The Current Status and Entropy Estimation Methodology in KCMVP

in ICMC16

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National Security Research Institute
SeogChung Seo, SangWoon Jang

Kookmin University
Yongjin Yeom

KCMVP?

KCMVP

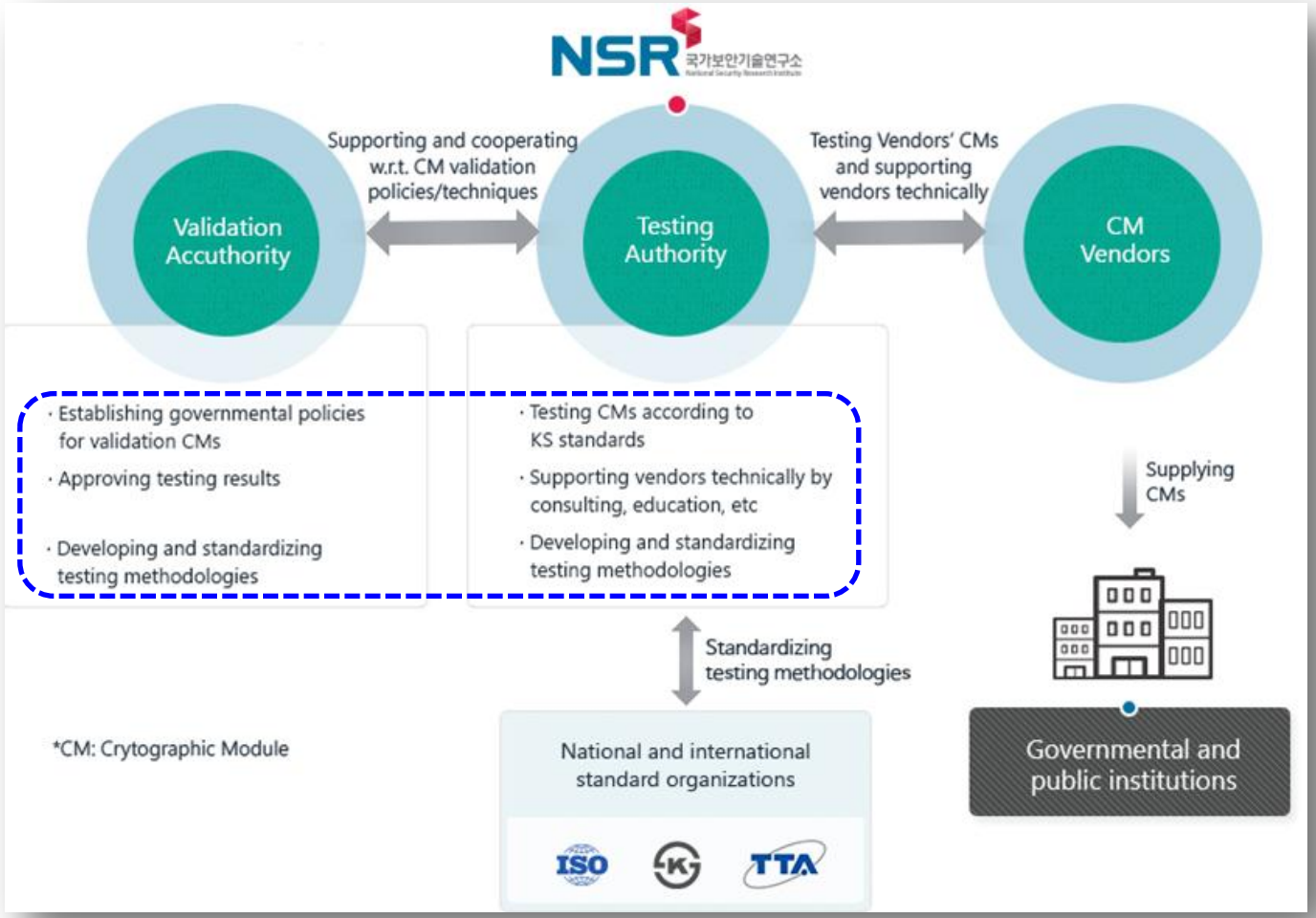
Korea Cryptographic Module Validation Program

