Challenges in Lightweight Crypto Standardization

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Fast Software Encryption 2015

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about me

- Doing (symmetric) crypto research for 10+ years.
- Guest researcher at NIST for 5+ years
- Participated in the SHA-3 project, password-based KDFs project, stream cipher, RNG project (SP800 90B), etc.

Outline

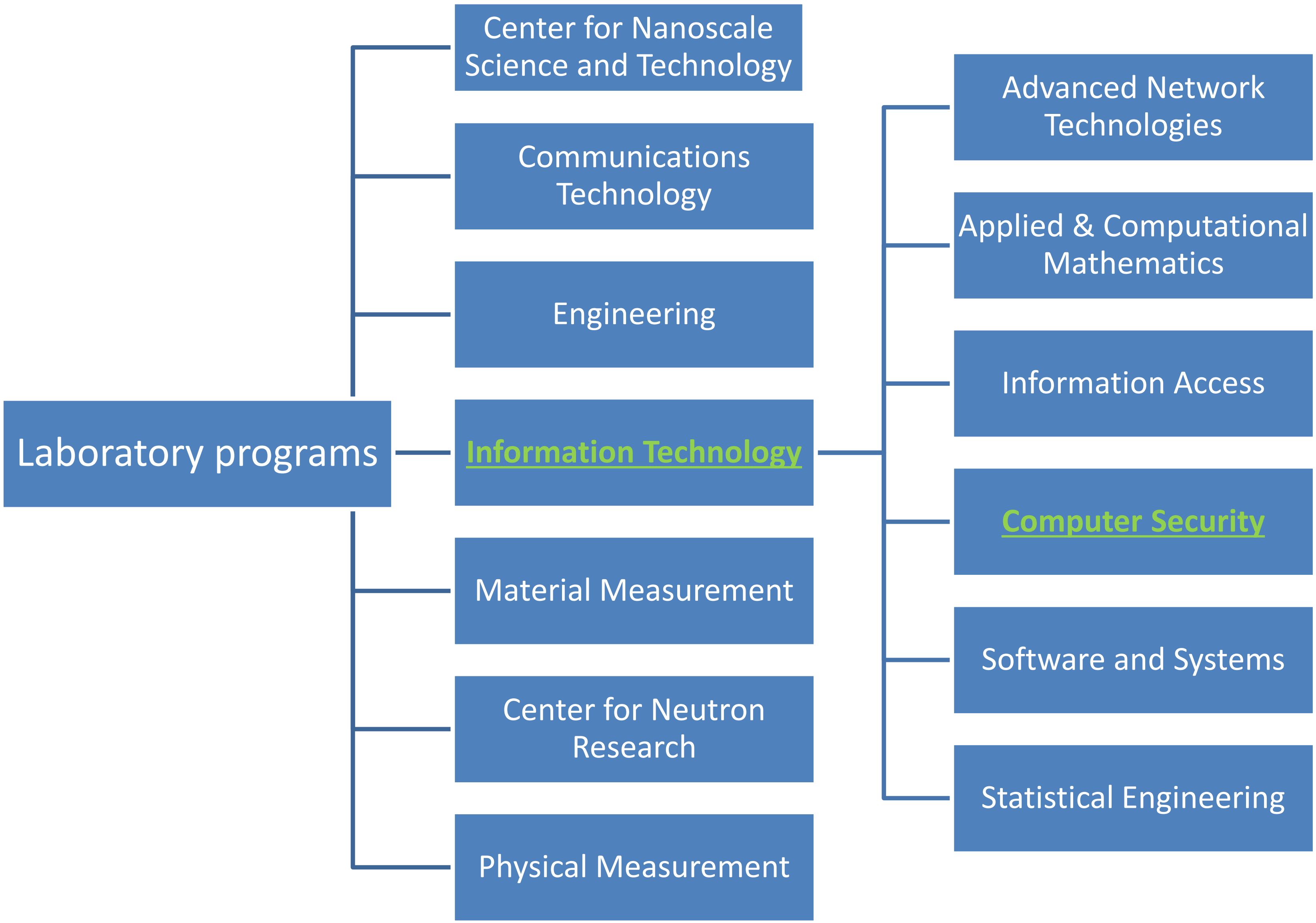
- *Lightweight crypto project at NIST*
- *Overview of the academic literature*
- *Overview of the standardization efforts*
- *Challenges in standardization*

National Institute of Standards and Technology
U.S. Department of Commerce

- Measurement science lab.
- Part of the US Department of Commerce
- Located at Gaithersburg, Maryland
- Founded in 1901, known as the National Bureau of Standards (NBS) prior to 1988
- Around 2700 employees, and 1,800 associates.

