Bundesamt für Sicherheit in der Informationstechnik

Overview of AIS 20/31

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Random Bit Generation Workshop 2023

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AIS 20 and AIS 31

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- AIS 20 and AIS 31
  - are evaluation guidelines for RNGs for cryptographic applications.
  - have been effective in the German certification scheme (Common Criteria) since 1999, resp. since 2001.
  - both refer to a joint mathematical-technical reference
    - for short usually also called AIS 20, AIS 31, or AIS 20/31 (depending on the context).
    - We follow this convention.
- The current version of the mathematical-technical reference has been effective since 2011.

New AIS 20/31

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- The mathematical-technical reference AIS 20/31 is currently being updated.
- September 2022: Draft version 2.35 published (co-authored by Matthias Peter and Werner Schindler)
- Comment period ended on February 15, 2023. **Thank you for all comments!**
- Intermediate document (version 2.36, considers numerous comments) will be online by Friday
https://www.bsi.bund.de/dok/randomnumbergenerators
- A hybrid workshop will be held next week in Bonn (June 5 - June 7).

AIS 20/31 and SP 800-90 [A,B,C]

- BSI and NIST have been in an ongoing process of harmonizing AIS 20/31 and SP 800-90[A,B,C].
- BSI and NIST: joint presentations at ICMC 2021, ICMC 2022, and ICMC 2023.
- Currently, BSI and NIST are working on a joint document that compares central features of AIS 20/31 and SP 800-90[A,B,C].
  - explains similarities and differences between functionality classes (AIS 20/31) and RBG constructions (SP 800-90 series)
  - More information is provided in the following presentation
    Kerry McKay: Bridging the Gap Between the SP 800-90 Series and AIS 20/31

AIS 20/31: Basic Philosophy

- The AIS 20 and the AIS 31 are technology neutral.
- The AIS 20 and the AIS 31 do not specify approved designs.
- Instead, functionality classes are defined.
  - Security requirements are specified that RNGs shall fulfil in order to comply.
  - The applicant for a certificate (usually the developer) and an accredited evaluation lab have to give evidence that the RNG meets the class-specific requirements.

Classification of RNGs

- **DRNGs** deterministic RNGs
  - the random numbers depend on
    - the seed,
    - (optional): + on reseeding + additional input
- **PTRNGs** physical true RNGs (short: physical RNGs)
  - physical noise source
    - exploits physical phenomena from dedicated hardware designs or physical experiments
- **NPTRNGs** non-physical true RNGs
  - non-physical noise source
    - no dedicated hardware design
    - typically, exploits system data (timing values, RAM data, etc.) or user's interaction (mouse movement etc.)

New AIS 20/31: Functionality classes

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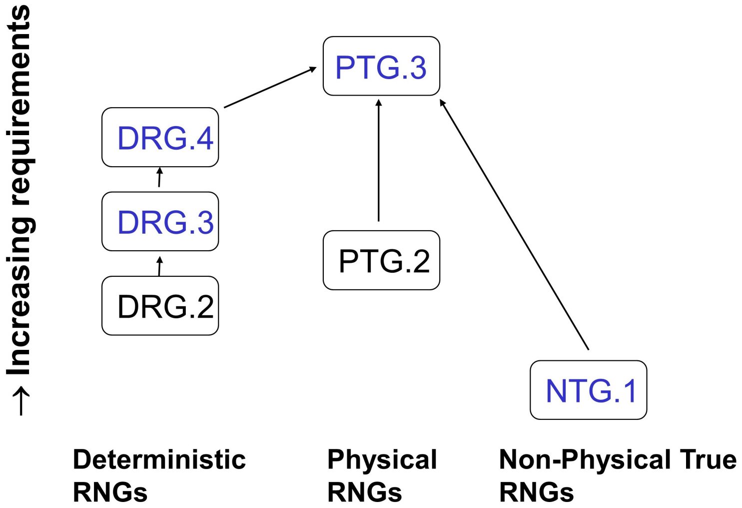

DRNG: functionality classes

- The functionality classes again ensure
  - DRG.2: backward secrecy and forward secrecy
  - DRG.3: + enhanced backward secrecy
  - DRG.4: + enhanced forward secrecy
    (requires hybrid DRNGs)
- Comparison with SP 800-90: Rough correspondences

  enhanced backward secrecy $\cong$ backtracking resistance
  enhanced forward secrecy $\cong$ prediction resistance

DRNGs: Important new features

- The notion of request has been introduced.
- The notion of effective internal state has been introduced.
- *Under suitable conditions* 'DRNG seeding DRNG' is permitted.