- Validating security and implementation conformance of a CM for the protection of sensitive information in governmental/public institutions
- CAVP is conducted in KCMVP process
- Since 2005

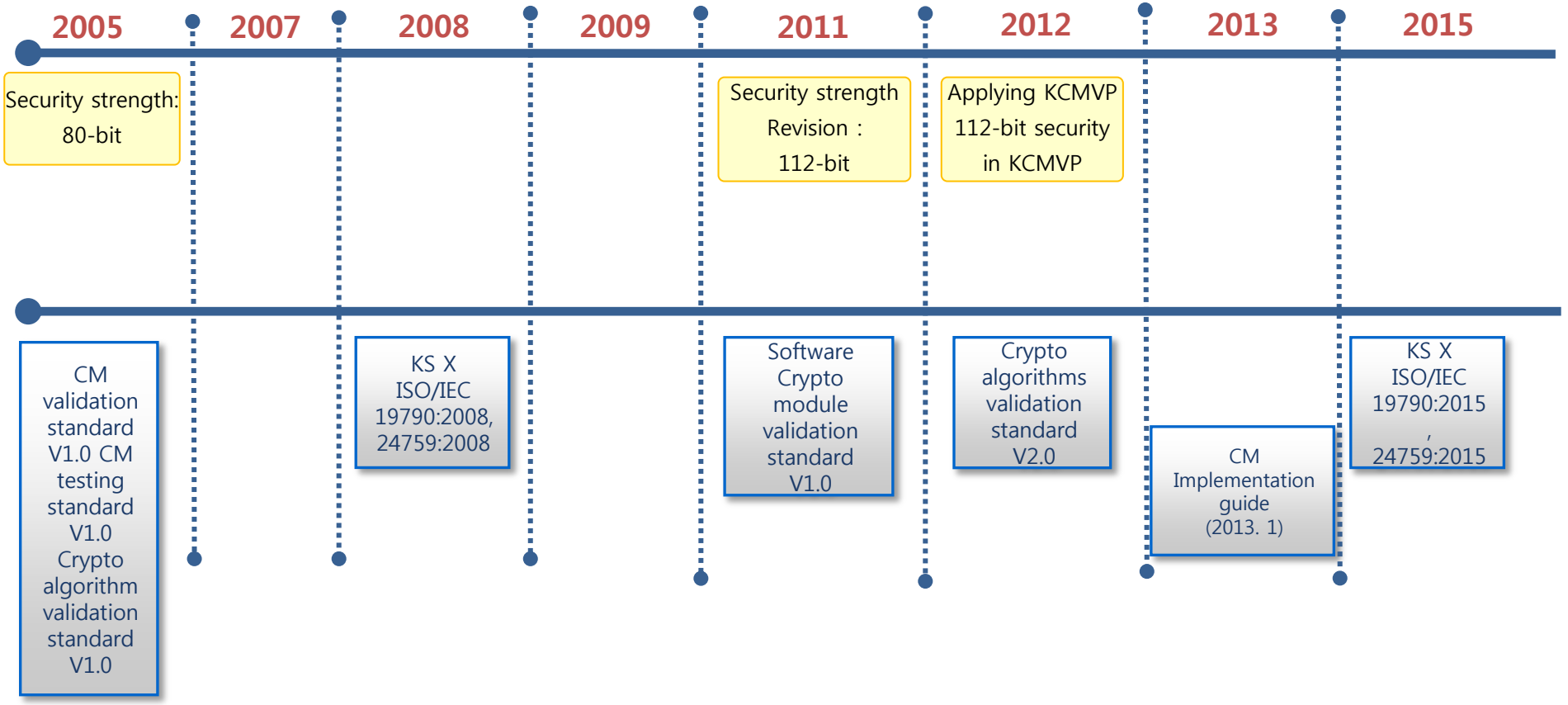
Standard

- Security Requirements : KS X ISO/IEC 19790:2015
- Test Requirements : KS X ISO/IEC 24759:2015
- Approved Algorithms : ISO/IEC, KS, TTA

KCMVP?