NIST's mission

to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade and improve the quality of life.


Laboratory programs
Center for Nanoscale Science and Technology
Communications Technology
Engineering
Information Technology
Material Measurement
Center for Neutron Research
Physical Measurement
Advanced Network Technologies
Applied & Computational Mathematics
Information Access
Computer Security
Software and Systems
Statistical Engineering

What do we do?

- *Algorithm specifications:*
  - Federal Information Processing Standards (FIPS) and Special Publications (SPs) specify a number of approved cryptographic algorithms.
- *General guidance on the use of cryptography:*
  - Covering selection, implementation, deployment and use of cryptography.
- *Guidelines in application-specific areas:*
  - Areas of particular need for the US government (e.g., PIV, TLS).
- *Testing:*
  - Providing assurance that crypto is implemented properly (e.g., FIPS 140 and CMVP)

Who do we work with ?

- *Academic Researchers:*
  - Development of new algorithms/modes/schemes, to advance science of cryptography
- *Industry:*
  - On adoption of cryptographic algorithms, feedback mechanism on standards
- *Standards Developing Organizations:*
  - Adoption and development of new standards
- *Government:*
  - Core user community

How do we develop standards?

- *International Competitions*
  - Engage community through an open competition
  - *e.g., AES, SHA-3*
- *Adoption of Existing Standards*
  - Collaboration with accredited standards organizations
  - *e.g., RSA, HMAC*
- *Open call for proposals*
  - Ongoing open invitation
  - e.g. modes of operations (SP 800 38)
- *Development of New Algorithms*
  - Used if no suitable standard exists
  - e.g., DRBGs

NIST IR 7977 *NIST Cryptographic Standards and Guidelines Development Process*

Example Research Projects

Post quantum crypto, Pairing-based crypto, Privacy enhancing crypto, Secure group communications, Circuit complexity, *Lightweight crypto,* etc.

Lightweight Crypto Project

Cryptographic solutions tailored to constrained environments.