Effective internal state

- Part of the internal state of a DRNG that an adversary does not know and cannot determine or guess (with significantly larger probability than for blind guessing) even if the adversary has seen many random numbers.
- Entropy (effective internal state) after (re-)seeding / after additional high-entropy input: $\geq$ 240 bits min-entropy
  - Under suitable conditions, alternatively $\geq$ 250 bits Shannon entropy can be claimed.
- Goal: Shall prevent multi-target attacks and attacks by quantum computers (Grover's algorithm).

DRNG seeding DRNG: seed tree

- Usually, DRNGs are seeded by true RNGs (recommended, if possible)
- There are scenarios in which no true RNG is available.
  Example: The DRNG of the operating system has been seeded by an NPTRNG, and the applications call this DRNG for seed material to seed their own DRNGs.
- When using seed material from another DRNG additional problems have to be considered.
- For all (possible) reseeding procedures each DRNG must use the same seeding DRNG as for the seeding procedure.
  - This requirement prevents seed cycles!
  - This implicitly defines a seed tree. Its root ('root DRNG') is seeded by a true RNG.
- The requirements of BSI and NIST are rather similar.

DRNG seeding DRNG: seed tree

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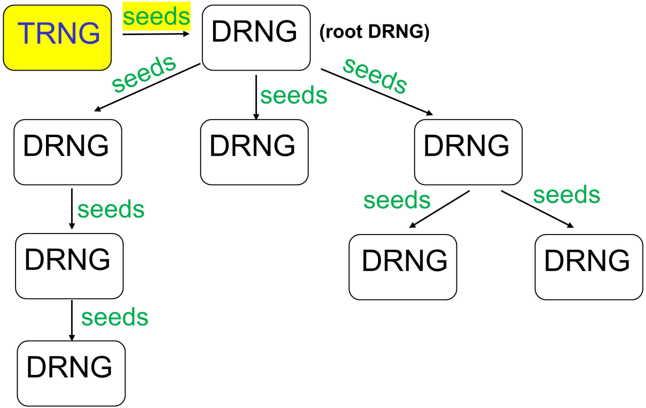

90A-compliant DRBGs: Conformity proofs

- AIS 20/31 contains a conformity proof for the Hash_DRBG to class DRG.3 (algorithmic properties).
- AIS 20/31 contains a conformity proof for the HMAC_DRBG to class DRG.3 (algorithmic properties).
  - For the central points of the proof AIS 20/31 refers to a paper of John Kelsey (NIST); paper to be published
- Applicants for certificates can simply refer to these conformity proofs.

Stochastic model

- The stochastic model is the 'core' of each PTRNG evaluation (PTG.2, PTG.3)
- Random numbers are interpreted as realizations of random variables.
- Aim: Verification of a lower entropy bound per *internal random bit* (= random bits after postprocessing)

Stochastic model (II)

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- The raw random numbers shall be (time-locally) stationarily distributed.
  - Slow drifts of the parameters are permitted as long as the entropy remains sufficiently large.
- Ideally, the stochastic model specifies a class of distributions that contains the (unknown) true distribution of the (usual case) raw random numbers during the lifetime of the PTRNG.

Stochastic model (III): Toy example in a nutshell

- A coin is tossed N times; '1' $\cong$ 'head' and '0' $\cong$ 'tail'
  - outcome: $x_1, \ldots, x_N \in \{0, 1\}$
- $x_1, \ldots, x_N \cong$ realizations of random variables $X_1, \ldots, X_N$.
  - Coins have no memory.
  - $\Longrightarrow X_1, \ldots, X_N$ may be assumed to be independent and identically $B(1, p)$-distributed (Bernoulli distribution)
  - parameter $p := \mathrm{Prob}(X_j = 1)$ is unknown
- Stochastic model: $X_1, \ldots, X_N$ are independent and identically $B(1, p)$-distributed with $p \in [0, 1]$.
  - The stochastic model fits to other coins, too, and would tolerate drifts of p for the same coin in course of time.
  - Estimate p on the basis of $x_1, \ldots, x_n$
  - Substitute its estimate $\tilde{p}$ into the (1-dimensional) entropy formula.

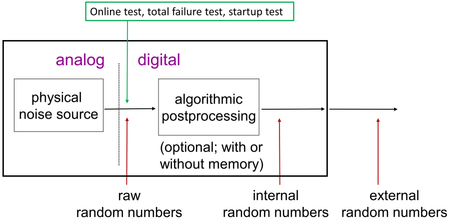
Stochastic model (IV)

- The applicant has to give evidence that the stochastic model fits to the physical noise source (includes digitization).
  - The stochastic model shall be based on the understanding of the noise source.
  - The argumentation should be supported by engineering or physical arguments, by findings from the literature, by tests on empirical data etc.
  - AIS 20/31 discusses in detail several stochastic models of real-world physical noise sources.
- Presentation: Johannes Mittmann (BSI): Use of stochastic models in RBG standards

Online test and total failure test

- The online test shall detect non-tolerable weaknesses (sufficiently) soon.
  - The online test shall be tailored to the stochastic model.
- The total failure test shall detect total failures of the noise source very fast. The output of weak random numbers must be prevented.
  - The justification shall be supported by engineering arguments (failure analysis).