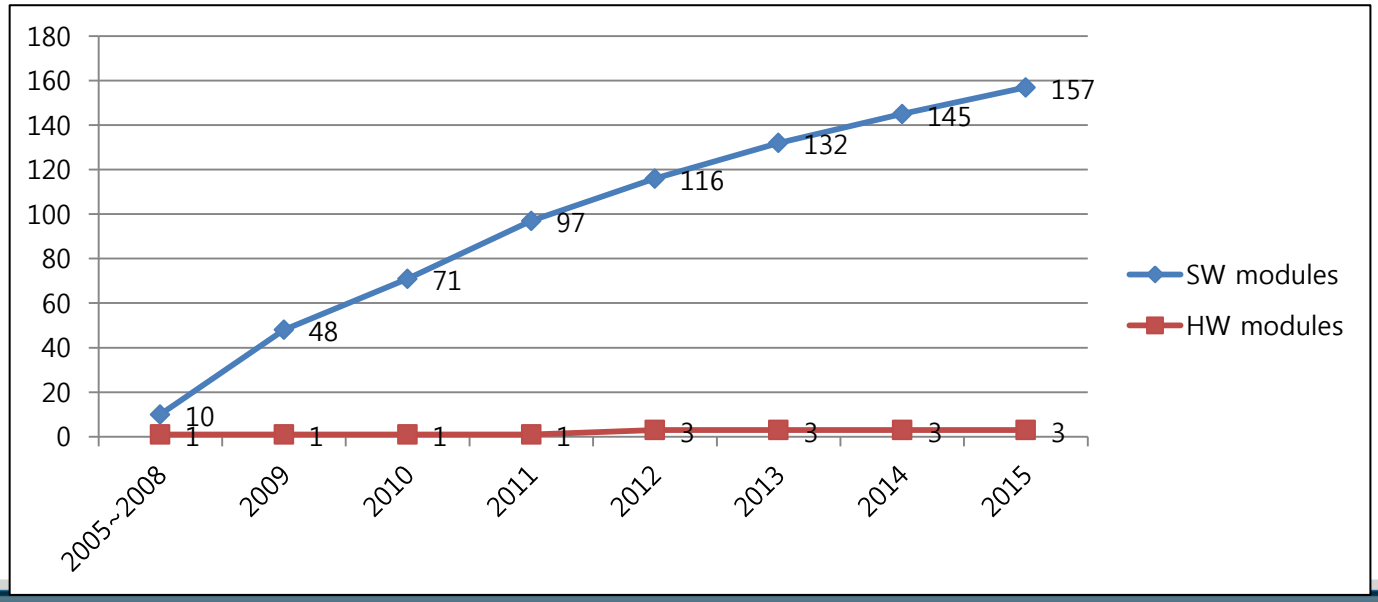

NSR
국가보안기술연구소
Validation Accuthority
Supporting and cooperating w.r.t. CM validation policies/techniques
Testing Authority
Testing Vendors' CMs and supporting vendors technically
CM Vendors
· Establishing governmental policies for validation CMs
· Approving testing results
· Developing and standardizing testing methodologies
· Testing CMs according to KS standards
· Supporting vendors technically by consulting, education, etc
· Developing and standardizing testing methodologies
Supplying CMs
Standardizing testing methodologies
*CM: Crytographic Module
National and international standard organizations
ISO
TTA
Governmental and public institutions

History of KCMVP



Current validation statistics in KCMVP

- 160 modules are validated
  - **SW modules: 157, HW modules: 3**
    - Library: 100(User library >> Kernel library, C > Java > C++)
    - Crypto Applications: 57
- Operational environments
  - **Windows > Linux/Unix > Java > Mobile(android, iOS)**