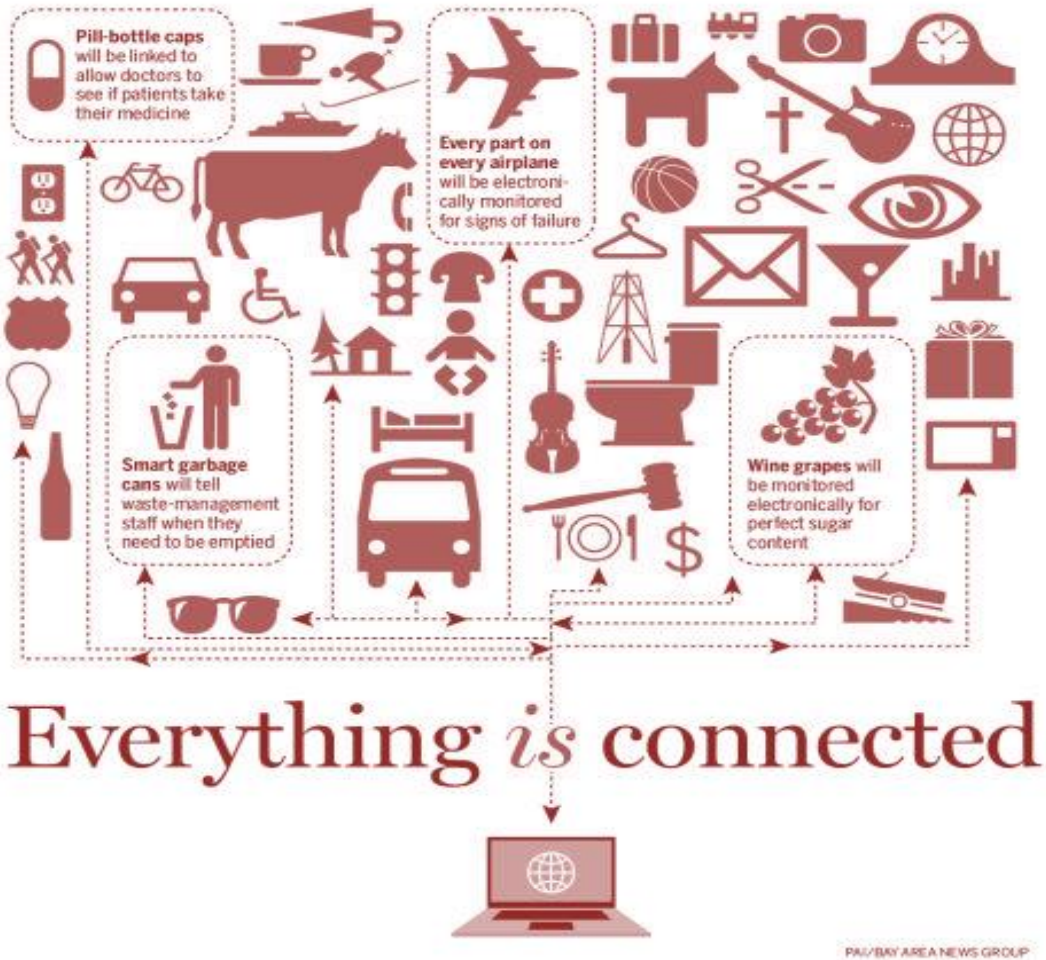
- Focus: Symmetric-key crypto primitives.

Not meant to be weak

Not meant to replace general-purpose crypto primitives

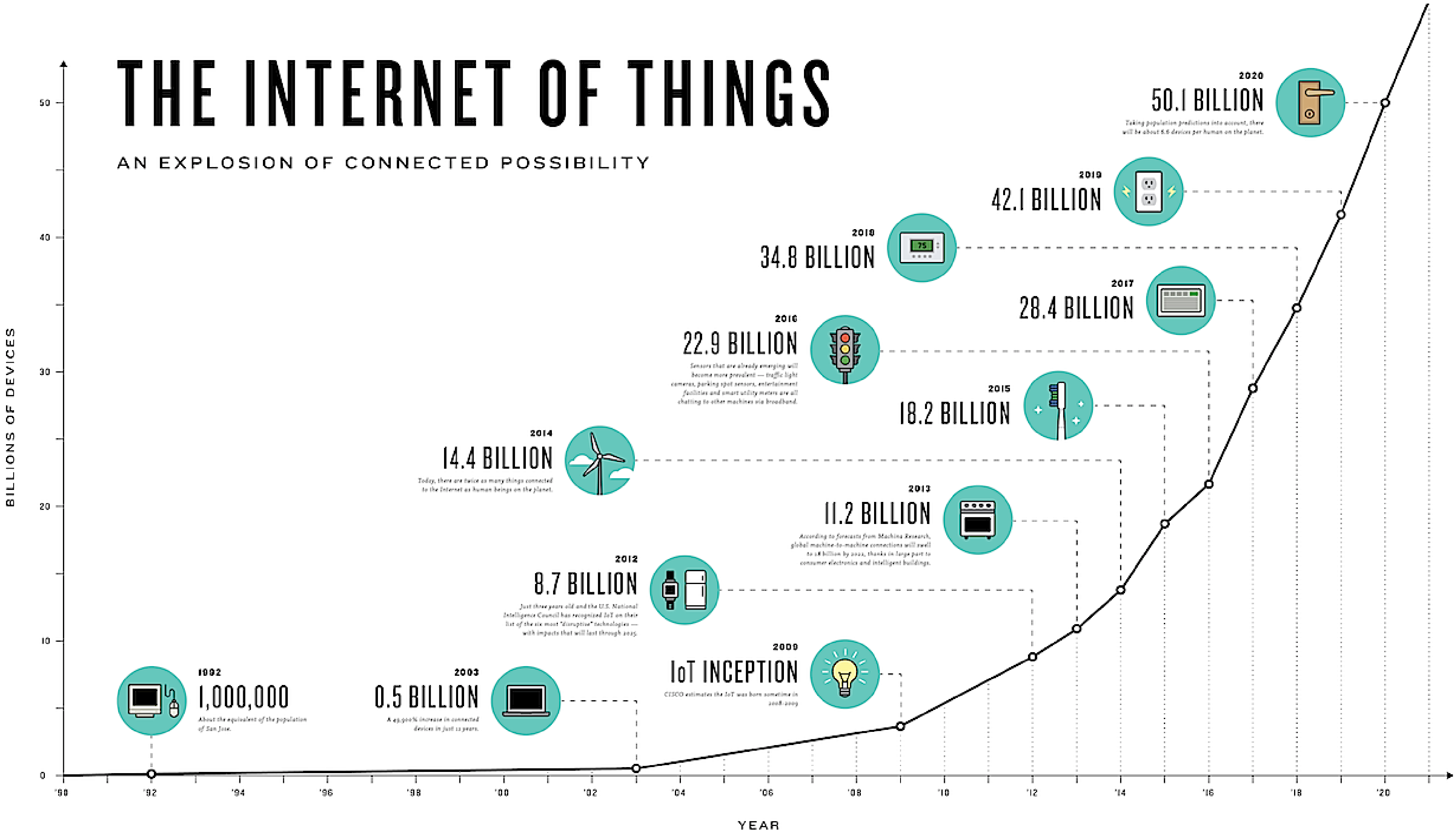
Our initial questions:

