centralized infrastructure for distributing *additional_input*.
- Is configurable to support multiple OEs.
  - Make the implementation invariant and push OE-specific details to configuration.



Our Proposed Solution

The RBGC Initial Randomness Source

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The RBGC Initial Randomness Source (IRS) RBG is central to the RBGC Root construction. To address these goals, it should:

- Produce strings that are either full entropy or have a defined security strength.
- Integrate input from all available healthy ESs, both validated and non-validated.
  - Compliantly segregate the output of validated ESs from the output of other ESs.
  - Use a conservative DRBG design that cryptographically integrates *additional_input*.
- When multiple validated ESs are available, degrade gracefully in the event of failures.

The RBGC IRS

Decisions, Decisions!

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The RBGC Initial Randomness Source (IRS) RBG implemented here:

- Uses a SHA2-256 Hash_DRBG with a security strength (s) of 256.
- Is an RBG that can be configured to:
  - Be (or act “much like”) a fault-tolerant RBG3(RS),
    - Only physical entropy sources can be counted for a true RBG3(RS).
    - In this mode, if the only validated ESs are non-physical, this results in an RBG2(NP) with prediction resistance for every request.
  - Or be a compliant RBG2.
- DRBG Instantiation is similar for the two cases.
  - A personalization string is provided by configuration.
  - $3s/2$ bits are provided from each validated entropy source.

The RBG2 Mode

Conservative and compliant.

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- The RBGC IRS is an RBG2, which establishes its reseed requirements.
  - On reseed, all of the healthy validated ESs have an opportunity to contribute s (256) bits of entropy.
  - There must be a Reseed operation if 2^{17} or more bits were output since the last reseed / instantiate.
  - If adequate entropy from validated ESs is present in a FIFO when a Generate is requested, then a Reseed is opportunistically performed.
  - Otherwise, buffered output from the non-validated ESs can still be integrated into the Generate function as *additional_input* (n.b.: this does not count as a "reseed" for the reseed cadence requirements).
- The DRBG generate size restrictions are enforced on a per-generation basis.

The RBG3(RS)-Like Mode

An extra assurance mode.

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- The RBGC IRS DRBG reseed cadence is the same as for the DRBG in an RBG3(RS).
  - Every generate is preceded by a (RBG3(RS)-Method-A style) Reseed.
  - s+64 (320) bits of entropy are requested from **each** of the healthy validated ESs.
- The RBG3(RS) DRBG generate size restrictions are enforced.
  - The RBGC IRS RBG DRBG produces at most s (256) bits per generate.

Reseed Similarities

In all cases, we use data from all available entropy sources.

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In both cases:

- The *seed_material* for the Reseed is the concatenation of the entropy strings produced by the healthy validated ESs.
- The RBGC IRS RBG also uses similar amounts of information from the non-validated ESs as *additional_input* for the Reseed.

Recent Developments

Certain IG drafts are relevant.

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The Draft IG D.T ENT.1 allows somewhat more flexibility in Get_entropy_bitstring():

- This only applies to RBGC constructions; it is unclear if this will apply to the IRS, which must itself be validated as an RBG2 or RBG3(RS).
- This only includes an allowance for ESs that are validated on some covered platform.
- This imposes additional error handling requirements.

The Cryptographic Boundary and the RBGC

Draft IG D.U allows only certain relationships between the cryptographic boundary and RBG boundary.

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- Each RBG has a boundary, and the relationship between this RBG boundary and a cryptographic boundary is discussed in the draft IG D.U.
- The RBGC Root definitionally contains the IRS (and its entropy sources) and the RBGC root DRBG.
- The RBGC and FIPS module must be contained within the same “computing platform” (TOEPP for software/firmware modules).
- The cryptographic boundary must contain:
  - The entire RBGC Root (including the IRS), or
  - An RBGC root DRBG which is seeded using data that crosses into the FIPS module, or
  - An RBGC non-root DRBG which is seeded using data that crosses into the FIPS module.
- When such data crosses the cryptographic boundary, the appropriate SSP I/O requirements apply.

That the That, Now!

SP 800-90C compliance can result in security improvements.

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- Use every entropy source but credit only the validated ones.
- Use the same binary and source base across many platforms and configure them on a per-platform basis.
- One IRS, two modes.
- CMVP is moving toward requiring SP 800-90C RBGs.

Thanks!

Any Questions?