Approved Algorithms in KCMVP

Types		Algorithms
Block cipher		ARIA-128/192/256, LEA-128/192/256, SEED, HIGHT
Hash function		SHA-224/256/384/512
MAC	Hash-based	HMAC(SHA-224/256/384/512)
	Block cipher-based	GCM(GMAC), CCM, CMAC
RBG	Hash_DRBG	SHA-224/256/384/512
	HMAC_DRBG	HMAC(SHA-224/256/384/512)
	CTR_DRBG	ARIA-128/192/256, LEA-128/192/256, SEED, HIGHT
Key establishment		DH, ECDH
Public key encryption		RSAES
Digital signature		RSA-PSS, KCDSA, ECDSA, EC-KCDSA

LEA: A 128-bit Block Cipher for Fast Encryption on Common Processors, WISA 2013, LNCS 8267, 2014.
HIGHT: A New Block Cipher Suitable for Low-Resource Device, CHES 2006, LNCS 4249, 2006.

KCMVP Test Process

CAVP
with KCAVS

Conformance test

CM Specification	- Understanding overall structure of CM - Checking approved mode & algorithms & CSP
Finite State Model	Consistency btw FSM and execution of CM
Roles, Services and Authentication	Supports concurrent users or not?
CM Ports and Interfaces	- Checking consistency btw documents and code - Checking unidentified information flows - Checking underlying cryptographic algorithms
Operational Environment	Testing CM on every operational environments
Key Management	- Conducting **Entropy analysis** - Checking key life management generation, store, input/output, zeroisation, etc - Checking underlying DRBGs
Self Tests	Conducting negative & positive selftests
Design Assurance	Checking development environments
Mitigation of Other Attacks	Conducting **Source code security analysis**

- Document review
- Source code analysis
- Func&Operational test

CAVP in KCMVP

- **CAVP test tool**
  - **KCAVS 4.1(revised at 2016)**
- **Most frequently used approved algorithms in KCMVP**
  - **Symmetric-key > Hash > MAC > RBG > Public key encryption > Digital signature > KE**
- **CAVP duration**
  - **Depends on types of algorithms**
    - KE > Public key algorithms > RBG > MAC/Hash > Symmetric
  - **Depends on vendor's knowledge on crypto and development**
  - **Need to develop CAVP test applications**

CAVP in KCMVP

- **Vendor's difficulties in CAVP**
  - **Effort to develop CAVP test applications → get better with sample codes**
  - **Lack of understanding CAVP process → get better with education**
    - DRBG test for RBG
    - MCT test for symmetric key
    - Public key algorithms (encryption, digital signature, KE), etc
  - **Format error → get handled with file I/O utilities**
  - **Algorithmic defects → easily find faults with log comparison**
    - Key/parameter generation in public key algorithms, CMAC/CCM, DRBG, etc
- **Our plan to develop methods for speeding CAVP up**
  - **Providing CAVP sample codes and utilities for easy file I/O**
    - Consider Endian, word size, operational environments, language
    - Consider algorithmic characteristics and CM's interfaces
    - Logging functions for tracking the algorithmic failure

Difficulties in Entropy Assessment

- It is infeasible to achieve perfect randomness in ideal coin-toss (unpredictable, unbiased, independent)
- It is required to prove (or show the evidence of) sufficient closeness to ideal randomness
- It is hard to develop criteria for lower bound of entropy estimations

Particularly for software modules,

- We have to justify whether the module collects sufficient entropy from the operating environment (not within the module)
- Most noise sources used in a software module are non-physical sources provided by OS