- Is there truly a demand?
- Is the technology mature enough to be standardized?



- Internet of Things
- Pervasive computing
- Ubiquitous computing
- Ambient intelligence
- Calm computing

http://www.mercurynews.com/business/ci_24836116/internet-things-seen-bonanza-bay-area-businesses



http://www.theconnectivist.com/2014/05/infographic-the-growth-of-the-internet-of-things/

The demand

- Applications
  - Healthcare monitoring systems
  - Automated management of supply chain
  - Public transportation
  - Telephone cards, etc.
- Involve sensitive information
- Constrained devices with limited memory, power supply, etc.
- NIST-approved crypto algorithms may not be suitable.

Is the technology mature enough to be standardized?

Academic Research

- Significant academic interest
  - Around 1400 papers on *lightweight cryptography* in the last 10 years (according to Google Scholar)

- Dedicated academic workshops
  - e.g. Lightsec, RFIDsec, Lightweight Crypto Day, Four workshops sponsored by the ECRYPT project, etc.

What has been done? – Symmetric Crypto

Improved implementations of AES

- In HW, 2400 GEs (Moradi et al., Eurocrypt 11), 2090-gate design (Mathew et al, 2014)
- In SW, using 8-bit AVR microcontrollers, 124.6 and 181.3 cpb for encryption/decryption with a code size < 2 Kbyte (Osvik et al.,FSE10).

AES should be used whenever possible!

What has been done?

- *Modifications of well-analyzed algorithms*
  - e.g. DESL, DESXL
- *Old interesting algorithms*
  - e.g. RC5, TEA, XTEA
- *New dedicated algorithms.*
  - e.g. CLEFIA, Fantomas, HIGHT, ICEBERG, KASUMI, LBlock, LED, KATAN/KTANTAN, Klein, mCrypton, MIBS, NOEKEON, Piccolo, PRESENT, PRINTcipher, PUFFIN, PUFFIN2, PRINCE, PRIDE, SEA, SIMON, SPECK, TWIS, TWINE …

Characteristics of new designs

- Many iterations of simple rounds
- Simple operations like XORs, rotation, 4X4 Sboxes, bit permutations
- Smaller block sizes
- Smaller key sizes
- Simpler key schedules
- Small security margins by design
  - Many designs, but many were broken in a short time

Different threat models

Different capabilities of attackers

- Limited number of known plaintexts/ciphertexts
- Less concern on related key attacks. From *ideal cipher* to *ideal permutation* assumption.