PTRNG: Functionality class PTG.2

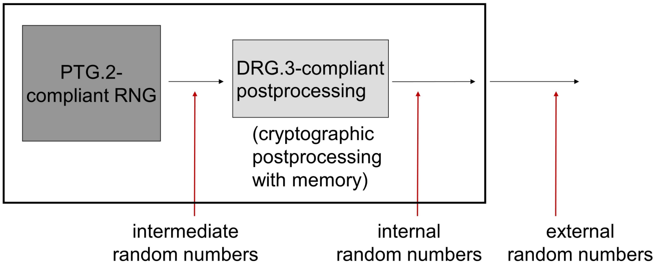


- ‘Pure’ PTRNG
  - algorithmic postprocessing (e.g., XOR)
  - ‘no postprocessing’ and cryptographic postprocessing are also permitted
- raw random numbers:
  - time-locally stationarily distributed
- Entropy (one or both claims are possible [selection])
  - Shannon entropy / output bit ≥ 0.9998.
  - Min-entropy / output bit ≥ 0.98.
- Effective online test and total failure test, startup test

PTRNG: Functionality class PTG.3

- Physical RNG with
  - strong, well-understood physical noise source
  - effective online test and total failure test, startup test
  - cryptographic postprocessing with memory
    - If the postprocessing algorithm runs autonomously it can be viewed as a DRG.3-compliant DRNG.

PTG.3: typical design



- The evaluation can be divided into two separate steps:
  - PTG.2-compliance of the 'inner' PTRNG
  - PTG.3-compliance of the entire RNG
    (possibly at a later date, with another applicant)
- Different companies can be involved in these evaluations.

PTG.3: Entropy claim

- The applicant (developer) can apply for Shannon entropy, for min-entropy, or for both [selection].
- (as before) The input rate of the cryptographic postprocessing is $\geq$ than its output rate.
- Furthermore, now individual entropy claims are possible (requires data compression!).
  - (Shannon entropy) claim $v_S \in [0.9998, 1 - 2^{-32}]$
  - (min-entropy) claim $v_M \in [0.98, 1 - 2^{-32}]$
  - Important special cases are treated in AIS 20/31. Explicit formulae are provided.

PTG.3: Example (entropy claim)

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- PTG.2-compliant RNG generates the intermediate bits. Assumptions:
  - min-entropy ≥ 0.98 per bit
  - output size (cryptographic postprocessing): 256 bits
  - The cryptographic postprocessing can be modelled by a random mapping (depends on the algorithm!)

- Then: input size (intermediate random numbers) $\geq 256 + 64 + 7 = 327$ bits
  $\rightarrow$ min-entropy / output bit $\geq 1 - 2^{-32}$.

NPTRNGs

- Main differences to PTRNGs
  - problem: designer / evaluator cannot control the environment where the NPTRNG is operated (typically run on PCs, servers, etc.)
  - usually does not allow precise stochastic modeling
  - instead: conservative entropy estimates and a large data compression rate
    - goal: derive a trustworthy lower entropy bound under conservative (realistic) assumptions on the noise source and the abilities of potential attackers

NTG.1

- min-entropy claim $v_M \in [0.98, 1 - 2^{-32}]$ per output bit
- No random numbers are output until at least two different noise sources have provided 220 bits min-entropy. The two noise sources shall employ different principles to provide randomness.

New AIS 20/31 (Structure of the document)

1. **Introduction**
2. **AIS 20 and AIS 31 — scope, limits, and concepts** [informative]
3. **Functionality classes** [normative]
   class requirements, application notes, general explanations
4. **Mathematical Background** [mainly informative]
5. **Examples** [mainly informative]

\+ **Glossary** [normative]

AIS 20/31 Workshop

- **Date:** Monday, June 5 - Wednesday, June 7 (2:30 pm - 7:00 pm CEST ('German time'))
- **Type:** hybrid (physical, virtual)
- **Registration:** by e-mail: ais-20-31@bsi.bund.de
- **Registration deadline:** extended to June 2, 2023
- participation is free of charge
- We are glad about your participation.
- **Workshop program:** `https://www.bsi.bund.de/SharedDocs/Termine/EN/2023/Presentation-Draft-AIS-20-31.html`

Contact

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