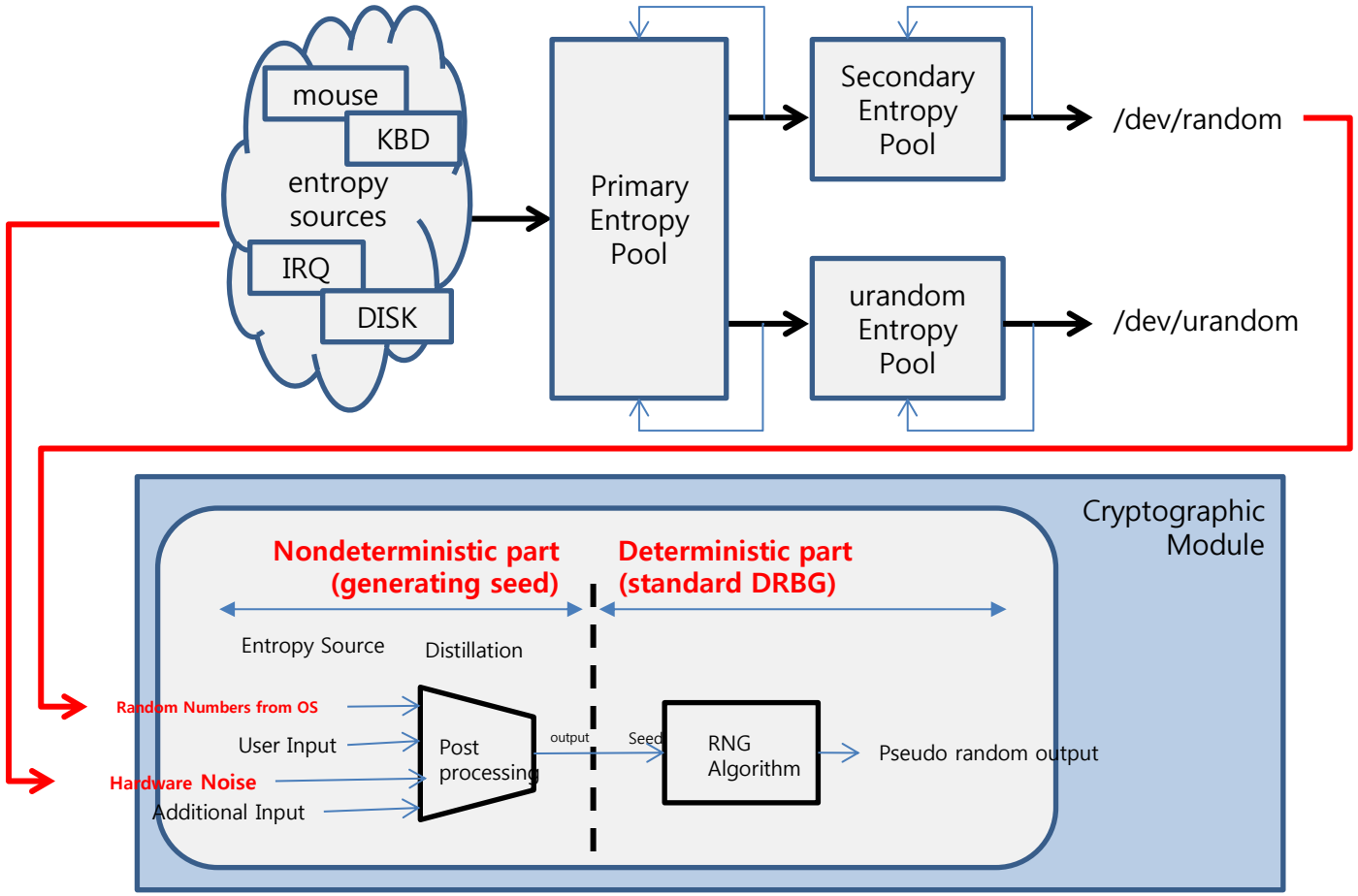
Referenced documents

- (SP 800-22) Statistical Randomness Tests
  - Suitable for evaluating final output of RNGs
  - Not applicable to digitized entropy sources (without post-processing/conditioning)
- (BSI AIS.31) Test for TRNGs
  - Evaluation criteria for TRNG(Physical RNG)s
  - Suitable for detecting physical failures (easy to pass)
- (SP 800-90B) Test for entropy sources (draft)
  - Conservative entropy assessment for noise sources

➔ Hard to adopt them to assess entropy in software modules

RNG in a software module

- Software module and its operating environment



Entropy sources in SW module

- Collecting entropy from the operating environment
- Not completely determined when the module is tested in KCMVP Lab.