Justifications:

- Limitations of the devices (e.g. battery life)
- Protection through the protocols

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Example: Prince

- Claims 126-n bit security for an attacker with access to an 2^n input/output pairs.
- Decryption for free = encryption with a related key.

Side channel attacks

Serious threat for constrained devices

- Attacker may have physical access.
- Devices are cheaper.

With countermeasures, the area increases by a factor of 3 to 5 compared to the non-protected implementations (Fisher, Gammel, ’05)

New designs with side-channel resistance:

- Fides, LS family, PICARO

Overview of Standardization Efforts

ISO International Organization for Standardization

NFC Forum

CEN

European Payments Council

IEC INTERNATIONAL ELECTROTECHNICAL COMMISSION

ANSI

IEEE

IETF

Bluetooth® SPECIAL INTEREST GROUP

CRYPTREC Cryptography Research and Evaluation Committees

oma Open Mobile Alliance For a Connected World

ECRYPT II

ETSI World Class Standards

RSA®

Federal Office for Information Security

3GPP™ A GLOBAL INITIATIVE

TRUSTED COMPUTING GROUP™

W3C®

ZigBee® Alliance

ISO/IEC - 29192

- *Part I:* General, First edition, 2012
- *Part II:* Block ciphers, 2012
  - 64-bit PRESENT (80, 128 bit key)
  - 128-bit CLEFIA (128, 192 or 256-bit key)
- *Part III:* Stream ciphers, 2012
  - Enocoro (80, 128 bits key)
  - Trivium (80 bit key)
- *Part IV:* Mechanisms using asymmetric techniques, 2013
  - Identification scheme cryptoGPS
  - Authentication and key exchange mechanism ALIKE
  - ID-based signature scheme IBS
- *Part V:* Hash functions - not published.

ISO/IEC - 29167

- A number of cryptographic suites designed for protecting application information transmitted across the RFID air interface, product authentication, and protecting access to resources on the tag.
- 10 Parts
- Algorithms :
  - PRESENT-80, ECC-DH, Grain-128A, AES OFB, Crypto suite XOR, ECDSA-ECDH, cryptoGPS, RAMON

International Organization for Standardization

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Industry-specific standards

- Proprietary designs

- Examples:
  - A5/1 (in GSM), E0 (in Bluetooth), Crypto1 (in Mifare RFID tags), Cryptomeria (C2) (for digital rights managements), Dect (cordless phones), DST40 (TI), KeeLoq (authentication in car locks), Kindle stream cipher

- Most reversed engineered, practically broken.

ECRYPT eSTREAM Project

a 4-year network of excellence funded project started in 2004 by European Network of Excellence for Cryptology (ECRYPT)

Goal: To identify new stream ciphers that might be suitable for widespread adoption and to stimulate work in stream ciphers.

Profile I : for software applications with high throughput requirements with key size of 256 bits.

Profile II : **for hardware applications with restricted resources with key size of 80 bits.**

ECRYPT II

Finalists of Profile II

- Grain
  - Widely analyzed
  - Tweaked twice
  - A new version Grain128a, featuring authentication
  - Flexible
- Trivium
  - Widely analyzed
  - Not tweaked, simple and elegant,
  - Flexible
- Mickey
  - Lightly analyzed, security depends on the hardness of analysis.
  - Less implementation flexibility, due to irregular clocking
  - Susceptible to timing and power analysis attacks

Lightweight versions of KECCAK

- In 2012, KECCAK was selected as SHA-3.
  - Instantiation of a sponge function
  - Permutation based, with seven different sizes {25, 50, 100, 200, 400, 800, 1600}.
  - Design of permutations follows the Matryoshka principle.

- Lightweight instance:
  - 200-bit permutation with, *r*=40, *c*=160, 12 rounds.
  - Security strength of 80 bits.
  - Offers tradeoffs
  - Reusing permutation for AE, hashing, etc.
  - Crunchy contest (practical attacks):
    - Preimage attacks up to 2 rounds, collision attacks up to 4 rounds.

Lightweight versions of KECCAK (cont.)