The problems are…

- KCMVP has to finish the entropy assessment without knowing that the exact operating environment (only knowing the OS)
- It is hard to collect sufficient data for entropy estimation

Examples of entropy sources

- System functions such as GetCurrentThreadID(), GetCurrentProcessID(), and GetCursorPos()
- Output of RNG in OS: /dev/random, CryptGenRandom(), etc.

Estimation of entropy rate

- When collecting entropy from the physical noise source,
  we assume that each sample is harvested independently
- Then entropy rate (entropy per bit) can be regarded as constant

➔ If we estimate the amount of entropy in a single sample conservatively),
total entropy is expected to increase linearly

➔ Entropy estimations in 800-90B focus on the lower bound of entropy per sample

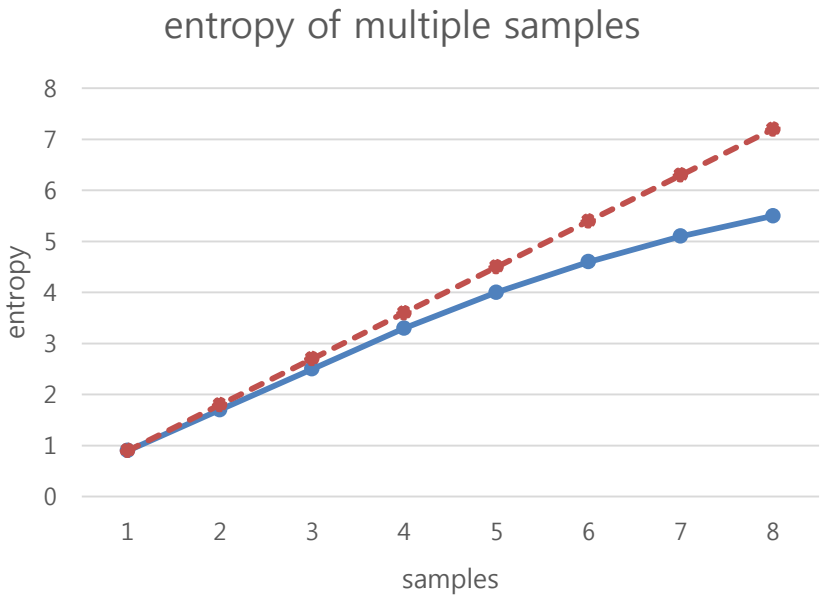
- However, samples are dependent (particularly in SW noise)
- Total entropy is not proportional to the number of samples
  (observed by the experiments)

Entropy estimation for multiple samples

- **Motivation**
  - CMVP requires to collect hundreds of bit of entropy for DRBG
  - How many times do we have to collect samples iteratively for sufficient entropy?
  - It is desirable to estimate the lower bound of entropy for multiple samples collected by repeated harvests

- **Observation**
  - Experimental results show that entropy does not increase linearly

➔ How can we find a lower bound?



Min-entropy of random variables

- **Notations**
  - Min-entropy of a random variable X : $H_\infty(X)$
  - Min-entropy of (X, Y) for the joint distribution : $H_\infty(X, Y)$
  - Product distribution $X \times Y$: $\mathrm{P}_{X \times Y}(X, Y) = P(X)P(Y)$

- **When we collect entropy from a single source repeatedly,**
  - Sequence of samplings : $X_1, X_2, \ldots, X_n$
  - Joint distribution (X_1, X_2) : distribution for double size sampling
  - Upper bound : $H_\infty(X_1, X_2) \leq H_\infty(X_1) + H_\infty(X_2) = 2H_\infty(X_1)$

➔ Can we have a lower bound for $H_\infty(X_1, X_2)$?

Lower bound Theorem for min-entropy

- **THEOREM for Lower bound**

  Let X_1 and X_2 be random variables for the repeated sampling model whose relative independence $RI(X_1, X_2)$ is bounded by ϵ ($RI(X_1, X_2) \leq \epsilon$). Then

$$H_\infty(X_1, X_2) \geq H_\infty(X_1) + H_\infty(X_2) - \epsilon \ln e \ .$$

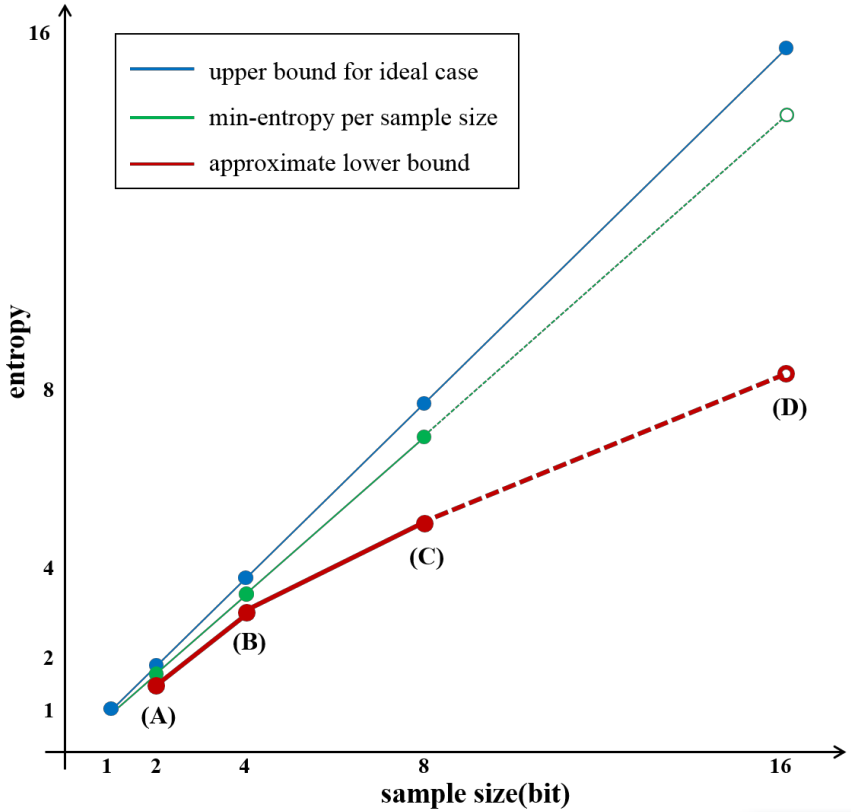
- **Remark**
  - Relative independence $RI(X, Y)$ is the rate of dependency defined as the smallest $\epsilon > 0$ s.t.

$$P_{X\times Y}(X, Y)\, exp(-\epsilon) \leq P_{(X,Y)}(X, Y) \leq P_{X\times Y}(X, Y)\, exp(\epsilon)$$

  - THEOREM says that if samples are collected repeatedly, the min-entropy of two adjacent samples has a lower bound determined by their relative independence
  - Applying THEOREM repeatedly, we have a lower bound for multiple samples