- Performance on constrained environments.
  - 9.3kGE on a 130 nm CMOS process technology, by designers
  - Kavun & Yalcin implemented 200, 400, 800 and 1600 versions with 2.52kGE, 5.09kGE, 13kGE and 20.79kGE, respectively.
  - Pessle & Hutter showed that 1600-bit version can be implemented with less than 5.5kGEs.
    - Low, but acceptable, throughput
    - 800-bit with 4.6kGE. (900GE less than full permutation and twice as fast.)
    - Don't include side channel resistance.

More research is needed for lightweight uses of KECCAK.

Challenges

Bridging the Gap

- Industry needs vs. Academic solutions
  - Various applications with different requirements, use cases, constraints, target devices, etc.

- Communicating with industry to bridge the gap.

  - Workshop, and other meetings.

Enforcing the threat model

- Less flexible, less misuse resistant, more constraints, assumptions about attackers.

- Challenge to enforce the limitations
  - # of known/chosen plaintext/ciphertext blocks
  - Uniqueness of the IVs (e.g. AES GCM)

- Development of the protocols is important.
  - Non-cryptographic protocols, Message formats

Selection of Key Size

Tradeoffs – Smaller key sizes to reduce cost

According to NIST SP 800-57:

<table>
<tr><th colspan="2">Security Strength</th><th>2011 through 2013</th><th>2014 through 2030</th><th>2031 and Beyond</th></tr>
<tr><td rowspan="2">80</td><td>Applying</td><td>Deprecated</td><td colspan="2">Disallowed</td></tr>
<tr><td>Processing</td><td colspan="3">Legacy use</td></tr>
<tr><td rowspan="2">112</td><td>Applying</td><td rowspan="2">Acceptable</td><td rowspan="2">Acceptable</td><td>Disallowed</td></tr>
<tr><td>Processing</td><td>Legacy use</td></tr>
<tr><td>128</td><td rowspan="3">Applying/Processing</td><td>Acceptable</td><td>Acceptable</td><td>Acceptable</td></tr>
<tr><td>192</td><td>Acceptable</td><td>Acceptable</td><td>Acceptable</td></tr>
<tr><td>256</td><td>Acceptable</td><td>Acceptable</td><td>Acceptable</td></tr>
</table>

Selecting a Primitive

- Due to the variability of applications/requirements,
  - Hard to select a *one-size-fits-all* algorithm

- Tradeoff between performance, security, cost are highly important.
  - Depends on the target technology
  - HW/SW optimized algorithms
  - Optimized for both

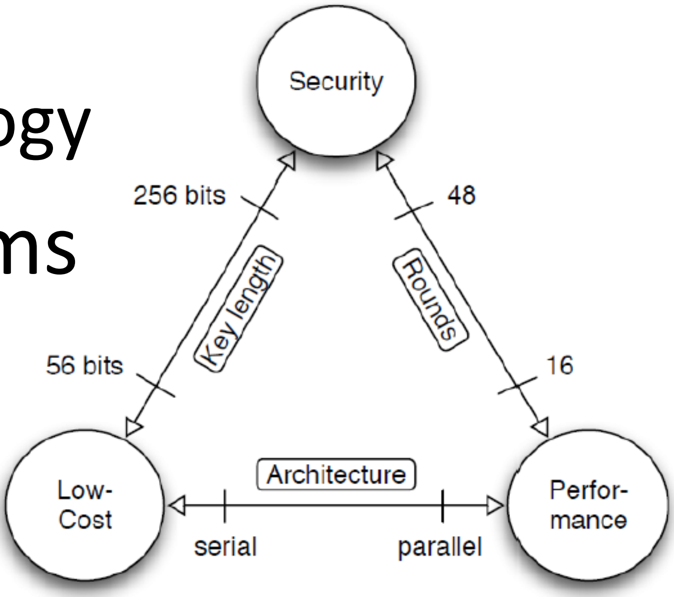
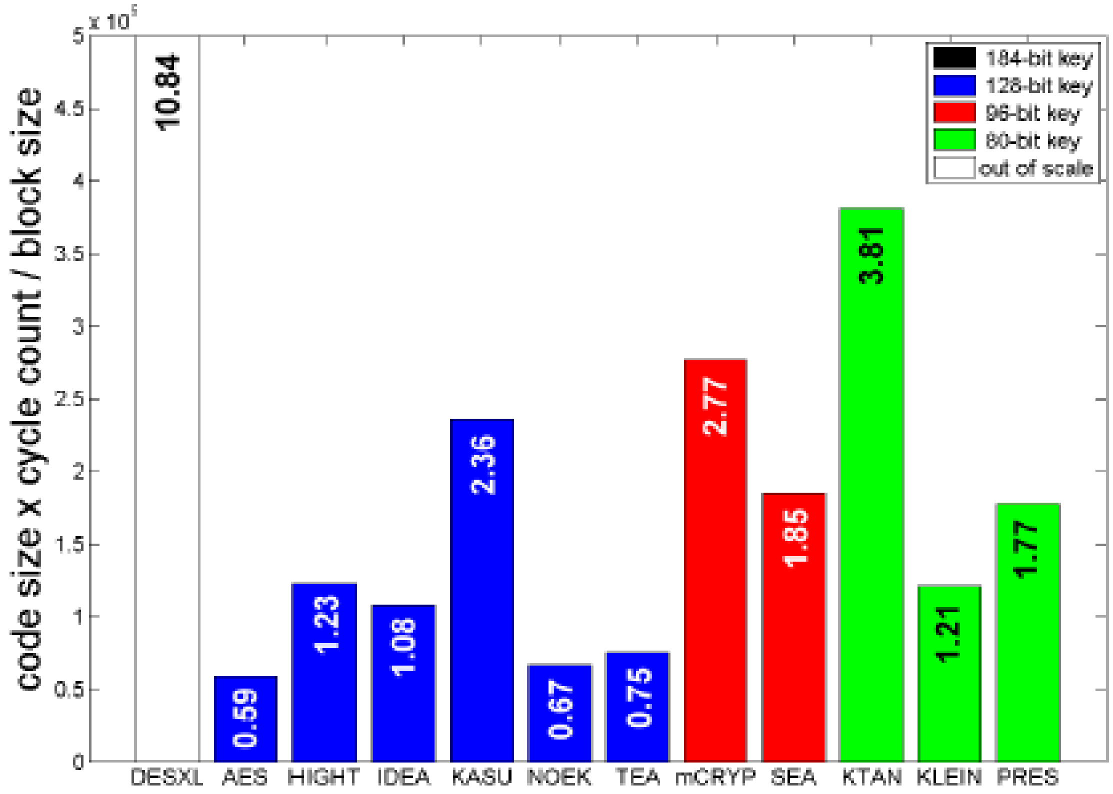


Figure: A. Poschmann, *Lightweight Cryptography: Cryptographic engineering for a pervasive world*

Performance Comparisons

Performance evaluation of 11 block ciphers using small microcontrollers. (from ECRYPT II Second Lightweight Crypto Status Report,2012)



http://www.ecrypt.eu.org/documents/D.SYM.8.pdf

Our Tentative Plan

- An algorithm or a portfolio of algorithms

- Possibilities
  - Adoption of existing standards
  - Open ongoing call for proposals

Tentative Schedule

Phase	***Objectives***	***Time***
Phase I	- Identify and evaluate the need - Survey latest developments - Announce intent	Late 2014 to June 2015
Phase II	- Workshop @NIST on July 20-21,2015 - Consider requirements and solutions	July - December 2015
Phase III	- Define specific plan - Develop SP (if applicable) - Maintenance	2016 -

Lightweight Crypto Workshop

Dates

Location: NIST Gaithersburg, MD

Date: July 20-21, 2015

Submission : April 1, 2015

Notification : May 15, 2015

Topics

- Requirements and characteristics of real-world applications
- RFID, SCADA, cyber-physical systems, and the Internet of Things
- Case studies of deployed systems
- Evaluation of threats, attacks and risks
- Restrictions and protections to reduce the risk of using lightweight primitives
- Design, analysis and implementation
- Lightweight public key cryptography
- Benchmarking of lightweight cryptographic algorithms in software and hardware
- Side channel attacks and countermeasures for constrained devices

Thanks!

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