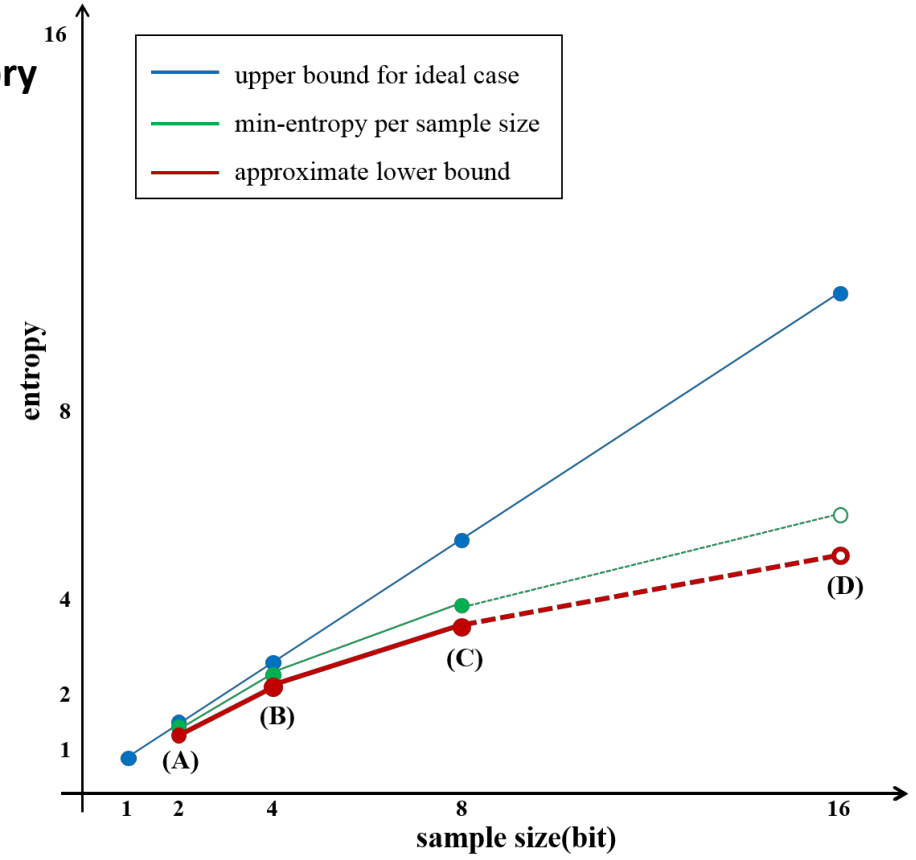
Example : min-entropy estimation

- Example: IID source
  - HW RNG: Quantum RNG (Quantis-USB by IDQ)
  - Sample size: 1 bit
  - 800-90B estimations for various sample sizes increase almost linearly
  - The lower bounds given by THEOREM seem to be very conservative



Example : min-entropy estimation

- Example: non-IID source
  - Entropy source: GPU (NVIDIA GTX780)
  - Rationale: Race conditions on shared memory
  - Sample size: 1 bit
  - 800-90B estimations (green curve) does not increase linearly (showing dependency)
  - The lower bounds given by THEOREM seem to be tight



Summary of entropy estimation

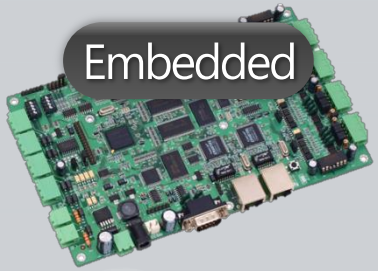
- In KCMVP,
  - Require minimum 112-bit entropy on raw noise data
  - Most of approved cryptographic modules are software modules
  - Entropy sources lies outside of the modules, mostly provided by OSes
  - It is recommended to collect entropy as many sources as possible

- Several approaches for estimating entropy for software modules
  - Lower bound estimations are important to ensure that the module collect sufficient entropy for DRBG
  - Because of the limitations of data size, we develop variants of existing statistical tests
  - Mutual information between consecutive samples are considered to estimate entropy

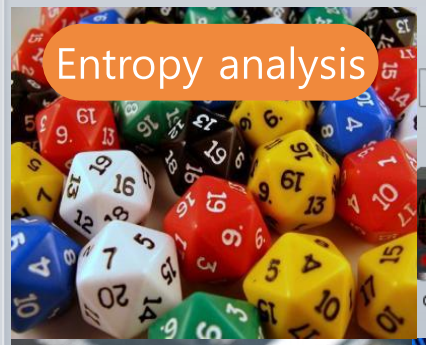
Future in KCMVP?

Developing new testing methods

New ICT CM Validation



Enhancing validation of core component techniques



Q & A

Q&A